Presented to the

Skagit County Board of Commissioners

Re-evaluation of Historical Floods on the Skagit R. nr. Concrete, WA

Presented on August 13, 2007, by

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Topics Covered

- Why is the 1921 peak discharge at the Skagit River near Concrete important?
- How flood discharges are calculated
- History of flood calculations at this site
- Slope-Area Results
- Stage-Discharge Rating-Curve Analysis
- Final Evaluation

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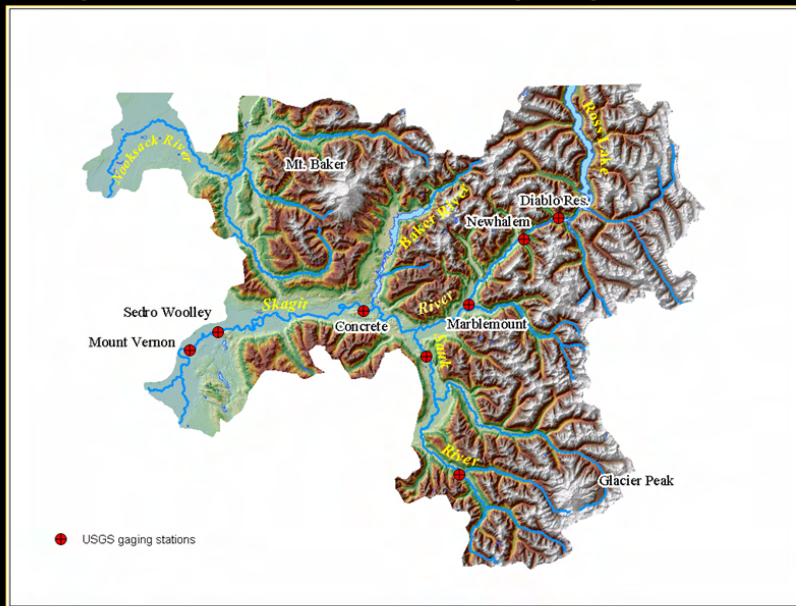
Skagit River Basin Gaging Stations



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Skagit River near Concrete

Looking downstream. Streamgage* (sta. no. 12194000) on left bank.

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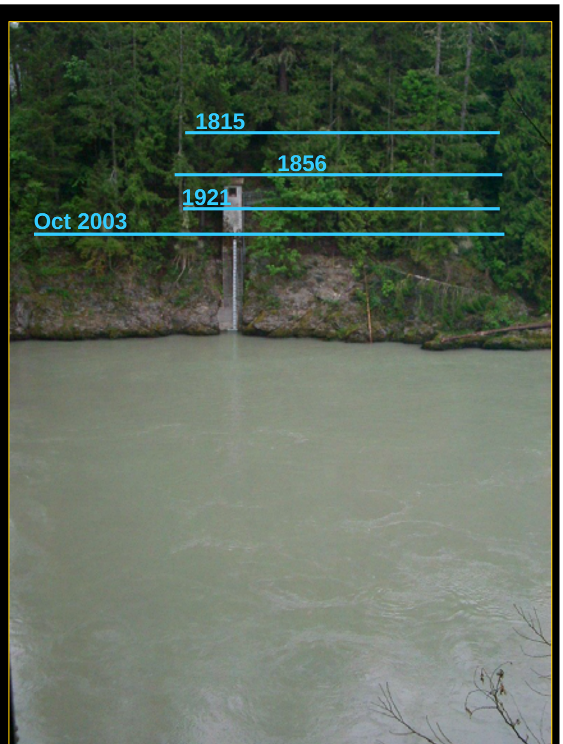
Skagit River near Concrete (cont'd)

- 1815 flood* at 69.3 ft gage height
- 1856 flood* at 57.3 ft gage height
- 1921 flood at 47.6 ft gage height
- 2003 flood at 42.2 ft gage height ($166,000\ ft^3/s$, highest since 1921)

- The 1921 peak discharge was used with rating extension to estimate the discharge for the other historic peaks (1897, 1909, and 1917).

* estimates in the USGS peak-flow data file



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Skagit River near Concrete (cont'd)

Left bank across from gage--Note scour line of October 2003 flood.

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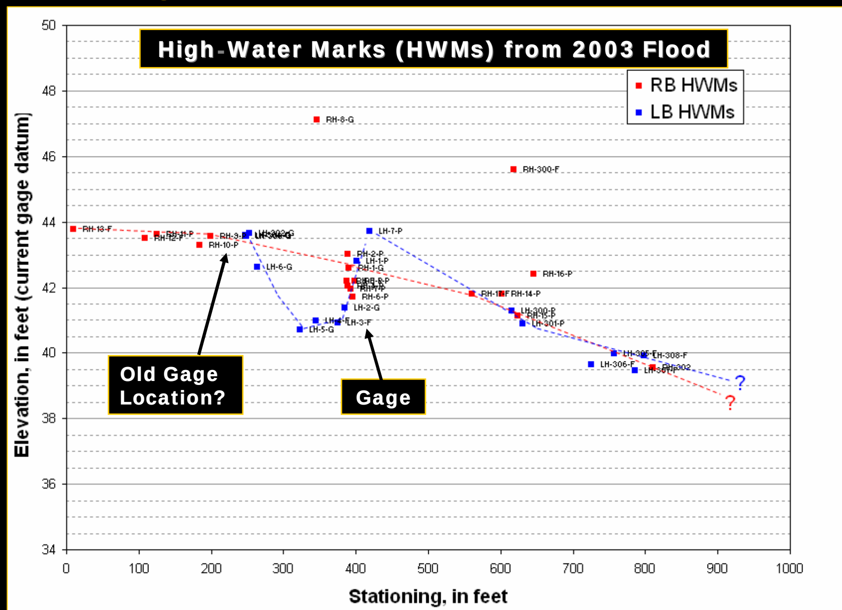
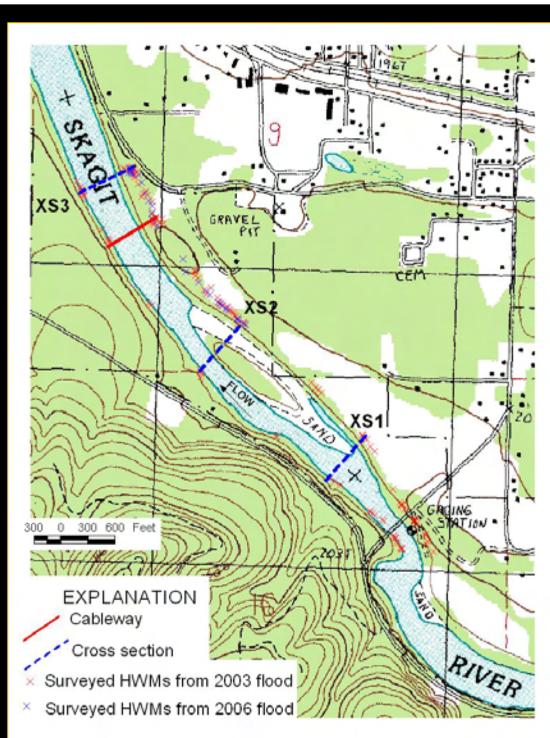
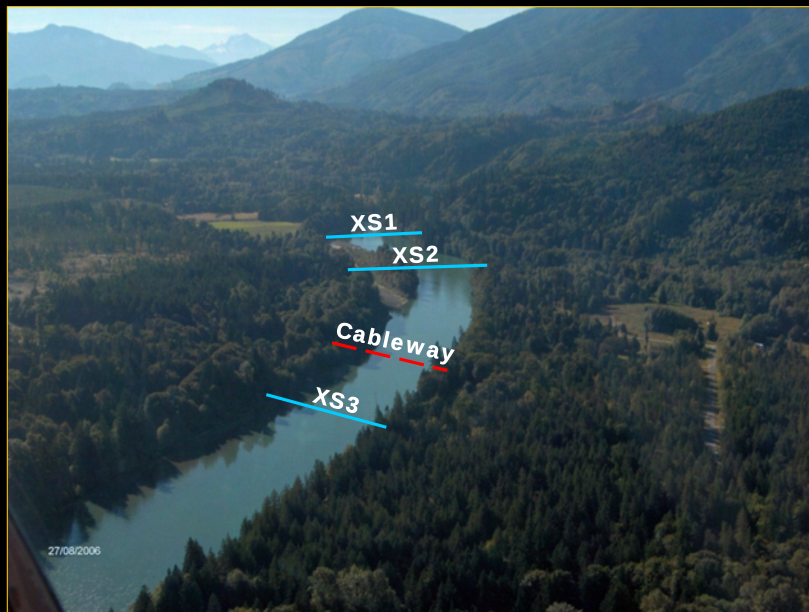
Skagit River near Concrete (cont'd)



Skagit River near Concrete
(cont'd)

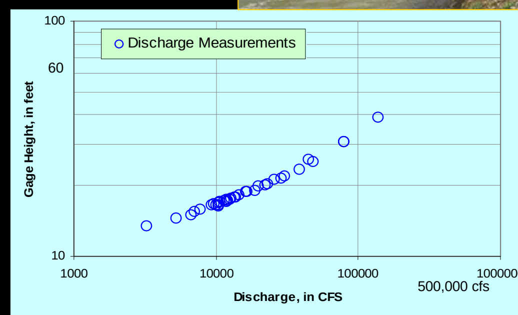


Skagit River near Concrete (cont'd)



Determining Flood Discharges

- Directly—Current-meter measurement (rare)
- Stage-Discharge Relation or Rating Curve (most common)
  - Defined by current-meter measurements
  - Peak-flow discharges determined by extension



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Determining Flood Discharges (cont'd)

- **Indirectly**
  - Slope Area
  - Width Contractions
- **Post-flood Survey**
  - Channel geometry
  - Water-surface profile or High-Water Marks (HWMs)
  - Channel Roughness (*n* value)

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Slope-Area Calculations

- **Manning's Equation: $Q = 1.486/n \, AR^{2/3}S^{1/2}$**

  where Q = discharge in ft³/s

  n = roughness coefficient

  A = cross section area

  R = hydraulic radius (A/wetted perimeter)

  S = friction or energy slope

  – ***Assume uniform, steady-state conditions***

- **Energy Equation:**

  $$(h+h_v)_1 = (h+h_v)_2 + (h_f)_{1\text{-}2} + k(\Delta h_v)_{1\text{-}2}$$

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Energy Equation for a reach is: $(h+h_v)_1 = (h+h_v)_2 + (h_f)_{1\text{-}2} + k(\Delta h_v)_{1\text{-}2}$ where

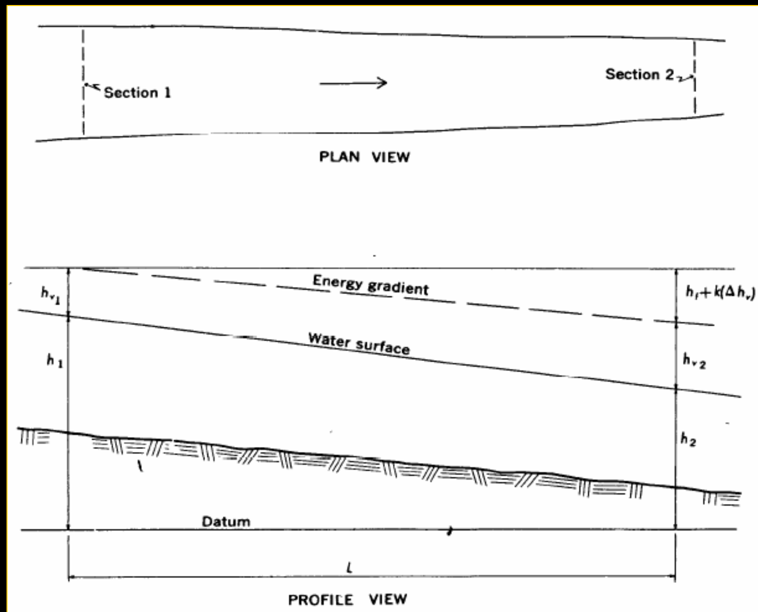
h = elevation of the water surface at the respective sections above a common datum;

h_v= velocity head at the respective section; hf = energy loss due to boundary friction in the reach; Δh_v= upstream velocity head minus the downstream velocity head;

$K(\Delta h_v)$ = energy loss due to acceleration of deceleration in a contracting or expanding reach,

and k = a coefficient, 0.5 for expanding reach and zero for contracting reaches.

Slope-Area Reach



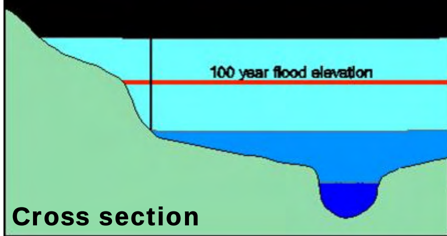
USGS Assigns Flow Computations an Accuracy Rating

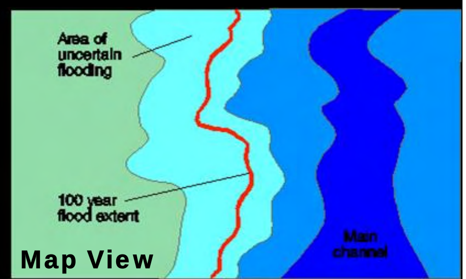
For Indirect Measurements:

- Good—within 10% of the real value
- Fair—within 15% of the real value
- Poor—25% or greater of the real value

- A difference of 36,000 cfs in a flood peak that is estimated at 240,000 cfs is 15%

Flood Hydrology Is Not an Exact Science





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History of Calculating the 1921 Peak Discharge

- **Winter 1922-23** Stewart surveys HWMs for the December 1921 peak, and computes a width-contraction and slope-area indirect measurement (average discharge= 240,000 ft^3/s).
  - "…floodmarks still were so clear that the profile of the flood could be determined within one or two tenths of a foot."
  - Uses the 1921 indirect measurement with the then current rating to estimate all known historic floods
  - Used channel roughness coefficient (*n* value) 0.033
  - Water-surface slope used instead of friction (or energy) slope
  - No subdivisions of the cross sections

- **1950's** Flynn and Benson use 1949 peak flow data for an *n* verification study and recalculate Stewart's slope area. They computed a peak flow of 225,000 ft^3/s. Bodhaine (1954) approves Flynn and Benson's analysis, but does not revise Stewart's estimate because it is a change of less than 10 percent.
  - No subdivision of the cross sections
  - *n* value = 0.0305

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History of Calculating the 1921 Peak Discharge (cont'd)

- December 2004 PIE report using 1-D HEC-RAS model, estimates 1921 peak at 202,000 ft^3/s. Will Thomas (FEMA) and Robert Jarrett (USGS) found errors in PIE analysis.

- 2005 Mastin and Kresch compute a range of *n* values based on 2003 peak discharge and a range of peak discharges for the 1921 peak from 215,000 to 266,000 ft^3/s.

- February 2007 Floodmarks not found in Hamilton House—Evidence of the magnitude of historic floods found to be inconclusive by NHC.

- April 2007 NHC report reviews 1922 [1921] flood and concludes, "the best estimate of the peak discharge for this event of 225,000 cfs as determined by Benson

- August 2007 Mastin revises earlier estimate using 2003 data with 2006 peak water surface profile and re-evaluates the 1921 calculation with Benson and Flynn 1949 peak-flow data
  - *n* value of main channel 0.0315
  - Cross section B and C subdivided
  - 1921 peak discharge calculated to be 228,000 ft^3/s, which is 5 percent less tan the estimate by Stewart

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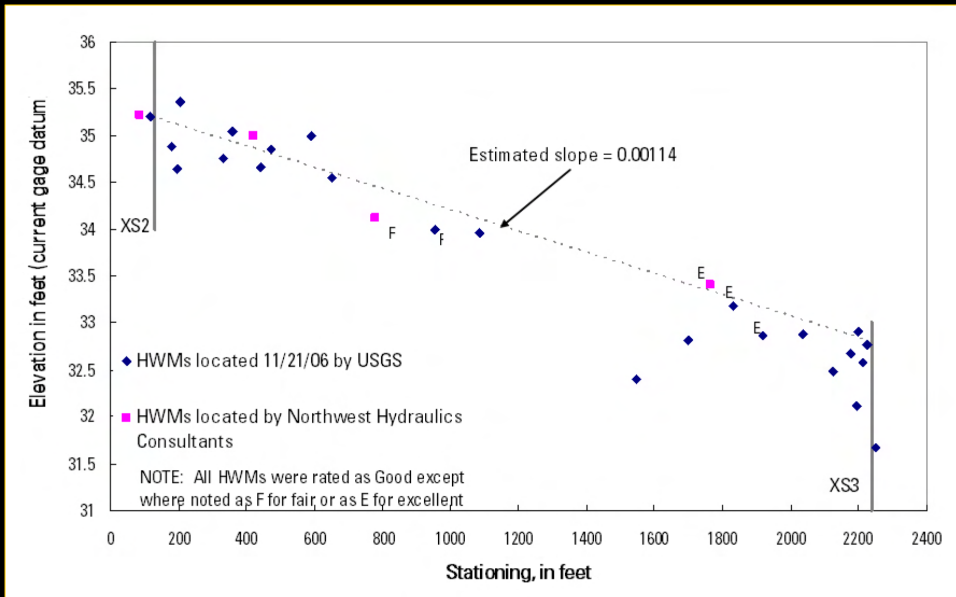
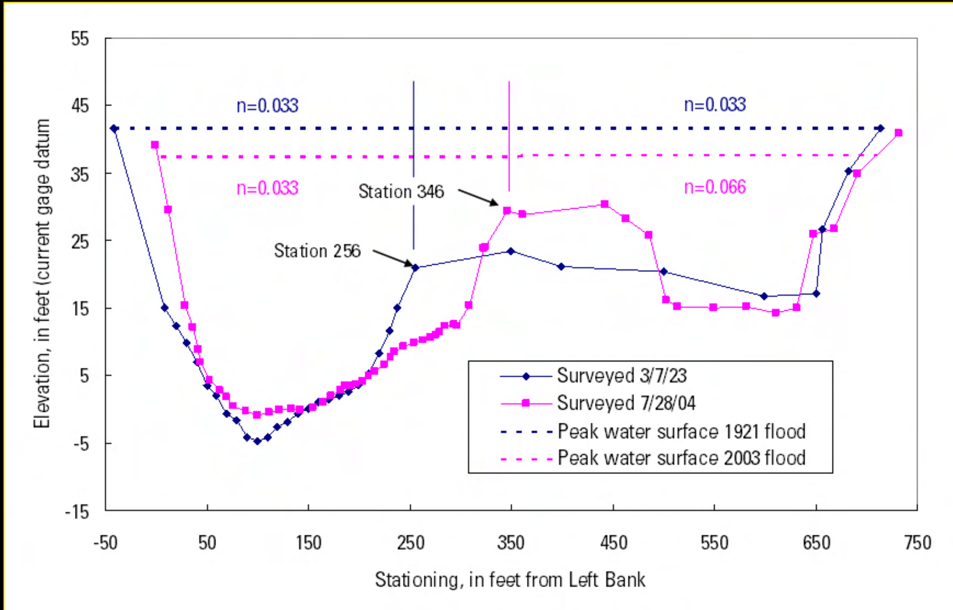
Slope-Area Reach



Cross Section 2 (XS2)



NOTE: *n* is the roughness coefficient; vertical lines indicate where the cross sections were subdivided

Results from the 2003/2006 Peak-Flow Analysis

- *n* value for the main channel is 0.033
- Recalculated 1921 peak using an *n* value of 0.033, subdivisions and the energy slope is 219,000 ft^3/s, which is 9 percent less than the estimate by Stewart
- Is this valid? Have things changed since 1921?

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Has the reach changed since 1921?

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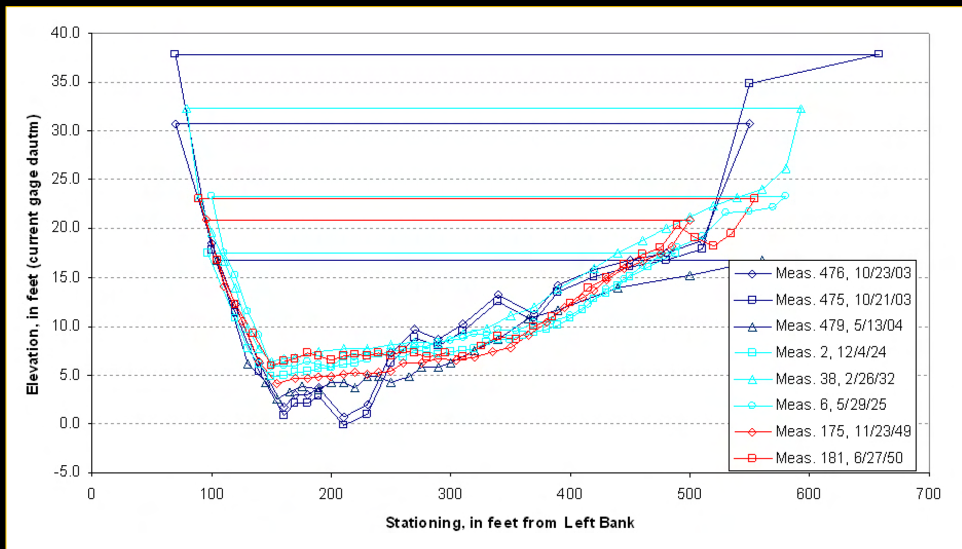
Cross-Section Surveys from Discharge Measurements at the Cableway Skagit R. nr Concrete, 12194000



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Skagit River near Concrete

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Skagit River near Concrete (cont'd)

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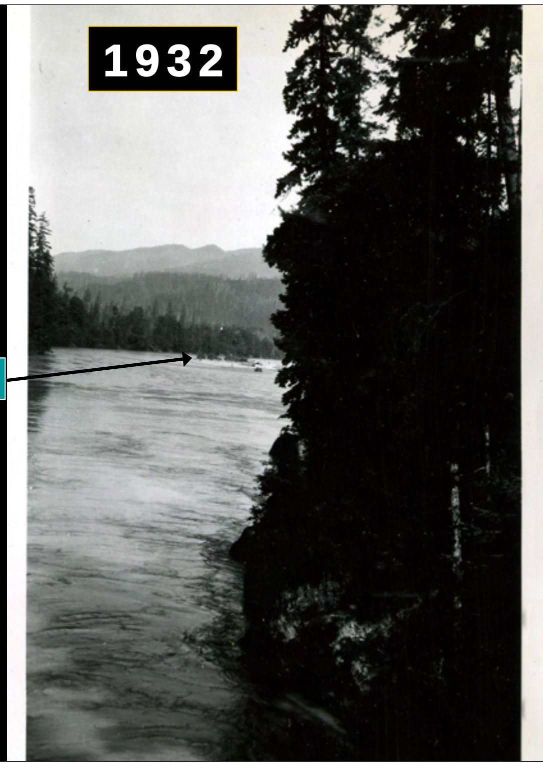

Skagit River near Concrete (cont'd)

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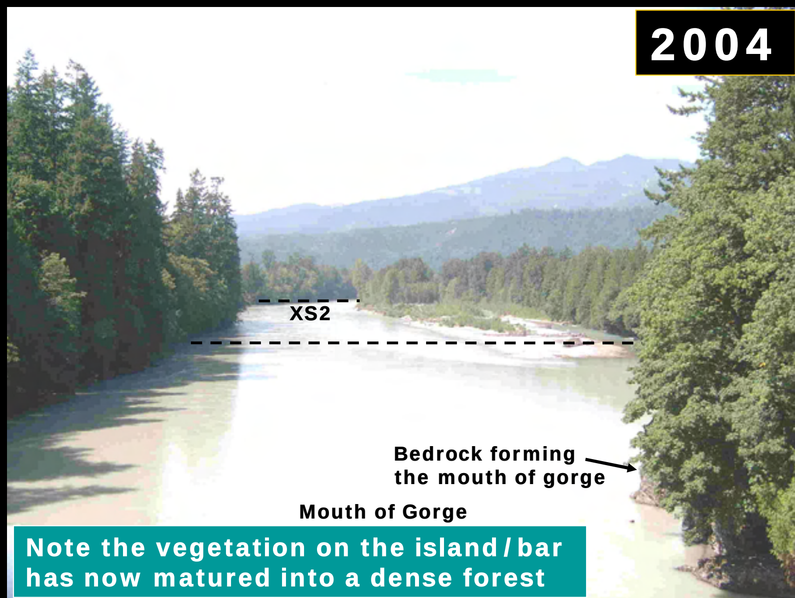

August 2004, looking downstream from Dalles Bridge

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Has the reach changed since 1921?

- Yes, the reach has changed since 1921 at cross section 2 (XS2) in the form of a dense forest.

- Are the reach changes since the inception of the forest on the island/bar addressed by the addition of sub sections and increased n value at XS2? Yes, to some extent, but it is difficult to assess the accuracy of the model with these changes.

- Evidence suggests that the reach conditions in 1949 were pretty much the same as in 1921.

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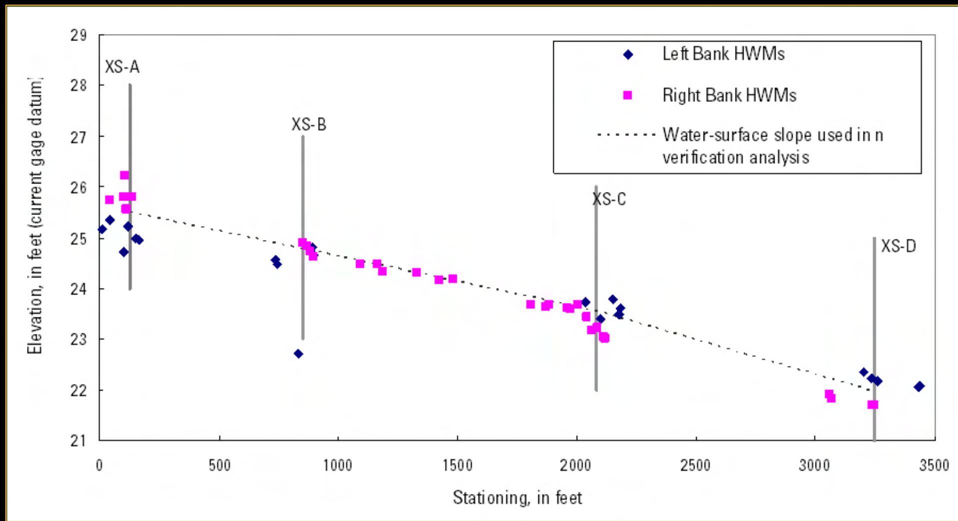
Water-Surface Slope of 1949 Flood



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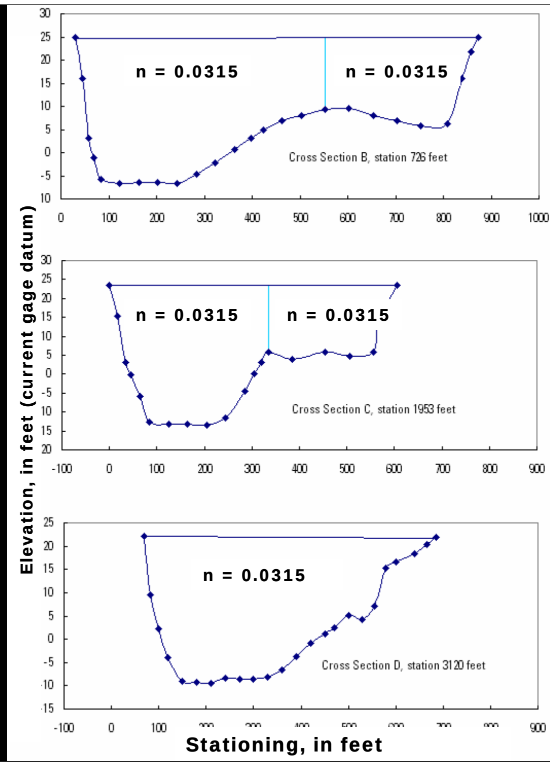
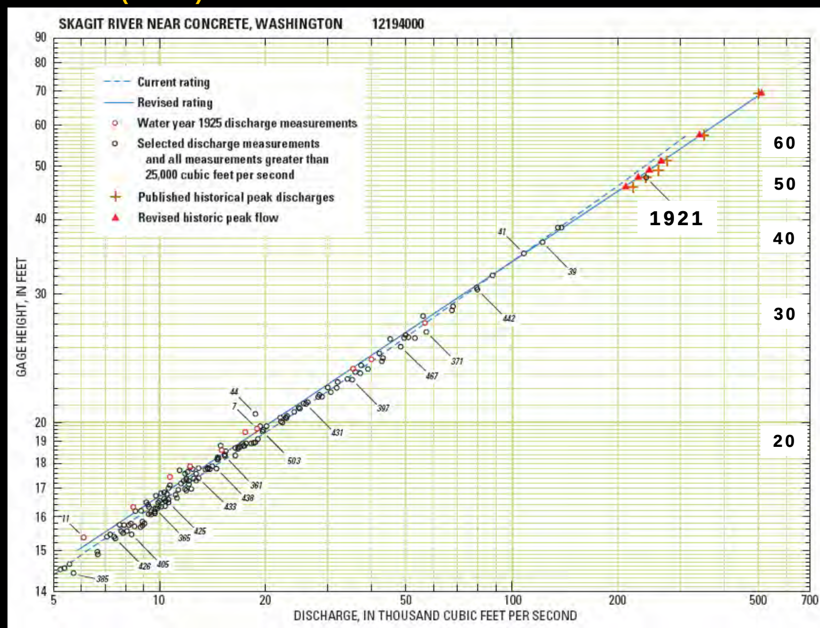
Results

Using this analysis, the peak discharge for the 1921 flood is 228,000 ft^3/s

Cross sections, subdivisions, and *n* values used in the re-evaluation of the Benson Flynn analysis



Results (cont'd)



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Historical Floods at Concrete

Year	Currently Published Discharge, ft^3/s	Gage Height, in feet (current gage datum)	Revised Peak Discharge	% difference
~1815	*500,000	69.3	*510,000	2.0
~1856	*350,000	57.3	*340,000	-2.9
1897	275,000	51.1	265,000	-3.6
1909	260,000	49.1	245,000	-5.8
1917	220,000	45.7	210,000	-4.5
1921	240,000	47.6	228,000	-5.0

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*estimates in the USGS peak-flow data file

Summary

- There are three lines of evidence that all point to the fact that Stewart's 1921 indirect peak estimate is slightly high
  1. *n* verification and recalculation using 2003/2006 peak data
  2. *n* verification and recalculation using 1949 peak data
  3. Stage-discharge rating extension

- All three of the recalculations are within the error bounds of Stewart's original calculation and the 10-percent guideline for revision. Even so, USGS has decided to revise the 1921 peak-flow estimate to 228,000 ft^3/s because each of the three recalculations is less than the published estimate and the 1921 peak-flow value is critical for flood planning.

- The *n*-verification using 1949 peak data is most accurate and it is used to recalculate the 1921 peak discharge.

- Rating extension is used with the 1921 peak discharge to estimate the magnitude of the other historical peak discharges.

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Questions?

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