

Arc Hydro in Action Webinar Series

2/25/21: Arc Hydro in ArcGIS Pro

3/11/21: Arc Hydro: Flooding & Forecasting

3/25/21: Arc Hydro: Hydrology & Hillslope

4/15/21: **Arc Hydro: Support for Hydrologic and Hydraulic Modeling**



▶ Audience view 100%
 ▶ Sharing
 ▶ Webcam
 ▶ Audio
 ▶ Dashboard
 ▶ Attendees: 1 of 1001 (max)
 ▶ Questions
 Show Answered Questions

X	Question	Asker

Send Privately Send to All

▶ Handouts: 0 of 5
 Drag & drop a file Choose a file

Chat

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Arc Hydro in ArcGIS Pro
 Webinar ID: 118-253-939

▼ Questions
 Show Answered Questions

X	Question	Asker	Rec'd	A...

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QR Code

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Welcome to the webinar!

To: All - Entire Audience Send

Announcements

Watch first three webinars at your convenience

- Arc Hydro in ArcGIS Pro
- Arc Hydro: Flooding & Forecasting
- Arc Hydro: Hydrology & Hillslope



- [Applied Meteorology Using ArcGIS \(webinar series\)](#)



Polling Questions

Did you attend or watch any of the first three webinars?

- Yes, Arc Hydro in ArcGIS Pro
- Yes, Arc Hydro: Flooding and Forecasting
- Yes, Arc Hydro: Hydrology & Hillslope
- No



Presenters:



Pete Singhofen, PE

President

**Streamline
Technologies**



Warren McKinnie

Senior Water Resources
Engineer

**Streamline
Technologies**



Dean Djokic, PhD

Water Resources
Practice Manager

Esri





Arc Hydro: Support for Hydrologic and Hydraulic Modeling

2021 "Arc Hydro in Action" Webinar Series



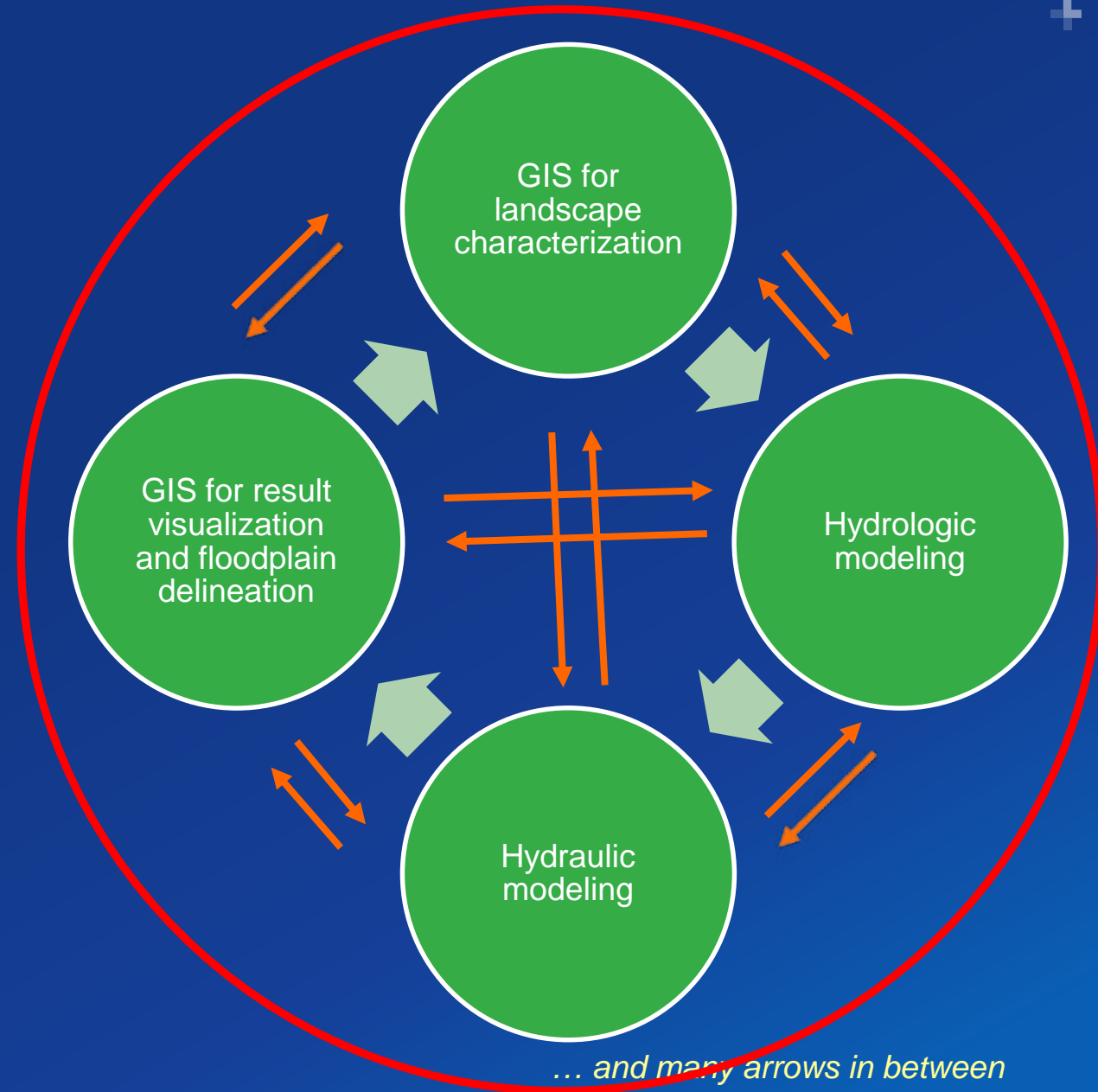
Webinar 4 Topics

- **Review of the series.**
 - Arc Hydro Groundwater
- **Fundamentals of model integration**
- **H&H modeling through use cases**
- **Final thoughts**
- **Questions**



GIS for Hydro Modeling “Cycle”

- **GIS** is used for landscape characterization and model parametrization.
- **Hydrology and Hydraulics (H&H)** is used for determination of flows, depths and velocities.
- **GIS** is used for result postprocessing and visualization.
- **GIS and H&H modeling** are closely connected as one impacts the other



Model Integration Use Cases

- **Tight coupling**
 - StreamStats (tight, but not so tight)
 - PEI Culvert Calculator
- **Groundwater – MODFLOW**
- **Lose coupling**
 - HEC-GeoHMS, HEC-GeoRAS
 - ICPR4

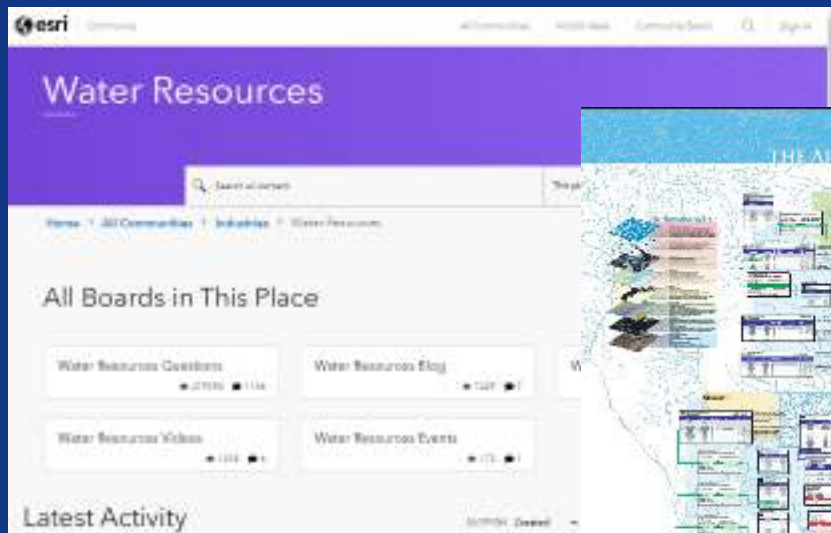


Review of Series

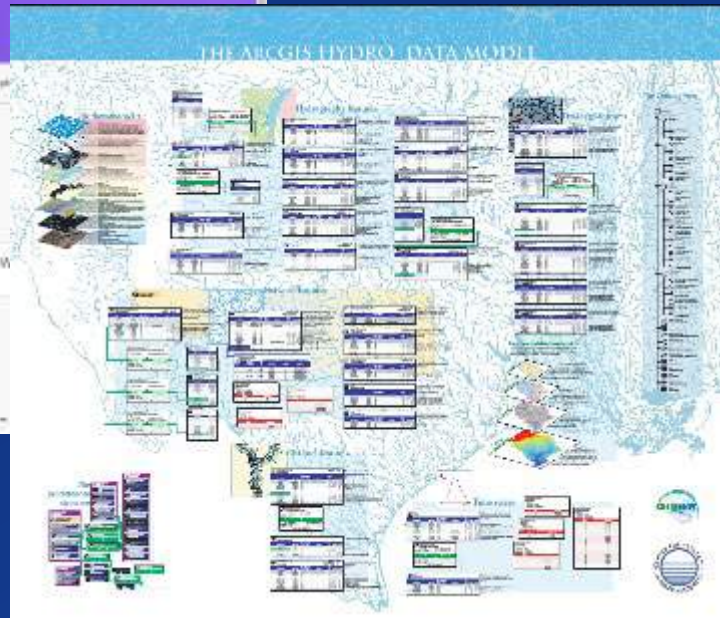


Arc Hydro: Vision

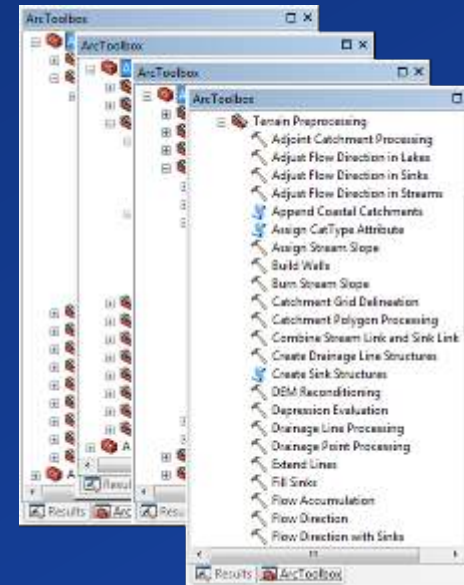
“Provide practical GIS framework for development of **integrated analytical systems** for water resources market.”



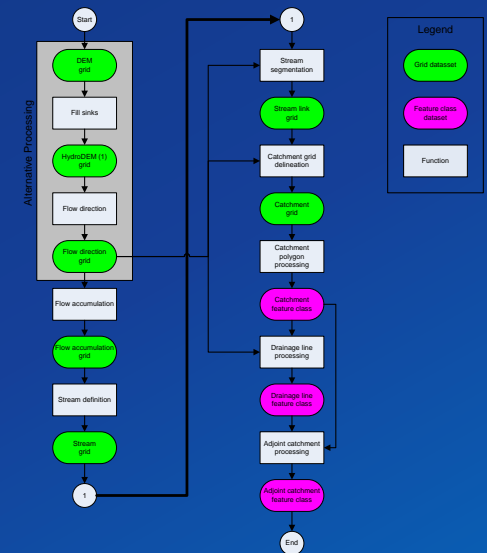
Community



Data Model



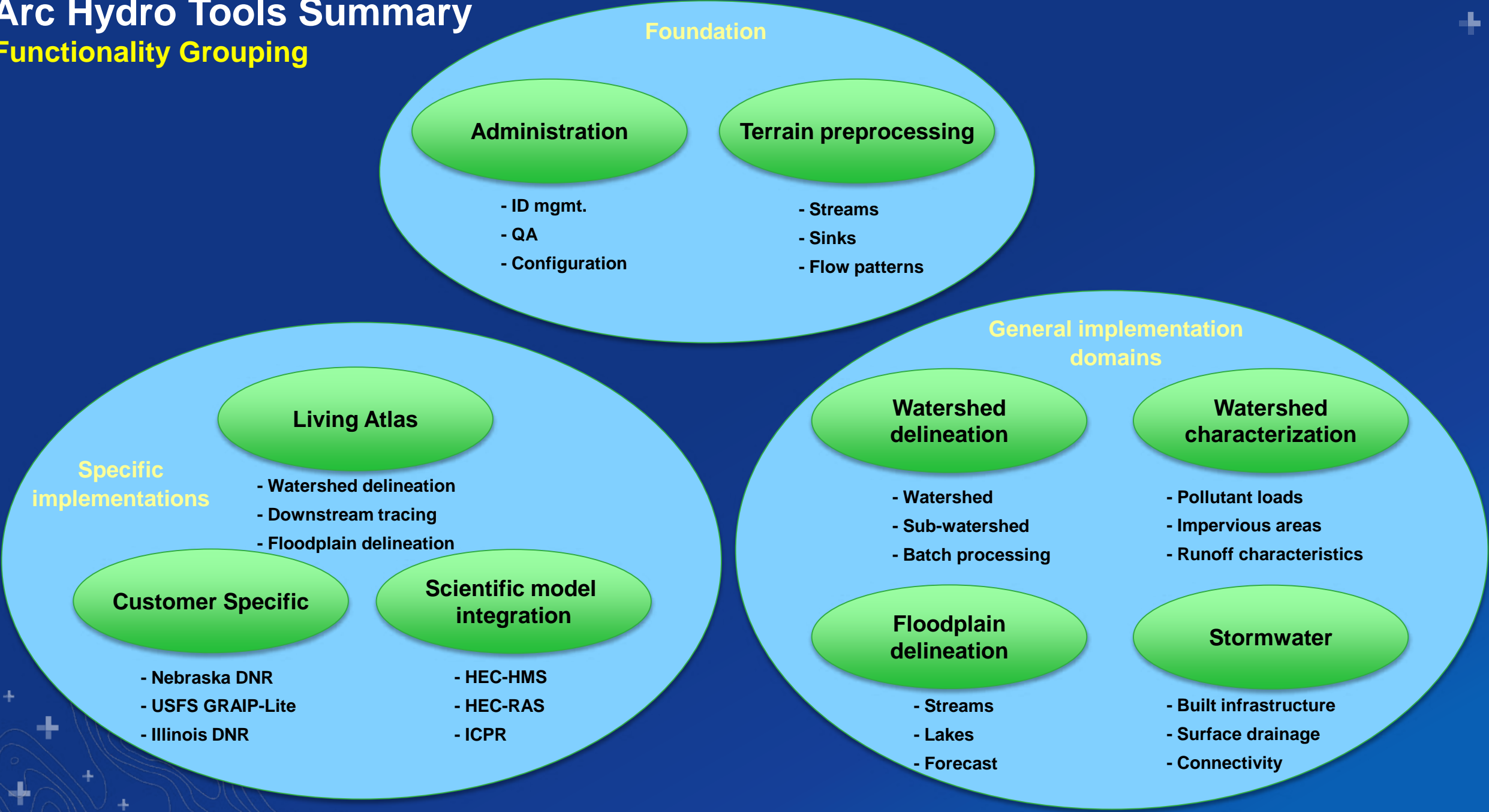
Tools



Workflows

Arc Hydro Tools Summary

Functionality Grouping



Foundation

Administration

- ID mgmt.
- QA
- Configuration

Terrain preprocessing

- Streams
- Sinks
- Flow patterns

General implementation domains

Watershed delineation

- Watershed
- Sub-watershed
- Batch processing

Watershed characterization

- Pollutant loads
- Impervious areas
- Runoff characteristics

Floodplain delineation

- Streams
- Lakes
- Forecast

Stormwater

- Built infrastructure
- Surface drainage
- Connectivity

Specific implementations

Living Atlas

- Watershed delineation
- Downstream tracing
- Floodplain delineation

Customer Specific

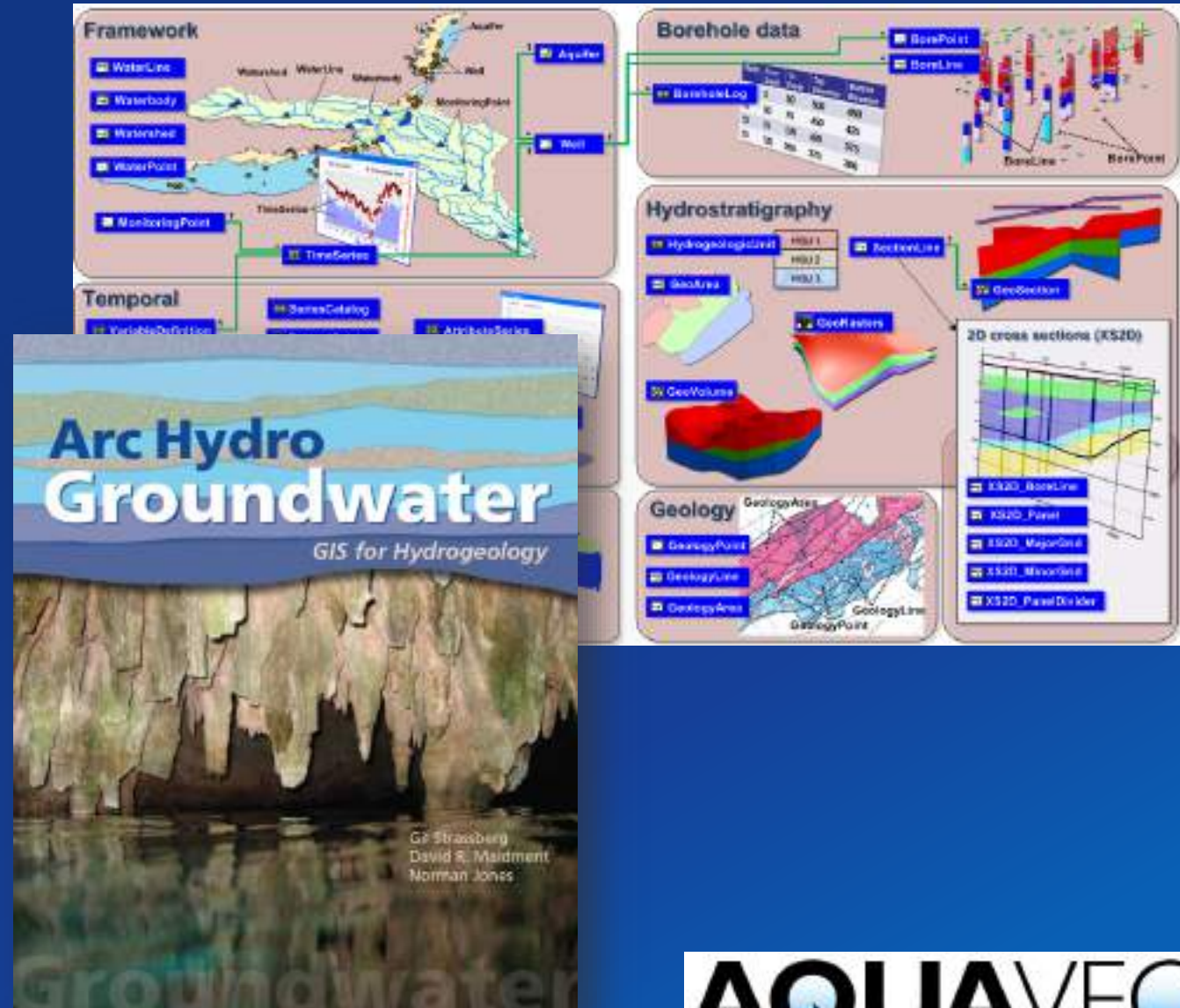
- Nebraska DNR
- USFS GRAIP-Lite
- Illinois DNR

Scientific model integration

- HEC-HMS
- HEC-RAS
- ICPR

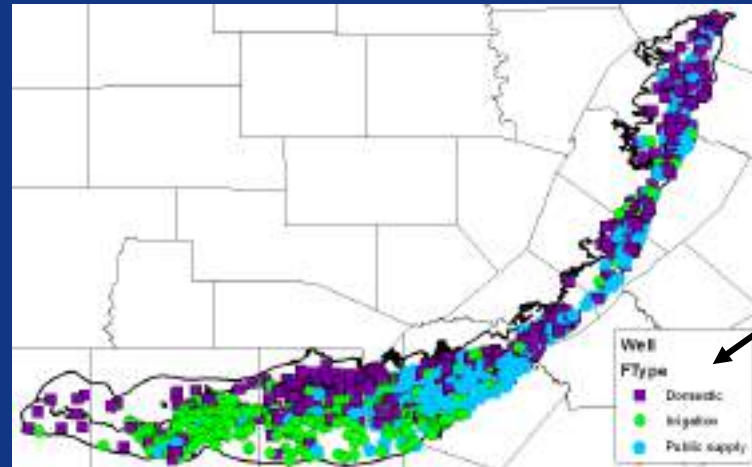
Arc Hydro Groundwater

- Project launched in 2004:
 - Dr. David Maidment @ Texas
 - Dr. Norm Jones @ BYU
 - Dr. Gil Strassberg @ Aquaveo
- 2006 – first draft (Gil's Ph.D. work)
- 2007 – Aquaveo – Esri agreement on tool development
- 2009 – AHGW tools released
- 2011 – book published

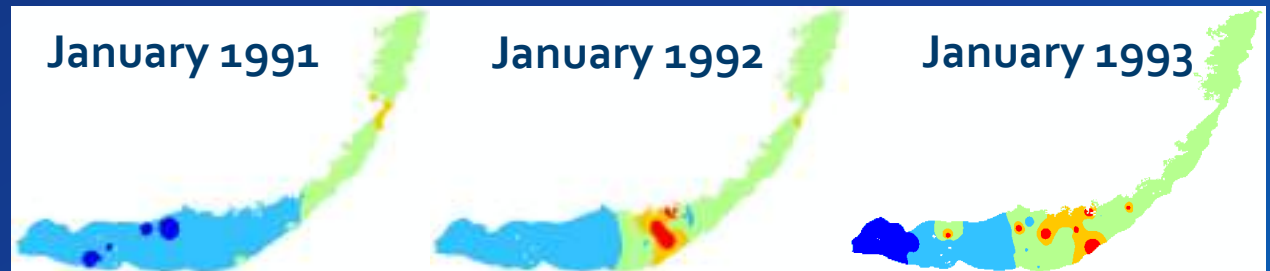
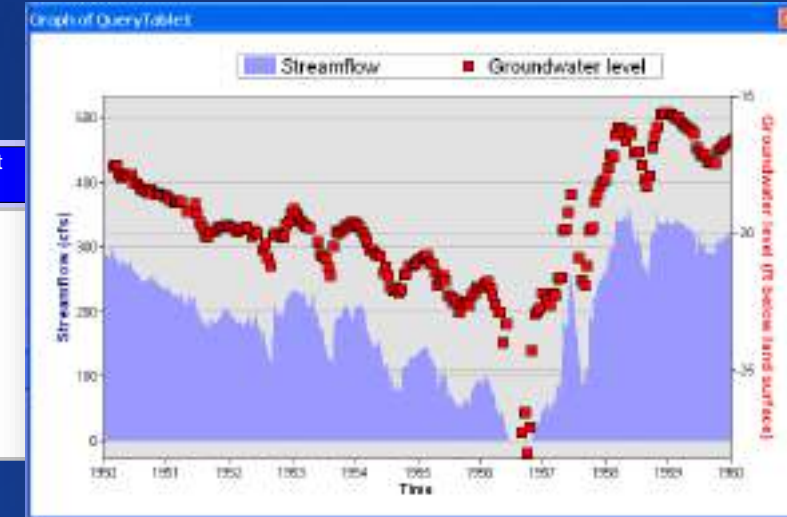


Arc Hydro Groundwater – Groundwater Analyst

- Well data management and visualization
- Time series plots
- Raster management

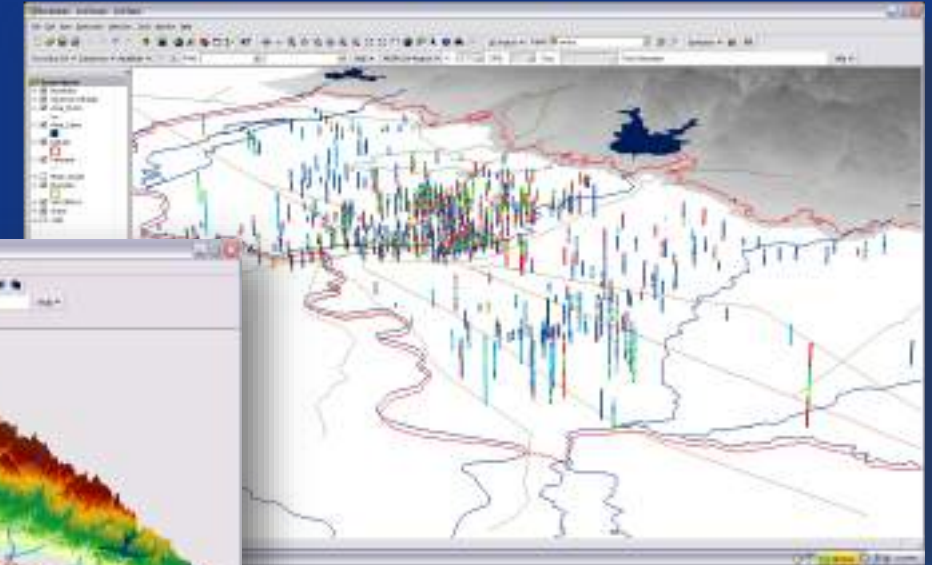
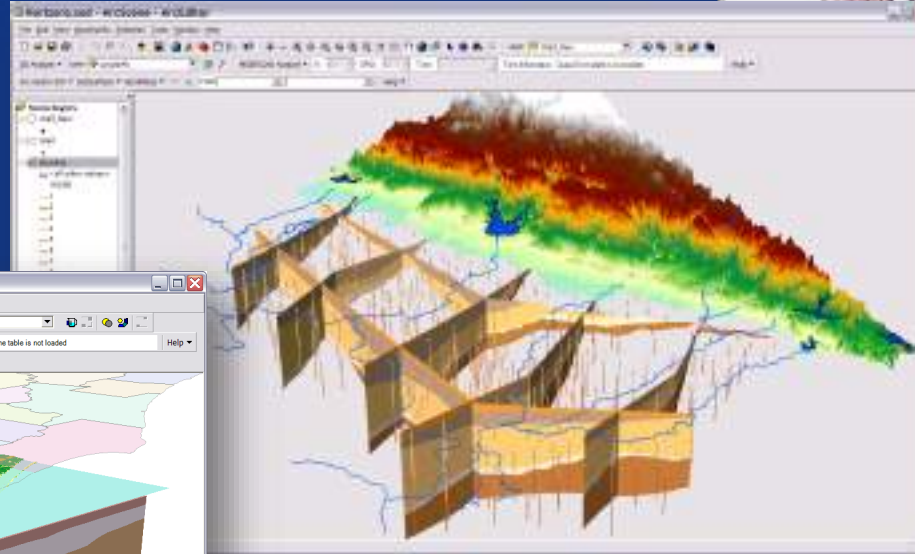
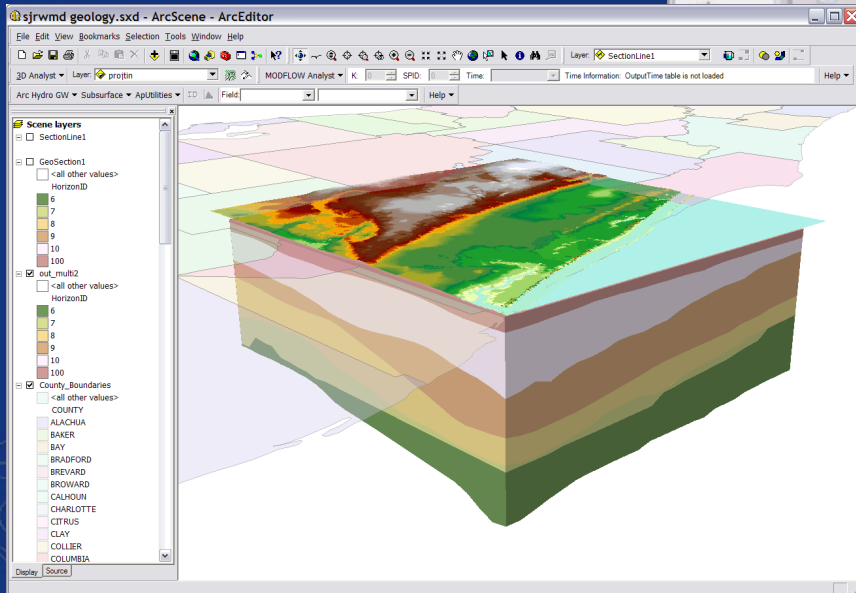


- Point dataset
- Well
- HydroID
- HydroCode
- LandElev
- WellDepth
- AquiferID
- AqCode
- HGUID
- FType



Arc Hydro Groundwater – Subsurface Analyst

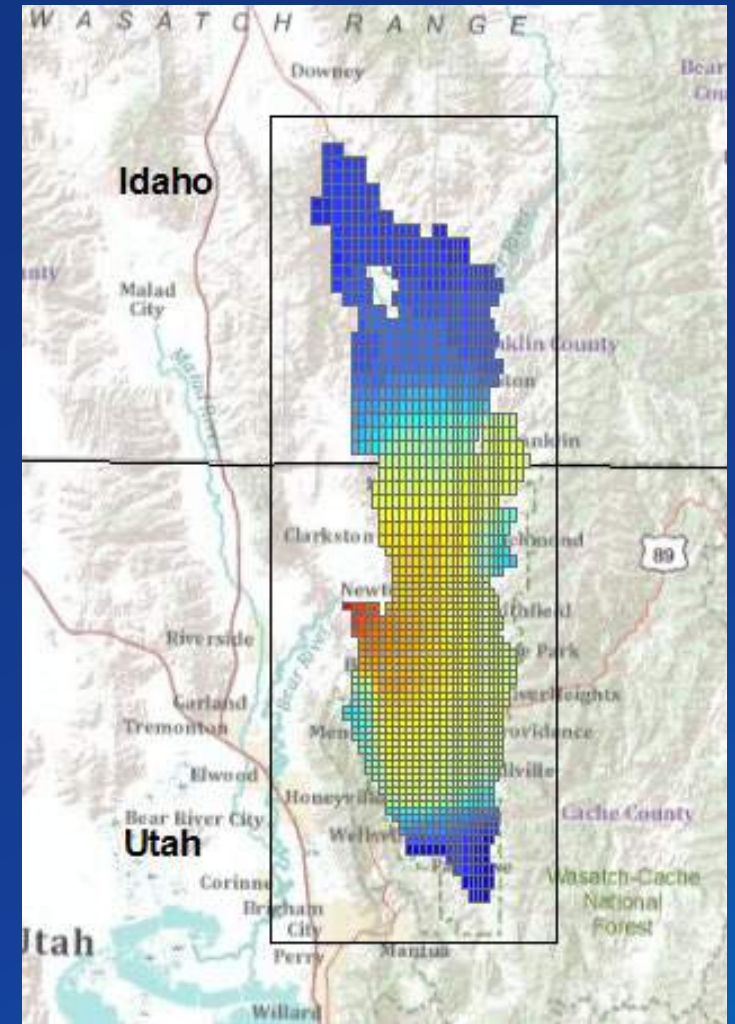
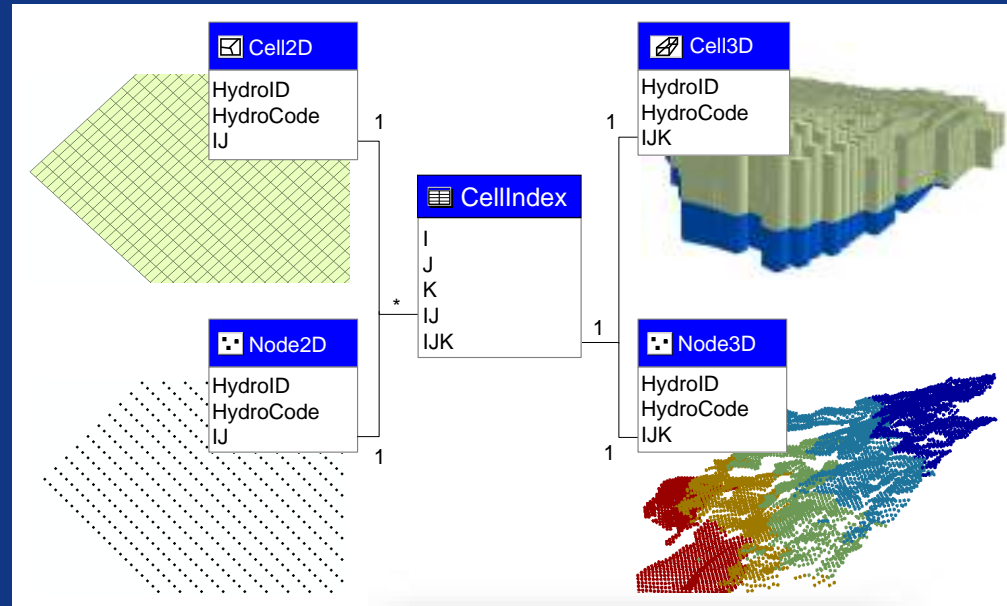
- Borehole management
- Borehole visualization
- Cross-sections
- GeoVolumes



Arc Hydro Groundwater – MODFLOW Analyst

- MODFLOW

- Develop
- Import
- Visualize
- Run



Quotes of the day/month/year/...

- “All models are wrong, but some are useful” (George Box ~1976)
- “Perfect is the enemy of the good” (Voltaire ~1770)
- “A fool with a tool is still a fool”
 - (reported by Ken Lanfear, USGS ret.)



Principles of Model Integration



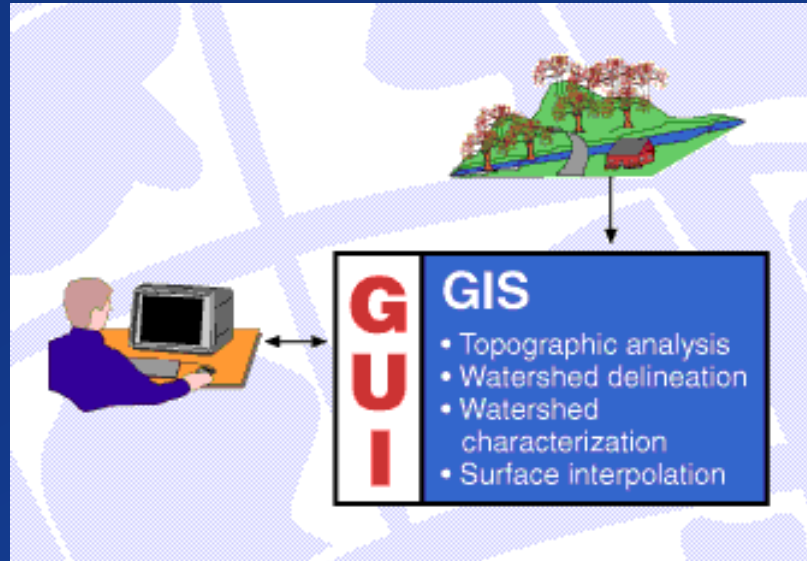
Model Integration Components

- **Data exchange**
 - How will the applications/models share the data
- **User interface**
 - How will the applications manage user interaction
- **Model/application control**
 - How will the applications control (each other's) execution
- **SW/HW infrastructure**
 - What infrastructure is available to support the integration process



Types of Model Integration - Modeling Support

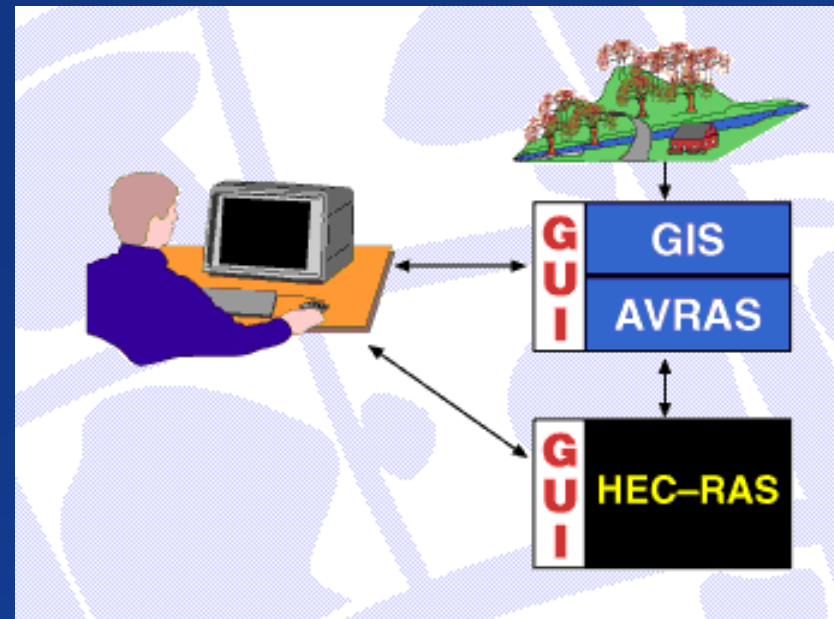
- Standard GIS tools are used to derive data and information used in water resources modeling (e.g. watershed boundaries, watershed characteristics, etc.)
- Data exploration and processing (e.g. develop layer of curve numbers based on land use and soil type layers)



Types of Model Integration - Linked

Loosely Coupled

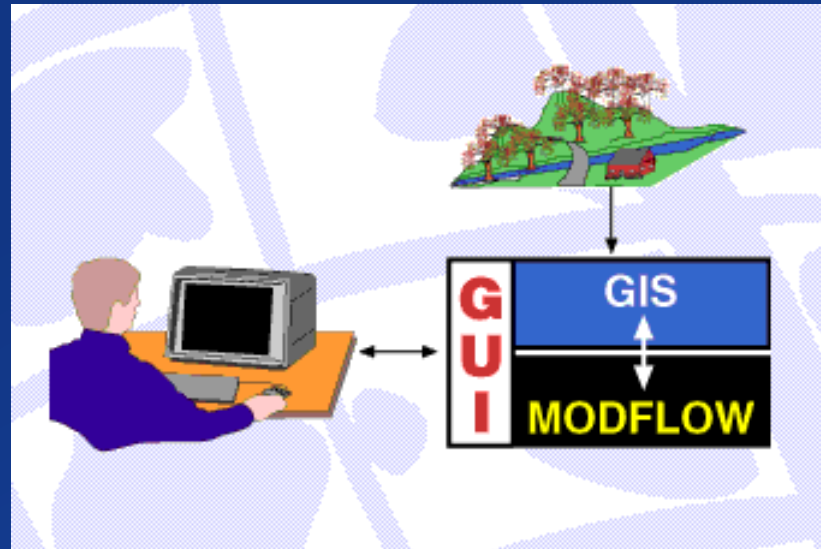
- GIS is linked to external models
- GIS preprocess and post-process model data for cost-efficient and visually effective results
- GIS and models maintain their distinctive user interfaces



Types of Model Integration - Integrated

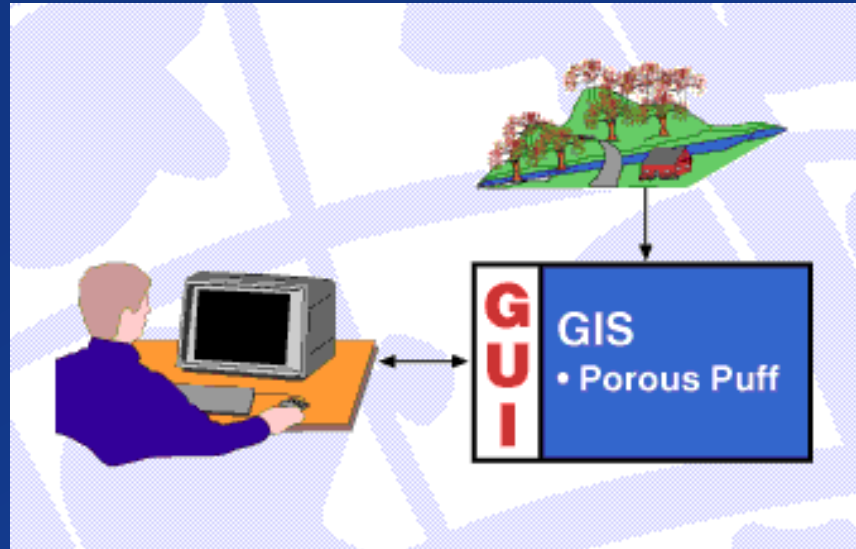
Tightly Coupled

- GIS is integrated with external models
- GIS preprocess and post-process model data for cost-efficient and visually effective results
- GIS and models share the same user interface



Types of Model Integration - Embedded

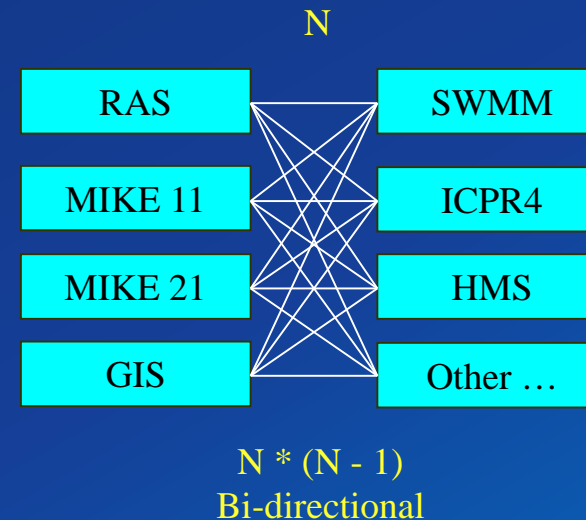
- Model functionality is implemented as a core GIS tool (e.g. Porous Puff dispersion model has been implemented as a Spatial Analyst function)



Integration Issues

- **Models:**
 - Data providers
 - Data consumers
 - Often both
- **Unspecified at the beginning of the integration exercise**
- **Proprietary**
 - Data
 - Control
- **Independence from integration platform**

- **Development out of “control”**
- **Maintenance “curse”**
 - **Long term cost of ownership**
- **Complexity increase (multiplicative) as you add more models**



Model Integration Approach

- **Model integration “platforms”.**
 - Stella
 - GoldSim
 - Vensim
 - MATLAB
 - ...
- **Esri universe**
 - Model Builder
 - Data Interoperability / FME
- **Custom solutions**



Model Integration Approach

- **Whatever works for particular situation – different conditions even for the same integration “problem” can result in a different integration method(s)**
 - **Tight or loose coupling**
 - **Technical issues**
 - **Legal issues**
 - **Access to the underlying model structure or not (NSS vs. Excel)**
- **Check out the existence of 3rd party solutions**
 - **Almost always cheaper to buy a solution than to develop one (except for simple tasks)**
- **Python and ArcPy as framework for developing complex integrated systems**



StreamStats



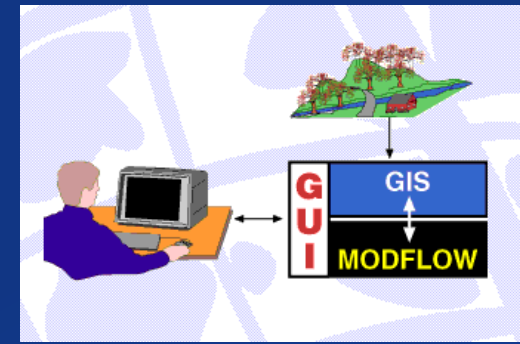
Regression Equations – USGS StreamStats

- 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)
- Regression equations take the form:

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

Regression equation for indicated Q_{reg}	MEV (log units)	AVP (log units)	SEM (percent)	SEP (percent)	Pseudo-R ² (percent)
Region 1, 2; n = 58					
$Q_{10} = 0.000815 A^{1.000} P^{2.00}$	0.065	0.069	64.3	66.7	91.6
$Q_{41} = 0.00141 A^{1.000} P^{2.11}$	0.063	0.067	63.0	65.3	91.6
$Q_{10} = 0.00238 A^{1.000} P^{2.31}$	0.063	0.066	62.8	65.0	91.4
$Q_{41} = 0.00294 A^{1.000} P^{2.31}$	0.062	0.066	62.3	64.5	91.4
$Q_{10} = 0.00616 A^{1.000} P^{2.21}$	0.065	0.069	64.3	66.7	90.4
$Q_{10} = 0.00962 A^{1.000} P^{2.10}$	0.070	0.074	66.8	69.4	89.4
$Q_{41} = 0.0148 A^{1.000} P^{2.11}$	0.075	0.080	70.0	72.9	88.2
$Q_{10} = 0.0191 A^{1.000} P^{2.12}$	0.080	0.086	72.7	75.8	87.2
$Q_{10} = 0.0239 A^{1.000} P^{2.11}$	0.086	0.093	76.2	79.7	85.9
$Q_{41} = 0.0288 A^{1.000} P^{2.10}$	0.093	0.100	79.7	83.5	84.7
$Q_{41} = 0.0355 A^{1.000} P^{2.00}$	0.101	0.108	84.0	88.2	83.1
Region 3; n = 13					
$Q_{10} = 8.15 A^{1.000}$	0.135	0.158	102	114	78.3
$Q_{41} = 11.7 A^{1.000}$	0.117	0.137	92.6	103	80.3
$Q_{10} = 17.2 A^{1.000}$	0.097	0.114	82.2	91.2	82.7
$Q_{41} = 20.1 A^{1.000}$	0.090	0.106	78.2	86.7	83.6
$Q_{10} = 35.6 A^{1.000}$	0.064	0.076	63.5	70.4	87.5
$Q_{10} = 51.8 A^{1.000}$	0.048	0.059	54.0	60.4	90.1
$Q_{41} = 75.7 A^{1.000}$	0.032	0.040	42.7	48.8	93.2
$Q_{10} = 95.9 A^{1.000}$	0.022	0.030	35.2	41.5	95.1
$Q_{41} = 117 A^{1.000}$	0.014	0.021	27.8	34.5	96.8
$Q_{10} = 140 A^{1.000}$	0.009	0.015	21.5	29.1	98.0
$Q_{41} = 171 A^{1.000}$	0.003	0.010	13.0	22.8	99.2
Region 4; n = 28					
$Q_{10} = 0.000592 A^{1.000} (F/100 + 1)^{1.12} P^{2.00}$	0.059	0.069	60.8	66.4	92.1
$Q_{41} = 0.00126 A^{1.000} (F/100 + 1)^{1.12} P^{2.00}$	0.051	0.060	55.9	61.0	92.8
$Q_{10} = 0.00272 A^{1.000} (F/100 + 1)^{1.12} P^{2.10}$	0.044	0.051	51.2	55.8	93.5
$Q_{41} = 0.00370 A^{1.000} (F/100 + 1)^{1.12} P^{2.10}$	0.040	0.047	48.5	52.9	94.0
$Q_{10} = 0.0123 A^{1.000} (F/100 + 1)^{1.12} P^{2.10}$	0.030	0.035	41.2	45.2	95.2
$Q_{10} = 0.0279 A^{1.000} (F/100 + 1)^{1.12} P^{2.10}$	0.025	0.031	38.0	42.0	95.6
$Q_{41} = 0.0773 A^{1.000} (F/100 + 1)^{1.12} P^{2.10}$	0.022	0.027	34.8	38.9	96.1
$Q_{10} = 0.149 A^{1.000} (F/100 + 1)^{1.12} P^{1.00}$	0.020	0.025	33.1	37.5	96.3
$Q_{41} = 0.292 A^{1.000} (F/100 + 1)^{1.12} P^{1.00}$	0.019	0.025	32.7	37.3	96.3
$Q_{41} = 0.534 A^{1.000} (F/100 + 1)^{1.12} P^{1.00}$	0.019	0.024	32.3	37.2	96.3
$Q_{41} = 1.09 A^{1.000} (F/100 + 1)^{1.12} P^{1.00}$	0.019	0.026	32.9	38.2	96.0

System/Integration Architecture



- **Integrated / tight coupling.**
 - GIS used for watershed delineation and characteristics extraction.
 - National Stream Statistics (NSS) application used for regression calculations.
- **While GIS and regression engine are separated and run independently, the (web) user interface “hides” that and a single front end is presented to the user.**
- **But is a black-box – no ability to control model parameter extraction methodology, data, or equations.**

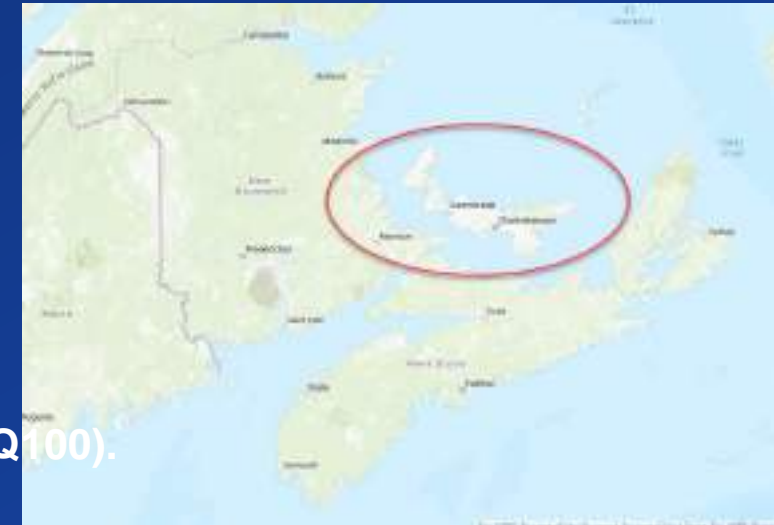
PEI Culvert Calculator



Prince Edward Island Culvert Calculator Project Overview



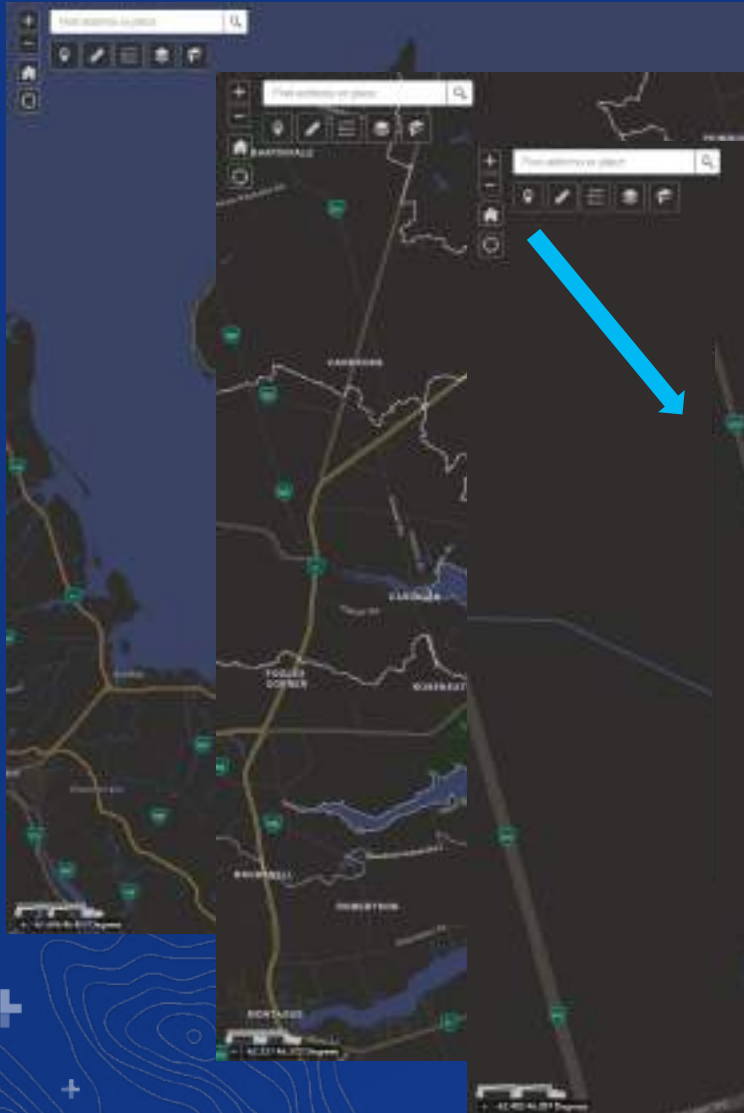
- **User:** PEI Department of Communities, Land and Environment
- **Goal:** Streamline road maintenance during short construction season. Automate small culvert repair and installation.
- **Implementation components:**
 - **Data:**
 - **Topography/hydrography:**
 - Local DEM and hydrography (DEM at 1m).
 - **Hydrology/hydraulics/design:**
 - Rational method including climate change precipitation adaptation (Q100).
 - Manning's equation (open channel) for sizing.
 - Road construction manual (DOT) for culvert design.
 - **Geoprocessing service for watershed delineation, characterization, and culvert sizing.**
 - **Web application (simple WAB app) for end user interaction.**





PEI Culvert Calculator Demo

Prince Edward Island Culvert Calculator Demo



Culvert Calculation Results

Date and Time Prepared: 3/2/2021 2:11:55 PM
 Provincial Property Number: xxx
 Community: POPLAR POINT
 Location:
 Latitude: 46.287136
 Longitude: -62.475624

Culvert

Box Culvert: 116.0000
 Pipe Culvert: 11.0000
 Slope: 0.0100
 Head Loss: 0.0000
 Head Loss: 0.0000
 Head Loss: 0.0000

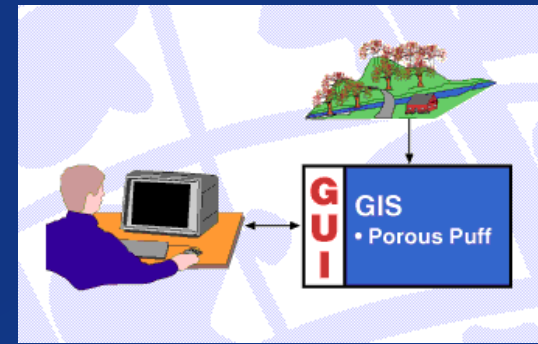
Catchment Data:
 Land catchment area: A = 2.553561 sqkm
 Distance from most remote point to structure: Dist = 3308.22 m
 Elevation difference from most remote point to structure: Dh = 27.19 m
 Time of concentration (Kipitch formula): tc = 57.088167 min
 Runoff coefficient: C = 0.5
 Intensity (from climate change adjusted IDF): i(100) = 52.67 mm/hr
 Weather Station utilized: Charlottetown

Calculated Flow Rate (Rational formula): Q = 18.637 m³/s



- Structure Options*:**
- Round Culvert
 - Corrugated metal: minimum 1500.0 mm diameter
 - Concrete: minimum 1050.0 mm diameter
 - Plastic: minimum 975.0 mm diameter
 - Box Culvert (closed bottom)
 - Concrete: minimum 1620000 mm² cross-sectional area
 - Box Culvert (open bottom)
 - Concrete: minimum 1620000 mm² cross-sectional area
 - Ellipse
 - Corrugated Metal: minimum 7068583 mm² cross-sectional area
 - Concrete: minimum 3463605 mm² cross-sectional area
- * Structure must be installed at a slope of 0.5% or less.

System/Integration Architecture



- **Embedded.**
- **GIS processing, hydrologic model, and engineering design are built into a single application (geoprocessing service).**
- **The (web) user interface provides a single front end for the user.**
- **But is a black-box – no ability to control model parameter extraction methodology, data, or equations.**

Structure Options*:

Round Culvert

Corrugated metal: minimum 1500.0 mm diameter

Concrete: minimum 1050.0 mm diameter

Plastic: minimum 975.0 mm diameter

Box Culvert (closed bottom)

Concrete: minimum 1620000 mm² cross-sectional area

Box Culvert (open bottom)

Concrete: minimum 1620000 mm² cross-sectional area

Ellipse

Corrugated Metal: minimum 7068583 mm² cross-sectional area

Concrete: minimum 3463605 mm² cross-sectional area

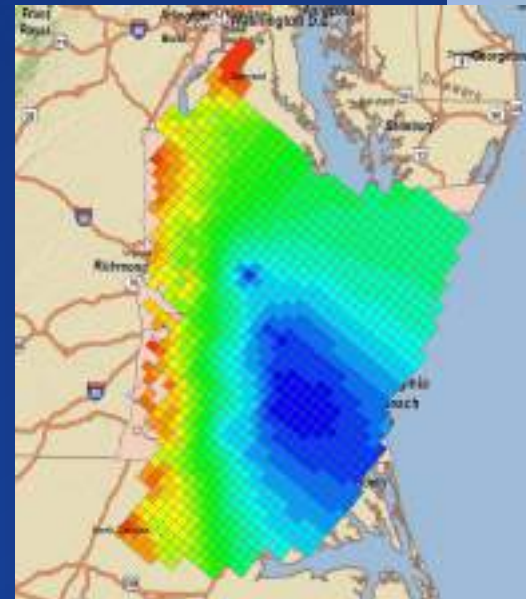
* Structure must be installed at a slope of 0.5% or less.

Groundwater Integration



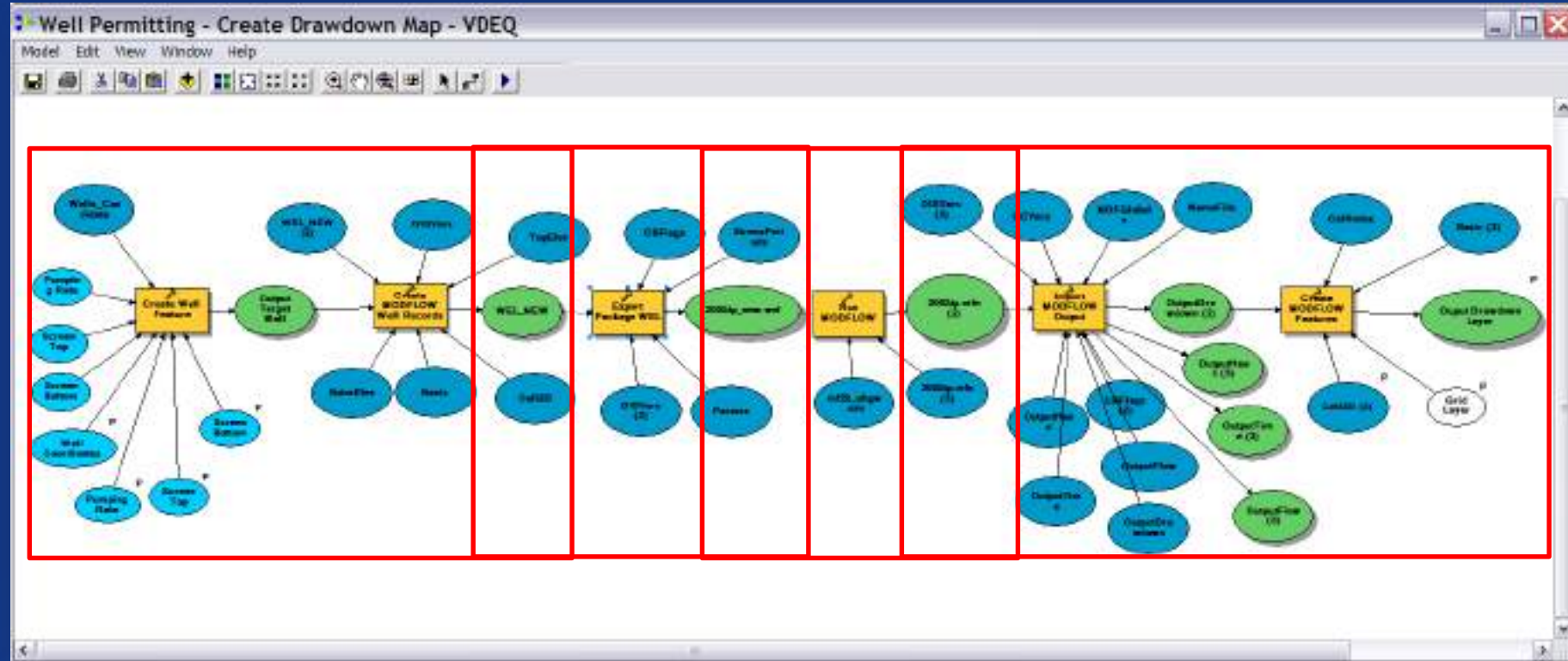
Automated Well Permitting – MODFLOW Analyst

- Calibrated regional model is imported to ArcGIS as a “baseline” model.
- Candidate wells are added to baseline model using well package.
- Impact of new well is analyzed using MODFLOW
- Results are imported into ArcGIS for presentation



Workflow

- Create new well
- Update well table
- Export well package file
- Run MODFLOW
- Import solution
- Build drawdown map layer
- Generate final map products



Step 1 – Create New Well

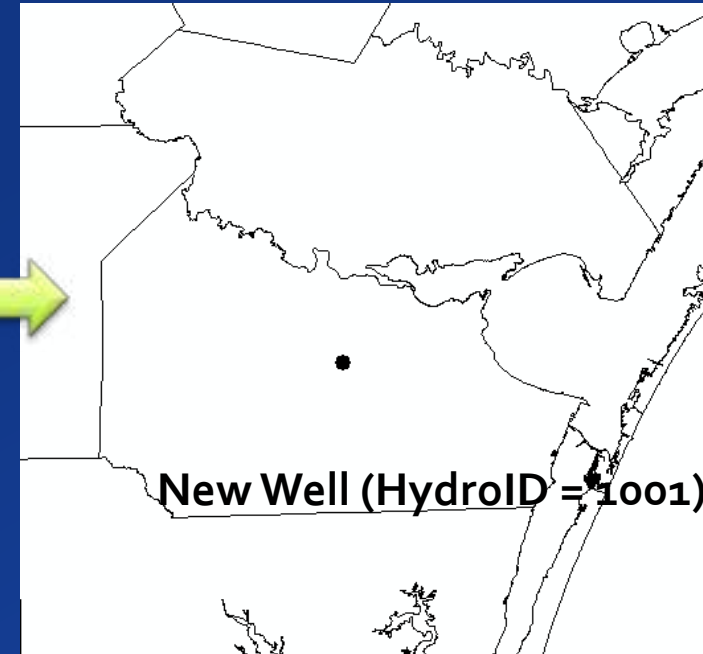
Create Well Feature

Input Well Features:
Well: Well
Pumping Rate (Q) Field: Q
Screen Top Field: ScreenTop
Screen Bottom Field: ScreenBot

Well Coordinates

X Coordinate	Y Coordinate
100	150
	-250
	100
	50

Buttons: OK, Cancel, Environments..., Show Help >>



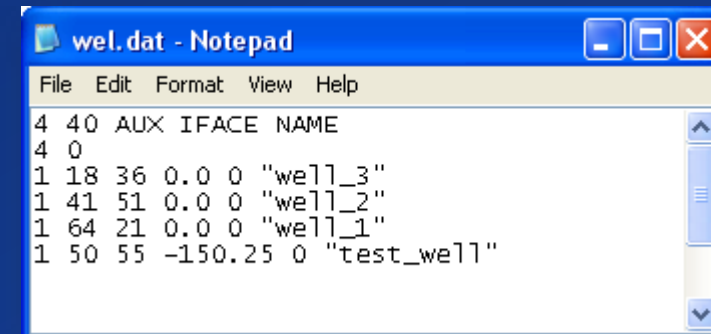
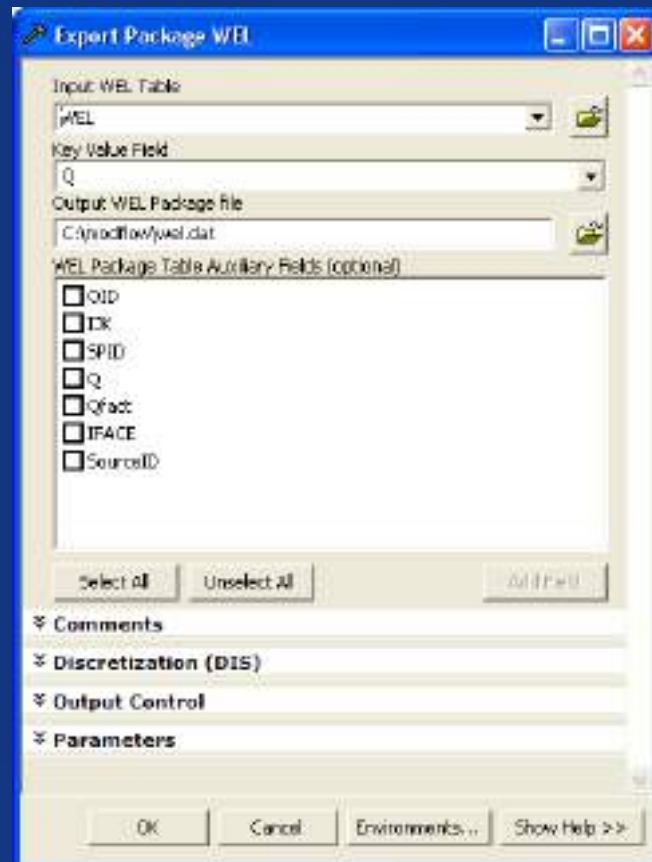
Step 2 – Create New Instances in WEL Table

CellID represents MODFLOW i, j, k values

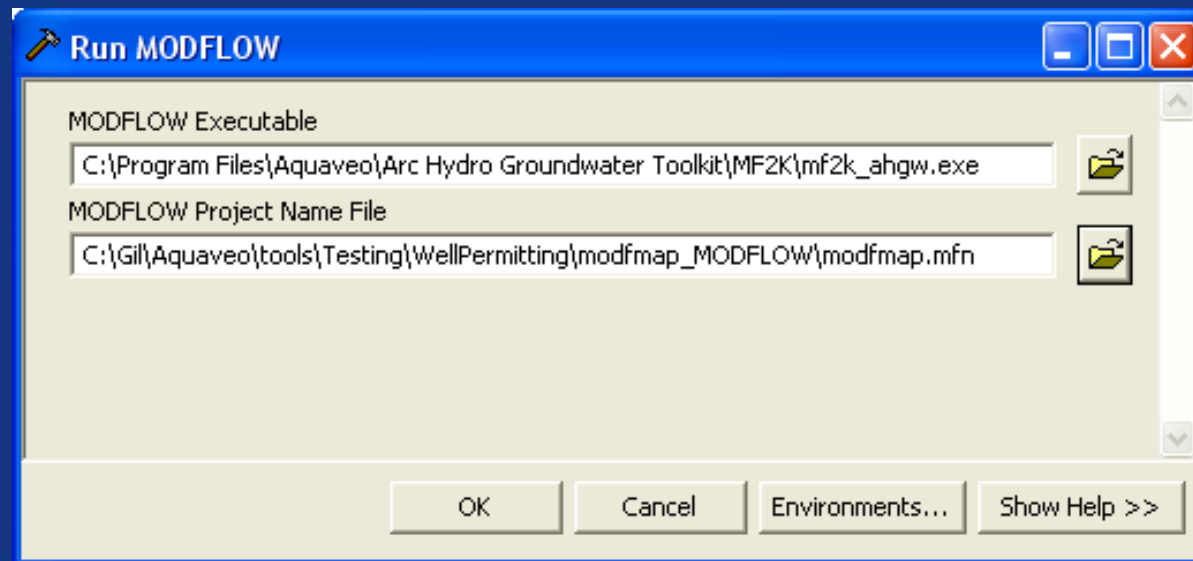
Object ID *	CellID	SPID	Q	Qfact	IFACE	SourceID
1	5024	1	-2830	<Null>	0	999
2	955	1	-680	<Null>	0	1000
3	1030	1	-150.2	<Null>	0	1001

SourceID is the HydroID of the well feature

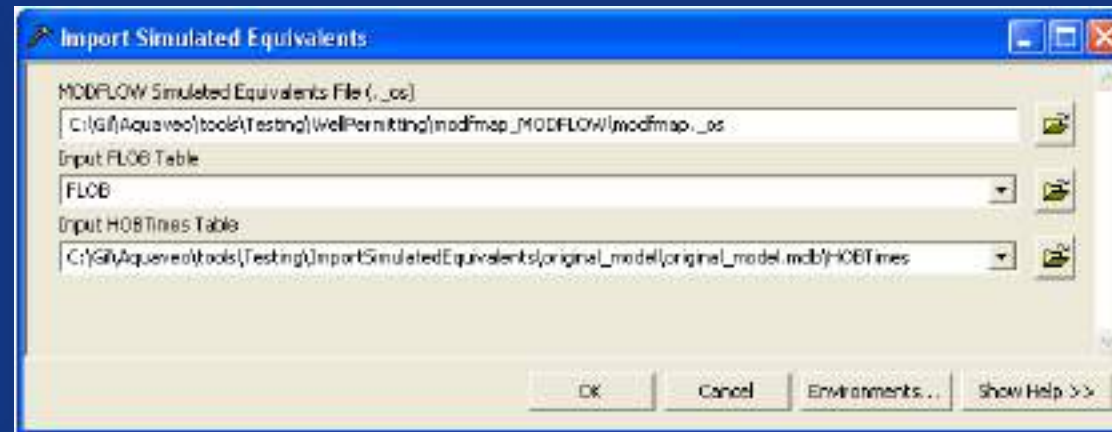
Step 3 – Export the New Well Data to MODFLOW Text File



Step 4 – Run MODFLOW



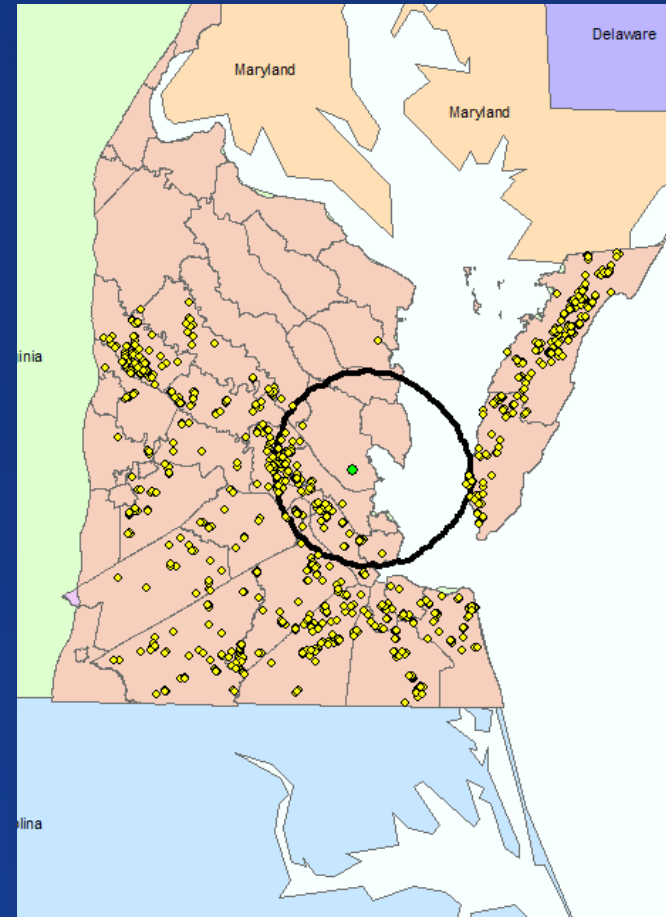
Step 5 – Read-in the Results



GIS Products

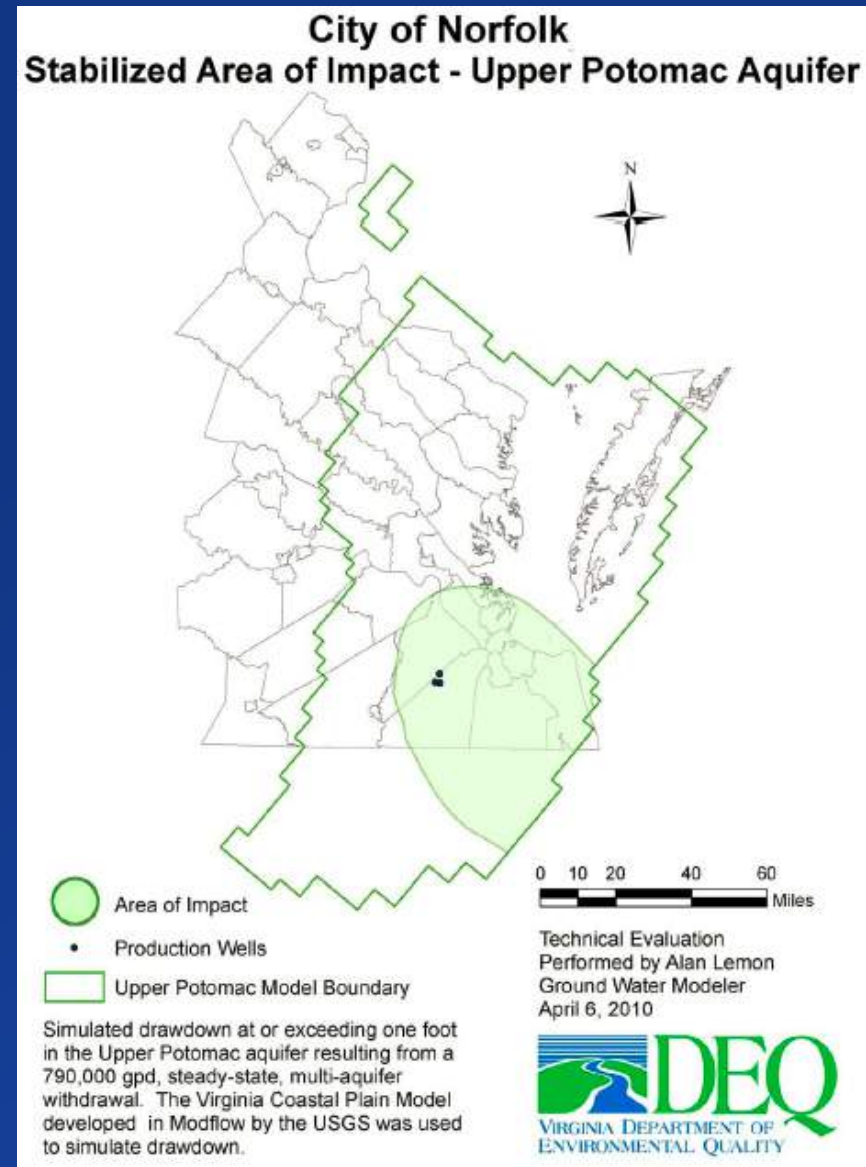
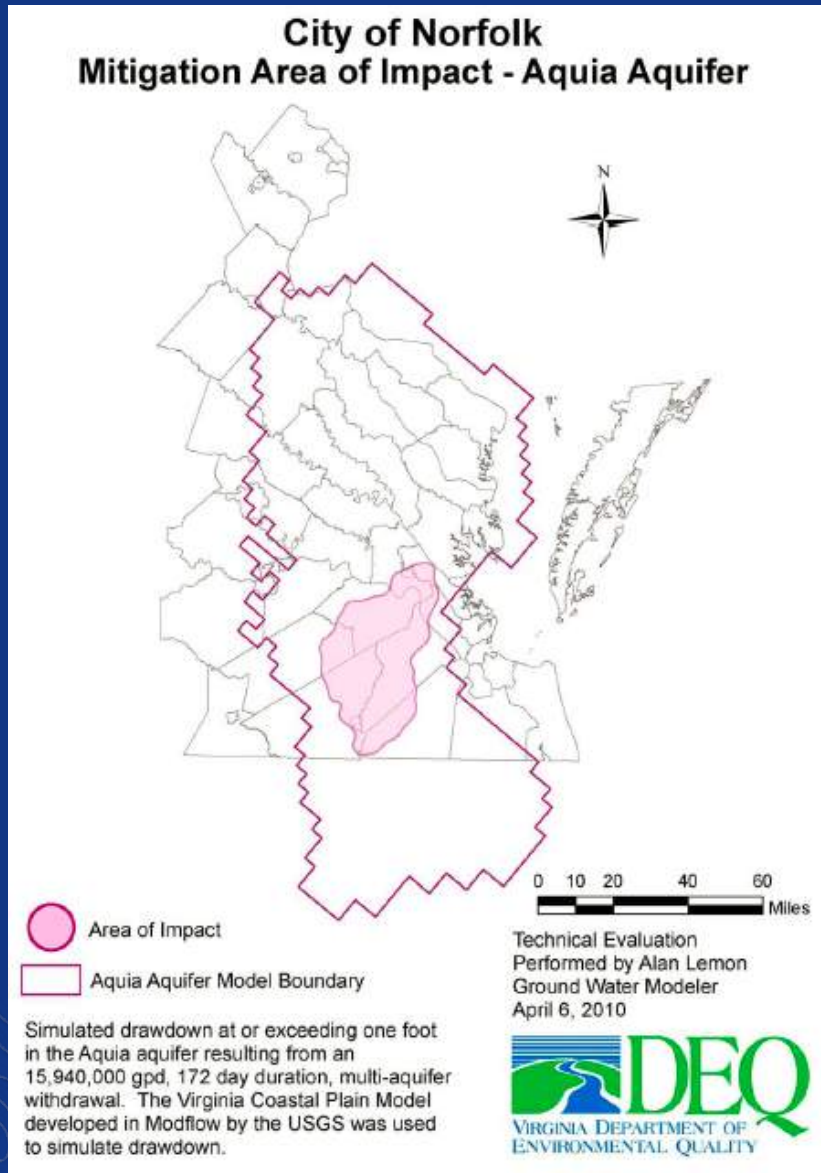


Area of Impact Cells

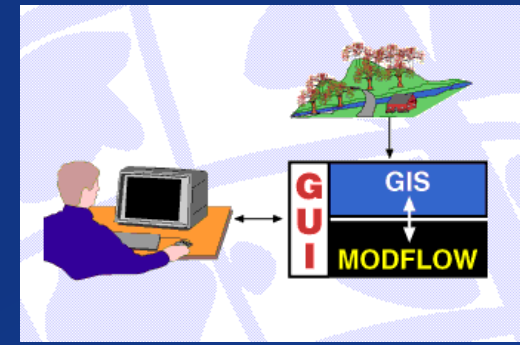


Area of Impact Contour

Report



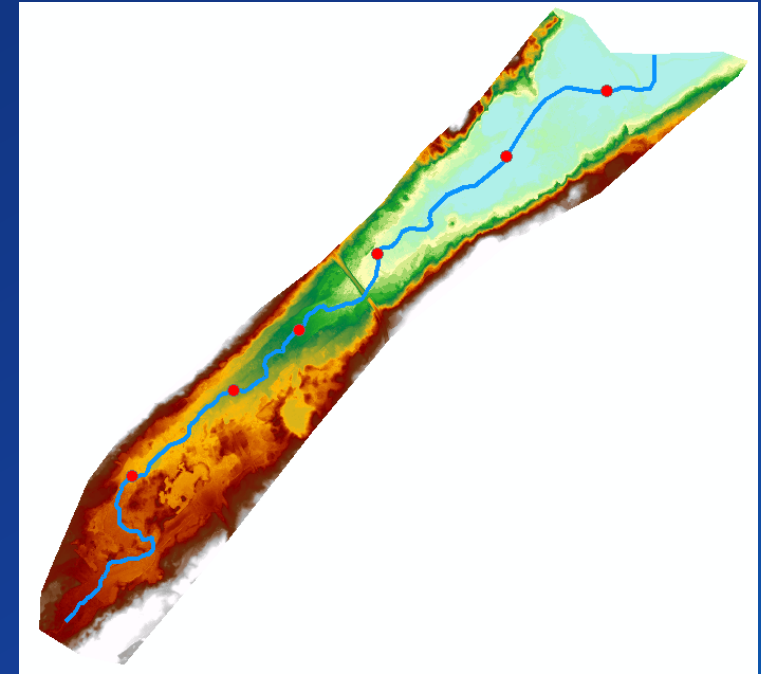
System/Integration Architecture



- **Integrated / tight coupling.**
 - GIS used for well placement and well characteristics extraction.
 - MODFLOW is used for groundwater modeling.
- **While GIS and MODFLOW engine are separated and run independently, the model builder user interface “hides” that and a single GIS front end is presented to the user.**
- **MODFLOW Analyst exposes many of MODFLOW capabilities through GIS interface so you have good control over MODFLOW and capacity to tweak it without having to be a MODFLOW expert.**

Floodplain Delineation Solutions Matrix

- Different levels of complexity are possible/needed to determine flood extents
- Simple, based on terrain and observations only:
 - “Flooding out” based on DEM, stream centerline, and point data
 - HAND approach (constant depth of flooding per reach)
- **Complex, based on hydraulic modeling (using external hydraulic models):**
 - **1D**
 - **2D**
 - **Full or simplified equations (Navier-Stokes / Saint-Venant / ...)**



Previous Polling Questions Results

Do you use hydraulic models for floodplain delineation?

- Yes = 47%
- No = 53%

If you are doing hydraulic modeling, what software do you use (81 - multi):

- DHI = 9%
- HEC-RAS = 65%
- ICPR4 = 6%
- INNOVYZE = 6%
- SWMM = 15%
- Other = 31%

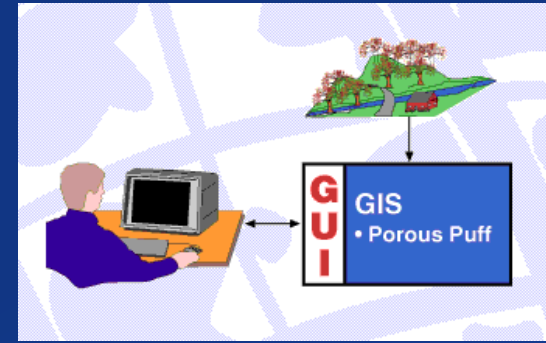
HEC-GeoHMS and HEC-GeoRAS



HEC-GeoHMS and HEC-GeoRAS Status

- **Products:**
 - HEC-GeoHMS – GIS companion product to HEC-HMS (pre-processing)
 - HEC-GeoRAS – GIS companion product to HEC-RAS (pre- and post-processing)
- **Development**
 - ArcGIS version (development by ESRI for HEC). Final HEC releases with version of ArcMap 10.2
 - No new functionality in many years
- **Maintenance**
 - Ongoing code maintenance by Arc Hydro team (through 10.8)
 - Support through Water Resources Community pages
- **Downloads**
 - Through Arc Hydro ftp site
- **No plans for porting to Pro in their current forms**

Geo Capabilities in HEC-HMS and HEC-RAS



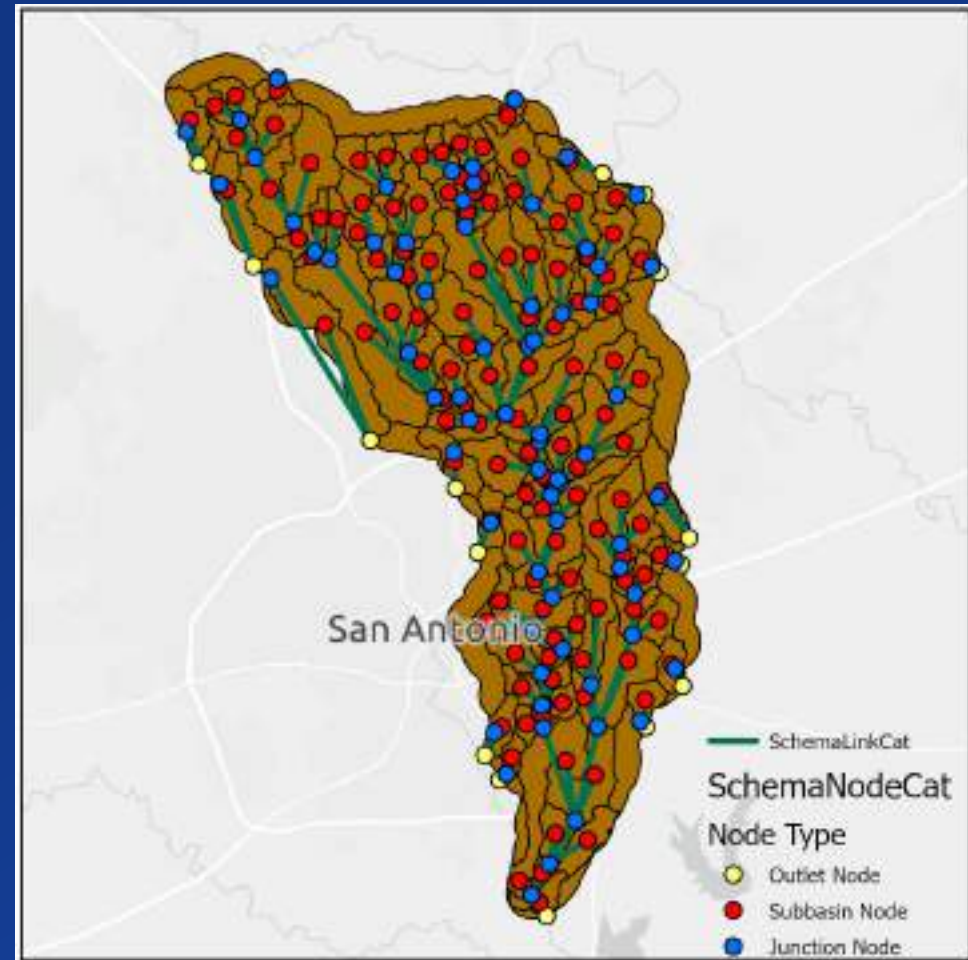
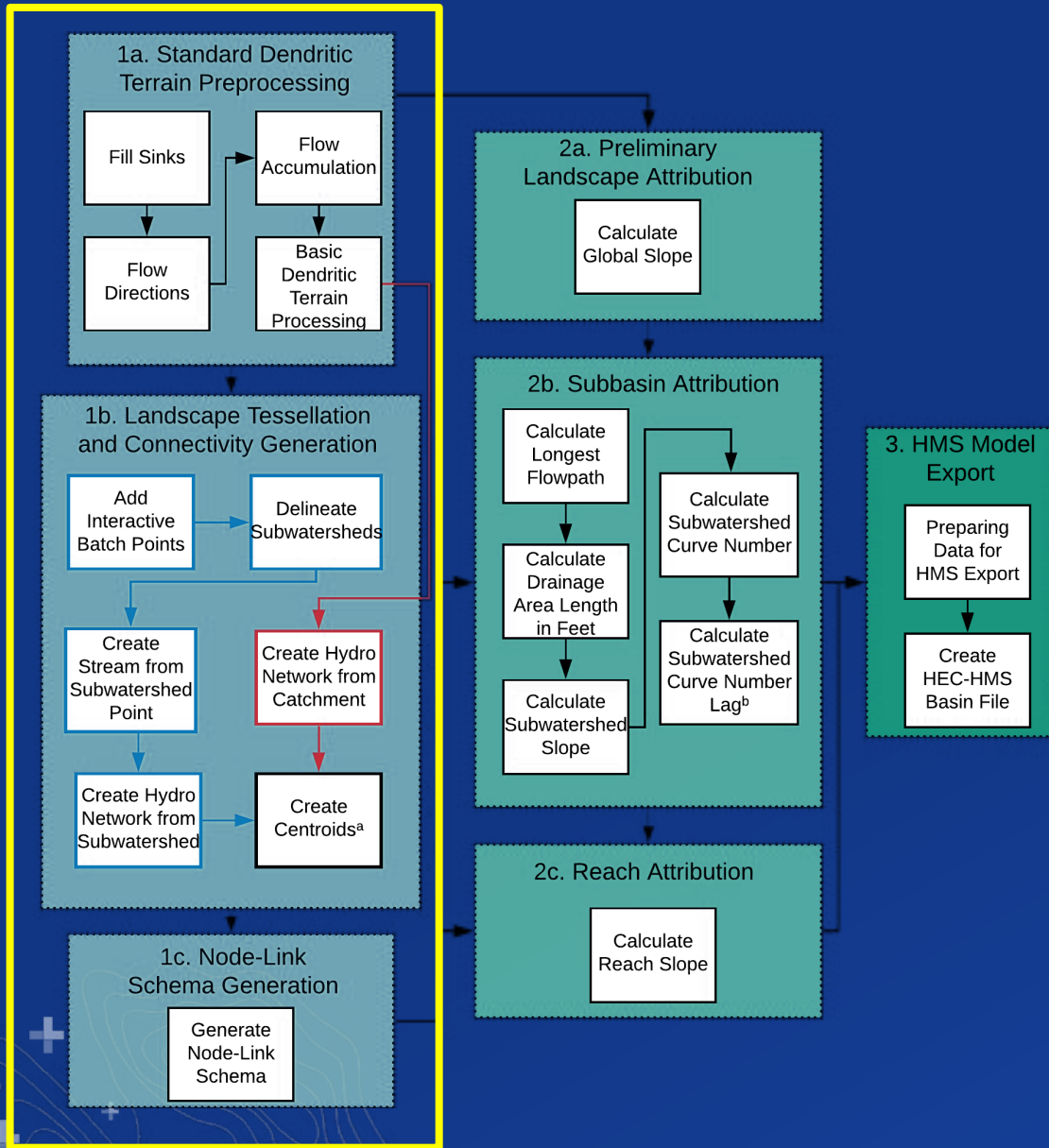
- HEC adding capabilities to use spatial data in their native products
- Integrated into HEC apps
 - HEC-HMS (since v4.4, 2020)
 - Similar to terrain preprocessing capabilities from HEC-GeoHMS
 - GIS menu
 - HEC-RAS – RAS Mapper
 - Extensive additions for 2D modeling support



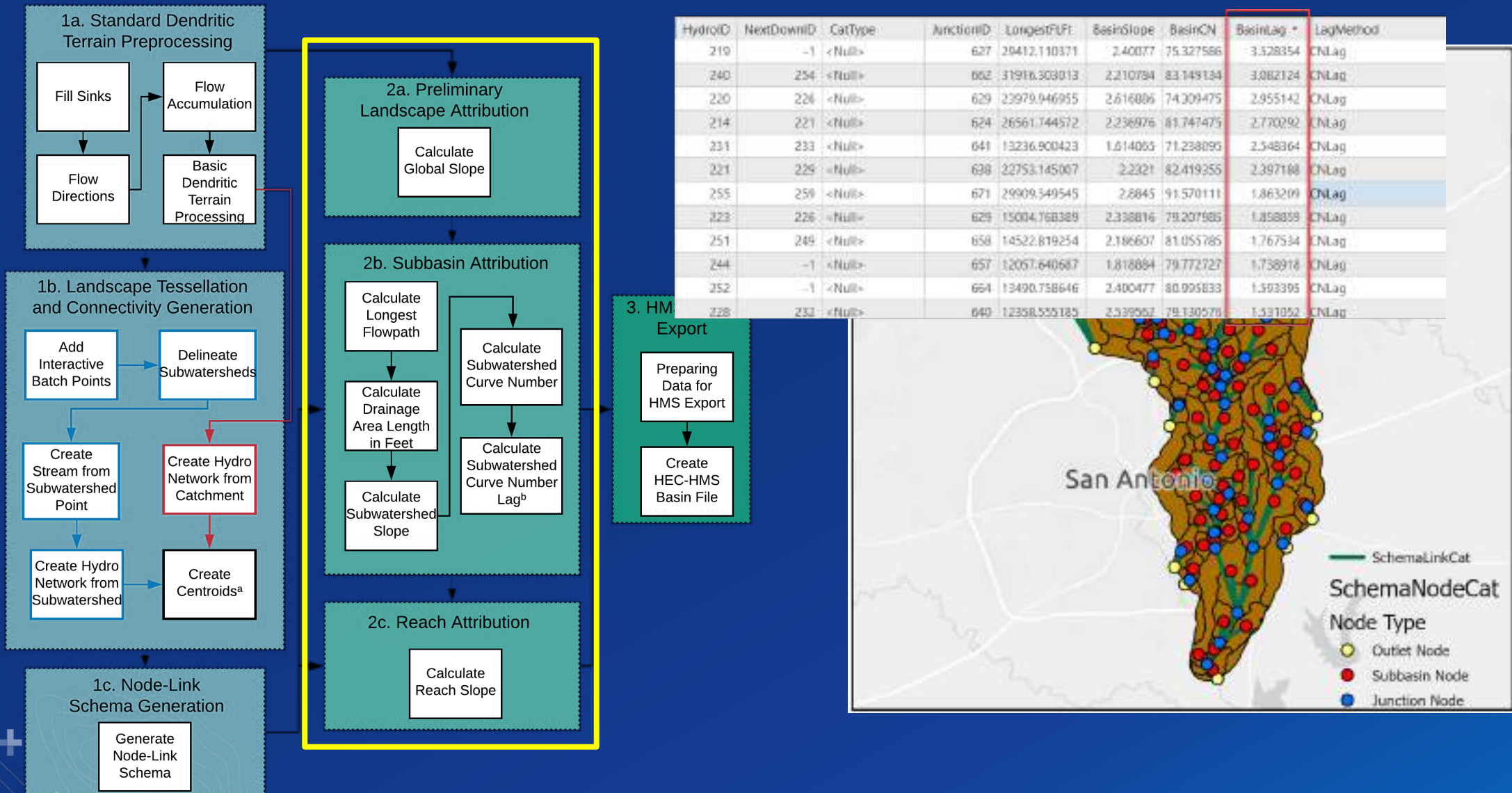
HEC-HMS Support in Arc Hydro for Pro



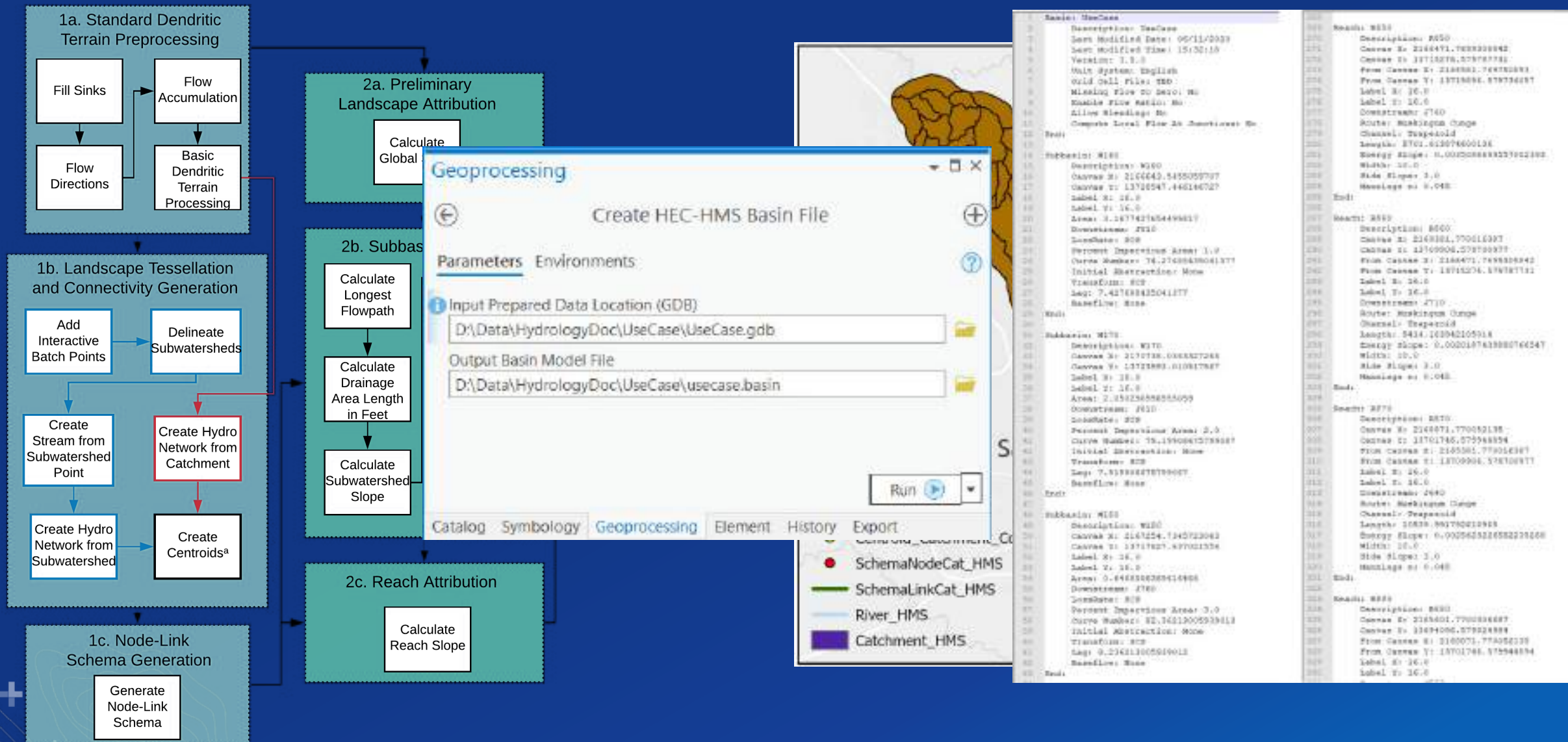
From Watershed Characterization to Simulating Hydrologic Processes



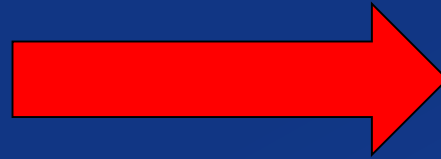
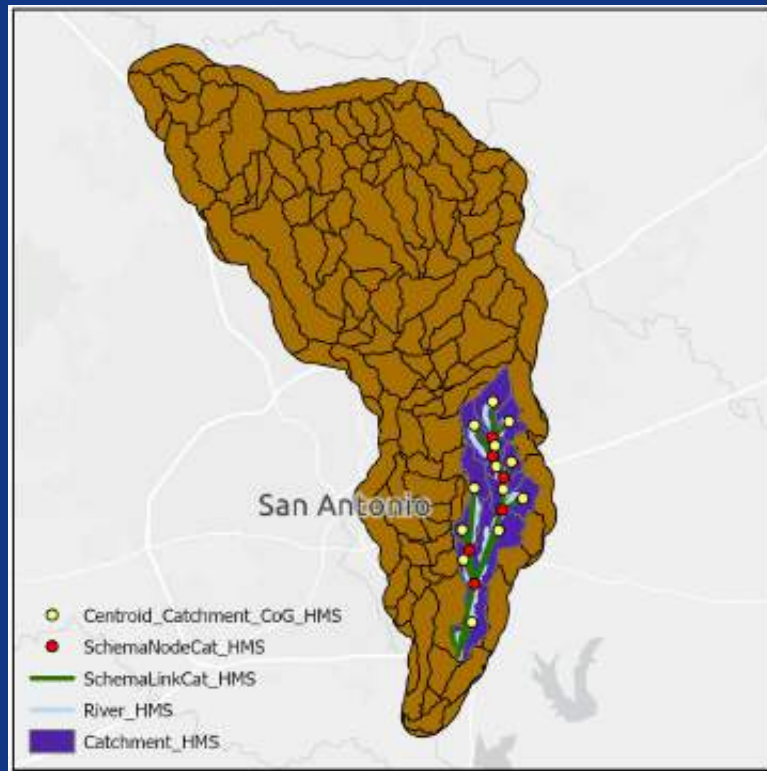
From Watershed Characterization to Simulating Hydrologic Processes



From Watershed Characterization to Simulating Hydrologic Processes



From Watershed Characterization to Simulating Hydrologic Processes



HEC-HMS 4.2.1 [C:\VH_Hydrology\HydroDoc\HydroDoc.hms]

File Edit View Components Parameters Compute Results Tools Help

Subbasin List Transform Options

Basin Name: SanCase
Elevation Name: W360
Description: W360
Elevation: 2080
Area (km2): 1.090
Latitude Degrees:
Latitude Minutes:
Latitude Seconds:
Longitude Degrees:
Longitude Minutes:
Longitude Seconds:
Canopy Method: None
Surface Method: None
Loss Method: SCS Curve Number
Transformation Method: SCS unit Hydrograph
Baseflow Method: None

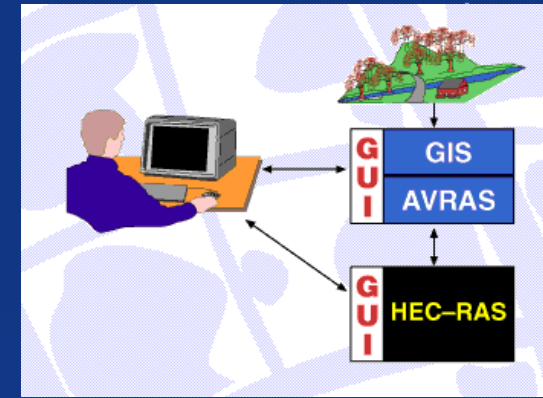
Basin Name: SanCase
Elevation Name: W360
Initial Abstraction (mm):
Curve Number: 70.830
Impervious (%): 11.0

Basin Name: SanCase
Elevation Name: W360
Graph Type: Standard (TRF-64)
Tag Time (hrs): 7.0000

Basin Name: SanCase
Elevation Name: W360
Observed Flow: None
Observed Stage: None
Observed SWS: None
Observed SWS(2): None
Obs-Discharge: None
Def Flow (M3/S):
Full Lakes:
W370 2000: Begin opening project "HydroDoc" in directory "C:
W370 2000: Finished opening project "HydroDoc" in directory "C:
W370 2000: Opened basin model "HydroDoc" at time 20/Jan/2
W370 2000: Opened basin model "SanCase" at time 20/Jan/20

The screenshot displays the HEC-HMS 4.2.1 software interface. The main window shows a network diagram of the watershed simulation model with various subbasins and links. The interface includes a menu bar, a toolbar, and several panels for configuring the model. The 'Subbasin List' panel is open, showing a list of subbasins with their names and elevations. The 'Transform' panel is also open, showing the configuration for the 'SanCase' subbasin, including the 'SCS Curve Number' method for loss and the 'SCS unit Hydrograph' method for transformation. The 'Graph Type' panel is open, showing the 'Standard (TRF-64)' graph type. The 'Observed' panel is open, showing the configuration for the 'SanCase' subbasin, including the 'Observed Flow' and 'Observed Stage' options.

System/Integration Architecture



- **Loose coupling.**
- **Only one specific HMS tool, the rest are standard Arc Hydro tools.**
 - Python export code (to ASCII file). This is different from HEC-GeoHMS that used XML and XSLT export methodology.
- **You can use the same tools to support any other node-link hydrologic model.**
 - Modify python code to export to a different model-specific output format.
- **Fully compliant with geoprocessing infrastructure so you can build automation around your specific modeling workflows (Model Builder, Python, Notebooks).**

HEC-RAS Support in Arc Hydro for Pro



HEC-RAS Preprocessing

- Export from geodatabase into sdf file

Geoprocessing

Geodatabase to SDF

Parameters Environments

Input Attributed 2D Cross Section Feature Class
RosilloXSCutLines

Input Attributed 3D Cross Section Feature Class
RosilloXSCutLines3D

Input Attributed River Feature Class
RosilloRiver

Input DEM
RosilloDEM10ft.tif

Output SDF File
I_HHModeling\Demos\Ex9\ex9exporttoras.sdf

Geometric Data

File Edit Options View Tables Tools GIS Tools Help

Tools River Reach Storage Area 2D Flow Area SA/2D Area Conn SA/2D Area BC Lines 2D Area Break Lines 2D Area Mann n Regions Pump Station RS

Editors Junct. Cross Section Brdg/Culv Inline Structure Lateral Structure Storage Area 2D Flow Area SA/2D Area Conn Pump Station HTab Param. View Picture

96270.04
95332.99
93281.25
91199.60
89971.85
86968.65
85980.57
84933.28
83262.66
81664.35
80849.95
79446.92
78379.28
76993.71
76146.25
74771.71
71535.90
68954.86
64156.18
63139.98
62499.50
60864.48
60142.98
59044.54
57495.92
56222.08
55169.39
54110.02
52529.21
50309.65
49108.07
47833.96
45789.23
43726.18
42944.01
42178.55
40952.99
37964.69
36771.36
35273.05
31669.68
29001.19
27359.82
25430.29
23570.26
22234.43
20394.46
18090.06
16247.10
12589.67
11643.62
9595.415
6552.920
3951.597
2940.484
1784.988
426.5206

Web for ArcGIS Beta 1

ver

osilloXSCutLines

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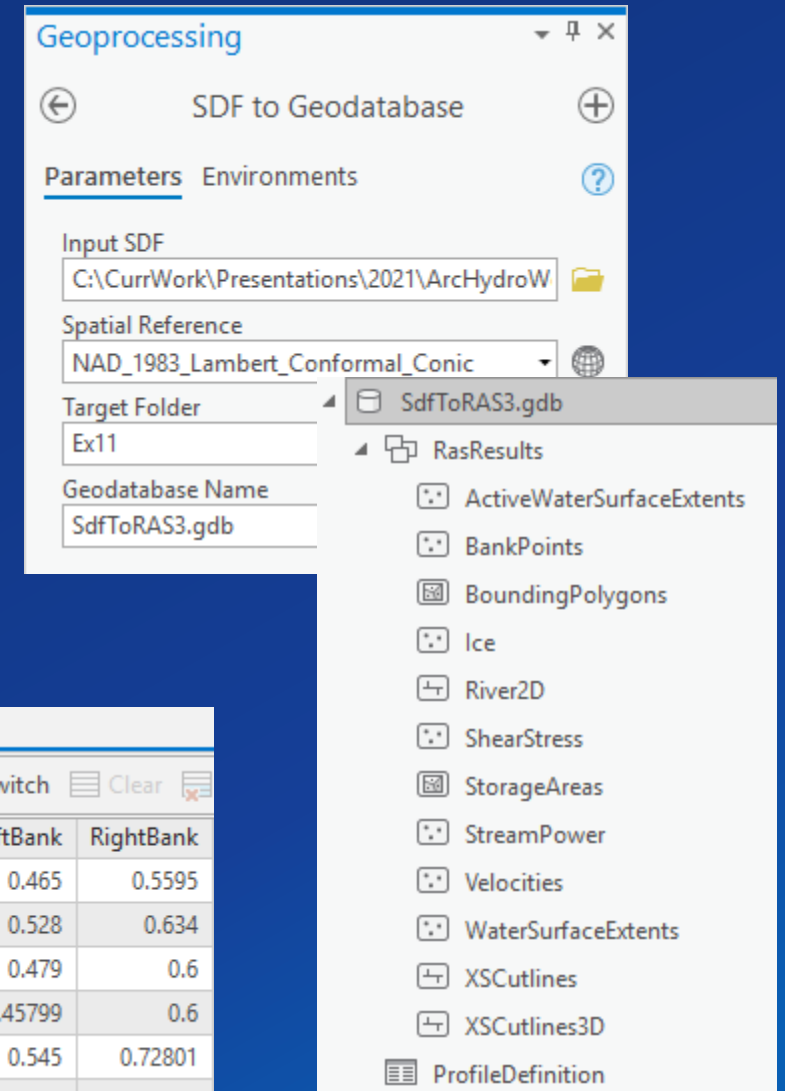
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1398.953121
607.156321
127.711921
68.802721
8.000021
6.888221
6.502921

31453.780045,
31451.979852,
31440.930005,
31432.499904,
31427.959887,
31417.609842,
31415.279794,
31412.820153,
31404.529815,
31401.830018,
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31386.149931,

2141099.67, 13873327.95

HEC-RAS Postprocessing

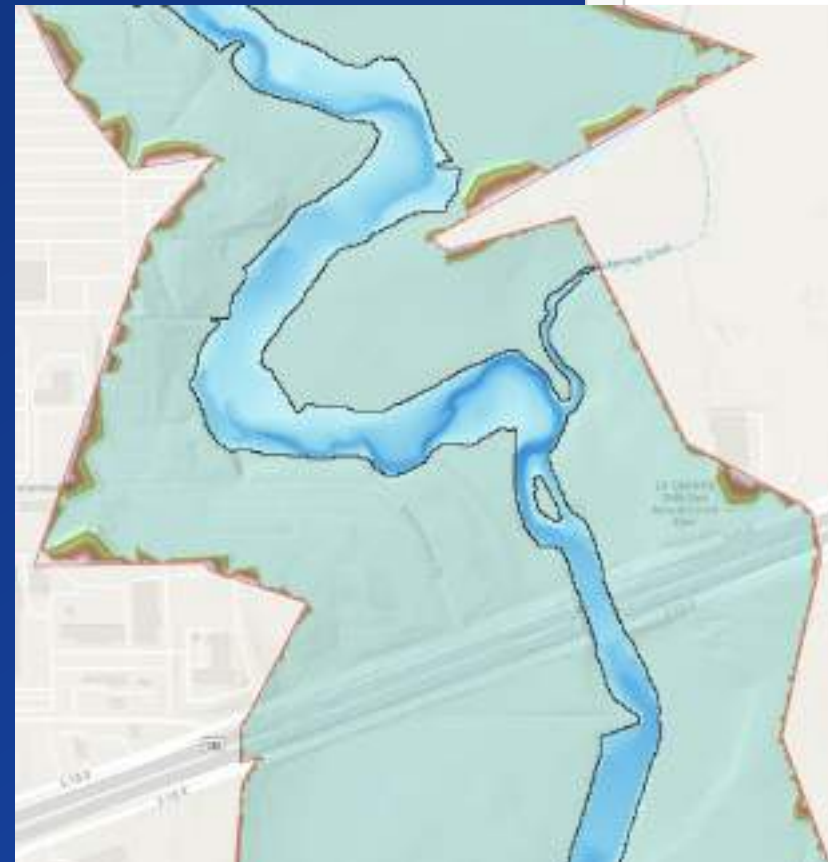
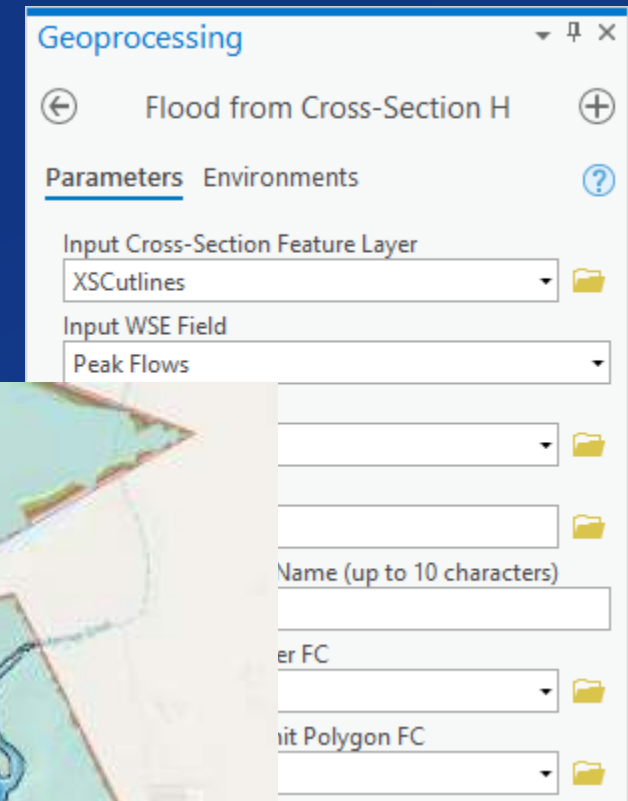
- Import from sdf file into geodatabase
 - XSCutlines
 - With WSE fields
 - River2D
 - BoundingPolygons
 - ...



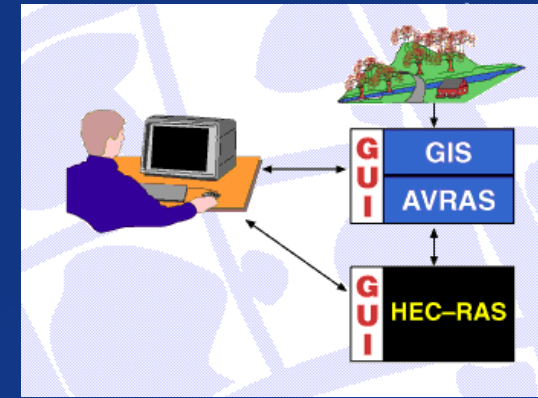
OID *	Shape *	RiverCode	ReachCode	ProfileM	Peak Flows	LeftBank	RightBank
1	Polyline	Rosillo	Upper	96270.04	755.785	0.465	0.5595
2	Polyline	Rosillo	Upper	95997.31	752.4846	0.528	0.634
3	Polyline	Rosillo	Upper	95759.74	751.8813	0.479	0.6
4	Polyline	Rosillo	Upper	95640.02	750.5233	0.45799	0.6
5	Polyline	Rosillo	Upper	95332.99	746.1621	0.545	0.72801
6	Polyline	Rosillo	Upper	95029.4	744.3393	0.498	0.622

HEC-RAS Postprocessing

- **Floodplain delineation from cross-sections**
 - Using DEM as terrain
 - Limit floodplain to directly connected areas
 - Limit floodplain to limiting polygon
- **Results:**
 - **Geodatabase:**
 - Flood polygon extents
 - **Surfaces:**
 - Depth
 - Water surface elevation



System/Integration Architecture



- Loose coupling.
- Two specific RAS tools, the rest are standard Arc Hydro tools.
 - Python export code (to ASCII file). This is different from HEC-GeoRAS that used XML and XSLT export methodology.
- You can use the same tools to support any other 1D hydraulic model.
 - Modify python code to export to a different model-specific output format.
- Fully compliant with geoprocessing infrastructure so you can build automation around your specific modeling workflows (Model Builder, Python, Notebooks).
- Adding few more functions on pre and post-processing.



Polling question

- Is integrated hydrologic and hydraulic modeling important for your work?
 - Yes
 - No
- Are you familiar with ICPR 4? (Interconnected Channel and Pond Routing Model)
 - Yes, I've used it
 - Yes, I've heard about it
 - No, I'm not familiar with ICPR 4
- Do you use real-time flow forecasting?
 - Yes
 - No
 - I know about flow forecasting but haven't used it

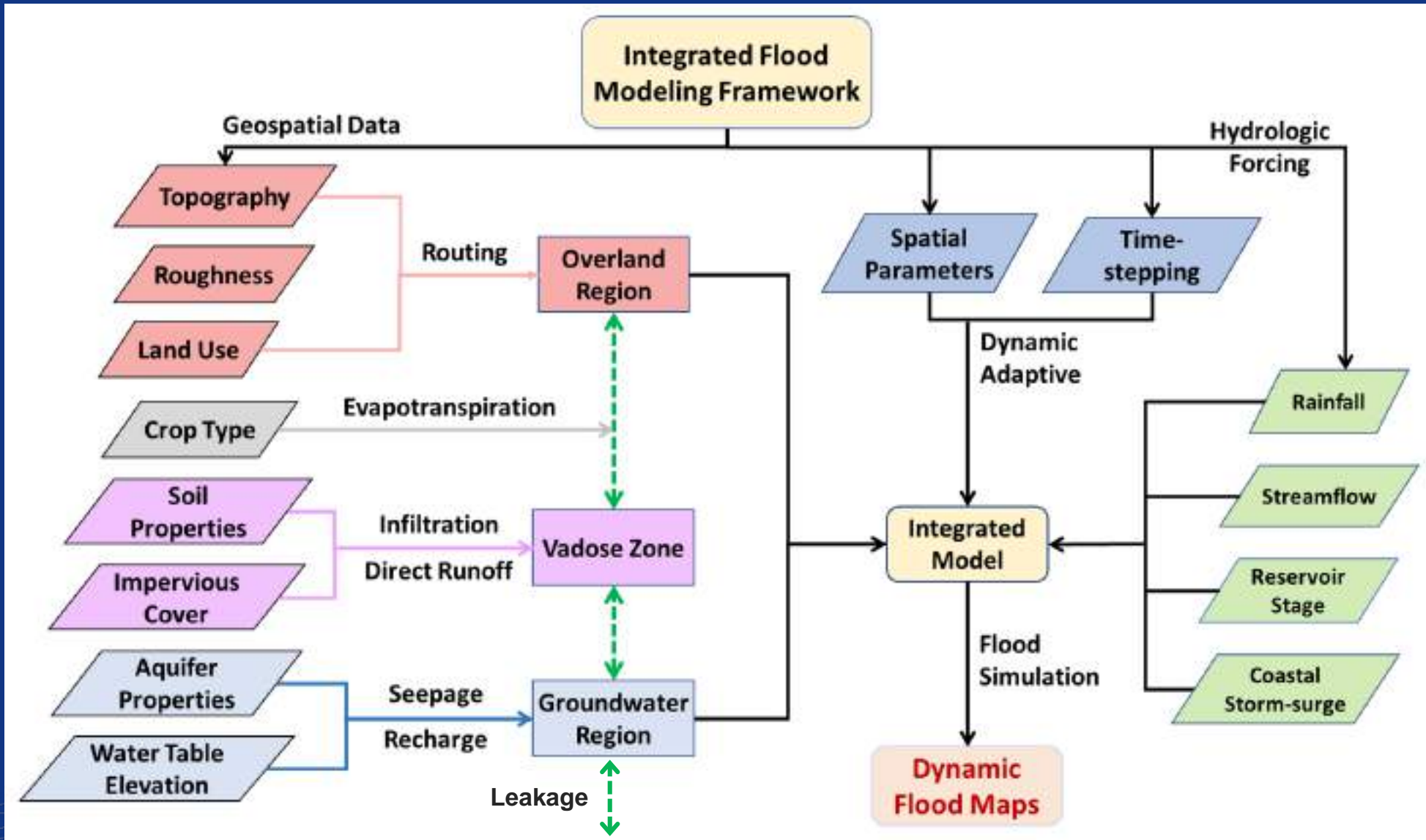
Interconnected Channel & Pond
Routing Model

ICPR4

Pete Singhofen & Warren McKinnie

ICPR4

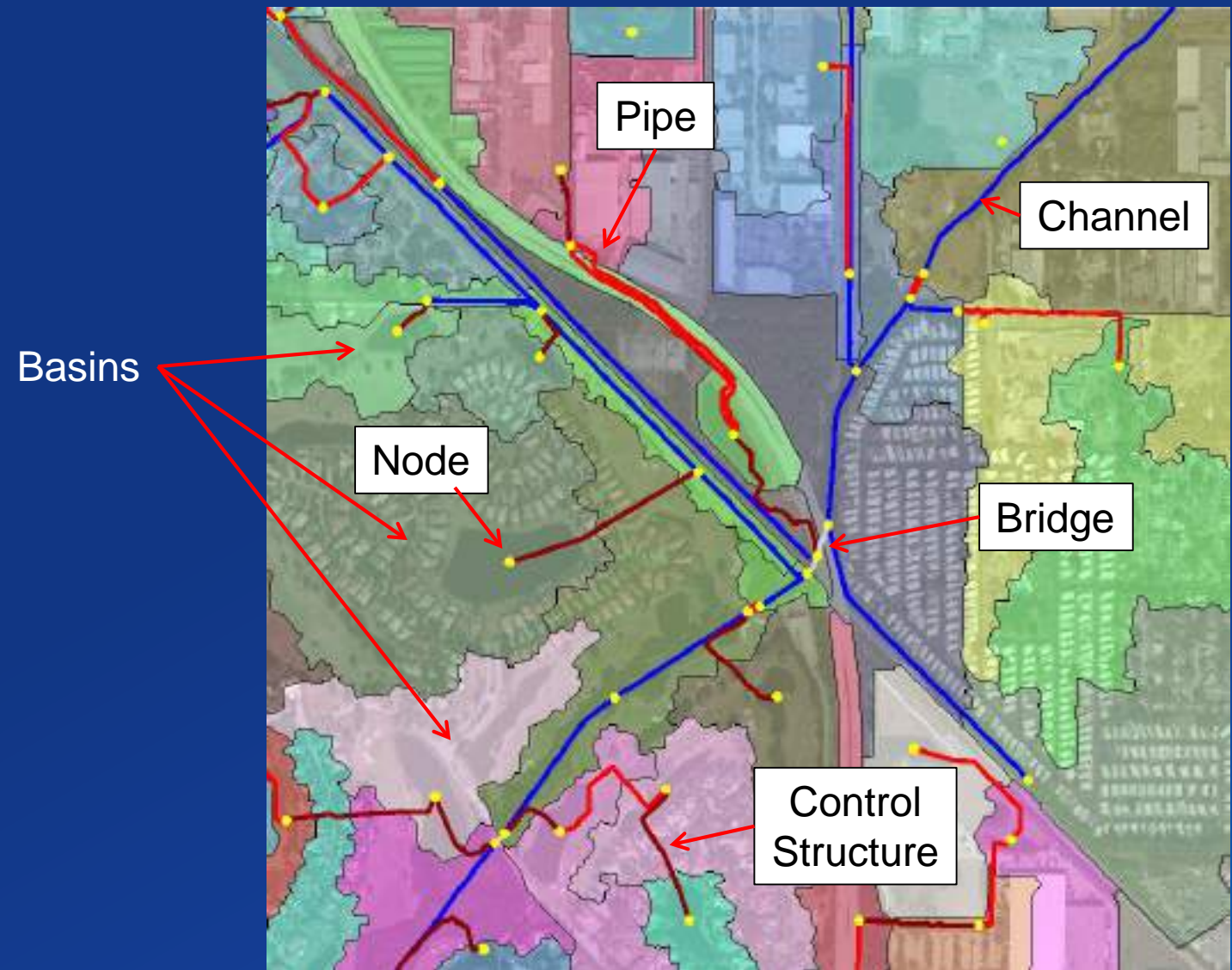
Arc Hydro



ICPR4 Building Blocks

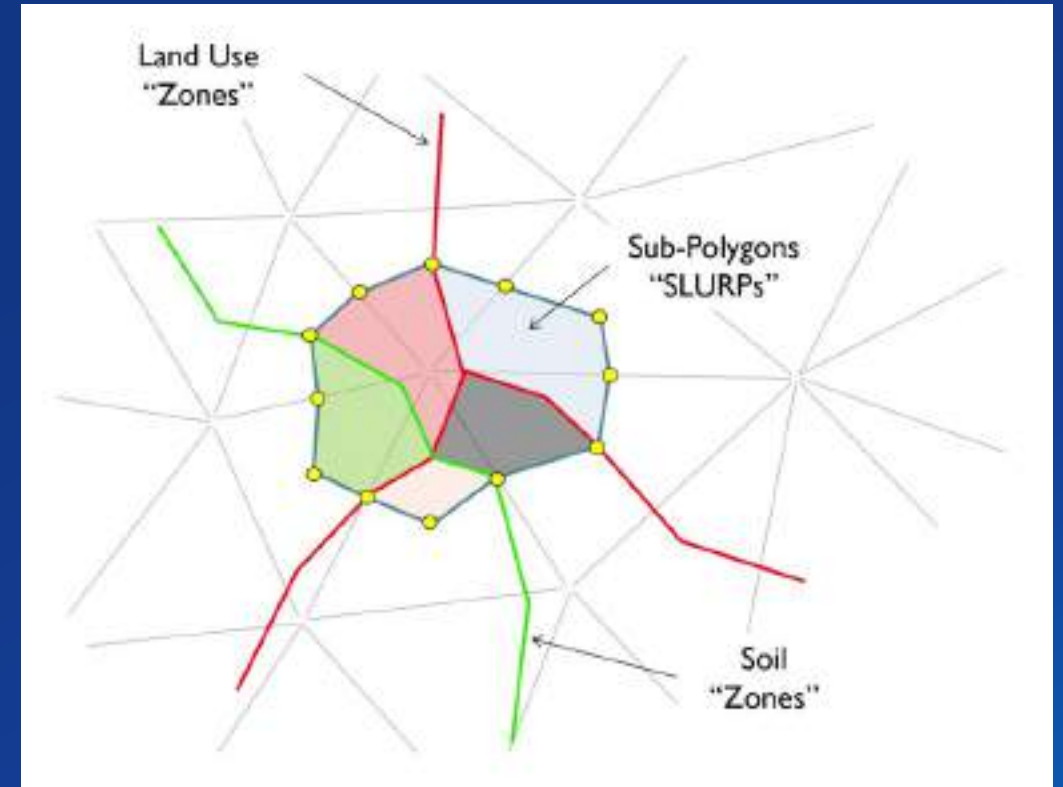
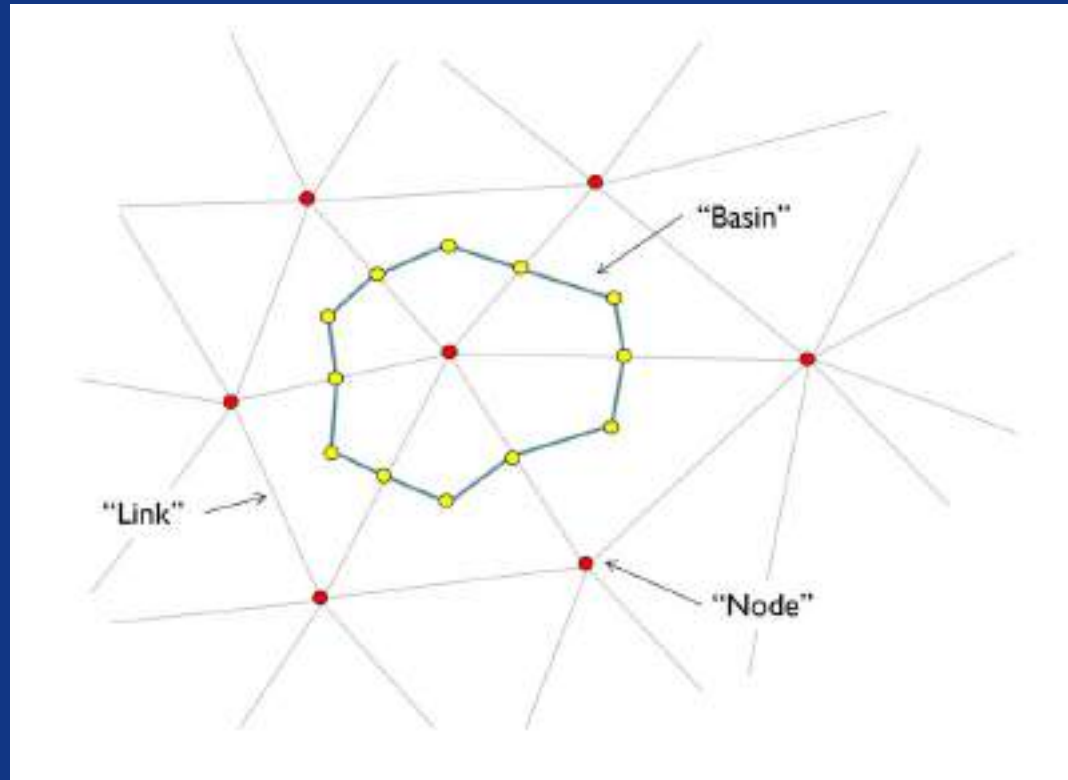
Nodes, Links, Basins

- Runoff hydrographs from “Basins” are delivered to “Nodes”
- Water surface elevations are calculated at “Nodes”
- Flows are calculated for “Links” based on WSEs at the connecting nodes



2D Overland Flow in ICPR4

Finite Volume Approach Based on Underlying
Triangular Computational Mesh



2D Overland Flow in ICPR4

Important Characteristics of a 2D Surface Model

1. Reasonably Replicate Terrain
 - a. Storage
 - b. Ridges and Valleys
 - c. Obstructions
2. Mechanisms to Interface with 1D Components
3. Boundary Condition Flexibility
 - a. Stage
 - b. External Flow

2D Graphical Elements

Exclusions...

Extrusions...

Breakpoints...

Breaklines...

Pond Control Volumes...

Channel Control Volumes...

Channels...

Weirs...

1D Node Interfaces...

Mapped Basins...

Basin Interface Points...

Basin Interface Lines...

Boundary Stage Points...

Boundary Stage Lines...

External Hydrograph Points...

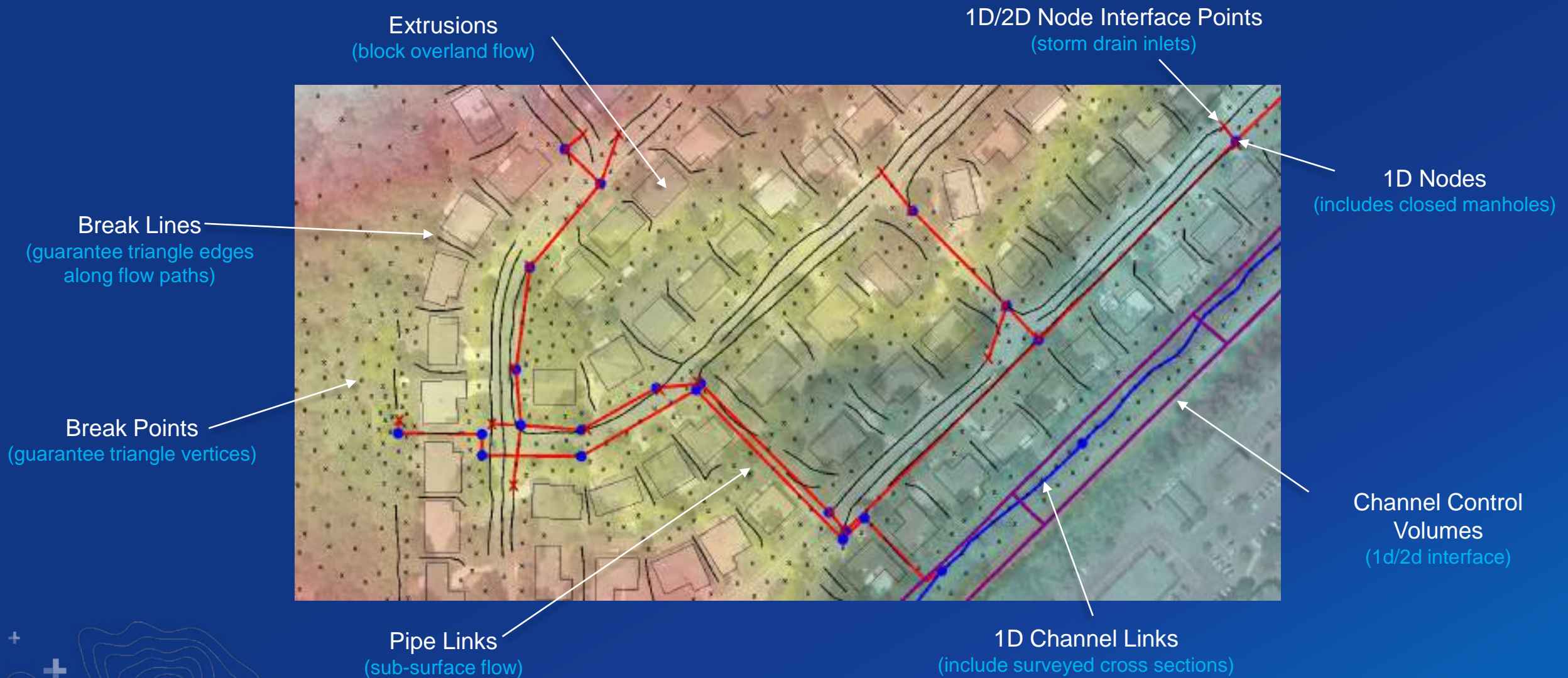
External Hydrograph Lines...

← Terrain
Characterization

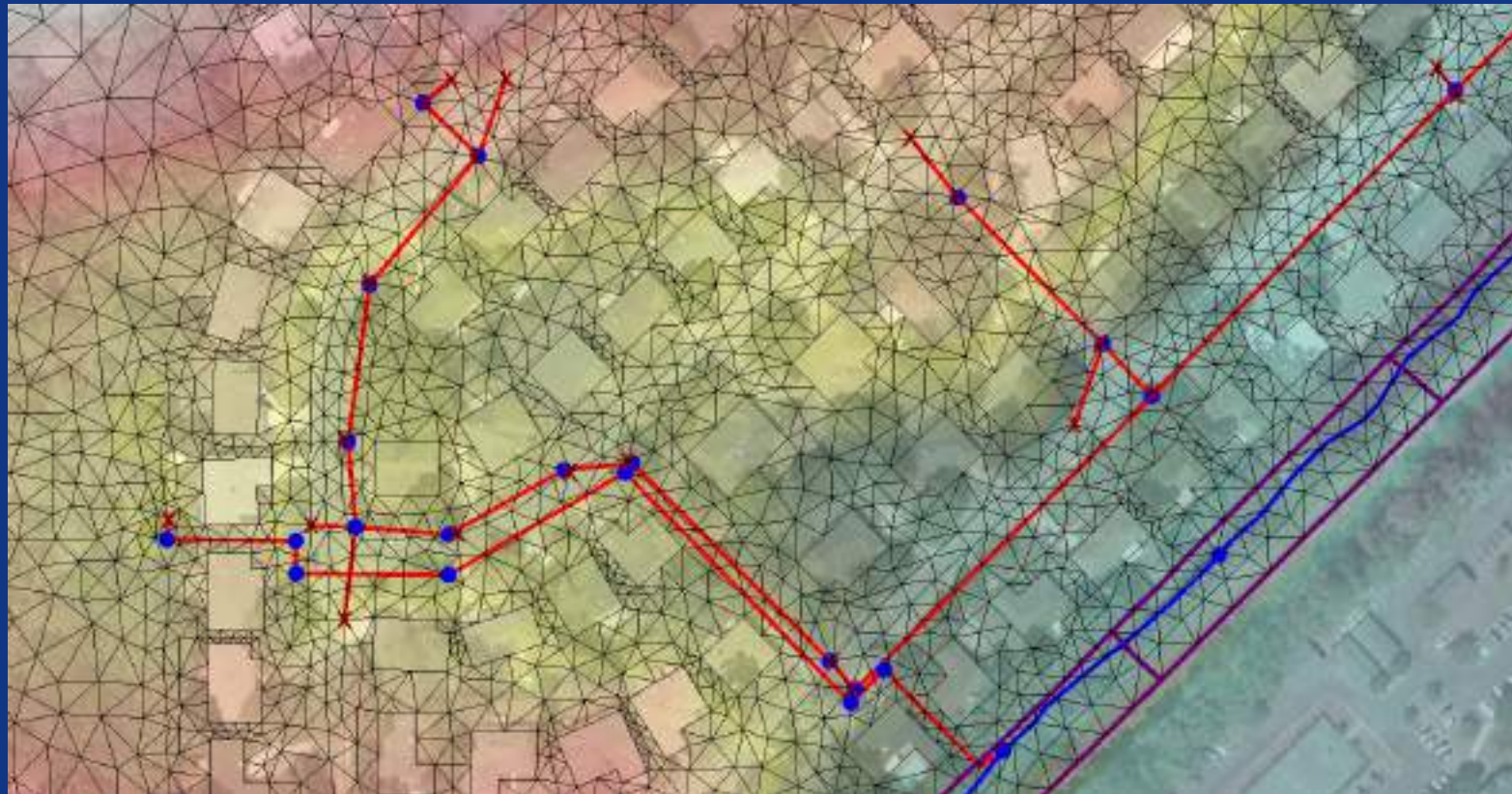
← Interface with
1D Elements

← Boundary
Conditions

2D Overland Flow in ICPR4



2D Overland Flow in ICPR4



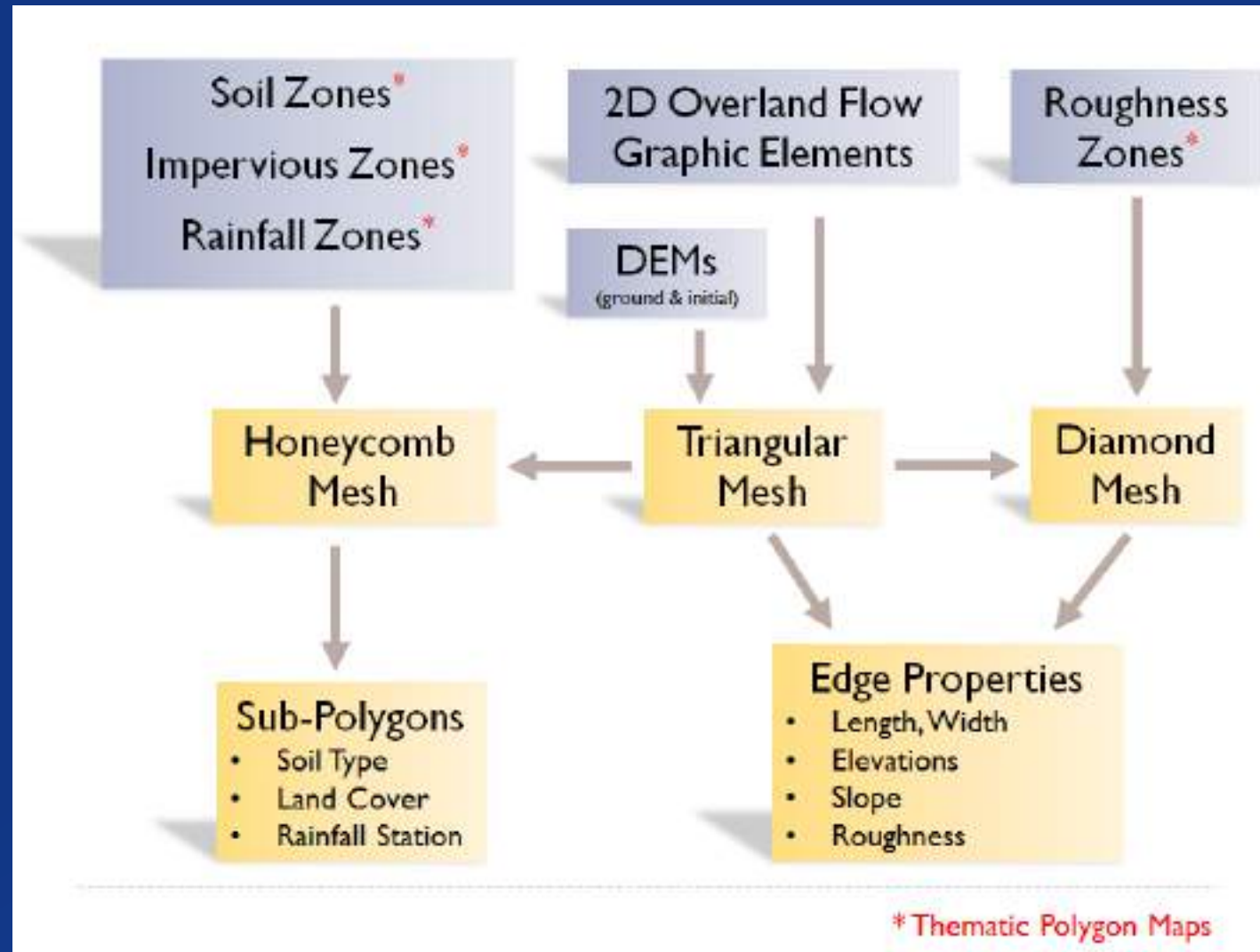
Triangular Mesh Generation

2D Overland Flow in ICPR4



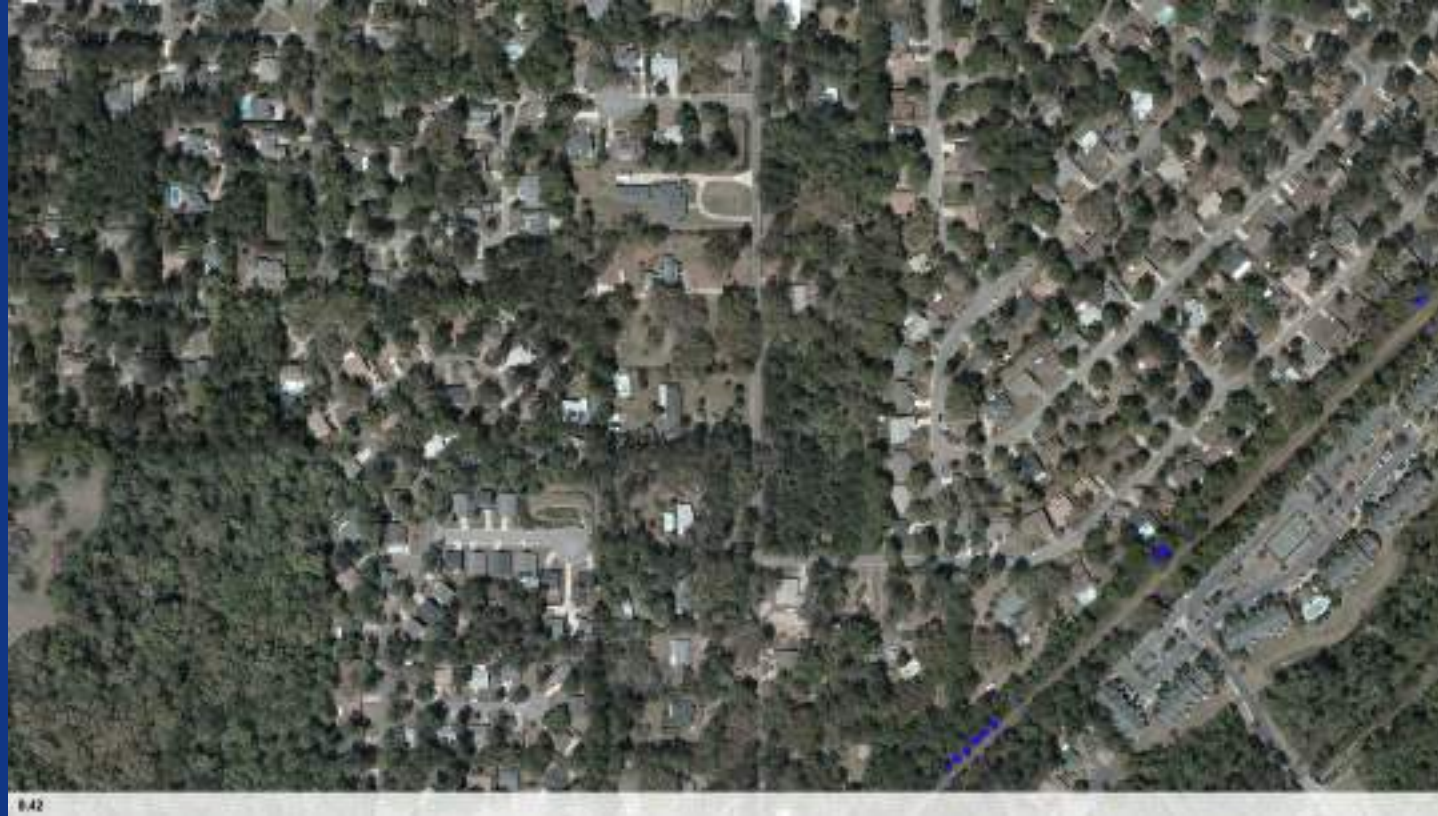
Honeycomb Mesh Generation

2D Overland Flow in ICPR4



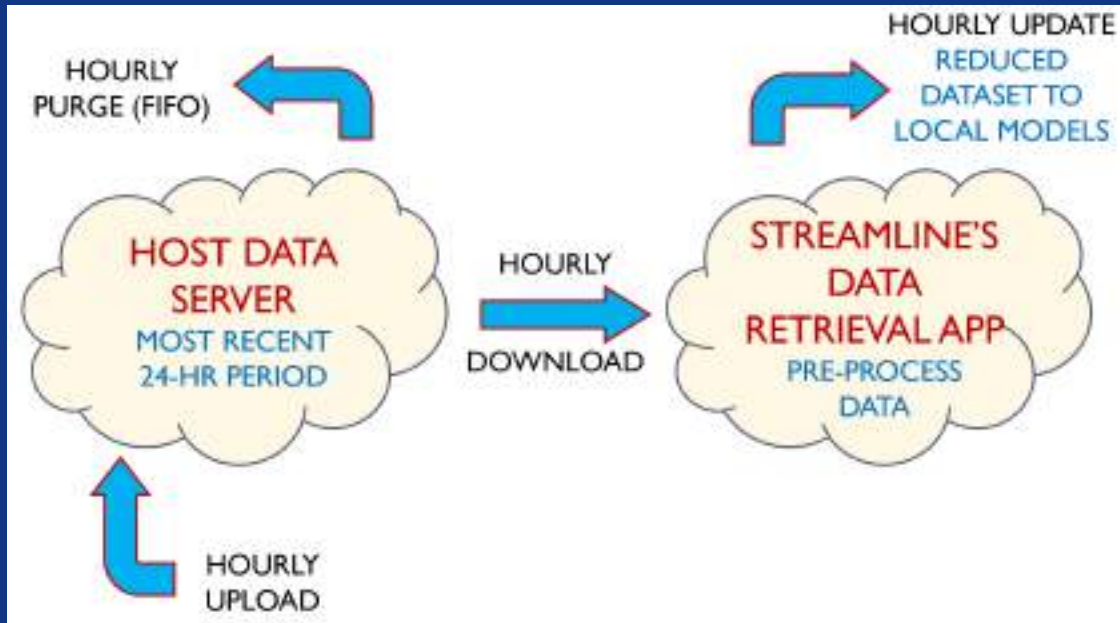
Mesh Parameterization Process

2D Overland Flow in ICPR4



100-yr 24-hr Storm
Flood Depths > 3"

Real-Time Flood Forecasting with ICPR4



National Water Model (NWM) Gridded Forcing Data Products (Rain/ET)

Near Real-Time

- Present Time Minus 1&2 Hours (Radar Only)
- Present Time Minus 3 Hours (Gage Adjusted)

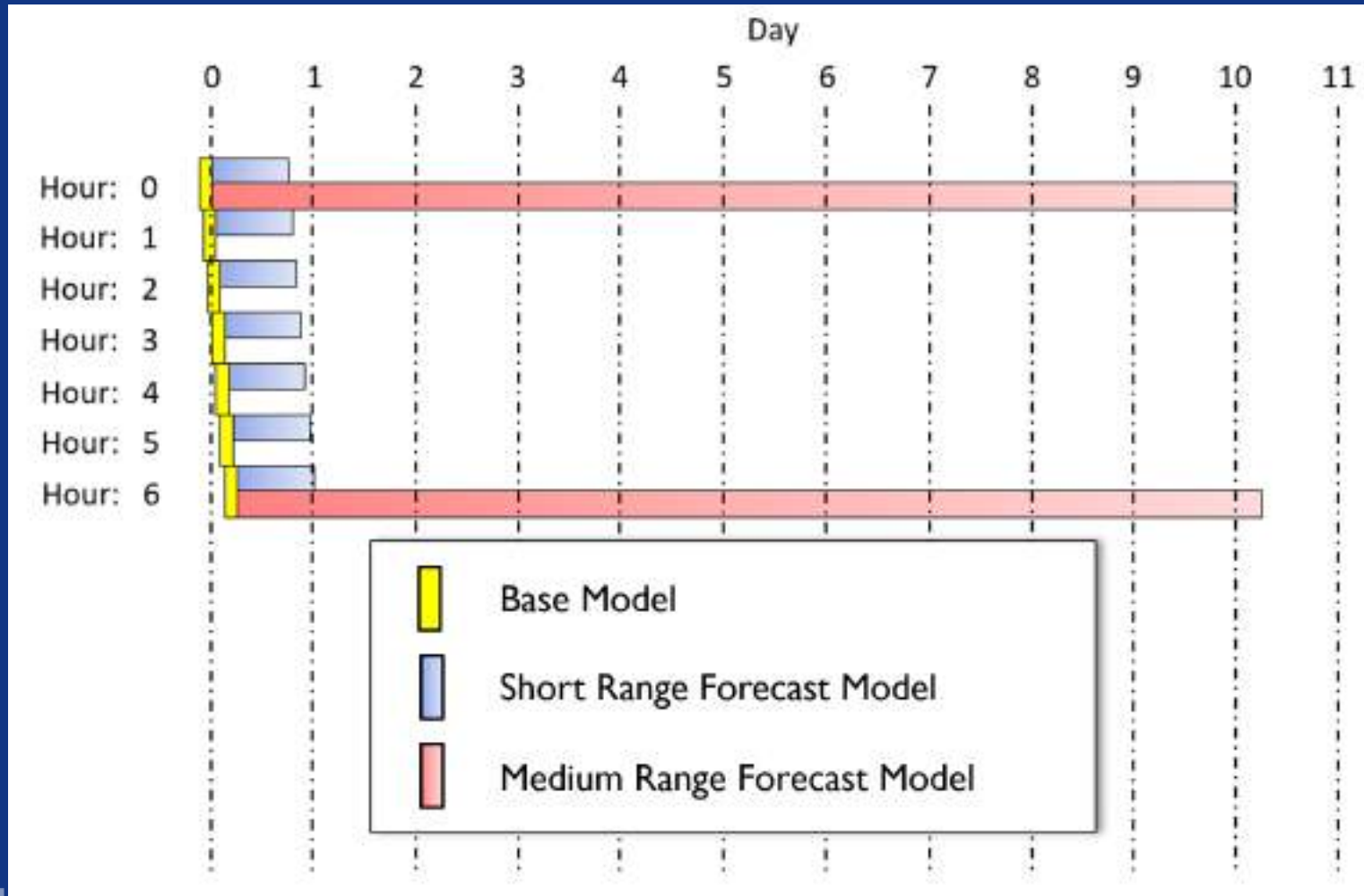
Short Range Forecast

- Forecast Duration: 18 hours in 1-hour Increments
- Forecast Frequency: Every hour

Medium Range Forecast

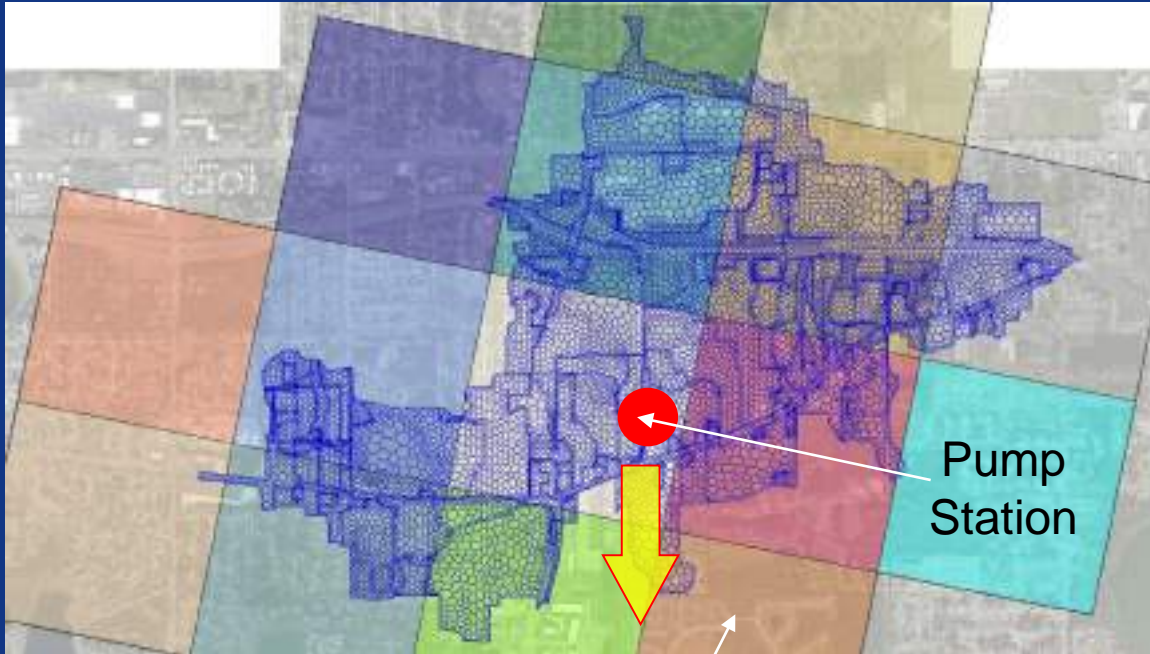
- Forecast Duration: 10 days in 1-hour Increments
- Forecast Frequency: Every 6 hours

Real-Time Flood Forecasting with ICPR4

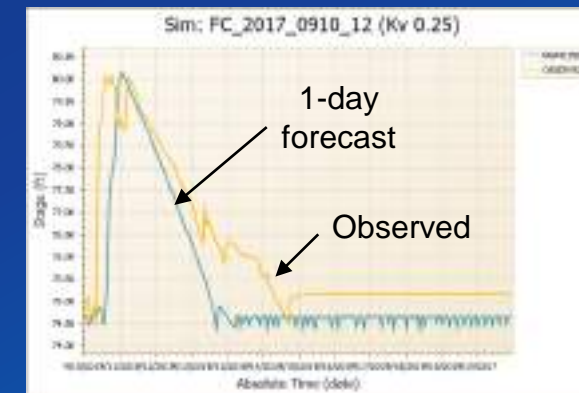
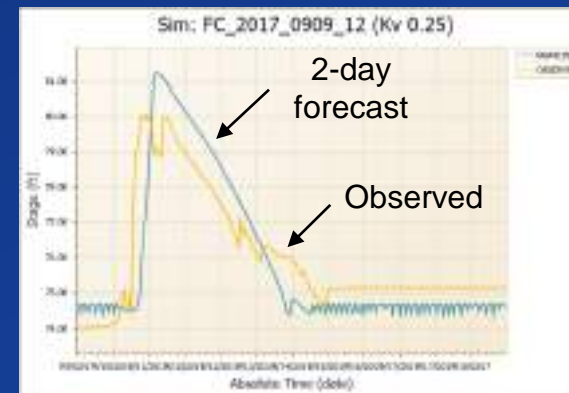
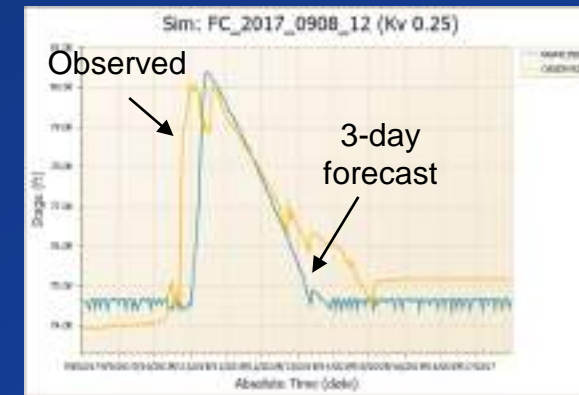
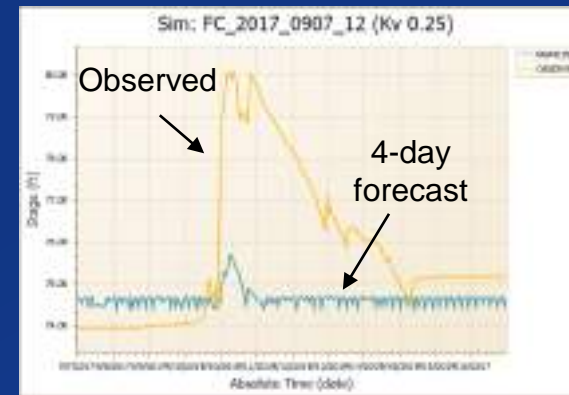
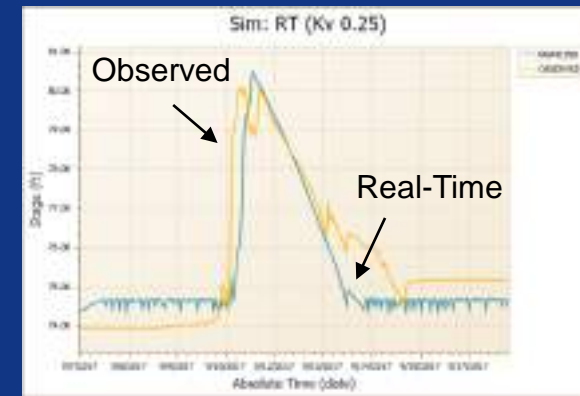


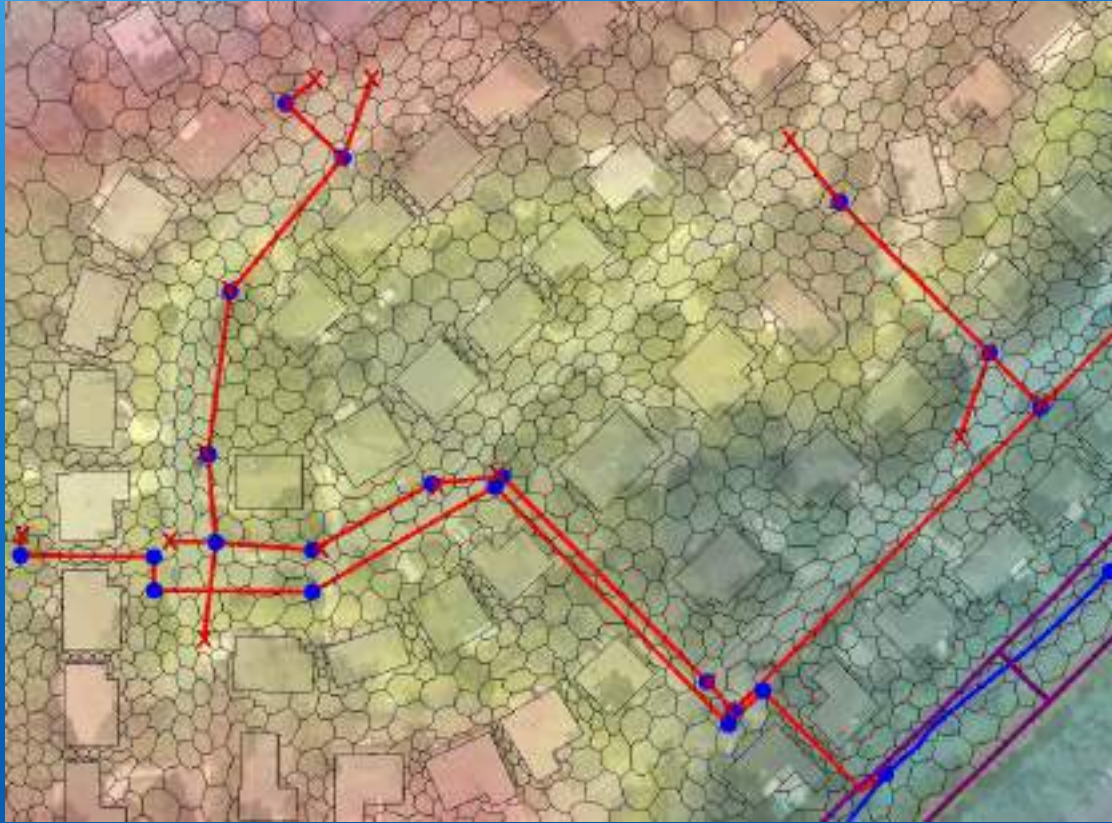
- Base model runs continuously in near real-time
- Base model maintains current surface water and groundwater levels and soil moisture conditions
- Forecasts are spawned from base model using it for initial conditions

Real-Time Flood Forecasting with ICPR4 Hurricane Irma



NWM 1-km²
Forcing Grid





GWIS/ICPR4 Demo

Final Thoughts



Final Thoughts

- **Model integration is an active area of Arc Hydro development.**
 - Let us know what you think, what you need.
- **Get involved with Arc Hydro.**
 - Use the **Community pages** to interact with each other and the Arc Hydro team.
 - More focused the better!
 - Or email us directly



Questions?



Getting involved

- [Arc Hydro Web Page](#)

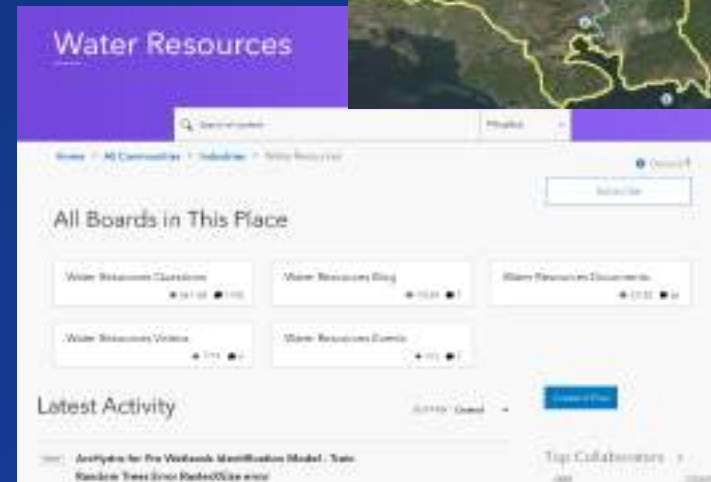


- [Water Resources Industry Web Page](#)

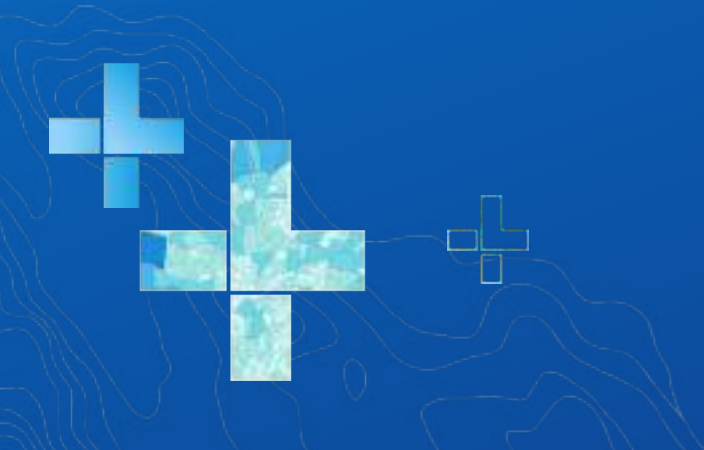


- [Arc Hydro Community](#)

- archydro@esri.com
- ddjokic@esri.com



In Closing



Announcing “Arc Hydro Office Hours”

- May 11th, 9-10 PDT. “Terrain and watershed processing in Arc Hydro”
 - <https://www.meetup.com/Esri-Water-Meetup/events/277554666/>



Tuesday, May 11, 2021

Water Resources Office Hours - Terrain & Watershed Processing in Arc Hydro

Hosted by
Christa C. and 2 others

Share

Details

Join the Esri professional services team for water resource focused office hours. Throughout 2021, Esri's hydro experts will be hosting virtual office hours to discuss common water resources workflows. During these sessions, the team will be giving a 10-minute presentation and then opening the floor up for discussion and Q&A.

May's office hour will focus on terrain and watershed processing in Arc Hydro.

These sessions are interactive, please come prepared to join the discussion.

Esri Water Meetup
Public group

Tuesday, May 11, 2021
9:00 AM to 10:00 AM PDT

Online event
Link visible for attendees

Arc Hydro in Action Webinar Series

- All webinar recordings will be available on demand.



Arc Hydro in ArcGIS Pro
Don't miss your opportunity to connect and have your questions answered by Esri's Arc Hydro expert, Dr. Dean Djokic.

Thursday, February 25, 2021
9:00 AM-10:00 AM (PST)

REGISTER TODAY!

This banner features a background image of a river flowing through a green, hilly landscape. The bottom portion of the banner shows a colorful topographic map overlay. The text is white and red, providing the title, description, date, time, and a call to action.

Arc Hydro: Flooding & Forecasting
Don't miss this opportunity to learn about Arc Hydro hydraulic capabilities from Esri's hydro expert, Dr. Dean Djokic.

This banner features a background image of a river flowing through a green, hilly landscape. The text is white, providing the title and description.

Arc Hydro: Hydrology & Hillslope
Don't miss this opportunity to learn from Esri's hydro experts and special guests Dr. Dana Lapides & Anneliese Sytma.

Thursday, March 25, 2021
9:00 AM-10:00 AM (PST)

REGISTER TODAY!

This banner features a background image of a river flowing through a green, hilly landscape. The bottom portion of the banner shows a colorful topographic map overlay. The text is white and red, providing the title, description, date, time, and a call to action.

Arc Hydro: Support for Hydrologic and Hydraulic Modeling
Join Esri's hydro expert, Dr. Dean Djokic, to learn what GIS can do for integrated hydrologic and hydraulic modeling.

Thursday, April 15, 2021
9:00 AM-10:00 AM (PST)

REGISTER TODAY!

This banner features a background image of a river flowing through a green, hilly landscape. The bottom portion of the banner shows a colorful topographic map overlay. The text is white and red, providing the title, description, date, time, and a call to action.

THANK YOU!



Pete
Singhofen



Gina
O'Neil



Warren
McKinnie



Anneliese
Sytsma



Dana
Lapidés



Christa
Campbell



Mariah
Salazar



Christine
Dartiguenave