Floodplain Modeling 101

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Presentation Goals

- Introduction to Indiana's and FEMA's floodplain modeling technical requirements for riverine modeling
- Provide locations for resources with additional guidance regarding floodplain modeling
- If time allows explore a few HEC-RAS example models

What is a Floodplain Model?

- Floodplain – an area of low, flat land along a stream or river that may flood
- Model – a system of data and inferences presented as a mathematical description of circumstances

Why do you Perform a Floodplain Analysis?

- To determine a Base Flood Elevation (Regulatory Flood)
- To determine Floodway limits
- To determine impacts of a proposed project

Typical Programs used for Floodplain Modeling

- FEMA
  - HEC-RAS (Most Common)
  - HEC-2
  - WSPRO
  - XP-SWMM
    - Limited applications

What is Needed to Model a Floodplain?

- Previous Models
- Geometry
- Flowrates (We are looking at steady flow only)

- If submitting to FEMA or IDNR
  - Must be a licensed Engineer or Surveyor directing the work

Previous Models / Revisions

- Local
  - Counties, Towns & Cities
- State
  - IDNR (Floodplain Information Portal)
  - http://www.in.gov/dnr/water/5647.htm
- Federal
  - Engineering Library (fee charged)
  - http://fema.maps.arcgis.com/home/index.html

Why are Previous Models Needed?

- Downstream tie in
- Upstream tie in
- Contain Effective, Corrected Effective, and or Existing Conditions modeling
  - Base conditions are very important for evaluating proposed projects

When a published detailed FIS/LOMR model or an unpublished IDNR Regulatory Model does not exist, a base condition hydraulic model meeting the IDNR requirements must be produced and submitted. Base conditions are defined by the Floodplain Management Rules as the physical situation (including stream crossings) existing on January 1, 1973. The model of base conditions is used to define the regulatory floodway. If the topography that existed on January 1, 1973 cannot be reasonably determined, then the best available mapping should be used to develop the base model.

What Types of Models Are there?

- Effective
  - FIS Panel modeling
  - There could be a variety of digital model types (HEC-RAS, HEC-2, WSPRO, ETC.)
- Duplicate Effective
  - If a digital Effective model is available this is the conversion of that model to your computer
  - This includes conversion of modeling input data (conversion tools available)
    - Can be done by hand as well
  - Errors not fixed, you just get it to run on your machine
- Corrected Effective (Typically Base Condition)
  - Fixes errors from Duplicate Effective model
  - Model where additional geometry is placed
  - ***Must not reflect man-made physical changes since the date of the Effective model
- Existing / Pre-Project
  - Updates Corrected Effective model to include changes since the Effective model was established
- Post Project (If needed)
  - Updates Existing model with a specific project

PROJECT EVALUATION TABLE
HYDRAULIC MODELING RESULTS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
LOCATION DESCRIPTION		PUBLISHED OR EFFECTIVE DATA (Ft, NGVD) (Based on FIS Table or Profile)	MODELING RESULTS				COMPARISONS			NOTES
Model Cross Section Station	Location Description		Duplicate Effective Model (Ft, NGVD)	Corrected Effective Model (Ft, NGVD) (model name)	Existing-Conditions Model (Ft, NGVD) (model name)	Proposed-Conditions Model (Ft, NGVD) (model name)	Cumulative Impacts w/o Project (ft) (6) - (5)	Cumulative Impacts with Project (ft) (7) – (5)	Project Impacts (ft) (7) – (6)	
	D/S end of study reach						-	-	-	
							-	-	-	
							-	-	-	
							-	-	-	
							-	-	-	
	property limit						-	-	-	
							-	-	-	
							-	-	-	
	example bridge						-	-	-	
							-	-	-	
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	property limit						-	-	-	
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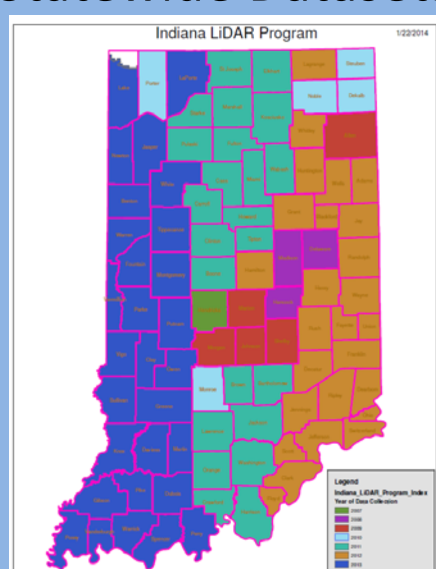
							-	-	-	
	U/S end of study reach						-	-	-	

Where do you Obtain Geometry

- Previous Modeling
- Statewide datasets
- Site specific Surveys
- Personnel site visits

Statewide Datasets



Important Considerations for Statewide Datasets

For floodplain modeling, it is very important to note that the LiDAR technology is not capable of determining elevations under water. Therefore, in such situations, use the LiDAR data with caution. If elevations of the stream bottom are known, then this information should be used to enhance the geometry in the hydraulic model. For small streams with very little water during the LiDAR data capturing process, the stream bottom elevations that are derived from LiDAR may be acceptable, but there may be limitations in determining channel dimensions because of the DEM pixel size in comparison to the channel. For larger streams, site survey or bathymetric methods should be investigated and incorporated into the hydraulic model as necessary.

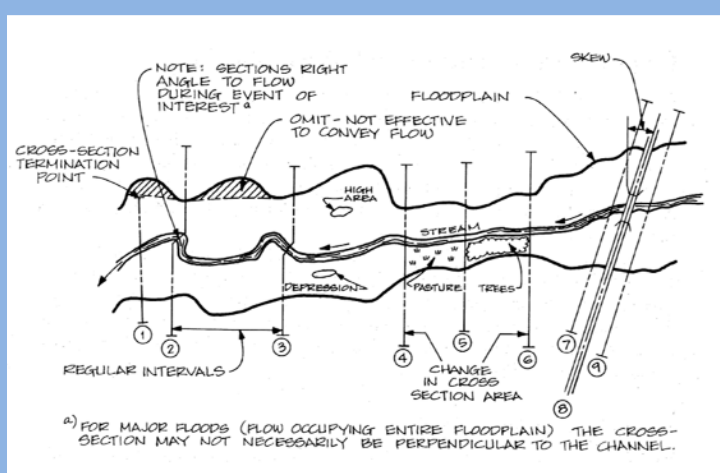
Important Things about Geometry

- Over document information
  - Document inside model
  - Document in paperwork
  - Document on mapping
- Document Vertical Datums
  - NAVD 88 (preferred)
  - NGVD 29
- Document Horizontal Datums
  - Remember some open data may be in metric when initially downloaded
- Do a double check of information
- More information is better than less

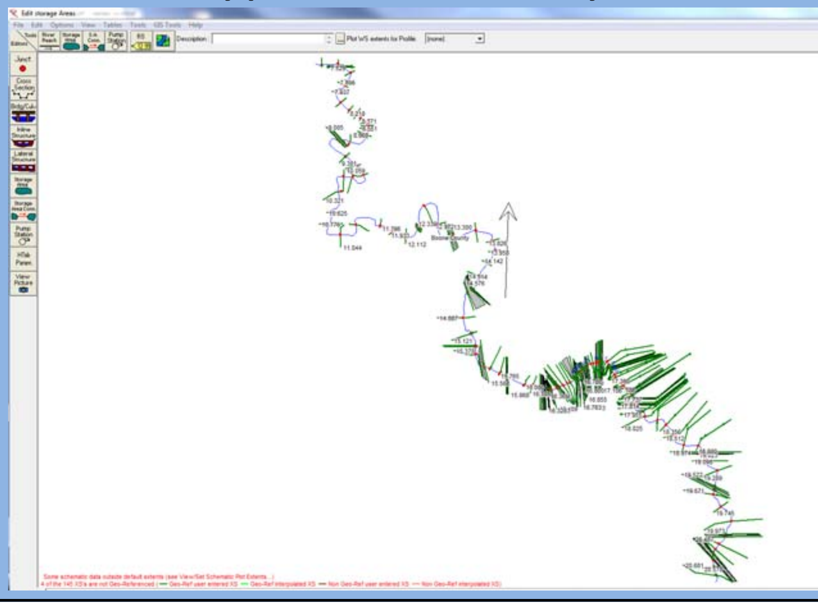
Important Considerations for Geometry

- River Sections are numbered from downstream to upstream (river miles preferred)
  - There is likely a numerical system already in place…USE IT!!!!
- Cross-Sections should never cross
- Include average conditions, but also point constrictions
- Multiple cross-sections at crossings
- Cross-Sections need to extend for the entire 100-year floodplain (full valley cross-section)
- Stationing on Cross-Sections is done left to right looking downstream
- Show starting points of Cross-Section stationing
- Place Cross-Sections where things change (slope, vegetation, buildings width, etc.)
- Within report and model document how the streambed portion of the cross-section was defined.
  - Is it different than contours (site specific survey?)
- Take photos and document vegetation for friction values of overbank areas and channel
- If you are submitting model to FEMA, Engineer will be required to sign and stamp crossing surveys

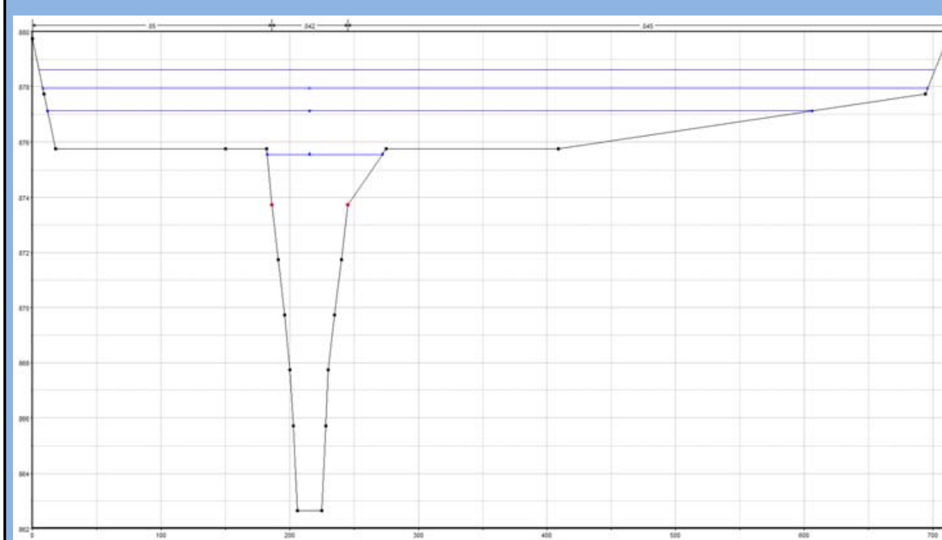
How to layout Cross-Sections



Typical Geometry

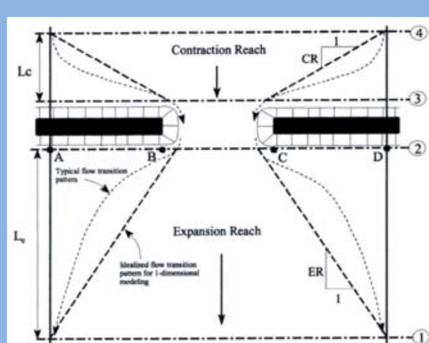


Typical Geometry



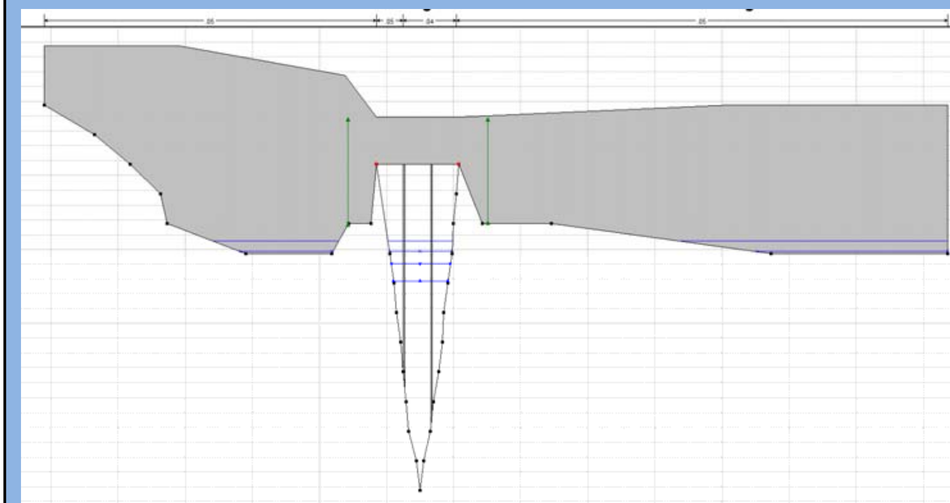
How to Survey Crossings

Cross-Sections at a Crossing



- 4 Cross-Sections required at a Crossing
- Typical contraction ratio 1:1
- Typical expansion ratio 2:1
- Make sure section 2 & 3 are on valley not on road fill
- Be sure to survey roadway section between 2 & 3
- Coefficients of contraction and expansion (0.3 & 0.5 respectively)
  - Non-Crossing areas typically 0.1 & 0.3
- Ineffective flow likely

Typical Bridge



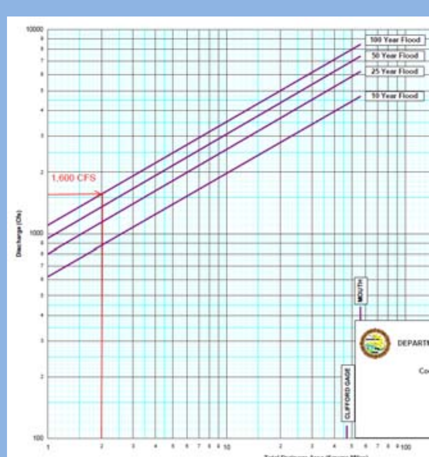
Friction Value Determination (Manning's n-Values)

- Remember you shouldn't change base condition n-Values without **SIGNIFICANT** justification
- Use HEC-RAS Reference Manuals
- Use aged or average conditions
- USGS Paper 2339
  - http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/16/stelprdb1044196.pdf
  - Shows pictures of typical n-values for wooded floodplains
- n-Values may change under bridges (less vegetation, riprap?)
  - Show with internal bridge cross-sections

Where do Flowrates Come From?

- Coordinated Discharges
- Previous Studies / Modeling
- IDNR Request
- Acceptable hydrologic models
  - TP 40 (NRCS Type B 6-Hour or Type II 24 Hour)
  - Critical Duration Methods
    - Bulletin 71 (Huff-Angel) Illinois State Water Survey Bulletin
    - NOAA Atlas 14
  - IDNR will not accept a discharge that is based on the effect of detention basins
    - Flood Control Structures approved under IC 14-28-1-29 may reduce discharges
    - Caveat for restrictive stream crossing such as Railroad grade (case by case basis)
- Engineering judgment used
- It is suggested to review several methods and select the most appropriate methodology for your particular circumstances
- Get the watershed right…Very important on smaller streams

Coordinated Discharge Graph



- http://www.in.gov/dnr/water/4898.htm
- Not every stream has a coordinated discharge graph
- If they do not appear to apply, you may need to perform a hydrologic model

Statement of Difficulty for Defining Hydrologic Response

In Indiana, watershed hydrologic response varies greatly depending on location. For example, runoff from a watershed in northern Indiana's "lake country" is dramatically different than a watershed in the rolling hills of the southeastern part of the state. These response differences impact assessment of watershed hydrology in many different ways. For example, when using the NRCS unit hydrograph method, the default unit hydrograph shape is typically not adjusted for the type of terrain or for storage in a watershed. Therefore, the engineer must fully understand the limitations of the methodology used for determining a discharge and the implications for properly applying it to the watershed and its location.

In the science of hydrology there are uncertainties and limitations for any method chosen for the estimation of peak discharges and runoff volumes for a watershed. Evaluation of the rainfall-runoff characteristics of a watershed, especially for rare frequency storms, is extremely complex with many interrelated variables, and existing data are typically too sparse and limited to provide the resulting degree of accuracy involved in many other engineering disciplines. When IDNR determines discharges, many different methods are used to estimate peak discharges and runoff volumes. Consequently, experience and engineering judgment are necessary aspects of making a final determination. Good engineering practice rarely includes one method to obtain a "final answer" for a discharge. Instead, challenge the results by applying other methods, running sensitivity analyses, and/or evaluating other similar watersheds where more information may be available.

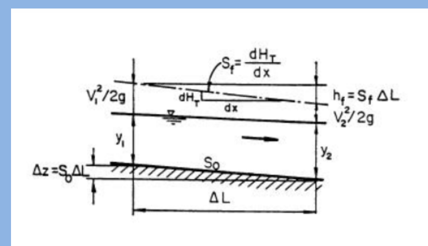
Many engineers use a hydrologic modeling program, such as HEC-1, HEC-HMS, or Technical Release 20 (TR-20) to determine discharges for a watershed. While these programs can be very complex and require detailed input data, the results only represent a "well worked out opinion," rather than an absolute answer. The results from these widely used models should be carefully evaluated to ascertain if assumptions inherent in the models adequately reflect the particular system being modeled.

Running HEC-RAS

- Standard Step Backwater method
  - Requires Boundary Condition
    - Elevation of 1% flood
    - Slope of Hydraulic Grade Line
  - "subcritical" flow typical
  - Extents must be downstream enough of the site in question
    - $L=150HD^{0.8}/S$
    - HD (Average Hydraulic Depth)
    - S (Slope per 100 feet)

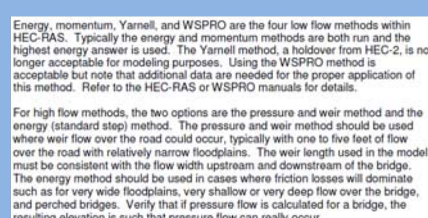
What does Standard Step Backwater Method Mean?

- Backbone of most Floodplain calculations
- Starts from known elevation
- Energy Equation
- Can be done by hand
- Recommend performing a few easy calculations to familiarize yourself with it
- Don’t ask me to do it now



Calculations through Crossings

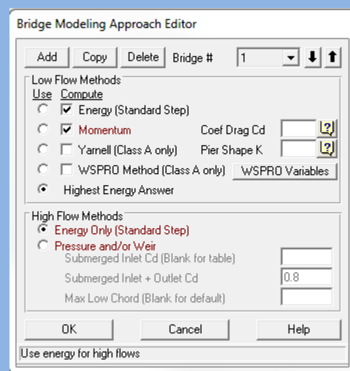
- 4 methods available within HEC-RAS for low flow (not overtopping roadway)
  - Only 3 recommended
  - Each will give you slightly different answers
- 2 methods for high flow (overtopping road) available



Energy, momentum, Yarnell, and WSPRO are the four low flow methods within HEC-RAS. Typically the energy and momentum methods are both run and the highest energy answer is used. The Yarnell method, a holdover from HEC-2, is no longer acceptable for modeling purposes. Using the WSPRO method is acceptable but note that additional data are needed for the proper application of this method. Refer to the HEC-RAS or WSPRO manuals for details.

For high flow methods, the two options are the pressure and weir method and the energy (standard step) method. The pressure and weir method should be used where weir flow over the road could occur, typically with one to five feet of flow over the road with relatively narrow floodplains. The weir length used in the model must be consistent with the flow width upstream and downstream of the bridge. The energy method should be used in cases where friction losses will dominate such as for very wide floodplains, very shallow or very deep flow over the bridge, and perched bridges. Verify that if pressure flow is calculated for a bridge, the resulting elevation is such that pressure flow can really occur.

HEC-RAS Bridge Modeling Approach Editor



Delineating a Floodplain

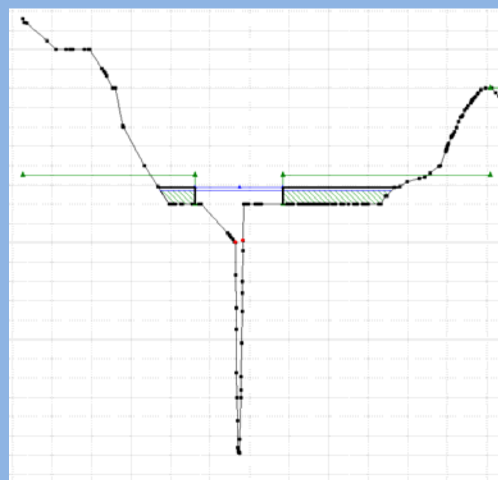
- Based on Elevation
- Stationing in Model Cross-Sections needs to match Stationing on Map
- Base Flood Elevations between sections are generally sloped
  - If there is a large elevations jump between sections without a crossing consider additional sections
  - There could be something wrong
- Be careful with interpolated cross-sections
  - They become difficult to justify

Delineating a Floodway

- Base on 100-year Peak
- Use Method 4 (equal conveyance reduction)
  - This is an automatic application within HEC-RAS
- Import to Method 1
  - This allows individual adjustment
  - Smooths floodway
  - Avoid Hourglass effect
  - Maximum surcharge of 0.14 for Indiana
  - Stationing of floodway encroachments from model must match what is shown on the map

Typical Floodplain / Floodway Map

Typical Floodplain / Floodway Cross-Section



Checking HEC-RAS

- Look for areas defaulting to critical depth
- Don't be afraid to add additional sections
- Look for weird data in your cross-sections
  - Too many points
  - Ridges
  - Areas that may need ineffective flow
  - Does your valley section contain the entire flow
- Bridges and Culverts sometimes can default to critical depth
  - Double check the data
  - Consider additional sections
  - Are ineffective flows appropriately considered?
    - Turn them off and see if it runs appropriately
- Run Check-RAS
  - Troubleshoot comments
  - Justify or modify
  - Rerun
  - Repeat as needed

I love this…Give me some more

- Most are 3 days
- Local
  - Rose Hulman Institute of Technology in conjunction with ASCE & INAFSM
    - Occurs roughly every 2 years
- National
  - Various colleges and institutions of higher learning
  - ASCE
  - ASFPM

References Noted

- Coordinated Discharge Graphs (State of Indiana)
  - http://www.in.gov/dnr/water/4898.htm
- USGS Paper 2339
  - http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/16/stelprdb1044196.pdf
- IDNR (Floodplain Information Portal)
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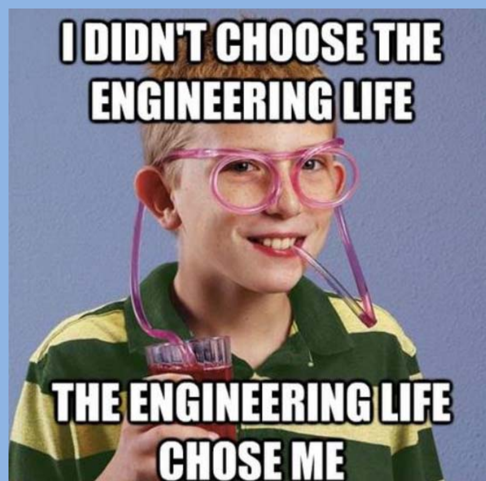
- Federal Engineering Library (fee charged)
  - http://fema.maps.arcgis.com/home/index.html
- USACE Hydrologic Engineering Center
  - http://www.hec.usace.army.mil/
- FEMA MT-2 Forms (Letter of Map Revision)
  - https://www.fema.gov/mt-2-application-forms-and-instructions

Questions


I DIDN'T CHOOSE THE
ENGINEERING LIFE
THE ENGINEERING LIFE
CHOSE ME