EXERCISE 5: SURFACE CREATION AND ANALYSIS TECHNIQUES

This exercise introduces you to the different surface interpolation techniques available in ArcGIS Spatial Analyst. You will also work with the Density tool for finding point and line density.

STEP 1: USE IDW INTERPOLATION

IDW interpolates by giving greater weight to the sample points closest to the cell, whose value is being interpolated. As the distance between input point and cell increases, the significance of the sample decreases.

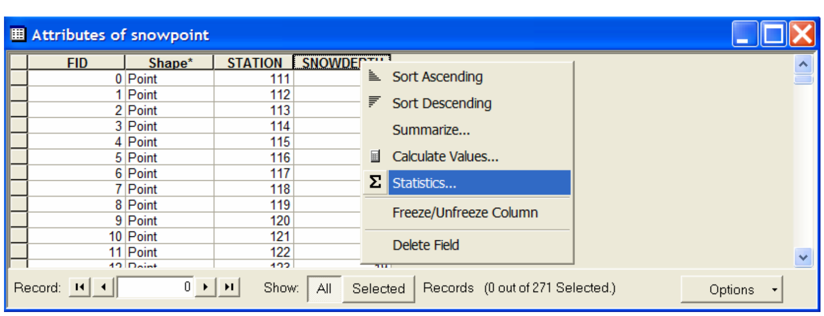
IDW will not interpolate values beyond the vertical extremes of the provided samples (e.g., it cannot find ridges or valleys if they are not represented in the sample set). The best results are obtained with dense sampling.

☐ Start ArcMap with A new empty map.
☐ Open the Arc Toolbox window, if necessary.
☐ Add the following layers to the map from your… \Exercise07 folder:
• *arlandmask.lyr*: Raster land/water mask for the study area
• *snowpoint.lyr*: Point features of snow depth samples in inches
☐ Expand the legend for *snowpoint*.
☐ *Right-click* in the ArcToolbox panel and click *Environments*.

Set these Environment Settings:
☐ Current Workspace: *\Exercise07*
☐ Scratch Workspace: *\Exercise07*
☐ Output Extent: Same as Layer ‘arlandmask”
☐ Cell Size: Same as Layer “arlandmask”
☐ Analysis Mask: arlandmask

☐ *Right-click* snowpoint and click *Open Attribute Table*.

The SNOWDEPTH field contains measures of average snow depth for each of the 271 sample points. You will use this field for your interpolation to create a surface of snow depth across the study area.



□ Right-click the column heading for the *SNOWDEPTH* field and click *Statistics*.

Notice that the minimum snow depth ranges from 0 to 28 inches, and the average snow depth is about 12 inches.

□ Close the *Statistics* of *snowpoint* window.
□ Close the *Attributes* of *snowpoint* table.

NOTE: The best results from IDW are obtained when sampling is sufficiently dense with regard to the local variation you are attempting to simulate. If the sampling of input points is sparse or very uneven, the results may not sufficiently represent the desired surface

□ *Run ... > Interpolation> IDW:*
□ Input point features: select *snowpoint*
□ Z value field: **SNOWDEPTH**
□ Output raster: type **IDW1**.
□ Power:**2**
□ Search radius: select *Variable*
□ Search radius settings:
□ Number of points: **12**
□ Accept the default for *Maximum distance*
□ Accept the default for *Input barrier polyline features*

Note: IDW lets the user control the significance of known points upon the interpolated values, based upon their distance from the output point. By defining a higher (power} option, more emphasis can he put onto the nearest points. Thus, nearby data will have the most influence, and the surface will have more detail (be less smooth). Specifying a lower value for power will provide a bit more influence to those surrounding points, which are a little farther. The power is a positive, real number. A common value is 2.

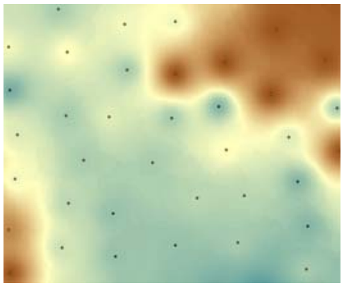
Both IDW and Kriging have the capacity to set a variable or fixed search radius. Using a variable search radius, you can specify the number of points to use when calculating the value of the interpolated cell. This makes the search radius variable for each interpolated cell, depending on how far it has to stretch to reach the specified number of input points.

With a fixed radius, the radius of the circle used to find input points is the same for each interpolated cell. The default radius is five times the cell size of the output grid. By specifying a minimum number of points, you can ensure that, within the fixed radius, at least a minimum number of input points will be used in the calculation of each interpolated cell.

Notice that the maximum and minimum values in the interpolated surface only occur at sample points.

☐ Right-click the *IDW1* layer and click *Properties*.

☐ Click the Source tab and review the *Statistics*.



Question 1: What is the significance of the minimum and maximum value?

The surface calculated using IDW depends on the selection of a power value and the neighborhood search strategy. The output surface is sensitive to clustering and the presence of outliers. IDW assumes that the surface is being driven by the local variation, which can be captured through the neighborhood.

☐ Click *Cancel*.

☐ Close the legends for *IDW1* and *arlandmask*.

STEP 2: USE SPLINE INTERPOLATION

The Spline interpolation deploys a 2-dimensional spline interpolation and is also known as a minimum-curvature spline interpolation. It results in a smooth surface that passes through all the sample points.

Generally, the greater the number of sample points included in the interpolation, the smoother the surface, The surface must have minimum curvature or "the cumulative sum of the squares of the second derivative terms of the surface, taken over each point on the surface, must be a minimum".

There are two forms of spline procedure: Regularized and Tension. The Regularized method creates a smooth, gradually changing surface with values that may lie outside the sample data range. The Tension method tunes the stiffness of the surface according to the character of the modeled phenomenon. It creates a less-smooth surface with values more closely constrained by the sample data range.

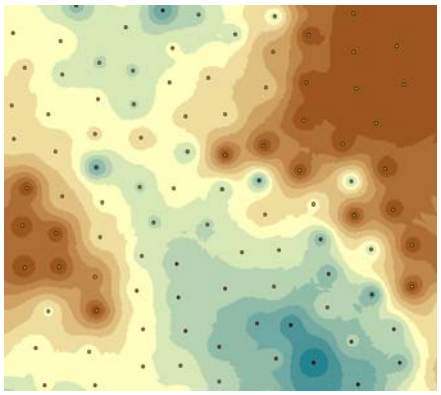
Let us investigate the spline interpolation method by using a Regularized spline.

NOTE: When using the REGULARIZED option, higher values used for the Weight parameter produce smoother surfaces. The values entered for this parameter must be equal to or greater than zero. The typical values that may be used are 0, .001, .01, .1, and .5.

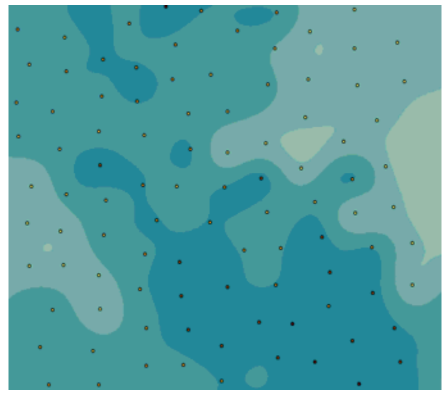
☐ *Run ... > Interpolation> Spline:*

- □ Input point features: select *snowpoint*
- □ Z value field: *SNOWDEPTH*
- □ Output raster: type **spline1req**
- □ Output cell size: **30**
- □ Spline type: *Regularized*
- □ Weight: **0.1**
- □ Number of points: **12**

- □ Turn the *spline1reg* layer off and on several times to compare it with the IDW interpolation.



IDW



Spline

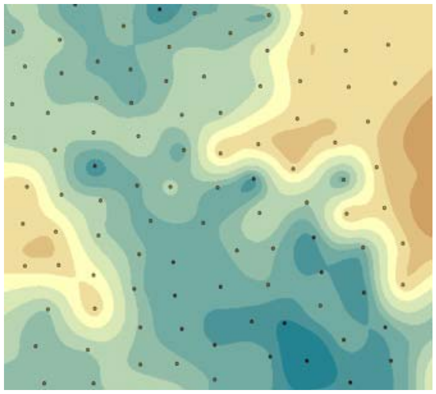
- □ Close the legend for *spline1reg*.

Next, you will use the Tension spline interpolation method.

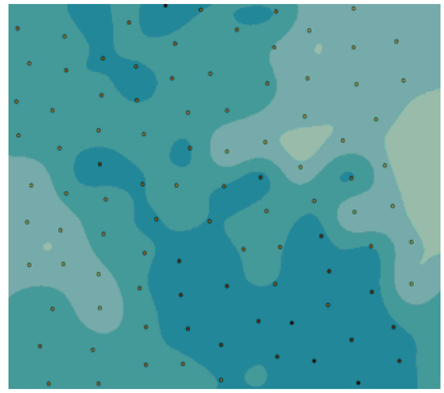
NOTE: When using the TENSION option, higher values entered for the Weight parameter result in somewhat coarser surfaces but surfaces that closely conform to the control points. The values entered have to be equal to or greater than zero. The typical values are 0, 1, 5, and 10.

- □ *Run ... > Interpolation> Spline:*
- □ Input point features: select *snowpoint*
- □ Z value field: *SNOWDEPTH*
- □ Output raster: type **spline2ten**
- □ Spline type: *tension*
- □ Weight: **0.1**
- □ Number of points: **12**

- □ Turn the *spline2ten* layer off and on several times to compare it with the regularized Spline



Tension Spline



Regularized Spline

☐ Close the legend for *spline2ten*.

STEP 3: USE KRIGING INTERPOLATION

Kriging is the most powerful and sophisticated raster interpolator. It requires advanced knowledge to use properly. Like all raster interpolators, it is employed iteratively, varying its parameters until the statistical 'best fit' has been found for the data. Two Kriging methods are available in ArcGIS Spatial Analyst: Ordinary and Universal. Ordinary Kriging is the most general and widely used Kriging method, and it is the default method. It assumes the constant mean is unknown (a reasonable assumption unless there is some scientific reason to reject this assumption).

Universal Kriging assumes that there is an overriding trend in the data (e.g., a prevailing wind), and it can be modeled by a deterministic function: a polynomial. This polynomial is subtracted from the original measured points, and the autocorrelation is modeled from the random errors. Once the model is fit to the random errors, before making a prediction, the polynomial is added back to the predictions to give you meaningful results. Universal Kriging should only be used when you know there is a trend in your data and you can give scientific justification to describe it.

Kriging is a very processor-intensive process. The speed of execution is dependent on the number of points in the inpnt dataset and the size of the search window.

This exercise does not attempt to teach you the details of Kriging; they are too complex for this course. Instead, you will learn how to use the Kriging tools. The online documentation contains more information on Kriging, including references for further research.

☐ *Run ... > Interpolation> Kriging:*
☐ Input point features: select *snowpoint*
☐ Z value field: *SNOWDEPTH*
☐ Output surface raster: type **krige_univ**
☐ Semi variogram properties:
  - Kriging method: check *Universal*

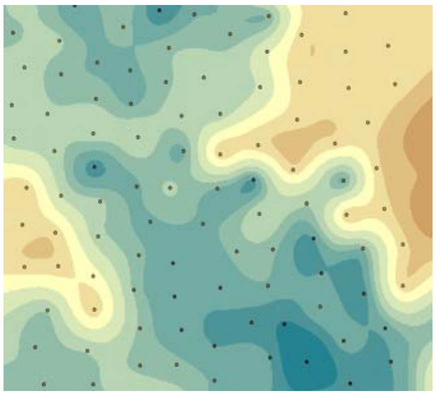
  - Semi variogram model: *Linear with linear drift*
  - Accept the default for Advanced options
- ☐ Output cell size: **30**
- ☐ Search radius: *Variable*
- ☐ Search radius settings:
- ☐ Number of points: **12**
  - Accept the default for Maximum distance
- ☐ Accept the default for *Output variance of prediction raster*

Notice that Kriging did not honor the mask (*arlandmask*) you set earlier and interpolated within the masked-out lakes. The next step uses Map Algebra to force the masked areas to be set to *NoData*.

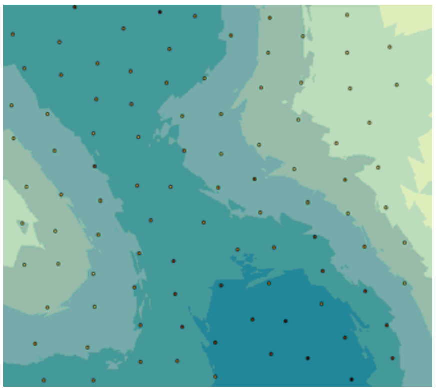
- ☐ *Run ... > Map Algebra > Single Output Map Algebra:*
- ☐ Map Algebra expre**ssion: type krige_univ**
- ☐ **Output raster: type krige_univ1**

This expression really just copies krige_univ to krige_univl, but since there is a processing mask in effect, all the masked-out cells are set to NoData in the output.

- ☐ Remove the *krige_univ* layer from your map.
- ☐ *Right-click* on the *krige_univ1* layer and click *Properties*.
- ☐ Click the Symbology tab.
- ☐ Set the renderer to *Classified*, using the *Equal Interval* method and **9** classes.
- ☐ Set the color ramp to *Surface* and close the *Layer Properties* dialog.
- ☐ Turn krige_univ1 off and on to compare it with spline2ten.



Tension Spline



Linear Drift Universal Kriging

As you have just observed, kriging is a complex procedure that requires greater knowledge about spatial statistics than can be conveyed in this exercise. Before using Kriging, you should have a thorough understanding of the fundamentals of kriging and have assessed the appropriateness of your data for modeling with this technique. If you do not have a good understanding of this procedure, it is strongly recommended that you review some additional references; some of these are given below.

Burrough, P.A. Principles of Geographical Information Systems for Land Resources Assessment. New York: Oxford University Press, 1986.

Heine, G.W. ‘A Controlled Study of Some Two-Dimensional lnterpoation Methods’. COGS Computer Contributions, Vol. 3, No. 2, 60- 72, 1986.

McBratney, A.B., and Webster, R. ‘Choosing Functions for Semivariograms of Soil Properties and Fitting Them to Sampling Estimates’. Journal of Soil Science, 37, 617-639, 1986.

Oliver, M.A. Kriging: ‘A Method of Interpolation for Geographical Information Systems’. International Journal of Geographic Information Systems, Vol.4, No.A 4, 313 -332, 1990.

Press, W.H. et al., Numerical Recipes in C, The Art of Scientific Computing. New York: Cambridge University Press, 1988.

Royle, A.G., Clausen F.L., and Frederiksen, P. ‘Practical Universal Kriging and Automatic Contouring’. Geoprocessing, 1, 377 -394,

STEP 4: EXPLORING NATURAL NEIGHBOR INTERPOLATION

The basic equation used in Natural Neighbor interpolation is identical to the one used in IDW interpolation. The difference between IDW interpolation and Natural Neighbor interpolation is the method used to compute the weights and the method used to select the subset of scatter points used for interpolation. Natural Neighbor interpolation employs a Thiessen polygon network of the scatter point set. The Thiessen polygon network is constructed from the Delauney triangulation of a scatter point set.

Natural Neighbor can efficiently handle large numbers of input points. Other interpolators may have difficulty with large point datasets Now investigate the interpolator and compare and contrast the results you obtain with those of other interpolators.

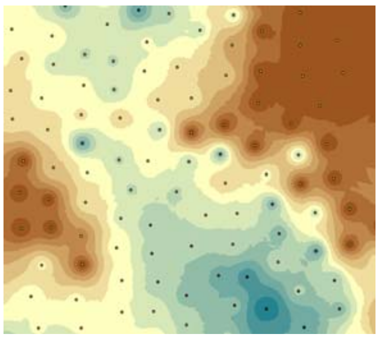
- □ *Run .. > Interpolation> Natural Neighbor:*
- □ Input point features: select *snowpoint*
- □ Z value field: *SNOWDEPTH*
- □ Output raster: type *natural1*

Notice that the natural neighbor interpolator creates a convex hull for the Thiessen polygons used to select the subset of sample points used to interpolate your new output cell values. This hull did not honor the mask (arlandmask) you set earlier and interpolated new cell values within the hull area. In the next step, you will use Map Algebra to enforce the mask.

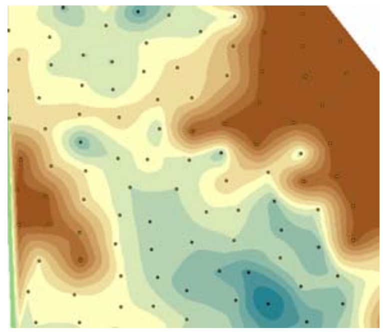
- ☐ *Run ... > Map Algebra > Single Output Map Algebra:*
  - Map Algebra expression: type **natural1**
  - Output raster: type **natural2**
- ☐ Right-click on the *natural2* layer and click *Properties*.
- ☐ Click the *Symbology* tab.
- ☐ Set the renderer to *Classified*, using the *Equal Interval* method and **9** classes.

- ☐ Set the *color ramp* to *Surface* and close the *Layer Properties* dialog.

- ☐ Turn off all layers except *natural2* and *idw1*



Inverse Distance Weighted



Natural Neighbors

- ☐ Turn *natural2* on and off to compare it with *idw1*.

All of the interpolators you have used in this exercise thus far can be used to interpolate almost any value that may be of significance to you. These could be values of population or statistical values. What you need to keep in mind is that none of these interpolators have been written to specifically interpolate surfaces. In a later exercise on hydrology, you will be using the Topo to Raster tool to interpolate a hydrologically correct surface from point, line, and polygon data.

NOTE: The Topo to Raster interpolation procedure has been designed to take advantage of many types of input data commonly available and the known characteristics of elevation surfaces. This method uses an iterative finite difference interpolation technique. It is optimized to have the computational efficiency of a local interpolation methods, such as Inverse Distance Weighted interpolation, without losing the surface continuity of global interpolation methods such as Kriging and Spline.

STEP 5: CALCULATE LINE DENSITY

Density surfaces are good for showing concentrations of point or line features. Density maps are predominantly created from point or line data. When you calculate density, you spread the value of the ‘population’ field out over the surface. The magnitude at each sample location (line or point) is distributed throughout the extent and a density value is calculated for each cell in the output raster.

□ Save your map as **Interpolation** in your . . ./*Exercise07* folder.

The choice of density tools you use will determine whether density will be calculated by looking at the density of the phenomena around each cell (Point Density and Line Density) or the known quantity associated with each point or line is spread around the point or line with the feature having the highest density (Kernel Density).

Density Tool	Description
Kernel Density	Calculates a magnitude per unit area from point or polyline features using a kernel function to fit a smoothly tapered surface to each point or polyline.
Line Density	Calculates a magnitude per unit area from polyline features that fall within a radius around each cell.
Point Density	Calculates a magnitude per unit area from point features that fall within a neighborhood around each cell.

You will not be exploring the Kernel density tools with the avroad layer, as your data is not detailed enough to gain any significantly different results using line density over Kernel density. But if you have data that lends itself to having magnitude or an order of magnitude/density extrapolated across a surface, then consider using Kernel density.

□ Turn off all layers and collapse their legends.
□ Insert a new *Data Frame* into your map.
□ Rename New Data Frame to *Exploring Density*

□ Add the following layers from the ... *Exercise07* folder
  - *arlandmask.lyr*
  - *avgnis.lyr*
  - *avroad.lyr*

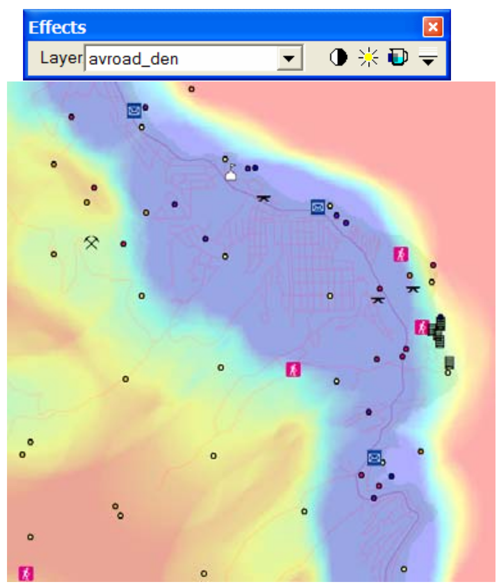
□ Ensure that your *Environment Settings* are still set as follows:

- Current Workspace: …*Exercise07*
- Scratch Workspace: ... *Exercise07*
- Output Extent: Same as Layer "*arlandmask*"
- Cell Size: Same as Layer "*arlandmask*"
- Analysis Mask: *arlandmask*

NOTE: Conceptually, with Line Density, a circle is drawn around each raster cell center using the Search radius. The length of the portion of each line that falls within the circle is multiplied by its population field value.

☐ *Run ... > Density> Line Density:*
☐ Input polyline features: select *avroad.lyr*
☐ Population field*: ROAD_CODE*
☐ Output raster: type **avroad_den**
☐ Output cell size: **30**
☐ Search Radius: **800**
☐ Area Units: select *SQUARE_KILOMETERS*

NOTE: Density is calculated in units of length per unit of area
☐ Move *avroad.lyr* below *avroad_den* in the Table of Contents.



☐ Set the transparency of *avroad_den* to 20%.

Notice that the values of avroad_den increase in areas with more roads. Some possible uses for the line density include the ability to map relative accessibility to an area by comparing road density with other factors. You may also use density of roads as a factor to understand the influence of man made roads on wildlife habitat.

☐ Turn off *avroad.lyr* and *avroad_den.*

Now investigate calculating point density.

STEP 6: CALCULATE POINT DENSITY

- ☐ Turn on *avgnis.lyr*
- ☐ Right-click *avgnis.lyr* and select *Open Attribute Table*.
- ☐ On the Attributes of *avgnis.lyr* window, click *Options > Select By Attributes.*

- ☐ Build the following expression.
  - **"GNIS_TYPE" = 'populated place'**

- ☐ Click *Apply*
- ☐ Click *Close*.
- ☐ Click the *Selected button* to show just the selected records.

Notice that 22 of the 254 points are populated places.

- ☐ Close the Attributes of *avgnis.lyr* table.

You have now selected all populated places. This selection will be honored by the geoprocessing tools for density that you will be using next.

For this step, you will execute a point density and experiment with the results.

NOTE: Point density calculates density by defining a neighborhood around each raster cell center, then it totals the number of points that fall within the neighborhood and divided this total by the area of the neighborhood.

- ☐ *Run ... > Density> Point Density:*
- ☐ Input point features: select *avgnislyr*
- ☐ Population field: *Capacity*
- ☐ Output raster: type **avgnis_den**
- ☐ Output cell size: **30**
- ☐ Neighborhood: select *Circle*
- ☐ Neighborhood Settings:
  - Search Radius: **1000**
  - Units: *Map*
- ☐ Area Units: select *SQUARE_KILOMETERS*

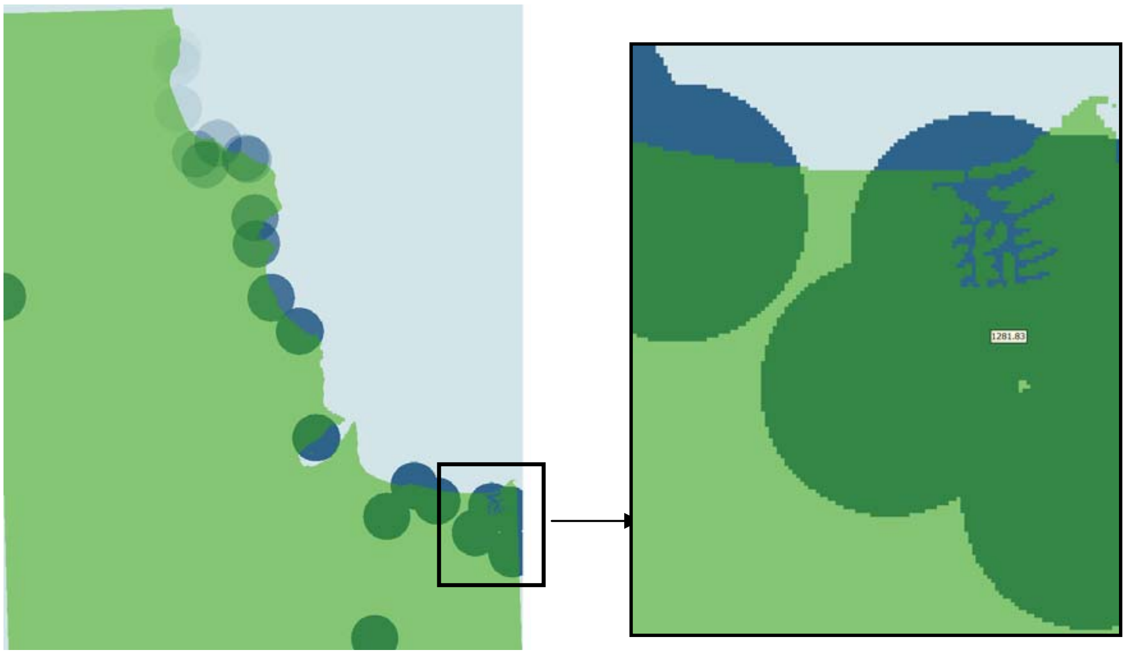
- ☐ *Right-click avgnis_den* and click *Properties*.

- ☐ On the *Display* tab, check *Show Map Tips* and click *OK*.

In this step, you will select populated places from the avgnis.lyr layer and then create a surface to show the density of settlements in your Lake Tahoe study area.

- ☐ Zoom to lower right of Tahoe area as shown in the graphic below:

- ☐ On the *Tools toolbar*, click the *Select elements tool*.



- ☐ Move your cursor inside the density areas and note the cell value of the map tip:

Notice that within one density area all the cell values are exactly the same. You have just observed one of the primary differences between Point Density and Kernel Density.

Now execute a Kernel Density and investigate the differences with Point Density.

> **NOTE: Kernel density fits a smooth curved surface over each point in the input feature class. The surface value is highest at the location of the point, and diminishes with increasing distance from the point, reaching 0 at the search radius distance from the point. The volume under the surface equals the Population field value for the point or I if none is specified.**

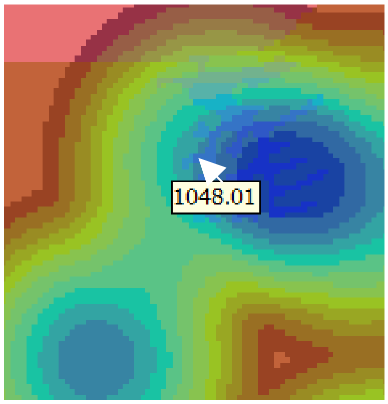
- ☐ *Run ... > Density> Kernel Density:*
- ☐ Input point or Polyline features ; select *avgnis.lyr*
- ☐ Population field: *Capacity*
- ☐ Output raster; type *avgnis_kern*
- ☐ Output cell size; **30**
- ☐ Search Radius: **1000**
- ☐ Area Units: select *SQUARE_KILOMETERS*

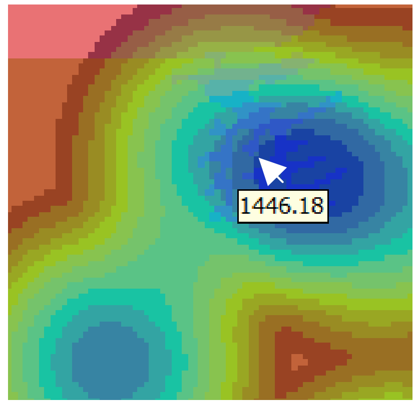
- ☐ For *avgnis_kern*, set the *Show Map Tips* property.

□ Ensure that you are still zoomed in to the lower right corner of the map.

□ Click the *Select elements tool*.

□ Move your cursor inside the density areas and note the cell value of the map tip.





You will notice that the difference between Point Density and Kernel Density is that in Point Density, a neighborhood is specified that calculates the density of the population around each output cell. Kernel Density spreads the known quantity of the population for each point out from the point location. In Kernel Density, the highest value is found at the point location and then tapers to zero at the search radius distance.

□ *Save your map*.

□ *Exit ArcMap*.