Calibrating a Steady Flow Hydraulics Model

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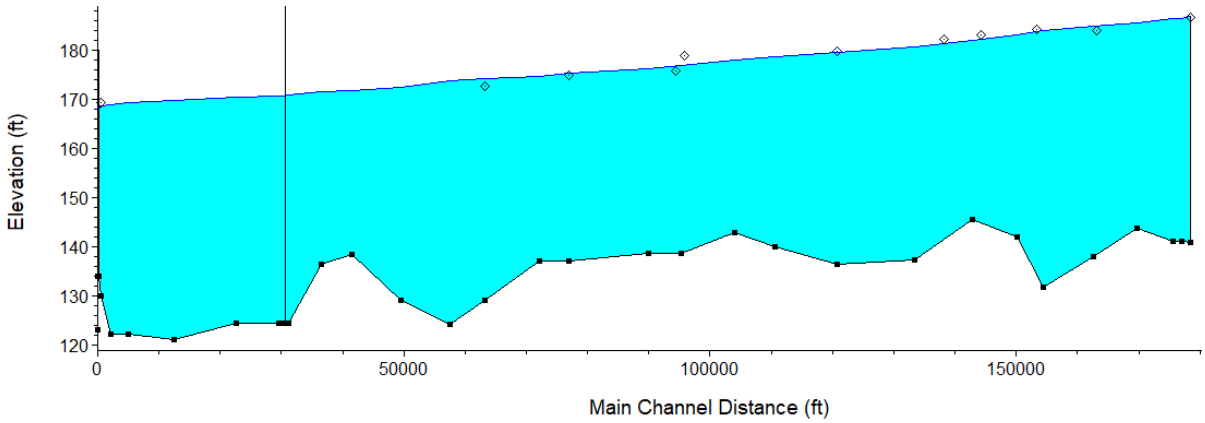
1

Calibration: A Definition

Calibration: adjusting uncertain model's parameters (e.g. roughness, ineffective flow areas, and hydraulic structure coefficients), *within reasonable ranges*, reproduces observed data to an acceptable accuracy.



Identifying Calibration Parameters

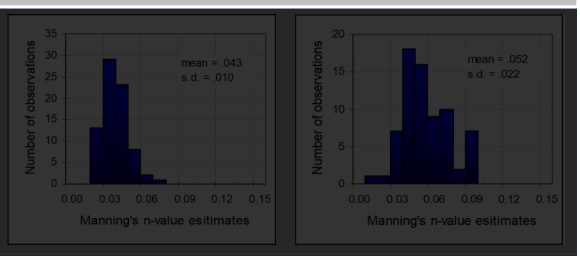
	Low Uncertainty	High Uncertainty
Low Sensitivity		
High Sensitivity		**Calibration Parameters**

3

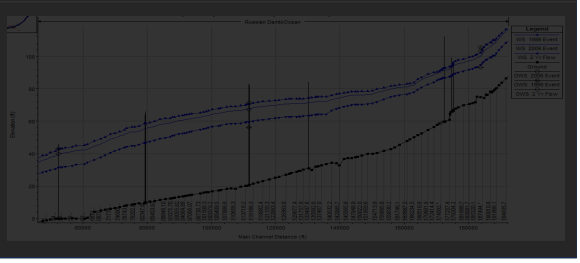
3

Evaluation Metrics

Adjustable Data/Parameters



Calibration Tools & 11 Steps



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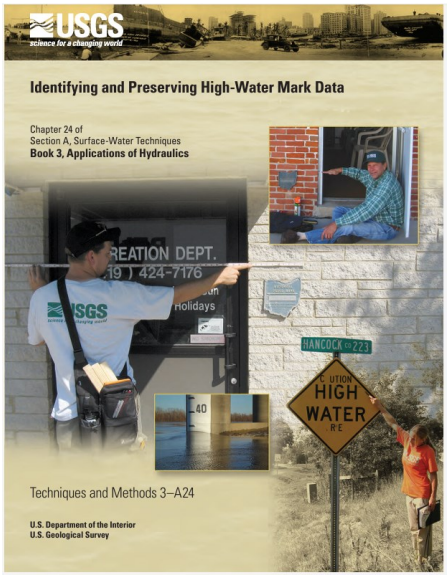
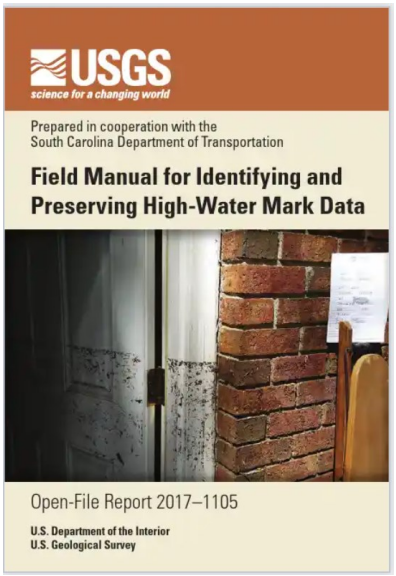
High-Water Marks

- High water marks are estimated from the upper limit of stains and debris deposits found on buildings, bridges, trees, and other structures.





Also USGS Video: https://youtu.be/uZYRQLMcVOA?si=NVF0xyPvuWevjISa

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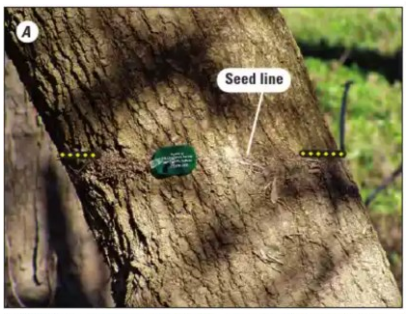
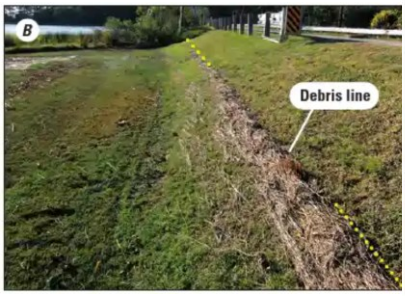
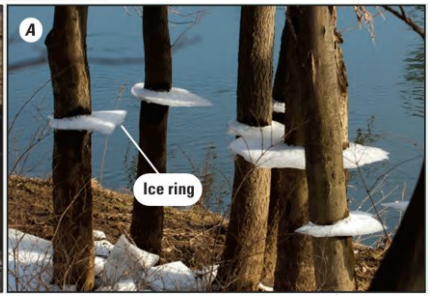


Types of High-Water Evidence

- Seed Line
- Mud Line
- Debris Line
- Cut Line
- Wash Line
- Ice Line

Tranquil vs Rapid





6

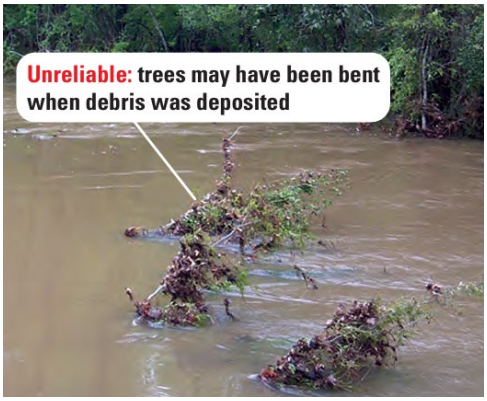
High-Water Marks : Sources of Uncertainty

- **Wind and wave actions** can cause the debris lines to be higher than the actual water surface.
- **Capillary action** causes stains on buildings to migrate upward.
- High-water marks in the overbank area are often higher than in the channel. **Overbank water** is moving slower and may be closer to **energy** gradeline.
- High-water marks on **bridge piers** are often equal to the **energy** gradeline, not the average water surface.

7

High-Water Marks : Sources of Uncertainty

- Be careful of debris on tree branches



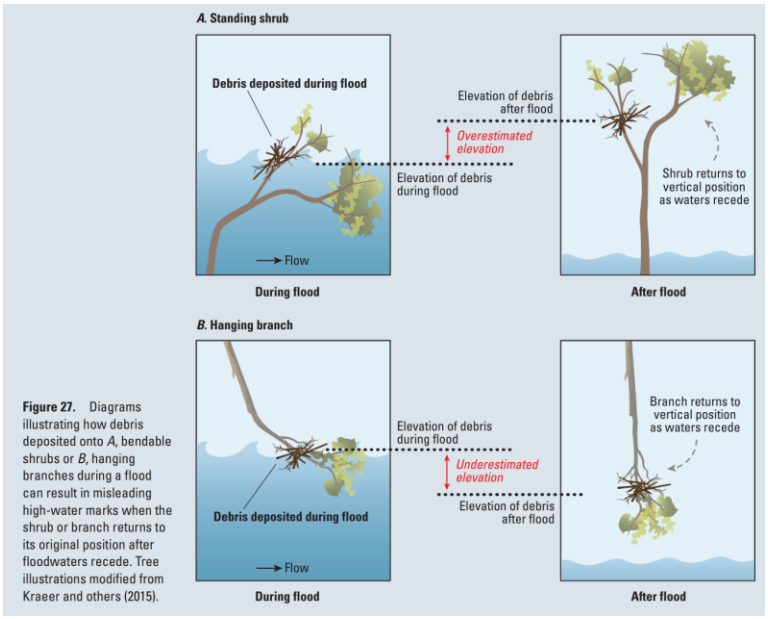


Figure 27. Diagrams illustrating how debris deposited onto *A*, bendable shrubs or *B*, hanging branches during a flood can result in misleading high-water marks when the shrub or branch returns to its original position after floodwaters recede. Tree illustrations modified from Kraeer and others (2015).

8

Historic High-Water Marks

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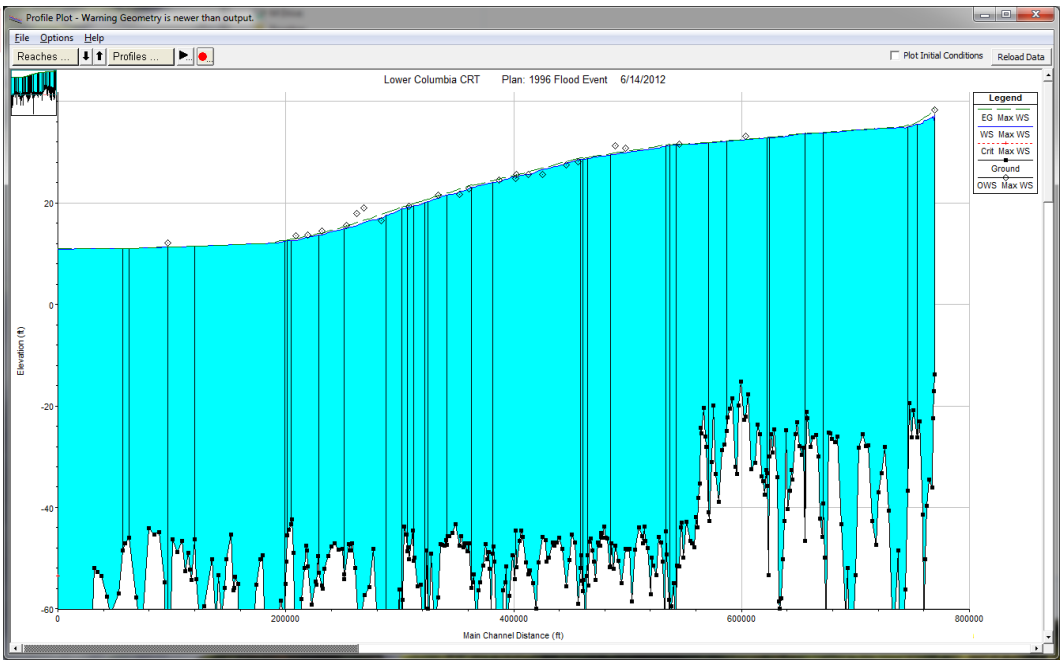
Flood Plain Boundaries
Drone and News Footage

12

Forensic High Water Marks: Newspapers and Interviews

13

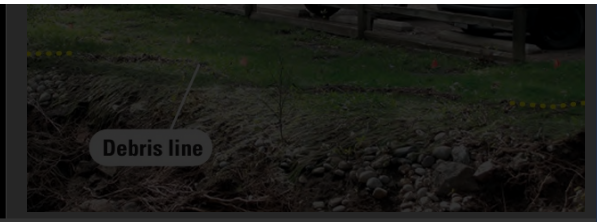
13



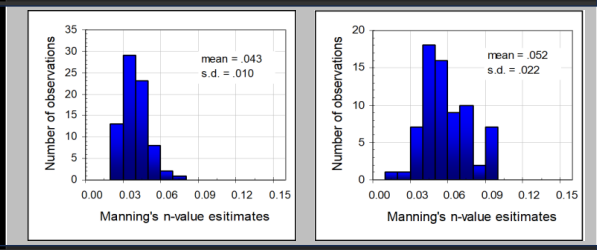
14

14

Evaluation Metrics



Adjustable Data/Parameters



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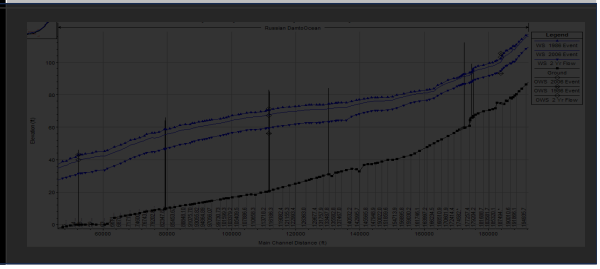

15

Top Five 1D Calibration Parameters

16

16

Common Calibration Parameters

- Hydrologic Data
- River and Floodplain Geometry
- Roughness Coefficients
- River and Floodplain Storage
- Hydraulic Structure Coefficients

17

17

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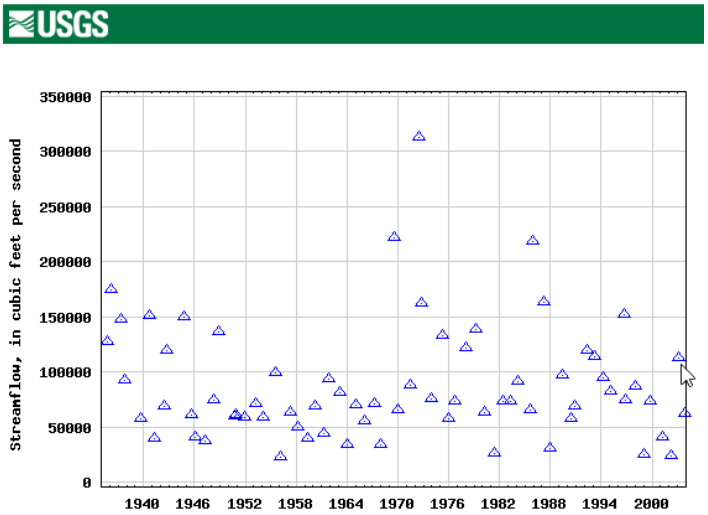
18

18

Hydrologic Data

- Errors in the stage record
- Errors in the flow record
- Ungaged Areas
- High Water Marks



19

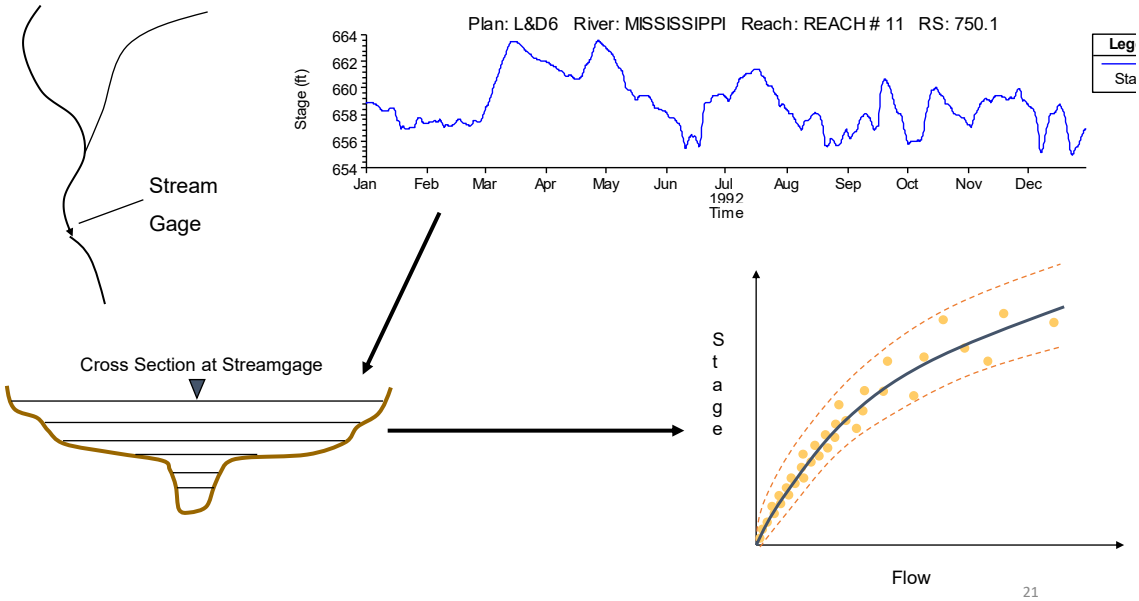
Stage Records

- Most accurate hydrologic input. Generally known within +/- 1.0 foot.

- Possible Errors:
  - Float gage gets stuck at a specific stage.
  - Recording systematically accumulates error with time.
  - Gage reader misses several days and guesses at stage recordings.
  - Error in the datum of the gage.

20

Stage Uncertainty at Stream gage Locations



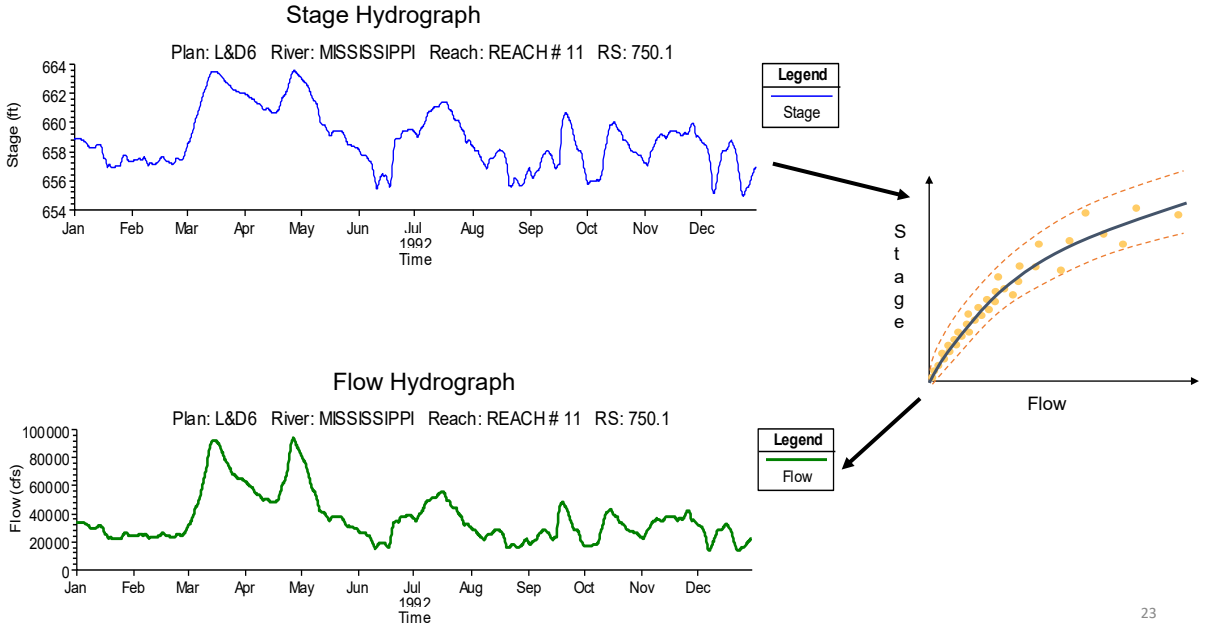
21

Flow Records

- Flow records are generally computed from observed stages using single valued rating curves. These rating curves are a best fit of measured data.
- USGS classifies very good flow measurements from a price current meter as +/- 5 percent.
- Discharge records for slope/area stations are at best +/- 10 percent of the true value.

22

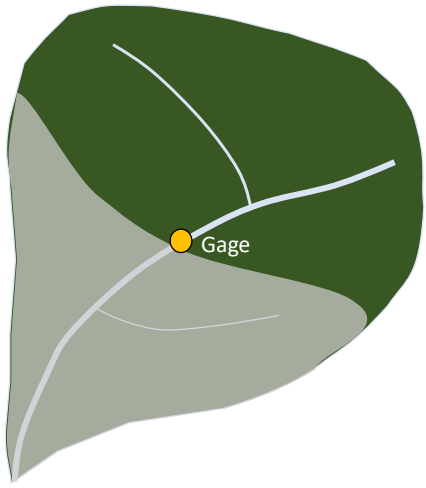
Flow Uncertainty at Stream gage Locations



23

Ungaged Drainage Areas

- For the model to be accurate, it must have flow input from all of the contributing areas.
- In many studies a significant portion of the area is ungaged.
- Discharge from ungaged areas can be estimated from:
  - Hydrologic models.
  - Regional regression equations.
  - Flow from a gaged watershed with similar hydrologic characteristics, multiplied by a simple drainage area ratio.



24

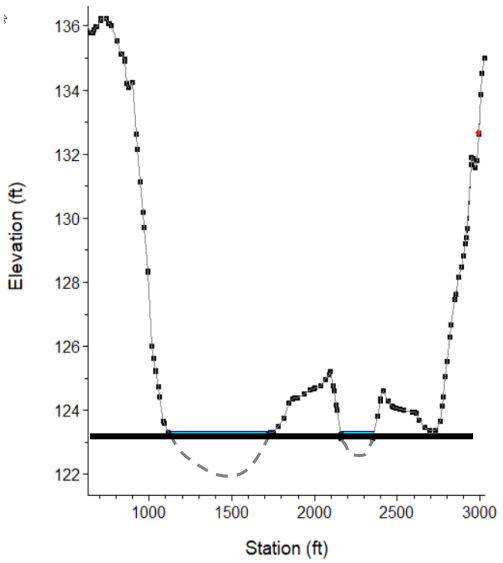
Common Calibration Parameters

- Hydrologic Data
- River and Floodplain Geometry
- Roughness Coefficients
- River and Floodplain Storage
- Hydraulic Structure Coefficients

25

River and Floodplain Geometry

- It is essential to have an adequate number of cross sections that accurately depict the channel and overbank geometry. This can be a great source of error when trying to calibrate.
- What is the accuracy level of the terrain data?
  - Surveyed Cross sections.
  - Aerial Survey Data (LIDAR, Stereo Imaging).
  - USGS DEM data.
- Does the Terrain Data include the channel data below the water surface?
- Are all hydraulic structures accurately depicted?



26

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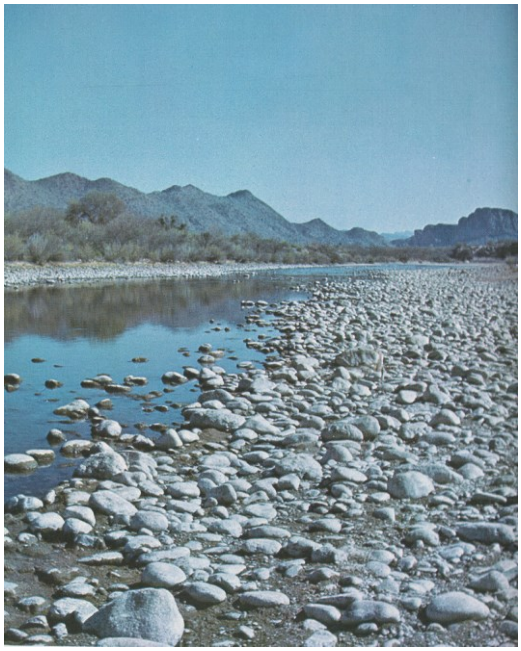
27

Manning's n values

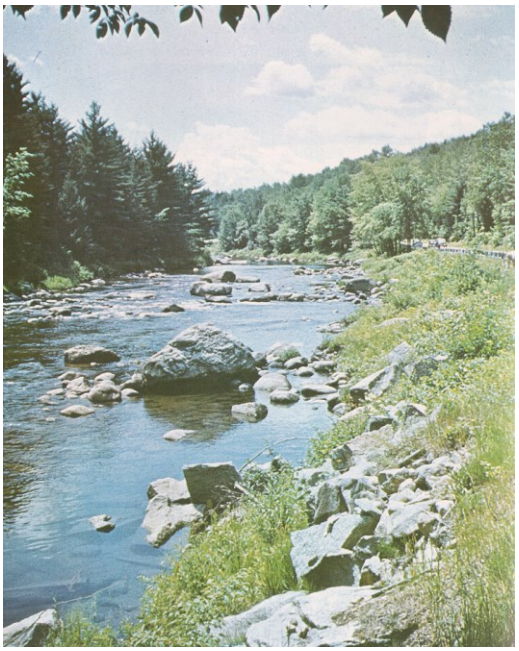
- Make Initial Estimates of Manning's n Values from Aerial Photos, Land use maps, and Field investigation using the following techniques:
  - Field observation (this requires experience).
  - Comparison with photos of calibrated streams.
  - Published documents with n values vs. land use types.
  - Channel n value formulas.
- Then Calibrate to any observed data that is available – Best Approach for obtaining Manning's n values.

28

Manning's n values



$n =$ 0.032



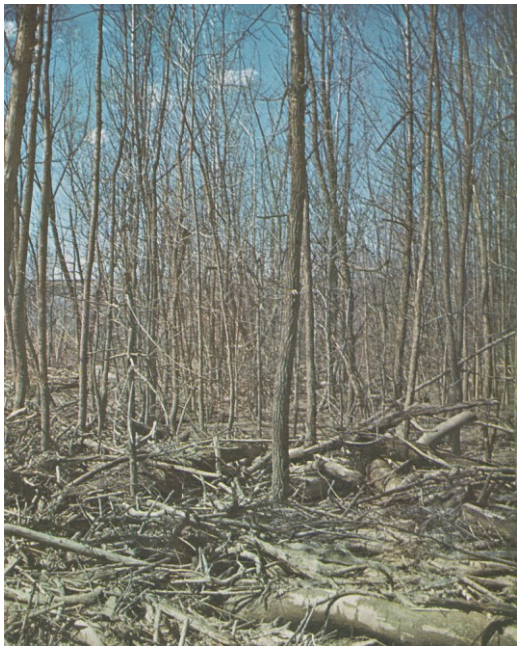
$n =$ 0.055

29

29

Manning's n values

$n =$ 0.075



$n =$ 0.097

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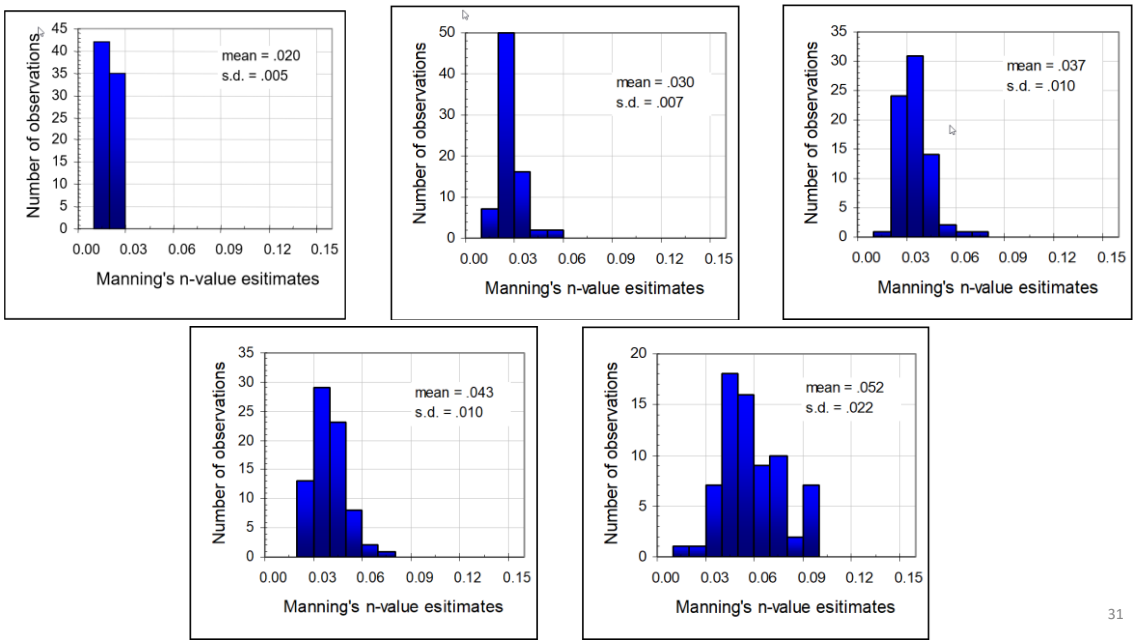
30

Uncertainty in Manning's n values



31

31

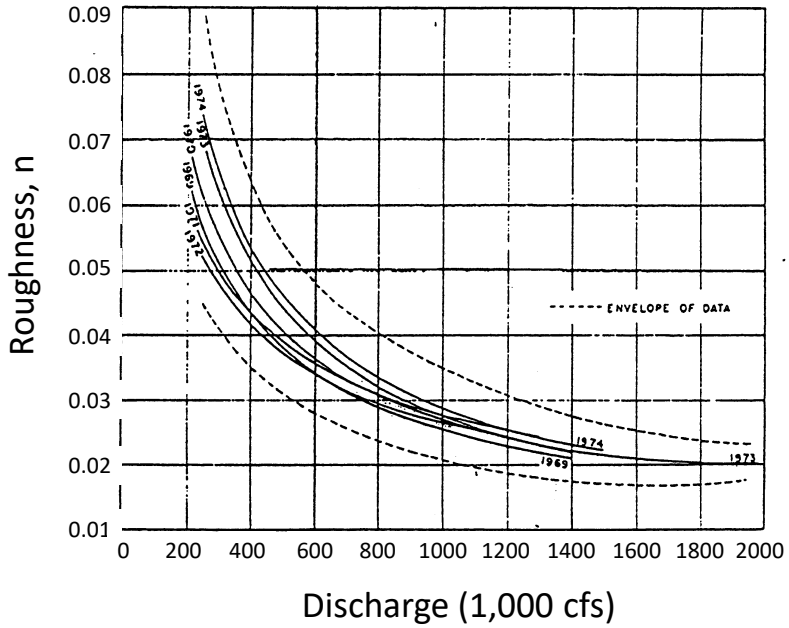
Roughness – Manning's n

- Generally, for a free flowing river, roughness decreases with increased stage and flow.
- However, if the banks of a river are rougher than the channel bottom (trees and brush), then the composite n value will increase with increased stage.
- Sediment and debris can also play an important role in changing the roughness.

32

32

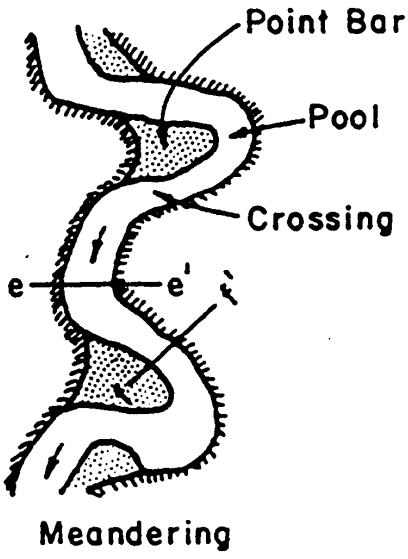
Roughness vs. Discharge

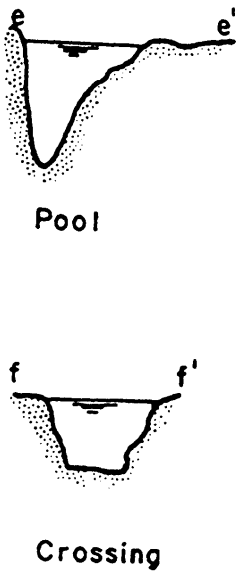


33

33

Morphology of a Meandering River

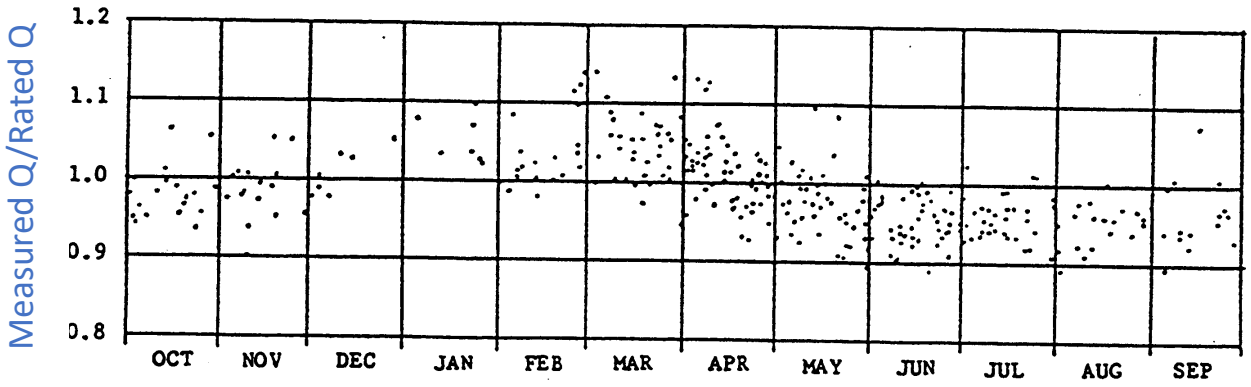




34

34

Changes in Roughness due to Temperature (Large Rivers)



35

35

Common Calibration Parameters

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36

36

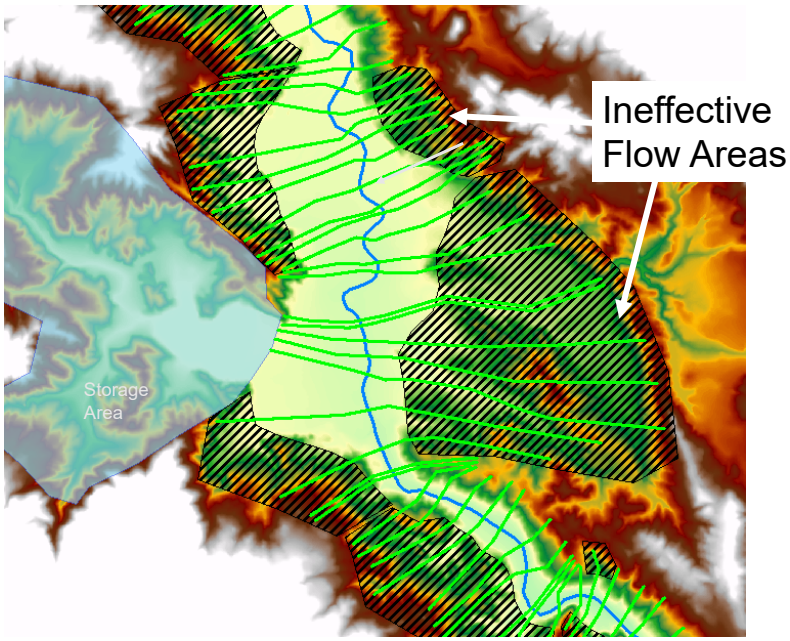
Cross Sectional Storage (Ineffective Flow Areas)

- Map all of the ineffective flow areas as polygons in the GIS (Topographic map).
- Or Map the active flood width on a topographic map (GIS Terrain model). The area outside of this should be treated as storage (Ineffective flow areas).
- Pay special attention to Ineffective flow areas around hydraulic structures such as Bridges; Culverts; Weirs; etc…

37

37

Example Ineffective Flow Areas



38

38

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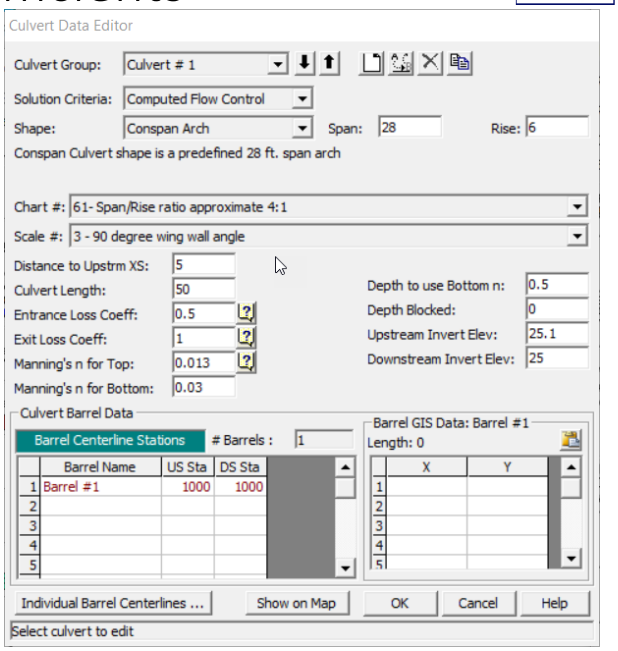
39

Hydraulic Structure Coefficients

- Hydraulic Coefficients at bridges and culverts tend to have a local effect on stage, and a minimum affect on the flow hydrograph.
- The effects of Inline weirs/spillways coefficients will depend upon the size of the structure.
- Lateral weir coefficients can have a significant role in the amount of water leaving the river system.

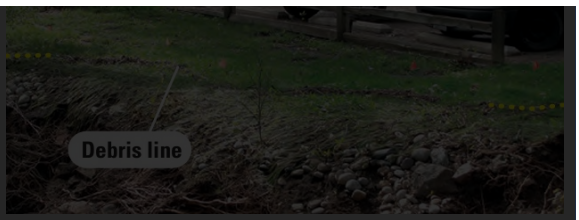


Additional Uncertainty

- Obstructions:
  - Debris
    - Mud and Debris
    - Debris blockages
  - Ice
- Erosion/deposition, bed forms, and sediment concentration can all affect n values.

41

Evaluation Metrics



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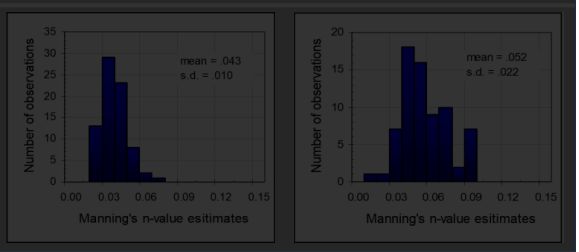

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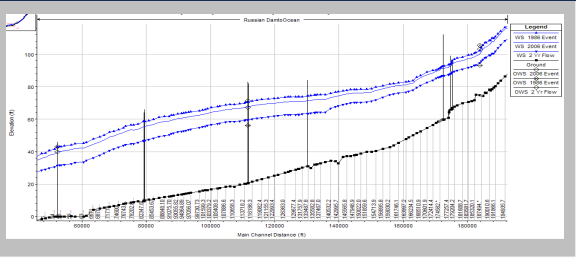


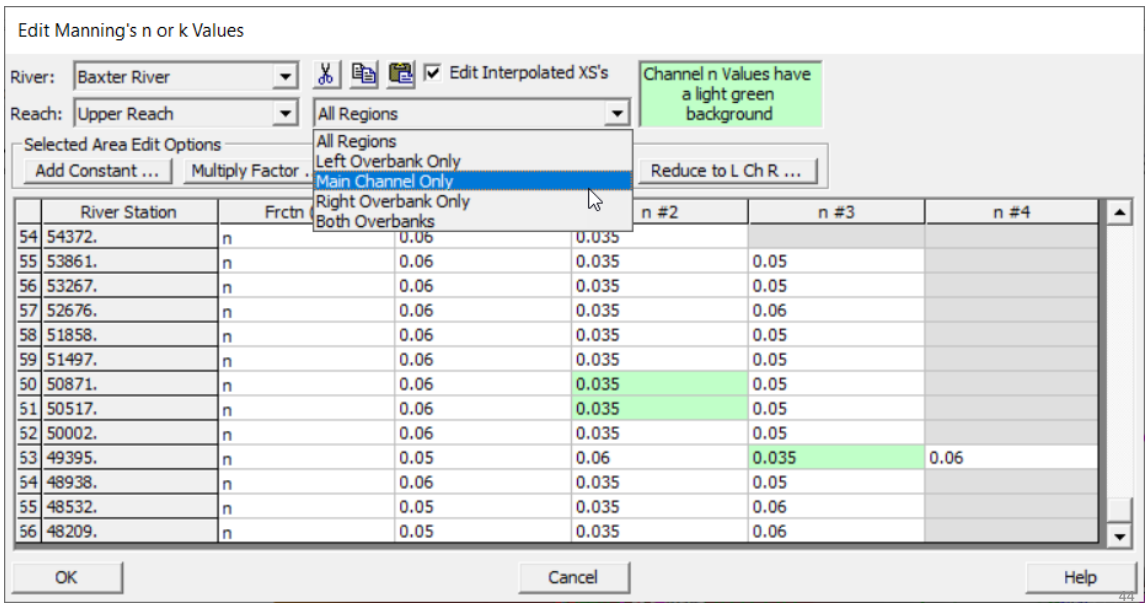
42

HEC-RAS Model Calibration Tools

- Manning's n value Input Tables.
- Flow Versus Roughness Factors Option.
- Graphical Plots
  - Profile plot.
  - Cross section plot.
- Tabular Output Tables.

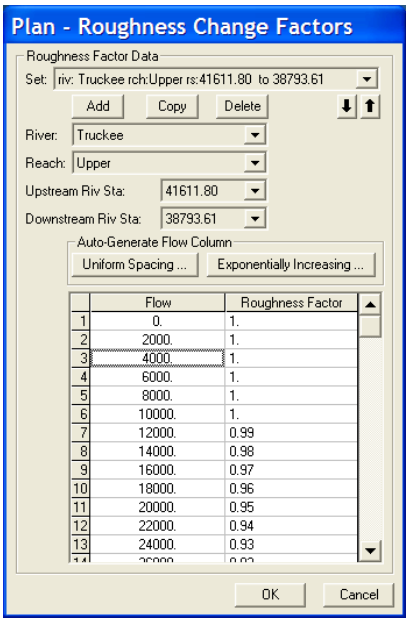
43

Manning's n Value Table



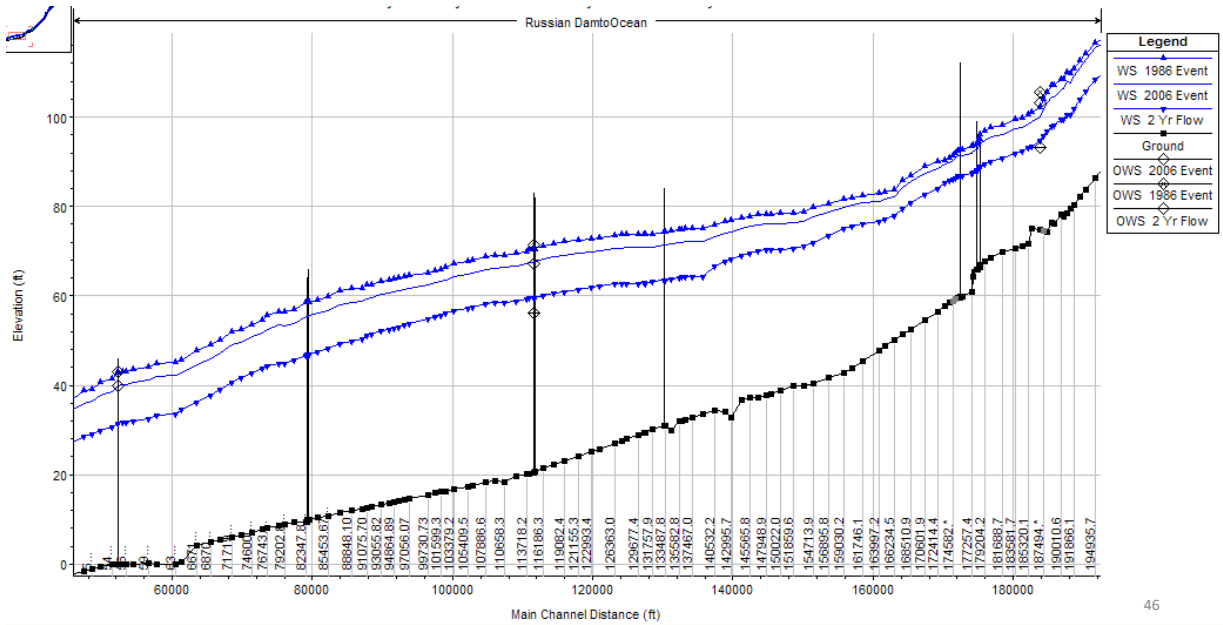
44

Flow vs. Roughness Factors



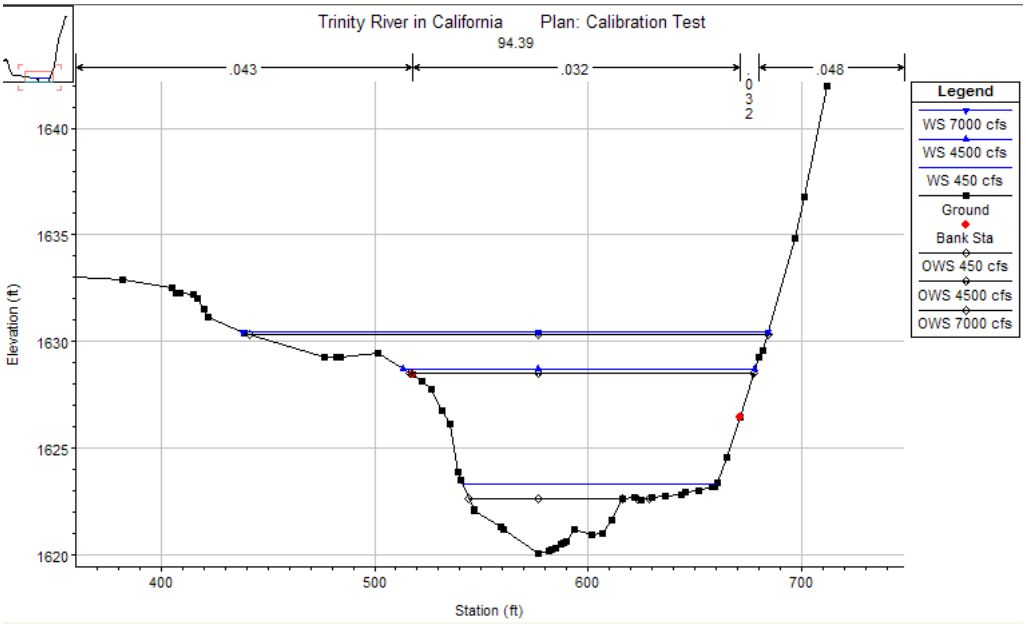
45

Profile Plot with Observed Data



46

Cross Section Plot with Observed Data



47

47

Tabular Output with Computed and Observed Water Surfaces

Profile Output Table - Calibration

File Options Std. Tables User Tables Locations Help

HEC-RAS Plan: Calibration River: Trinity Reach: Lew_DC — Reload Data

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Obs WS (ft)	Diff	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Wic (ft)
Lew_DC	95.03	450 cfs	500.00	1627.30	1629.75	1629.12	0.63	1629.87	0.002017	2.75	182.12	120.(
Lew_DC	95.03	4500 cfs	5050.00	1627.30	1633.39	1633.25	0.14	1633.89	0.002460	5.65	893.54	228.(
Lew_DC	95.03	7000 cfs	7450.00	1627.30	1634.54	1634.43	0.11	1635.17	0.002307	6.36	1173.86	268.(
Lew_DC	94.99	450 cfs	500.00	1626.95	1628.32			1628.78	0.015268	5.46	91.60	99.(
Lew_DC	94.99	4500 cfs	5050.00	1626.95	1632.37			1633.11	0.004091	6.89	734.98	233.(
Lew_DC	94.99	7000 cfs	7450.00	1626.95	1633.82	1634.03	-0.21	1634.54	0.002902	6.81	1106.40	264.(
Lew_DC	94.93	450 cfs	500.00	1623.23	1626.93	1627.15	-0.22	1627.05	0.001598	2.71	184.69	99.(
Lew_DC	94.93	4500 cfs	5050.00	1623.23	1631.74	1631.65	0.09	1632.27	0.001601	6.32	1047.56	245.(
Lew_DC	94.93	7000 cfs	7450.00	1623.23	1633.21	1633.19	0.02	1633.85	0.001561	7.14	1436.09	274.(
Lew_DC	94.85	450 cfs	500.00	1620.15	1626.87			1626.90	0.000122	1.26	395.92	99.(
Lew_DC	94.85	4500 cfs	5050.00	1620.15	1631.38			1631.77	0.000804	5.29	1170.07	245.(
Lew_DC	94.85	7000 cfs	7450.00	1620.15	1632.82			1633.33	0.000893	6.20	1533.04	260.(
Lew_DC	94.75	450 cfs	500.00	1623.39	1626.50	1626.67	-0.17	1626.69	0.005720	3.45	144.97	147.(
Lew_DC	94.75	4500 cfs	5050.00	1623.39	1630.57	1630.22	0.35	1631.10	0.002216	5.85	881.38	218.(
Lew_DC	94.75	7000 cfs	7450.00	1623.39	1632.07	1631.97	0.10	1632.68	0.001773	6.35	1221.77	240.(

Observed Water Surface.

48

48

Steps in the Calibration Process

1. Run a range of observed discharges from low to high, depending on the purpose of the model.

2. Make sure you have defined the ineffective flow areas as accurate as possible before calibrating Manning's n values.

3. Start by calibrating main channel n values for low flows up to the bank full flow (generally the 1.5 – 2 yr flow).

4. Start downstream and work your way upstream (downstream computed water surfaces/energy effect computed upstream water surfaces).

Steps in the Calibration Process - Cont

5. Modify n-values over consistent reaches rather than section by section. Look at reach slope, size of material, vegetation, etc…

6. After you think you have a good start on the main channel n values, calibrate higher events by adjusting overbank Manning's n values first. Then main channel adjustments if necessary .

7. Adjust hydraulic structure coefficients if observed data is available just upstream of the structure.

8. Fine tune calibration for stages low to high by using "Discharge-Roughness Factors" when and where appropriate.

Steps to in the Calibration Process - Cont

9. Two sets of Geometry and Manning's n values may be necessary if significant seasonal affects are present (i.e. roughness in channel or overbanks is very different in winter vs. summer).

10. Verify the model calibration by running other flow events that were not used in the calibration process (if possible).

11. If further adjustment is deemed necessary from verification runs, make adjustments and re-run all events.

51

51

Calibration Suggestions and Warnings

- Do not force a calibration to fit with unrealistic Manning's n values and/or ineffective flow areas.

- Downstream boundary conditions can have a great affect on the computed water surface in the lower end of the model. If downstream boundary condition is unknown (i.e. using Normal Depth), make sure it is far enough downstream so it does not affect calibration where you do have observed data.

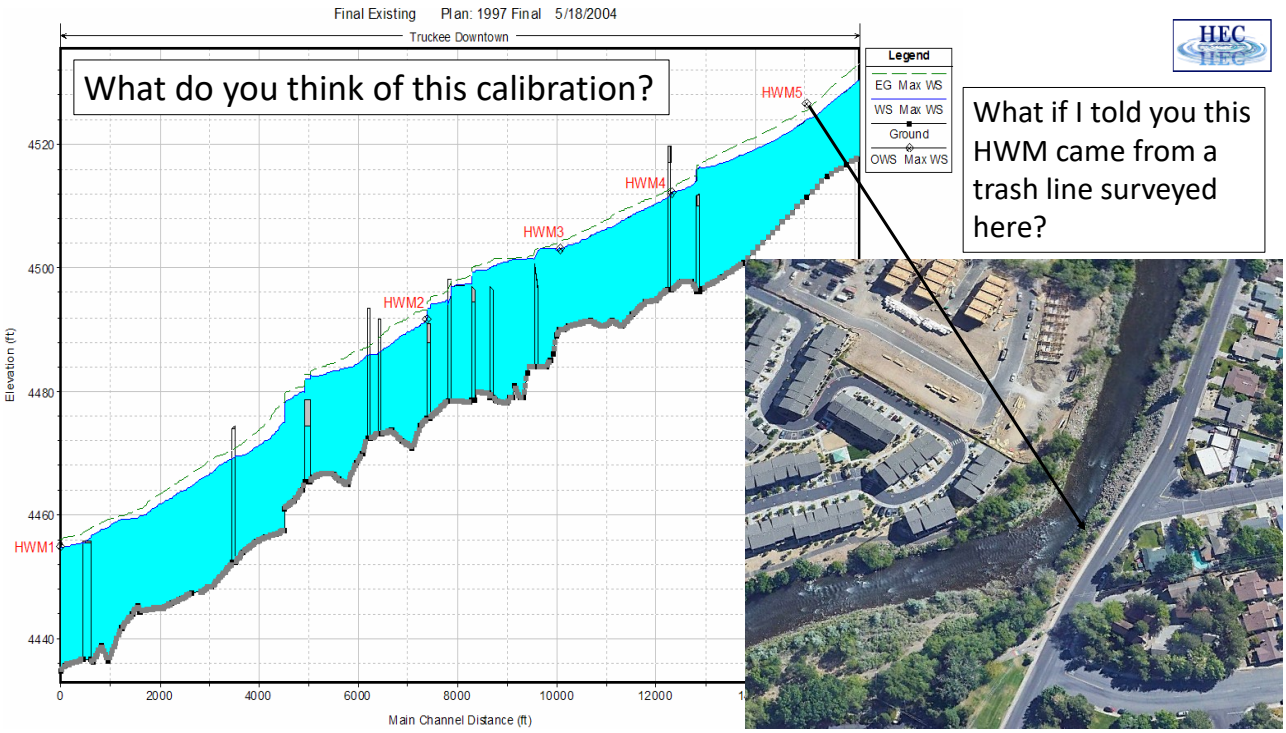
52

52

Calibration Suggestions and Warnings - Continued

- Discrepancies may arise from a lack of quality cross section data, or not enough cross sections spaced at appropriate intervals.
- Calibration should be based on floods that encompass a wide range of flows (depending on purpose of the study).
- Accurately depicting significant flow changes along the river can significantly affect the model calibration.

53



54