

Lecture 5 Interpolation Techniques

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Lecture Outline

1. Introduction to Interpolation Technique
2. Overview - Interpolation to Raster
3. Triangulated Irregular Network (TIN)
4. Inverse Distance Weighting (IDW)
5. Natural Neighbor Interpolation
6. Spline Interpolation
7. Kriging Interpolation
8. References

Interpolating to raster:

- Triangulated Irregular Network (TIN)
 - Thiessen polygon
 - IDW
 - Natural Neighbor
 - Spline
 - Kriging

1.2. Method of Surface Representation

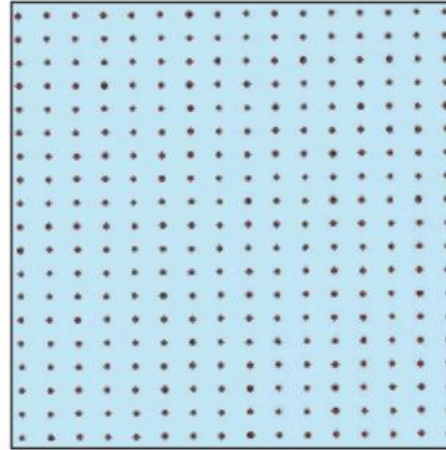
Points can be used to create surface Raster.

Surface raster are made up of grid cells That each grid cells represents x,y including the z value.

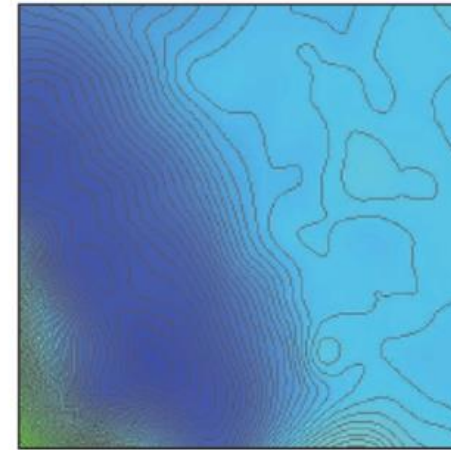
The surface representation is done by storing x,y and Z values:

X, y – defines the location of a sample.

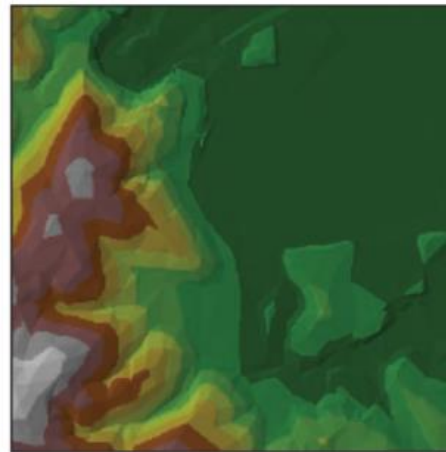
Z value– defines the change characteristics on the created surface.



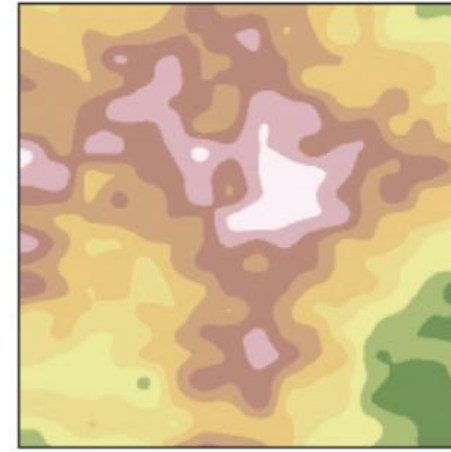
Points



Contours



TINs



Grids

1.2. Surface Representation

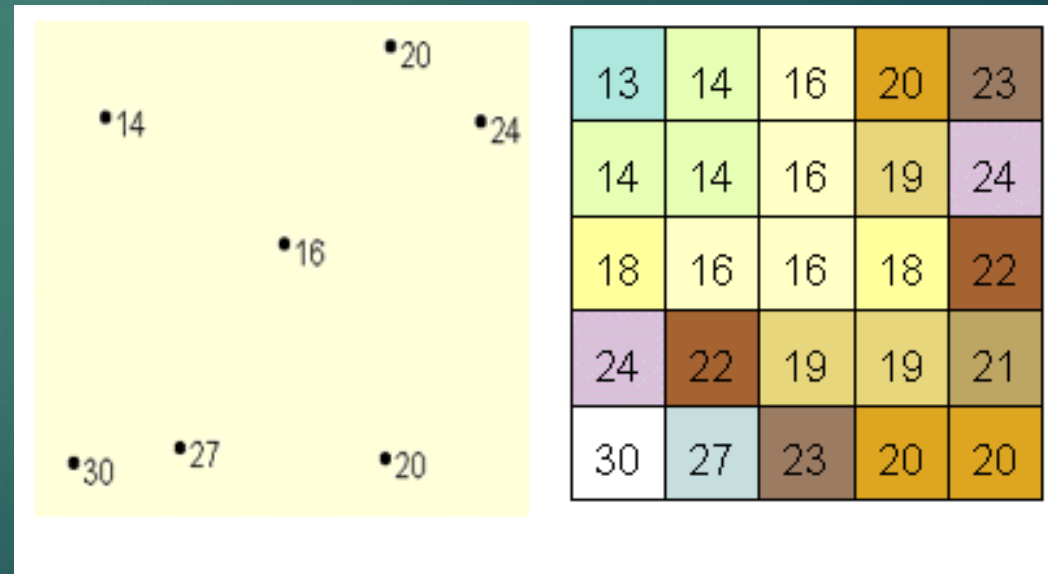
The surfaces can be use to represents:

- Terrestrial surfaces that depict the earth surface.
- Statistical surface that depicts demography including other type of data.
- Mathematical surfaces that are based on arithmetic expressions

2. Overview - Interpolation to Raster

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- 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:
 - elevation,
 - rainfall,
 - Wi-Fi Strength
 - chemical concentrations,
 - noise levels,
 - Pollution
- Unknown values are predicted with a mathematical formula that uses the values of nearby known points.



2.1. Basics to Raster Interpolation

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Interpolation is used to predict the values of cells at locations that lacks sample points.

Assuming that spatially distributed objects are spatially correlated;

In other words, things that are close together tend to have similar characteristics.

For instance, if it is raining on one side of the street, you can predict with a high level of confidence that it is also raining on the other side of the street.

Having this assumption in mind, it is easy to see that the values of points close to sampled points are more likely to be similar than those that are farther apart.

2.2. The Correlation/Relationship

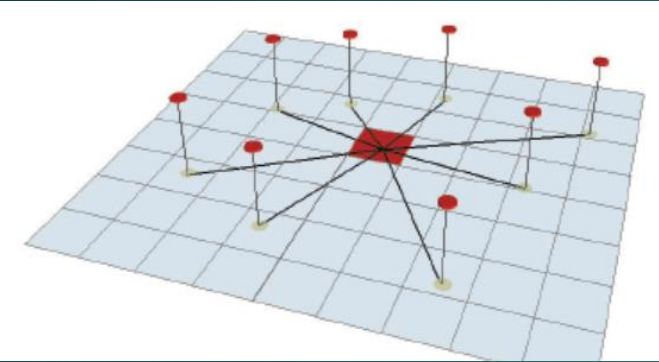
The Correlation algorithm is use to measure:

1. Similarity of objects within an area
2. The Degree to which a spatial phenomena is correlated to itself in space
3. The level of interdependence between the variables
4. Nature and Strength of the interdependence

It is to note that, different interpolation methods will almost always produce different results.

2.3. Maximum Number of Interpolation Points

Maximum Number



The characteristics of an interpolated surface is control by number of sample interpolation points used.

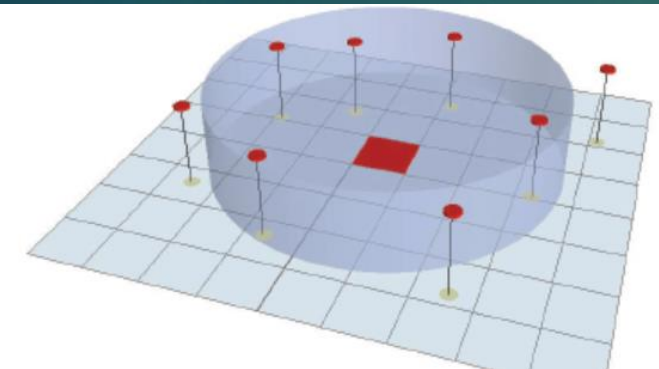
Each points carrying a z values.

Limiting the input point means to specify the maximum number of points.

The search for nearest points is carried out until maximum number of points are reach.

The assigning of radius value assist in this

Fixed Radius



2.4. Barriers Affecting Interpolation

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The barriers also controls how surfaces are interpolated.

It creates linear discontinuity.

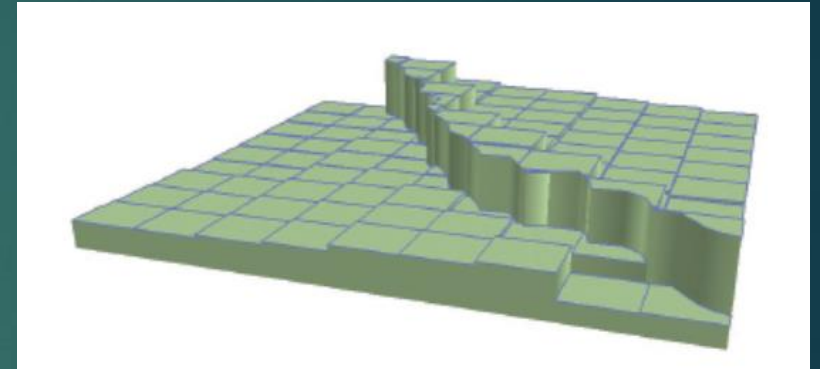
The barriers can be:

rivers,
cliffs,
fault lines
Other...

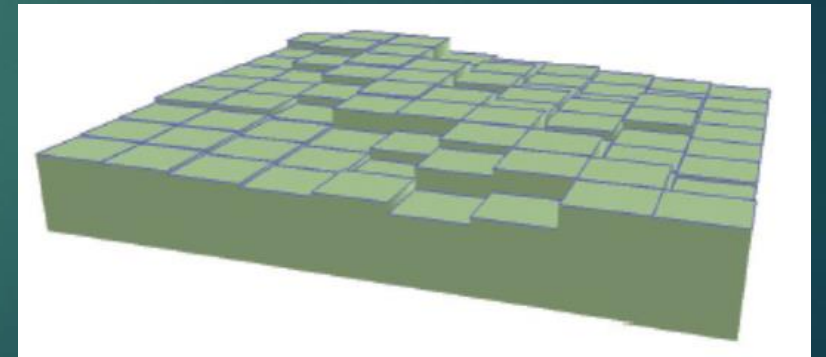
Some interpolation techniques Supports barrier. Like;

- IDW
- Spline

With Barrier



Without Barrier



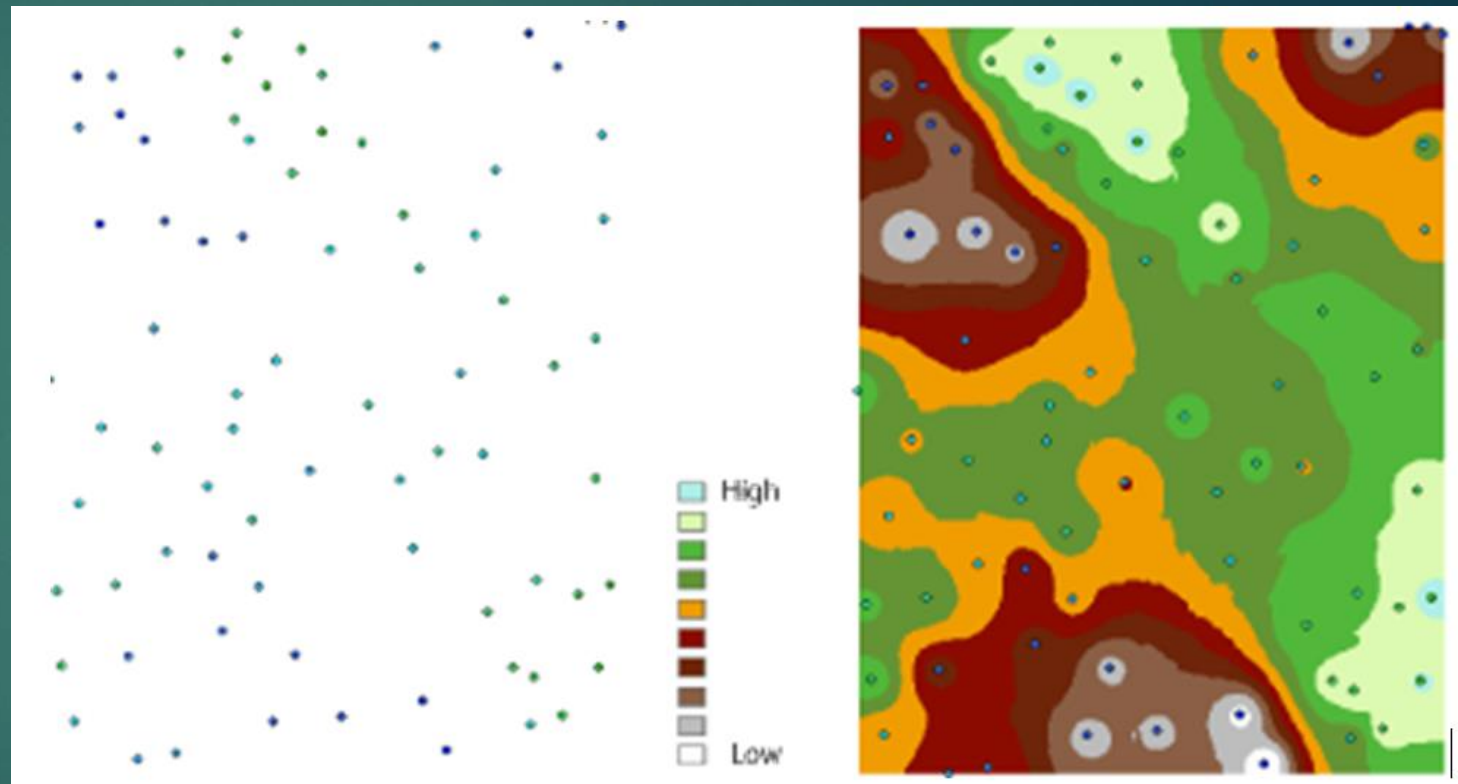
2.5. Example of Point Interpolation

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Each symbol in the point layer represents a location where the elevation has been measured.

Each point carries a elevation value.

By interpolating, the values between these input points will be predicted.



3. Triangulated Irregular Network (TIN)

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Differentiation of Raster Surface and TIN;

There are two representations to model surfaces that is use by ArcInfor/other GIS software:

1. Raster
2. TINs.

Raster represent a surface as a regular grid of locations with sampled or interpolated z-values.

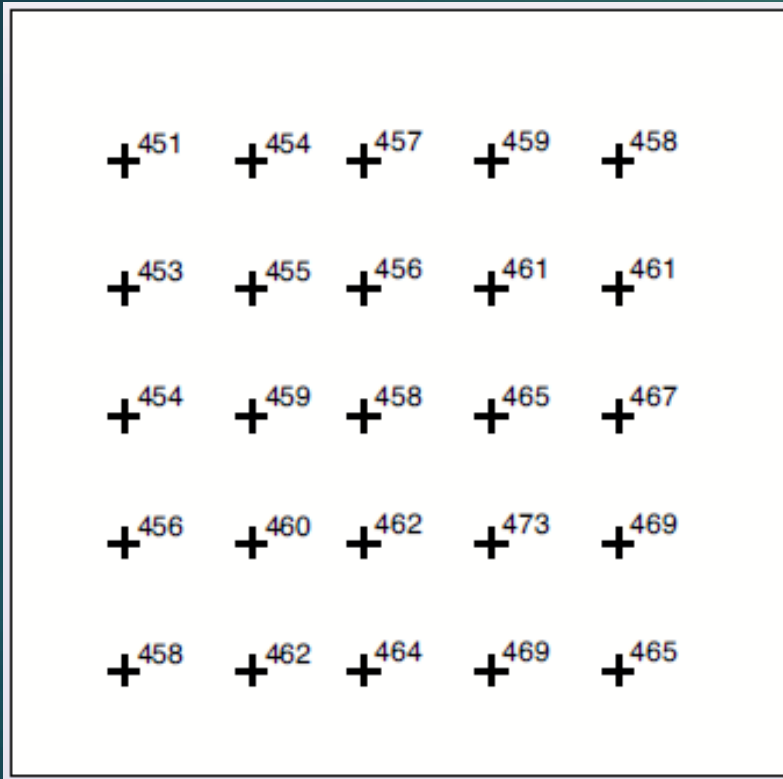
TINs represent a surface as a set of irregularly located points that form a network of triangles with z-values at each node.

Both raster and TIN representations have merit for surface modeling;

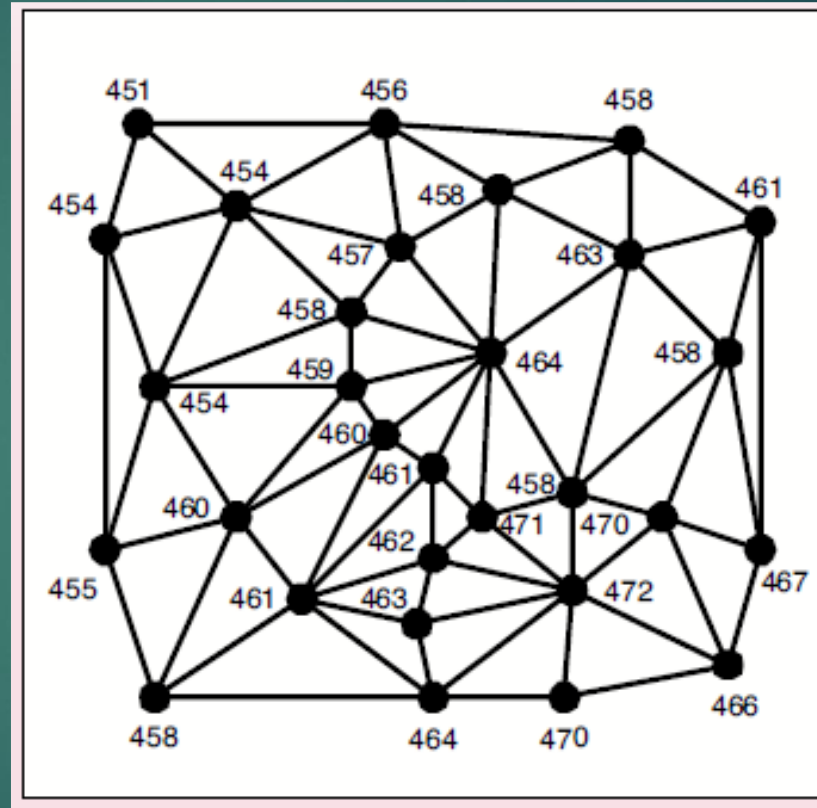
A TIN data model is composed of:

- Nodes,
- Edges,
- Triangles,
- Topology

3.1. Illustration of Representation between TIN and Raster



Raster Representation of a surface



TIN Representation of a surface

3.2. Nodes

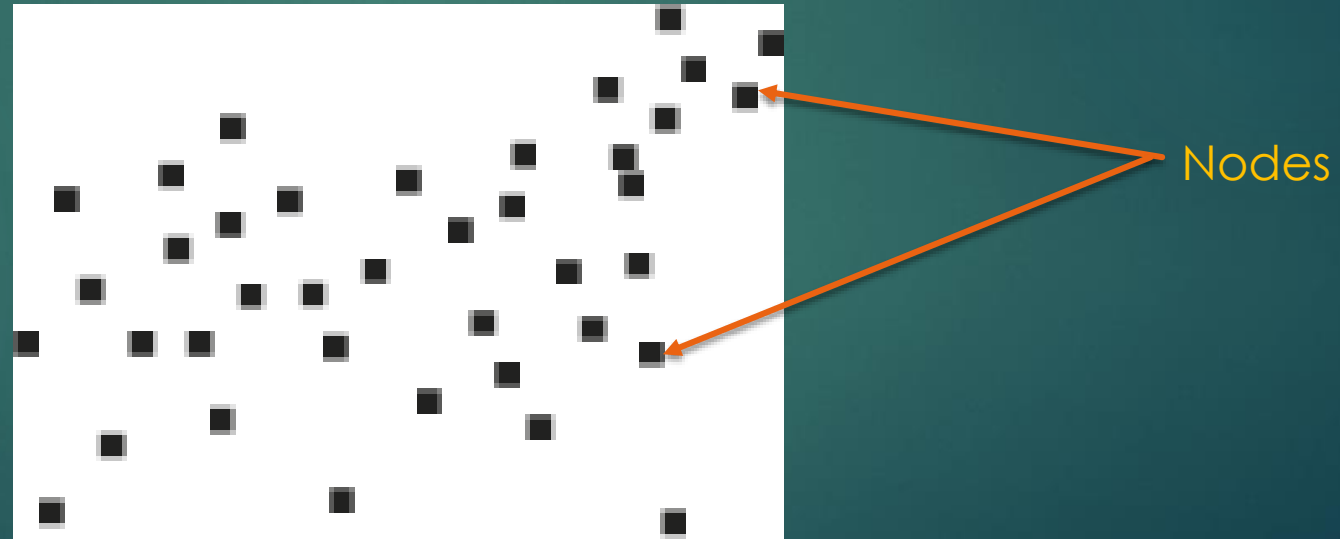
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Nodes are the fundamental building blocks of a TIN.

The nodes originate from the points and line vertices contained in the input data sources.

Every node is incorporated in the TIN triangulation.

Every node in the TIN surface model must have a z-value.



3.3. Edges

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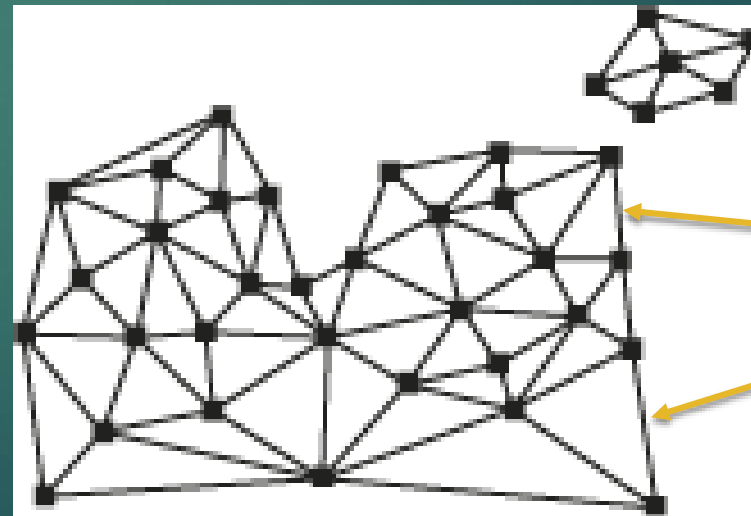
Every node is joined with its nearest neighbors by edges to form triangles, which satisfy the [Delaunay criterion](#).

Each edge has two nodes, but a node may have two or more edges.

Because edges have a node with a z-value at each end, it is possible to calculate a slope along the edge from one node to the other.

Breakline features are always maintained as edges in the TIN triangulation.

These breakline TIN edges are flagged internally as either hard or soft edges.



Edges

3.4. Triangles

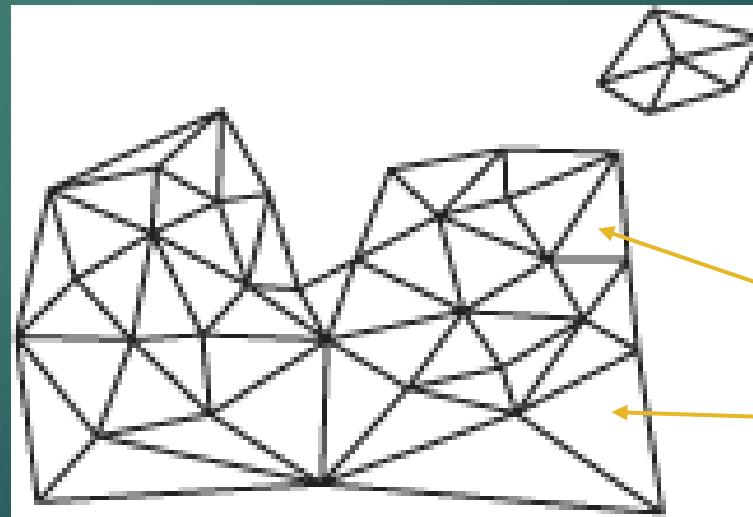
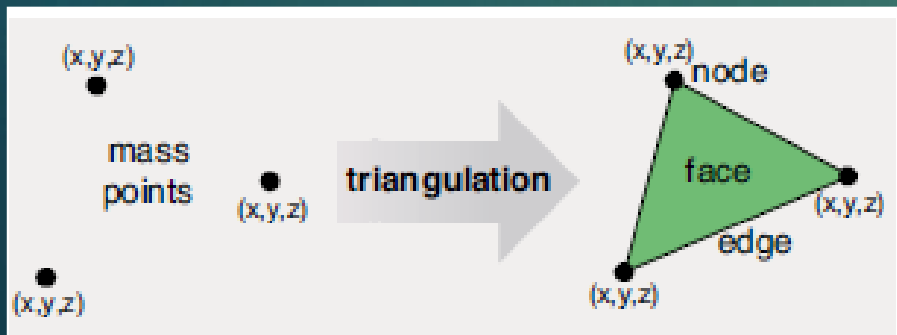
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Each triangular facet (Face) describes the behavior of a portion of the TIN's surface.

The x , y , and z coordinate values of a triangle's three nodes can be used to derive information about the facet, such as slope, aspect, surface area, and surface length.

Considering the entire set of triangles as a whole, it is possible to derive additional information about the surface like:

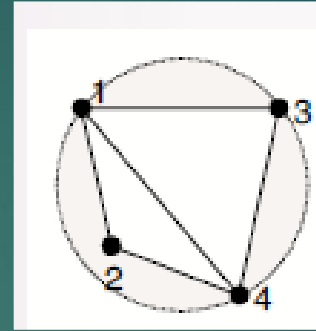
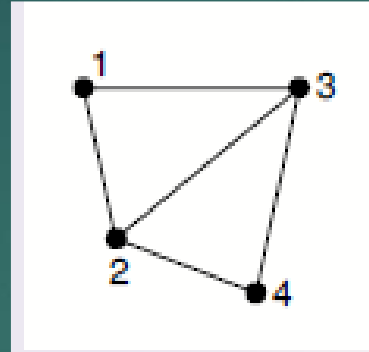
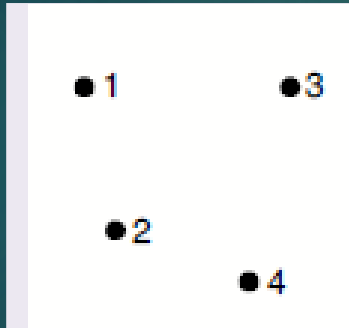
- volume,
- surface profiles,
- visibility analysis.



Triangles

3.5. Delaunay criterion

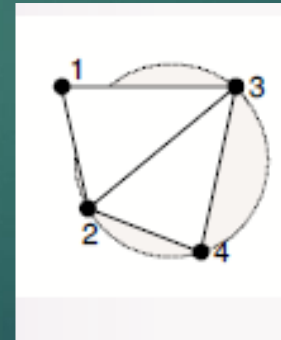
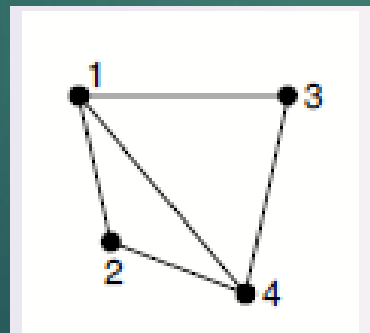
Delaunay triangulation
Uses an algorithm to
optimize the
Surface
representation



This triangulation fails the
Delaunay criteria/test

Taking into account
4 mass points, 2
triangulations are
possible.
Which is the Valid TIN

The definition of the
Delaunay triangulation
specifies that any circle
around three nodes in a
triangle will
not include any other node.



This triangulation satisfies
the Delaunay criteria/test

3.6. Create TIN In ArcMap

The screenshot shows the ArcMap interface with a terrain map. The 'Create TIN' dialog box is open, displaying the following fields and options:

- Output TIN:** C:\Users\Survey 02\Documents\ArcGIS\CreateTin
- Coordinate System (optional):** [Empty field]
- Input Feature Class (optional):** [Empty field]
- Input Features Table:**

Input Features	Height Field	SF Type	Tag Field

Help Panel:

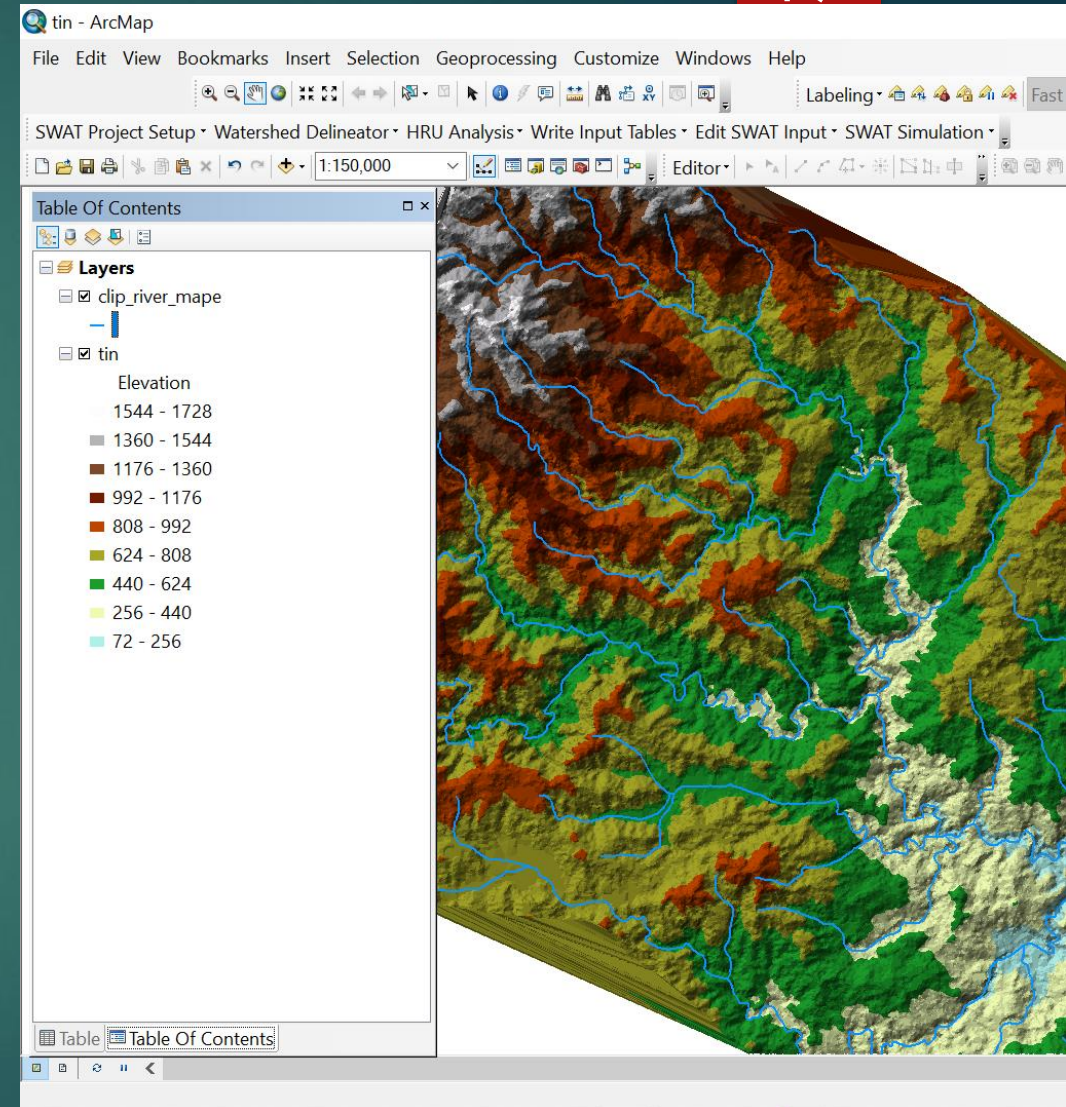
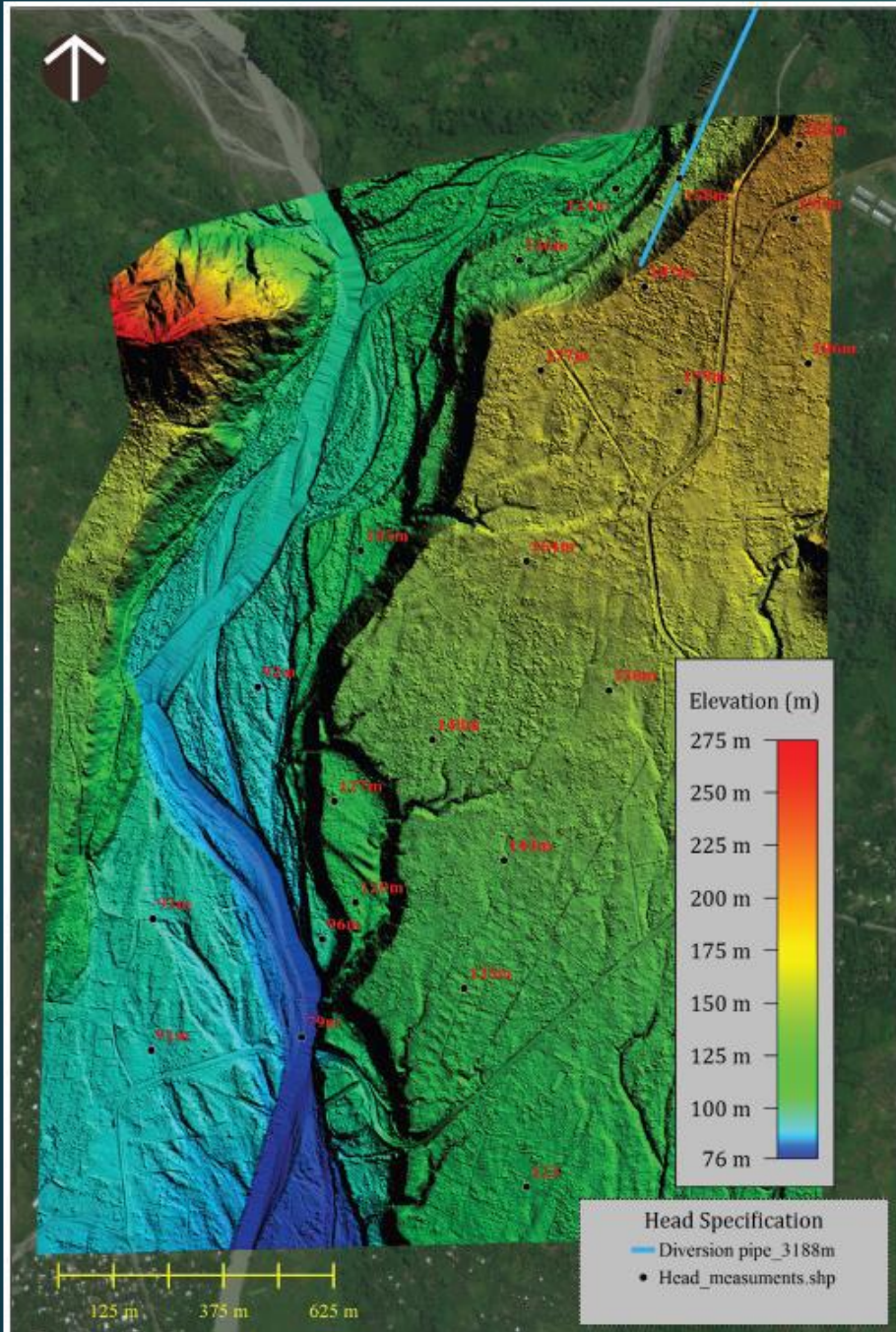
The input features and their related properties that will contribute to the definition of the TIN.

- **Input Features**— The feature whose geometry will be imported to the TIN.
- **Height Field**— The source of elevation for the input features. Any numeric field from the input feature's attribute table can be used, along with Shape.Z for the Z values of 3D features, and

Buttons at the bottom: OK, Cancel, Environments..., << Hide Help, Tool Help

3.7. Created TIN

Seeking for Hydro Power potential at Busu River & Maramabi River. Lae and Nawae District



3.8. Topology

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The topological structure of a TIN is defined by maintaining information defining each triangle's nodes, edge numbers, type, and adjacency to other triangles.

For each triangle, a TIN records:

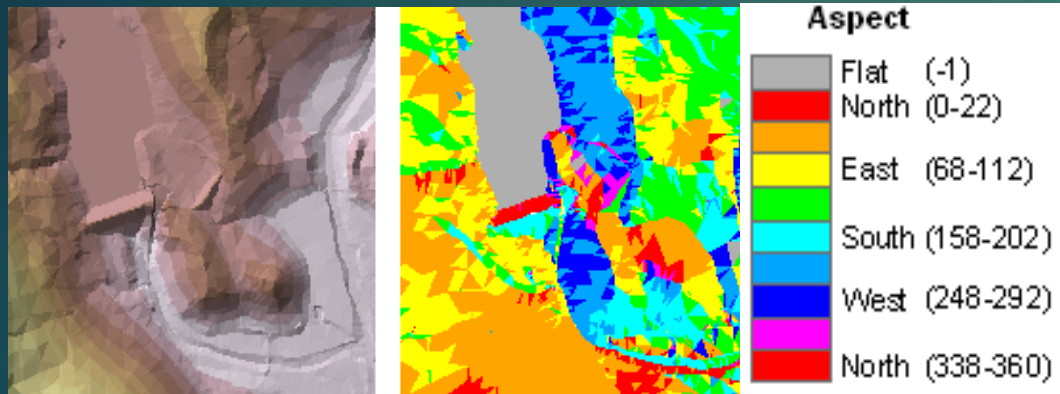
- The triangle number
- The numbers of each adjacent triangle
- The three nodes defining the triangle
- The x,y coordinates of each node
- The surface z-value of each node
- The edge type of each triangle edge (hard or soft)

3.9. Extracting information from a TIN

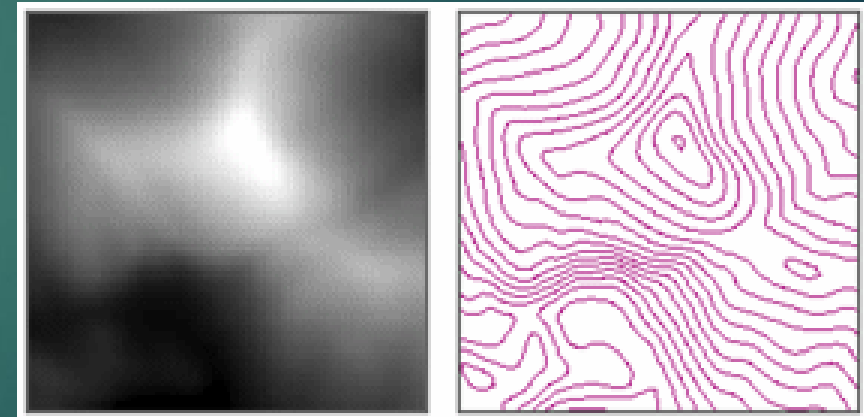
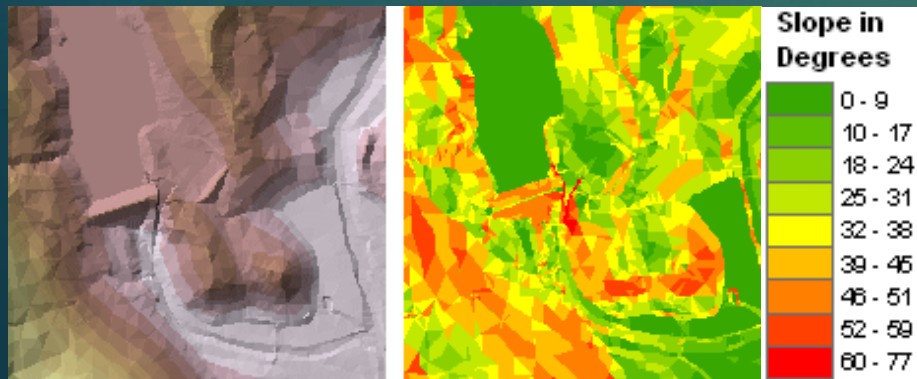
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TINs store slope and aspect information as attributes of the TIN facets.

Contours can readily extracted from TIN



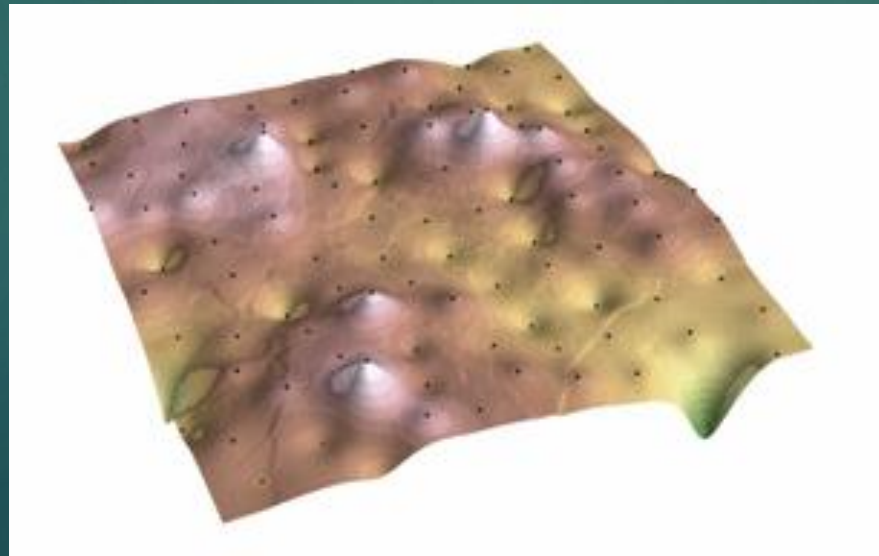
The [Contour](#) tool extracts lines of constant value (isolines) from a raster surface. The [TIN Contour](#) tool extracts a line feature class of contours from a TIN surface.



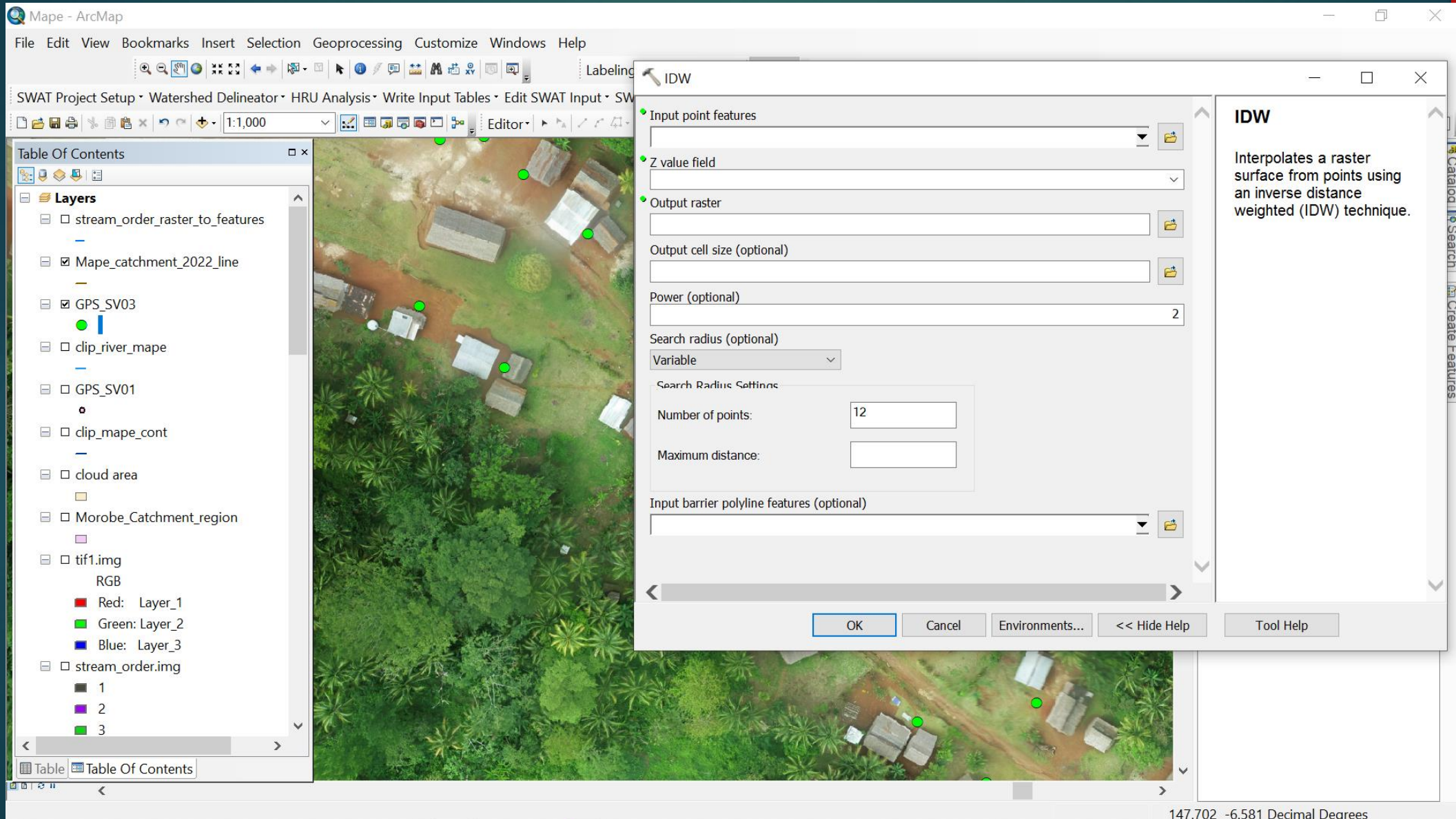
4. Inverse Distance Weighting (IDW)

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- ✓ The IDW function is the simple and most popularly used
- ✓ It is used when the set of points is dense enough.
- ✓ IDW determines cell values using linear weighted combination set of sample points
- ✓ The weight assigned is a function of the distance of an input point from the output cell location
- ✓ The greater the distance, the less influence the cell has on the output value.



4.1. ArcMap IDW Spatial Analysts tool



5. Natural Neighbor Interpolation

Natural Neighbors interpolation is like IDW interpolation, except that the data points used to interpolate the surface values for each cell are identified and weighted using a Delauney triangulation, as in a TIN.

Reliably works with much larger datasets than the other interpolation methods.

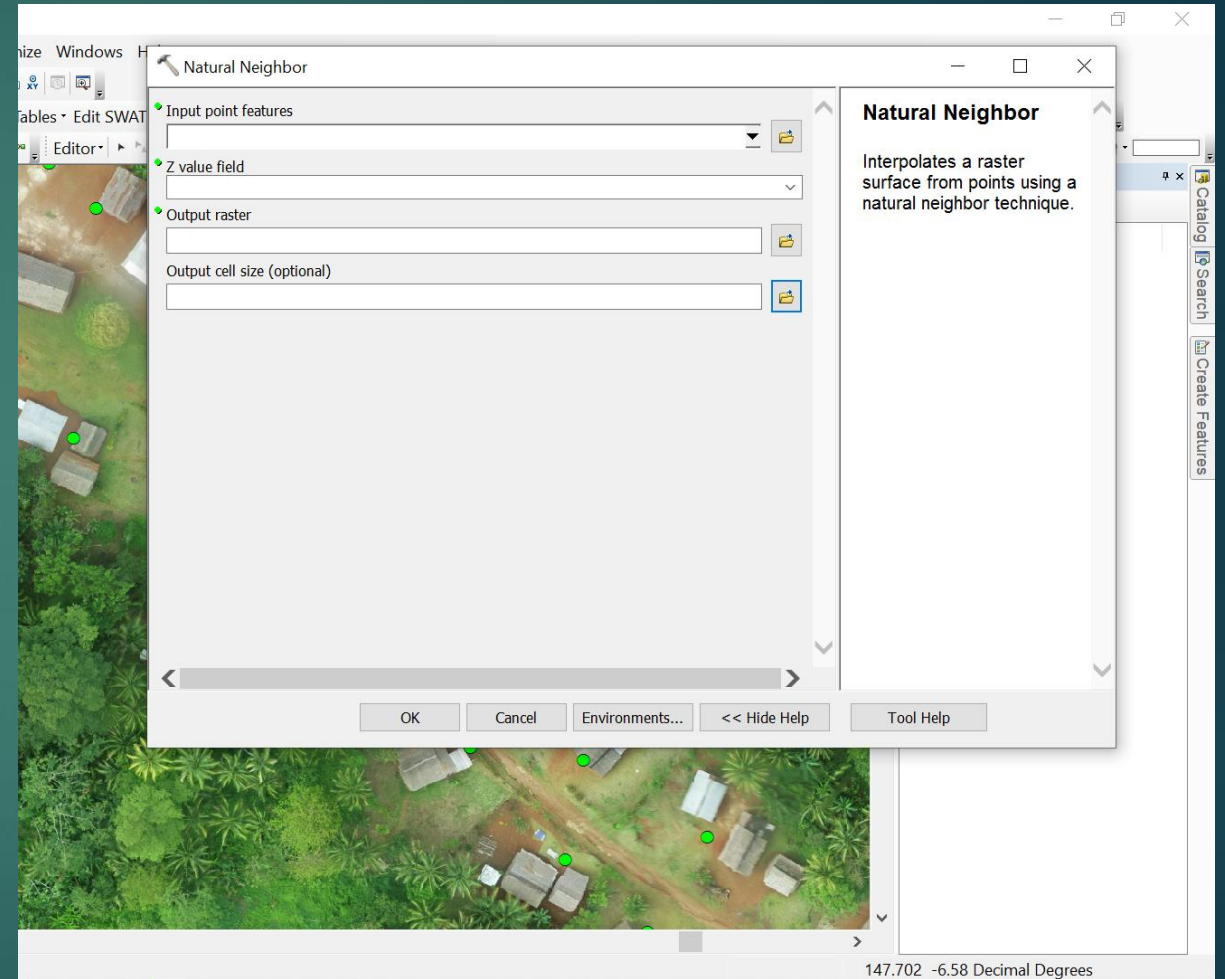
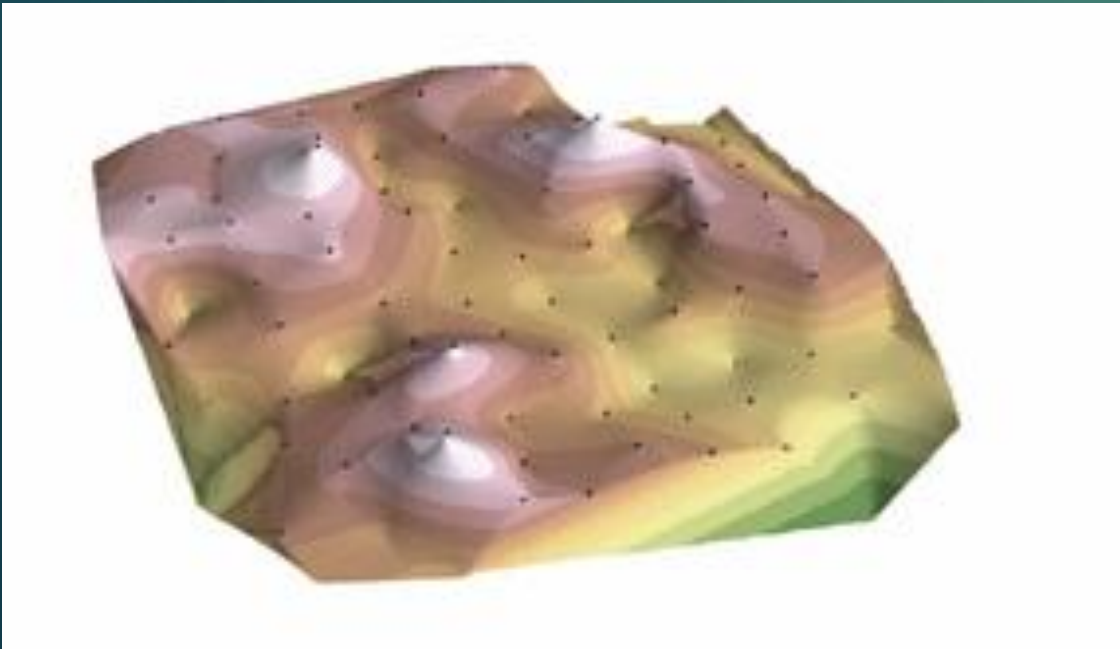


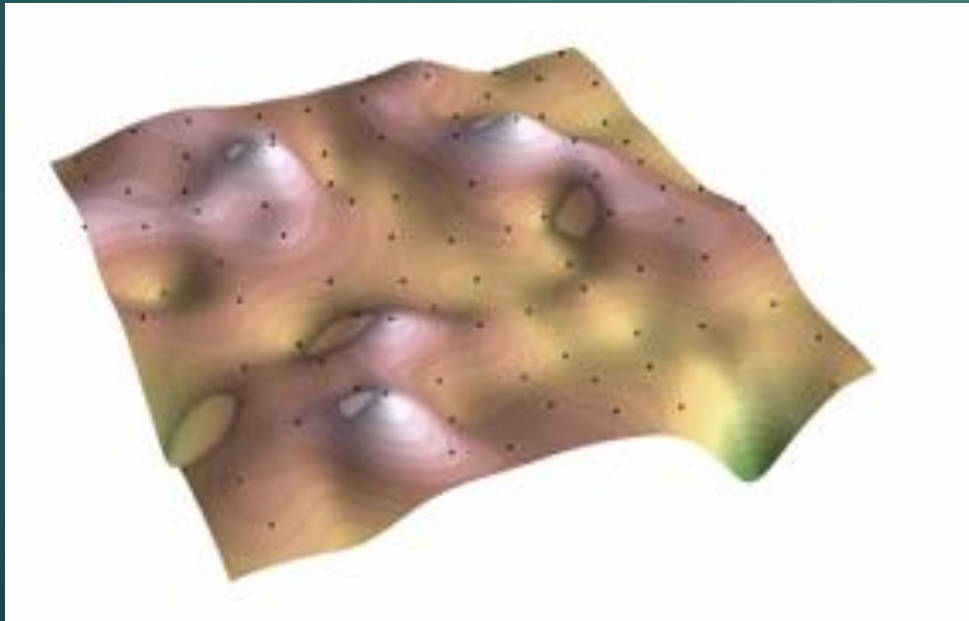
Image Source: T.Sekac (2022)



6. Spline Interpolation

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- ✓ The Spline method is an interpolation method that 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 useful for surfaces that vary smoothly, such as water table heights.
- ✓ It interpolates a surface from points using a minimum curvature spline technique.



6.1. Spline Interpolation Methods

There are two spline interpolation methods:

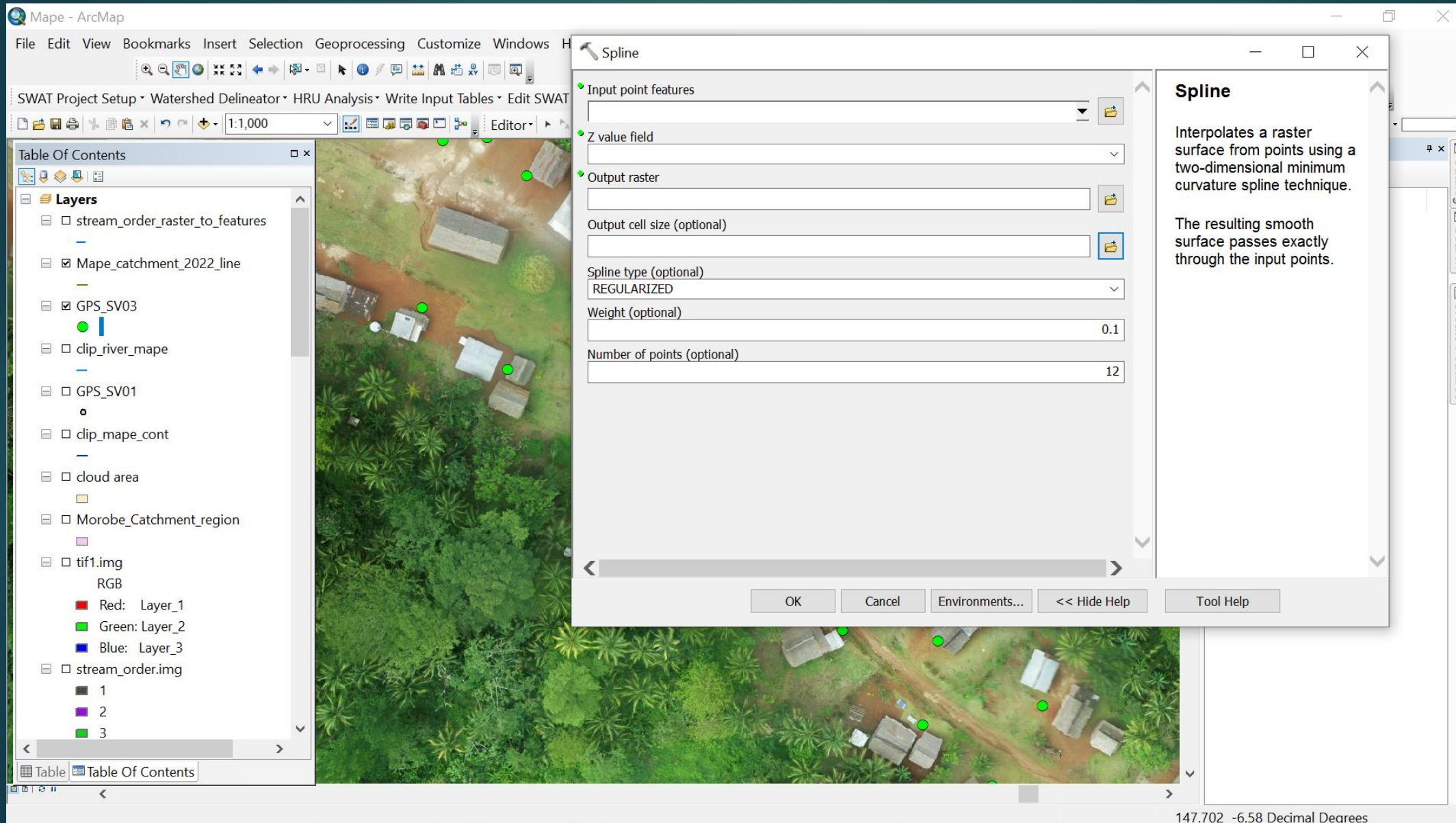
1. Regularized
2. Tension.

The Regularized method creates a smooth, gradually changing surface with values that may lie outside the sample data range.

The Tension method controls 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.

6.2. ArcMap Spline Interpolation Spatial Analyst tool



7. Kriging Interpolation

Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values.

The IDW and Spline interpolation methods are referred to as deterministic interpolation methods because they are directly based on the surrounding measured values.

However, kriging interpolation methods are based on statistical models that include autocorrelation, that is the relationships among the measured points.

Because of this, the Kriging technique has the capability of:

1. producing a prediction surface,
2. provide some measure of the certainty or accuracy of the predictions made.

7.1. The kriging formula

Kriging is similar to IDW in that it weights the surrounding measured values to derive a prediction for an unmeasured location.

The general formula for both interpolators is formed as a weighted sum of the data:

$$\hat{Z}(s_0) = \sum_{i=1}^N \lambda_i Z(s_i)$$

Where;

$Z(s_i)$ = the measured value at the i th location

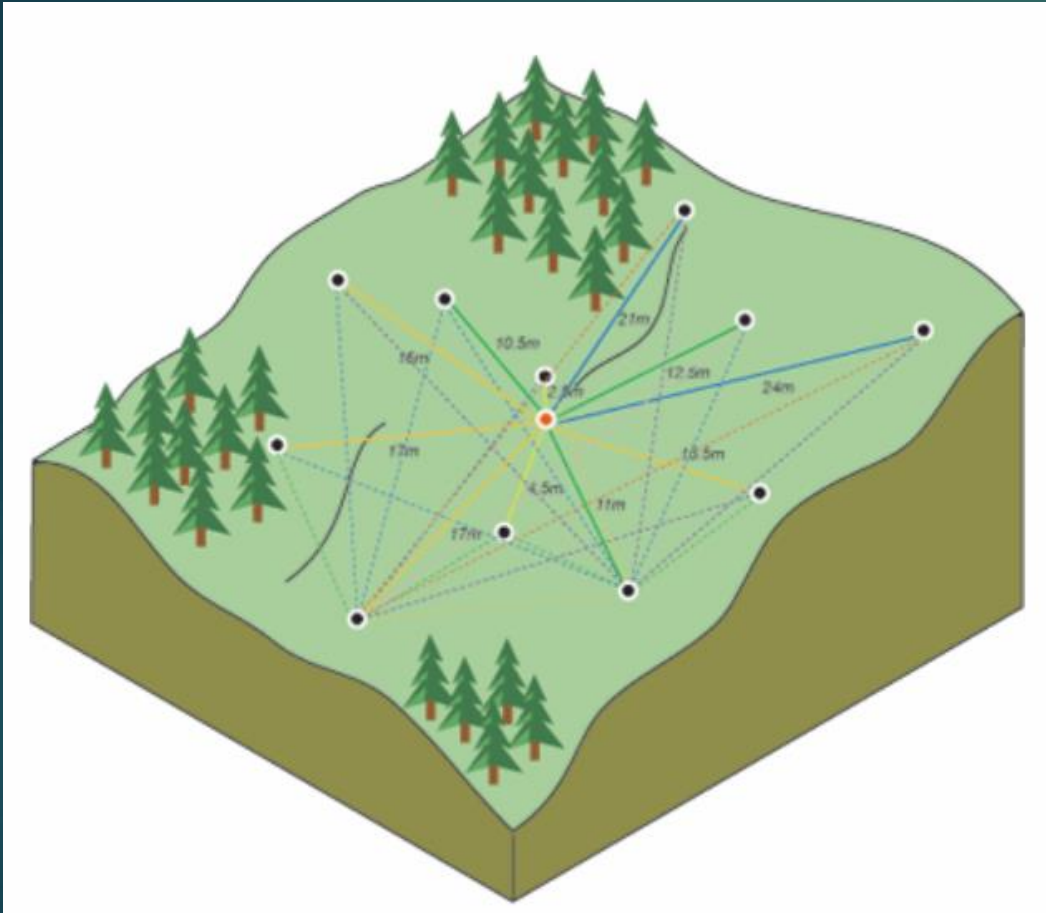
λ_i = an unknown weight for the measured value at the i th location

S_0 = the prediction location

N = the number of measured values

7.2. Kriging Spatial Modeling Schematic Diagram

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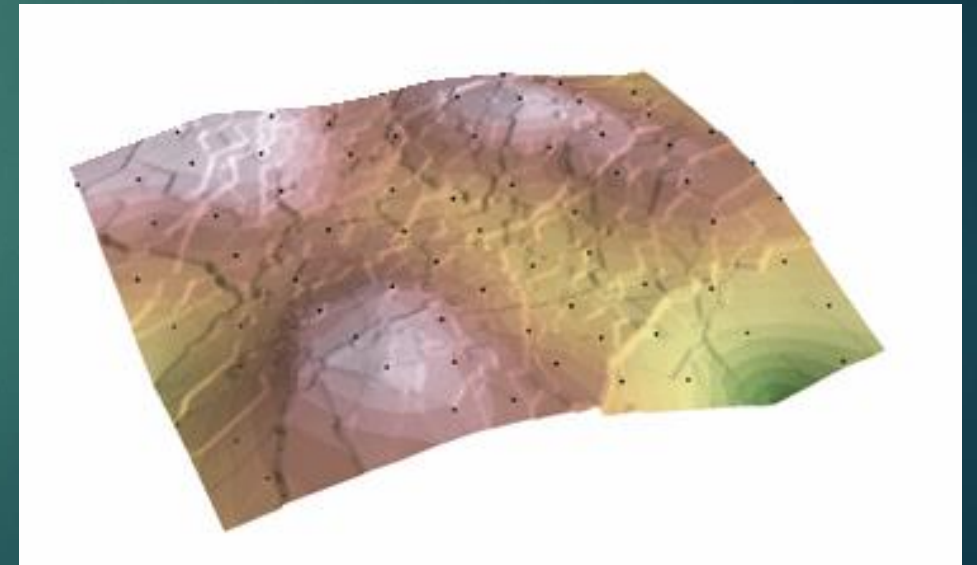


In IDW, the weight, λ_i , depends solely on the distance to the prediction location.

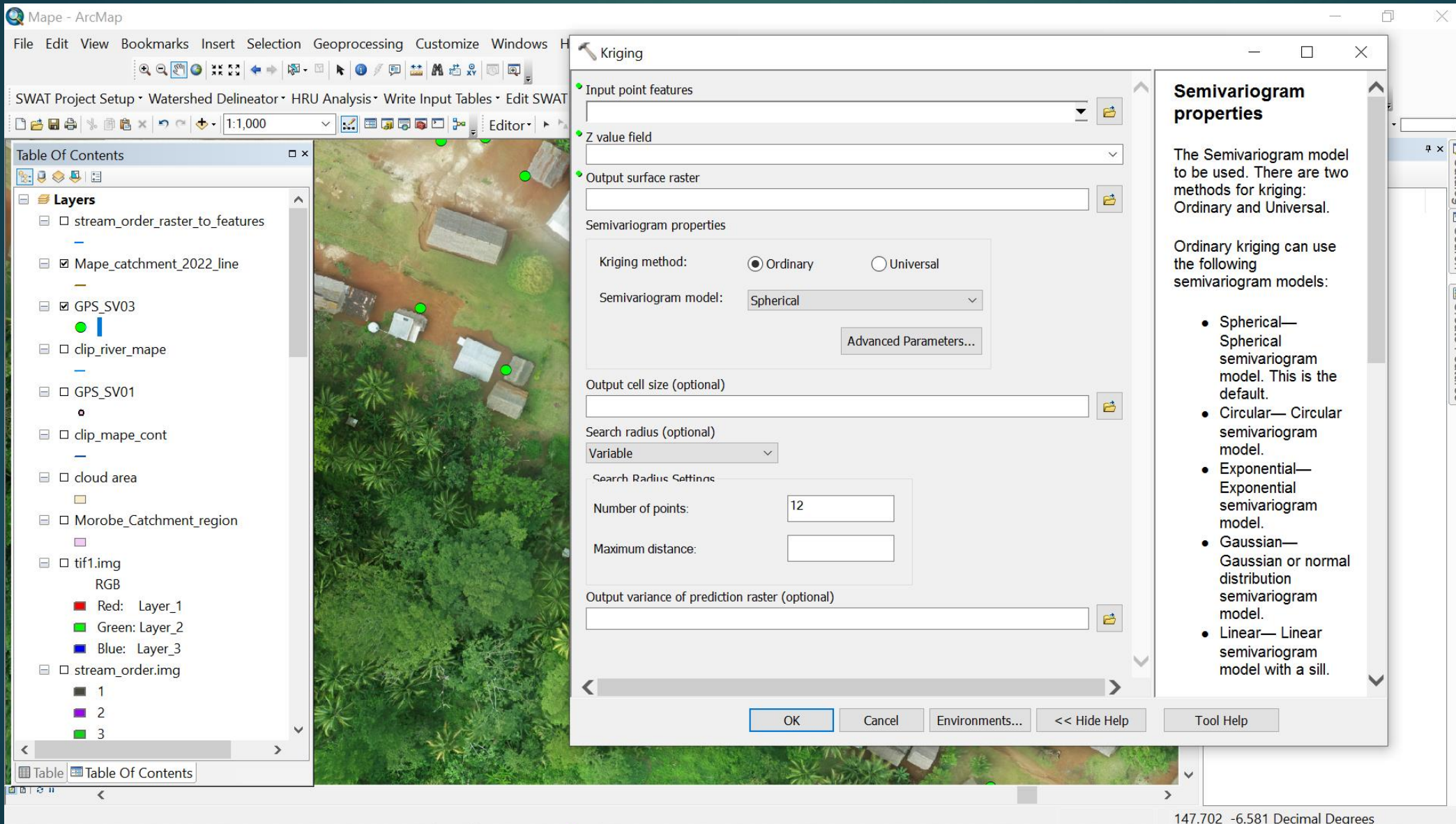
However, with the kriging method, the weights are based not only on the distance between the measured points and the prediction location but also on the overall spatial arrangement of the measured points.

Pairing of one point (the red point) with all other measured locations.

This process continues for each measured point.



7.3. ArcMap Kriging Spatial Analyst Tool



8. References

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Zeiler, M., (1999). Modeling Our World – The ESRI Guide to Geodatabase Design (Book).
Retrieve from: http://downloads2.esri.com/support/documentation/ao_/Modeling_our_World.pdf

Childs, C., (2004). Interpolating Surfaces in ArcGIS Spatial Analysts. ArcUser. Retrieve from:
<file:///C:/Users/Survey%2002/Downloads/interpolating.pdf>

ESRI, (2016). How Kriging Works. Retrieve From: <https://desktop.arcgis.com/en/arcmap/10.4/tools/3d-analyst-toolbox/how-kriging-works.htm>

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