

Characterizing Landscapes for Visualization Through "Bump Mapping" and Spatial Analyst

"Bump mapping" is a term used in 3d raster graphics, which refers to perturbing an object's surface with textures and patterns. These perturbations or "bumps" add tremendous realism to the object and to the visualization by synthetically emulating the fine organic textures and modulated light and shadows found in nature. This same technique can be applied in a GIS setting to add realism and interest to a cartographic presentation. Detail attracts a reader's attention when looking at maps of landscapes. "Bump mapping" as a technique is clearly in the realm of "cartographic realism." The cartographic realism movement is predicated on the idea that you can incite greater geographic understanding in the mind of a map reader if you express landscape more "realistically." In the cartographic realism genre, landscapes features are shown as an image backdrop and are characterized using iconic symbols similar to what the viewer might see if he/she was looking at the real thing, but in a straight-down aerial context, say from an airplane. For example, a conifer forest might be symbolized as a series of sharp bumps colored dark green, crops might be symbolized as raised rows colored yellow and tan, cliffs might indicate abrupt jagged cubes colored dark brown and gray, and so on. The point being that with increased realism, at least in the mind of the map reader, complex landscapes can more easily interpreted and understood when they are symbolized with images that bring forward a memory of the object being shown. That being said, its easy to realize the importance of bump mapping as a tool in developing the proper characterization for a multitude of landscape classes that might be shown on a map.

INTRODUCTION

This paper presents a very simple example of "bump mapping" technique. Bump mapping, as applied in a mapping sense, is simply creating a "characterization image" of a landscape and then using it as a cartographic backdrop in a map. This characterization may be based on aerial imagery, classified imagery, oblique photography, or even the cartographer's personal knowledge of the area. ESRI's Spatial Analyst extension and ArcMap display system offer an excellent environment for developing maps in the cartographic realism genre. The Spatial Analyst extension offers the tremendous analytical and mathematical capabilities for building graphical enhancements to spatial data for mapping purposes. Using the display transparency in ArcMap makes it possible to control many different bump mapping and cartographic effects for just the right characterization.

The study area for the example used in this presentation is a portion of Kiger Gorge, Oregon. This particular landscape can be categorized in very simple terms. There are basically three elements in this presentation to be concerned with: 1) A steep-walled gorge of glacial origin with rocks, crags and strata, 2) distinctive patches of aspens and willows and 3) high desert patches of sagebrush and grasses. Other environmental elements are important, of course, but will not be emphasized graphically. Figure 1 below shows a traditional map of the area. Based on this graphic, one has no notion about the real make-up of this canyon. This presentation will step through building a "bump mapped" landscape backdrop for this are which will illustrate the advantages of the the technique.

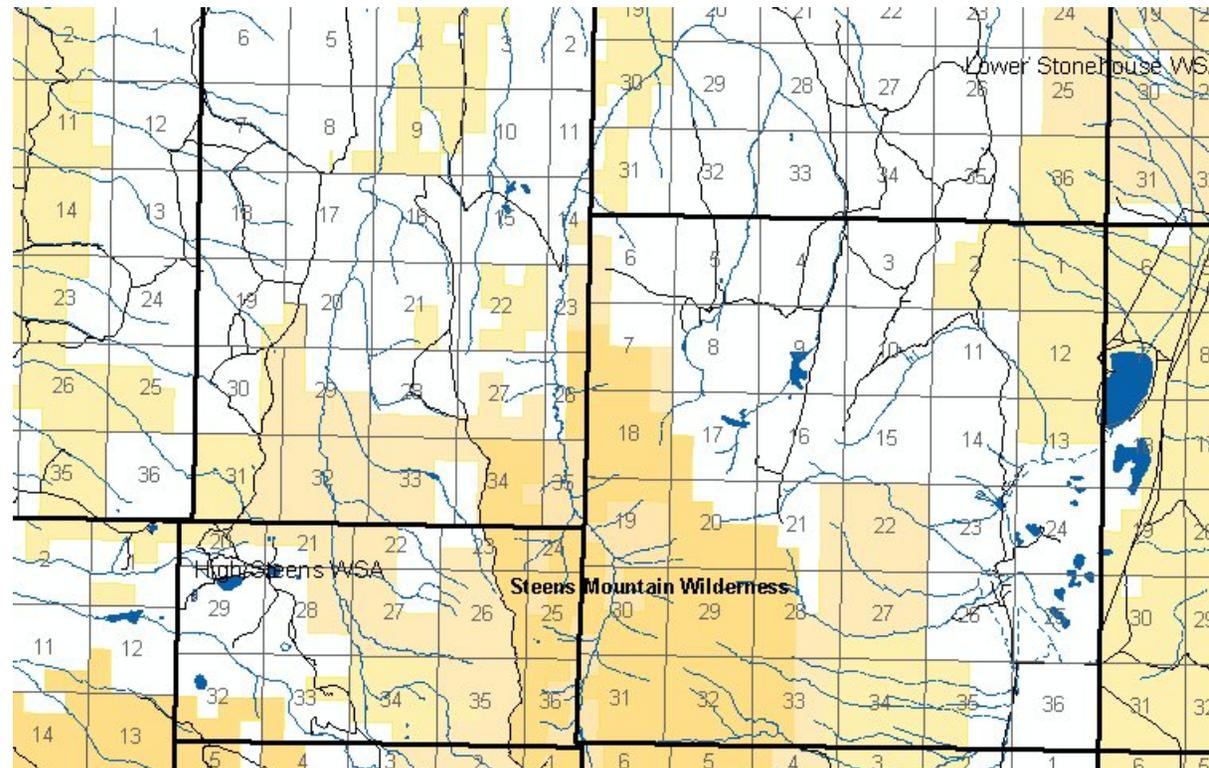


Figure 1. Small portion of Kiger Gorge, Oregon

Figure 2 is an actual photograph of Kiger Gorge taken in the same vicinity as Figure 1. Notice many of the land cover details, such as the aspen groves along the creek and the rock out-croppings on the steeper walls of the canyon. There is also snow and grass in the area. The question addressed in this paper and with these techniques is "How can these types of features be shown effectively on a map?"



Kiger Gorge

Figure 2. Photograph of Kiger Gorge, Oregon.

Developing a Landscape Characterization

Characterizing a landscape for a backdrop to a map created in the cartographic realism genre can be divided into two parts, first, establishing a terrain hillshade image and then superimposing a landcover characterization upon it.

Task 1. Establish a terrain base

The first task is very easy, given the vast amount and coverage of excellent elevation data and the modern software available. Generating hillshade map from elevation data is simple using Spatial Analyst. Simply load the Spatial Analyst extension, use the pulldown menu for analysis, select "Surface Analysis," then Hillshade, fill out the form and the program will generate the product. Based on elevation information and given sun angle, a gray scale backdrop can be created which gives the illusion of terrain. This is a popular technique and accepted method for terrain representation on traditional maps. It provides more information about the landscape than not, but there is room for additional information. Hillshade is a "map" of illumination Figure 3 shows the look of Kiger Gorge using traditional hillshade as a bump map.

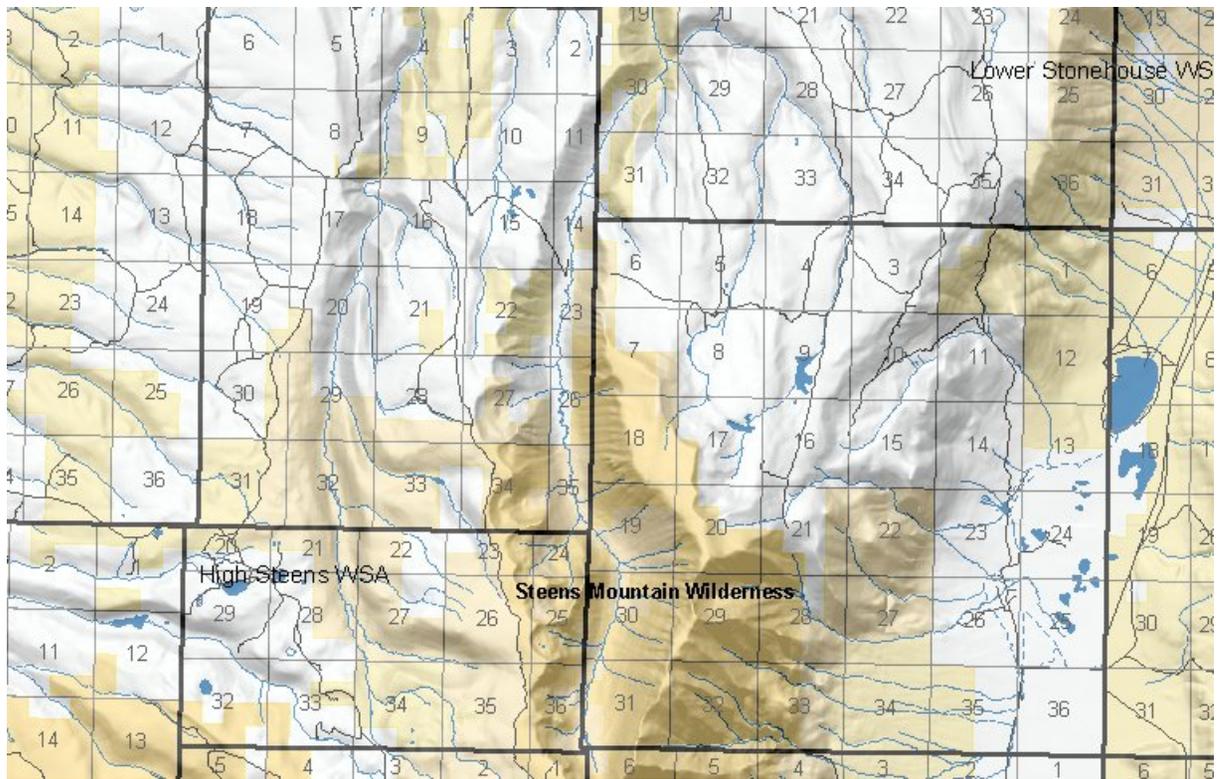


Figure 3. Small portion of Kiger Gorge, Oregon with a "hillshade" bump map.

Cartographers often use "painted relief" as a method to add realism to a map. Figure 4 shows the same area using an color ramp based on elevations and the bump mapped with hillshade. The effects are striking and dramatic, but are not indicative of the land cover or other landscape patterns. Figure 5 is an enlargement of the area that will be used in subsequent illustrations.



Figure 4. Small portion of Kiger Gorge, Oregon with a "hillshade" bump map and elevation color ramp.

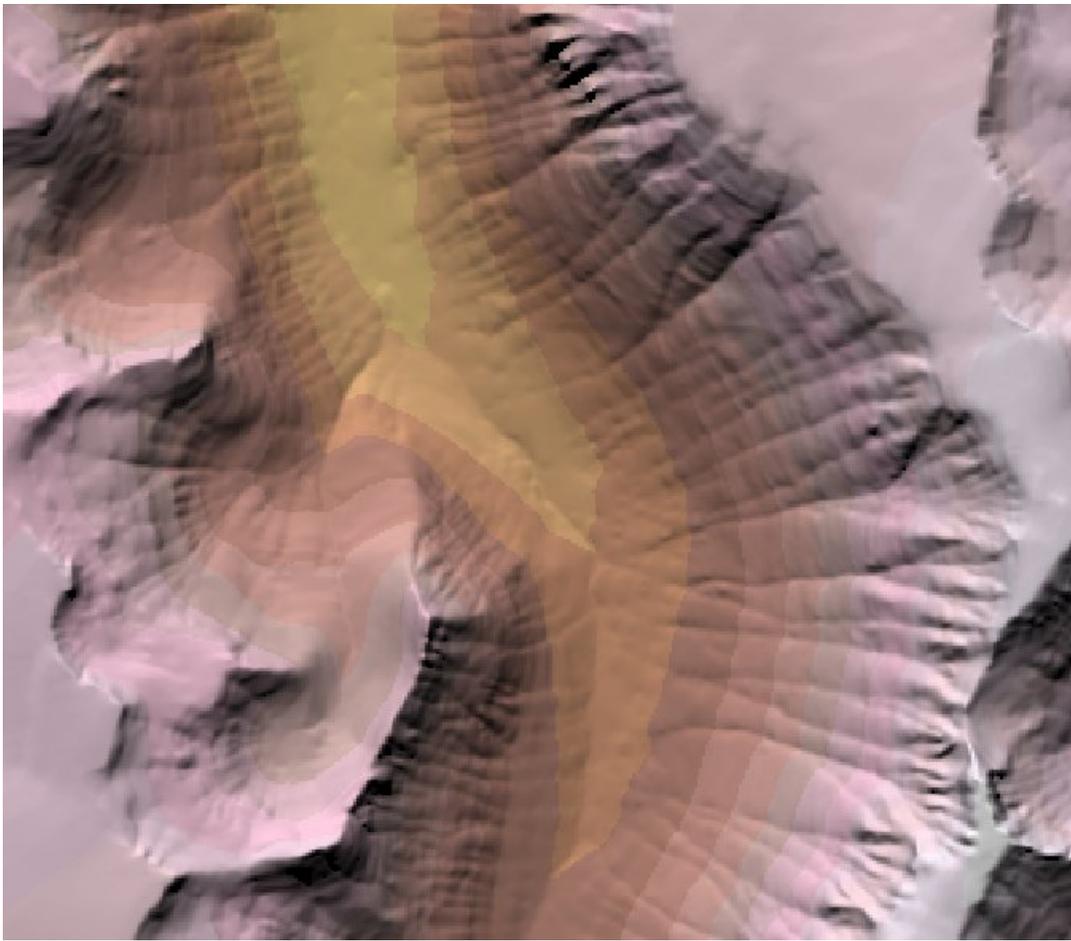


Figure 5. Enlarged area of Kiger Gorge, Oregon with a "hillshade" bump map and elevation color ramp.

Task 2. Building "Bumps" that represent Aspens and Willows

The second task is really several tasks leading to a landscape characterization. These steps are not nearly as easy as running the hillshade function. Characterizing land cover patterns and landscape objects relies on some basic understanding of the geography of an area as well as good sources of information. But, for purposes of explanation, there are three basic elements that come into play when characterizing landscapes: 1) class distribution; 2) class patterns and texture; and 3) class objects. Class distribution is the broad pattern land cover classes form upon the landscape. These distributions are frequently shown as polygons on land use or land cover maps, perhaps general vegetation maps. Within each land cover class, are the class patterns and textures. These patterns are indicative of how the objects that make-up a land cover class are placed on the surface. For example, aspen stands in the Kiger Gorge area are very dense and apparently random in their growth. A farmer's crops, in a nearby area, are planted in regular rows. Based on the general within class patterns and textures, one will find landscape objects, such as trees, shrubs, rocks, buildings, crops, etc. These are the things that form unique patterns and contribute to a distinctive environment and are mapped as a unique land cover class.

Step 1. Acquire Land Cover Class Distribution Map

The first step in developing a land cover characterization of course would be to develop or acquire a land cover classification of the area of interest. A suitable map of the Kiger Gorge area did not exist, so for purposes of this paper, a rudimentary image classification was performed on a USGS Digital Ortho Photo file (DOQ - Black and White, One Meter Resolution.) Since only three categories were of interest, this process was very simple. Dark areas (DOQ values < 50) along Kiger Creek were called Willows, dark areas (DOQ values < 50) on slopes < 20 percent were called aspens and mid-range gray areas on slopes < 15 percent were the Sagebrush/grass class. Each of these categories were isolated onto their own grid format file. Figure 6 illustrates a portion of the Aspens distribution file. This data was developed using the Spatial Analyst extension. The DOQ and slope data were loaded into ArcMap with the extension loaded, then the raster calculator menu was selected and the following command was typed into the calculator:

Aspens = con(DOQc1 < 50 and Kiger_slope < 20,1,0)

The program then outputs a grid format file where the cells met the criteria. Figure 7 shows the Raster Calculator in Spatial Analyst.

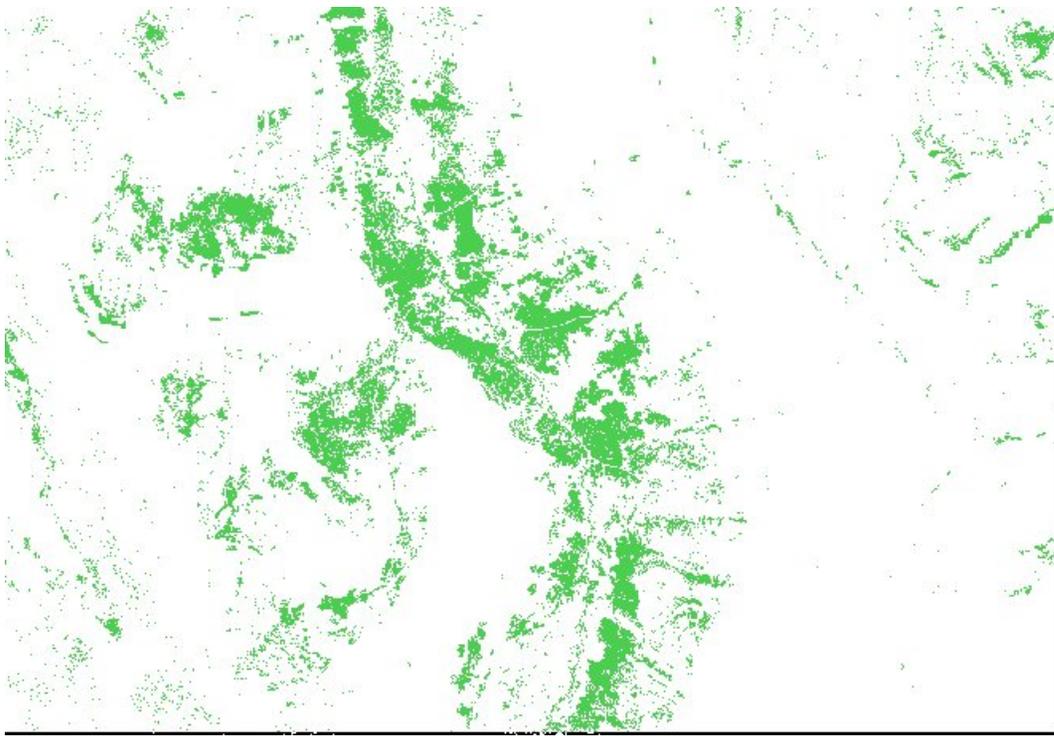


Figure 6. Small portion of Kiger Gorge, Oregon show distribution of Aspens (Green) land cover class.

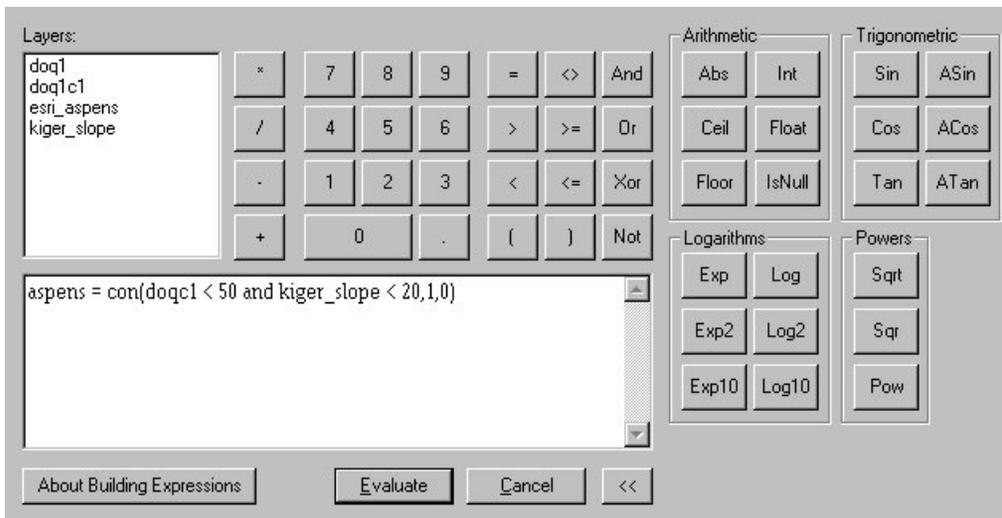


Figure 7. Example of Spatial Analyst's Raster Calculator.

Step 2. Develop Class Pattern and Texture Method for each Land Cover Class Distribution

As stated previously, each Land cover class has unique characteristics which separate it from other classes. In the case of characterizing the Aspen stands in the Kiger Gorge area, the trees are organized in dense stands with a few openings. The placement of each tree appears to be fairly random as opposed to a regular pattern of rows and columns. The mathematical capabilities of Spatial Analyst provide the capability to create and develop patterns which can meet these and other criteria. Using the raster calculator, commands can be given which can provide the ability to adjust the spacing, size and "randomness" of the pattern. Figures 8,9,10 show examples of different

patterns created through the raster calculator. The command used to build the pattern is part of the caption.

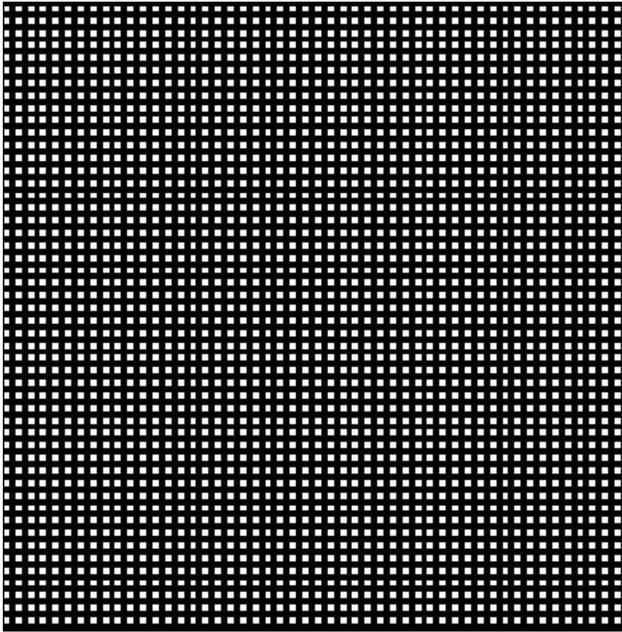


Figure 8. Spatial Analyst command to create a point every 10 meters of X and Y with a no randomness (Standard Deviation of 0) and creating a rectangle that is 5 by 5 cells:

```
pattern = focalmax(con( ($rowmap mod int(normal() * 0 + 10) eq 0)and ($colmap mod int(normal() * 0 + 10) eq 0),255,0),rectangle,5,5)
```

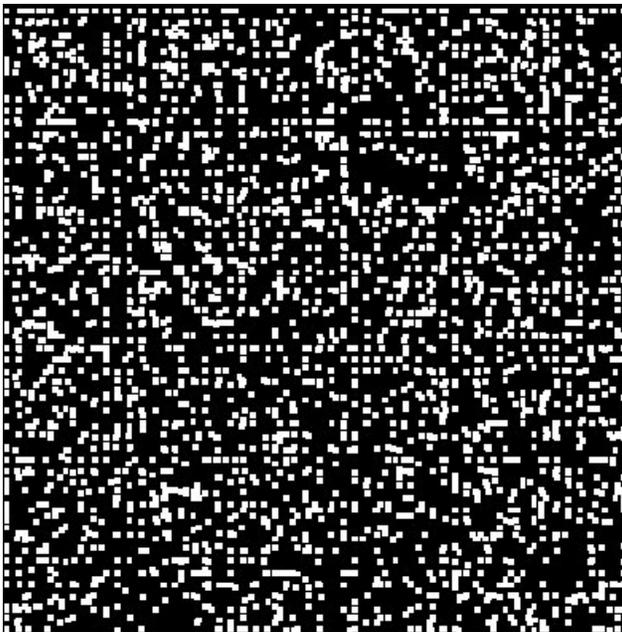


Figure 9. Spatial Analyst command to create a point every 10 meters of X and Y with a randomness of 1 (Standard Deviation of 1) and creating a rectangle that is 5 by 5 cells:

```
pattern = focalmax(con( ($rowmap mod int(normal() * 1 + 10) eq 0)and ($colmap mod int(normal() * 1 + 10) eq 0),255,0),rectangle,5,5)
```

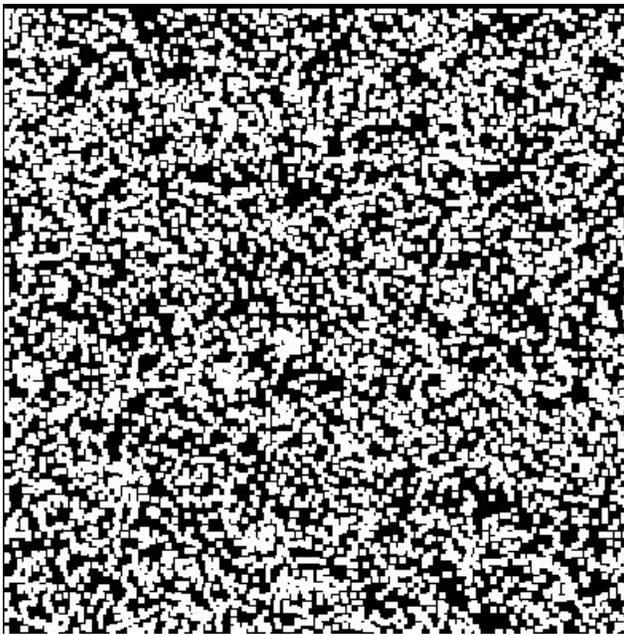


Figure 10. Spatial Analyst command to create a point every 10 meters of X and Y with a randomness of 10 (Standard Deviation of 10) and creating a rectangle that is 5 by 5 cells:

```
pattern = focalmax(con( ($rowmap mod int(normal() * 10 + 10) eq 0)and ($colmap mod int(normal() * 10 + 10) eq 0),255,0),rectangle,5,5)
```

These commands use the built-in spatial analyst variables "\$rowmap and \$colmap" to specify which rows and columns will have values, while the focalmax commands expands these values into 5x5 cell rectangles. Using this functionality, which very simple, almost an infinite variety of patterns can be created, though it may take some experimentation to find just the right pattern.

Step 3. Construct "kernals" to represent landscape objects

Once the class distribution and the pattern for a particular land cover class has been established, the next step is to build an object that characterizes the make-up of that class. In our example which uses aspens, a round shape or hemisphere is appropriate, aspens are essentially spherical when seen from the "map view". Constructing this kernal is also possible using Spatial Analyst, as well as many other simple shapes. The trick to building a hemisphere is to utilize the euclidean distance function of spatial analyst, then use the pythagorean theorem to build the sphere. This process takes two commands to create the final output and is shown in Figure 11. Commands for creating two other shapes, a cone and a cube, are given in figures 12, and 13.

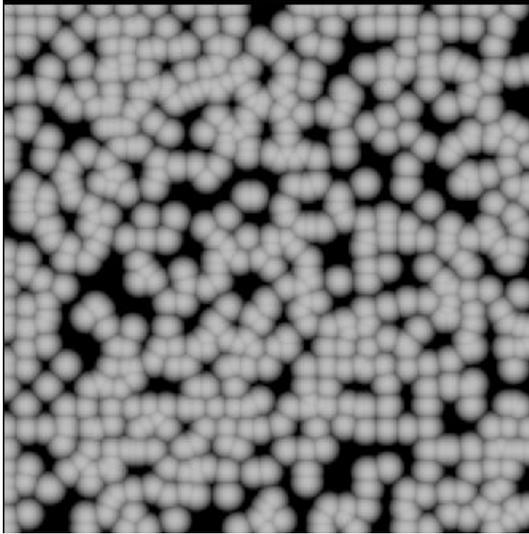


Figure 11. Spatial Analyst command to create a point every 20 meters of X and Y with a randomness of (Standard Deviation of 1) and creating a hemisphere that has a radius of 10 meters:

```
pattern = eucdistance(con(~ ($rowmap mod int(normal() * 1 + 20) eq 0)and ~ ($colmap mod int(normal() * 1 + 20) eq 0),255),##,10,##)
```

The second commands converts a distance grid to hemispherical shapes.

```
spheres = sqrt(pow(10,2) - pow(pattern,2))
```

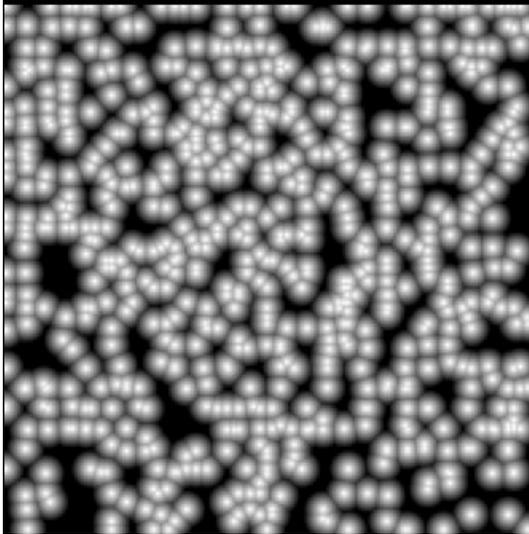


Figure 12. Spatial Analyst command to create a point every 20 meters of X and Y with a randomness of (Standard Deviation of 1) and creating a cone that has a radius of 10 and height of 40 meters:

```
pattern = abs(eucdistance(con( ($rowmap mod int(normal() * 1 + 20) eq 0)and ($colmap mod int(normal() * 1 + 20) eq 0),255),##,10,##)- 10) * (40 / 10)
```

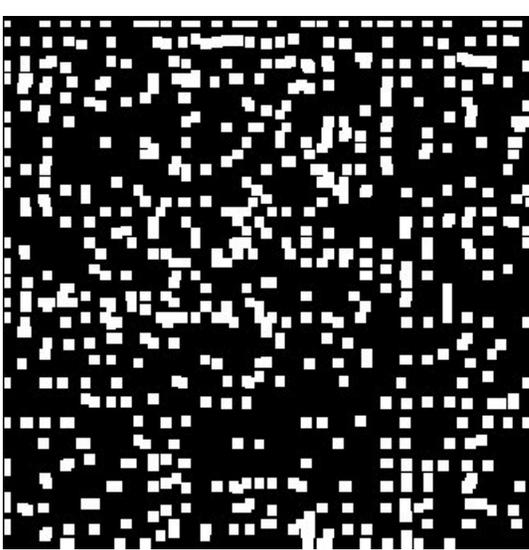
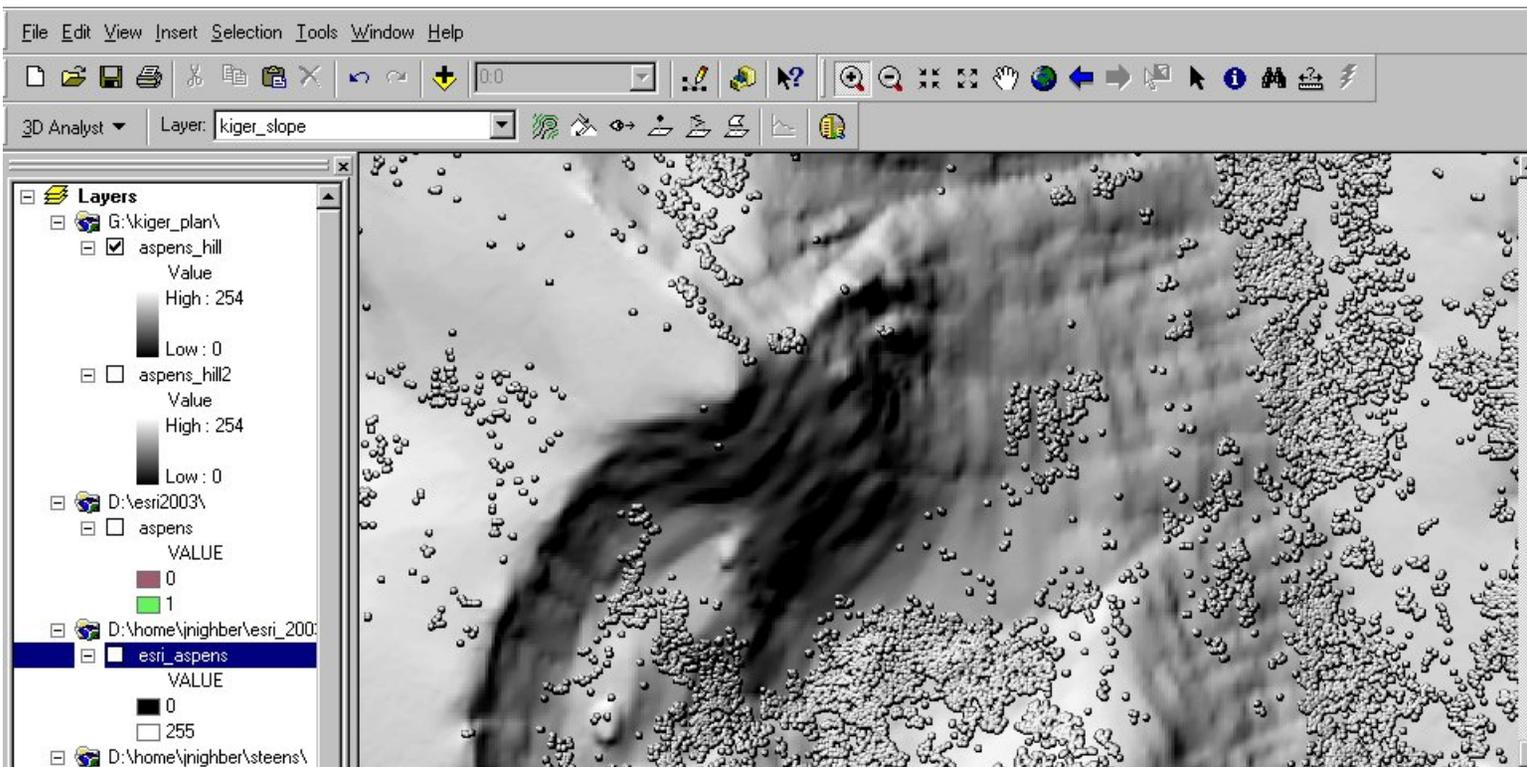


Figure 13. Spatial Analyst command to create a point every 20 meters of X and Y with a randomness of (Standard Deviation of 1) and creating a 10 meter cube:

*pattern = focalmax(con(~ \$\$rowmap mod int(normal() * 1 + 20) eq 0 and ~ \$\$colmap mod int(normal() * 1 + 20) eq 0,1,0),~ rectangle,10,10) * 10*

Step 3. Combining Pattern and Kernal Grids with Distribution grids and Elevation data

Now that the distribution, pattern and kernal types have been determined, it is time to add them to the elevation surface and create a bump-mapped hillshade which can be combined transparently with colors in Arcmap. This can be also accomplished with the Raster Calculator. You can use a combination of commands for this process, including the hillshade function. The aspen pattern was generated using a 12 meter xy spacing with randomness of 1 and a 8 meter radius hemispherical kernal.



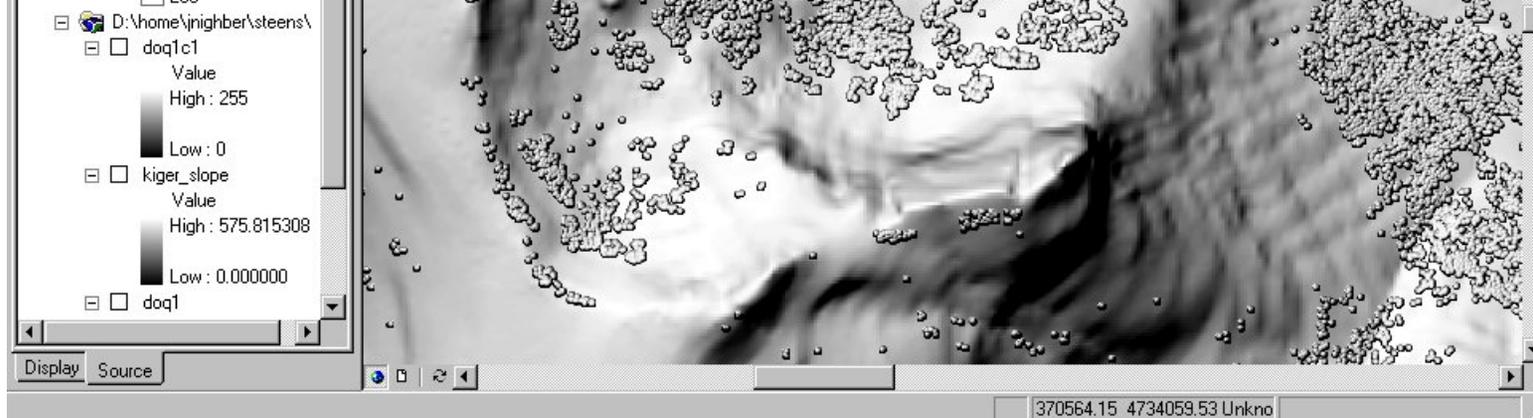
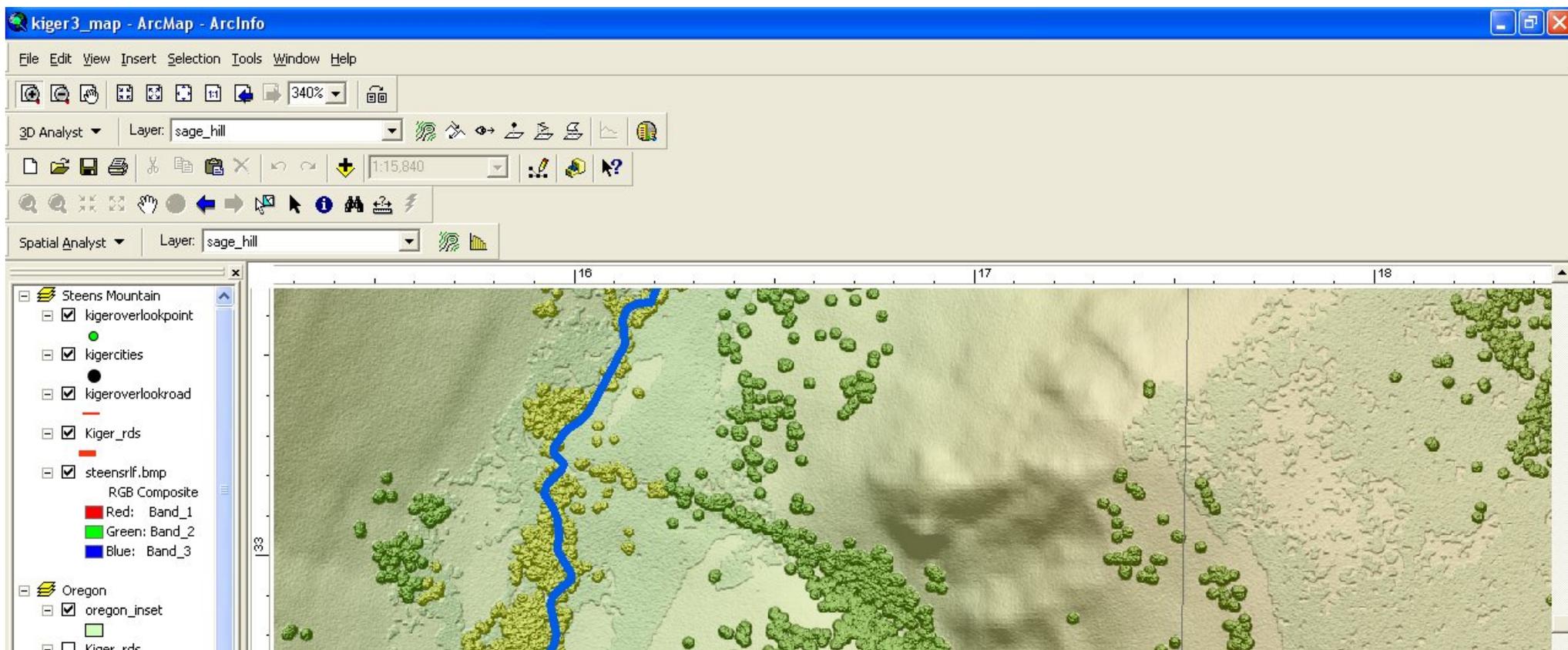


Figure 14. This is a screen shot from Arcmap which shows a hillshade of the aspen distribution and the spherical kernals using the specified pattern. The Spatial Analyst command used to combine kernal-ized pattern with elevation data and create a hillshade image:

esri_aspens = hillshade(con(isnull(esri_aspens,elevation,elevation + pattern),345,65)

Step 4. Adding color and other map elements.

Now that the bumped hillshade has been created, it time for the final steps of adding color and additional land cover classes, coloration and incorporation into a final map as a backdrop. Add the final hillshade map, once all the land cover classes have been added to ArcMap. Assign it a 50 percent transparency and display it last in the stack. Add each of the land cover types (the kernal-ized patterned data) and assign the entire theme a single color, such as green for aspens and display them before the hillshade in the stack. Add an elevation map and choose any of the earth-toned pastel color ramps available in ArcMap style sets. Display this last in the stack with 50 percent transparency. Now you have a land cover map with a realistic flair. Figures 15,16 and 17 are actual screen shots of portions of the Kiger Gorge map.



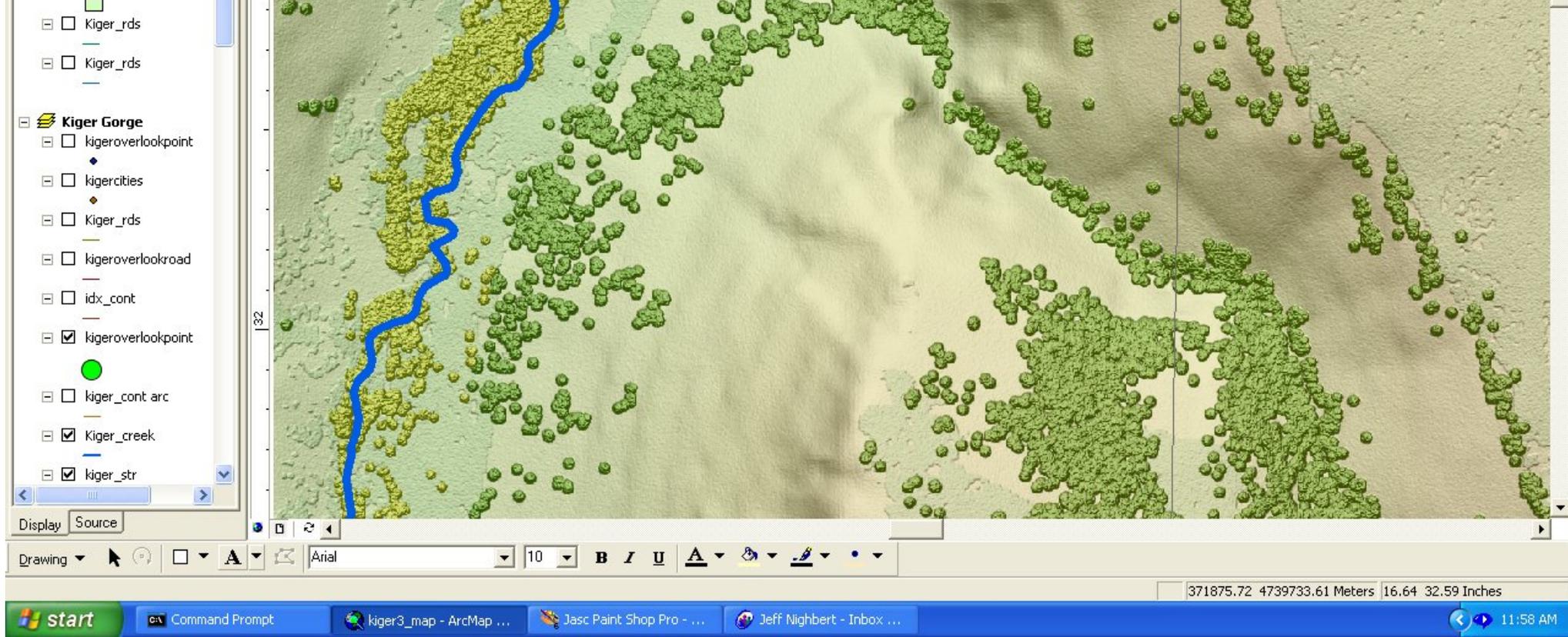


Figure 15. Enlargement of a portion of Kiger Gorge. Showing bump mapped aspens.

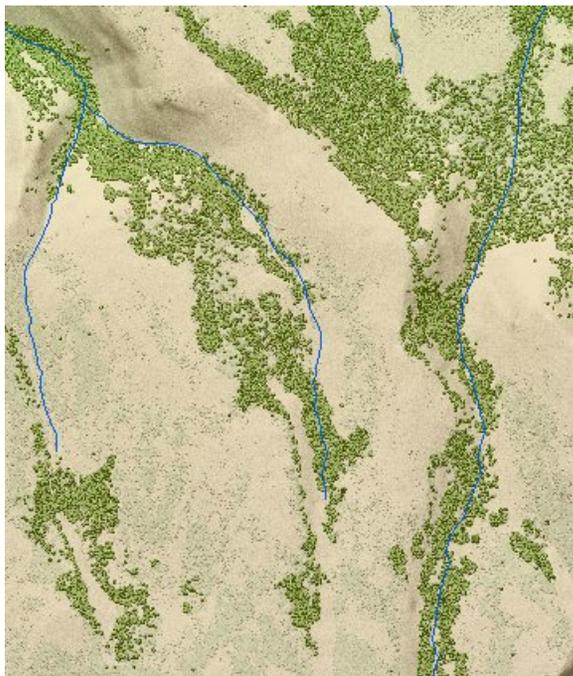


Figure 16. Enlargement of a portion of Kiger Gorge. Showing bump mapped aspens.

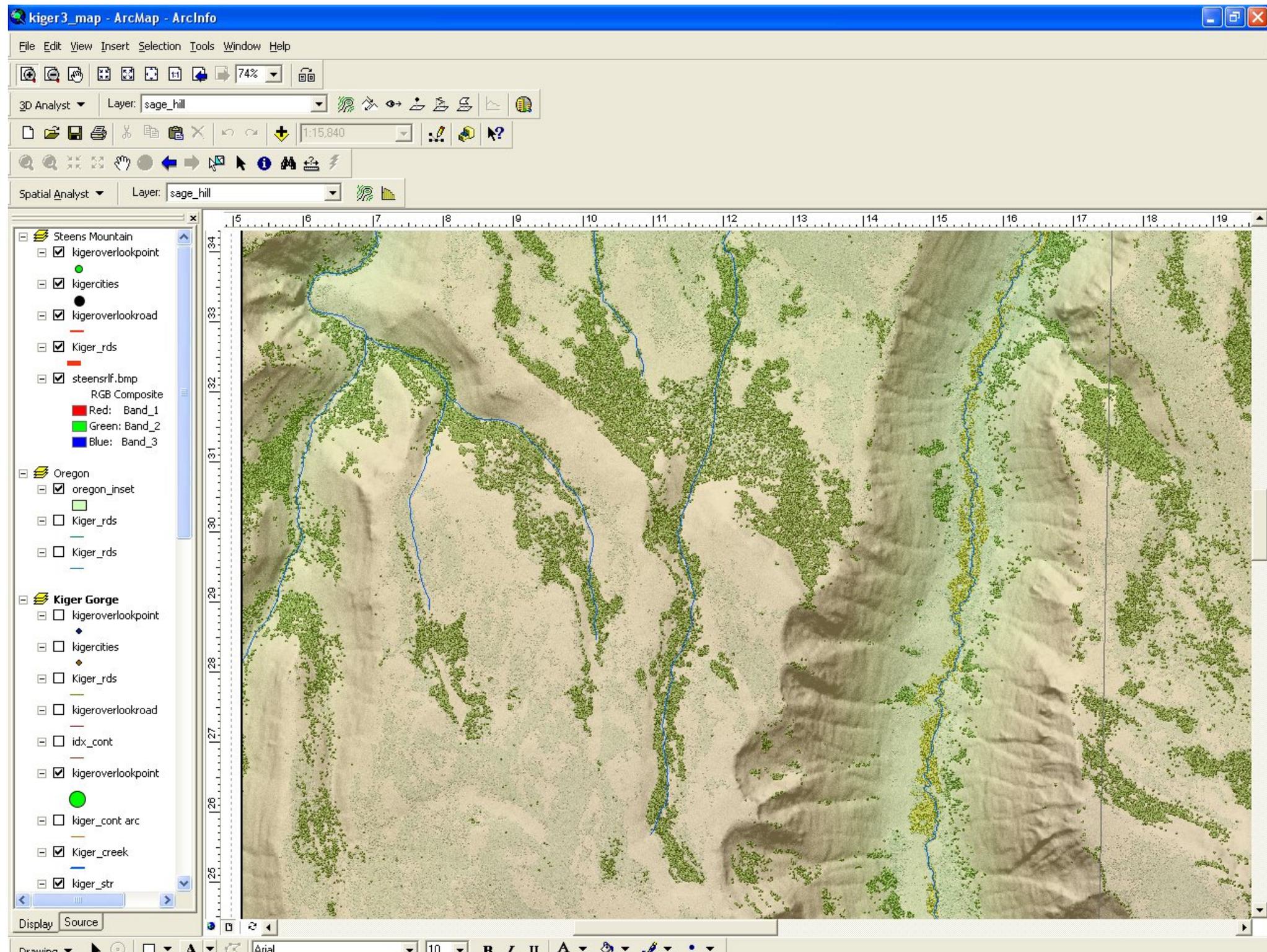




Figure 17. Enlargement of a portion of Kiger Gorge. Showing bump mapped aspens.

CONCLUSIONS

The above example demonstrates one method of applying materials and texture to create maps in the "cartographic realism genre.". It illustrates that new technology provides cartographers options for creating richer and more interesting cartographic products. With this technology, more realistic and informational maps can be designed, more complex geography can be communicated and maps can be of better service to everyone.

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One of the fundamental problems in creating realistic bumps for a particular land cover type is finding an adequate source of information. Often times land cover maps are polygon based and lack sufficient detail for realistic bump mapping. Photographic sources, such as Digital Orthophoto quads or scanned ortho-rectified photography are an excellent source for bump patterns but present a number of challenges for use: 1) shadowing, shadows on photo products will not match the traditional northwest lighting cartographers use, 2) too much detail, information from photos is unsorted and pulling out the correct informations may take a lot of additional work, and 3) photo artifacts, photos from different lighting schemes cause unwanted variations in tonal and content quality. Probably the best source for bump mapping would be classified imagery at sufficient detail to match the desired cartographic scale. Classification of imagery often removes shadowing and tonal artifacts from the source. It also sorts the information into extractable layers, yet it remains raster based, so it can be easily adapted to bump mapping methods. For this demonstration, a simple land cover classification was performed using Digital Orthophotos and Landsat TM satellite information of the area. Based on field accounts of the area and apriori knowledge, interpretation of the DOQ was simple, but needed refinement. On DOQs of the area, aspens and willow patches can be seen in the darker tones of the images. Unfortunately, rock, cliff faces and shadows also take on those values. DOQs are very poor spectrally, so additional information was needed to extract the desired aspen and willow stands. Fortunately, Landsat imagery was also available for the area. Using a simple correlation model, which used both types of imagery it was possible to extract these stands. Basically all areas on the DOQ which were darker than 1 standard deviation less than the mean was compared to all areas greater than the mean on landsat Band 4. The results were that most of the confusion between rock, shadow and aspens was resolved and an aspen layer was created. Spatial analyst was used in this process. Oregon. Seven land cover categories were mapped for the area: Water, Snow, Barren, Grass, Shrub, and Lava. Simplicity was maintained for this demonstration. In actual practice more elaborate schemes would probably be used. The graphic below shows only a small portion of the entire study area