Geographic Surfaces

- Up to this point, we have talked about spatial data models that operate in **two dimensions**
- How about the **3rd** dimension?
  - **Surface** – the continuous variation in space of a third dimension (elevation in a physical context, but it could be other 'virtual' 3rd dimensions for other purposes, e.g. modeling population density using a surface)
- We can use either the vector or raster data model to represent a surface, but **raster** models are **most commonly** used for because they are good at representing **continuous variation**

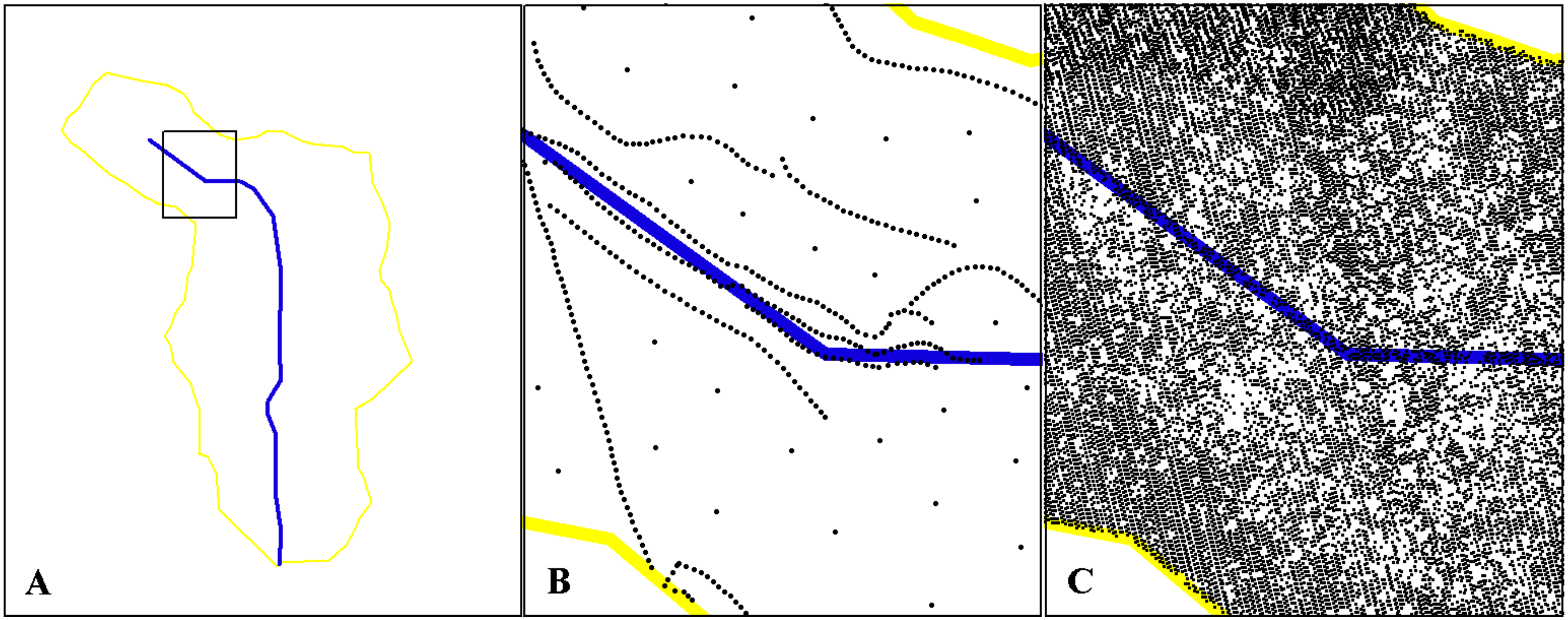
Representing terrain using data

- We can **represent terrain** using various sorts of digital elevation models (DEMs). We will briefly look at each of these representations:
  - **Raster grid** – a cell-based model with elevations associated with each cell
  - **Triangulated Irregular Network** (TIN) – a model made up of triangular facets
  - **Contours** – a vector/arc based model with elevations associated with each contour
- From DEMs, we can derive **how water moves through a landscape** (via drainage networks) by using a variety of **spatial analysis** operations

Spot Elevations – The Starting Point

- **Where** do DEMs come from?
  - We create them from **another representation** of terrain
- Fundamentally, terrain data is collected in the field as a **set of spot elevations**
- Traditionally, **survey or photogrammetric** methods are used to collect these
- Now we have an alternative source at a higher density – **LIDAR** (LIght Detection And Ranging)
- Why does the **density** of spot elevations matter?

Spot Elevation Density



•Figure B shows spot elevations collected by **photogrammetry**

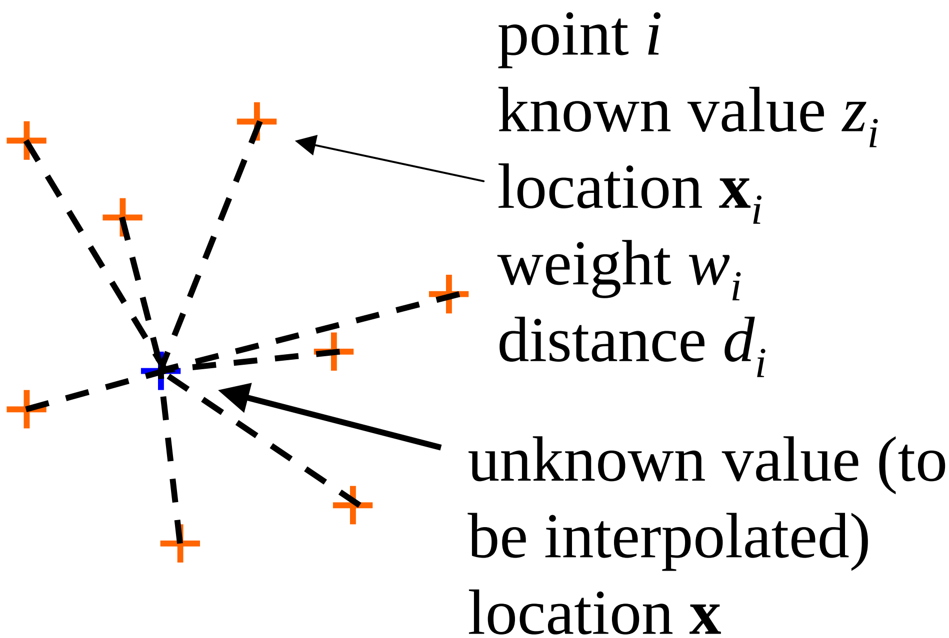
•Figure C show spot elevations collected using **LIDAR**

•**Higher density** of spot elevations supports a DEM with **more detail** → Produces a more detailed representation of terrain

Interpolating a DEM

- Getting from a set of spot elevations to a DEM requires the use of **interpolation:**
- Interpolation **creates a continuous field** representation (like a raster grid, or TIN, or contours) **from discrete objects** (like spot elevation samples)
  - This is **necessary**: There isn't really a way to **capture a continuous field** other than by **sampling it discretely** at some **chosen resolution** …
  - Our **models of reality** will always be **less detailed than reality** itself, but we hope to **capture enough variation** to support whatever purposes we have in mind

Inverse Distance Weighting (IDW)



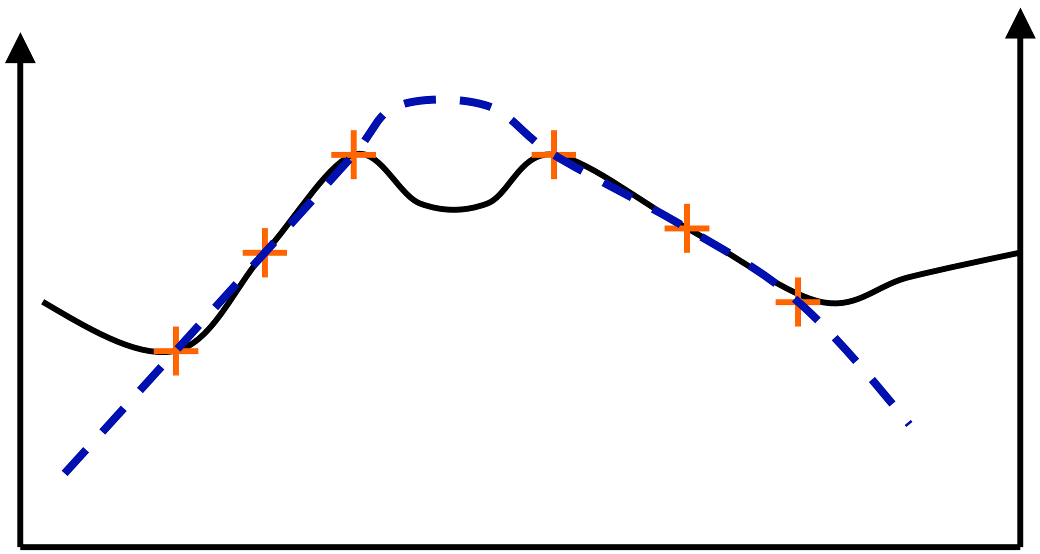
$$z(\mathbf{x}) = \sum_i w_i z_i \Big/ \sum_i w_i$$

The estimate is a weighted average

$$w_i = 1 \big/ d_i^2$$

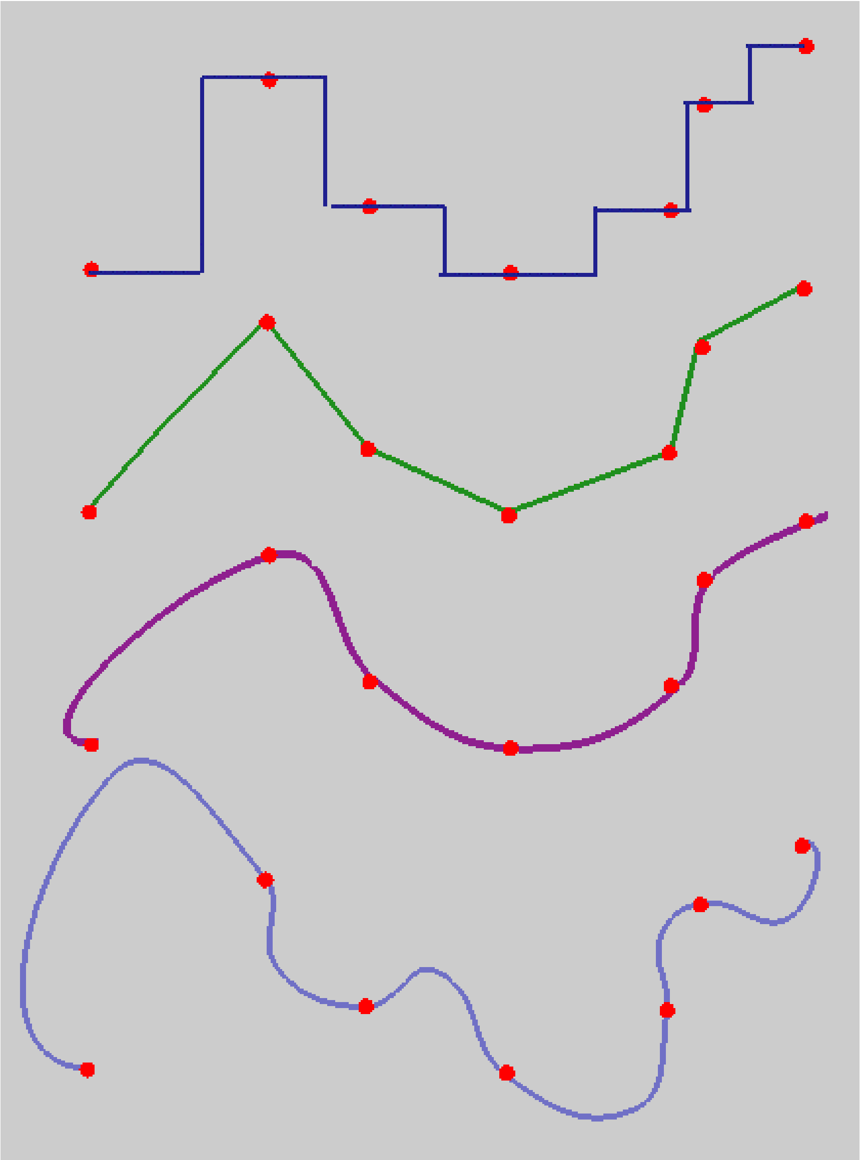
Weights decline with distance

Issues with IDW



- This set of six data points clearly suggests a **hill profile** (dashed line). But in areas where there is little or no data the interpolator will move towards the **overall mean** (solid line)
- There are **other interpolation methods** that can do better in this situation …

The Interpolation Problem



http://skagit.meas.ncsu.edu/~helena/gmslab/viz/interp1d.html

- If we look at interpolation in a **2-dimensional** sense (as shown to the left), what we are trying to do is:

- **Find a function** that passes through (or close to) a set of points

- There is **no unique solution** to this problem, so we want to pick a function that produces a result that has the **properties we want** in our surface

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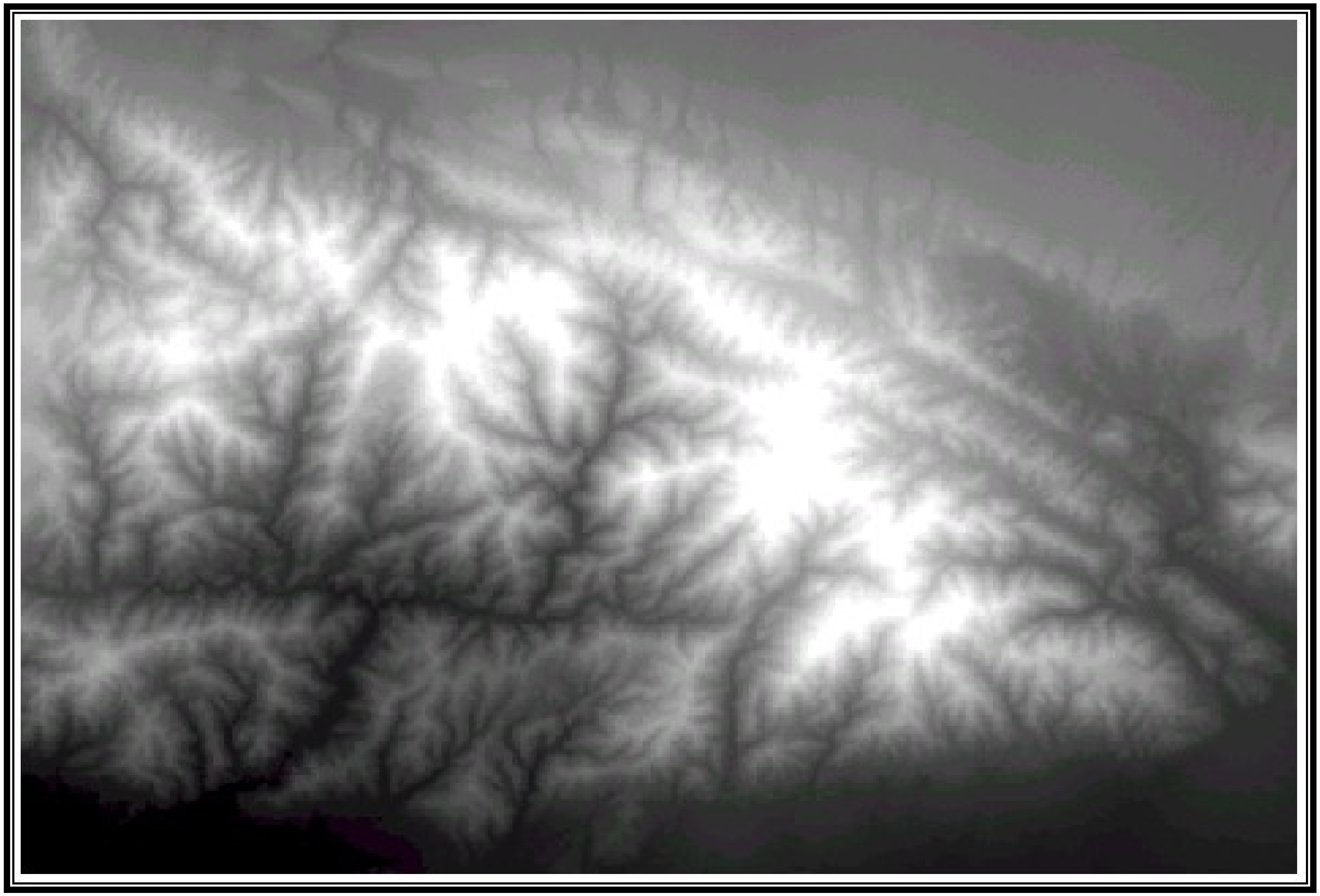
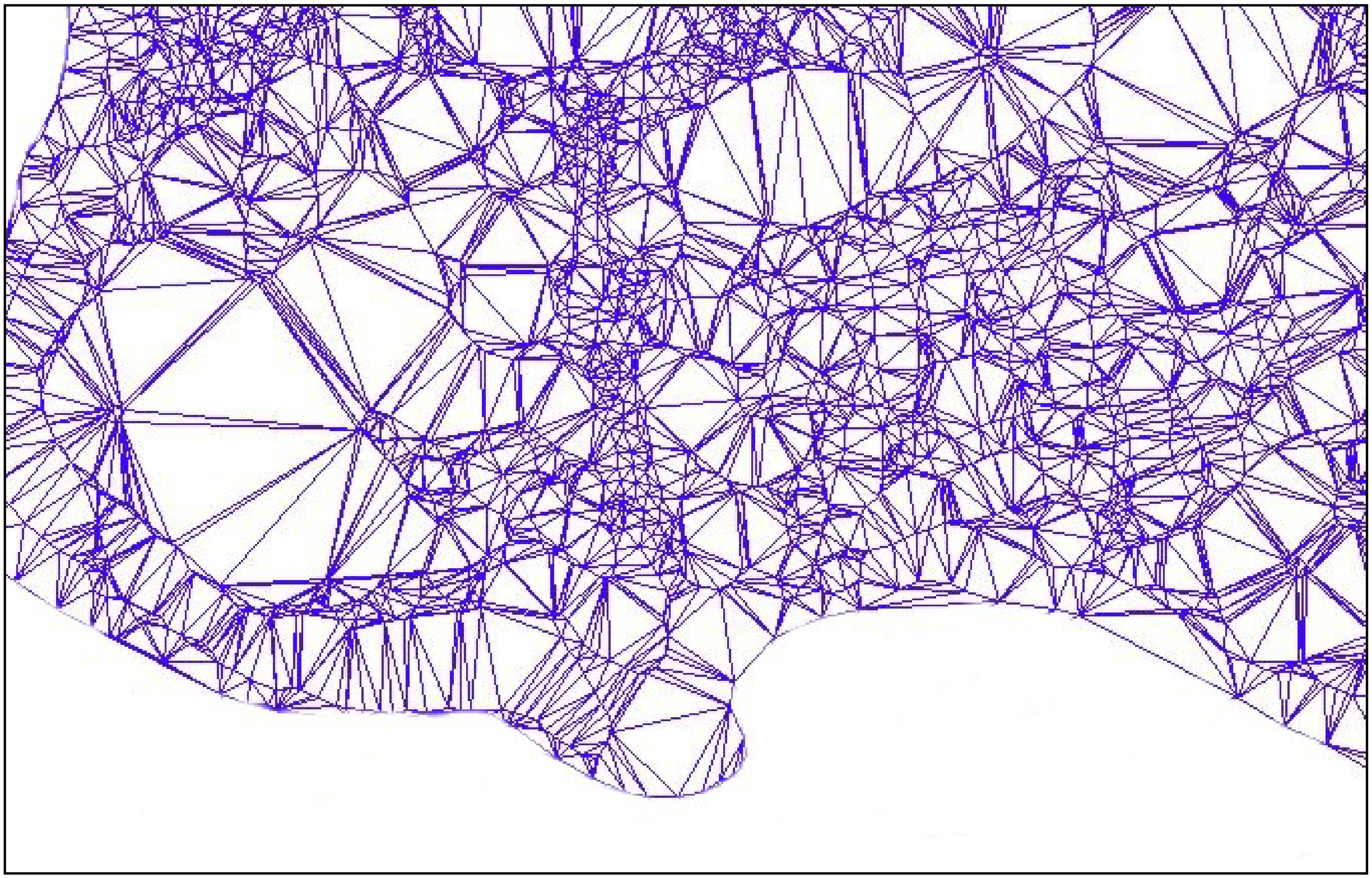
Digital Elevation Models

Raster Grid



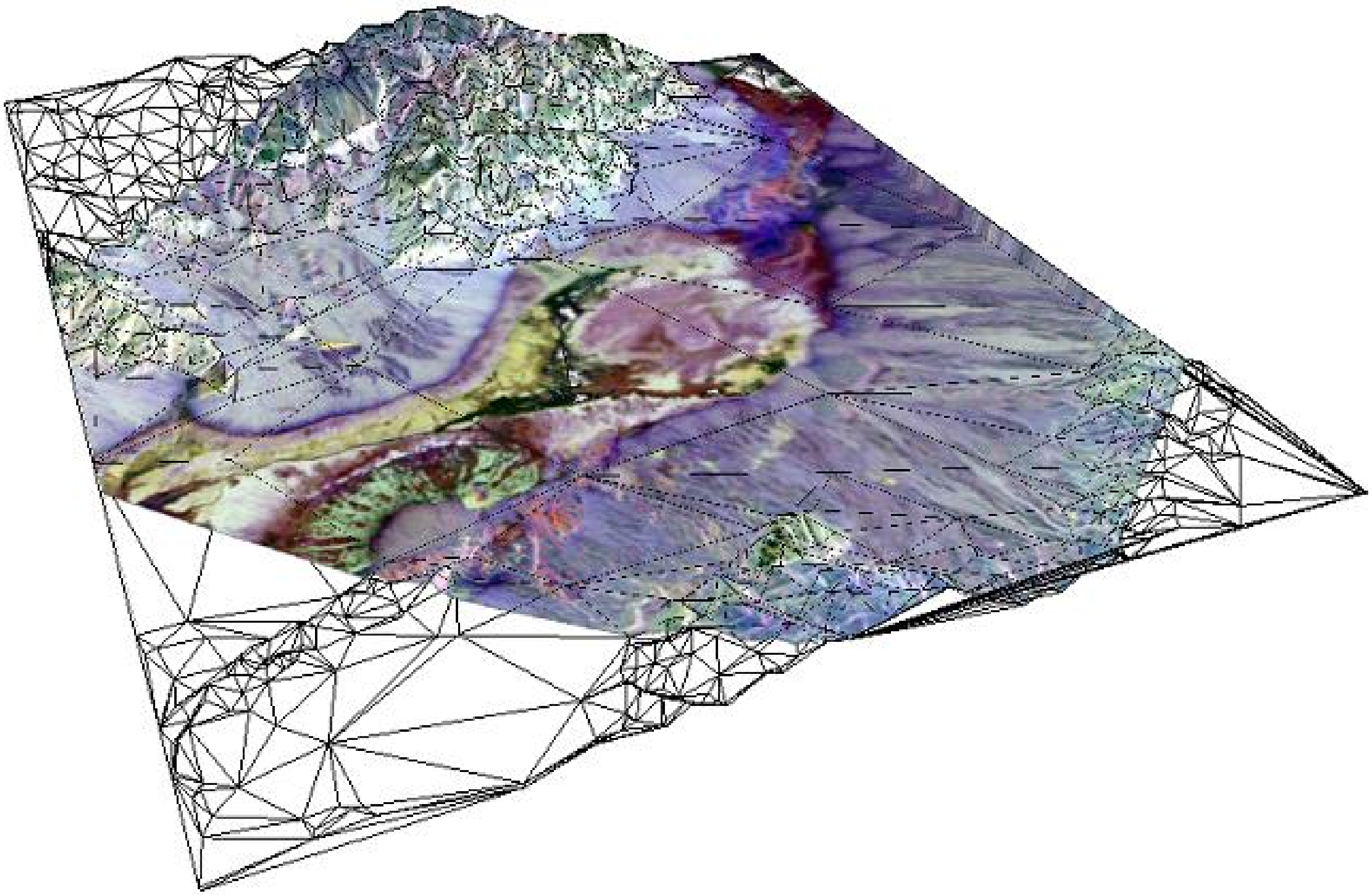
Digital Elevation Models

Triangulated Irregular Network (TIN)



Digital Elevation Models

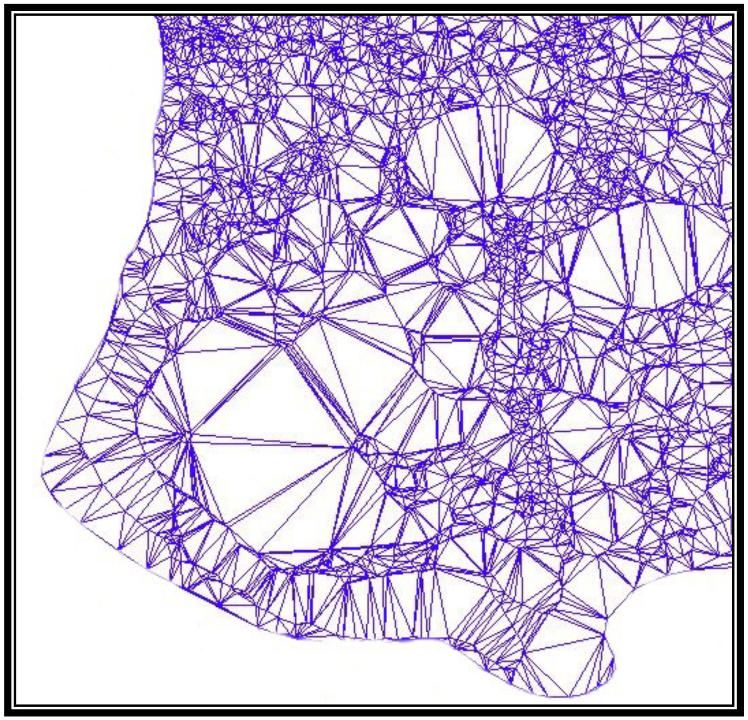
Triangulated Irregular Network (TIN)



Triangulated Irregular Networks

- Vector models can also be used to represent a surface
- One type of these models is called **triangulated irregular networks** (TINs)

Point elevations
are joined together
with straight lines
to form a mosaic
of irregular triangles

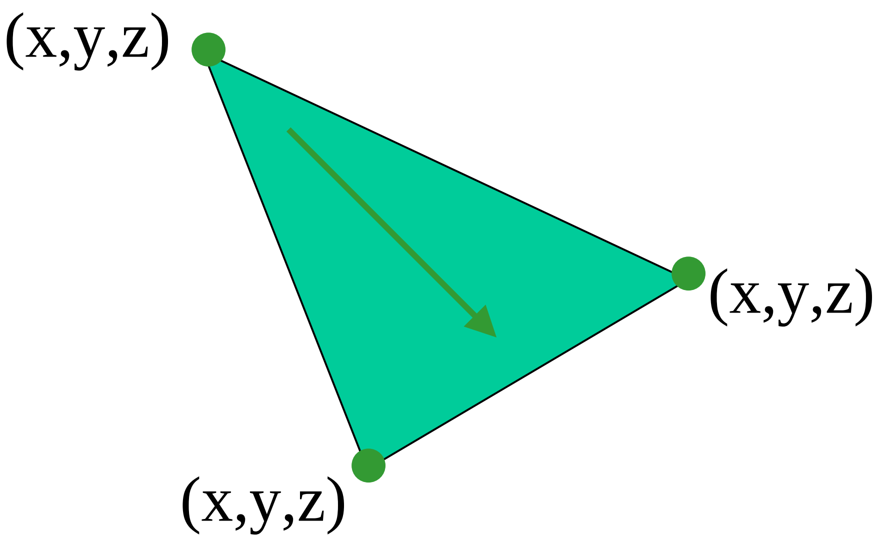


Triangulated Irregular Networks

- Triangle **vertices** represent certain kinds of terrain features – **peaks & depressions**
- The **edges** of the triangles represent other terrain features – **ridges & valleys**
- Elevation at any **vertex** is known
- Elevation can be **calculated** at **other points** on the surface using using geometry
- **Tightly-packed** triangles indicate **rapid terrain change** (variable density of representation)
- **Large** triangles indicate **little** change (flat areas)

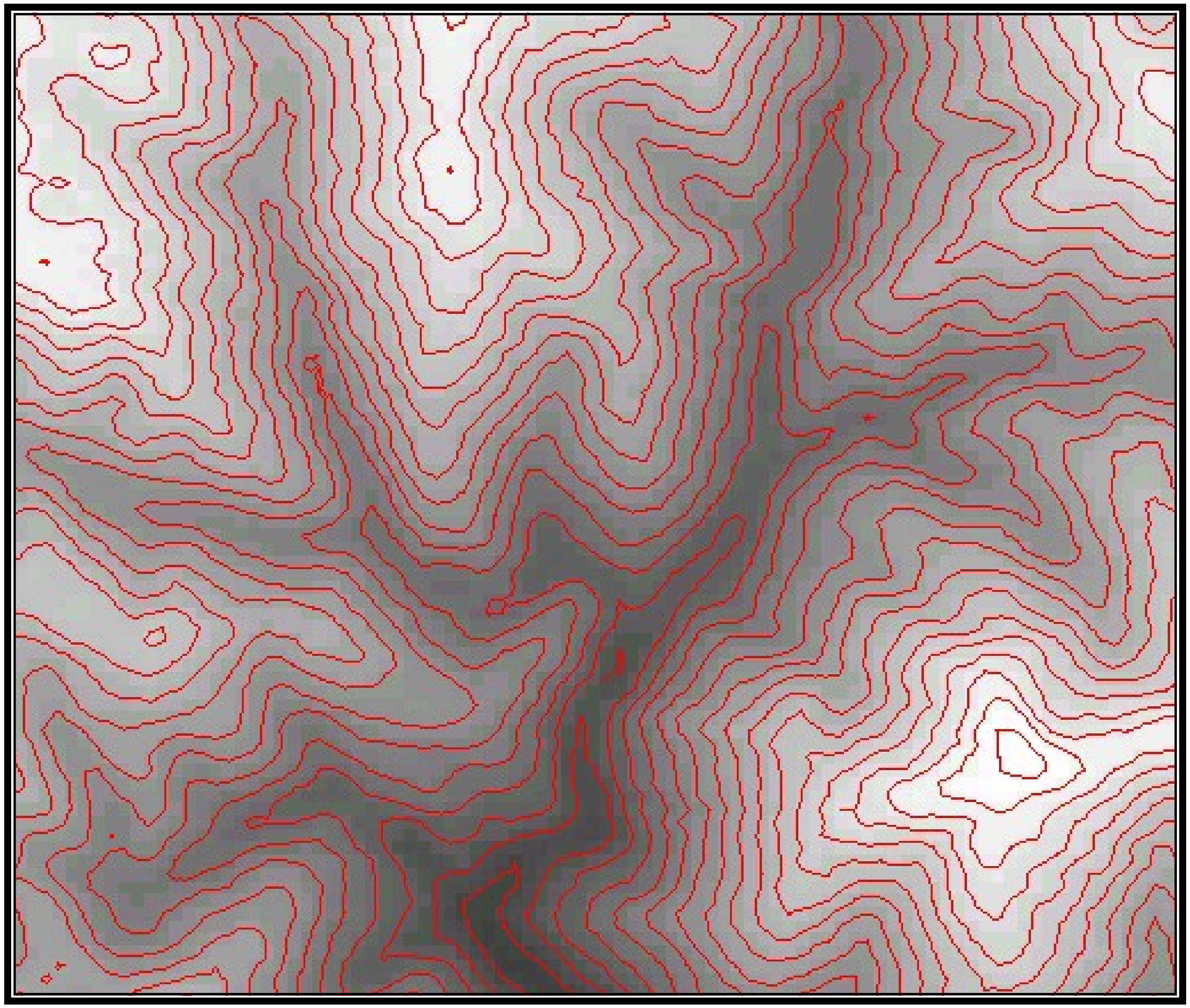
Triangulated Irregular Networks

- Slope and aspect can also be **derived** from a TIN
- **Slope** can be **calculated** using simple geometry
- The **direction** of a triangle's face can be used to obtain **aspect**



Digital Elevation Models

Contours

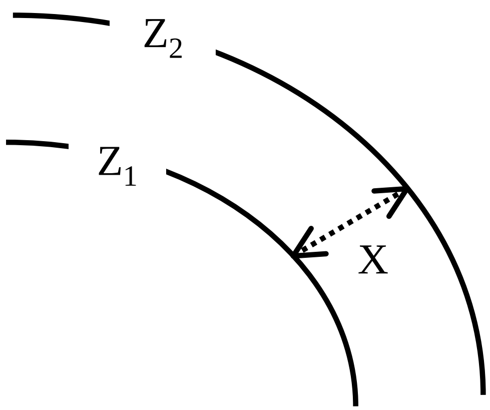


Contours

- Contours represent terrain using **isolines or isopleths**, which are lines of constant value
- Terrain features are represented by the shape of the isolines (their path and how close they are together)
- Elevation on any **contour line** is known
- Elevation can be **calculated/interpolated** at **other points** on the surface by measuring the distance to nearby isolines
- **Tightly-packed** isolines indicate **rapid terrain change** (variable density of representation)
- **Large** spaces between contour lines indicate **little** change (flat areas)

Contours

- Slope can also be **derived** from contours
- **Slope** can be **calculated** by taking rise / run, where **rise** is the **difference in elevation** between two contour lines ($Z_1 - Z_2$) and **run** is the **distance between them** (X), ideally measured orthogonal to both contour lines



Contours

- Through visual interpretation, we can **find critical points** in the landscape (points where the first derivative, slope, is zero):
  - **Peaks** at local maxima
  - **Pits** at local minima
  - **Passes** at saddle points
- Further, we can **connect critical points** to find some useful sorts of lines:
  - A slope line that connects a pass to a peak is a **ridge line**
  - A slope line that connects a pass to a pit is a **course line**

Governing Rules of Water Movement

- Like all physical processes, the flow of water always occurs across some form of **energy gradient** from high to low…
  - e.g., a topographic (slope) gradient from high to low elevation
  - Or a **concentration gradient, pressure gradient**, etc.
- All other things being equal, in a fluvial landscape that **has some relief**, water movement near the surface is going to follow the **topographic gradient downhill**
- Thus, by **modeling terrain** using a continuous surface, we can learn some useful things about the **movement of water** through a landscape

Watershed (a.k.a. Drainage Basin, Catchment)

- A geomorphically distinct **landscape unit** defined by topographic boundaries, or drainage 'divides' that acts as a spatially discrete hydrological system

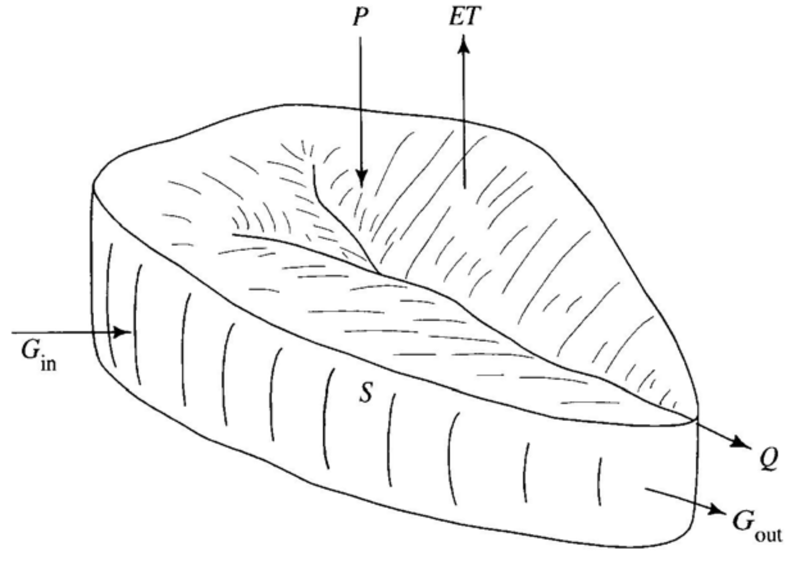
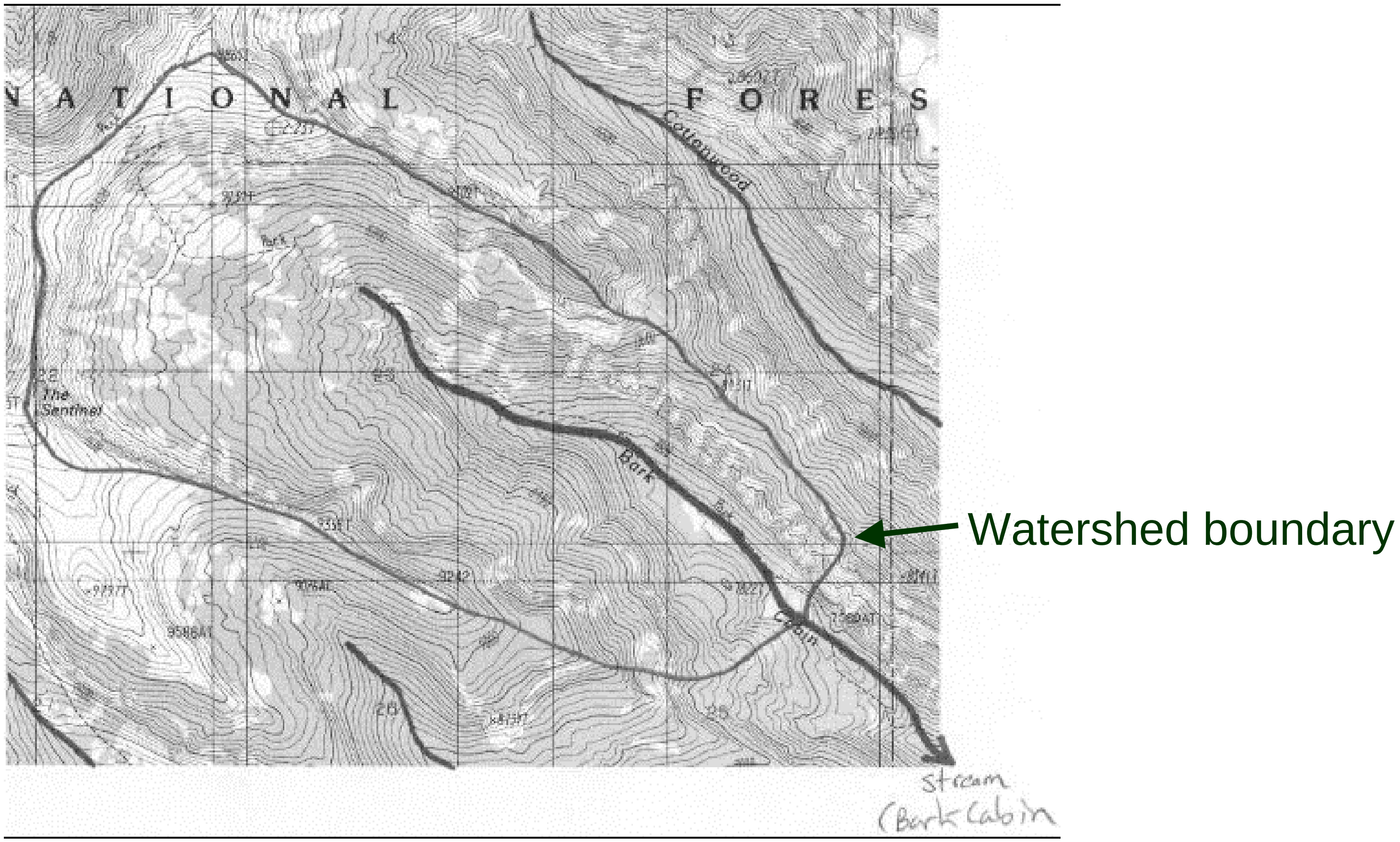


FIGURE 2-3
Schematic diagram of a watershed, showing the components of the regional water balance: P = precipitation, ET = evapotranspiration, Q = stream outflow, G_{in} = ground-water inflow, G_{out} = ground-water outflow.

Watershed Delineation using Contours



Watershed Delineation using Contours

- **Watershed boundaries** can be determined by finding ridge lines (locate the appropriate critical points, and join them, perpendicular to the contour lines)
- **Stream channels** (which are specific course lines) also flow perpendicularly to the contour lines, from passes to pits
- The **boundary lines** are drawn through the center of saddles (pass critical points) and closed contour lines (peak critical points)