Report of Participation
The Introduction to ArcGIS
Spatial Analyst Extension Course

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PREFACE

Firstly we, Ms.Siripom Pangsone and Mr.Wirote Laongmanee Would like to thanks to the SEAFDEC/TD for giving us the opportunity to attend the INTRODUCTION TO ARCGIS SPATIAL ANALYST EXTENSION COURSE at ESRI (Thailand), Bangkok on 15 – 17 July 2002.

Due to the fisheries matter, our task could not avoid to deal with some certain areas like "coastal", "sea" and "ocean". We have to analyst our data and present on the map. Generally ArcGIS (ArcView 8.1) the desktop GIS product of ESRI Inc. is our tool to produce them, beside this product there is extension to work with spatial data called "Spatial Analyst Extension". With this special module, we can easily perform spatial analysis with our fisheries data, easily to provide answers to simple spatial questions, such as "Where should you do the fishing?" or "How far the our FADs drift per day?". With this module, we could model the phenomena and predict the occurring easily. We can provide this information to the decision maker in order to manage our resources.

With this training course we got the concept of module working, the way to create, convert, raster calculate, raster modeling and etc., which could be work with our fisheries data.

Ms.Siripom Pangsone
29 July 2002

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Overview of Spatial Analyst

The Spatial Analyst is an extension to ArcGIS8.1. This piece of software help you solve diverse types of spatial problems that are related to the terrain. It provides powerful tools for performing spatial analysis. You can create data, identify spatial relationships between datasets, locate suitable sites, etc. These are only few example usage of the Spatial Analyst.

Modeling

You can model the landscape with many tools that the Spatial Analyst offers. This software is flexible in what data types can be used in the analysis. Images, ArcInfo grids, and other raster datasets can all be used in the analysis.

Raster Analysis

You can perform the raster analysis using the Spatial Analyst using the Raster Calculator where Map Algebra expressions can be written with the help of several functions that perform many different tasks required in the analysis model.

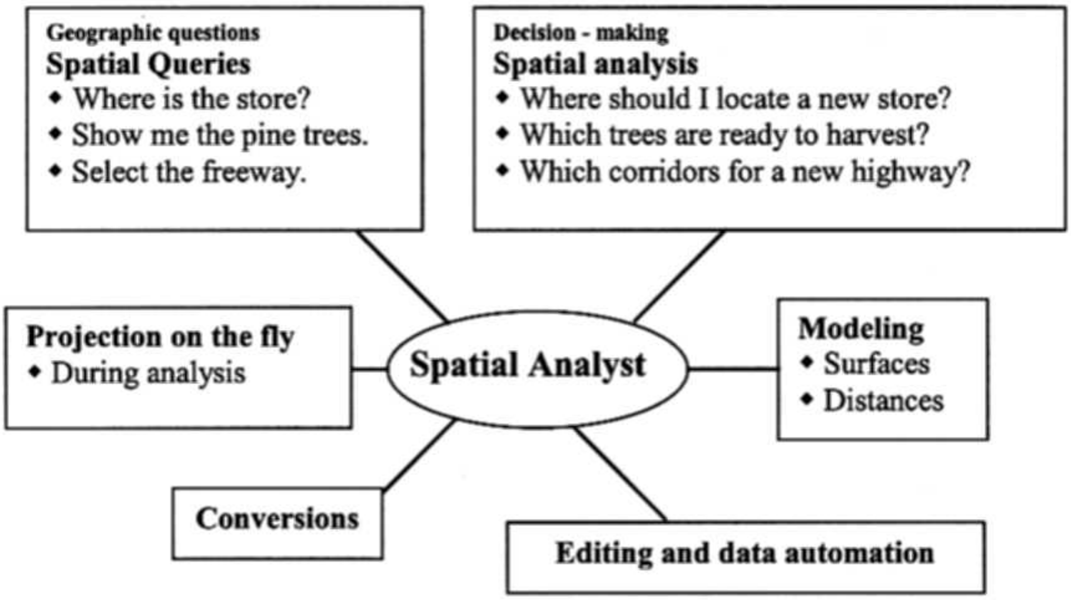

Figure 1 Using of the Spatial Analyst

Spatial Analyst and ArcInfo GRID

The comparison of Spatial Analyst in ArcView 8.1 and ArcView 3.2

ArcView 8.1 Spatial Analyst Extension	ArcInfo GRID	ArcView 3.2 Spatial Analyst Extension
•Ease of use of ArcView 3.2 •Spatial Analyst Extension •More ArcInfo GRID Functionality •Analysis on all raster formats	•Map Algebra •Command line •ArcTools	•Map Algebra •Map Query dialog •Map Calculator dialog •Uses grid themes

Raster concepts

Geography as raster
- A matrix of equal-sized cells
- Organized as rows/columns
- Each cell stores a value

Why use raster?
- Easier than vector in many analyses
- Fast overlays with complex data
- Allows: Locational view of data, Surface analysis (visibility, etc.), Distances (weighted, decay distances, etc.)

Discrete and continuous data
- Discrete data: has attribute table
  - Models bounded data: Land use, zoning
  - Stored as integer values
- Continuous data
  - Models surfaces: Elevation, distance
  - Stored as floating-point or integer values

Raster registration and georeferencing
- Raster data should be registered to real-world coordinates (a projection).
- If all rasters are registered to a common projection, they are registered to one another.

Resampling
- Automatically occurs if analysis cell size is set. If input and output cell has different cell size, the output cell center will identify the input value that in same location of output cell center.

The GRID data model
- Native data structure in the Spatial Analyst: analysis results in grids
- Stores data values (not colors)
- May have an attribute table and can participate in relationships
- Manage in ArcCatalog

Raster attributes
- Integer grid's Value Attribute Table (VAT)
  - One record per zone (unique values)
  - VALUE, COUNT fields
  - Other user-defined fields: can add field to define that what it meant.
  - Relate to other tables in ArcMap
- Floating-point grid
  - No attribute table

Regions and zones
- Region = Contiguous same-value cells
- Zone = Contiguous or non-contiguous same-value cells (one row in VAT)

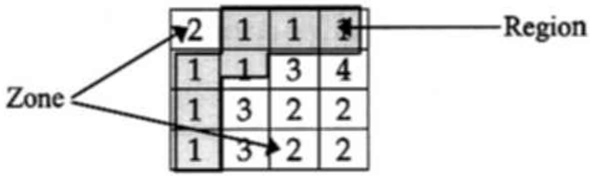

Figure 2 Region and Zone in Raster dataset

The analysis environment

- Controls output raster creation: Projection, Cell size, Analysis extent, and Analysis mask
- Snap layer
- Clipping

Projection on the fly

- Set an output analysis coordinate system
- Raster inputs can be projected during analysis operation

Snap extent

- **Snaps all layers to the cell registration of the specified layer**
- All layers will share: Lower-left corner and cell size of the specified layer
- Used to resample grids to the same: Registration, Cell size

Analysis mask

- Defines areas where the analysis should be performed
- No Data in the mask creates No Data in output
- Can create a mask with attribute selection

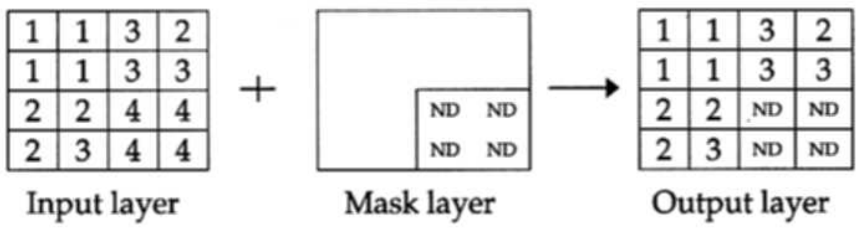

Figure 3 The Analysis Mask

Map Algebra

Map Algebra is a language based loosely on the Map Algebra concepts. It is a high-level computational language for performing cartographic spatial analysis using raster data.

Expressions

Map Algebra uses math-like expressions that return numeric values and are written to temporary output grid. Expressions either return integer or floating point numbers.

Objects

Objects refer to the Map Algebra input data: rasters, shapefiles (vectors), tables and constants.

Operators

Operators work against one or more objects to develop new values. Map Algebra has many operators: arithmetic, relational, Boolean, logical, combinatorial and bitwise.

Functions

Functions are the most important part of the language. Functions perform specialized tasks, such as computing slope from elevation, and usually return numeric values. Functions are classified according to the area they process: local, focal, block, zonal and global.

The analysis environment

The analysis environment controls the creation of new grids created with Map Algebra expressions. It set the cell size and spatial extent of the new grid.

You can access Map Algebra through the Raster Calculator dialog and for the programmer Map Algebra expressions may also be processed in code using the ArcObjects.

The language of raster

Map Algebra is the analysis language for Spatial Analysis. It is a simple syntax similar to any algebra. A temporary grid (specifically) is always returned by a Map Algebra expression. The input can be as simple as a single raster layer or shapefile, or as complex as a compound expression using many operators, functions and input data.

The Raster Calculator

- Use to enter and evaluate Map Algebra expressions. You can build expressions either by typing them into the expression box, or by clicking the various buttons found on the dialog, or by a combination of clicking and typing.

Expression syntax rules

- Delimit element with blanks: Layers, operators and other elements of the language must normally be delimited with blanks. There are exceptions, like parenthesis.
- Operators are evaluated by precedence level
- Override operator precedence with parentheses
- Nested parenthetical expressions evaluate first

Function syntax rules

Functions are the major element of the Map Algebra language; all Map Algebra functions in the Spatial Analyst return their output as a grid.

- Functions are the "power" behind Map Algebra.
- Arguments in parentheses and comma-delimited
- Treat as object in expressions (they return values)
- Some Arguments may be functions or expressions

Expression results

Functions or operators that do not return a grid dataset cannot be used in raster Calculator.

- Always return temporary grids: automatically named and added to table of content
- Output is integer if all inputs integer, otherwise returns float grid
- Functions that convert data types: Map Algebra has several functions that convert between integer and floating point. These are INT, FLOAT, CEIL and FLOOR. There is no function to round floating point numbers to a whole number.

This Map Algebra expression rounds to integer: INT([Elevation] + 0.5)

Expression evaluation

- Expressions are processed as follows:
  1. Define an empty output grid based on the analysis environment.
  2. Position to the next output cell (start at raw 0, column 0).
  3. Resampling input raster to determine corresponding cell values.
  4. Evaluate the expression and write the result to the output raster
  5. Repeat steps 2, 3 and 4 for all output raster cells.

Map Algebra objects

- Objects used as function arguments or in expressions
  - Raster: grids and images – as layers or paths
  - Vector: shapefiles – as paths only
  - Numbers – integer or decimal
  - Constants – PI, E, DEG, GAMMA, PHI
  - Tables – used by a few functions

User attributes in expressions

- You may use any numeric .VAT fields in expressions
- Reference with [Layer].field notation e.g. [Vegetation].Suit + [Soil].Suit
  - [Layer] alone is assumed to be [Layer].Value
- You may join tables to grids .VAT file
  - Use joined fields for symbology, selection
  - Cannot use in Map Algebra expressions

Special call values in Map Algebra

- Logical: non-zero values are True. Zero is False.
- NoData: if any input is NoData, the output is NoData

Map Algebra Operators

- Map Algebra supports many operators. Most may be entered either as algebraic symbols or as character abbreviations.
- Work with two inputs, like [Slope] GE 10

Map Algebra functions

- Do most of the works in Map Algebra: hundreds of function; many used only in Raster Calculator
- Can classify by processing method
    - Local functions operate only on the current cell, with no input from any other cell. Each cell is processed, starting at top left.
    - Focal and Block functions operate on the neighborhood of input cells that surround the current output cell. You can use any shape or size of neighborhood. Neighborhood is a moving window over input.

General syntax: FOCALxxx([InLayer], *neighborhood*, {DATA | NODATA})

Focal neighborhoods: You may define the neighborhood geometry: rectangle, circle annulus and Wedge. The default is a 3x3 rectangle. And you can create a custom neighborhood with a kernel file.

Custom neighborhoods may be created with neighborhood notation. The notation sets column and row offsets from the current input grid cell. The value of the cell thus identified is used rather than the value of the current input cell. You can create your own focal function: [Layer](col_offset,row_offset)

- Zonal functions operate on zones defined in one layer and return statistics from a second later summarized by the zones. A zone is a collection of cells containing the same value. The cells do not need to be connected. Require two input rasters: Zone and Value.

General syntax: ZONALxxx(<zone_grid>, <value_grid>, {DATA | NODATA})

- Global functions operate on the entire grid. They may need all of the values in the grid to calculate the value for a given cell. Most global functions perform distance measurement, although there are others. REGIONGROUP assigns unique IDs.

The CON function

- IF–THEN–ELSE function for Map Algebra

CON(<condition>, <true_expression>,{fales_expression})

IF TEST THEN ELSE

- May be a simple IF–THEN–ELSE

CON([Slope] < 20, 1, 0)

- Or nest CONs for an ELSE-IF

```
CON([Slope] < 20, 1,
    CON([Slope] < 40, 2, ←——— First CONs {false_expression}
        CON([Slope] < 90, 3, 5) ) ) ← Second CONs {false_expression}
```

Working with NoData

- The ISNULL function tests the current cell to see if it contains NoData and returns either 1 or 0 (true or false). It is normally used in conjunction with the CON function to replace the NoData value with something else.

General syntax: ISNULL(<raster>)

- The SETNULL function applies a test against the current cell and, if the test is true, replaces its value with NoData. If the test is false, it writes the results of the expression to the cell

General syntax: SETNULL(<condition>, {expression})

Building a raster database

Locating data

•Using online data sources: There are large amounts of spatial data available from both local and international Government and Commercial sources. For example: The National Atlas of the United States of America, NOAA, and etc.

•Using Geographic Network data: The Geographic Network is based on the collaboration of public and private organizations that publish and share GIS information on the Internet. It provides access to a wide variety of geographic contents including static map images, dynamic map services, downloadable data, and data clearinghouses.

•Accessing map services: connect through ArcCatalog or connect to the Geography Network in ArcMap

•Data search in ArcCatalog: Search by Name and Location, Geography, Date, Metadata

Results: Located in the Catalog tree, Shortcuts point to the data, Can be used anywhere data is used

Data Conversion

•Populating a database is one of most critical processes involved in building a GIS system. ArcGIS provides a multitude of tools to aid this process. Using the Spatial analyst graphical user interface in ArcMap, you can convert any feature that ArcMap displays to a raster data source. Likewise any raster can be converted to a feature data source. And you can use other conversion tools in ArcToolbox, ArcObjects and ArcCatalog.

•Converting features to raster: Polygons, lines and point features from any type of source file can be converted to a raster, using both string and numeric fields. When convert points, cells assigned value of the point found within each cell. Cells that do not contain a point are given the value of No Data. When convert polygons, cells assigned value of the polygon found at the center of each cell. When convert lines, cells assigned value of the line that intersects each cell.

Georeferencing

•Georeferencing is the process of establishing a relationship between the raster's (row, column) coordinate system, sometimes called image space, and a real-world (x, y) coordinate system, called map space.

•The georeferencing process:

1. Add both the image to be rectified (source file) and the rectified reference map or image.
2. Fit raster display to the area of source data.
3. Select a series of To and From points and establish links.
4. Adjust or Auto Adjust.
5. Assess the accuracy of the alignment and discard poor links with high residual error.
6. Repeat step 3 through 5 until error is acceptable.

7. Save the transformation: Update Georeferencing, Rectify (save as a new raster)

•Creating links: - Links tie the raw raster to a rectified map or raster
- Should be evenly distributed over the entire raster
- Avoid feature that will change position with time

•Assessing accuracy: at least four links

Assessing the accuracy of the alignment is an essential and importance step in using the Georeferencing tool. This can be done visually by checking to see if features in both themes align well or not. The software does provide you with a mathematical measure of the accuracy of the transformation from one coordinate system to another. This is called the Root Mean Square error (RMS). RMS errors are provided for each link and a total RMS value is calculated for the entire image. Units are pixels of the source image.

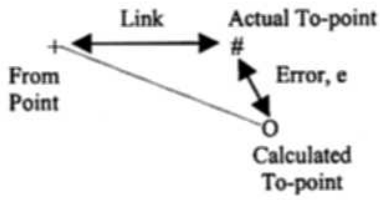

Figure 4 Root Mean Square error (RMS error)

•Acceptable error: There will be a certain amount of error, but the actual amount you should tolerate during an image alignment depends on a number of factors. Remember that RMS provides only guideline. If you determine that a pair of links is accurate, this is more important than RMS.

•Update georeferencing vs. rectify

When you rectify a raster dataset, project it, convert the raster dataset from one projection to another, or change the cell size, you are performing a geometric transformation. As the final step in the alignment process, you have to decide whether to rectify or resample or update the georeferencing of your aligned image. Both are mechanisms to associate your image with a real-world coordinate system and a projection.

•Resampling methods

Resampling is a process of determining new values for cells in an output raster that result from applying some geometric transformation to an input raster. The input raster may be in a different coordinate system, at a different resolution, or rotated or shifted with respect to the output grid. This method does not alter the value of the input cells.

Raster processing tools

Remove heterogeneous data

- Smooth or filter data
- Emphasize (or de-emphasize) a zone at the expense of adjacent cells
- Emphasize or detect edges
- Merge grids
- Clean ragged edges between zones

•Generalization

Block functions compute an aggregated output value based on the values of the input cells within a neighborhood. The input grid is first partitioned into non-overlapping rectangular blocks that are as the defined neighborhood. The neighborhood is centered within the block, and the computation is performed on the input cells within the neighborhood. The result is written to all of the output cells that fall within the block.

Aggregate is similar to BlockStats. Like BlockStats, Aggregate used a statistic to calculate values, but instead of assigning the value to the neighborhood, Aggregate resamples and changes the output cell size to a larger cell size, thereby reducing the resolution. Aggregate generates a reduced-resolution version of a grid where each output cell contain the SUM, MIN, MAX, MEAN, or MEDIAN of the input cells that are encompassed by the extent of the output cell.

•Smoothing and edge enhancement

- Thin: Makes raster lines one pixel wide
- Shrink: Shrinks the selected zones by a specified number of cells
- BoundaryClean: •Cleans ragged edge between zones for integer grids
  •Priority can be set using zone value or zone area
  •Uses an expand and shrink process

•Merge (Integer) and Mosaic (Floating Point)

Merge and mosaic combine several spatially adjacent raster datasets into a single, larger dataset. The difference between the two is in merge, the cell is assign to the last input value from the series of input raster datasets but in mosaic will smoothes the transition between the adjacent raster datasets in the overlapping areas. These functions are used when several raster datasets come from a tiled, continuous data sources such as adjacent satellite scenes, neighboring towns, or states that are separately managed.

Storing raster data

•Store as Grid by set the workspace storage, ArcSDE raster by using ArcToolbox, Metadata.

Surface creation

Surface in GIS

•Surface representation

Spatial analyst can represent surfaces with three common methods: elevation points, contour lines, and surface grids. Spatial Analyst does not support triangulated irregular network (TIN) datasets.

•Sampling a surface

Surfaces represent continuously changing phenomena. It would be difficult, or nearly impossible in some cases, to visit every location in a study area to collect data like elevation or rainfall. The alternative is to collect the data at sample locations and then use those sample locations to interpolate or estimate values for the rest of the surface.

The sample can be regularly or randomly spaced. The more input points and the greater their distribution, the more reliable the results. The attribute of surface data, that being measured, is referred to as the Z value. The cell values in the output grid theme are best estimates or interpolated values. Certain assumptions are made when making these estimates. When estimated values, error increases with distance from the samples or known values.

Interpolating to raster

Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data.

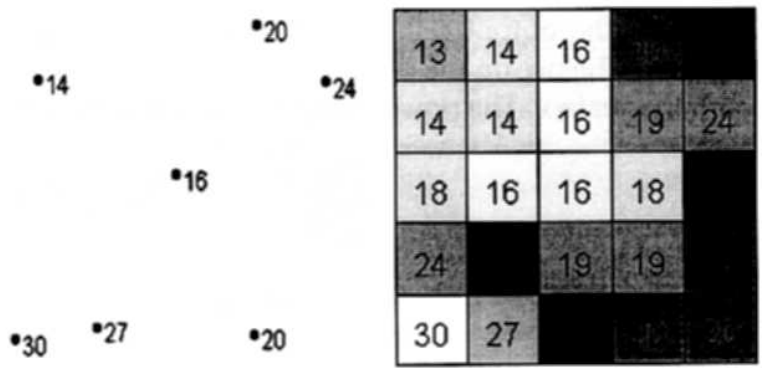

Figure 5 Interpolation method

The left-hand graphic above shows a point dataset of known values. The right-hand graphic shows a raster interpolated from these points. Unknown values are predicted with a mathematical formula that uses the values of nearby known points.

Interpolators

Spatial analyst offers five functions that generate surface grids from point data: IDW, Spline, Trend, Kriging, and PointInterp. Each provides a different approach for determining an output cell value. Spline, IDW (Inverse Distance Weighted) and Krignig appear as choices in the Interpolate to raster dialog box that is presented to the user when creating a surface. Trend and PointInterp are accessed with map algebra.

•IDW (Inverse Distance Weighted)

The IDW should be used when have a dense set of points, dense enough to capture the extent of local surface variation needed in the analysis. This function determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance.

The output value is limited to the range of the input values used to interpolate. Because the IDW is a weight distance average, the average cannot be greater than the highest or less than the lowest input. Therefore, it cannot create ridges or valleys if these extremes have not already been sampled. Also, because of the averaging, the output surface will not pass through the sample points.

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

Power is the exponent of distance. The power option lets the user control the significance of input points upon the interpolated values, based on their distance from the output cell. A larger power results in more distant points having less influence on the output. Normally, lower power values will tend to smooth the surface. The power is a positive, real number.

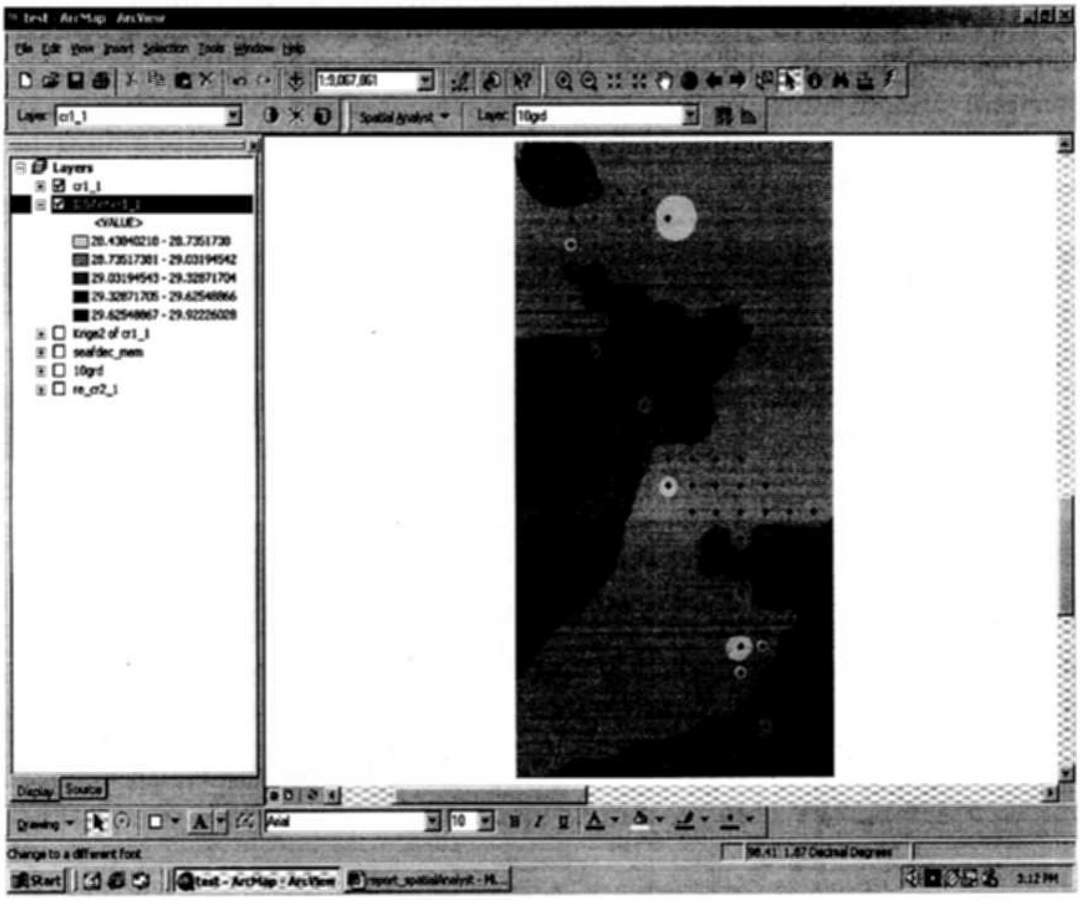

Figure 6 Interpolated Temperature by using IDW method

•<u>Spline</u>

Spline estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points. It is like bending a sheet of rubber to pass through the points while minimizing the total curvature of the surface. It fits a mathematical function to a specified number of nearest input points while passing through the sample points. This method is best for gently varying surfaces such as elevation, water table heights, or pollution concentrations.

A spline passes exactly through the input data points in such a way as to minimize certain aspect of curvature.

Spline has two types:

- The Regularize method
- The Tension method

•<u>The Regularize method</u> creates a smooth, gradually changing surface with values that may lie outside the sample data range. Higher values of {weight} smooth more. Weight defines the weight of the third derivatives of the surface in the curvature minimization expression. The values must be equal to or less than zero.

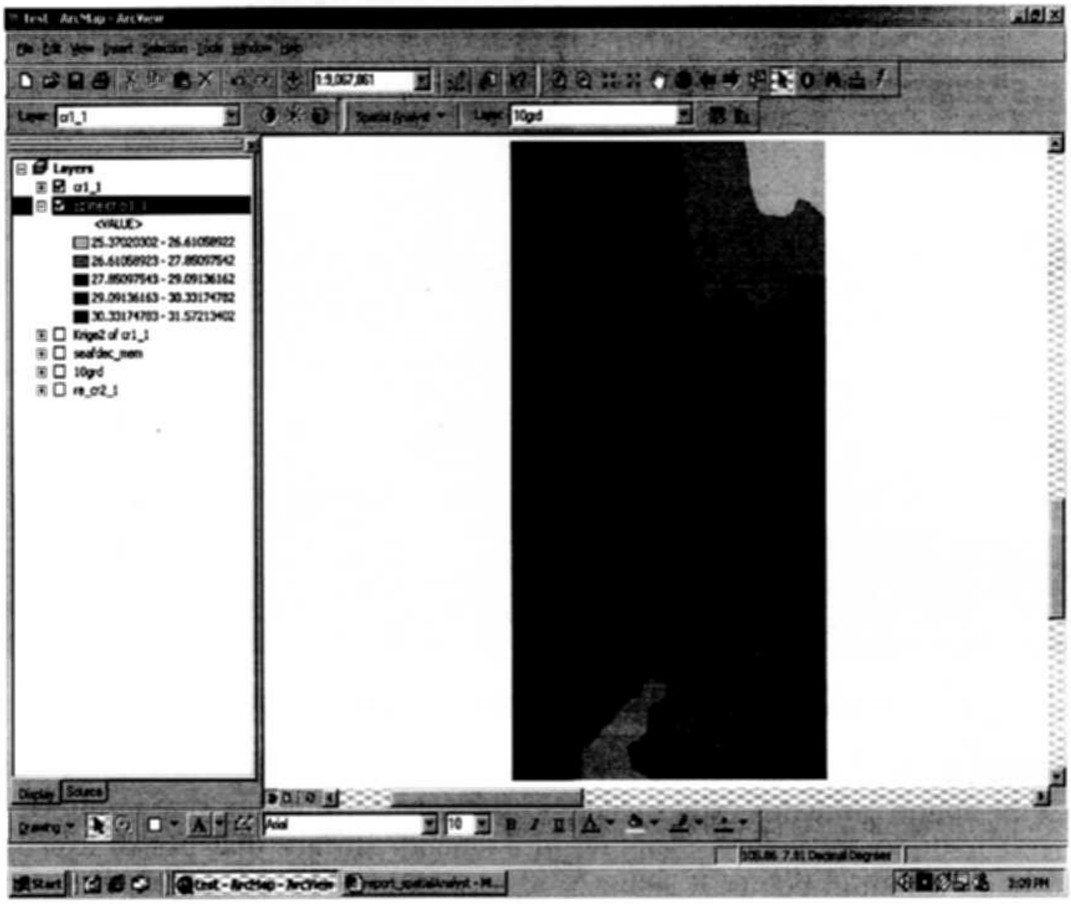

Figure 7 Interpolated Temperature by using Spline: Regularize method

•<u>The Tension method</u> 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. Higher values of {weight} coarsen more than lower values. Weight defines the weight of tension. The values must be equal to or greater than zero.

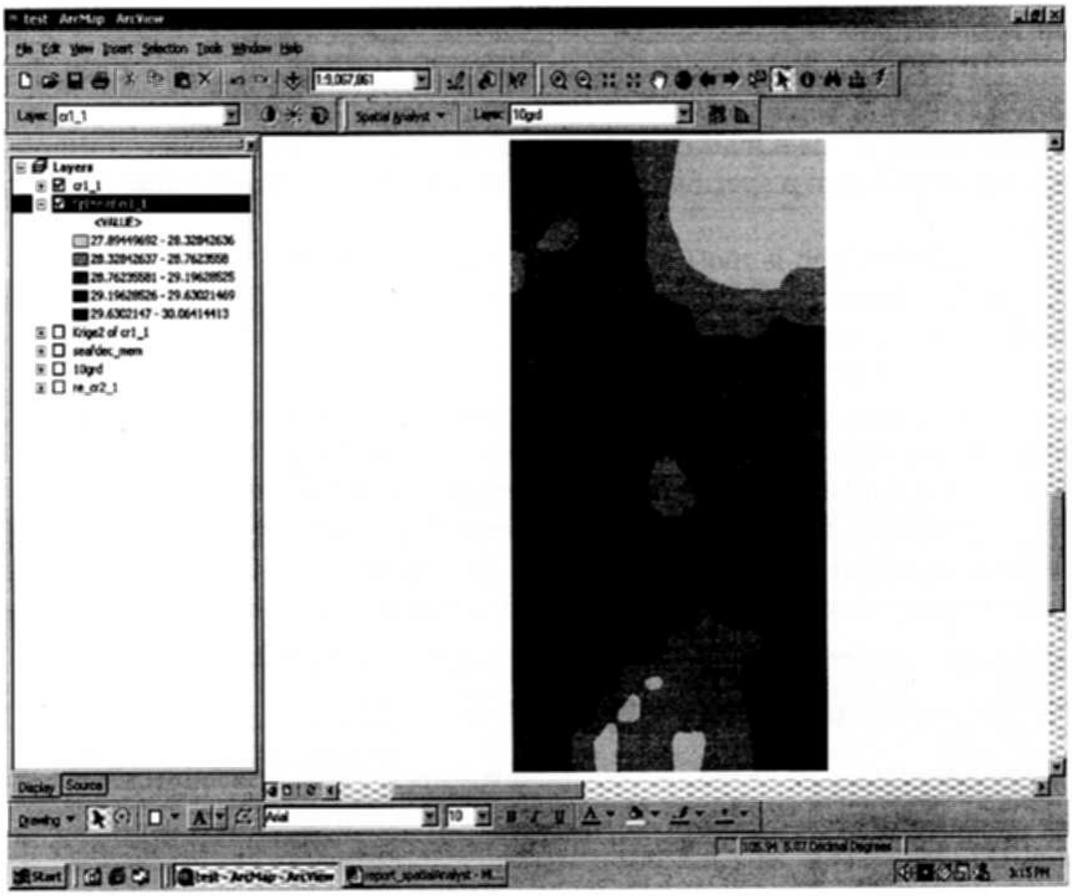

Figure 8 Interpolated Temperature by using Spline: Tension method

•<u>Trend</u>

Trend is use when interested in finding trends in the input sample data. This method fits the mathematical function (a polynomial of specified order) to all input points. This method uses a least-squares regression fit, which results in a surface that minimizes the variance of the surface in relation to the input values. The surface is constructed so that for every input point, the total of the differences between the actual values and the estimated values (the variance) will be a smallest possible. The resulting surface rarely goes through the input points.

• Kriging

Kriging is a powerful statistical interpolation method used in diverse application, such as health science, pollution modeling, and etc. Kriging is based on regionalized variable theory, which assumes that that the spatial variation in the data being modeled is statistically homogeneous throughout the surface. The same pattern of variation can be observed at all locations on the surface.

It assumes that the distance or direction or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. Kriging fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location.

This function is most appropriate when you know there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology.

There are two Kriging methods

•Ordinary Kriging assumes that there is no underlying trend (structure drift) in the data, and the surface may be interpolated using a solely local trend and a mathematical model to estimate the spatial variance.

Ordinary Kriging is the most general and widely used and is the default. It assumes the constant mean is unknown. This is a reasonable assumption unless there is some scientific reason to reject this assumption.

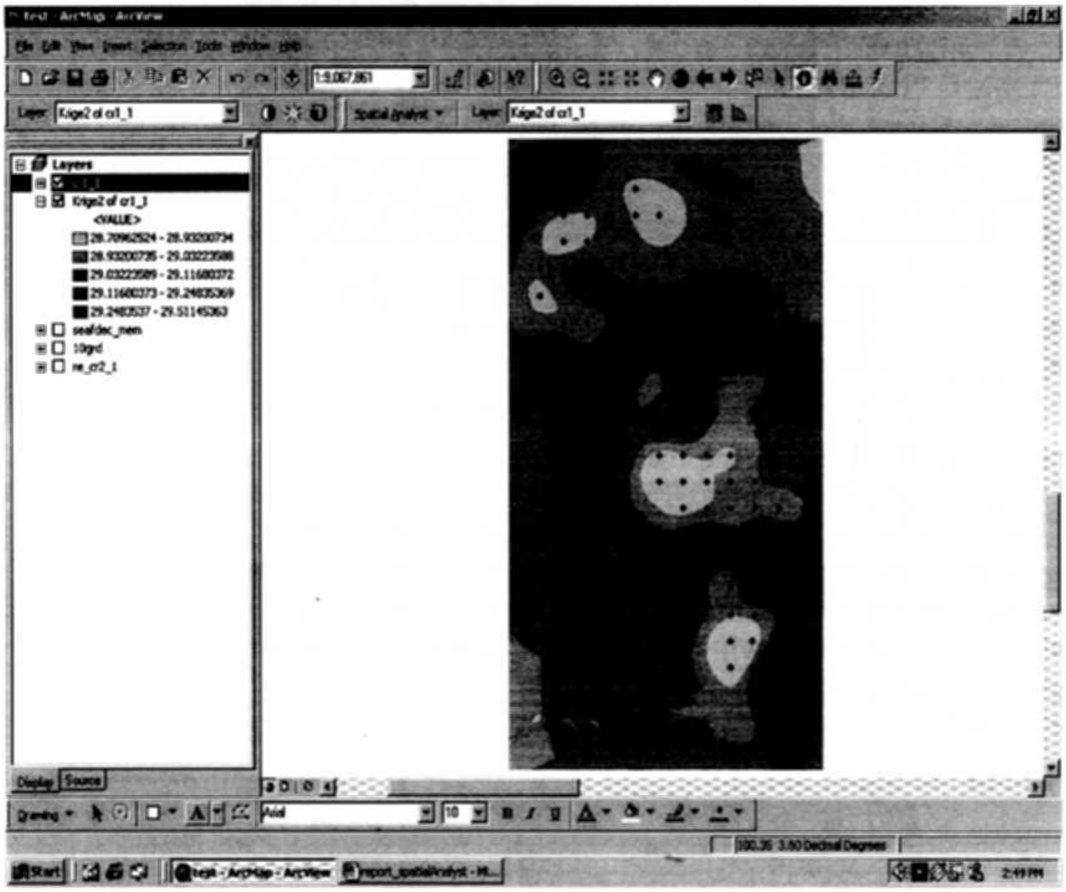

Figure 9 Interpolated Temperature by using Ordinary Kriging method

•Universal Kriging assumes that there is an overriding trend in the data, and it can be modeled by a deterministic function, a polynomial.

Universal Kriging should only be used when you know there is a trend in your data and you can give a scientific justification to describe it. It assumes that the Spatail variation in the data is the sum of three components: an underlying trend in the data, a random but spatially correlated component, and random noise representing a residual error.

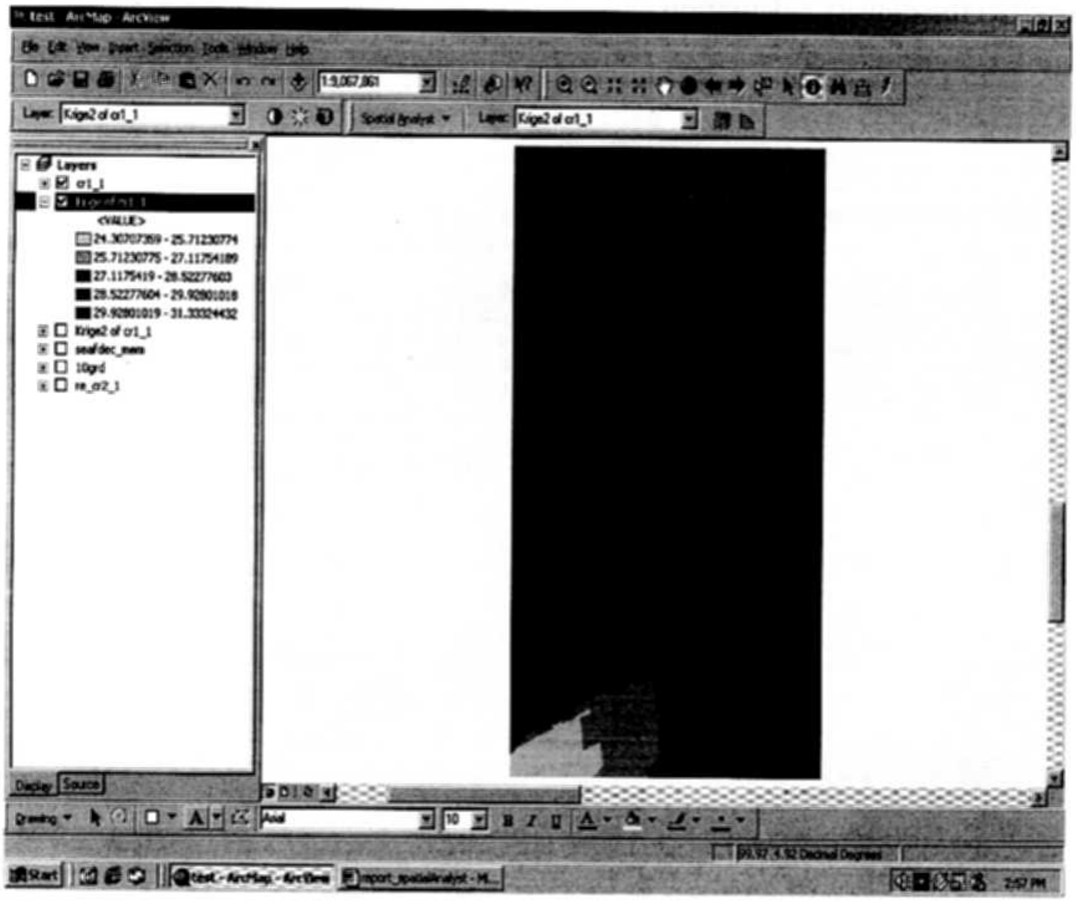

Figure 10 Interpolated Temperature by using Universal Kriging method

•PointInterp (PointStatistics)

PointInterp interpolates a surface from point features in a specified neighborhood around each output grid cell, using a specified distance weighting function. This means that the influence of a particular point's z-value on the interpolated grid cell value will depend on how far the point is from the cell being interpolated.

The IDW option of PointInterp is similar to the Grid function IDW but PointInterp does not have an option to use barriers, and it has different options for choosing which points are used to interpolate each grid cell. PointInterp also offers smoothing of data points and exponential interpolation, which are not available in other surface interpolation functions.

◆Density

Distance calculates the number of features within the given area. It has two kind of a surface: point density and line density. This method performs statistics on a point or line theme and used an optional population field. Without population field, it calculates straight number of features per area unit. This method has two type, simple and kernel; kernel uses a smoothing function. The search radius is the distance from each cell whose points will be used in the density calculation.

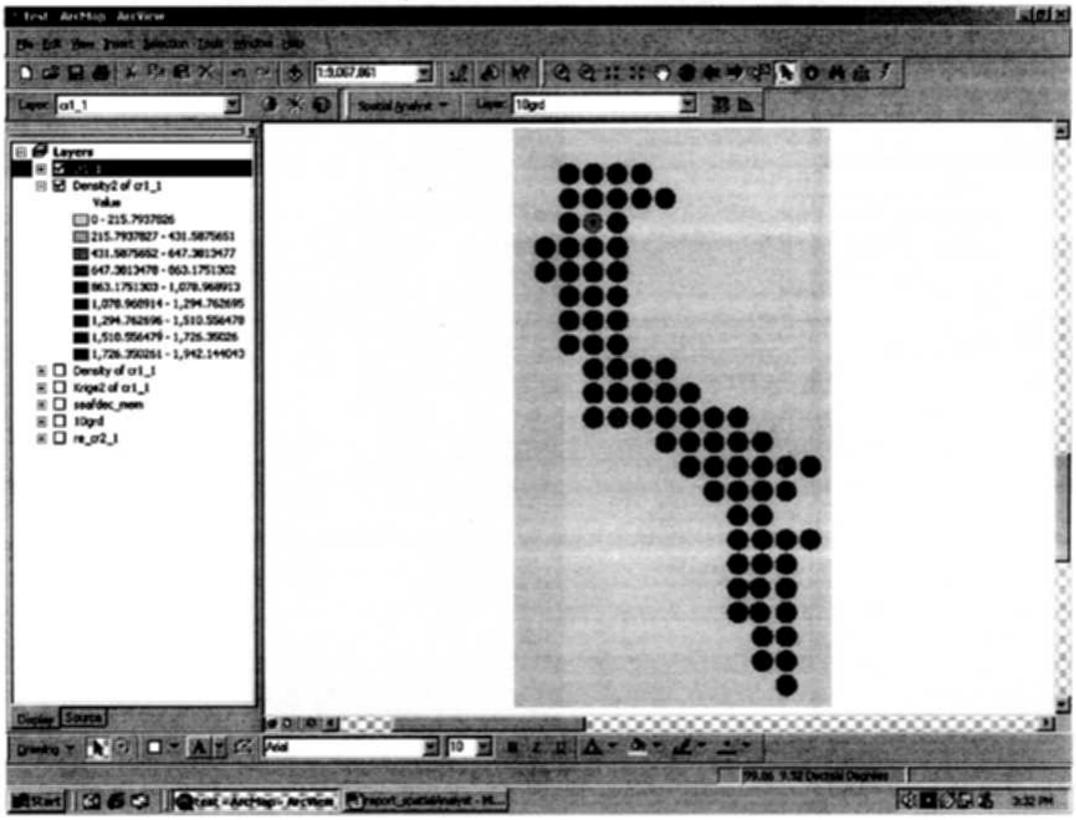

Figure 11 Interpolated by using Density: Simple method

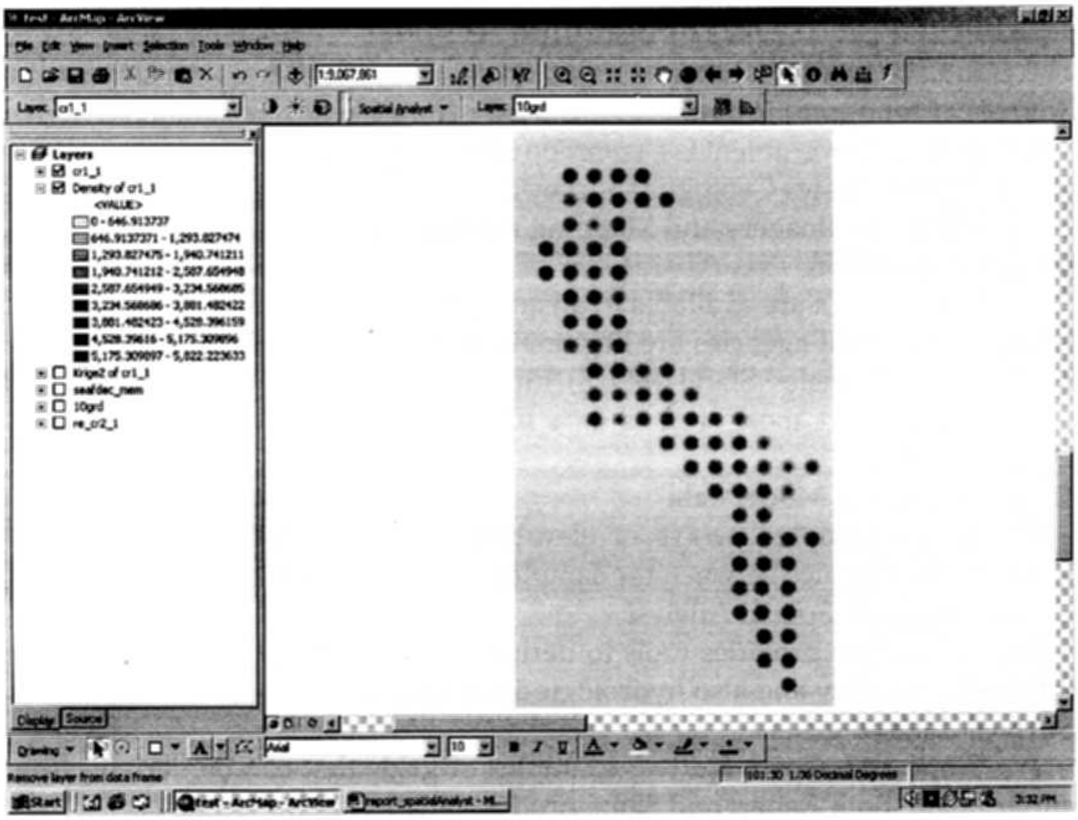

Figure 12 Interpolated by using Density: Kernel method

Contouring

Spatial analyst has tools for creating contour lines from either a collection of sample points in a shape file or from a surface. The result is a shape file containing line features.

- Isolines are lines on a map connecting points of equal values.
- Generate contour line coverage from surface grid.
- IDW or Spline is the interpolation methods.
- Contour interval is the change in z value between the contour lines (distance between z values).
- Base contour is a starting location. It is not the minimum contour. It refers to a starting point from which contours go both above and below based on the contour interval.

Hillshade

Hillshade computes the hypothetical illumination of a surface by setting a position for a light source and calculating illumination values of each cell based on its relative orientation to the light. Which is in turn based on the slope and aspect of the cell. Hillshade returns gray-scale values in the range of 0 to 255.

- Azimuth is the angular direction of the sun (its compass direction). Legal values range from 0 to 360. The default is 315 degrees - northwest – that is appropriate for cartographic use.
- Altitude is the angle of the sun above the horizon. Legal values range from 0 to 90. The default is 45 degrees, which is appropriate for cartographic use.

Visibility Analysis

The shape of a terrain surface dramatically affects what parts of the surface someone standing at a giving point can see. What is visible from a location is an important element in determining the value of real estate, the location of communication towers, or the placement of military forces. Visibility analysis can be used whenever you need to know which location can be seen from one or more observation points or lines.

- Controlling visibility in a viewshed by set parameters as observer point attributes
    - SPOT
    - OFFSET A
    - OFFSET B
    - AZIMUTH1
    - AZIMUTH2
    - VERT1
    - VERT2

Hydrologic modeling

Hydrology solutions in Spatial Analyst

Watershed delineation is one of the most commonly performed activities in hydrologic and environment analysis. DEM's provide good terrain representation from which watershed and streams can be delineated.

Processing surface hydrology

•Surface hydrology: the shape of a surface determines how water will flow across it.

The surface hydrology functions are used to evaluate and predict the behavior of water (or other surface flow natural systems such as sediment or mudflow), as it moves over the surface of the earth. You can use these functions to delineated drainage basins and streamlines, and to create output that are useful in other applications and analysis.

The surface hydrology functions use data derived from a grid of elevation.

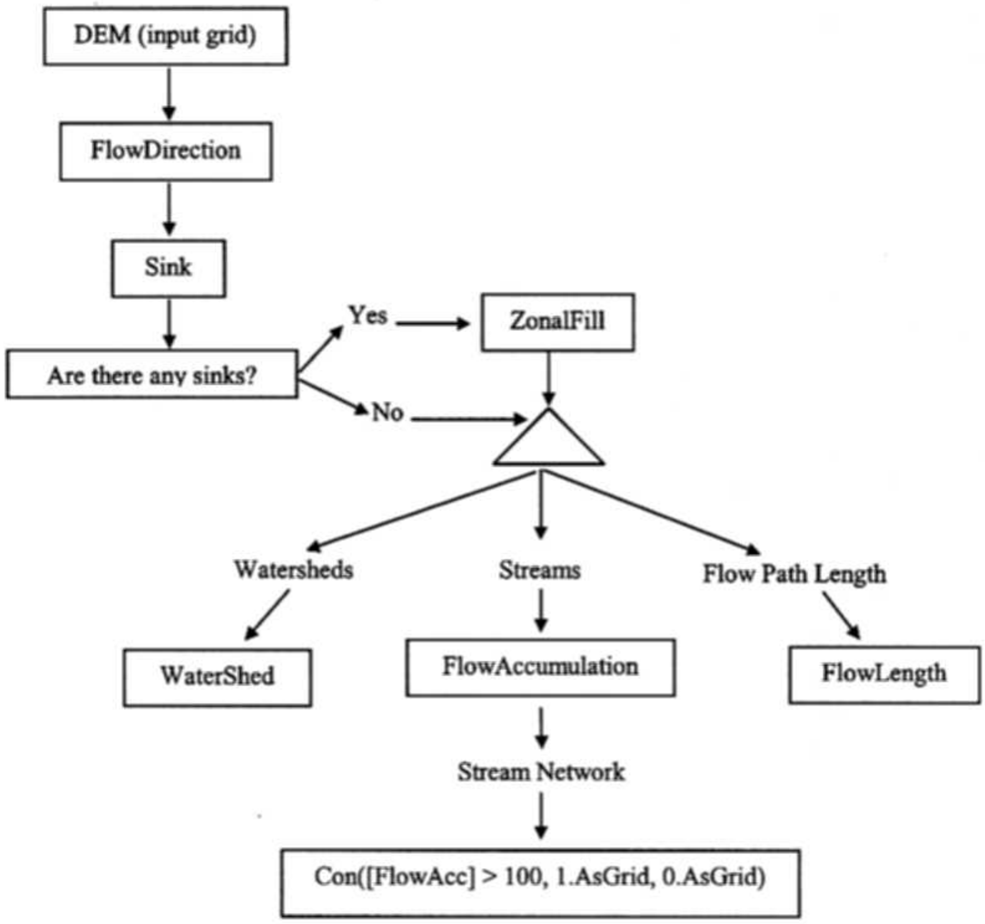

Figure 14 The diagram of Surface Hydrology processing

Flow direction

Flow direction calculates the direction of flow for each cell to its steepest downslope neighbor. Flow direction is calculated from an elevation grid. Flow direction grids are the very basis for all other hydrology analysis functions. The direction of flow is determined by finding the direction of steepest descent from each cell.

Steepest descent = change in z value/distance.

- Direction of Flow: If the descent to all eight neighbors is equal, then the neighborhood is enlarged until a solution is found.
- Make sure that the elevation surface is a hydrologically correct surface. It is important to consider the sinks (pits) and peaks of the elevation surface.
- If forceEdge is TRUE, all cells on the edge of the surface will flow away from the surface. If forceEdge is Fault, flow is calculated normally for edge calls with the edge being slightly lower than cell.
- The output drop grid records the maximum change in elevation in the direction of flow for each cell. It can be used to find the most extreme slopes along a flow path.

Surface generation considerations

Surface hydrologic analysis begins with the creation of a hydrologically correct surface. Most topographic surfaces have erroneous sinks and peaks (one or two cells below or above the local surface) that serve as barrier to flow. These barriers should be removed before analysis begins.

Most sinks reflect errors or natural anomalies in the elevation data. These might be occurring because of glaciated surfaces. Thus, these types of terrain can cause inconsistent results. One sink can change the whole analysis.

- Identifying sinks

A sink is an area surrounded by higher elevation values. Some sinks and peaks are naturally occurring features. It is important to remove sinks before attempting any surface hydrology analysis. Water flowing into a sink is trapped, and the drainage path stops at that cell. The Sink request creates a grid that identifies areas of internal drainage. The input grid is a grid of flow direction

- Filling sink

Filling sinks requires the use of the ZonalFill and Flow Direction functions. When finished, the Sink request should be used again to make sure that no more sinks. If there are new sinks that did not fill, you will have to use ZonalFill and Flow Direction and Sink again. You may perform these three steps several times until all sinks have been filled.

Flow accumulation

Flow accumulation calculates the value of flow from one cell to another, accumulating values from all uphill cells into each cell. A layer of flow direction is required. Most cells will have very small accumulation values, but the few cell that represent major streams will accumulates very large values. Cells with high flow accumulation are areas of concentrated flow.

- This function used to estimate rainfall or sediment volumes within a watershed (WeightGrid). The optional weight grid can be used to assign a weight to cells.

Stream networks

◆Use output from FlowAccumulation request to derive a stream network grid. Then you can select cells that have a flow accumulation value higher than a threshold that you set. The output of these functions will be a grid delineating a stream network.

StreamLink

StreamLink arbitrarily unique numbers to each link of the stream network. Each link is represented with one record in the layer's value attribute table (VAT).

StreamLink can be used to create the source grid for WaterShed. This will be a uniquely identified watershed around each stream.

◆All cells in a stream segment are assigned the same value and thus can be used to define a watershed.

StreamOrder

The StreamOrder function assigns Strahler or Shreve orders to stream grids created from flow accumulation output. Stream order is a method for assigning values to stream segments or branch to indicate their position in the hierarchy. The Stream order can be used to infer the size of a stream and is often used as input into other modeling software for predicting flood potential.

Watersheds and pour points

The Watershed request finds the uphill area that contributes runoff to the set of user-specified pour points or source cells. Drainage basin, watershed, basin, catchments area, and contributing area are synonymous terms referring to an area of drainage that contributes water and other substances to a common outlet.

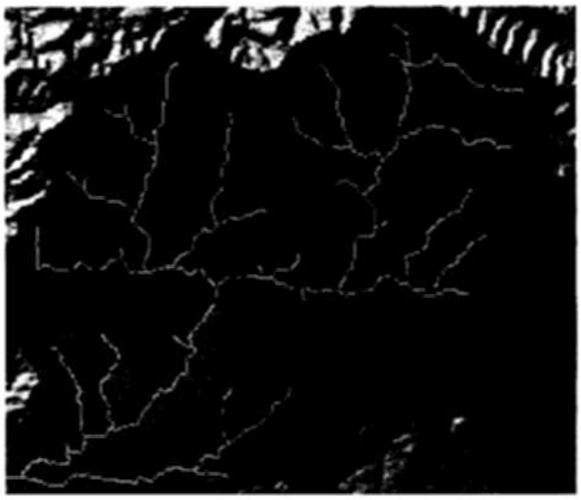

Figure 15 Watersheds for each section of a stream network

•Pour points: the common outlet is referred to as the pour point. The pour point is the lowest point along the boundary of the drainage basin. Water flows out of the basin at this point.

Flow length

The output from FlowLength can be used to find the length of the longest flow path within a given basin. This is one of the values needed to calculate time of concentration for a basin. You would use ZonalStats with the Maximum option with the outputs of WaterShed and FlowLength to find the longest path.

The accumulated flow length is calculated to each cell. The input grid contains flow direction. An optional weight grid may contain impedance to move through a cell.

•The downstream length is the length of the flow path from a cell to its pour point.

•The upstream length is the length of the flow path from a cell to the top of its basin.

Distance tools

Euclidean distance

Euclidean (Straight-line) distance operations measure the straight-line distance from every cell to the closest cell containing an object of interest. The object of interest cell is referred to as a source cell and, for example may contain a store, water well, historic building, or bird nest site.

◆Euclidean distance

•Finds distance

Point, line polygon, or non-null cells can be used when calculating distance. A distance measure for each output cell is calculated. Calculates distance from a source cell center to all other cell centers and can set maximum distance for calculating.

•Buffer zones

A buffer is a zone of specified distance around features. Buffers are useful in proximity analysis.

•Finds direction of each cell relative to the source cell.

•Allocates each cell to the nearest source cell.

•Cells closest to store 1 are assigned a value of 1.

•Calculating Euclidean distance

Calculates straight distance from cell center to cell center and calculates the hypotenuse of a triangle. Source cells are assigned a value of 0.

◆Euclidean allocation and direction

The allocation option creates output rasters that measure straight-line distance between every cell in the output raster to the nearest source cell in the input raster. Resulting output rasters may be distance, direction, or allocation.

•Source

The source raster contain cells that represent sources or object of interest. Only the source cells have a value, all other cells should have a No Data value.

•Direction

The direction raster contains the azimuth direction from every output cell to the nearest source cell. The directions are measured in decimal degrees, where north is 360 degrees (0 is reverse for the source cells), and are also computed from cell-center to cell-center.

•Allocation

Cells in thee output allocation raster contain the value of the nearest source cell. The allocation raster is a way of assigning space to the source objects and is similar to creating Thiessen polygons.

- **Weighted distance**

The weighted distance functions modify the straight-line distance by some other factor, which is a cost to travel through any given cell. This function computes the minimum travel cost from each cell to the nearest source cell, based on the cell's distance from the source cell and the cost of travel through it. This modeling is useful whenever movement is based on geographic factors, like animal migration studies, oil spill dispersion, and etc. Distance is measured in cost units, not in geographic units.

•Source, destination, cost surface rasters

•The source raster is identical to those used in Euclidean distance and allocation functions. The source raster may contain one or many cells that represent one or many zones or regions. The source objects are used to measure distance. The source raster is used with a cost surface raster in The Cost Weighted Distance tool to accumulate travel costs from the sources.

•The destination raster may contain one or many cells that represent one or many zones or regions. The destination raster is used with an accumulated travel cost grid and a direction raster in the Shortest Path tool.

•Modeling the cost surface

The cost surface is usually created with a model that can consider many variables that affect travel cost. When modeling, may consider variables that impede movement through a cell.

The cost surface is a raster defining the impedance, friction, or cost to move planimetrically through a cell.

•Cost distance

•Cost weight distance requires source and cost surface raster. This function is used to create an accumulative travel cost raster.

•The weight Distance functions can create three output rasters. The allocation raster is the only one they have in common.

Accumulative cost raster is not the linear distance from a cell to its source. Rather, it contains the sum of the minimum travel costs that would accumulate by traveling along the least-cast path that connect the cell to its nearest source.

Distance raster provides the direction for each cell to its source along the least-cast path. Each cell is assigned a code that identifies which of its neighbors is on the least-cost path back to the source.

Allocation raster is similar to the Euclidean Distance allocation raster because each cell is assigned to its nearest source (in terms of accumulated travel cost).

•The direction raster provides the direction for each cell to its source, along a least-cost path. Each cell is assigned a code that identifies which of its neighbors is on the least-cost path back to the source.

•Weighting distance measurements with a cost: uses units of distance (cell size) and units of cost. Weights and accumulates cost away from the source for each cell.

•The distance-weighted cost has two links

1. Orthogonal link cost is the cost at cell 1 plus the cost at cell 2 divided by two. The cell size or the distance between the two cell centers is accounted for when calculating the diagonal links.

Orthogonal direction cost Distance * (cost1 + cost2) / 2

2. Diagonal link cost is the cost at cell 1 plus the cost at cell 2 divided by two. The average cost is multiplied by the diagonal distance between the two cells. This distance is the square root of a squared plus b squared

Diagonal direction cost $\sqrt{2}$ Distance * (cost1 + cost2) / 2

•The Shortest Path tool uses the accumulative travel cost and direction rasters to find the least-cost path from any given starting cell to the nearest source.

•The least-cost path is a one cell wide path of lowest accumulated travel cost connecting two points (a source and a destination).

Building models

Modeling spatial problems

- A model is a filter that helps extract information from volumes of complex data.
  - Models simplify reality
  - Models combine geographic layers to answer questions.

Types of models

- Representation models show objects in the landscape. These models capture the spatial relationships between geographic objects.
- Suitability models used to find the best location for something. Relatively easy and standard methodology.
- Process models show the landscape as condition change (fire spreads, river flood, oil slicks move). Often difficult and no standard methodology.

Binary Suitability models

- Use for simple problems like a query.
- Classify layers into good (1) and bad (0)
  - Logical And, Add or Multiply together: [ski] = [snow] & [slope] & [sun]
- Advantages: easy
- Disadvantages: all layers have same importance; all good have same importance, no "next-best" sites

Weight suitability models

- Use for complex problems
- Classify layers into suitability 1-9 (9 = best)
  Weight and add together: [ski] = ([snow] * .5) + ([slope] * .3) + ([sun] * .2)
- Advantages: all values have relative importance; all layers have relative importance, Returns suitability on a scale 1-9.
- Disadvantages: Preference assessment is harder.

Define the model

- This is a team activity: Define the problem, Identify issues, determine how to measure, Obtain GIS data.

Break big model apart

- Clarifies relationships: makes problem easier to solve

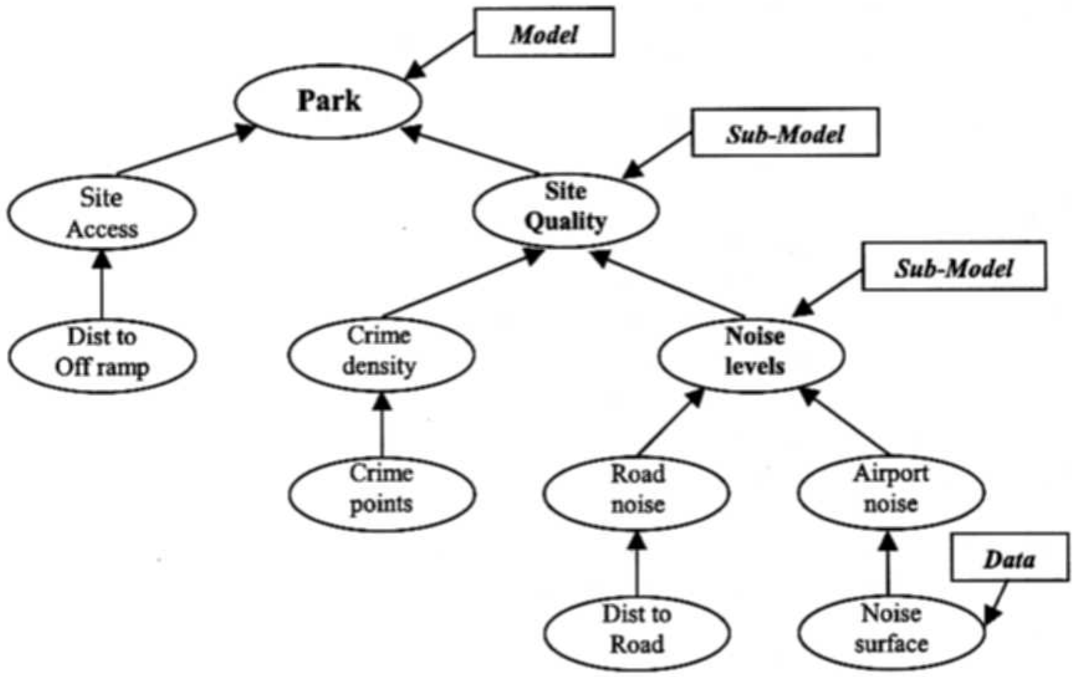

Figure 16 Example of Park model diagram

Measure the issues

- Base data is seldom useful to measure issues
- May be very easy: Spatial Analyst function, like distance to road
- May be harder: Write another model, like travel to roads

A word about data

- Valid math depends on the data type

•Nominal measurements are unique values assigned to things to identify them. No math is legal with nominal data.

•Ordinal measure rank things relative to one another. They only indicate that one thing is more important than another, not how much more important it is. But you can test for relative value.

•Interval measures reflect the magnitude of the difference between one value and another, but not between a value and zero. Addition and subtraction are valid between interval values, but multiplication and division are not. Interval data may be scaled into ratio by multiplying it with a constant.

•Ratio measures are the magnitude of the difference between a value and zero point. All math is valid between ratio values.

Building a scale

•Suitable scale should be linear and typically range from 1 - 9 (worst to best). And must use the same scale for all layers in the model

•Suitability is an interval scale: mapping a layer's values onto the suitability scale uses a process called preference assessment and results in the layers values Being placed on an interval scale of suitability.

Determine Suitability and weights

•Preference assessment process: suitability assignment and weight assignment

•Normally done by a team use various techniques.

•The hard part of model development

Convert measures into suitability

•You cannot mathematically combine layers that measure different things. The result is meaningless.

•Must put on common scale of suitability: values must measure the same thing.

•Done by reclassifying measures: reclassify layers into interval measures of suitability.

The Reclassify dialog

•Often the best choice for reclassifying into suitability

•Reclassifying coded values: Nominal data are easily reclassified from the main dialog. You assign a "New value" of suitability for each "Old value", or code. To simplify the job, there are tools for grouping codes together using ranges and/or lists of "old values".

•Reclassifying measured values: Ratio data are often best classified statistically. Using any of the many statistical classification tools found in the embedded Classify dialog, you create ranges of input values then assign suitability back in the main Reclassify dialog.

Reclassification with equation

•An option with ratio data: need mathematical relationship between data and suitability.

•Form of the equation: You may implement almost any mathematical function in Map algebra – linear, exponential, inverse squared or parabolic to name a few.

•Advantages: Preference assessment may be easier. If you can simply state that the suitability decreases with distance until at some point it becomes zero, that is easier than trying to define ranges of distance and assigning suitability to each range.

•Disadvantages: you need to be able to determine the mathematical relationship that exists between the data and suitability, and you must be able to express the relationships as mathematical function.

Weight and combine the layers

- For each sub-model
  - Multiply suitability layers by weights. Weights must add up to 1
  - Add the weighted layers together
- Repeat to combine sub-models
- Uses one Map Algebra expression per sub-model. The Map Algebra expression used to weight and add the reclassified suitability layers together is trivial; you must multiply each layer by its weight and add them up.

Find the best locations

- The model creates a floating point raster of suitability values in the range of 1-9. The raster is actually a surface of suitability, similar to surface of elevation.
- You need to delineate the potential sites as discrete areas, which are the alternative sites. By exploring the model results with Reclassify statistics and histogram.
- Create candidate sites: select cells with highest scores, define regions with unique Ids, and eliminate small areas.

Advance display techniques

Raster data properties

- Imagery (e.g. LANDSAT)
    - Single band: Grey scale, Pseudo color
    - Multi band: each measures how much RGB
- Other rasters (e.g. grids)
    - Integer raster: Numerical attribute, Grey scale (color measurement)

Types of ArcMap display randerers

- Discrete data: unique values assign a color for each value.
- Continuous data
    - Single-band raster
    - Classified - classify values into categories
    - Stretched – draw large number of values in spectral imagery
    - Multi-band raster

  - RGB Composite and Stretched: draw a three-band composite, can draw more than 3 bands, and can change the band combination.

Resampling during display

Can used in Display tab and select the resampling method from list box. Resampling during display has 3 methods are

- Nearest neighborhood (for Discrete data)
- Bilinear interpolation (for Continuous data): this smoother than Cubic convolution.
- Cubic convolution (for Continuous data)

Color ramp stretching

Can choose in symbology tab in stretch type list box. You can choose None, Custom, Standard Deviations, Histogram Equalize, Minimum maximum of stretch type.

Creating a new symbol style and editing a color ramp

- In style manager, you can create your own symbol style.
- Edit color ramp in color ramp properties and save to style.
- You can displays color to No Data in symbology tab

The Effects toolbar

Allows interactive display. You can select layer and adjust contrast, brightness and transparency.

Drawing raster features on raster

- Make NoData transparency
- May need to dimple both rasters

Drawing vector features on raster

- Points, lines, polygons
- Transparency mainly for shaded polygons

Labeling on raster
- Contrasting label colors and raster color
- Halo labels improve legibility

Special techniques for rendering 3D rasters and visualization
- Multidirectional, oblique-weighted shaded relief
- Drawing tree symbols on a hillshade
- Using landscape patterns to texturize painted relief
- 3D visualization

Customizing the Spatial Analyst

Customizing ArcGIS

ArcGIS is built on a family of COM objects known as ArcObjects. You can use ArcObjects 4 ways: with VBA, as a stand-alone application, to extend the functionality, and to extend the data model.

Spatial Analyst Object model

The Spatial Analyst Object model is composed of a collection of objects to perform raster analysis. There are two main types of objects: objects that support the overall Spatial Analyst environment and objects that perform analysis operations.

- Must add as a reference in your VB / VBA project:
  - ESRI Spatial Analyst Extension Object Library
  - ESRI Spatial Analyst shared Object Library

The Raster Object Model illustrates the related components that provide access to raster data and the interfaces to manage and visualize that data. These components can be conceptually organized into three areas: raster data on disk, raster data in memory, and raster data visualization.

Pixel Block accesses individual pixels: allows for custom neighborhood analysis.

Steps for running a SPAT function

- Check for a license
- Set the Analysis environment
- Access input data
- Perform an operation
- Use the output

Input data for SPAT functions

- Raster Dataset (on disk)
- Raster (virtual representation)
  - If multi-band, first band is used
  - Some functions process multiple bands
- Raster Band
- Raster Descriptors (Query)
- Feature Class and Descriptor: automatically convert to raster
- Non-GRID formats are converted to GRID for analysis
  - May want to convert highly compressed data before processing

Spatial reference

- Best if all inputs have the same spatial reference
- Project on-the-fly if inputs have different spatial reference
  - Not real accurate
  - Acceptable for mid-latitudes and small areas (within 2 degrees)
- If not specified, first raster with a spatial reference sets the output.
  - If no raster has a spatial reference, the first feature class is used.
  - If no spatial reference is defined for any of the inputs the output is unknown.

Perform an operation
- Declare variable, Create object, and Call function

Three SPAT programming styles
- Pure object: easier for object-oriented programmer
- Single line map algebra: easier for people who know map algebra
- Multi-line map algebra: can use tables and feature classes

SPAT function output
- All output is temporary until it is made permanent.
  - Make Permanent on the RasterDataset object
  - Add ArcMap to retain reference to raster
- Functions that have multiple outputs create a multi-band raster
  - First band is band 0

Reference

ESRI (2001). Working with ArgGIS Spatial Analyst (for ArcView 8). ESRI (Thailand) Co., Ltd., Bangkok.