Example: Brown County, IN
From NED 1”, UTM Zone 16, 30 m cells
170-322 meters, mean 230 m., std dev 31 m.

Direction & Accumulation
Used GRASS r.terraflow
Flow Accum Stats:
   N = 80,711
   Min: 1
   Max: 33,586
   Mean: 98
   StdDev: 1169

Deriving Streams
Set cutoff at 1270 cells (mean + 1 SD)
Converted to vector
   r.to.vect

Identifying Watersheds
   Used r.watershed
   Set basin cutoff at 5000 cells, 1000 cells

Pits
Can infest a DEM
   1551 pit cells in Brown County DEM
Not all pits are artificial!

Why are there Artificial Pits?
Valleys and channels smaller than cell size
Errors in data / production method
Will improving DEM resolution help?
r.mapcalc 'pits = if(ned == ned_fill, null(), 1)
   ned_fill from r.terraflow

How to Deal with Pits
Wholly automatically
   What's usually done in practice
   Can lead to problems
Interactively
   More sensitive approach
   May be time-intensive

Filling up Pits
Visit each pit cell
Raise z-value until even with lowest surrounding cell
May require iteration
   If pits are bigger than single cells
   Flood-filling depressions
Cutting through Pits
Enlarge window until lower cells found
Link direct route to the lower cells
  Ignore intermediate elevations

Pit Example
In ArcGIS, Flow Accumulation for Brown County
  Run Flowdirection, then FlowAccumulation on FD
Filled and Unfilled DEMs
  Filled values range to 33630, unfilled to 2510

SRTM Case Study
Island of Hispaniola
  Dominican Republic/Haiti
  Range: -58 – 2484 m., mean: 749, SD 634 m.
  Includes lowest point in the DR, Lake Enriquillo
3" SRTM DEM downloaded
Projected to UTM zone 19
  90 m. cells
  669 rows (60 km) x 629 columns (57 km)

Relief and Imagery

Lake Level
Lake height is at -39 meters (Wikipedia)
  Fluctuates pretty widely
r.mapcalc 'srtm_lake = if(srtm < -39, -39, srtm)'
r.terraflow, r.watershed then implemented

Its the Pits

Flow Accumulation
r.watershed
Only internally-drained cells
  N = 418087
  1 – 251092 cells
  Mean 291
  SD 5281 cells

Handling Flat Areas
r.terraflow
  N = 356929
  1 – 47653 cells
  Mean 123
  SD 1188 cells
Streams
Can be generated with r.watershed
   Each segment gets its own nominal value
stream500 = if(FA > 500, 1, null())  (Red)
stream2k = if(FA > 2000, 1, null())  (Cyan)
stream10k = if(FA > 10000, 1, null())  (Blue)

More about Streams
Generated via accumulation are raster
May be useful to vectorize
Allows using them as reaches, etc

Junctions
In nature, rare to see more than 2 streams at a junction
With D8, possible to have 5
   3-4 relatively likely

Stream Order
Stream classification system
Based on order of upstream reaches
Strahler Ordering
   1: Stream with no upstream reaches
   2: Stream with more than one order 1 reach
   3: Stream with more than one order 2 reach
Note that order is scale-independent!

Strahler Ordering Examples
v.strahler add-on (GRASS)
Spatial Analyst → Hydrology → Stream Order (ArcMap)

Level 1 – Level 2 Streams
Subsection of Santa Barbara, CA 7.5' DEM
   Level 1: range 0-58, mean 19.4, sd 12.3
   Level 2: range 2-56, mean 19.0, sd 11.2

Visualizing Flowdirection
SB Level 2 Data

Niles Surface Flow - ArcGIS
Horizontal following artifact, plus pits
Must fill pits in ArcGIS
GRASS handles them internally
   r.watershed & r.terraflow

Burning in Streams
Available vector stream data can be useful
How to employ with DEM?
'Burn in' stream locations on DEM
   Rasterize stream layer
   Set stream value to a (small) negative number
'Add' stream grid to DEM

Example
Cass County, MI
  Downloaded from MI Center for Geo. Info. (MCGI)
  1,156 rows, 1,291 columns, 30 m. cells
  MI GeoRef Coordinate System
  252,707 of 1.5 million cells are in sinks!

Vector Data
MCGI lakes, rivers, wetlands, streams
Lots of water!
Matches many of the sinks!

Sub-Region
18 x 20 km region in southern Cass County

Burn-In
Convert vector water maps to raster
  v.to.rast
Set null values in the rasters to 0
Combine the water raster maps
  water = rivers_r + lakes_r + ...
Subtract from the DEM (multiplying by 2 here)
  dem_burn = dem – (2 * water)
Also see r.carve
Run r.watershed or r.terraflow on this

Filled vs. Burned-In Flow

Burn In Stream Differences

Summary
Pits and Sinks
Streams
  Morphology / Order
  Vector Streams
Examples
  Brown County, IN
  Haiti
  Comparing DEM series
Burning in Streams
  Cass County

Exam Thursday!