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# **Hydrologic and Hydraulic Modeling with ArcGIS**

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# Overview

- **Core GIS tools for surface water analysis**
- **DEM data and processing**
  - Demo
- **Application tools for Hydrologic and Hydraulic Modeling**
- **Q&A**

# Water Resources Issues

- **Not enough (droughts)**
- **Too much (floods)**
- **Of wrong kind (water quality)**
- **In a wrong place (spatial distribution)**
- **At the wrong time (temporal distribution)**

# Focus on Surface Water Quantity

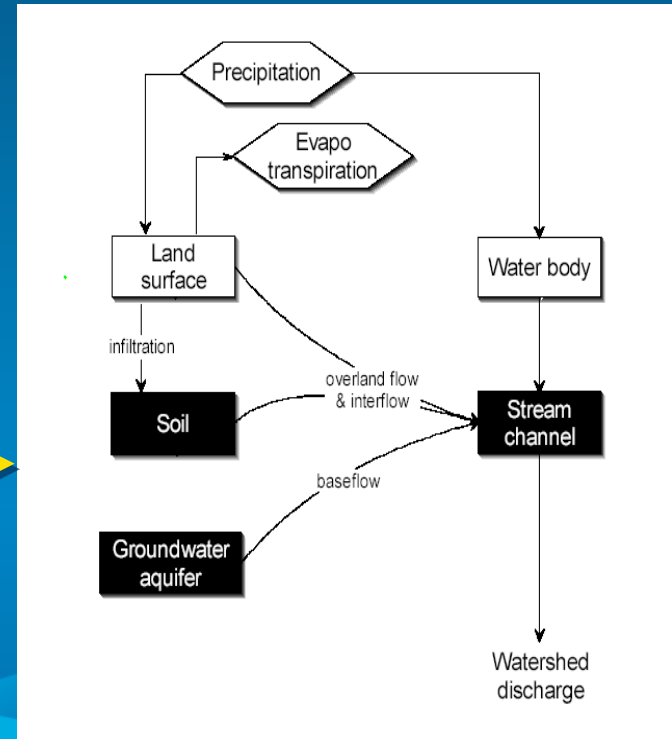
- How much water is there?
  - *Hydrologic modeling* (precipitation-runoff modeling), determines for a given storm on a landscape, how much water will become runoff.
- Where will it go?
  - *Hydraulic modeling* takes the quantity of water and the shape of the landscape and stream channel and determines how deep and fast the water will be, and what area it will cover in the event of a flood.

# Hydrologic Modeling

- **Goal:** Find stream discharge,  $Q$ , at a location for a given precipitation event.
- There are many ways to calculate  $Q$ .
  - Statistical methods
    - USGS regression equations (NFF, StreamStats)
  - “Physical” modeling (rainfall-runoff models)
    - HEC-HMS, SMS, etc.
- *GIS is used to summarize terrain and hydrologic characteristics of the watershed for input to a model.*

# Hydrologic Modeling

- Map natural processes onto software tasks.
- Aggregate landscape characteristics and define the layout.
  - **“Lumped parameter model”**



# Hydraulic Modeling

- **Goal:** Predict water surface elevations to create flood inundation maps.
  - Also predict velocity, sedimentation, quality
- **Input:** Channel and floodplain geometry with hydraulic characteristics, plus discharge '**Q**' and initial water surface level.
- **Output:** Water surface elevation at each cross section and other characteristics.
- *GIS is used to summarize terrain and hydraulic characteristics of the channel for input to a model and post process hydraulic modeling results (surface determination).*

# GIS Data for Hydrologic and Hydraulic Modeling

- Digital Elevation Model and land cover
  - <http://seamless.usgs.gov/>
  - <http://edna.usgs.gov/>
  - <http://www.horizon-systems.com/nhdplus/>
- Watershed boundaries
  - <http://www.ncgc.nrcs.usda.gov/products/datasets/watershed/>
- Hydrography
  - <http://nhd.usgs.gov/>
- Soils
  - <http://www.soils.usda.gov/survey/geography/statsgo/>



# GIS Data for Hydrologic and Hydraulic Modeling

- Current and historic water records
  - <http://waterdata.usgs.gov/nwis>
  - <http://www.epa.gov/STORET/index.html>
  - <http://his.cuahsi.org/>
- Climate and precipitation
  - <http://www.weather.gov/gis/>
  - <http://www.ncdc.noaa.gov/oa/ncdc.html>
- Channel geometry (cross sections)

# Drainage System

## Watershed

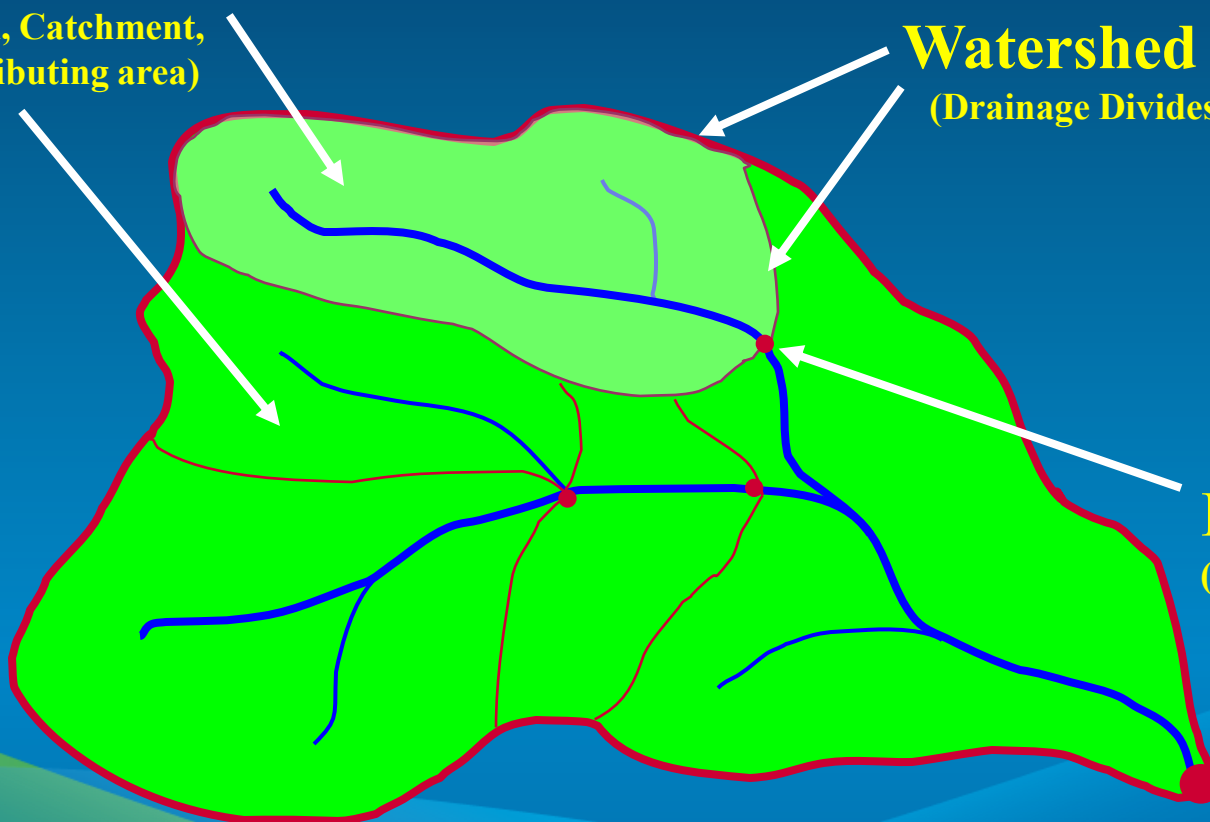
(Basin, Catchment, Contributing area)

## Watershed Boundaries

(Drainage Divides)

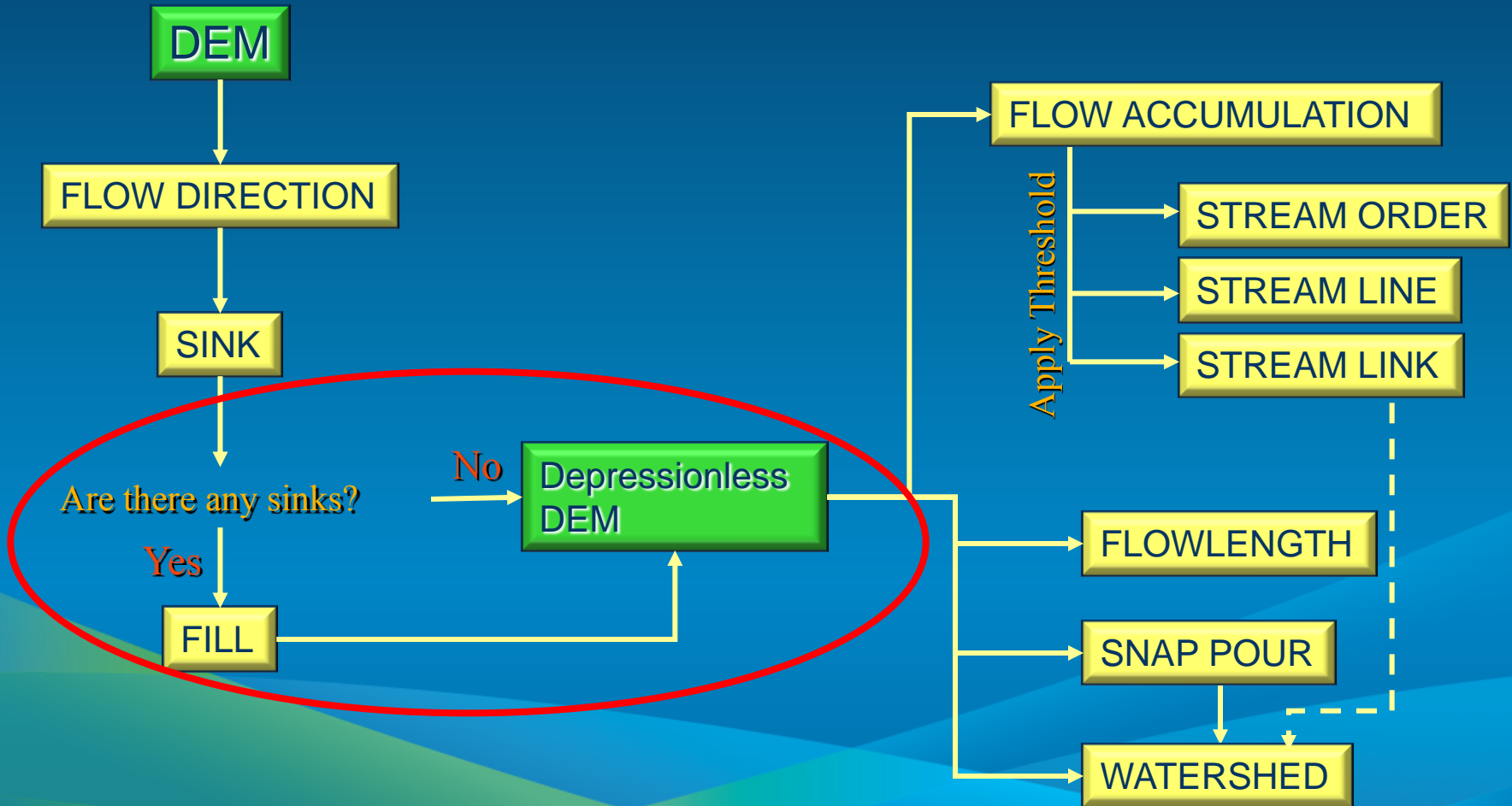
## Pour Points

(Outlets)



# GIS Tools for Describing Surface Water Movement

- Dendritic morphology – simple process



# Flow Direction

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

Elevation



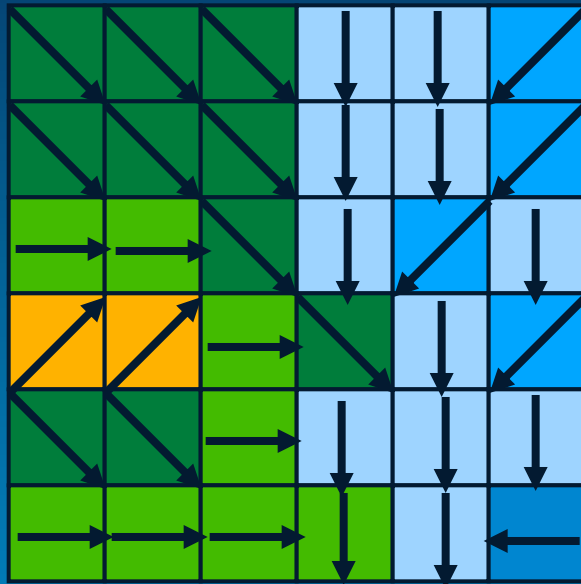
2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

Flow Direction

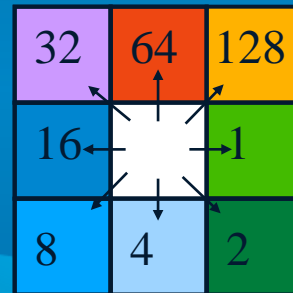
32	64	128
16		1
8	4	2

Direction Coding

# Flow Accumulation



0	0	0	0	0	0
0	1	1	2	2	0
0	3	7	5	4	0
0	0	0	20	0	1
0	0	0	1	24	0
0	2	4	7	35	2



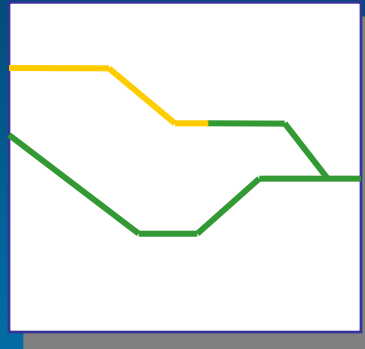
Direction Coding

# Creating Vector Streams

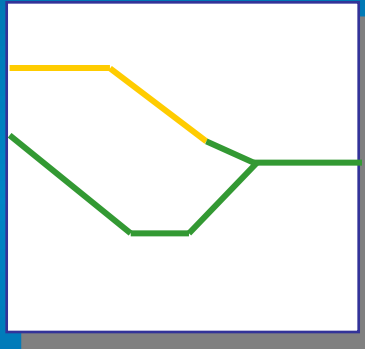
Value = No Data



NET\_GRID



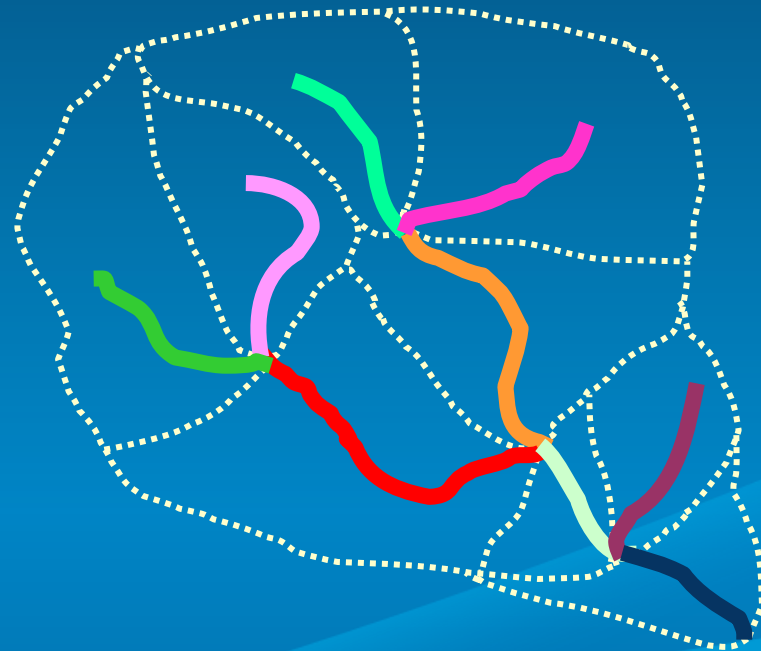
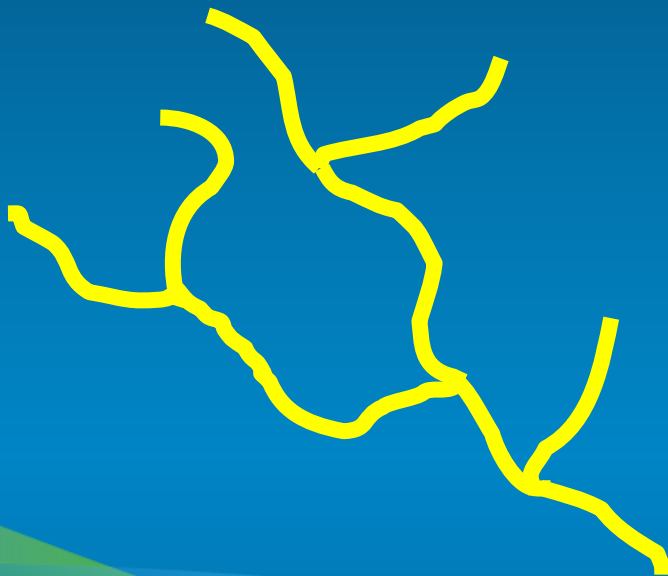
StreamToFeature



RasterToFeature

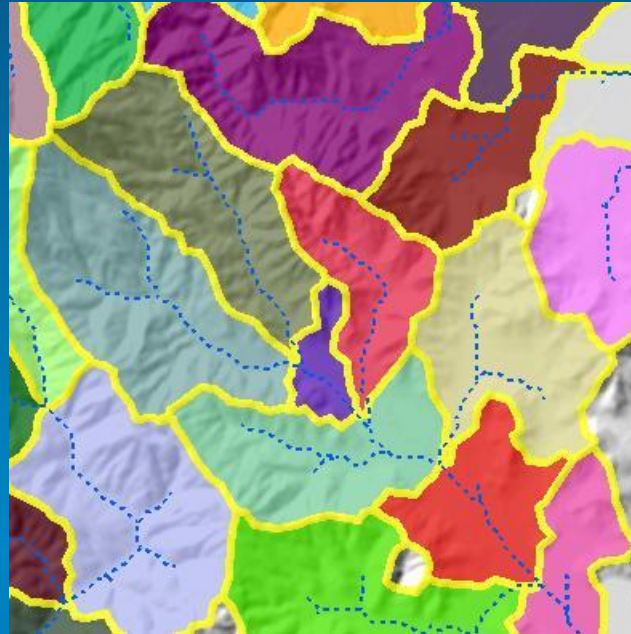
# Stream Link

- Assign a unique value to each stream segment.
  - Can be used as input to Watershed tool



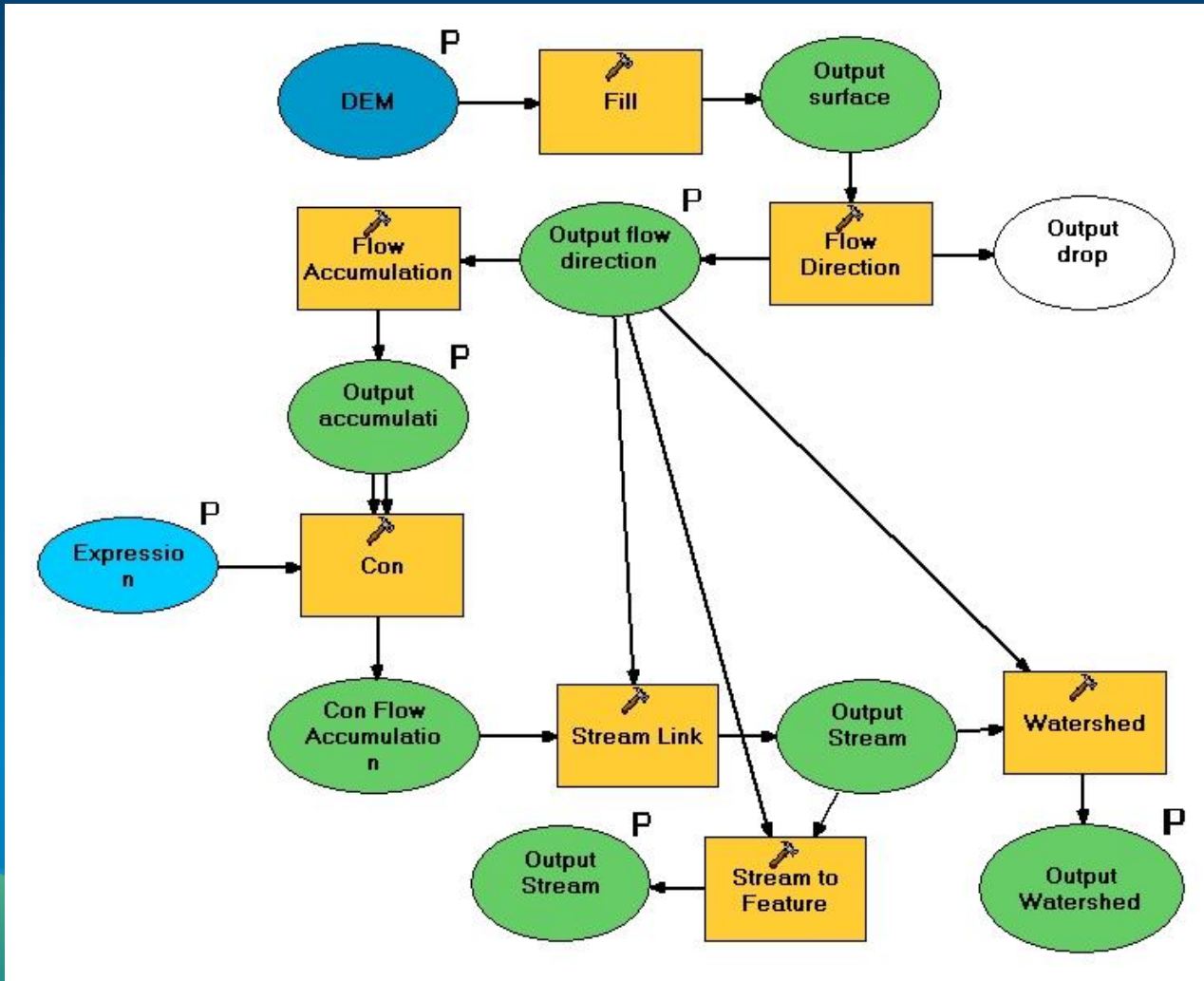
# Watershed, subwatershed, drainage area

- Delineate the contributing area to a cell or group of cells.





# Using the Tools in Model Builder



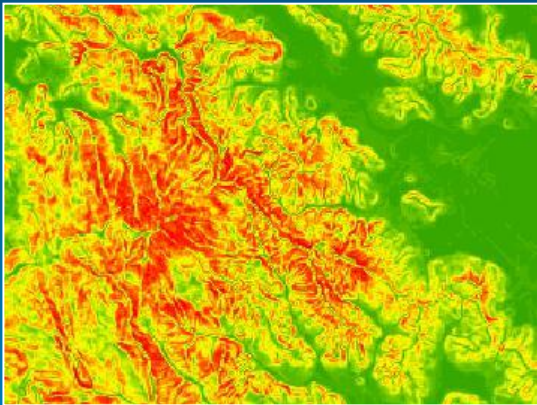
# Summarizing Watershed Characteristics

- Use the Zonal Statistics tool.
- A “**zone**” is all the areas/cells with the same value.
- Calculate a statistic within the zones for each cell in a raster.
- Input zones can be feature or raster.
- Output as a raster, summary table, or chart.
  - Max. flow length per watershed
  - Average slope per watershed
  - Average curve number per watershed

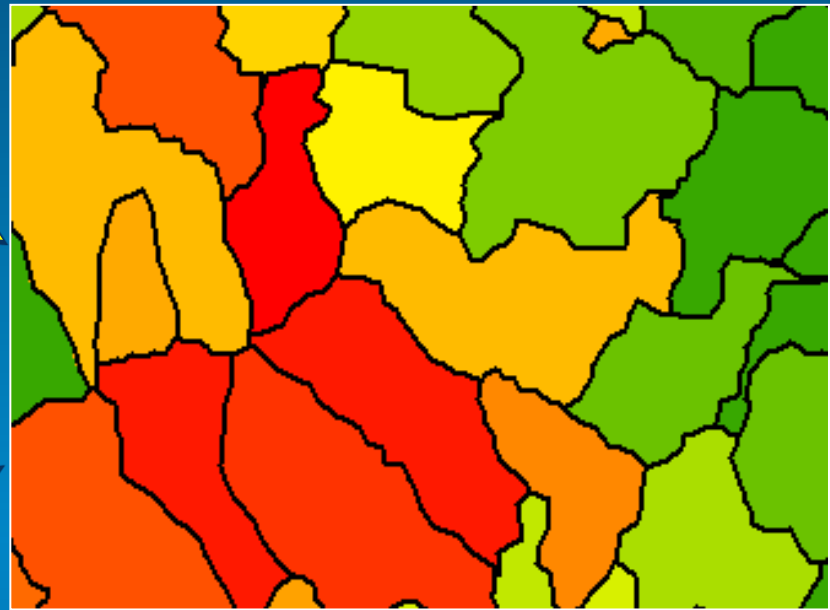
# Summarizing Watershed Characteristics

- Using Zonal Statistics

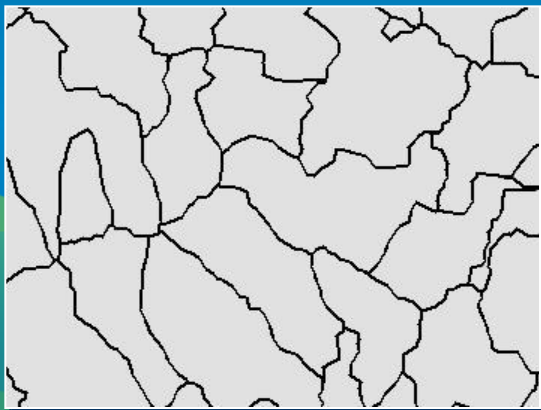
Slope



Mean Slope per Watershed



Watersheds



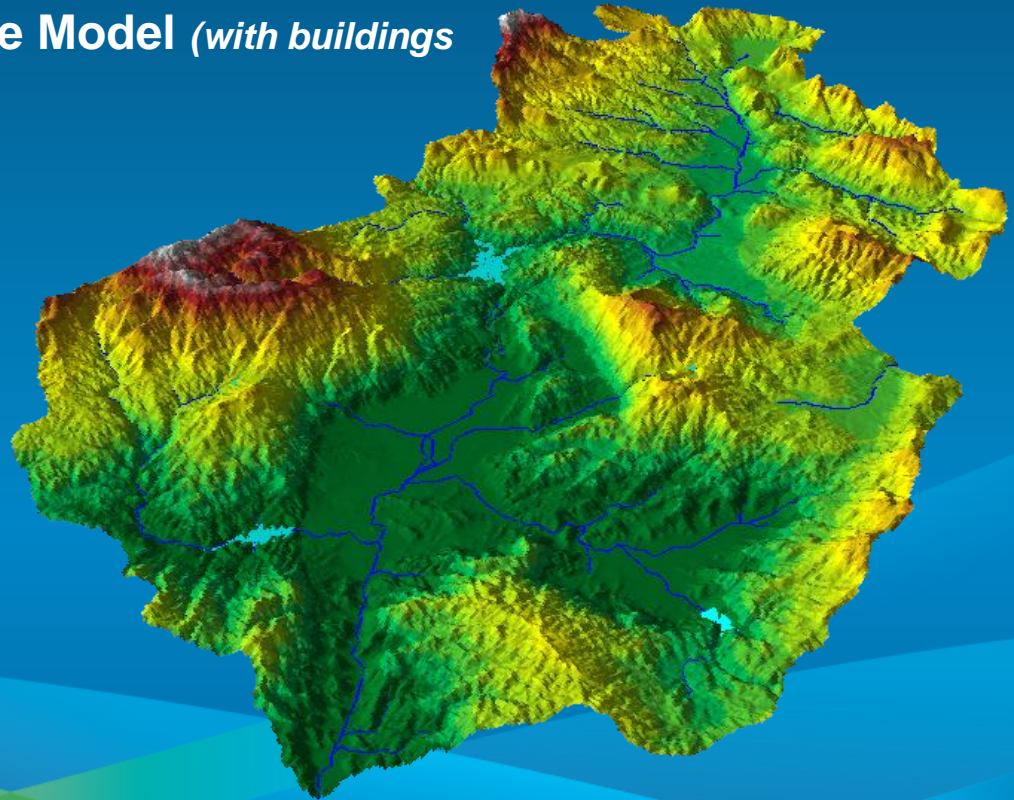
# Elevation Data

- **Types**

- **DEM: Digital Elevation Model** (*bare Earth*)
- **DSM: Digital Surface Model** (*with buildings and trees*)

- **Data Structure**

- Raster
- TIN
- Terrain dataset



# Where Do You Get DEM Data?

- **Sources**

- Existing data: USGS DEM, NED, DTED, ETOPO30, SRTM
- LiDAR, IfSAR
- Generated photogrammetrically
- Interpolated from points and lines

- **What cell size and accuracy?**

- Horizontal and Vertical resolution must be appropriate for the landscape and scale being modeled.

# DEM Construction Considerations

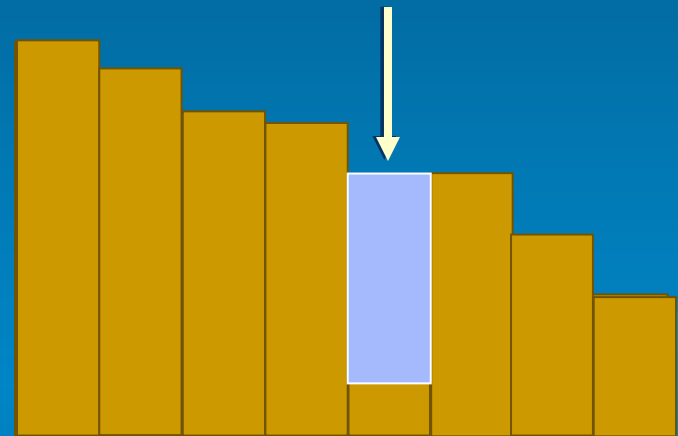
- Resolution and extent
- Projection (for hydrology – use equal area)
- Source elevation data
- Interpolation techniques
  - For hydrologic applications, use **TopoToRaster**.
    - Avoids problems with contour input
    - Creates hydrologically correct DEM

# DEM Errors – Sinks and Spikes

- **Sinks: when sinks are (or are not) sinks – lakes, depressions,...**

- **Global fill**
- **Dealing with internal basins**
- **Selective fill**
  - **Depth**
  - **Area**
  - **Volume**
  - **“you just know it”**

Filled sink





# DEM Editing

- **Streams: When streams are not where they “should” be**
  - Flat areas – Difficulty in determining the flow pattern
  - Barriers (roads) diverting the flow paths
    - How to “model” bridges and culverts in DEM
    - How to model dams
  - Imposing the flow pattern - to burn or not to burn (beware of the scale issues and artifacts – Saunders, 2000.)
    - Simple burn
    - AGREE
    - OMNR



## DEM Editing (cont.)

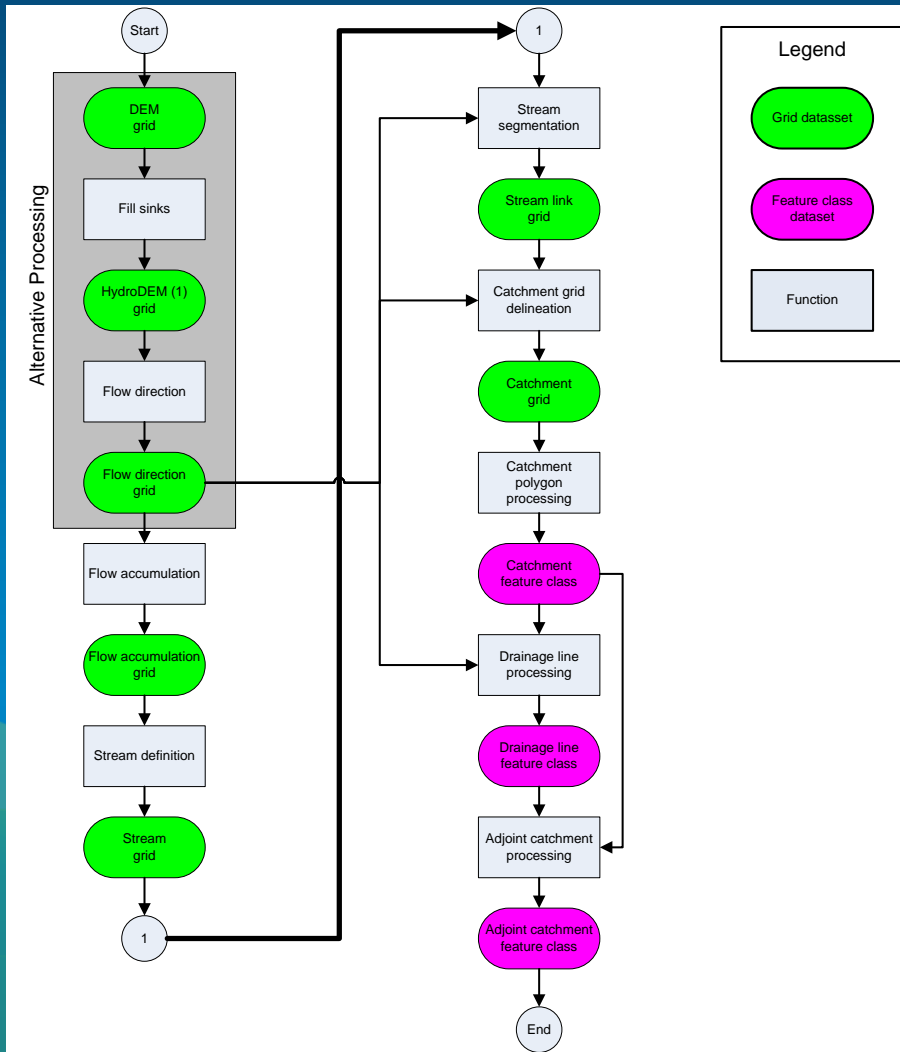
- **Watersheds—When watershed boundaries are not where they “should” be**
  - **To fence or not to fence**
  - **Ineffective flow areas**

# What If You Do Not Have Dendritic Morphology?

- **Arc Hydro tools for terrain preprocessing:**
  - **Modified dendritic process**
    - Burning streams
    - Fencing boundaries
    - Bowling lakes
    - Flow splits
  - **Deranged terrains**
    - Selective filling of sinks
    - Streams draining into sinks
  - **Combined dendritic/deranged**

# Workflows, Workflows, Workflows

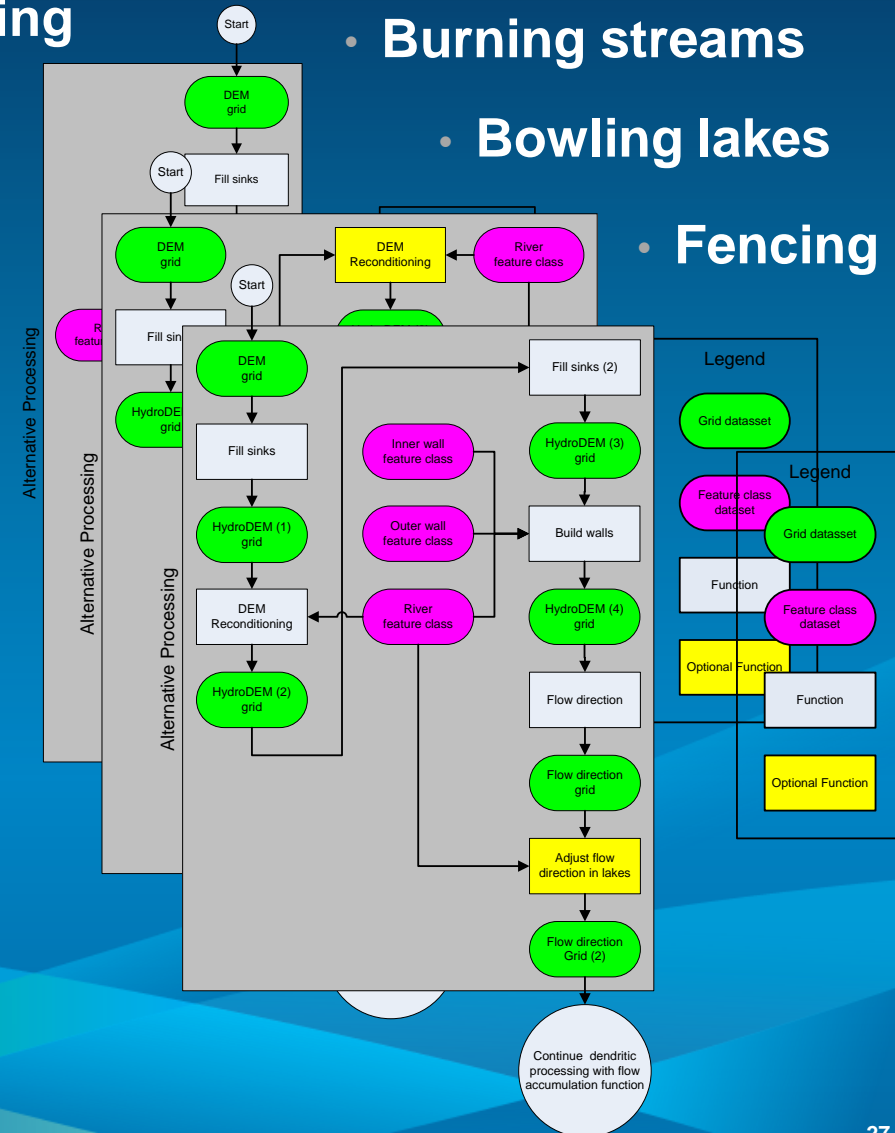
- “Basic” dendritic preprocessing



- Burning streams

- Bowling lakes

- Fencing



# Where is this functionality?

- **ArcGIS Spatial Analyst**
  - Tools in the Spatial Analyst Toolbox
  - Sample Toolbar on ArcObjects Online
  - HydrologyOp containing ArcObjects methods
  - *Example ModelBuilder model on the Geoprocessing Center Web site*
- **Arc Hydro**
  - Tools in the Arc Hydro Toolbox
  - Arc Hydro Toolbar

# Arc Hydro



# Arc Hydro

- Extension of geodatabase model for support of water resources applications (template data model)
- Culmination of a three-year process (1999–2002) led by D. R. Maidment through GIS in Water Resources Consortium (Arc Hydro book)
- Collection of tools for support of Arc Hydro geodatabase design and basic water resources functions
- **Starting point** for water resources database and application development

# Data Model Purpose

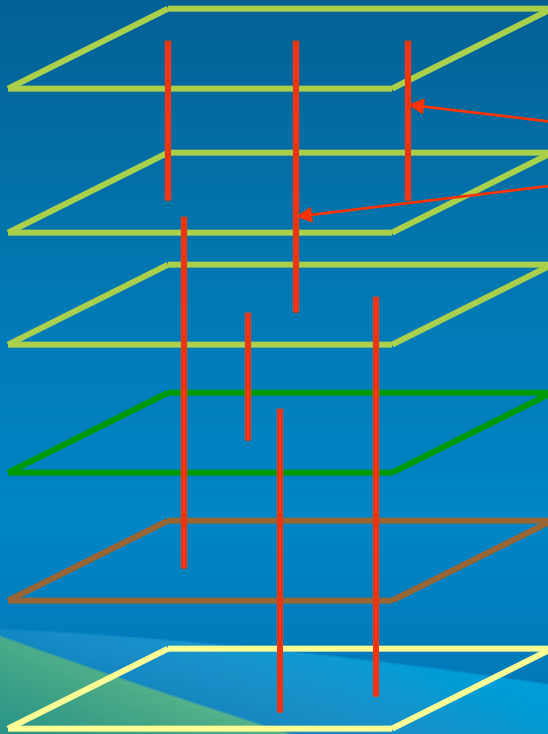
- **Target audience: Water resources (surface) community interested in quick start in ArcGIS implementation**
- **Starting point for project model design**
- **Not a “do all” design**
- **Not implementation/application specific, but provides the key components to develop on top of**

**The user needs to add additional data structures for their specific requirements – there’s still work to be done!**

# What makes Arc Hydro different?

*ArcGIS: All features are labeled with a unique ObjectID within a feature layer.*

*Arc Hydro: All features are labeled with a unique HydroID across the geodatabase.*



**HydroID to ID relationships** link neighboring features and help to trace water movement.

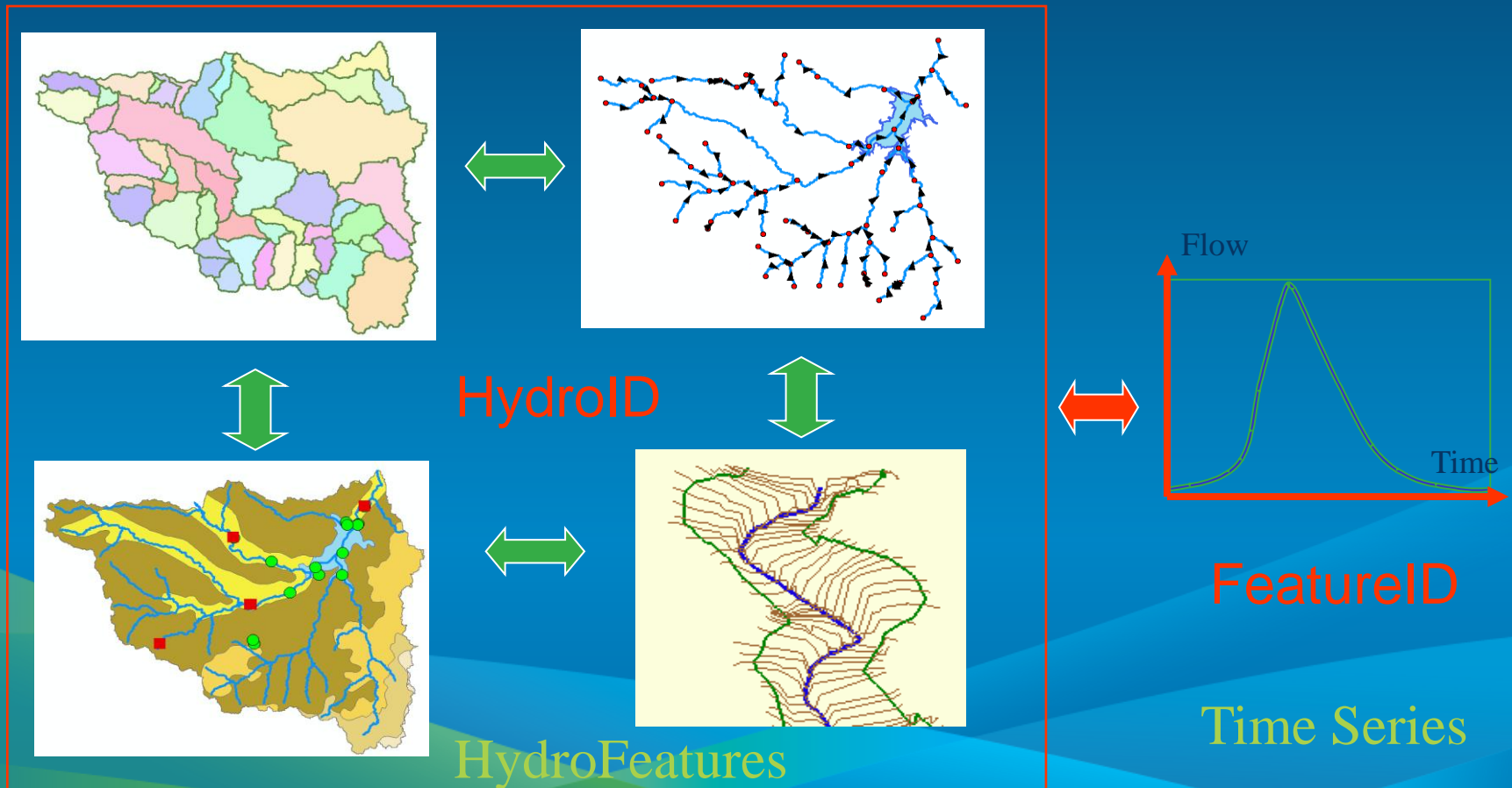


Arc Hydro is a unique “flavor” or style of doing GIS.



# What makes Arc Hydro different?

Arc Hydro connects space and time:  
HydroFeatures are linked to time series.



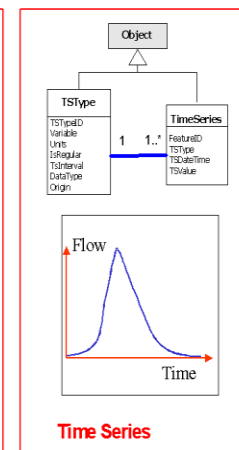
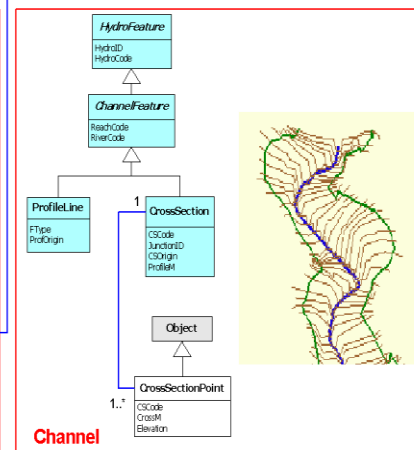
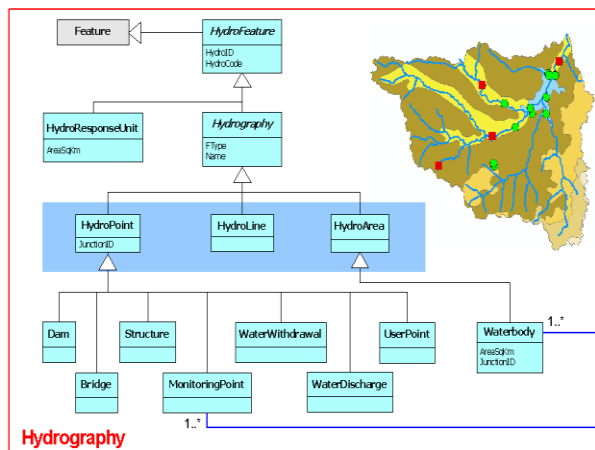
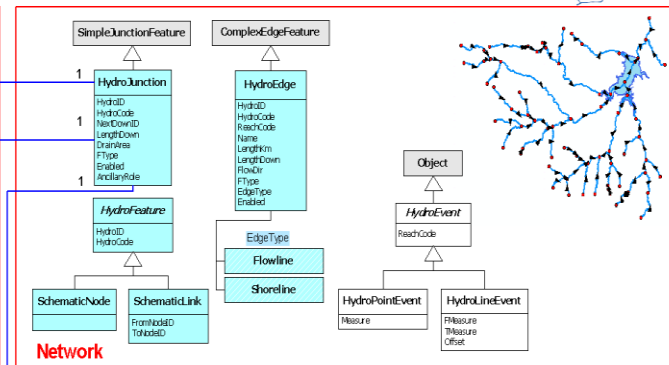
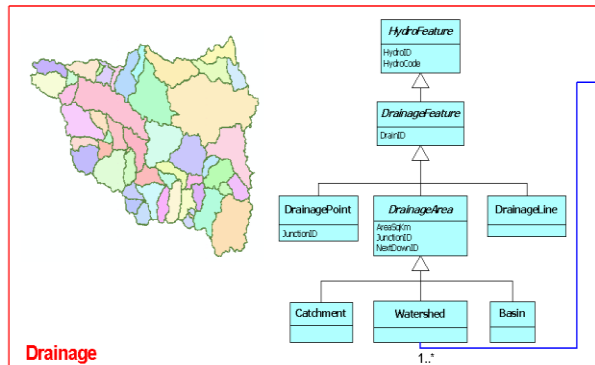
# Arc Hydro Data Model

## ArcGIS Hydro Data Model

<http://arconline.esri.com/arconline/datamodels/water.cfm>

<http://www.cwr.utexas.edu/giswr>

GIS in Water Resources  
Consortium



# Arc Hydro Data Model Details

- Detailed representation at the end of corresponding chapters in the book (e.g., p. 51)

Field name	Data type	Allow nulls	Default value	Domain	Precision	Scale	Length
OBJECTID	OID						
Shape	Geometry	Yes					
Enabled	Small Integer	Yes	1	EnabledDomain	0	0	2
HydroID	Integer	Yes			0		
HydroCode	String	Yes					30
ReachCode	String	Yes					30
Name	String	Yes					100
LengthKm	Double	Yes			0	0	
LengthDown	Double	Yes			0	0	
FlowDir	Integer	Yes	1	HydroFlowDirections	0		
FType	String	Yes					30
EdgeType	Integer	Yes	1	HydroEdgeType	0		
Shape_Length	Double	Yes			0	0	

Hydro edges are the network of lines describing map hydrography. There are two types: flowlines, which trace water movement, and shorelines, which form the interface between land and water.

Unique feature identifier in the geodatabase  
Permanent public identifier of the feature  
An identifier for a river or stream segment  
Geographic name  
Length of the edge in kilometers  
Length to nearest downstream sink (usually the basin outlet)  
Defines the direction of flow on the edge  
Descriptor of feature type  
Defines the edge as being either a flowline or a shoreline

**Coded value domain**  
**EnabledDomain**

Description  
Field type: Small Integer  
Split policy: Default Value  
Merge policy: Default Value

Code	Description
0	False
1	True

**Coded value domain**  
**HydroFlowDirections**

Description  
Field type: Integer  
Split policy: Default Value  
Merge policy: Default Value

Code	Description
0	Uninitialized
1	With Digitized
2	Against Digitized
3	Indeterminate

**Coded value domain**  
**HydroEdgeType**

Description  
Field type: Integer  
Split policy: Default Value  
Merge policy: Default Value

Code	Description
1	Flowline
2	Shoreline

**Subtypes of HydroEdge**

Subtype field: EdgeType  
Default subtype: ?

List of defined default values and domains for subtypes in this class

Subtype Code	Subtype Description	Field name	Default value	Domain
1	Flowline	Enabled	1	EnabledDomain
		FlowDir	1	HydroFlowDirections
		EdgeType	1	HydroEdgeType
2	Shoreline	Enabled	1	EnabledDomain
		FlowDir	1	HydroFlowDirections
		EdgeType	2	HydroEdgeType

# THE ARCGIS HYDRO DATA MODEL

## The thematic layers



## The geodatabase structure



## Hydrography features

Hydrography features include:

- Stream network:** Features like *Stream*, *StreamLink*, *StreamOrder*, *StreamValue*, *StreamWeight*, *StreamValue2*, *StreamWeight2*, *StreamValue3*, *StreamWeight3*, *StreamValue4*, *StreamWeight4*, *StreamValue5*, *StreamWeight5*, *StreamValue6*, *StreamWeight6*, *StreamValue7*, *StreamWeight7*, *StreamValue8*, *StreamWeight8*, *StreamValue9*, *StreamWeight9*, *StreamValue10*, *StreamWeight10*.
- Point features:** *StreamPoint*, *StreamPoint2*, *StreamPoint3*, *StreamPoint4*, *StreamPoint5*, *StreamPoint6*, *StreamPoint7*, *StreamPoint8*, *StreamPoint9*, *StreamPoint10*.
- Flow accumulation:** *FlowAccumulation*, *FlowAccumulation2*, *FlowAccumulation3*, *FlowAccumulation4*, *FlowAccumulation5*, *FlowAccumulation6*, *FlowAccumulation7*, *FlowAccumulation8*, *FlowAccumulation9*, *FlowAccumulation10*.

## Drainage features

Drainage features include:

- Flow direction:** *FlowDirection*, *FlowDirection2*, *FlowDirection3*, *FlowDirection4*, *FlowDirection5*, *FlowDirection6*, *FlowDirection7*, *FlowDirection8*, *FlowDirection9*, *FlowDirection10*.
- Flow length:** *FlowLength*, *FlowLength2*, *FlowLength3*, *FlowLength4*, *FlowLength5*, *FlowLength6*, *FlowLength7*, *FlowLength8*, *FlowLength9*, *FlowLength10*.
- Flow accumulation:** *FlowAccumulation*, *FlowAccumulation2*, *FlowAccumulation3*, *FlowAccumulation4*, *FlowAccumulation5*, *FlowAccumulation6*, *FlowAccumulation7*, *FlowAccumulation8*, *FlowAccumulation9*, *FlowAccumulation10*.

## Network features

Network features include:

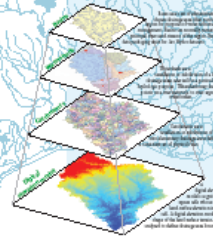
- Flow accumulation:** *FlowAccumulation*, *FlowAccumulation2*, *FlowAccumulation3*, *FlowAccumulation4*, *FlowAccumulation5*, *FlowAccumulation6*, *FlowAccumulation7*, *FlowAccumulation8*, *FlowAccumulation9*, *FlowAccumulation10*.
- Flow length:** *FlowLength*, *FlowLength2*, *FlowLength3*, *FlowLength4*, *FlowLength5*, *FlowLength6*, *FlowLength7*, *FlowLength8*, *FlowLength9*, *FlowLength10*.
- Flow direction:** *FlowDirection*, *FlowDirection2*, *FlowDirection3*, *FlowDirection4*, *FlowDirection5*, *FlowDirection6*, *FlowDirection7*, *FlowDirection8*, *FlowDirection9*, *FlowDirection10*.

## Channel features

Channel features include:

- Channel network:** *Channel*, *ChannelLink*, *ChannelOrder*, *ChannelValue*, *ChannelWeight*, *ChannelValue2*, *ChannelWeight2*, *ChannelValue3*, *ChannelWeight3*, *ChannelValue4*, *ChannelWeight4*, *ChannelValue5*, *ChannelWeight5*, *ChannelValue6*, *ChannelWeight6*, *ChannelValue7*, *ChannelWeight7*, *ChannelValue8*, *ChannelWeight8*, *ChannelValue9*, *ChannelWeight9*, *ChannelValue10*, *ChannelWeight10*.
- Channel point:** *ChannelPoint*, *ChannelPoint2*, *ChannelPoint3*, *ChannelPoint4*, *ChannelPoint5*, *ChannelPoint6*, *ChannelPoint7*, *ChannelPoint8*, *ChannelPoint9*, *ChannelPoint10*.

## Scales of representation and data systems

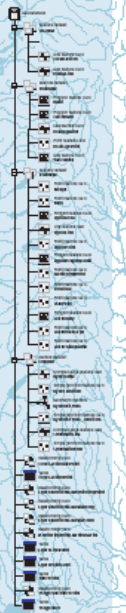


## Time series

Time series features include:

- Flow accumulation:** *FlowAccumulation*, *FlowAccumulation2*, *FlowAccumulation3*, *FlowAccumulation4*, *FlowAccumulation5*, *FlowAccumulation6*, *FlowAccumulation7*, *FlowAccumulation8*, *FlowAccumulation9*, *FlowAccumulation10*.
- Flow length:** *FlowLength*, *FlowLength2*, *FlowLength3*, *FlowLength4*, *FlowLength5*, *FlowLength6*, *FlowLength7*, *FlowLength8*, *FlowLength9*, *FlowLength10*.
- Flow direction:** *FlowDirection*, *FlowDirection2*, *FlowDirection3*, *FlowDirection4*, *FlowDirection5*, *FlowDirection6*, *FlowDirection7*, *FlowDirection8*, *FlowDirection9*, *FlowDirection10*.

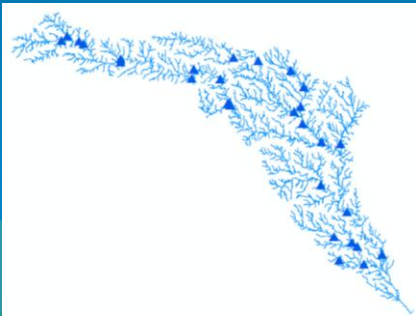
## The Catalog view



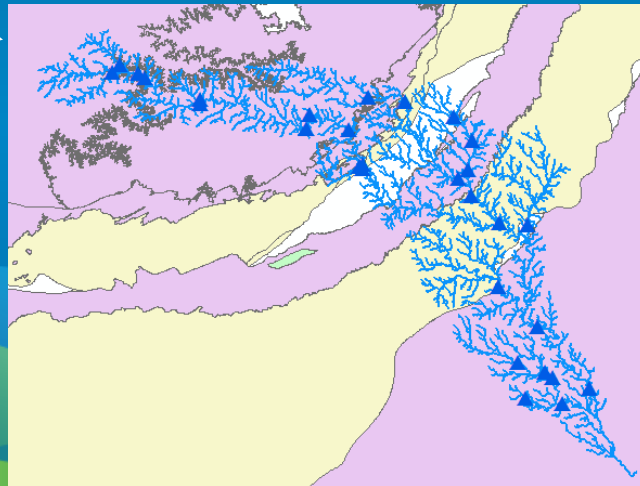
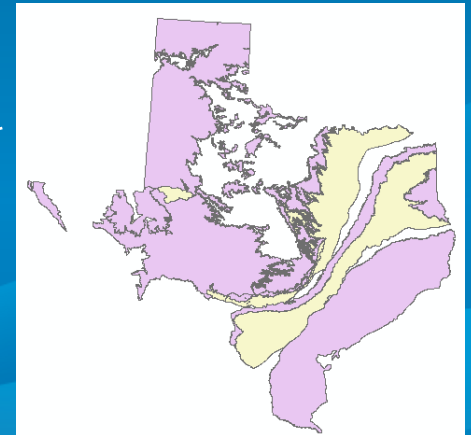
# Integration of Surface Water and Groundwater Data

- Describe the relationship between surface water features (e.g., streams and water bodies) with groundwater features (aquifers, wells).
- Enable the connection with the surface water data model.
- Groundwater data model and tools developed and maintained by AQUAVEO.

Hydro network



Aquifers





# What are Arc Hydro Tools?

- **A set of freely available ArcMap-based tools that are a companion to the Arc Hydro data model**
- **Developed and maintained by ESRI Water Resources Team (not a core product or a sample)**
- **Hundred (150) + tools organized in one main and several supporting toolbars in ArcMap**
  - **Geoprocessing (toolbox) implementation of most of the existing tools. All new tools are developed in gp environment.**

# What do Arc Hydro Tools do?

- **“Exercise” Arc Hydro data model (manage key identifiers—HydroID, JunctionID, Next DownID, etc.)**
- **Provide functionality common to water resources analyses**
  - **Terrain analysis**
  - **Watershed delineation and characterization**
  - **Tracing and accumulation through networks**
  - **Schema (node-link) development**
  - **Specialized data I/O (XML, Excel, etc.)**
  - **Customizable**

# “Why Should I Care” about Arc Hydro Tools?

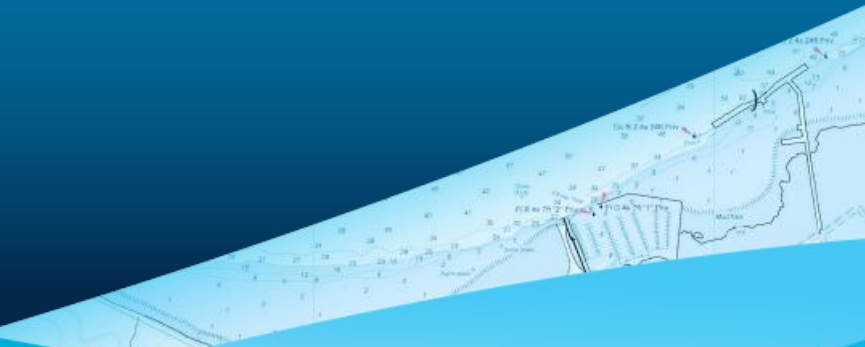
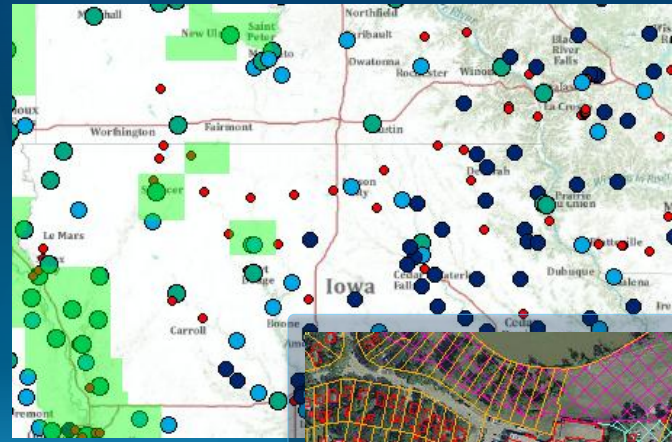
- **Economy of development**
  - Why reinvent the wheel?
  - Established configuration methodology
  - Established development framework
- **Industry “standard”**
  - Established techniques rolled into a publicly available utility
- **Training and support**
- **Free maintenance – ESRI’s commitment to the water resources community**
  - Bug fixes
  - Performance optimization
  - Release updates



# Arc Hydro Tools Documentation

- **Online help**
- **Tutorial**
- **Various how-to documents**
- **Instructor-led training**

# Arc Hydro Demo



# Hydrologic and Hydraulic Modeling Support with GIS



# How “Things” Build Up

- Database design
  - Data preparation
  - Terrain preparation
  - “Watershed” delineation
  - “Watershed” characterization
- 

**Generic**

- Parameterization
- 

**Semigeneric**

- Model pre- and postprocessing

**Model Specific**

# Section Overview

- **Stream statistics**
- **Hydrologic modeling (HEC-HMS, GeoHMS)**
- **Hydraulic modeling (HEC-RAS, GeoRAS)**
- **H&H integration considerations**

# Hydrology: Stream Statistics



# Regression Equations

- **Used to estimate streamflow statistics, both high and low flows, for ungaged sites (in uncontrolled flow environment)**
- **Relate streamflow statistics to measured basin characteristics**
- **Developed by all 48 USGS districts on a state-by-state basis through the cooperative program (usually sponsored by DOT)**
- **Often not used because of large efforts needed to determine basin characteristics**
- **Users often measure basin characteristics inaccurately.**

# Example Regression Equation

- Regression equations take the form:

$$Q_{100} = 0.471A^{0.715}E^{0.827}SH^{0.472}$$

- Where

**A** is drainage area, in square miles

**E** is mean basin elevation, in feet

**SH** is a shape factor, dimensionless



# Basin Characteristics Used for Peak Flows

Basin characteristic	# of States using this (including PR)
Drainage area or contributing drainage area (square miles)	51
Main-channel slope (feet per mile)	27
Mean annual precipitation (inches)	19
Surface water storage (Lakes, ponds, swamps)	16
Rainfall amount for a given duration (inches)	14
Elevation of watershed	13
Forest cover (percent)	8
Channel length (miles)	6
Minimum mean January temperature (degrees F)	4
Basin shape ((length) <sup>2</sup> per drainage area)	4
Soils characteristics	3
Mean basin slope (feet per foot or feet per mile)	2
Mean annual snowfall (inches)	2
Area of stratified drift (percent)	1
Runoff coefficient	1
Drainage frequency (number of first order streams per sq. mi.)	1
Mean annual runoff (inches)	1
Normal daily May-March temp (degrees F)	1
Impervious Cover (percent)	1
Annual PET (inches)	1

... and many others

# Role of GIS

- **Speed up the process (instead of hours, minutes).**
- **Provide a common (single) access to the methodology (for users and maintenance).**
- **Systematize methodology and datasets used in the process (repeatability).**
- **Provide better tools for deriving characteristics for regression equation determination.**
- **Provide a map-based user interface.**
- **Web and desktop implementation are based on Arc Hydro.**

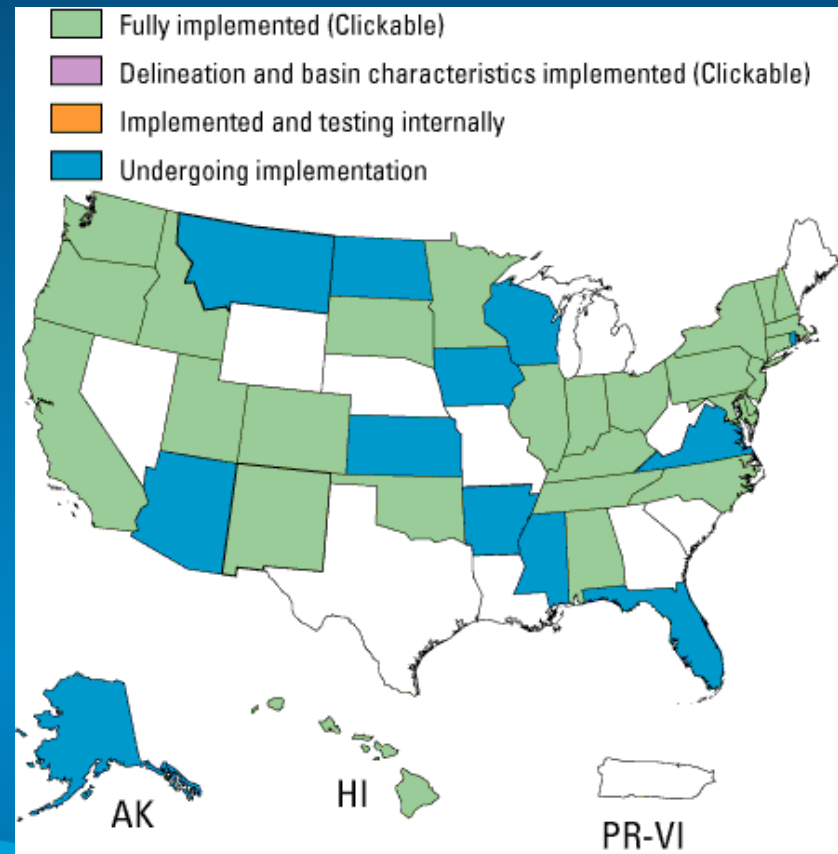
# Arc Hydro Tools Role

- **StreamStats fully implemented within Arc Hydro environment**
  - **Terrain preprocessing**
  - **Local and global watershed delineation**
  - **Extracting local characteristics**
  - **Assembly of global characteristics**
- **Characteristics developed for StreamStats available to wider audience (e.g., hydrologic modeling support)**
- **Desktop and Web implementations**

# StreamStats Implementation Activities

July 2012

- USGS lead effort
- State-based
- ArcGIS Server technology
- Hosted in Denver
- Extended functionality



Source: <http://water.usgs.gov/osw/streamstats/ssonline.html>

# State Site (ID)

USGS StreamStats - Windows Internet Explorer  
http://streamstatsags.cr.usgs.gov/id\_ss/default.aspx?stabbr=id&dt=1342926894210

**USGS**  
*Idaho StreamStats*

Zoom To: 1:5,000,000

Results >>>  
Map Contents >>>  
Navigation >>>  
Overview >>>

USGS some base map material provided by Maptech, Inc. (Copyright © 2008)

Accessibility FOIA Privacy Policies and Notices  
U.S. Department of the Interior | U.S. Geological Survey  
URL: [http://streamstatsags.cr.usgs.gov/id\\_ss/default.aspx](http://streamstatsags.cr.usgs.gov/id_ss/default.aspx)  
Page Contact Information: StreamStats Help  
Page Last Modified: 07/21/2012 20:15:02

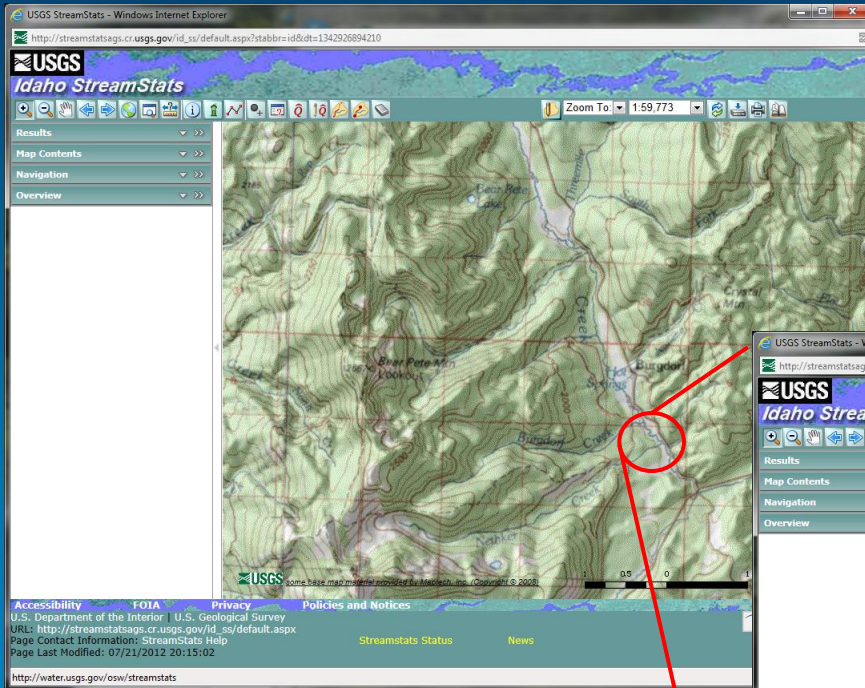
Streamstats Status News

USA.gov  
TAKE PRIDE IN AMERICA

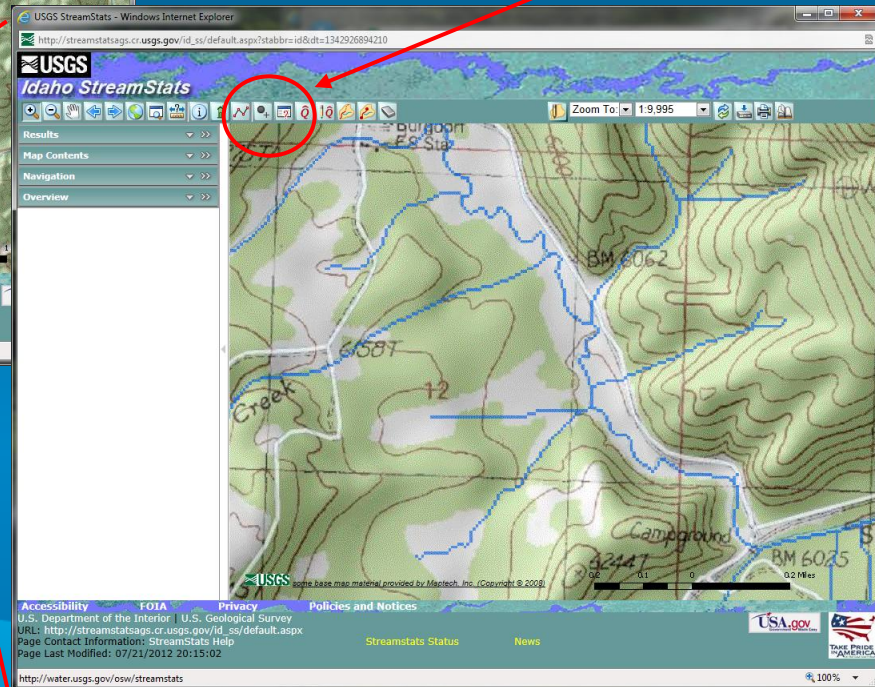
http://water.usgs.gov/osw/streamstats 100%



# Main Site - Navigation



Need to zoom in to see the stream to snap on.





# Watershed Delineation - Web

The screenshot displays the USGS StreamStats web application in a Windows Internet Explorer browser. The browser's address bar shows the URL: [http://streamstatsags.cr.usgs.gov/id\\_ss/default.aspx?stabbr=id&dt=1342926894210](http://streamstatsags.cr.usgs.gov/id_ss/default.aspx?stabbr=id&dt=1342926894210). The application header features the USGS logo and the text "Idaho StreamStats". Below the header is a navigation toolbar with various icons for map interaction, including zoom, pan, and print. A "Zoom To:" dropdown menu is set to 1:137,052. On the left side, there is a vertical menu with expandable sections: "Results", "Map Contents", "Navigation", and "Overview". The main area of the application is a topographic map showing a watershed delineation in pink. The map includes a scale bar at the bottom right, ranging from 0 to 3 miles. At the bottom of the application, there is a footer with links for "Accessibility", "FOIA", "Privacy", and "Policies and Notices". It also includes the text "U.S. Department of the Interior | U.S. Geological Survey", the URL "http://streamstatsags.cr.usgs.gov/id\_ss/default.aspx", "Page Contact Information: StreamStats Help", and "Page Last Modified: 07/21/2012 20:15:02". There are also links for "Streamstats Status" and "News". The footer also contains the "USA.gov" logo and the "TAKE PRIDE IN AMERICA" logo. The browser's status bar at the bottom shows the URL <http://water.usgs.gov/osw/streamstats> and a zoom level of 100%.

# Results - Web

- **Watershed delineation**
  - 20-30 seconds, not much difference with respect to size of the watershed
- **Parameter computations**
  - 10s – 1 minute, depends on the region (what parameters to get) and somewhat on the size

Streamflow Statistics Report - Windows Internet Explorer  
http://streamstatsags.cr.usgs.gov/gisimg/Reports/FlowStatsReport1299737\_201272121

**USGS**  
*Idaho StreamStats*

### Streamstats Ungaged Site Report

Date: Sat Jul 21 2012 21:29:52 Mountain Daylight Time  
Site Location: Idaho  
NAD27 Latitude: 45.2580 (45 15 29)  
NAD27 Longitude: -115.8969 (-115 53 49)  
NAD83 Latitude: 45.2579 (45 15 28)  
NAD83 Longitude: -115.8978 (-115 53 52)  
Drainage Area: 45.95 mi2  
Percent Urban: 0 %  
Percent Impervious: 0.0984 %

#### Peak-Flow Basin Characteristics

100% Peak Flow Region 5 (46 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	46	3.6	12228
Mean Annual Precipitation (inches)	42.6	19.8	49.73
N Facing Slopes gt 30pct from 30m DEM (percent)	10	2.5	32.9

#### Peak-Flow Streamflow Statistics

Statistic	Flow (ft <sup>3</sup> /s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK1_5	918	41		452	1870
PK2	1050	40		477	2300
PK2_33	1060	39		553	2050
PK5	1290	38		678	2450
PK10	1460	39		761	2790
PK25	1640	39		850	3180
PK50	1770	40		902	3470
PK100	1940	41		975	3880
PK200	2060	42		1020	4180
PK500	2210	44		1060	4610



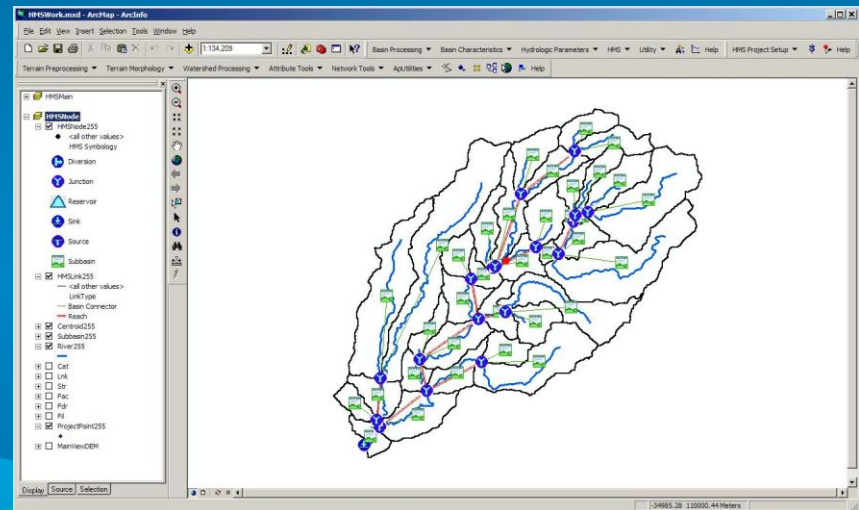
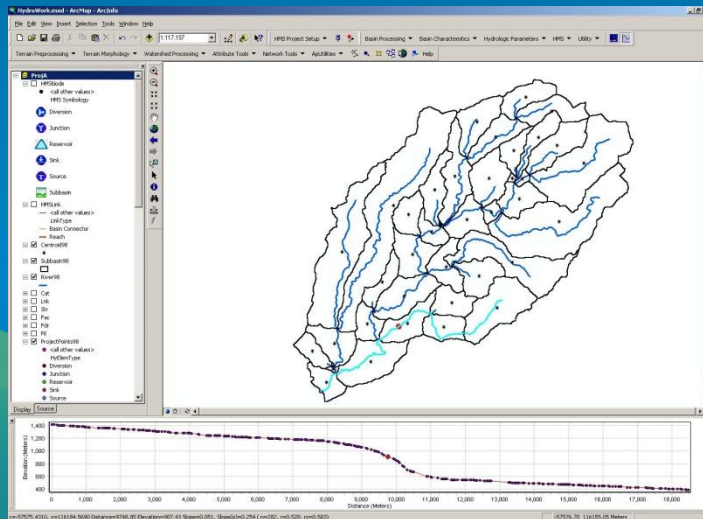
# H&H Integration Overview

## (HMS-RAS Focus)



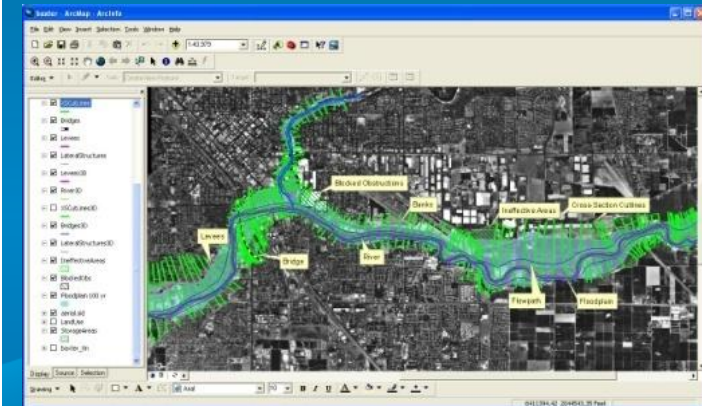
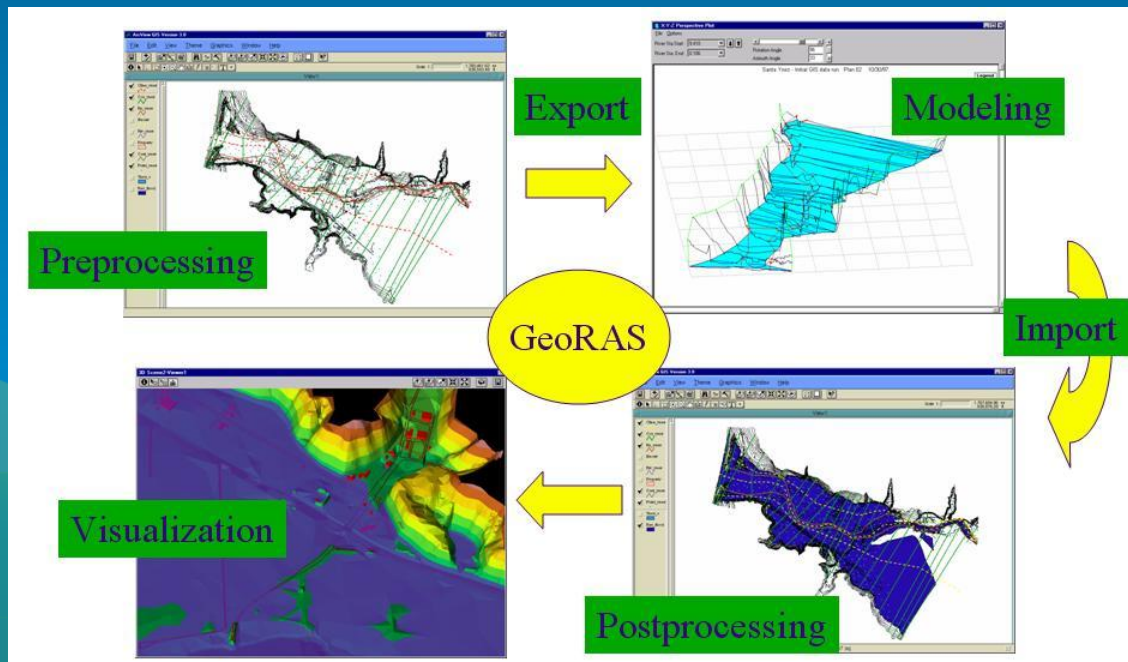
# HEC-GeoHMS

- **HEC-HMS: Hydrologic Engineering Center Hydrologic Modeling System:** allows modeling of precipitation – runoff processes.
- **HEC-GeoHMS:**
  - ArcGIS preprocessor for HMS
  - Transforms the drainage paths and watershed boundaries based on DEM into a hydrologic data structure that can be used to model the watershed response to precipitation



# HEC-GeoRAS

- HEC-RAS: Hydrologic Engineering Center River Analysis System: allows performing one-dimensional open channel steady and unsteady flow calculations.
- HEC-GeoRAS:
  - Prepare geometric data for import into HEC-RAS
  - Processes simulation results exported from HEC-RAS



# Integration Approach

- **Mix of planning, GIS, and H&H modeling operations (not a push-button operation)**
- **Types of integration**
  - **Modeling support (preparing data for model input)**
    - (e.g., land use/soils/CN or rainfall processing – Arc Hydro or general GIS data processing)
  - **Linked**
    - GeoHMS
    - GeoRAS
  - **Integrated**
    - DSS

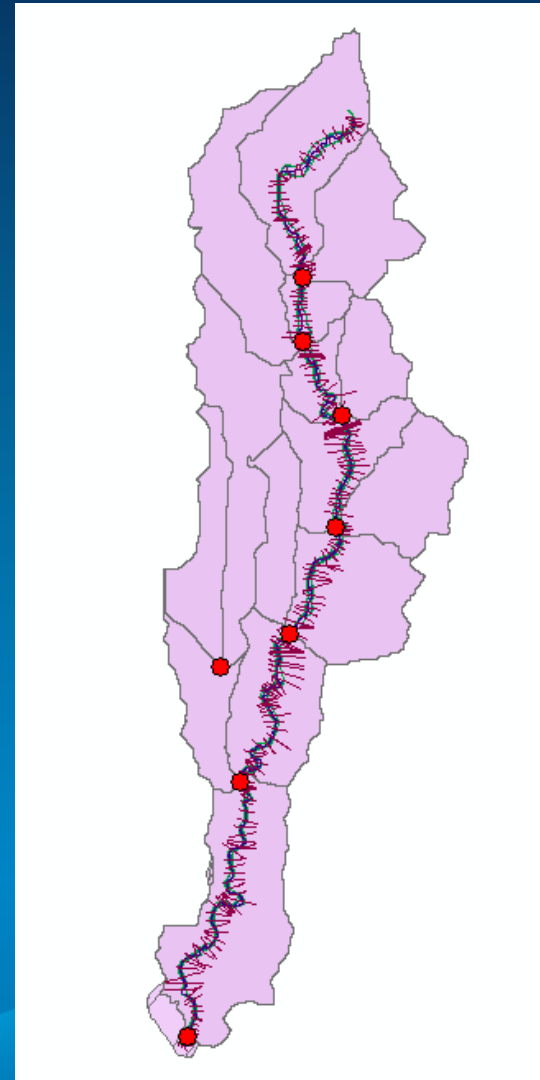
# Integration Approach <sup>(2)</sup>

- **Key steps**

- **Plan (roughly) hydrologic and hydraulic model layouts—flow exchange locations.**
  - **E.g., location of HMS modeling elements and RAS cross sections**
- **Identify sources of precipitation input into the hydrologic model and techniques for their incorporation into the dataset.**
  - **E.g., Nexrad rainfall**
- **Develop the GeoHMS model (and precipitation submodel).**
- **Finalize and run the HMS model and generate results (DSS).**
- **Develop the GeoRAS model.**
- **Finalize and run RAS, taking HMS results as input.**
- **Feedback between HMS and RAS is manual.**
  - **E.g., modification of time of concentration or routing parameters**

# Integration Planning

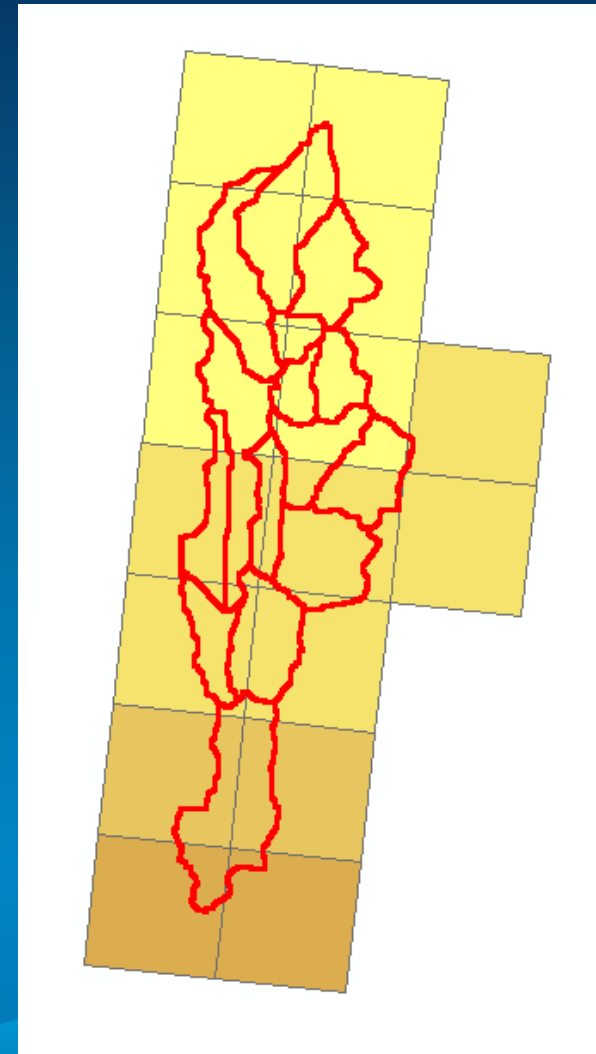
- Identify where outputs from one model (HMS) become input to the second one (RAS).
  - Place hydrologic elements (subbasins, reaches, junctions) to capture flows at points of interest (confluences, structures).
  - Place hydraulic elements (cross sections) at points of interest.
  - Identify/Specify element-naming conventions between the two models (persistent or transient names).





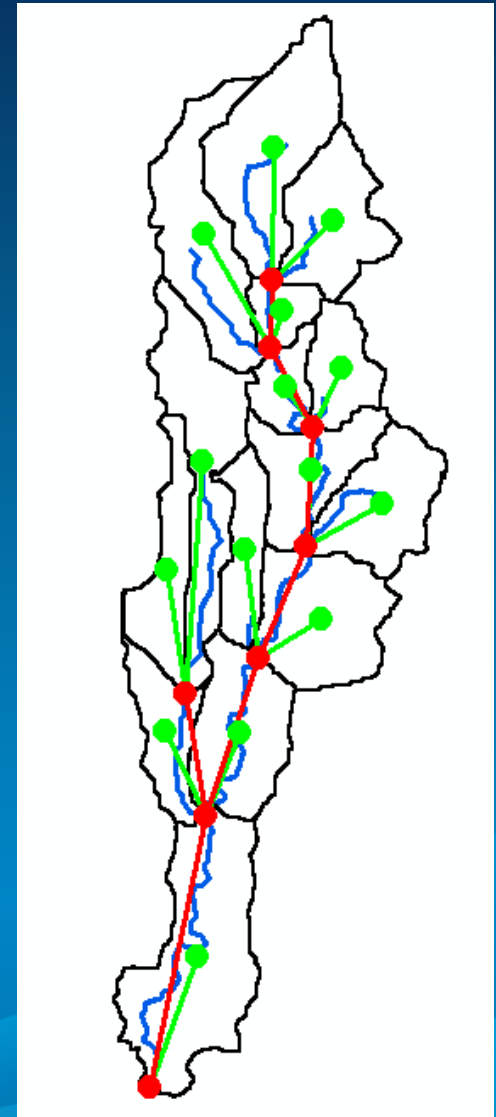
# Precipitation Sources

- Identify sources of precipitation input into the hydrologic model and techniques for their incorporation into the dataset.
  - Point (rain gauge)
  - Polygon (Nexrad cells)
  - Surface (TIN/GRID)



# Develop GeoHMS Model

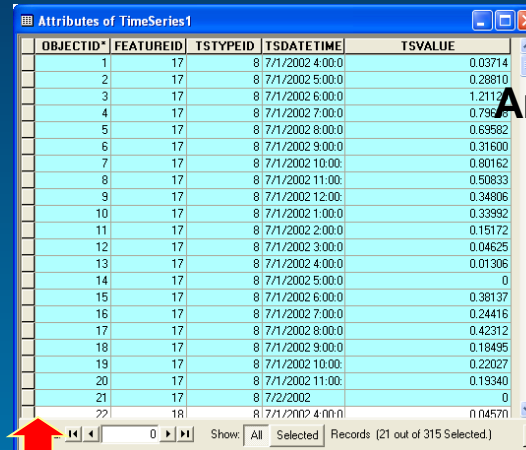
- Follow all principles in development of a hydrologic model.
- In addition, take into consideration integration planning aspects developed earlier.
  - Placement of flow exchange points
  - Naming conventions
- Incorporate precipitation submodel.
  - Develop Arc Hydro time series for the final subbasin delineation and export to DSS.
- Export to HMS.





# Meteorological Component

- Develop a custom “gauge” for each subbasin or for each rainfall observation element with corresponding weights for subbasins.

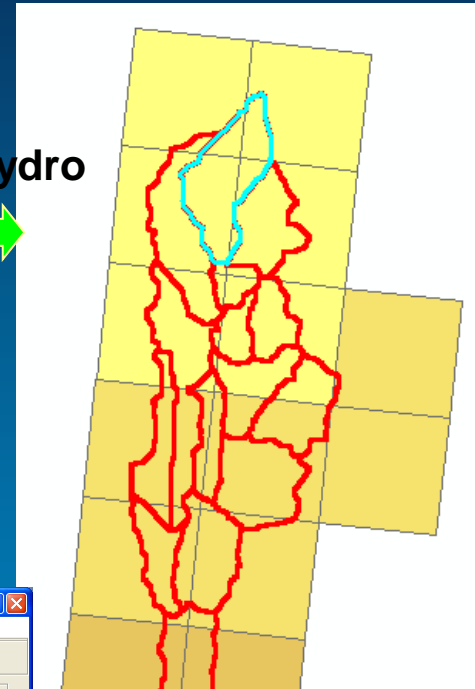


OBJECTID*	FEATUREID	TSTYPEID	TSDATETIME	TSVALUE
1	17	8	7/1/2002 4:00:0	0.03714
2	17	8	7/1/2002 5:00:0	0.28810
3	17	8	7/1/2002 6:00:0	1.21177
4	17	8	7/1/2002 7:00:0	0.79669
5	17	8	7/1/2002 8:00:0	0.69582
6	17	8	7/1/2002 9:00:0	0.31500
7	17	8	7/1/2002 10:00:0	0.80162
8	17	8	7/1/2002 11:00:0	0.50833
9	17	8	7/1/2002 12:00:0	0.34806
10	17	8	7/1/2002 1:00:0	0.33992
11	17	8	7/1/2002 2:00:0	0.15172
12	17	8	7/1/2002 3:00:0	0.04625
13	17	8	7/1/2002 4:00:0	0.01306
14	17	8	7/1/2002 5:00:0	0
15	17	8	7/1/2002 6:00:0	0.38137
16	17	8	7/1/2002 7:00:0	0.24416
17	17	8	7/1/2002 8:00:0	0.42312
18	17	8	7/1/2002 9:00:0	0.18495
19	17	8	7/1/2002 10:00:0	0.22027
20	17	8	7/1/2002 11:00:0	0.19340
21	17	8	7/2/2002	0
22	18	8	7/1/2002 4:00:0	0.04570

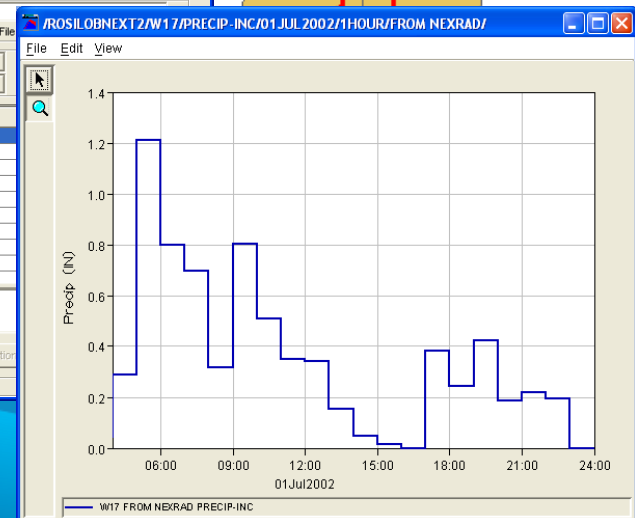
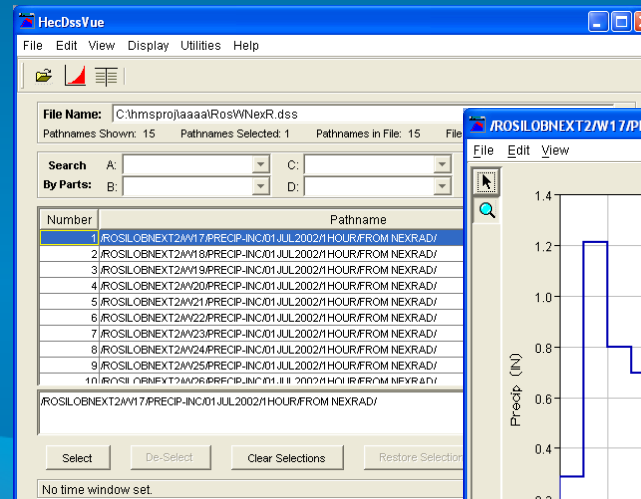
Arc Hydro



Arc Hydro to DSS transfer



- Export the time series for the subbasin “gauge” from Arc Hydro time series data structure into DSS.



DSS



# Finalize and Run HMS

- Complete HMS model with any additional parameters including meteorological model and control specifications.
- Follow all principles in HMS model development (calibration, etc.).

The screenshot displays the Basin Model software interface for project p012308\_1. The main window shows a watershed map with various subbasins and gauges labeled (e.g., W170, W180, W190, W200, W210, W230, W260, W280, J66, J61, J56, J49, J44, J39). Overlaid on the map are several configuration windows:

- Basin Model [p012308\_1]**: The main map window showing the watershed layout.
- Basin Models Tree**: A tree view showing the project structure, including Basin Models, Meteorologic Models, Control Specifications, and Time-Series Data.
- Subbasin List**: A table listing subbasins and their corresponding gauges.

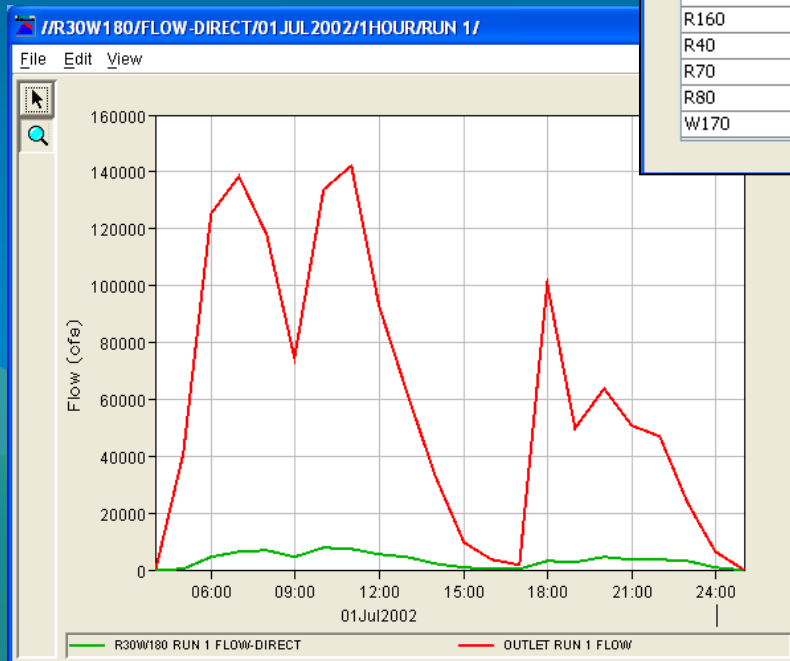
Subbasin Name	Gauge
W170	W170
W180	W180
W190	W190
W200	W200
- Subbasin Properties (W170)**: Configuration for subbasin W170, including Basin Name (p012308\_1), Element Name (W170), Initial Abstraction (IN) (0), Curve Number (74.276), and Impervious (%) (0.0).
- Control Specifications (Rosillo Standard)**: Configuration for the Rosillo Standard control specification, including Description (Standard Rosillo Design Run), Start Date (01Jan2000), Start Time (00:00), End Date (02Jan2000), End Time (00:00), and Time Interval (10 Minutes).
- Subbasin Properties (W170 - Loss Transform)**: Configuration for the Loss Transform method, including Basin Name (p012308\_1), Element Name (W170), and Lag Time (MIN) (177.89).
- Subbasin Properties (W170 - Options)**: Configuration for the Options method, including Basin Name (p012308\_1), Element Name (W170), Description, Downstream (J66), Area (MI2) (3.1678), Loss Method (SCS Curve Number), Transform Method (SCS Unit Hydrograph), and Baseflow Method (--None--).

# Finalize and Run HMS (2)

- Do the final run and generate results (DSS).

HMS View

DSS View



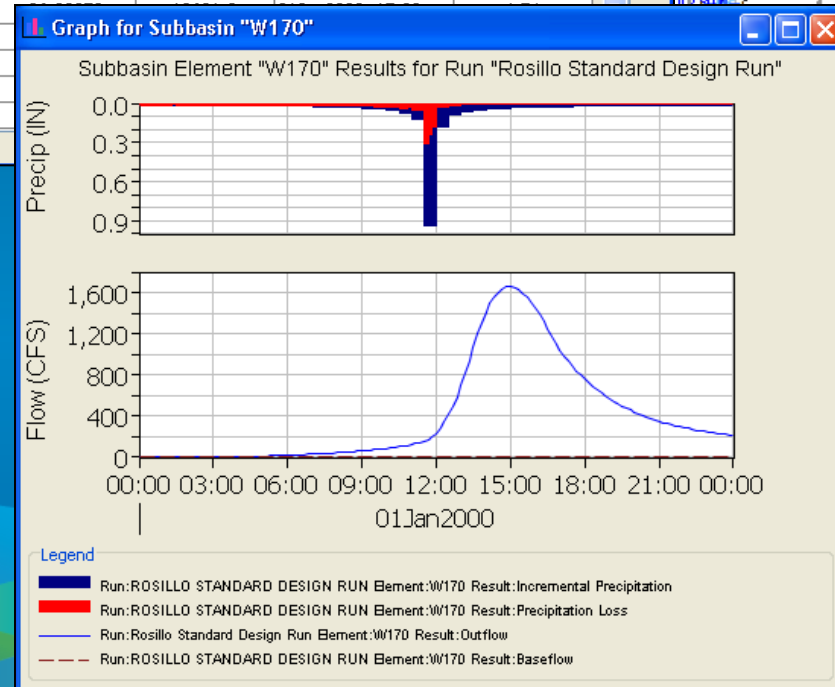
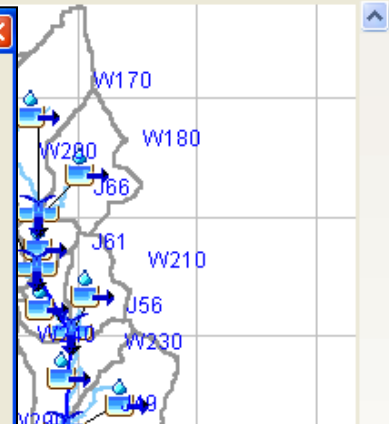
Global Summary Results for Run "Rosillo Standard Design Run"

Project: p012308\_1    Simulation Run: Rosillo Standard Design Run

Start of Run: 01Jan2000, 00:00    Basin Model: p012308\_1  
 End of Run: 02Jan2000, 00:00    Meteorologic Model: p012308\_1  
 Compute Time: 23Jan2008, 22:06:40    Control Specifications: Rosillo Standard

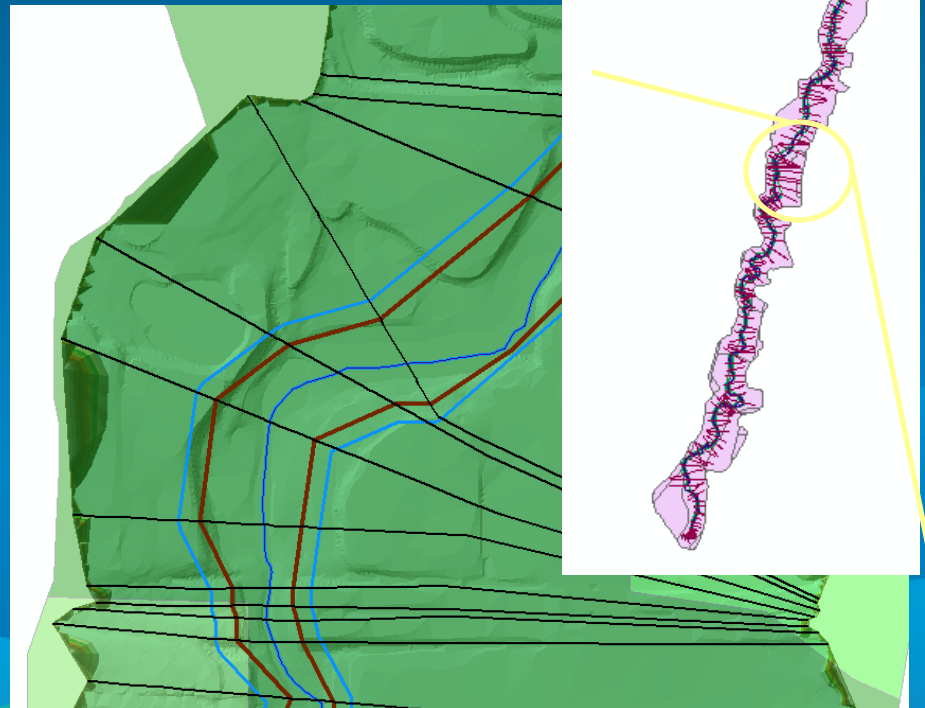
Volume Units:  IN     AC-FT

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
R110	14.39850	8861.1	01Jan2000, 14:00	5.15
R140	4.53340	802.9	01Jan2000, 23:00	1.89
R150	18.20900	11576.7	01Jan2000, 14:20	5.27
R160				
R40				
R70				
R80				
W170				



# Develop GeoRAS Model (preprocessing)

- Follow all principles in development of a hydraulic model for element placement (confluences, structures, ...)
- In addition, take into consideration integration planning aspects developed earlier
  - Naming conventions (add name of the HMS element to the cross-section that will get the element's flows)
- Export to RAS



# Finalize and Run RAS

- Complete RAS model with any additional parameters including initial and boundary conditions.
- Follow all principles in RAS model development (calibration, etc.).

The screenshot displays the HEC-RAS software interface. The main window shows a river reach map with various data points. Two dialog boxes are open:

**Steady Flow Data - NormalDepth Run 1**

Enter/Edit Number of Profiles (2000 max): 1    Reach Boundary Conditions    Apply Data

Locations of Flow Data Changes

River: Rosillo    Reach: Upper    River Sta.: 96270.05    Add A Flow Change Location

Flow Change Location			Profile Names and Flow Rates	
River	Reach	RS	Peak Flows	
1	Rosillo	96270.0E	19443.55	
2	Rosillo	79446.8E	19443.55	
3	Rosillo	74689.1E	32777.76	
4	Rosillo	64156.1E	41599.27	
5	Rosillo	55586.7E	59869.55	
6	Rosillo	44931.4	80382.88	
7	Rosillo	28705.8E	121592.4	
8	Rosillo	3.67378E	142012	

**DSS Set Locations for DSS Connections**

River: Rosillo    Delete row from table

Reach: Upper    River Sta.: 96270.05    Add selected location to table

	River	Reach	RS	DSS File	Part A
1	Rosillo	Upper	79446.88	C:\hmsproj\aaaa\	
2	Rosillo	Upper	74689.13	C:\hmsproj\aaaa\	
3	Rosillo	Upper	64156.13	C:\hmsproj\aaaa\	
4	Rosillo	Upper	55586.71	C:\hmsproj\aaaa\	
5	Rosillo	Upper	44931.4	C:\hmsproj\aaaa\	

DSS File: C:\hmsproj\aaaa\aaaa.dss    Update Catalog

Filter	Part A	Part B	Part C	Part D	Part E	Part F
1		J36	FLOW	01JUL2002	1HOUR	RUN 1
2		J39	FLOW	01JUL2002	1HOUR	RUN 1
3		J44	FLOW	01JUL2002	1HOUR	RUN 1
4		J49	FLOW	01JUL2002	1HOUR	RUN 1
5		J56	FLOW	01JUL2002	1HOUR	RUN 1
6		J61	FLOW	01JUL2002	1HOUR	RUN 1
7		J66	FLOW	01JUL2002	1HOUR	RUN 1
8		OUTLET	FLOW	01JUL2002	1HOUR	RUN 1

Select DSS Pathname    << Previous    Next >>

Plot Selected Pathname    OK    Cancel

The background map shows a river reach with various data points and a graph titled 'NexradRun Plan: Run 1 with normal depth 3/3/2005'. The graph plots flow rate against station number (0 to 1200). The legend indicates: EG Peak Flows (black line), VWS Peak Flows (red line), Crft Peak Flows (green line), Ground (blue line), and Bank Sta (red dots).

# Finalize and Run RAS (2)

- Do the final run and generate results (export to .sdf file).

**Cross Section Output**

File Type Options Help

River: Rosillo Profile: Peak Flows

Reach: Upper RS: 96270.05 Plan: plan1

Plan: plan1 Rosillo Upper RS: 96270.05 Profile: Peak Flows		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	769.97	Wt. n-Val.	0.035	0.040	0.040
Vel Head (ft)	4.78	Reach Len. (ft)	294.20	272.74	243.54
W.S. Elev (ft)	765.19	Flow Area (sq ft)	48.55	737.52	332.43
Crit W.S. (ft)	765.19	Area (sq ft)	48.55	737.52	332.43
E.G. Slope (ft/ft)	0.025348	Flow (cfs)	610.05	13466.30	5367.19
Q Total (cfs)	19443.55	Top Width (ft)	9.66	66.60	38.73
Top Width (ft)	114.99	Avg. Vel. (ft/s)	12.57	18.26	16.15
Vel Total (ft/s)	17.38	Hydr. Depth (ft)	5.02	11.07	8.58
Max Chl Dpth (ft)	15.19	Conv. Total (cfs)	3831.7	84581.0	33711.0
Conv. Total (cfs)	122123.6	Wetted Per. (ft)	29.25	135.97	93.77
Length Wtd. (ft)	264.90	Shear (lb/sq ft)	2.63	8.58	5.61
Min Ch El (ft)	750.00	Stream Power (lb/ft s)	33.01	156.73	90.58
Alpha	1.02	Cum Volume (acre-ft)	12436.43	8097.76	8851.39
Frictn Loss (ft)	3.06	Cum SA (acres)	1054.24	576.89	753.63
C & E Loss (ft)	0.97				

**Errors, Warnings and Notes**

**Warning:** The energy equation could not be balanced within the specified number of iterations. The program used critical depth for the water surface and continued on with the calculations.

**Warning:** Divided flow computed for this cross-section.

**Warning:** The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.

**Warning:** The conveyance ratio (upstream conveyance divided by downstream conveyance) is less than

Select Profile

**Profile Plot**

File Options Help

Reaches ... Profiles ...

Nextrad

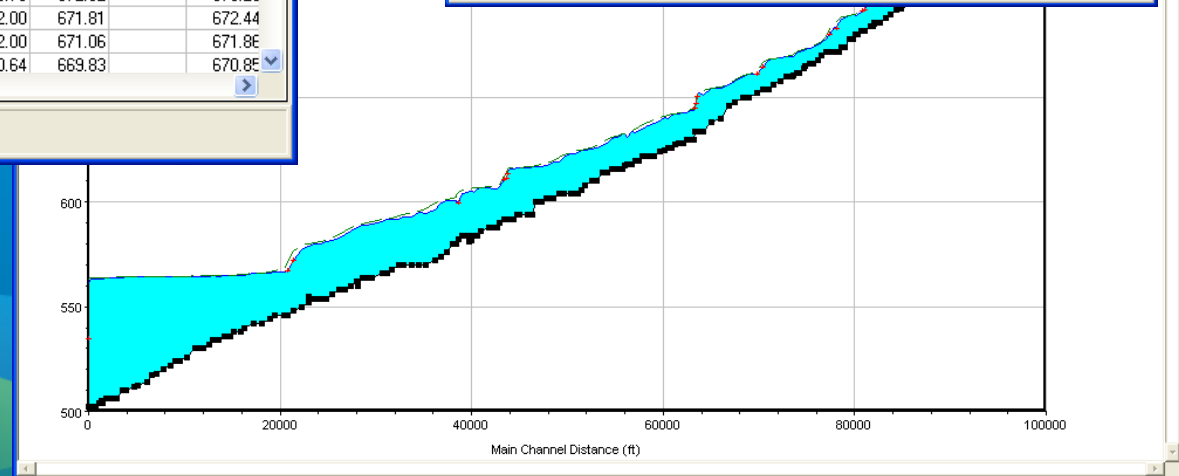
**Profile Output Table - Standard Table 1**

File Options Std. Tables Locations Help

HEC-RAS Plan: plan1 River: Rosillo Reach: Upper Profile: Peak Flows Reload Data

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)
Upper	75626.59	Peak Flows	19443.55	666.00	674.09	674.4E	
Upper	75251.3	Peak Flows	19443.55	666.00	673.66	673.9E	
Upper	74771.74	Peak Flows	19443.55	665.15	672.89	673.3E	
Upper	74689.13 J61	Peak Flows	32777.76	663.75	672.62	673.2E	
Upper	74204.02	Peak Flows	32777.76	662.00	671.81	672.44	
Upper	73943.38	Peak Flows	32777.76	662.00	671.06	671.8E	
Upper	73599.31	Peak Flows	32777.76	660.64	669.83	670.8E	

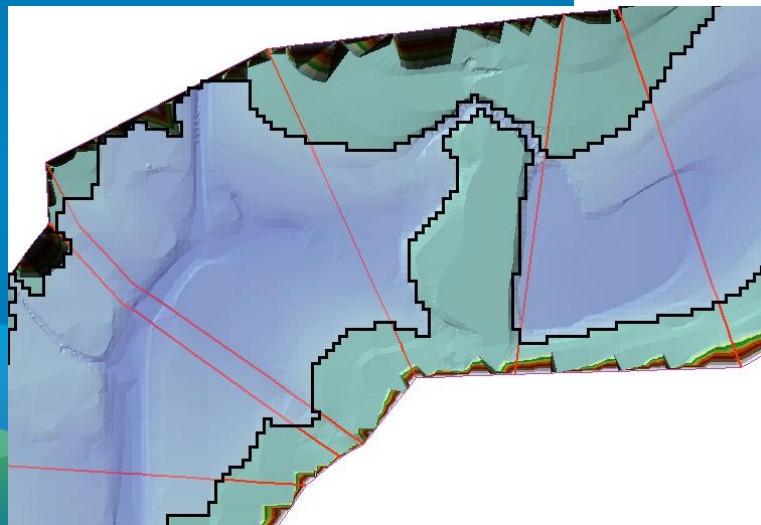
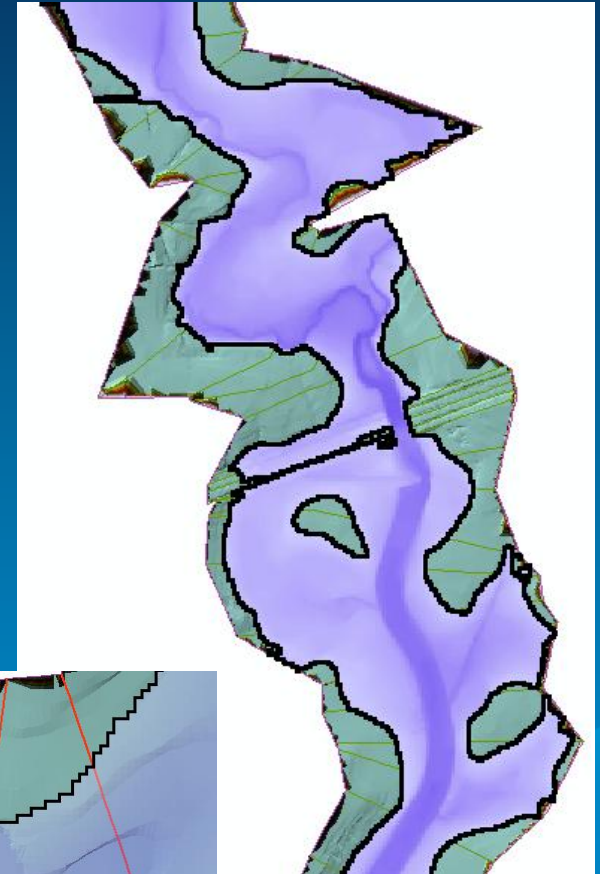
Total flow in cross section.





# Process RAS Results in GeoRAS

- Construct the floodplain based on the results in the .sdf.
- Review the results with respect to spatial integrity (extents of cross sections, ineffective flow areas, disconnected flood areas, etc.).
- Clean results.
- Revisit RAS.

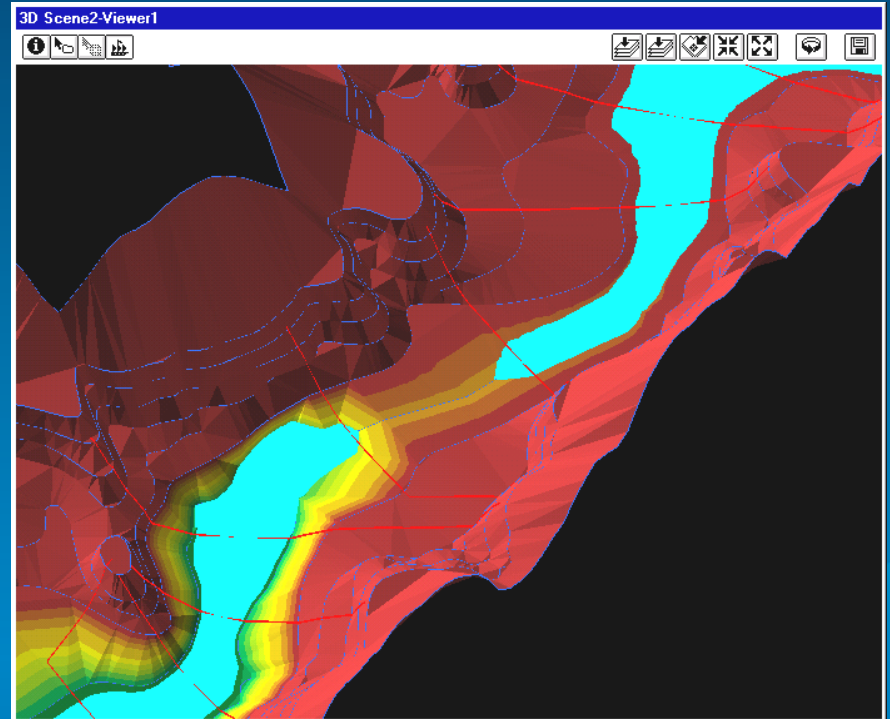
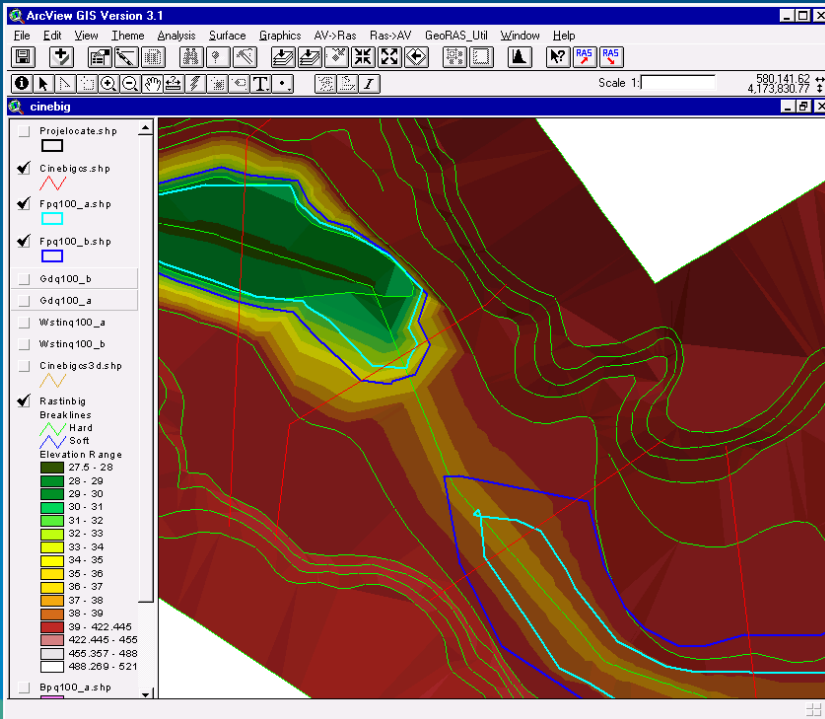


# GIS–HMS–RAS Feedback

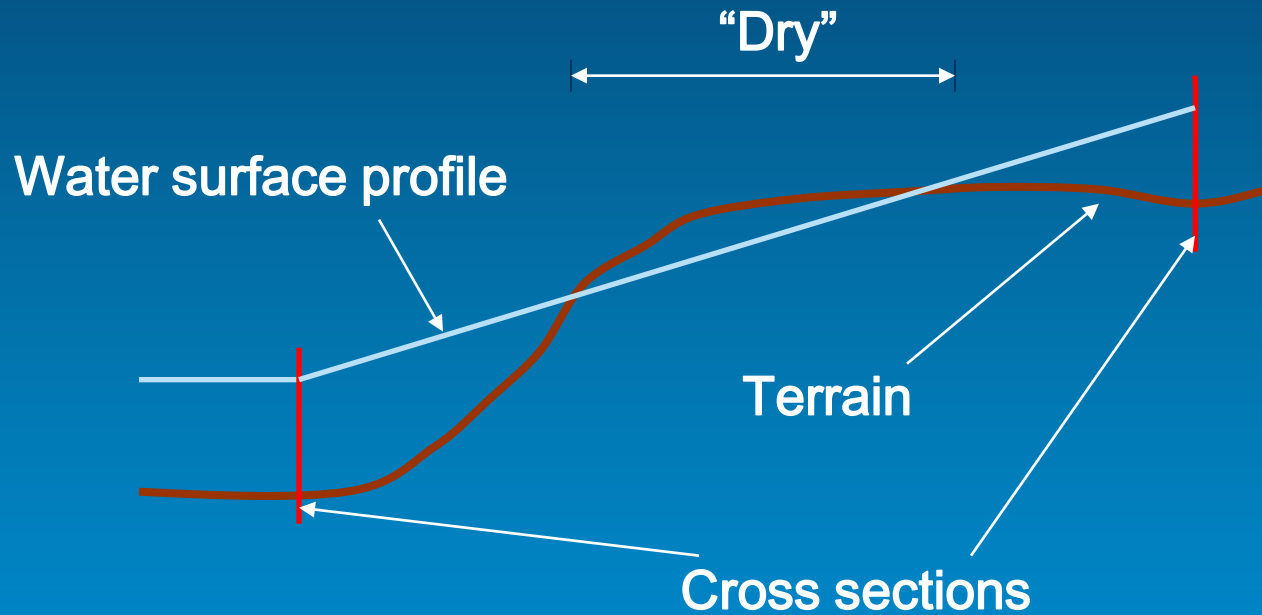
- **At present, it is manual and at the discretion of the modeler.**
  - **GIS–H&H interaction**
  - **H–H interaction**
- **Visualization in both pre- and postprocessing is not just a “pretty picture.”**
  - **Flyover in preprocessing (GeoHMS and GeoRAS)**
    - **Identification of data problems**
    - **Modeling element placement**
  - **Postprocessing (GeoRAS)**
    - **Validity of element placement**



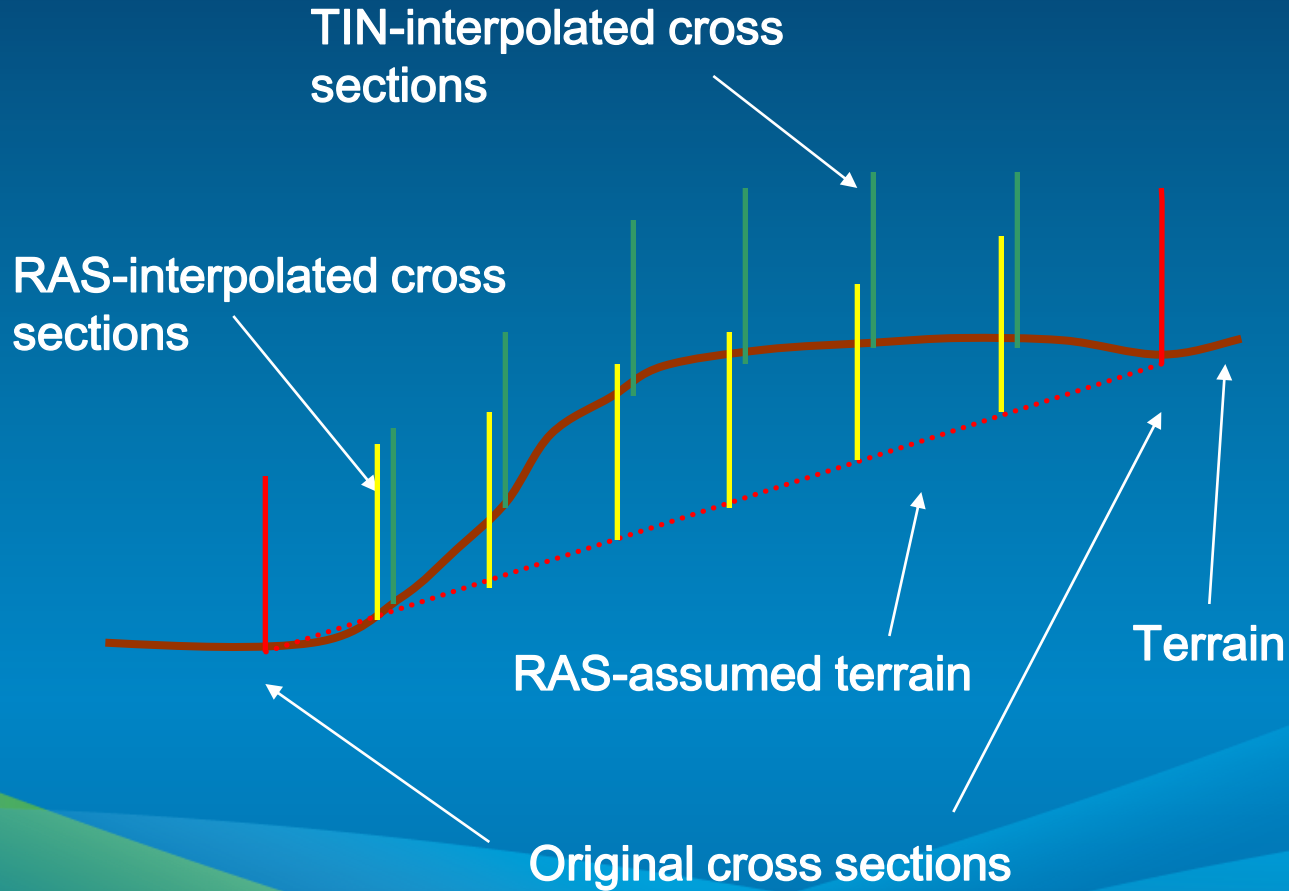
# Floodplain Discontinuity



# Floodplain Discontinuity (cont.)



# Cross-Section Interpolation



# Summary

**GIS provides many capabilities for support of H&H**

- **Integrated, multi-purpose database for storage of H&H and related data.**
- **Consistent methodology for spatial data processing and analytical functionality, such as terrain processing, watershed delineation and characterization.**
- **Pre- and post-processing for H&H models significantly reduces time for data preparation for modeling support.**
- **Environment for integrated solution management:**
  - **Emergency management**
  - **Design**
  - **Decision support**



- Thank you for attending
- Have fun at UC2012
- Open for Questions
  
- Please fill out the evaluation:

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