Geography 4203 / 5203
GIS and Spatial Modeling

Terrain and Hydrologic Models

Announcements

- 1st readings abstracts due 5PM Wed Sept 9th
- Readings discussion in class Thurs Sept 10th
- Instructions on class website
  - Which articles, what content, what format

Remember:

undergrads need hand in only 6 abstracts (or 3 pairs) this semester;

grads hand in 3 pairs PLUS create and present a powerpoint on another article

Last Lecture

- Terrain Variables
- Slope: gradient, aspect, curvature
- Impact of resolution changes
- Mathematical approaches for computation

Today's Outline

- Surface Modeling = hydrologic functions
- Hydrologic functions are composite operations – they build upon each other
- Often imply variables such as slope or aspect
- You will see some mathematical approaches for hydrologic functions

Back to: Why Terrain Matters…

- Hydrological features as derivatives from terrain
- Topography influences and is shaped by hydrological processes
- Catchments as central unit in understanding the landscape and impacts on it



Hydrologic Functions

- Water … our life
- Water … rosion, water quality … ent, disaster mitiga…
- Hydro… suite of comm…


http://news.nationalgeographic.com/news/2006/08/photogalleries/katrina-new-orleans/photo6.html

http://rcswww.urz.tu-dresden.de/~uzeuner/tharandt/tharandt3.htm

The Suite of Hydrologic Functions

Like terrain variables, a suite of hydrologic functions in most GIS software

- Flow direction
- Sinks / pits and fill
- Flow accumulation
- Drainage network
- Watershed

You'll work with these in lab 3

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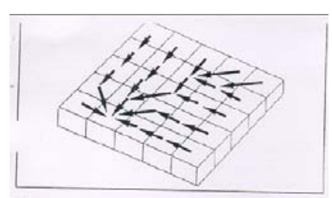

Figure 8.10. Local drain direction vectors to indicate steepest downhill path

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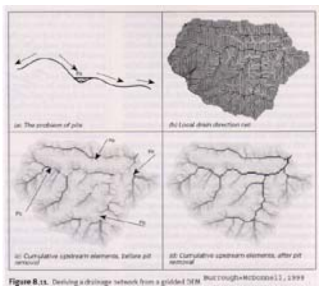

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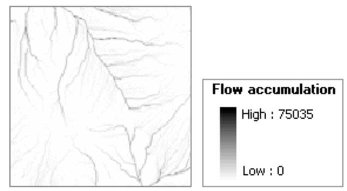

NOTE – this is still a grid

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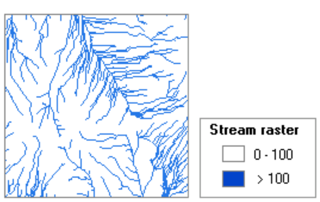

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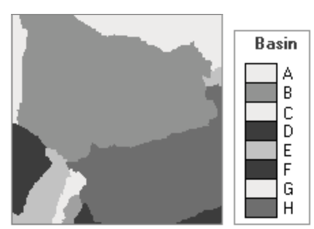
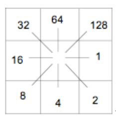
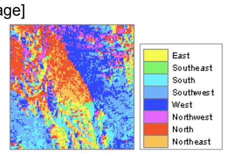


Flow Direction

- Direction of water flow on or below the surface
- Mostly in the direction of steepest descent within adjacent cells ("local aspect")

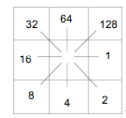
- Given in angles [0,360˚] (azimuth in degrees)
- Alternatively direction expressed by index indicating the neighbor to which water flows
  - D8 approach most common (Jensen and Domingue (1988)
  - [8 directions, powers of two for efficient storage]



Flow Direction and D8 Method

- Intervals of 45 degrees
  - What is the consequence of such rough intervals?
- Where steepest descent occurs in several directions, all are assigned and later identified as a sink
  - Assign direction
  - Increase neighborhood and search again
  - Where else is flow direction problematic?



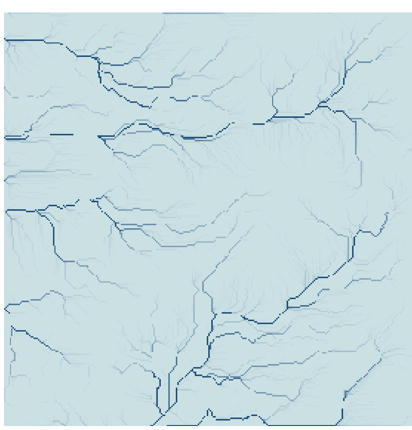
- Weights related to distance to center pixel

$$\text{FlowDirection} = 2^{j-1} \text{ where } j = i \text{ for } \left\{ \max_{i=1,8} \left\{ \varphi(i) \frac{z_9 - z_i}{\lambda} \right\} \right\}$$

(ϕ is 1 for NEWS, 1/√2 for diagonals, λ is cell size)

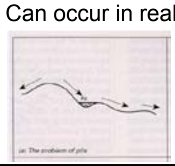
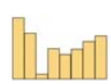
Cumulative upstream elements

Notice the gaps



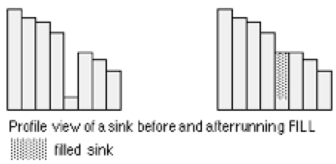
Identifying Pits / Sinks

- Random errors in DEM grids create cell elevations that are lower than surrounding values
- Consequence: No direction of descent
- As artifacts from interpolation (water flows in but not out)
- Can occur in reality (caves, karst)


Filling the Pits

- Computational artifact pits should be removed
- Thresholds below which a pit is not removed
  - smaller-than-expected errors
  - less-than-true pit depths
- Identify pits by searching the grid pixel by pixel
  - Radial search
  - Sink filling (increase elev to lowest surrounding value)
  - Why not some other value (mean, e.g.)



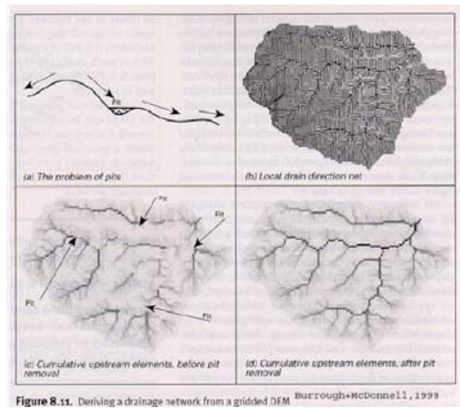
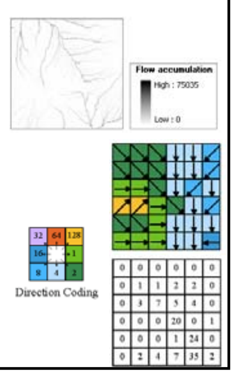


Figure 8.11. Deriving a drainage network from a gridded DEM

Flow Accumulation

- Uses flow direction (after sinks filled)
- Sum of upstream elements draining into the considered pixel
- Visit pixels in turn
  - count for each cell how many neighbors drain into it
  - if neighbor drains, test its neighbor cells
  - repeat until margins reached or no upstream cells exist
- All cells contain a value – highest values for major stream channels)

(but repeat "it's still a grid" – no features yet)



Drainage Networks

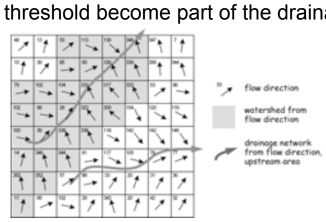
- Different approaches and varying perspectives about how to define and identify elements of a drainage network
  - Any cell that has > threshold flow accumulation
    - A form of slicing, like the elevation slices to form lakes
  1) Convergence of flow directions
  2) Use flow accumulation to define watershed area
- What happens if there are sinks in the area?

Drainage Networks by Convergence of Flow Directions

- Set of cells through which surface water flows
- Based on flow direction (drains occur where flow directions converge)
- Thus convergence of flow direction as indicator to produce maps of likely stream locations (prior to field surveys)

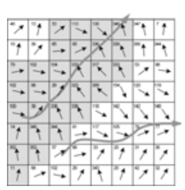
Drainage Networks by Flow Accumulation Area

- Any cell with a contributing area > defined threshold
- Subsurface properties not included
- Watershed for each cell is calculated and compared to threshold area
- Cells above threshold become part of the drainage network



Upslope Area

- Applied to a DEM
- Return values: Area that drains through a cell
- Meaning: Cell values are watershed area for each individual cell
- Initial estimator for a drainage network (index of stream occurrence based on threshold uphill area)
- Indicates if cell is w/in "permanent stream channel" or not

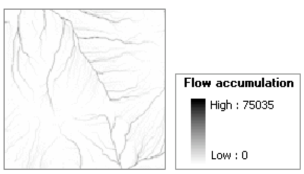


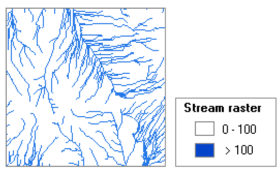
Calculating Upslope Area

- Start at a local "high point" (max)
- Sum area as one moves down-slope
- At next local max, do the same and accumulate areas from before
- Repeat the process until no further local max's left
- So, how to make sure you derive the watershed of entire drainage channel system?

Stream Network Raster

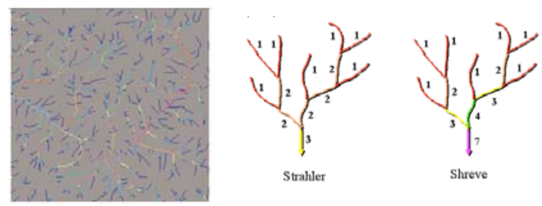
- Conditional queries from flow accumulation (input precipitation could come from a second grid)
- Derive a Boolean raster showing the elements of a channel system





Stream Order and Stream Link

- Order linked streams within a stream network
  - several ways to sequence (Strahler and Shreve, in ArcGIS)
- Assign unique values to each tributary segment for quick computation of watersheds based on junctions



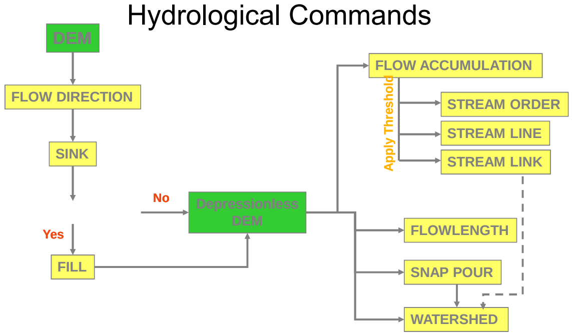
Watershed

- Area that contributes flow to a point on the landscape
- Which point?
  - The uphill area that drains to any point on a landscape is the watershed for that point
  - Water falling anywhere upstream within a watershed will pass through that point
- Vocabulary: basins / contributing areas / catchments / drainages / sub-basins / sub-catchments

Identifying Watersheds

- Use flow direction surfaces
- Flow direction is followed “uphill” from a point, until a downhill flow direction cell is reached
- Recursively create uphill list (accumulative) to find all contributing cells

Watershed Delineation and the Suite of Hydrological Commands



from Kopp et al., 2005, presentation at ESRI Int. Preconf

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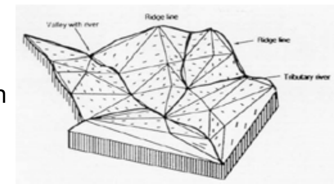


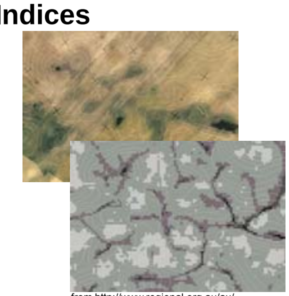
Figure 6.24 Modelling terrain: concept of a triangulation closely following the major terrain features. Burrough and McDonnell, 199

Which would be easier or more challenging to derive using TINs? Why?

Further Use of Hydrology Functions: Wetness Indices

- Compound index for plant community compositions or to derive likelihood / intensity of flooding (rainfall until soil saturation)
- Identify locally convergent or divergent terrain positions
- Increased soil wetness due to large upslope areas (A_s) and low slopes (β)

$$W = \ln\left[\frac{A_S}{\tan\beta}\right]$$



from http://www.regional.org.au/au/

For **homogenous** soil, otherwise **transmissivity** is needed

Extensions of Wetness Index

- Compare W with precipitation and amount of (surface) soil water content in specific catchments

$$W = \ln\left[\frac{A_S}{\tan\beta}\right]$$

A_s = upslope area
β = slope

- Incorporate plan curvature and aspect with relationships to surface soil water
- Stream power to estimate erosion $W = A_S * \tan\beta$ (homogeneous soils) or in discharge models

Summary

- Hydrologic functions based on elevation and derivative measures
- Understand modeling approaches for hydrological processes in the landscape
- Basic principles and mechanics for simple and compound indices, pointed way to extensions for other disciplinary models
- Learn some terms and understood their meaning, derivation, and interrelationship for hydrologic modeling