CE-G0800 GIS in in Water Resources

Spring 2022

Hydrological Network Analysis

By

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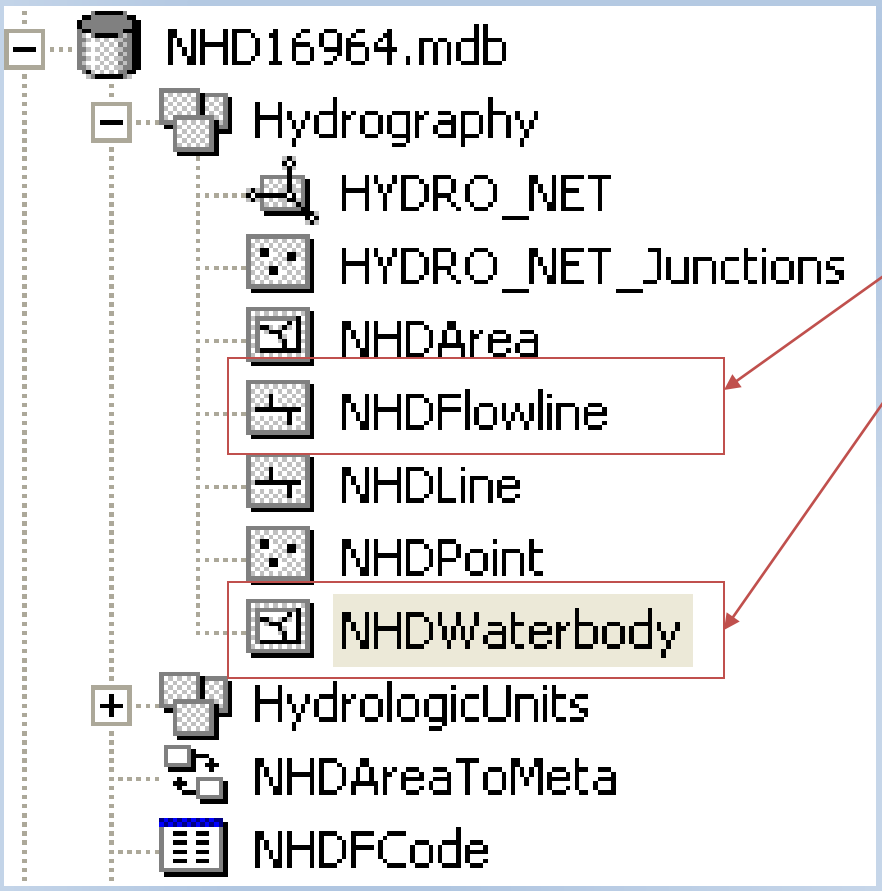
Raster to Vector Transition

- We learned the flow of water through the landscape based on the raster (DEM) data structures
- Today we are making a transition in which we are going to use vector network data to describe water pathways.
- We will connect the land and water flow systems by attaching the catchments and watersheds derived from raster data processing to our vector networks

Some terminology

- Hydrography – the mapping of water features
  - Blue line features on topographic maps (streams, rivers, lakes,…)
  - More generally, hydrography also includes the mapping of bathymetry and extent of estuaries and coastal waters
- National Hydrography Dataset (NHD) – a data model for storing topographic map hydrography
  - Medium resolution (1:100K) is complete for US
  - High resolution (1:24K) is complete for most of the US
- NHDPlus – a new data model integrating 1:100K resolution NHD with catchments and derived attributes from the National Elevation Dataset

National Hydrography Dataset

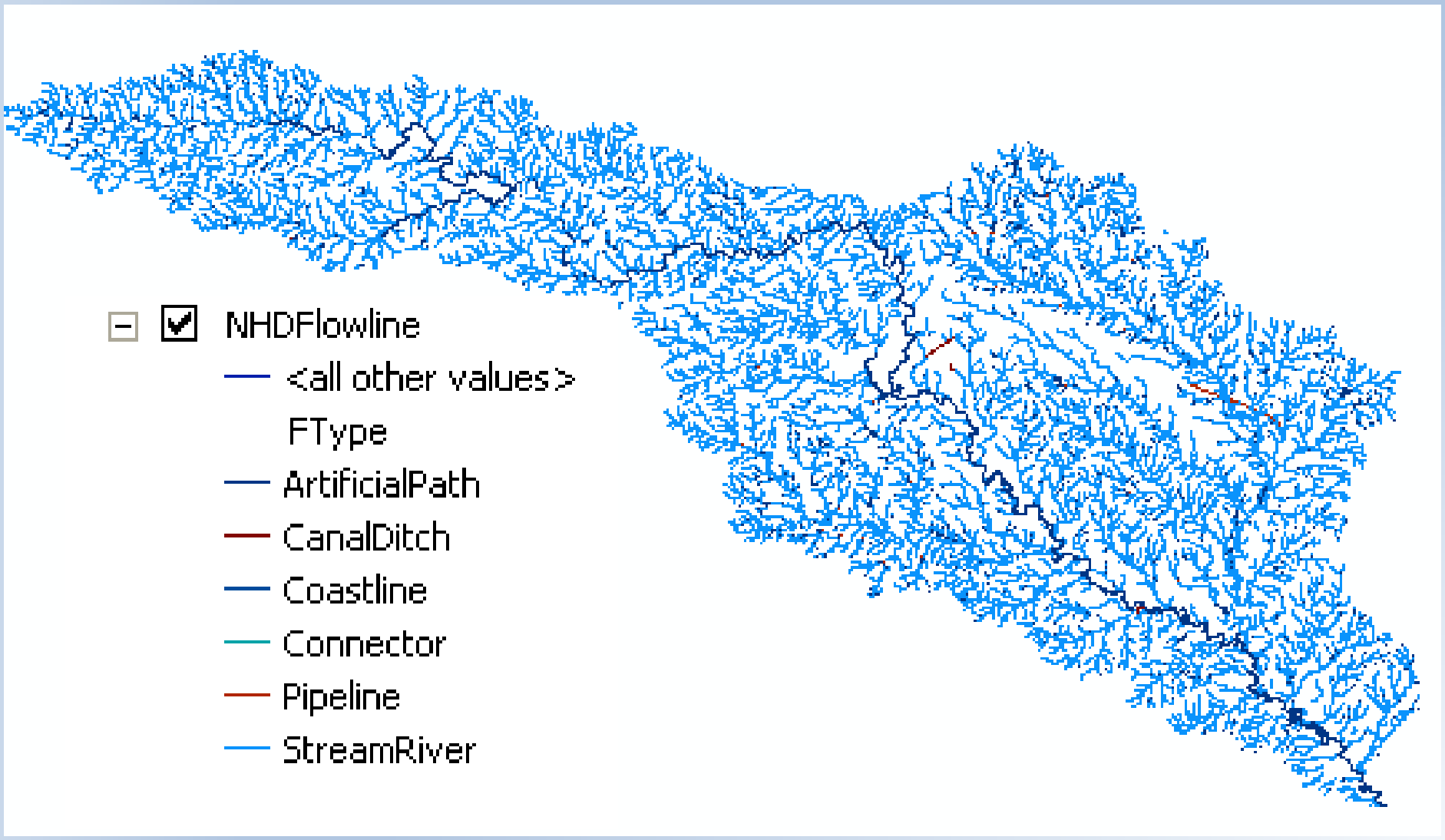


Key feature classes

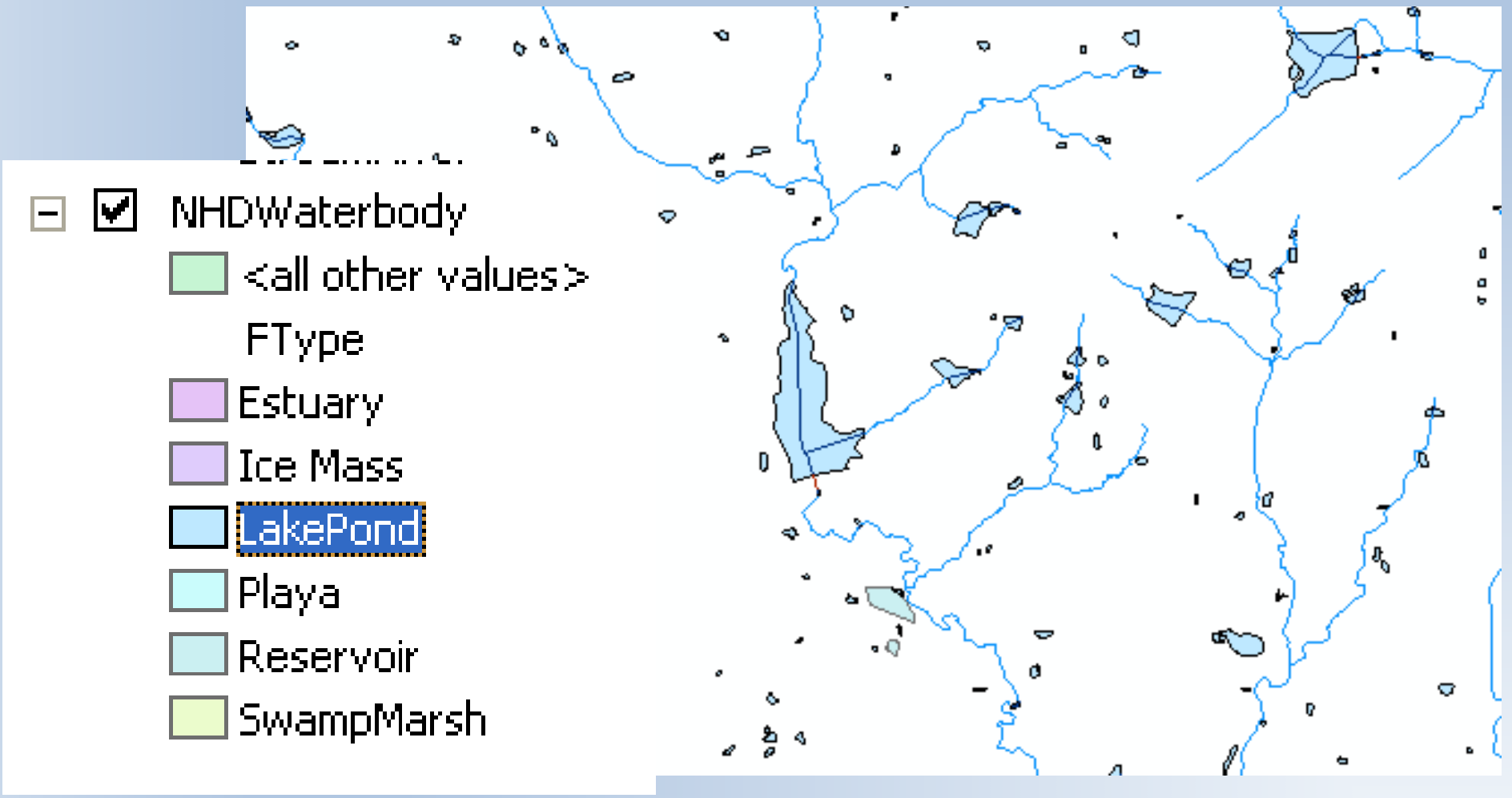
Five feature classes with NHDFLowline built into A geometric network

NHDPoint, NHDLine, NHDArea are point, line and area water features on map apart from flowlines and waterbodies

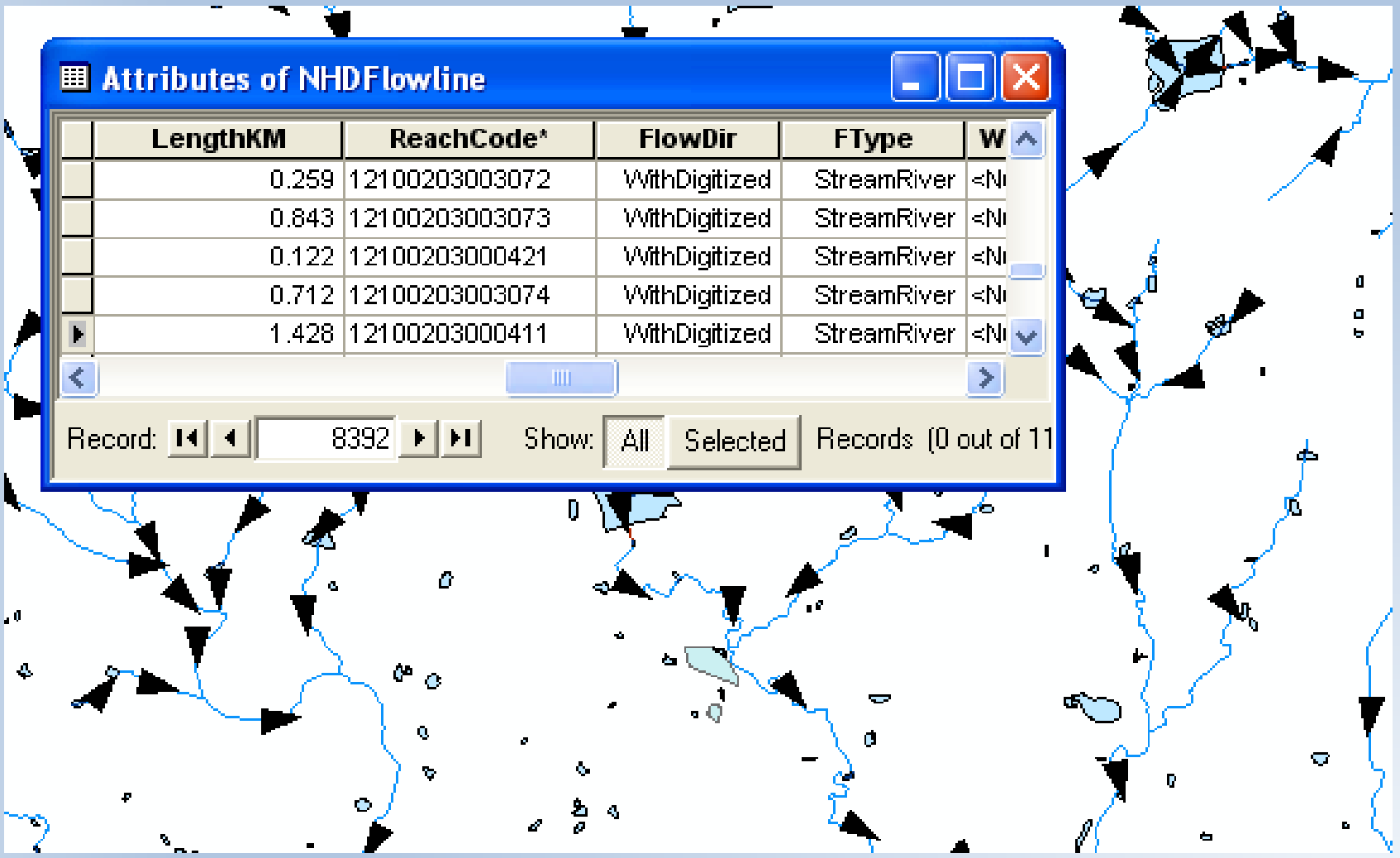
National Hydrography Dataset



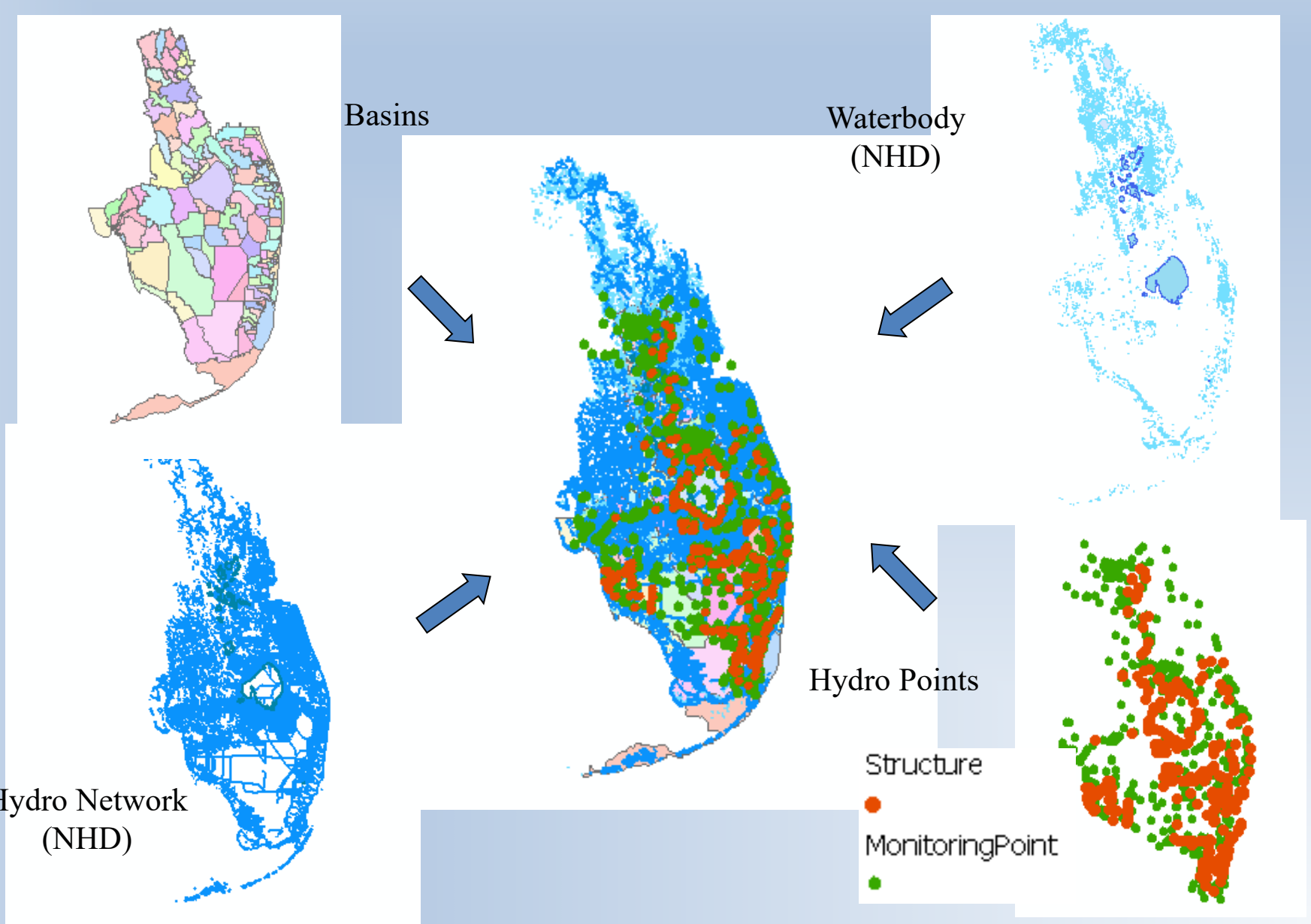
NHD Waterbody



NHD Geometric Network

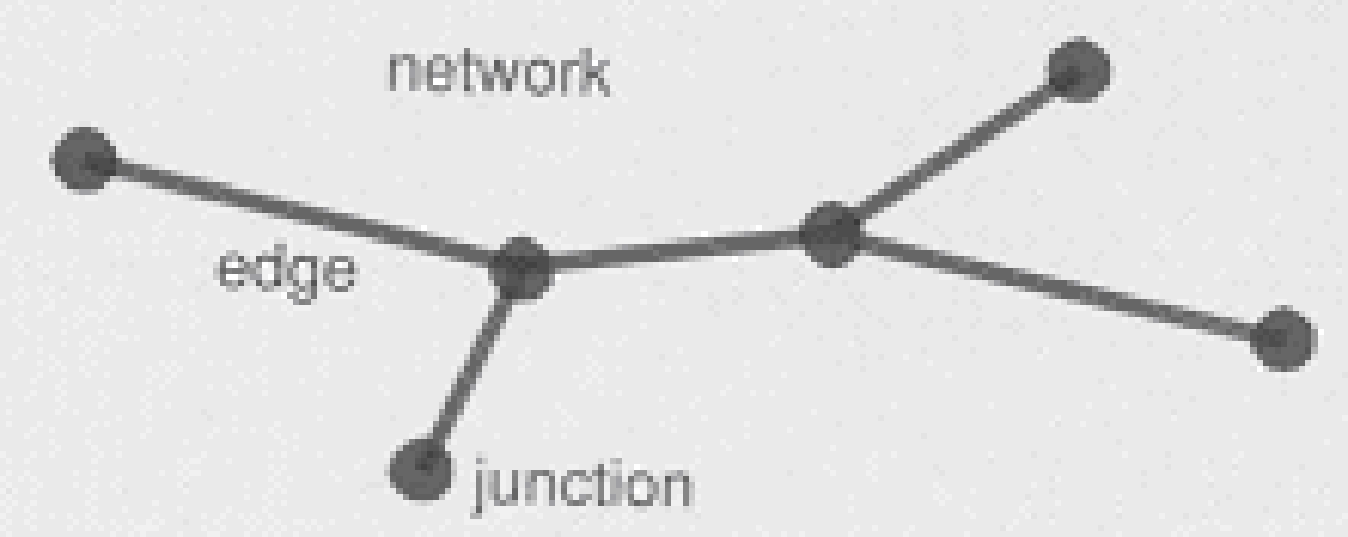


Example of NHD data



Network Definition

- A **network** is a set of edges and junctions that are topologically connected to each other.



Geometric networks

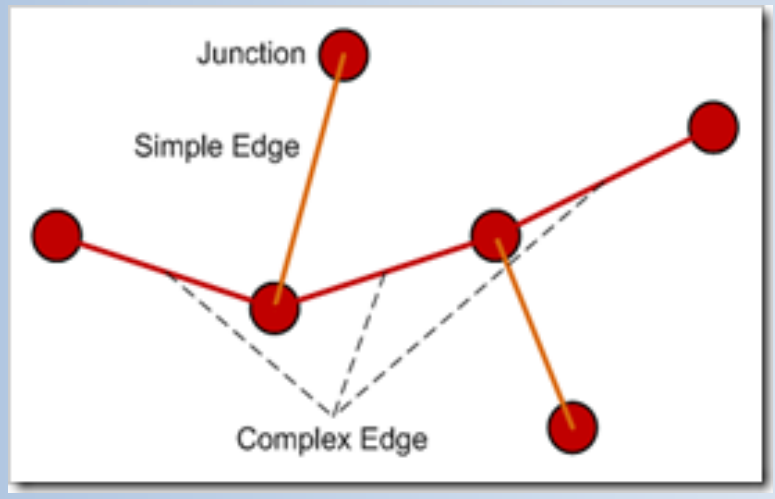
Geometric networks are composed of two main elements: Edges and Junctions.

- **Edges**—An edge is a feature that has a length through which some commodity flows. Edges are created from line feature classes in a feature dataset .
- **Junctions**—A junction is a feature that allows two or more edges to connect and facilitates the transfer of flow and resources between edges. Junctions are created from point feature classes in a feature dataset.

Edges and junctions in a network are topologically connected to each other—edges must connect to other edges at junctions, and the flow from edges in the network is transferred to other edges through junctions.

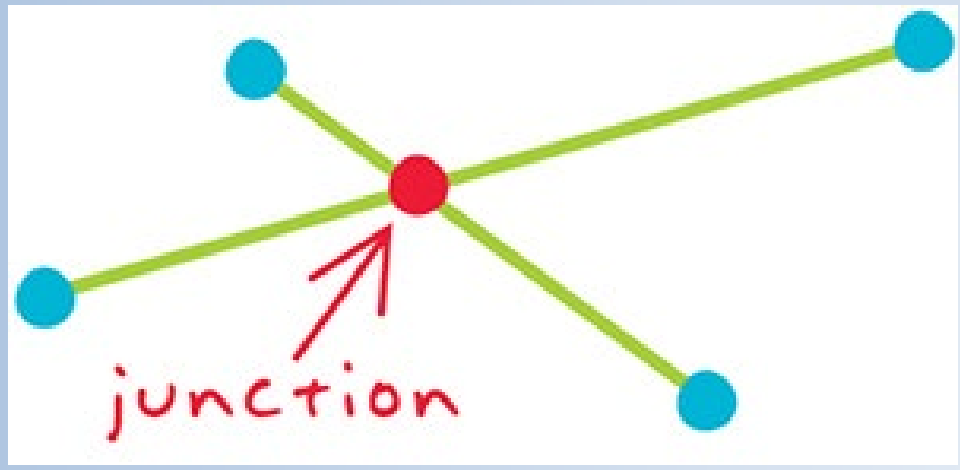
Edges and Junctions

- Simple feature classes: points and lines
- Network feature classes: junctions and edges
- Edges can be
  - Simple: one attribute record for a single edge
  - Complex: one attribute record for several edges in a linear sequence



Junctions

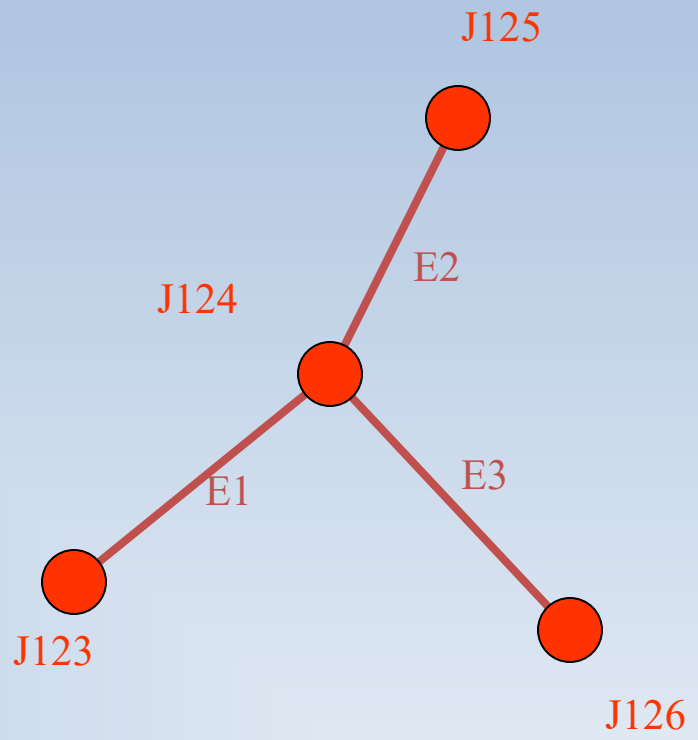
- Junctions exist at all points where edges join
  - If necessary, they are added during network building (generic junctions)
- Junctions can be placed on the interior of an edge e.g. stream gage
- Any number of point feature classes can be built into junctions on a single network



Logical Network: Connectivity Table

p. 132 of Modeling our World

Junction	Adjacent Junction and Edge		
J123	J124, E1		
J124	J123, E1	J125, E2	J126, E3
J125	J124, E2		
J126	J124, E3		

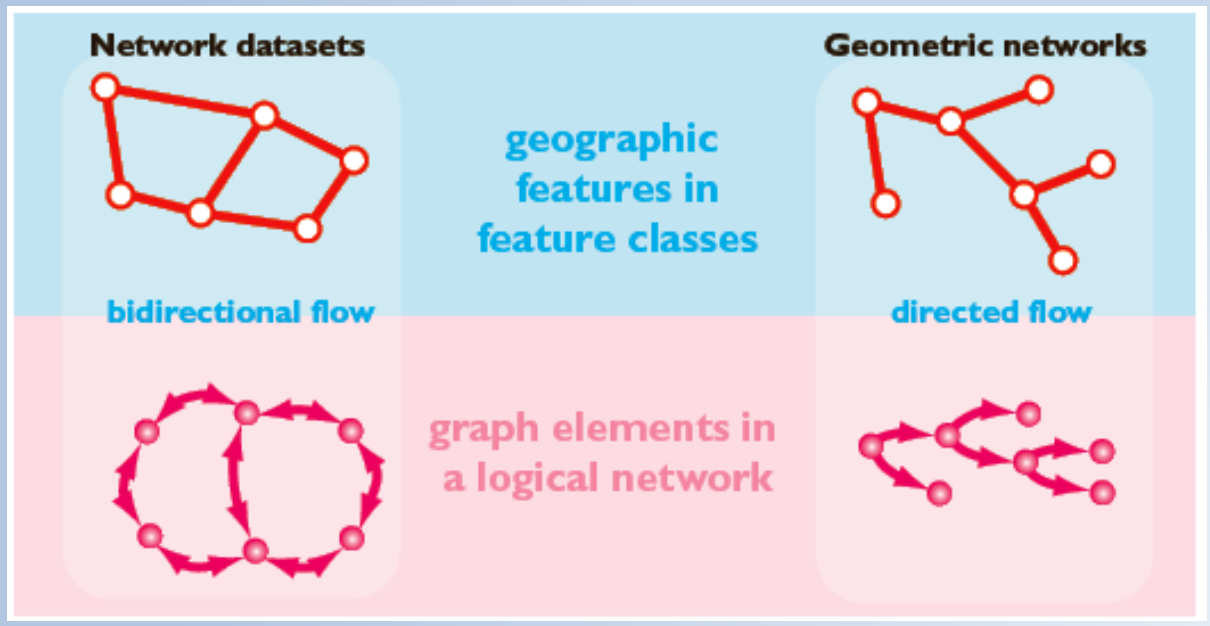


Network Model in GIS

- Three components
  - Geometric model: (x,y,z,m) coordinates of edges and junctions
  - Logical model: which edges are connected to what junctions
  - Addressing model: location on the network using measure

Network datasets and geometric networks

- Networks model the transportation of people and resources, such as water, electricity, gas, and communications.
- Networks constrain flow to edges, such as streets and river reaches, which join at junctions, such as intersections and confluences.
- The geodatabase has two core network models—the network dataset models transportation networks and the geometric network models directed-flow systems—such as, river networks and utility lines.



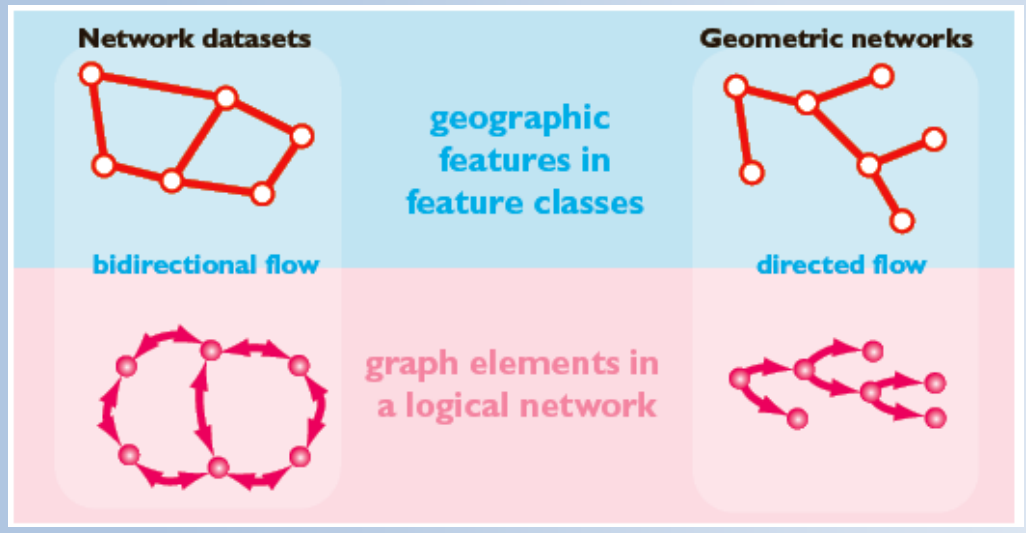
Network datasets and geometric networks

Geometric networks (utility and river networks)

- River networks and utility networks—like electrical, gas, sewer, and water lines—allow travel on edges in only one direction at a time. The agent in the network—for instance, the oil flowing in a pipeline—can't choose which direction to travel; rather, the path it takes is determined by external forces: gravity, electromagnetism, water pressure, and so on.

Network datasets (transportation networks)

- Transportation networks—like street, pedestrian, and railroad networks—can allow travel on edges in both directions. The agent on the network—for instance, a truck driver traveling on roads—is generally free to decide the direction of traversal as well as the destination.

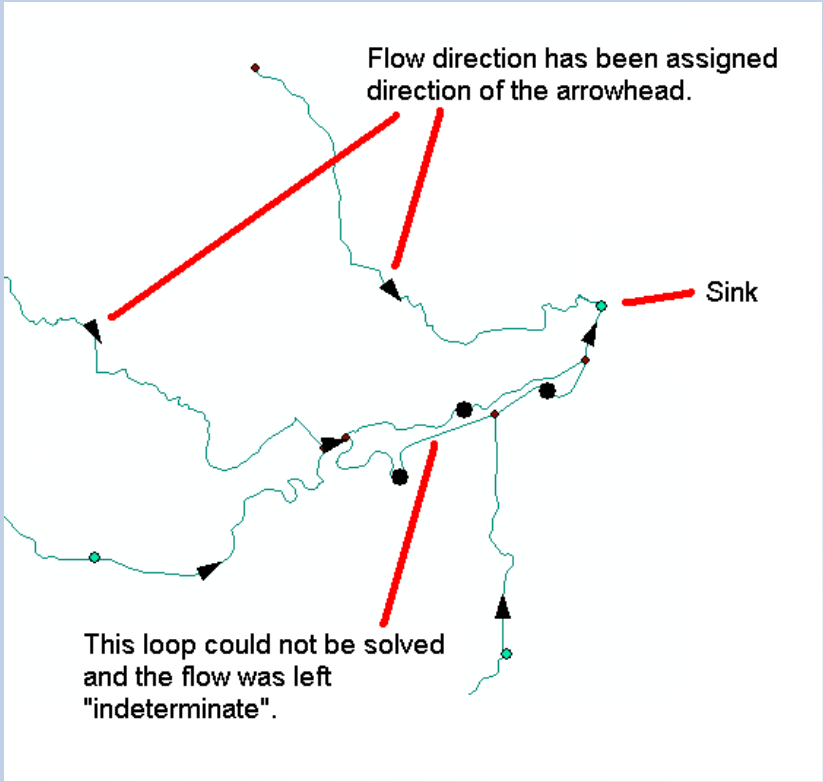


Comparison

	Network dataset	Geometric network
Application	For transportation modeling	For utilities and natural resources modeling
Analysis	Pathfinding and allocation operations	Network tracing functionality
Sources	A network dataset is built from junction, edge, and turn sources, which are simple feature classes in a geodatabase feature dataset or shapefiles.	A geometric network is initially built from simple line features, from which simple edge, complex edge, and junction feature classes are made.
Features	Network sources are simple point and line feature classes. Some feature classes build the junction-edge connectivity model and other feature classes define turns, used to restrict the traversability of the network.	Features in a geometric network are in one of these network classes: junction, simple edge, and complex edge.
Connectivity	Connectivity in a network dataset is non-reactive and refreshed with a network build.	Geometric networks dynamically update and validate connectivity with every edit.
Turns	Turns are line features that follow two or more connected street lines and model traffic scenarios such as restricted left or U-turns.	Geometric networks do not model turns.
Topology	Network source feature classes in a geodatabase can participate in topologies.	Geometric network feature classes cannot participate in topologies.
Attributes	Network datasets have an attribute model with costs, descriptors, restrictions, and hierarchy.	Geometric networks have a simpler attribute model using weights.
Workflow	Network connectivity is built on demand, similar to validating topology. Once any source feature class is edited, the network is invalid and must be rebuilt.	Network connectivity is continually maintained with every edit.
Multimodal modeling	A network dataset can model multimodal systems using connectivity groups.	A geometric network uses complex edges for a simple hierarchy and is not suited for multimodal systems.

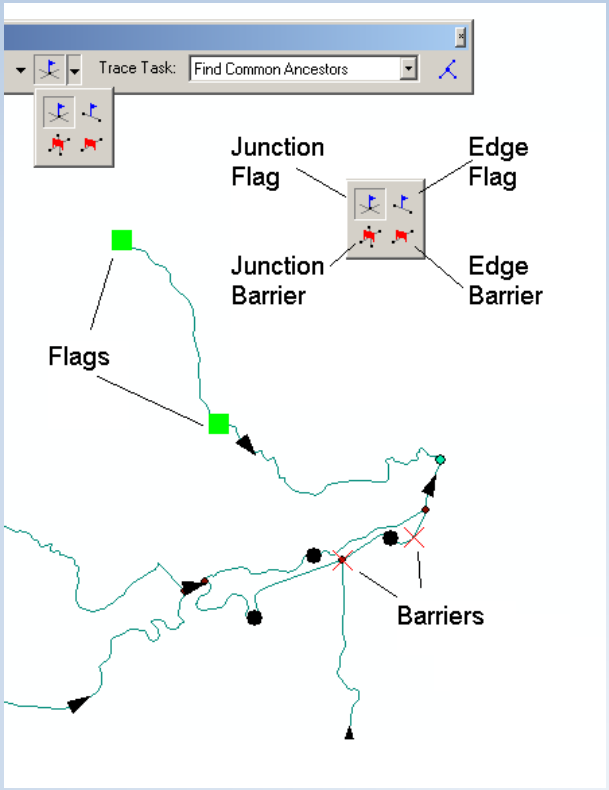
Flow to a sink

- A sink is a cell or set of spatially connected cells whose flow direction cannot be assigned one of the eight valid values in a flow direction raster.
- Sinks are considered to have undefined flow directions and are assigned a value that is the sum of their possible directions.



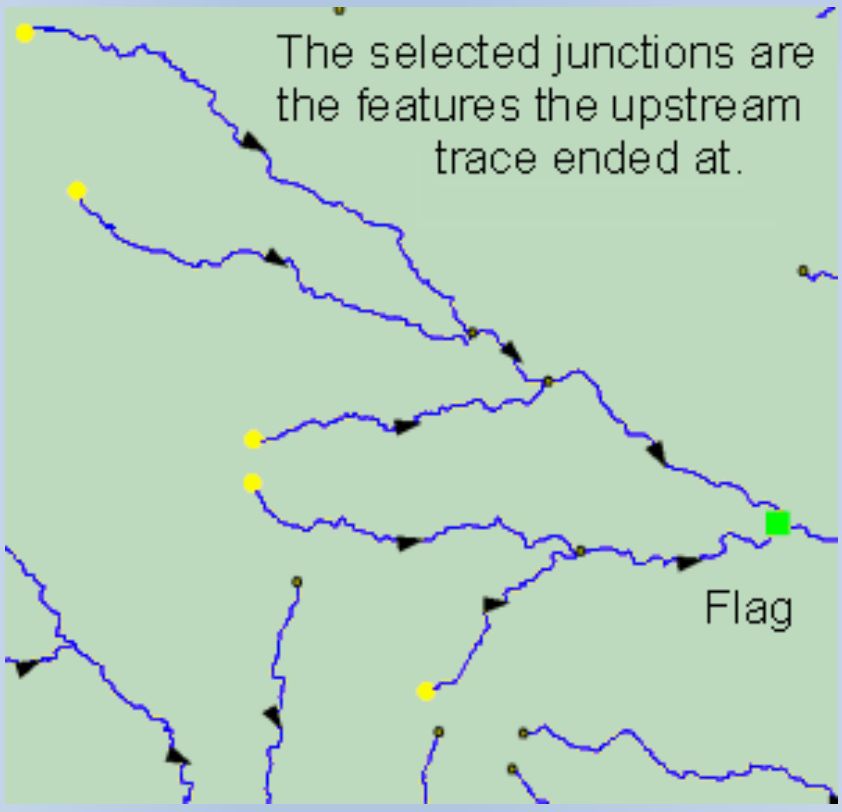
Flags

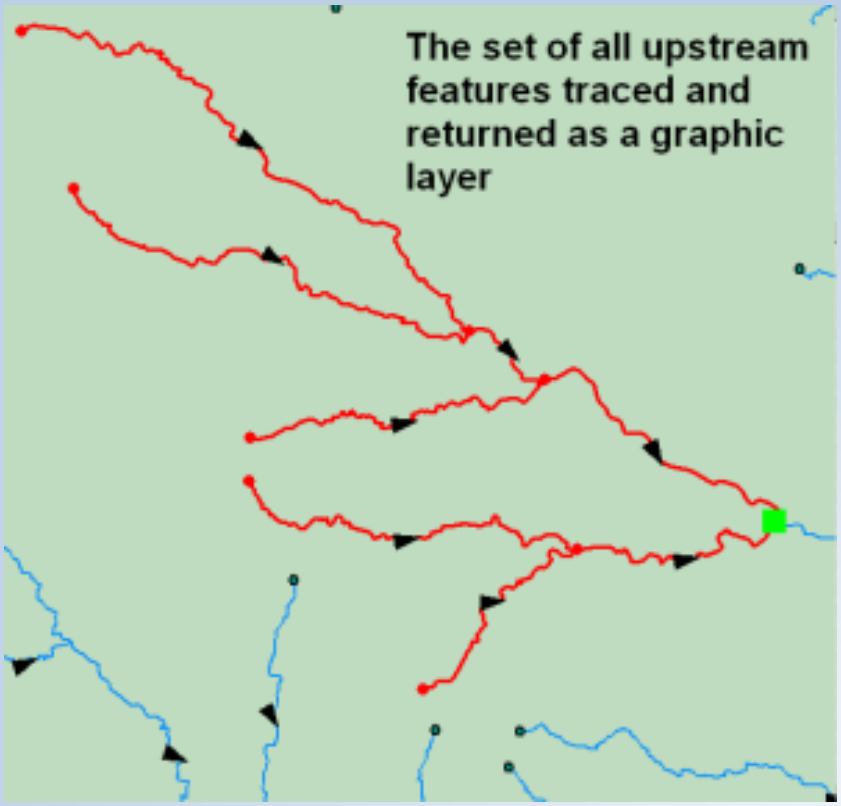
- Flags define the starting points for traces. For example, if you are performing an upstream trace, you use a flag to specify where the upstream trace will begin. Flags can be placed anywhere along edges or on junctions.
- When performing the trace operation, ArcMap uses the underlying edge or junction feature as the starting point. Network elements connected to these edges or junctions are considered for inclusion in the trace result.



Upstream Trace Solvers

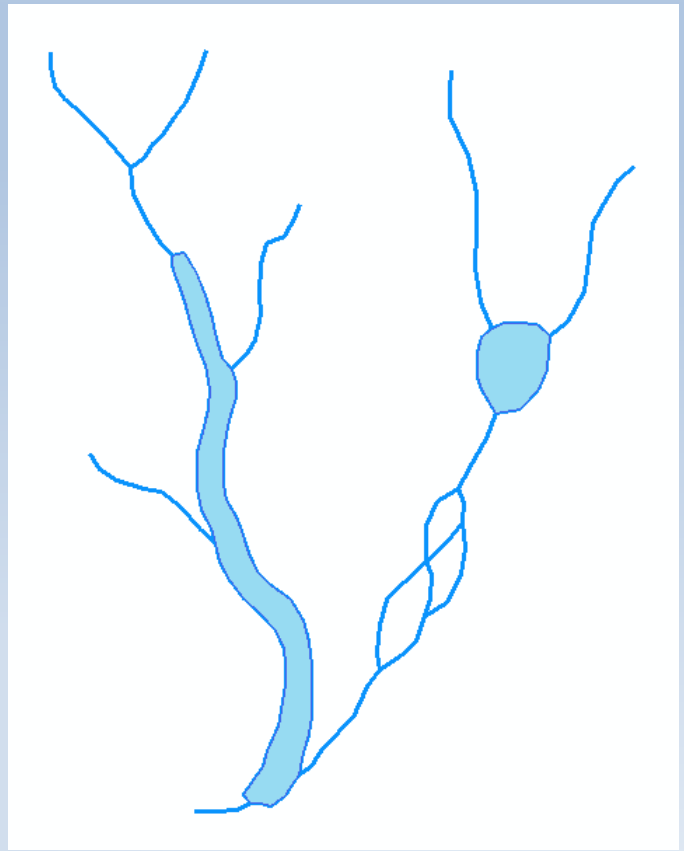
- The *Trace Solver* provides tools for tracing strems, storm, and water lines.





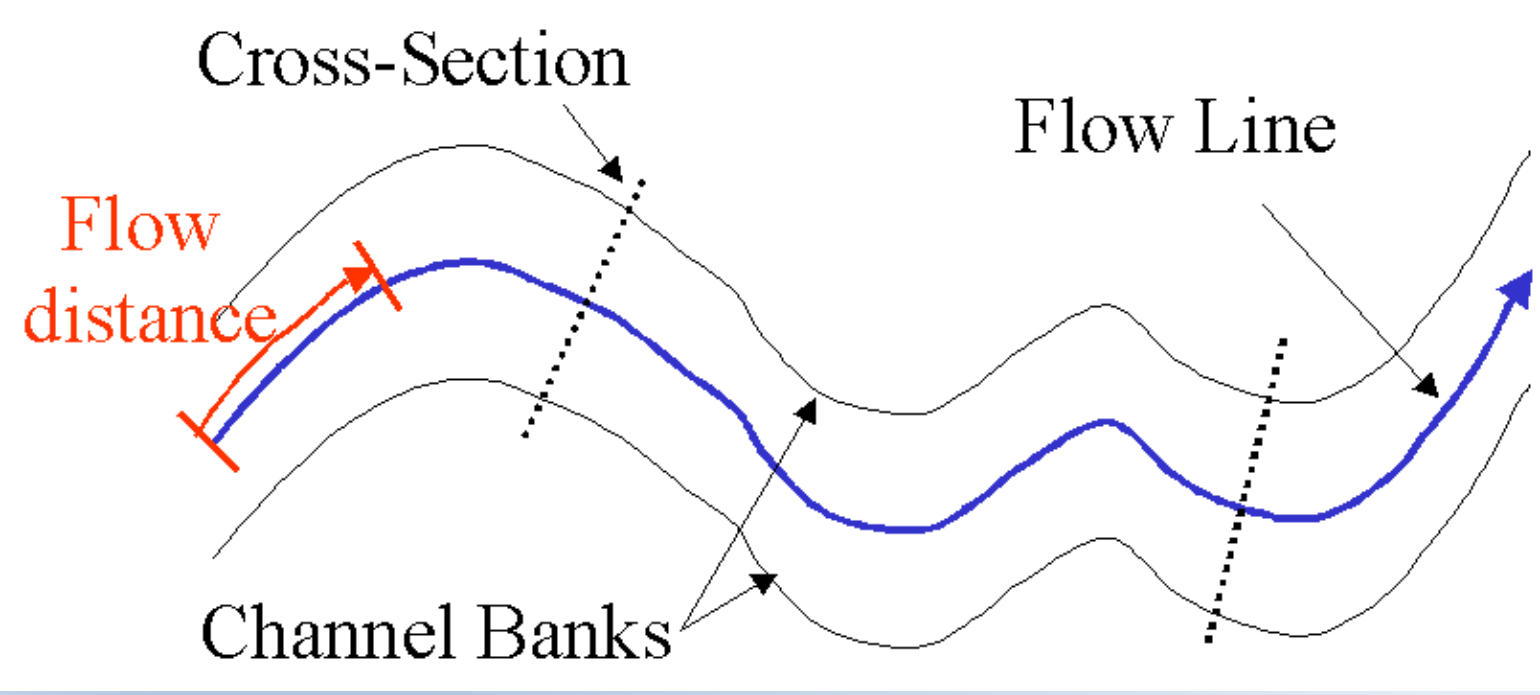
Hydrologic Networks

- Hydrologic data includes:
  - Single-line streams
  - Double-line streams
  - Braided streams
  - Manmade channel systems
  - Waterbodies

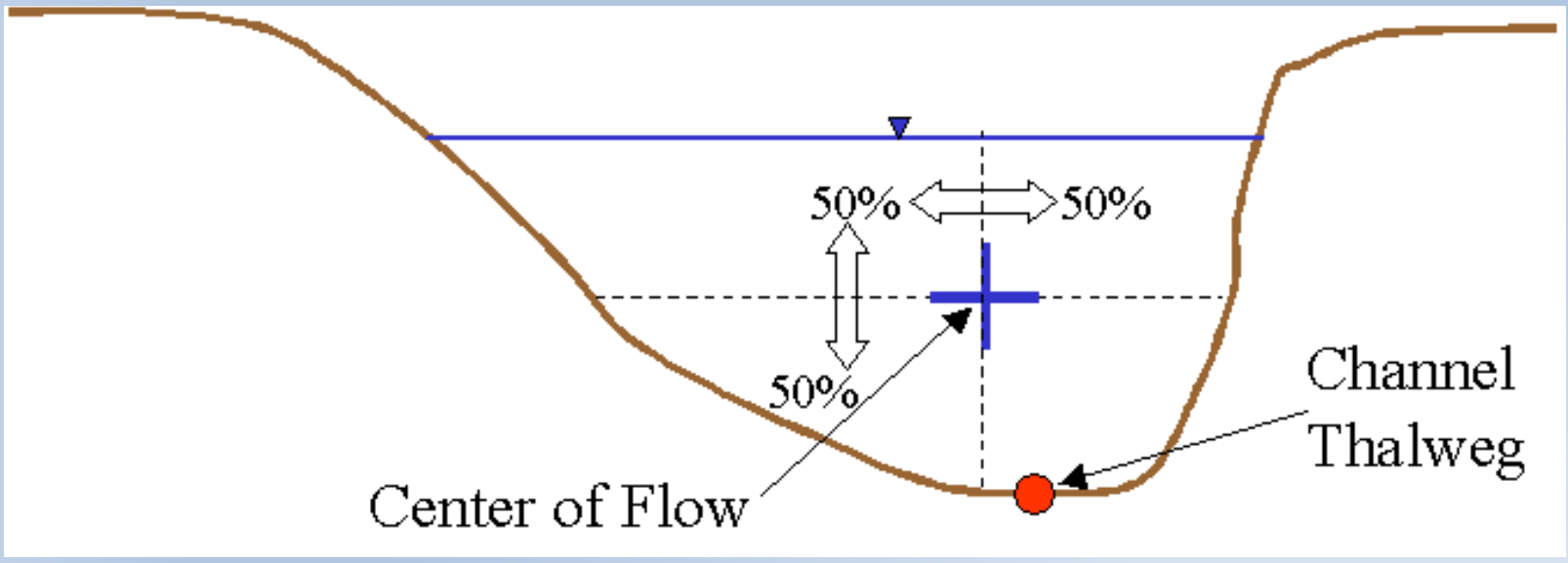


Flow Line

- Traces movement of water in a one-dimensional flow system



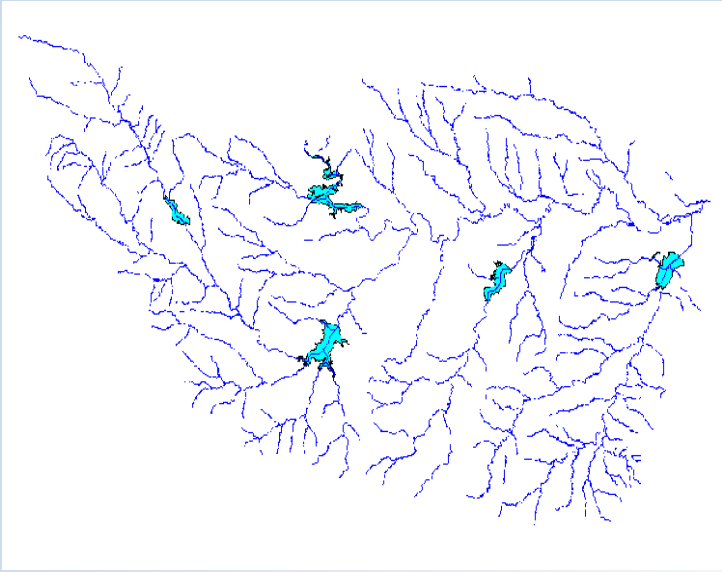
Location of the Flowline



Thalweg is the line of lowest elevation within a valley or watercourse.

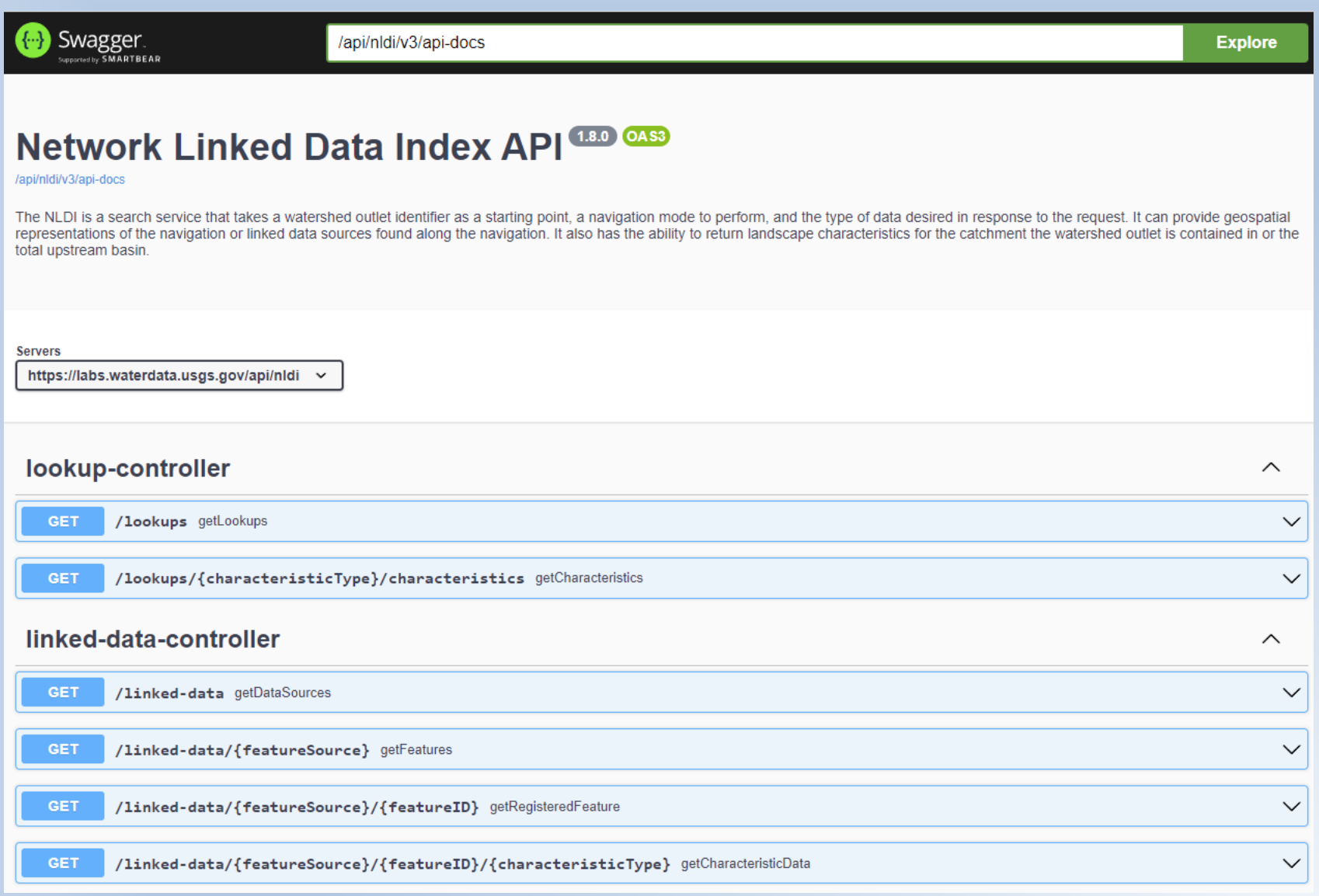
Introduction to the Hydro Network

- The hydro Network-Linked Data Index (NLDI) is a system that can index spatial and river network-linked data and navigate the river network to allow discovery of indexed information. Four components make up the system:
  - A core river network and inter-node catchment dataset from the NHDPlus.
  - A network navigation capability that traverses the river network data.
  - Multiple indexing capabilities that can crawl registered sources and add them to the index.
  - Navigation services that provide programmers access to the navigation capabilities and indexed content.

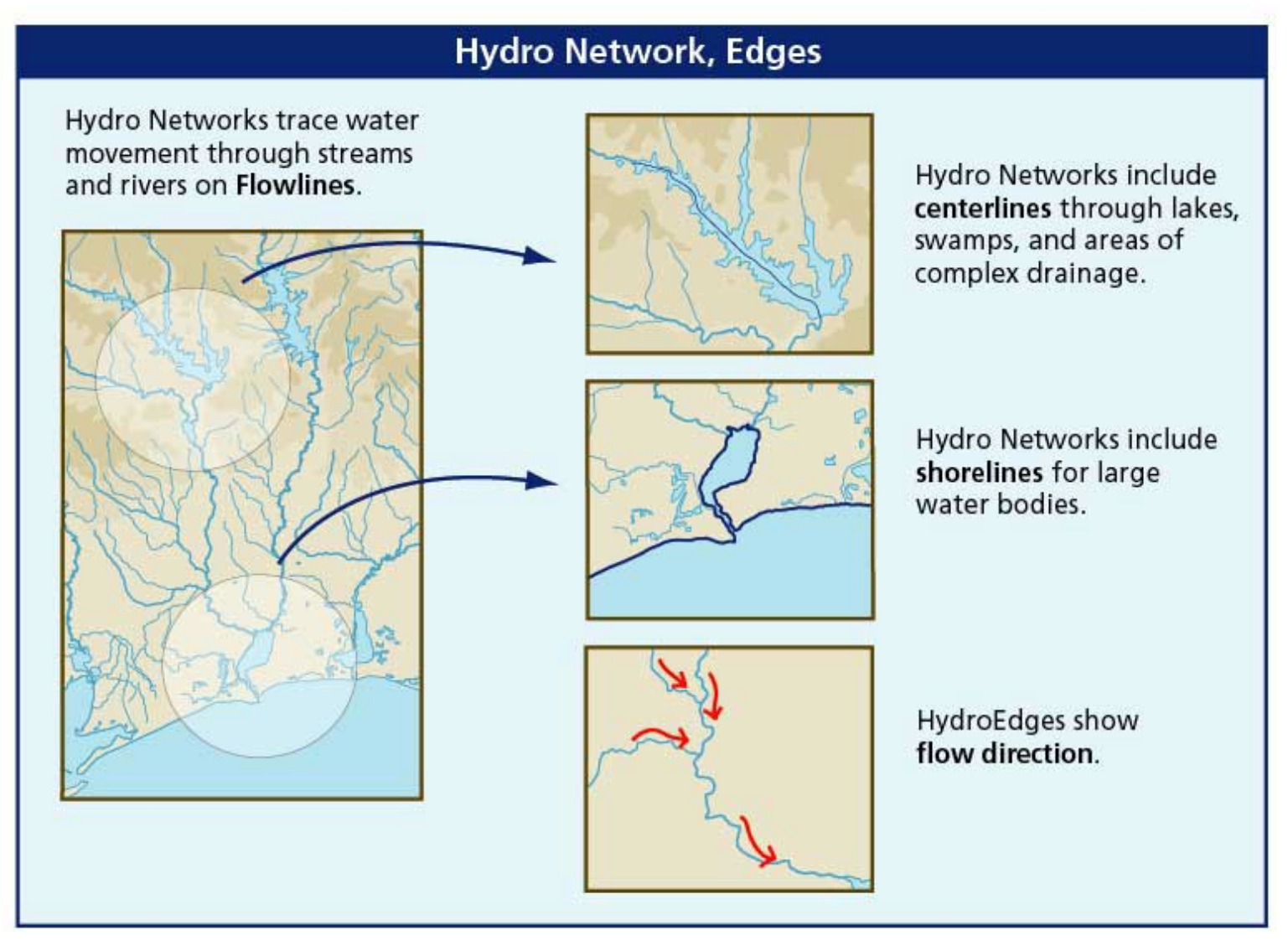


https://waterdata.usgs.gov/blog/nldi-intro/

NLDI service

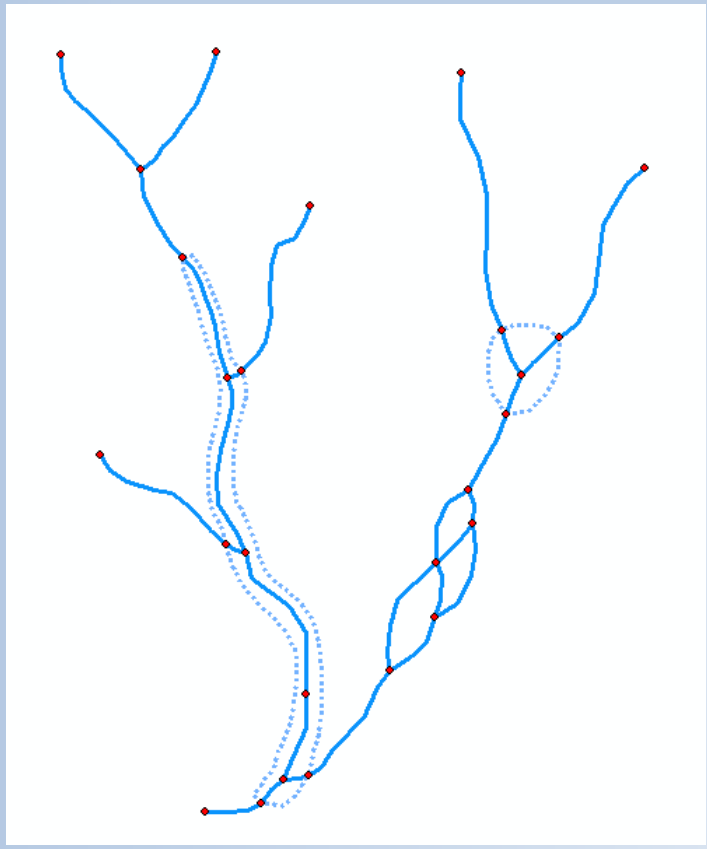


Flowlines and Shorelines

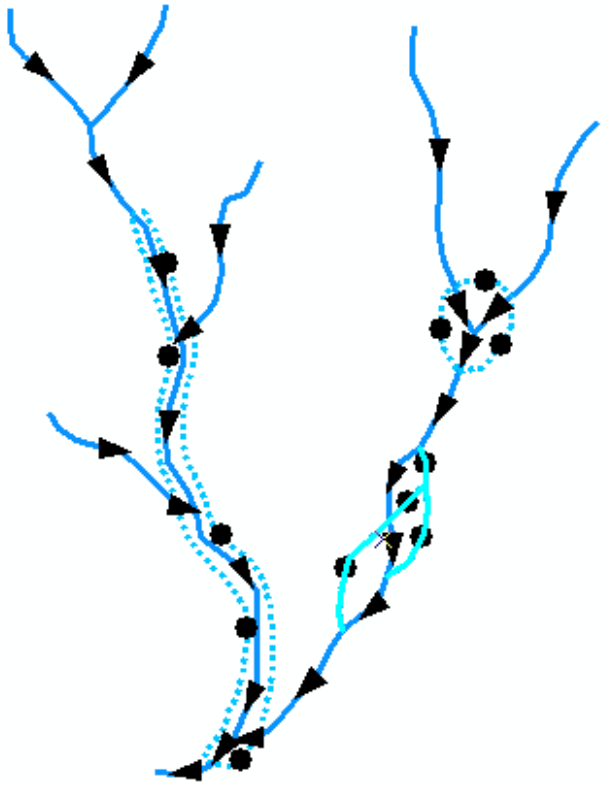


Network Building

- Define flow-paths within double-line streams and waterbodies.
- Define network sinks and sources.



Uninitialized Flow Direction

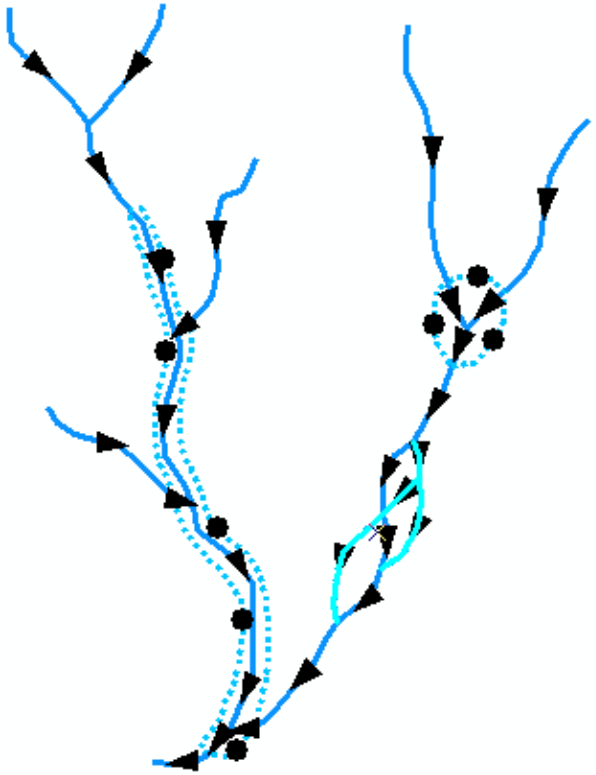


Attributes of HydroEdge

LengthKm	LengthDown	FlowDir	FType	EdgeType
<Null>	3100.648625	AgainstDigitized	<Null>	
<Null>	6661.314075	AgainstDigitized	<Null>	
<Null>	10026.725681	Uninitialized	<Null>	
<Null>	8538.955149	AgainstDigitized	<Null>	
<Null>	0	Uninitialized	<Null>	
<Null>	0	Uninitialized	<Null>	
<Null>	10026.725681	AgainstDigitized	<Null>	
<Null>	12332.168515	Uninitialized	<Null>	
<Null>	12332.168515	AgainstDigitized	<Null>	

Record: 19 Show: All Selected Records (4 out of 36 Selected.)

Assigned Flow Direction



Attributes of HydroEdge

LengthKm	LengthDown	FlowDir	FType	EdgeType
<Null>	3100.648625	AgainstDigitized	<Null>	
<Null>	6661.314075	AgainstDigitized	<Null>	
<Null>	10026.725681	AgainstDigitized	<Null>	
<Null>	8538.955149	AgainstDigitized	<Null>	
<Null>	0	AgainstDigitized	<Null>	
<Null>	0	AgainstDigitized	<Null>	
<Null>	10026.725681	AgainstDigitized	<Null>	
<Null>	12332.168515	AgainstDigitized	<Null>	
<Null>	12332.168515	AgainstDigitized	<Null>	

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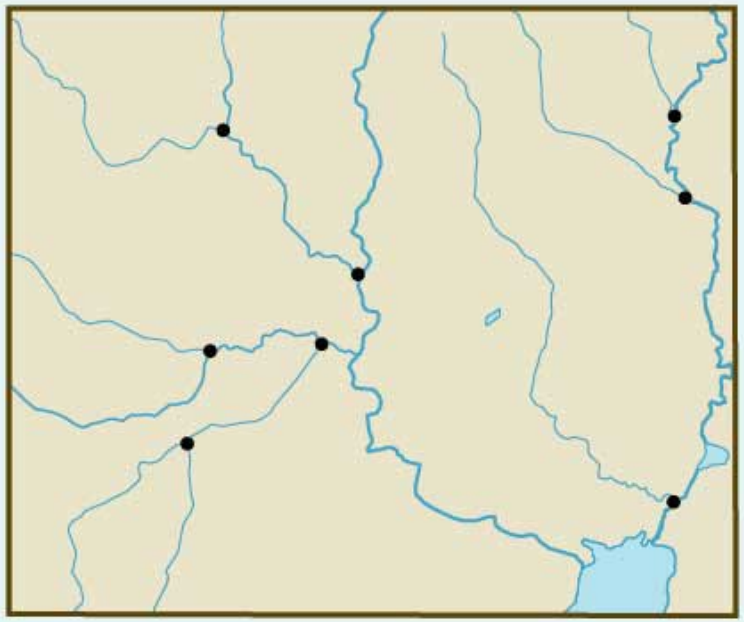
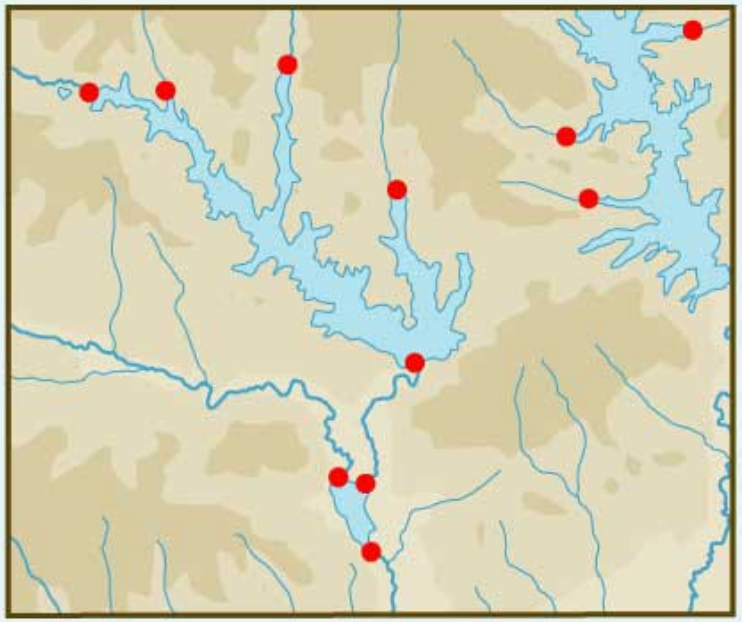
Hydro Network Junctions

Hydro Network, Junctions

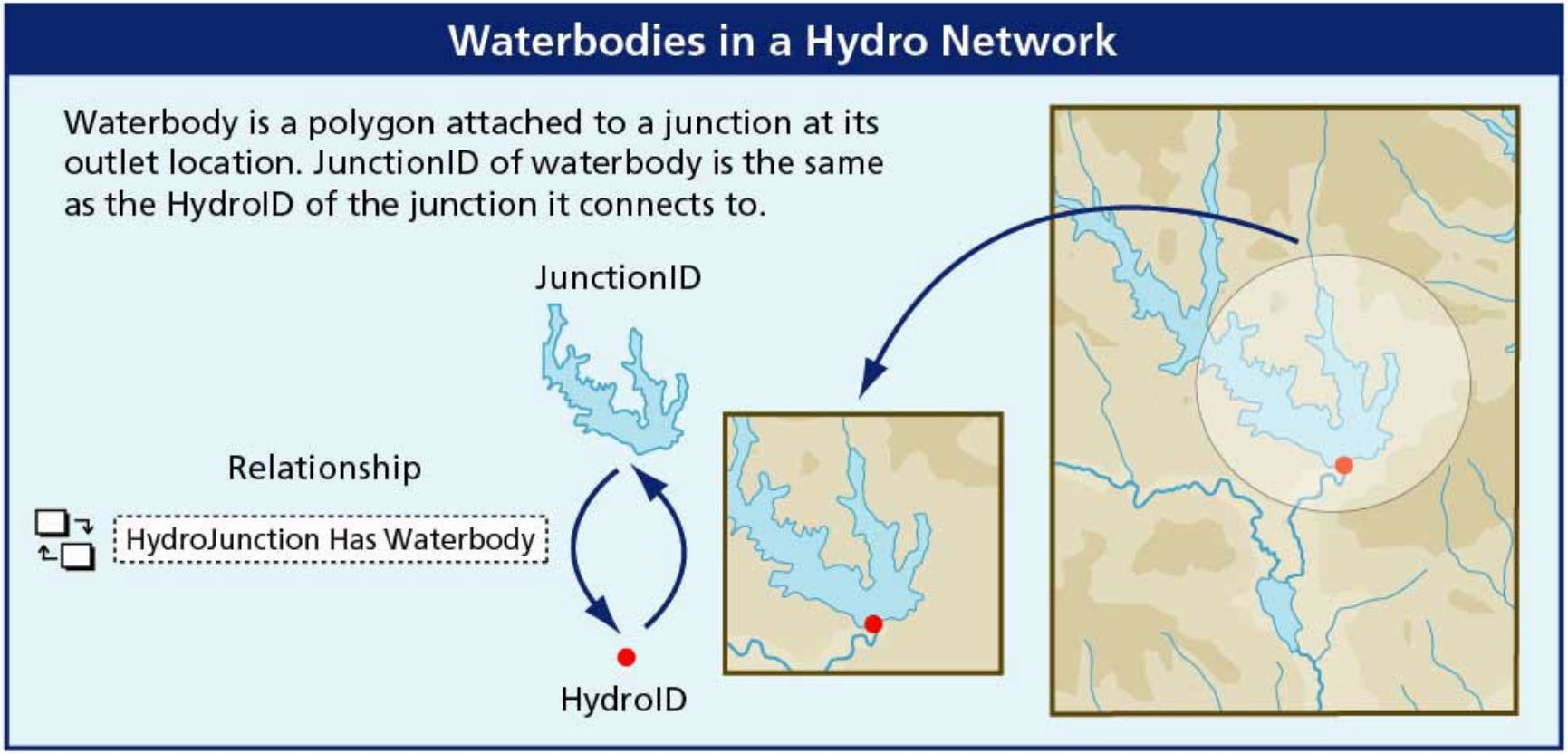
Generic Junction is wherever two edges meet.



Hydro Junction is where other features are attached to the network.



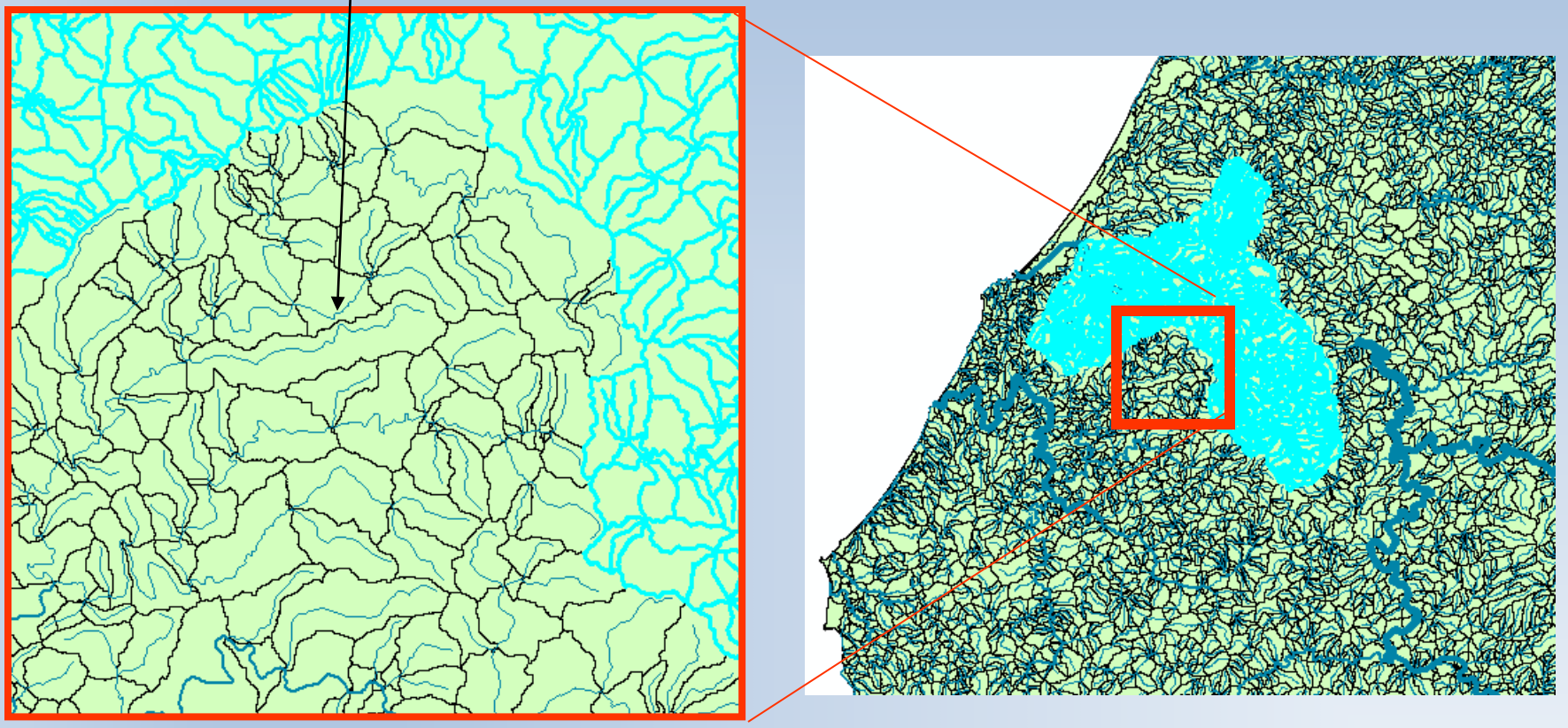
Connecting Waterbodies using Relationships



NHDPlus Reach Catchments ~ 3km^2

Average reach length = 2km

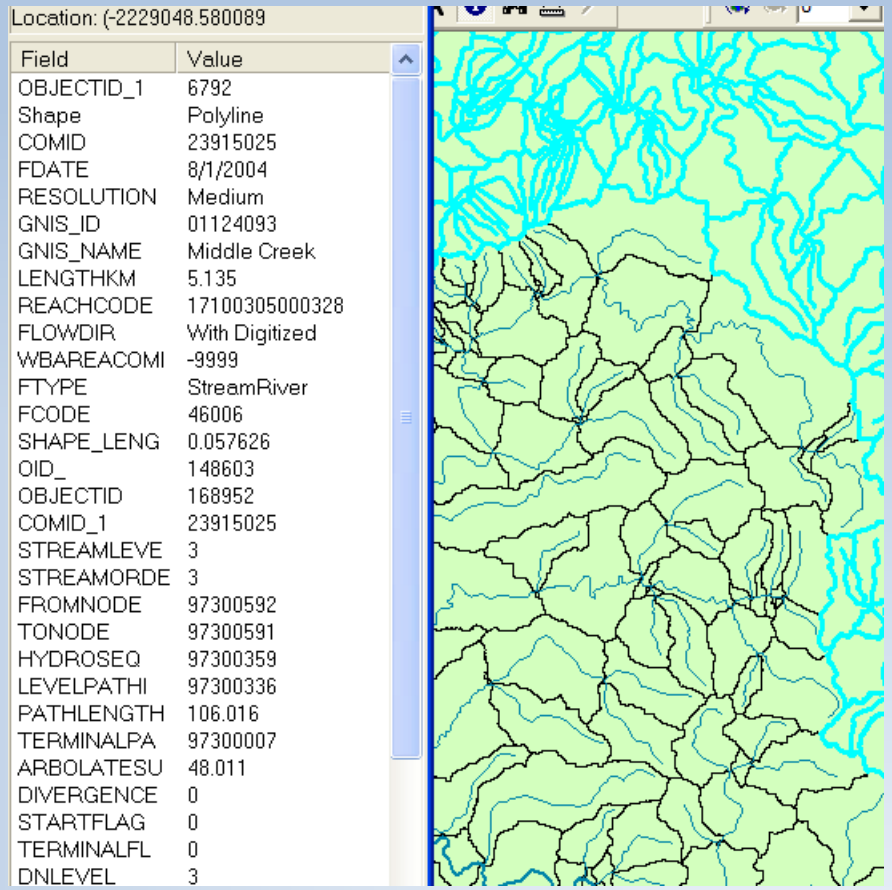
2.3 million reaches for continental US



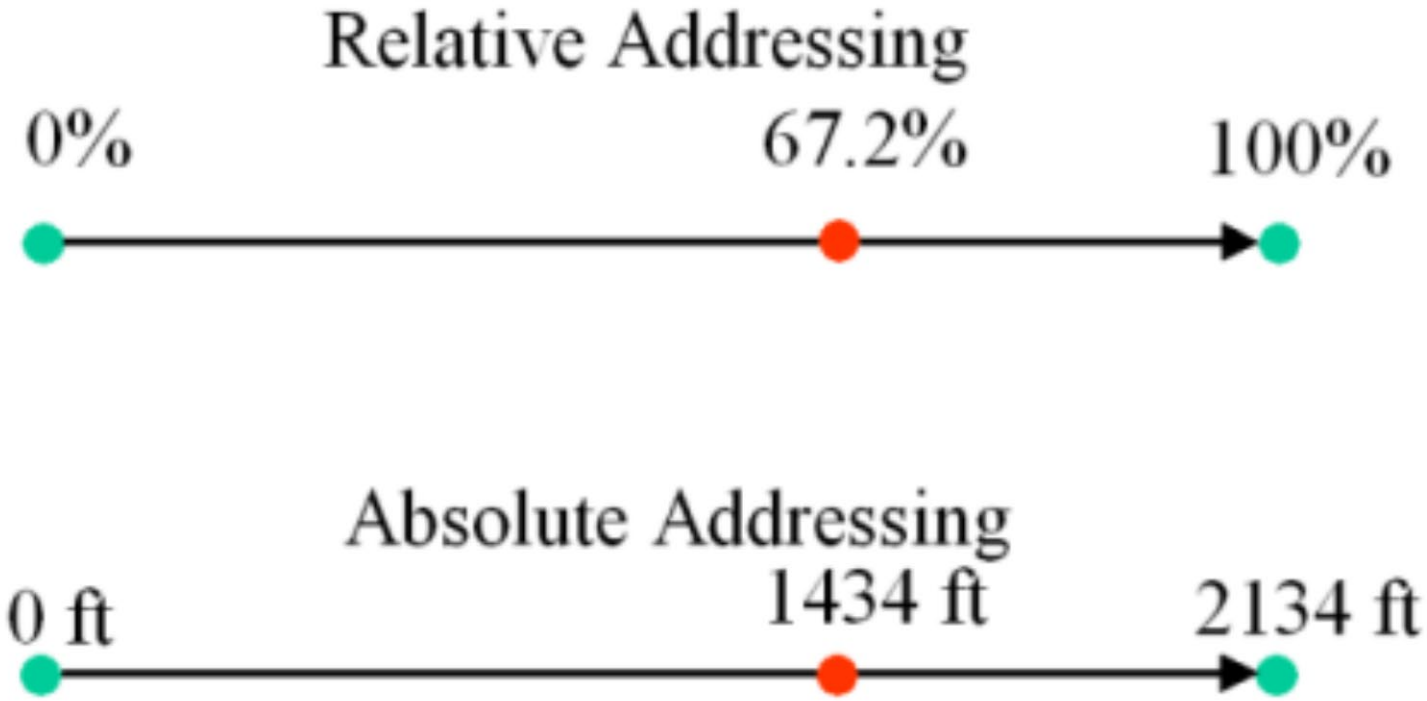
About 1000 reach catchments in each 8-digit HUC

Reach Attributes

- Slope
- Elevation
- Mean annual flow
  - Corresponding velocity
- Drainage area
- % of upstream drainage area in different land uses
- Stream order



Addressing


Relative Addressing
0%
67.2%
100%
Absolute Addressing
0 ft
1434 ft
2134 ft

Summary Concepts

- A network is a connected set of points (junctions) and lines (edges) that supports tracing functions
  - Three data model components
    - Geographic (x,y,z)
    - Logical (point-line topology connections)
    - Addressing (position m along the line)
- Features can be geometrically connected (network) or relationally connected (HydroID)

Summary Concepts (2)

- Land-water connections
  - Area flows to a line model (one Catchment is connected to one flowline) – used in NHDPlus and by Arc Hydro DrainID connections
  - Area flows to line at a point model (one Watershed contains many streams that drain to a Junction at the outlet) – used in Arc Hydro where HydroID of the HydroJunction is JunctionID of the Watershed

Summary Concepts (3)

- Linear referencing can be used to locate point and line "events" on a network
- This is like (x,y) event themes that you used earlier to map stream gage locations in geographic space
- With linear referencing the locations are in "network space" but can be converted to regular features if necessary