He'e Holua: Selecting the Best Places for Lava Sledding on Maui

Lesson Overview

In this activity, learners will select the best locations to go He'e Holua—lava sledding—on Maui. The sites will be selected based on slope of the land, land use, direction that the slope faces, and distance from roads and trails. In so doing, learners will understand the spatial relationships between features in the physical environment, how to perform spatial queries, and how to make an informed geographic decision.

Requirements: ArcGIS 9.x, the Spatial Analyst extension, and the 3D Analyst extension.

Student Instructions

You have become passionate about helping to revive the 2,000-year-old Hawaiian tradition of He'e Holua, or lava sledding. Serving traditionally as a sport and as a vehicle for Hawaiians to honor their gods. After reaching the top of a slope, Hawaiians would stand up, lie down, or kneel atop sleds carved from kauila or ohia trees measuring 12 feet long by 6 inches wide, and speed down human-made courses of hardened lava rocks sprinkled with grass.

Note: He'e Holua is an inherently dangerous activity.

Your goal is to select the best places on Maui to invite people to try He'e Holua. You want to select sites that are:

Geography Standards
• How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.
• The physical & human characteristics of places.
• The process-patterns-functions of settlement.
• How physical systems affect human systems.

Science Standards
• Science in Social Perspectives: Types of Resources.
• Motions and Forces
• Populations and Ecosystems
• Change, Constancy, and Measurement
• Structure of the Earth System
• Environmental Quality
• Science and Technology in Local, National, and Global Challenges

Mathematics Standards
• Understand measurable attributes of objects and the units, systems, and processes of measurement.
• Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
• Problem-solving, reasoning and proof, communication, and representation.

Environmental Studies Standards

Historical Thinking Standards
• Historical Analysis and Interpretation: Consider multiple perspectives
• Historical Issues-Analysis and Decision-Making: Formulate a course of action on an issue.

Technology Standards
• Students demonstrate sound understanding of the nature and operation of technology systems and are proficient in the use of technology.
• Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.
• Students use technology to enhance learning, increase productivity, and promote creativity.
• Students use productivity tools to collaborate in constructing models, prepare publications, and produce other creative works.
• Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.
• Students use technology to locate, evaluate, and collect information from a variety of sources.
• Students use technology tools to process data and report results.
• Students use technology resources for solving problems and making informed decisions.
• Students employ technology in the development of strategies for solving problems in the real world.

[1] On a slope of at least 15 degrees so that the ride will be exciting, but not 30 degrees or over so that you won't die on your first attempt.

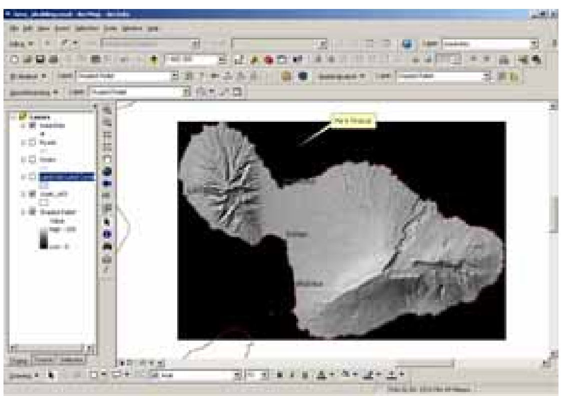
[2] On an elevation of at least 7,000 feet so that the view will be excellent while you are sledding.

[3] On a west-facing slope, so that you can see the sun setting while you are sledding and so that you do not have winds carrying rain coming in from the east impeding your sledding.

[4] On bare rock or bare ground, so you can practice the *real* He'e Holua like the ancient Hawaiians did.

[5] Not more than 500 meters from the nearest road or trail, so that you won't have to drag your sled over long distances across country.

Start ArcGIS and access ArcMap. Open an existing map entitled lava_sledding.mxd from the folder that your instructor directs you to. You should see a map that looks like the image below.



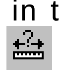
This map shows the Maui coastline with a shaded relief map based on digital elevation data.

Use the zoom in tool  to draw a box around the areas you wish to examine more closely. You can always go back to the full extent of your map layers using the globe  tool. Note that the "full extent of the map layers" in this project is beyond Maui. Therefore, it might be easier to zoom to the extent of each map layer by right-clicking on the layer and selecting "zoom to layer." Alternatively, you can go to View→ Bookmarks and select "Maui", or create your own bookmarks!

To perform some of your spatial analysis, you will need to turn on a few extensions and toolbars. First, access the tools menu and select Extensions. On the Extensions choice box, select the 3D Analyst and Spatial Analyst extensions. Second, access Access the View menu and select Toolbars. Select the 3D Analyst and Spatial Analyst toolbars.

You decide to first address criterion [1]—finding areas of a suitable slope. To find out which areas meet the criterion, you need an elevation layer. Turn on the **demras** layer. This data was compiled from topographic maps that show the elevation on Maui.

1) Based on the range of values in the demras layer, would you say that the elevations are in feet or meters?

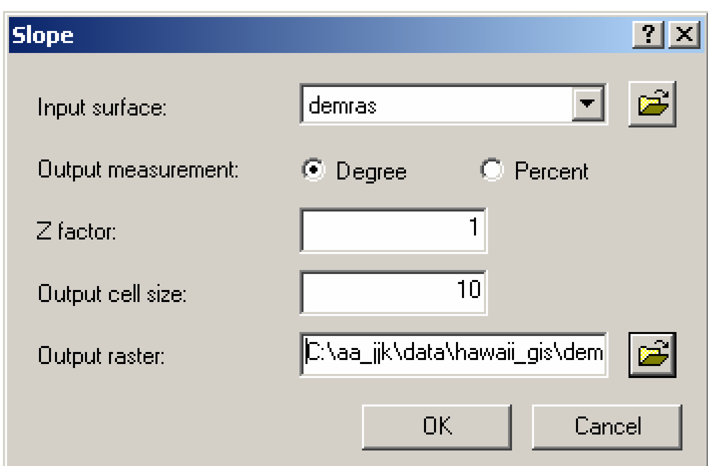
2) Zoom in on an area on Maui where the elevation changes rapidly within a short distance, such as in the western highlands, at a scale of under 1:1000. Use the measure tool  to measure the width of a single pixel, or data square, in the image. What is the width of each of the elevation pixels?

This type of data organized as a series of rows and columns of pixels is called *raster data.*

Zoom back out to Maui.

Select the following from the Spatial Analysis toolbar:
Surface Analysis→ Slope

In the slope dialog box, select demras as your input surface, degree as your measurement (slopes in degrees), and give the output raster layer a logical short name (such as "slope") and store it in the location specified by your instructor.

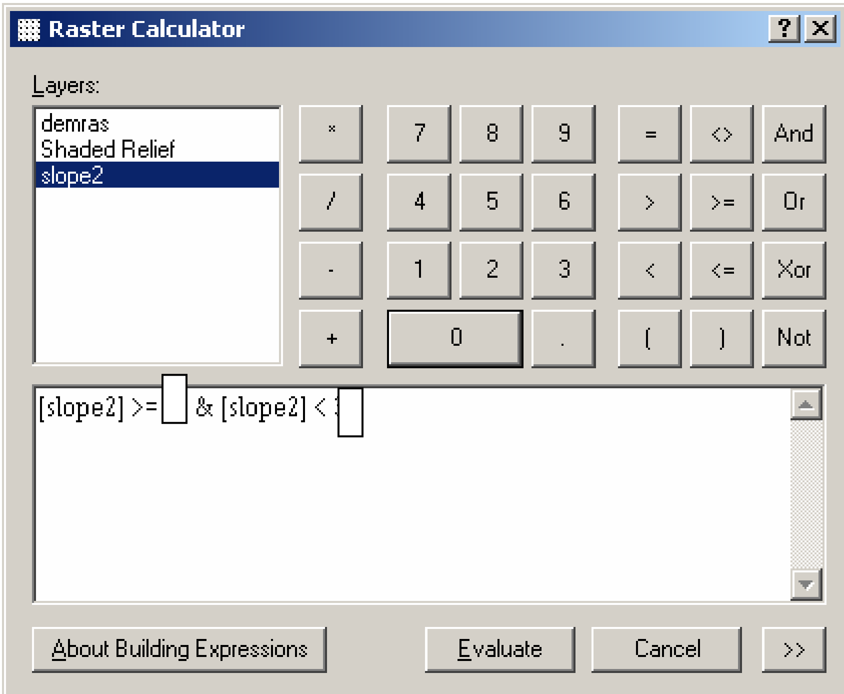


3) Note in the dialog box that the output cell size is 10 meters. Does this make sense, based on what you measured earlier? Why or why not?

Select OK. Save the output raster as an ESRI GRID.

4) Look at the legend created for your new slope layer. What is the maximum slope on Maui based on the elevation data?

Under the Spatial Analyst toolbar, access Raster Calculator:



In the raster calculator expression window, build the expression by clicking on the slope raster layer, the operators, and the numbers.

5) Based on the criterion for the slope, what are the 2 values that need to be in the expression (in the 2 small boxes, above) in the raster calculator dialog to select the appropriate slope?

Look at your map. Your new layer is titled "Calculation." Change the name to "Suitable Slope." The value "1" is assigned to all of the areas where the slopes are appropriate.

6) Describe the places on Maui on which the selected slopes are located.

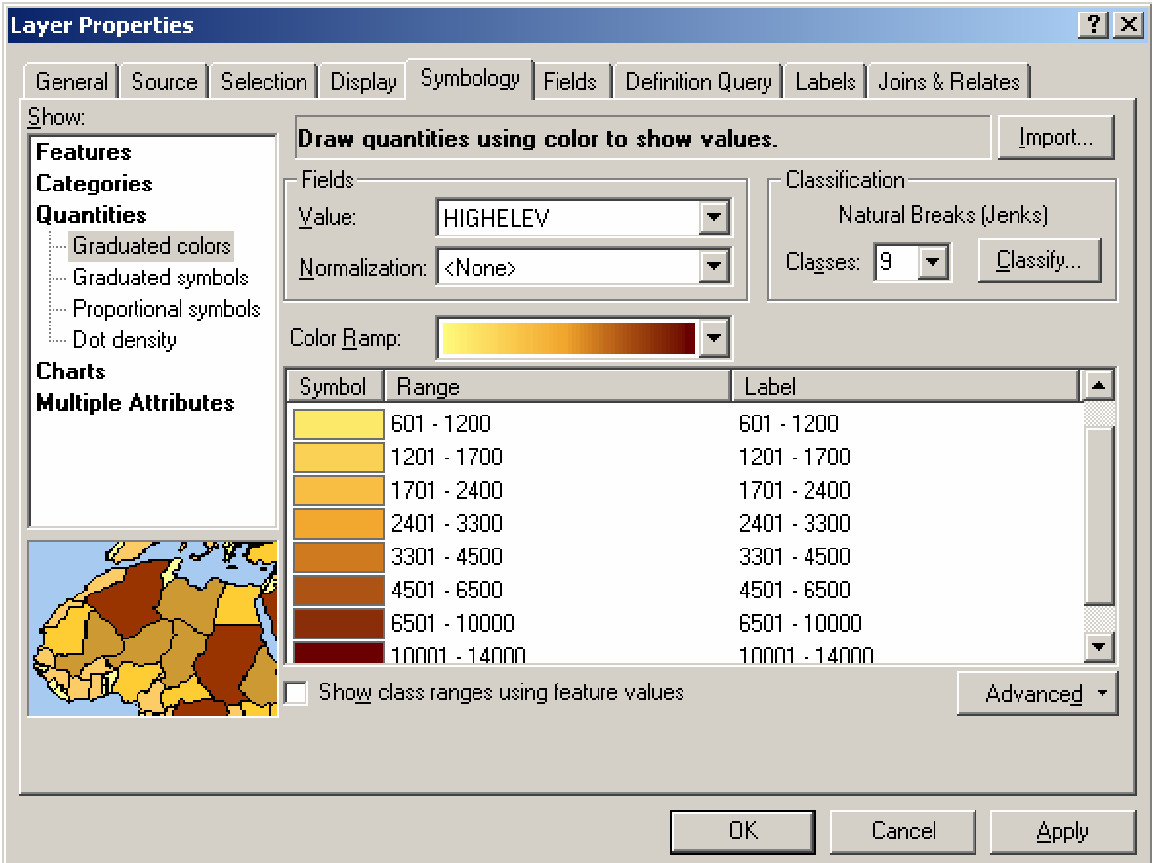
Right-click on the Suitable Slopes layer and select "Properties." Select the "Display" tab and make it 50% transparent. Turn off the demras layer and turn on the shaded relief layer.

7) Do these suitable slope locations surprise you? Why or why not?

You have addressed criterion [1]—finding areas of suitable slope to go lava sledding. Next, address criterion [2]—finding areas of suitable elevation.

Remember—you want the view to be a good one, and so you need a high elevation!

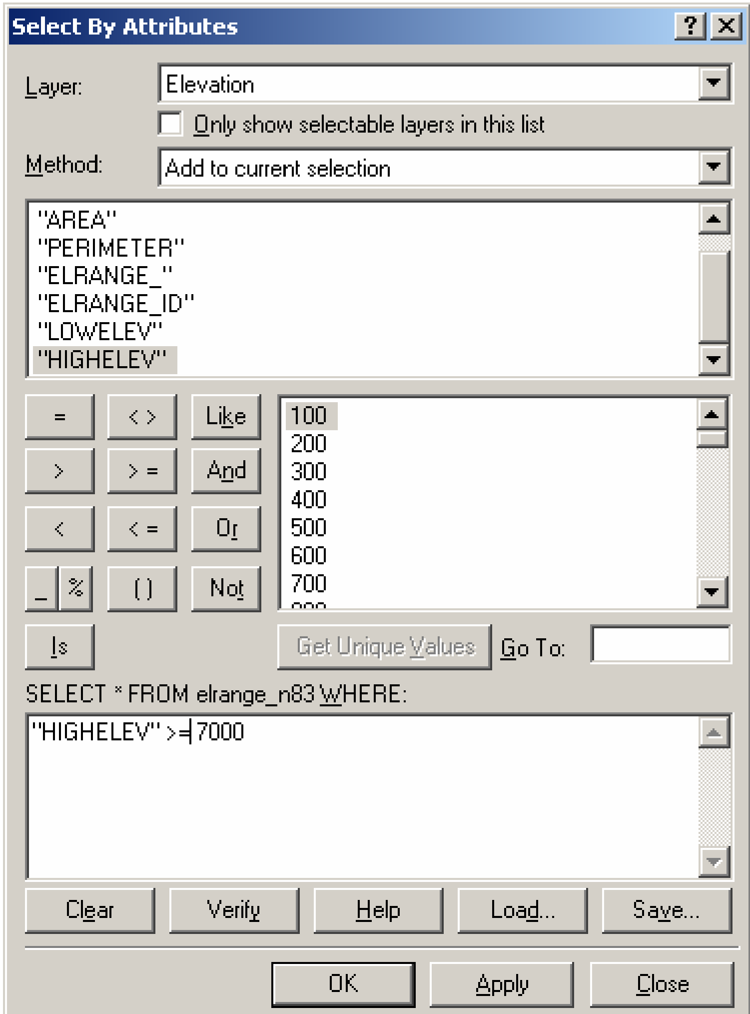
Turn on the elevation layer. Right click on it and select "Properties." Go to the symbology tab and symbolize the map layer as graduated color based on the field "HighElev." Make 9 categories, as follows:



8) Based on the values for Highelev, do you think these are in feet or meters?

Zoom in on a "boundary" between the elevation zones to a scale of 1:1000. Note that you don't see the pixels as you did with the demras and slope layers. That is because this elevation layer is *vector data*—comprised of points, lines, and polygons. With vector data, you don't use the raster calculator to select values, but rather, the Select By Attribute function.

Access the Selection menu on the top and then Select By Attribute. Make the elevation layer the layer you are selecting from, and then select the areas where the highelev is greater than or equal to 7000, adding all values, as follows:

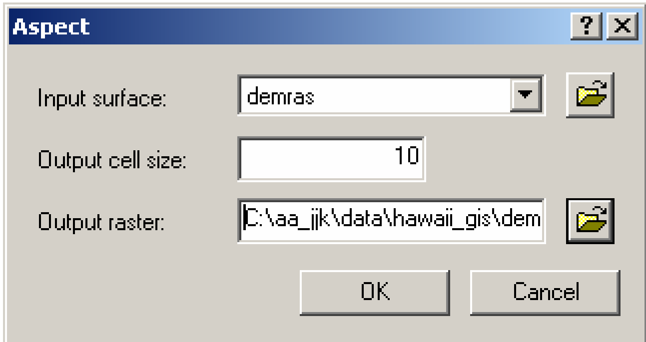


Look at your map. The cyan lines are areas at least 7,000 feet in elevation.

9) Describe where the areas at least 7,000 feet are in Maui. Does the location of the high elevations surprise you? Why or why not?

Try making this layer semi-transparent and overlaying it against the shaded relief.

You are now ready for criterion [3]—selecting areas on a west-facing slope. You have a slope layer, but not the *direction* that the slopes face. To calculate the slope direction, you need to create the layer from the original elevation data (demras). Slope direction is called *aspect.* Use the Spatial Analyst→ Surface Analysis→ Aspect function to create an aspect map as follows. Save the output as a file named "aspect" in the folder that you are using for your project.



Turn off the elevation layer and turn on the aspect layer. Note that the directions the slopes are facing are associated with raster cells with a numeric value. Each direction is associated with a certain range on the 360-degree compass. For example, east has the range of 67.5 to 112.5 degrees on the compass.

10) Make at least 3 observations about the directions that slopes face on Maui.

11) Why are slopes so constant over large distances on Maui?

12) Based on the range data, what number would you assign to each of the following directions? Fill in the table below

Direction	Numeric Value
Due North	
Due East	
Due South	
Due West	

13) Criteria 3 is to select west-facing slopes. What is not due west, but the **range** of west-facing slopes?

You are now ready to select the west-facing slopes, and because this is raster data, you will need to use the raster calculator.

Use Spatial Analyst→ Raster Calculator as you did earlier to make your selection of the west facing slopes. Remember to use Aspect as your input layer.

14) What is the expression that you used in the raster calculator to select the west facing slopes?

Rename your new raster layer "West Facing Slopes" and notice again that the west facing slopes have a value of 1.

You are now ready to examine criteria [4]—whether ground is bare rock, so you can sled like the ancient Hawaiians did. The land use land cover layer is the layer you now need to turn on and examine.

15) Is land use land cover vector data or raster data?

Right click on the table and examine the landcover field.

16) Does this field give a description of the land use land cover in each of the land use land cover polygons?

The Land Use and Land Cover (LULC) data consists of historical land use and land cover classification data that was based primarily on the manual interpretation of 1970's and 1980's aerial photography. Secondary sources included land use maps and surveys.

The LandCover Codes describe the land use land cover as follows:

Level I	Level II
1 Urban or Built-up land	11 Residential
	12 Commercial and Services
	13 Industrial
	14 Transportation, Communications and Utilities
	15 Industrial and Commercial Complexes
	16 Mixed Urban or Built-up Land
	17 Other Urban or Built-up Land
2 Agricultural Land	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland
	32 Shrub and Brush Rangeland
	33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land
	42 Evergreen Forest Land
	43 Mixed Forest Land
5 Water	51 Streams and Canals
	52 Lakes
	53 Reservoirs
	54 Bays and Estuaries
6 Wetland	61 Forested Wetland

	62 Nonforested Wetland
7 Barren Land	71 Dry Salt Flats 72 Beaches 73 Sandy Areas Other than Beaches 74 Bare Exposed Rock 75 Strip Mines, Quarries, and Gravel Pits 76 Transitional Areas 77 Mixed Barren Land
8 Tundra	81 Shrub and Brush Tundra 82 Herbaceous Tundra 83 Bare Ground 84 Wet Tundra 85 Mixed Tundra
9 Perennial Snow or Ice	91 Perennial Snowfields 92 Glaciers

Your next step is to select the land that is bare exposed rock.

17) Using the Selection→ Select By Attribute, what expression will you build that will give you a land use land cover map with bare exposed rock selected?

Perform this selection, and then examine your resulting map.

18) Describe the areas on Maui that where bare exposed rock exists. Do the locations surprise you? Why or why not?

Right-click on the land use land cover map layer, and open the table.

19) How many land use land cover polygons do you have selected; i.e. how many polygons are bare exposed rock?

You have addressed criteria 1 through 4, but have not yet considered the last criterion [5]. Since you don't want to carry your sled for too long a distance from your vehicle, you want the sledding sites to be within 500 meters from the nearest road or trail. You'll save this step for last, after you've narrowed the search to areas that meet all other criteria.

You now have all of the criteria met, but the results of your analysis are in 4 different layers:

[1] Your suitable slopes of at least 15 degrees so that the ride will be exciting, but not 30 degrees or over so that you won't die on your first attempt.

[2] Your elevations of at least 7,000 feet so that the view will be excellent while you are sledding.

[3] Your west-facing slopes, so that you can see the sun setting while you are sledding and so that you do not have winds carrying rain coming in from the east that would impede your sledding.

[4] Your bare rock land use land cover, so you can practice the *real* He'e Holua like the ancient Hawaiians did.

[5] Your areas of not more than 500 meters from the nearest road or trail, so that you won't have to drag your sled over long distances across country. Remember that you're saving this step for last.

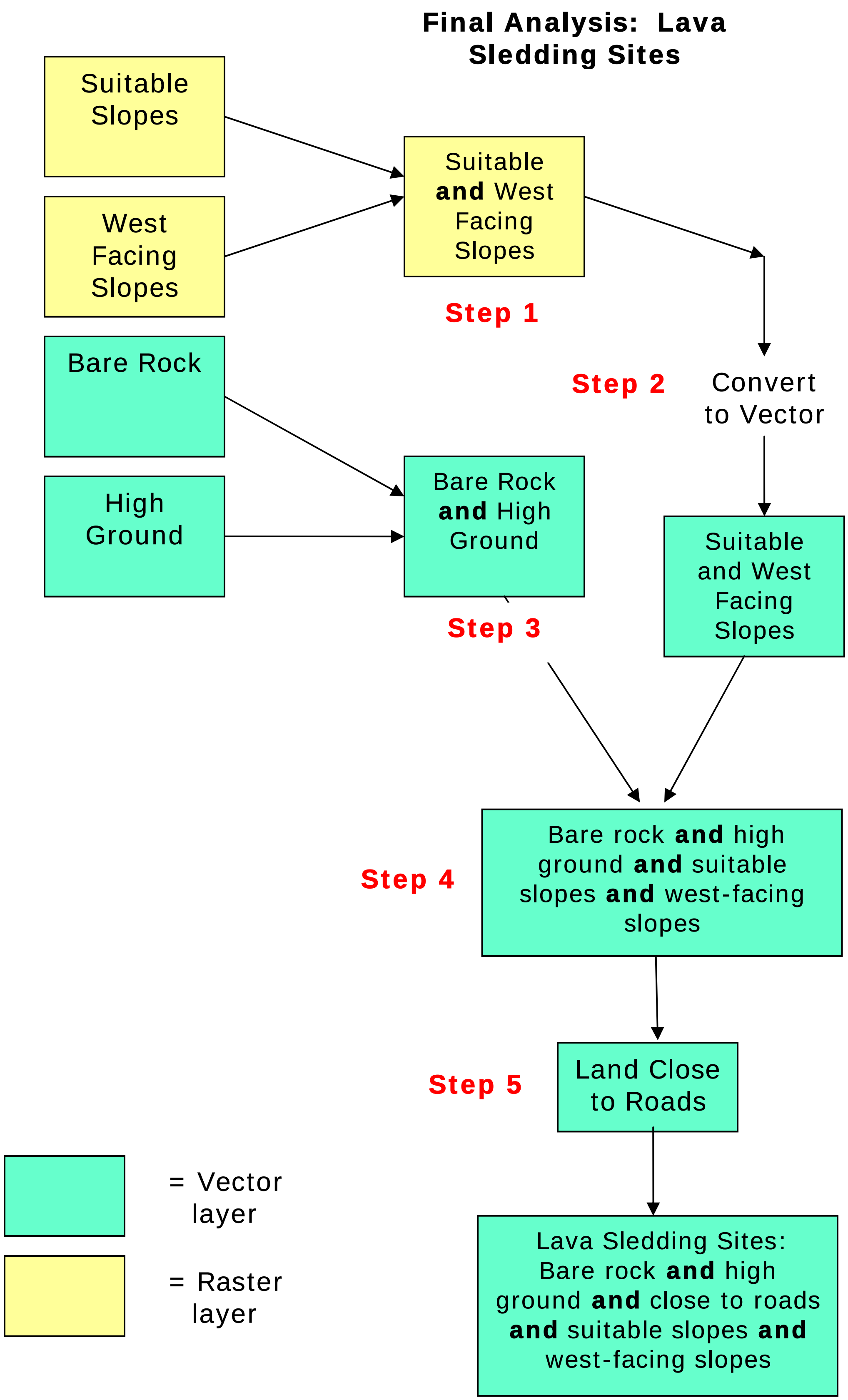
In the final steps, below, you will intersect these layers for your final possible lava sledding sites. You'll have to use several different methods because some of your data are raster and some are vector. One easy way to determine the difference is to zoom in closely to each layer. If you see the individual pixels, then it is raster. Another way to determine the difference is to right-click on each layer, select Properties, and select the Source tab. If the source is an ESRI GRID or an image, it is raster. If it is a shape file, then it is vector.

20) Indicate which layers in the list [1] through [4] above are raster, and which are vector:

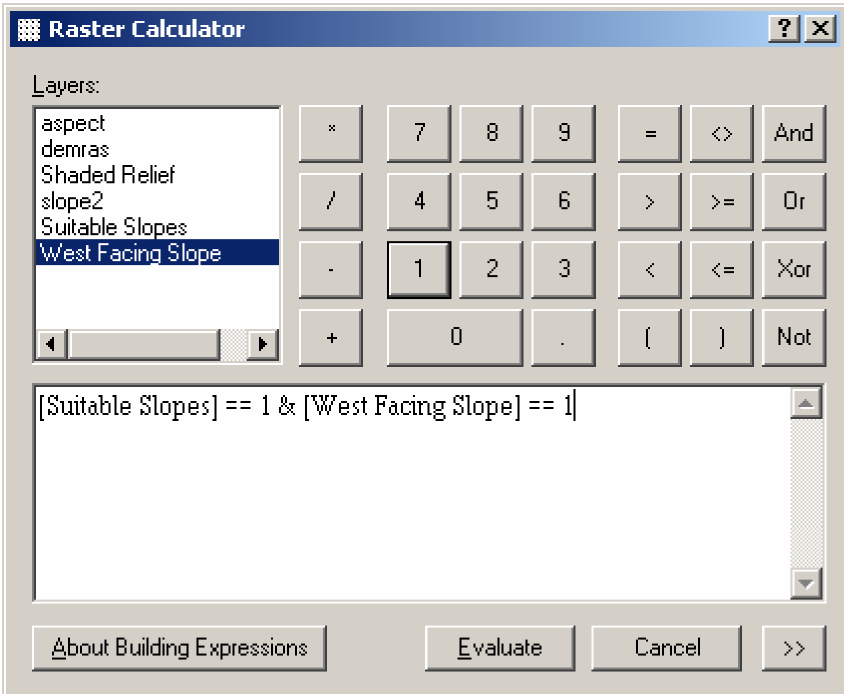
Layer	Raster (indicate with X)	Vector (indicate with X)
Suitable Slopes		
High Elevations		
West-Facing Slopes		
Bare Rock		

You have a choice: You can either convert all the raster layers to vector for the final sledding sites layer, or convert all of the vector layers to raster for the final sites layer. The choice you make now will slightly affect the shape of the areas under consideration, since vector data is stored as points, lines, and polygons, while raster data is stored as square pixels. For this lesson, let's do some in each mode, working with vector analysis tools if the data is in vector, and raster analysis tools if the data is in raster format.

The spatial analysis and processing you will need to do can be visualized as follows:


Final Analysis: Lava Sledding Sites
Suitable Slopes
West Facing Slopes
Suitable **and** West Facing Slopes
Step 1
Step 2
Convert to Vector
Bare Rock
High Ground
Bare Rock **and** High Ground
Suitable and West Facing Slopes
Step 3
Step 4
Bare rock **and** high ground **and** suitable slopes **and** west-facing slopes
Step 5
Land Close to Roads
= Vector layer
= Raster layer
Lava Sledding Sites: Bare rock **and** high ground **and** close to roads **and** suitable slopes **and** west-facing slopes

You have 2 raster layers, so first, use the raster calculator to generate a raster layer that shows all of the areas where the degree of slope is suitable **and** the slope is west facing, as follows:



Note that the double equals sign == is obtained by single-clicking on the equals sign. It performs a relational-equal-to operation on two layers on a cell-by-cell basis within the Analysis window. In other words, it checks the suitable slope layer for any cells that are equal to 1 and, at the same time, checks those same locations for values of "1" in the west facing slope layer.

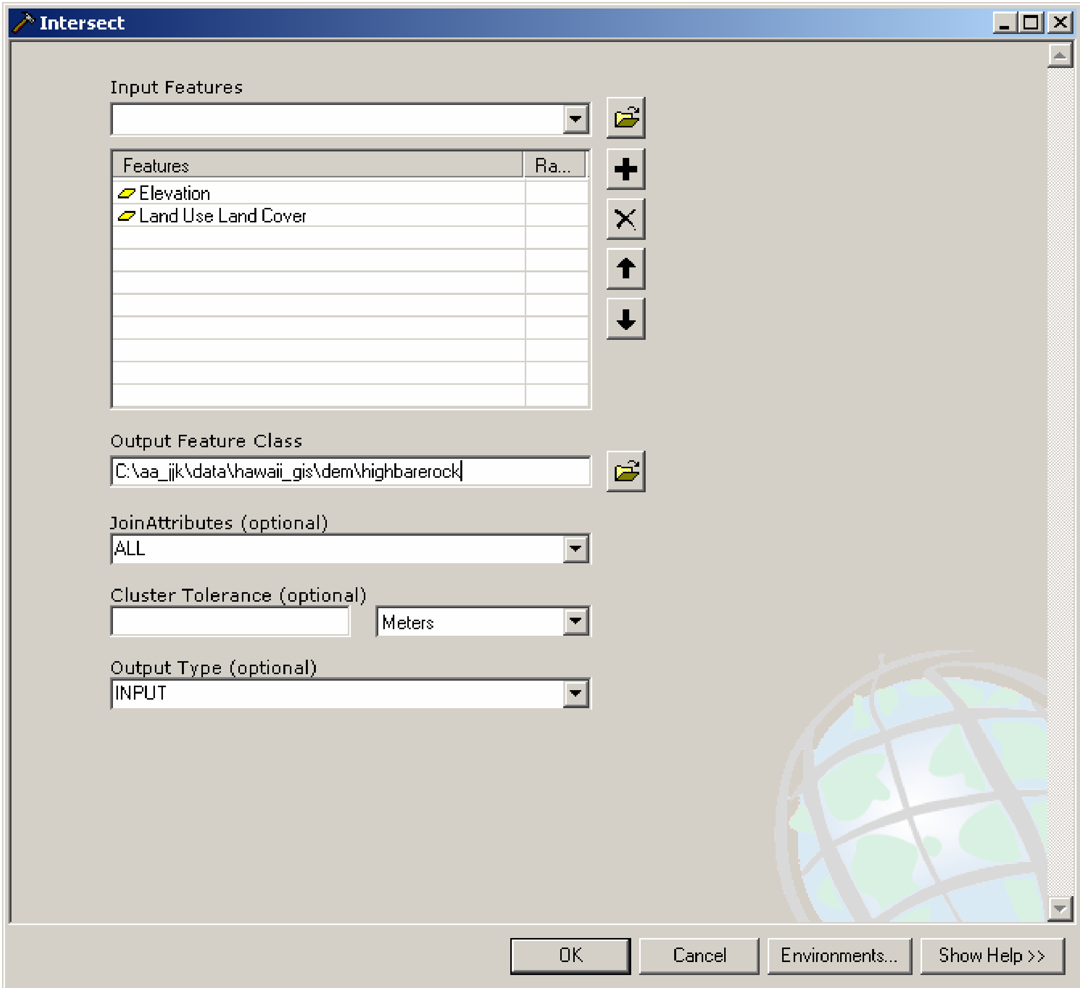
After selecting "Evaluate," you will see a new raster map layer in your table of contents. Rename this new map layer "suitable and west." You have just performed Step 1 in the table on the previous page.

21) Analyze the "suitable and west" map layer. Is **more** land under consideration for lava sledding in this layer than in either of the suitable slopes or west-facing maps, or **less** land? Why?

Next, you need to convert the raster layer "suitable and west" to vector in Step 2 in your process diagram. Do this by accessing the ArcToolbox→ Conversion Tools→ From Raster→ Raster to Polygon, and save your output in an appropriate folder and with an appropriate name so you can remember it later, such as suitwestvector.

22) Zoom into an area and compare the differences between the suitable and west raster layer and the suitwestvector vector layer. Name two differences between the two layers.

Next, you’re ready for Step 3—selecting areas that are on bare rock **and** high ground. These are both vector layers, so you can use ArcToolbox → Analysis → Overlay → Intersect, and input the 2 layers as follows:



The intersection will only consider the selected areas in the 2 input layers. In other words, it will intersect only the high parts of the elevation layer and the bare rock parts of the land use land cover layer. Name the result something suitable, such as highbarerock and place it into an appropriate folder.

23) Zoom to the Haleakala volcano and state how the land in the layer “highbarerock” that is bare rock and high in elevation compares in location and total land area to either of the input layers.

You’re now on Step 4 in your diagram above. First, open the table for suitwestvector. Note the field gridcode. Gridcode contains attributes from your earlier work where you were determining the suitable slopes that faced west. If you intersect it now with the high bare rock layer, you’ll be considering ALL of the polygons in the suitable west vector layer, not just those that truly are suitable. Therefore, you need to first use Select By Attribute and select all of the areas in the table where gridcode == 1.

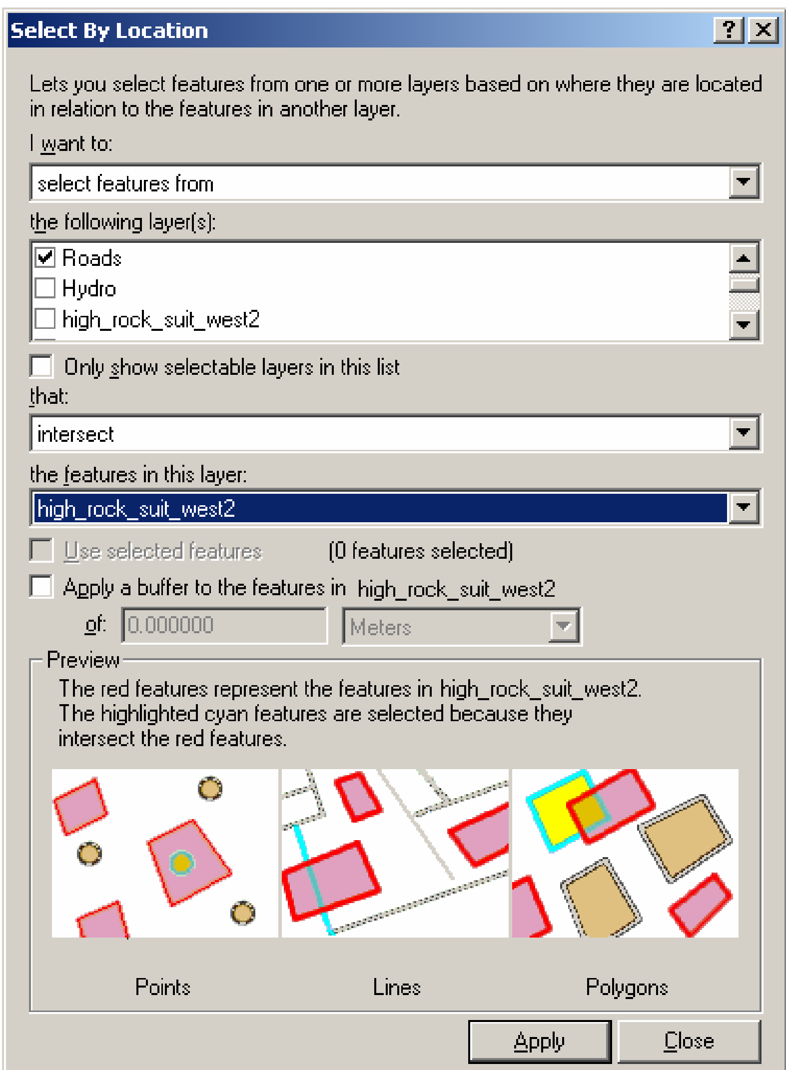
Now you're ready to use the Intersect command again, and this time, use highbarerock and suitwestvector as your input layers. Name your output layer high_rock_suit_west and place in the appropriate folder.

Zoom to Maui. Turn all layers off except the coastline of Maui and your high_rock_suit_west layer.

24) In what area of Maui are you considering for your lava sledding?

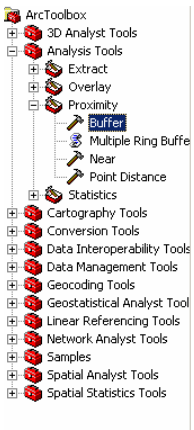
Turn on the roads layer. You might notice that this layer actually includes some lines that are not true roads, but rather, are trails.

Use Selection→ Select By Location as illustrated below to find roads and trails that intersect your land areas suitable for lava sledding:

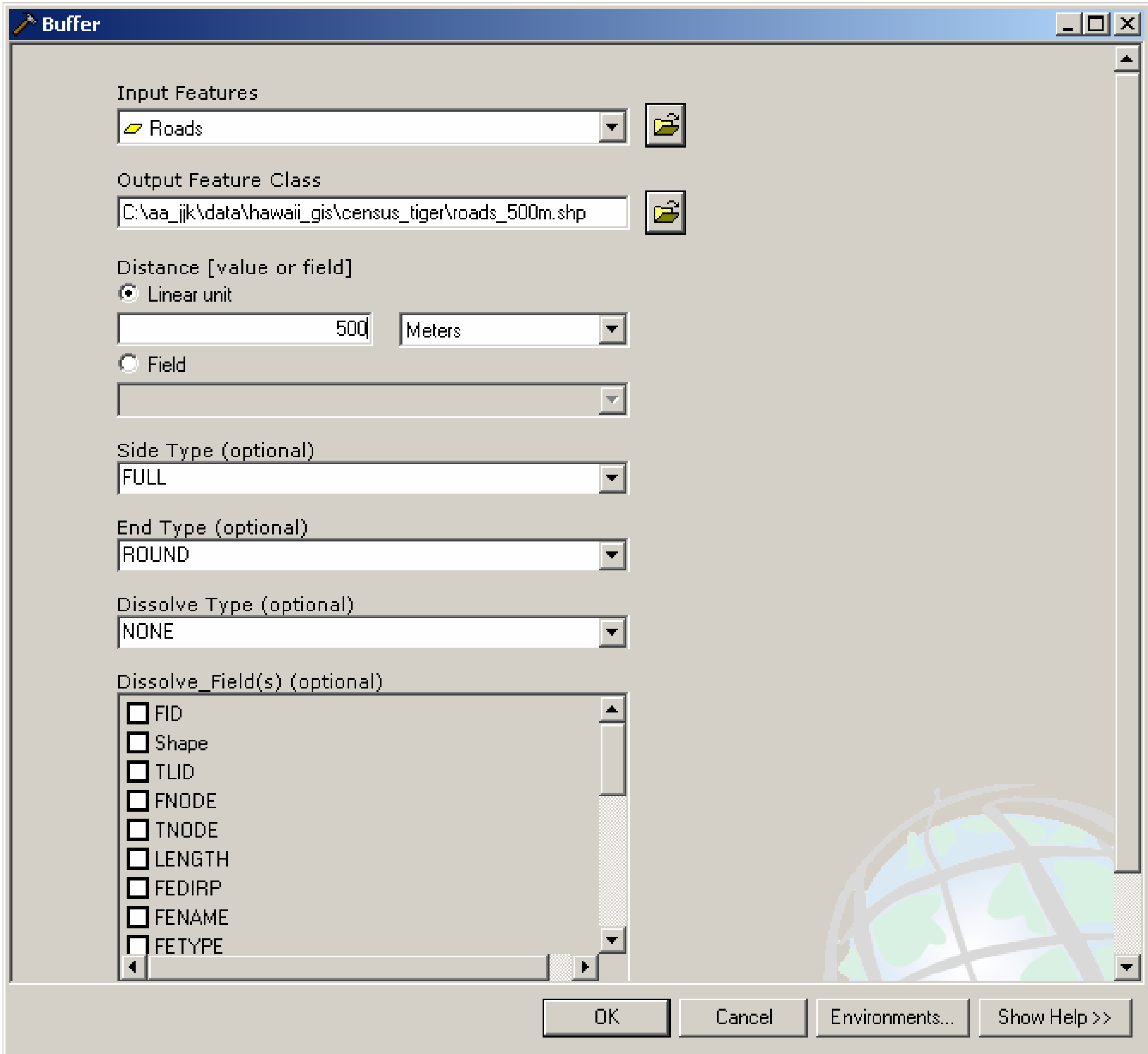


Next, you need to find the areas closer than 500 meters from the nearest road/trail by *buffering* the roads layer to this distance. The resulting areas will be within 500 meters from the nearest road.

Access ArcToolbox via the red toolbox button, and find the Buffer tool under Analysis→ Proximity→ Buffer, as indicated below:



Buffer the selected roads as indicated below to find all areas within 500 meters of the roads. Save your data as an "output feature class" in the folder indicated by your instructor and give it a logical name, such as roads_500m, in an appropriate data folder on your computer, as follows:



25) Describe your roads buffer map. Does it make sense? Why or why not?

Lastly, intersect your roads buffer with the suitable land. These are your final sites to consider for lava sledding.

26) Describe the pattern and location of these final sites.

27) What other data would be helpful to determine the best sites to go lava sledding?

28) Present the results of your investigations from this lesson to the class in a 5-minute oral report on where you have located the best sites to consider for lava sledding. Use the maps and data you have been studying in your presentation.