

Skagit River Reevaluation of 1921 Flood Peak Discharge

presented at

Technical Conference

Wednesday, March 17, 2010



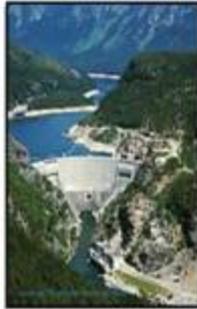
SKAGIT RIVER BASIN



PUGET SOUND, WASHINGTON



Upper Baker Dam



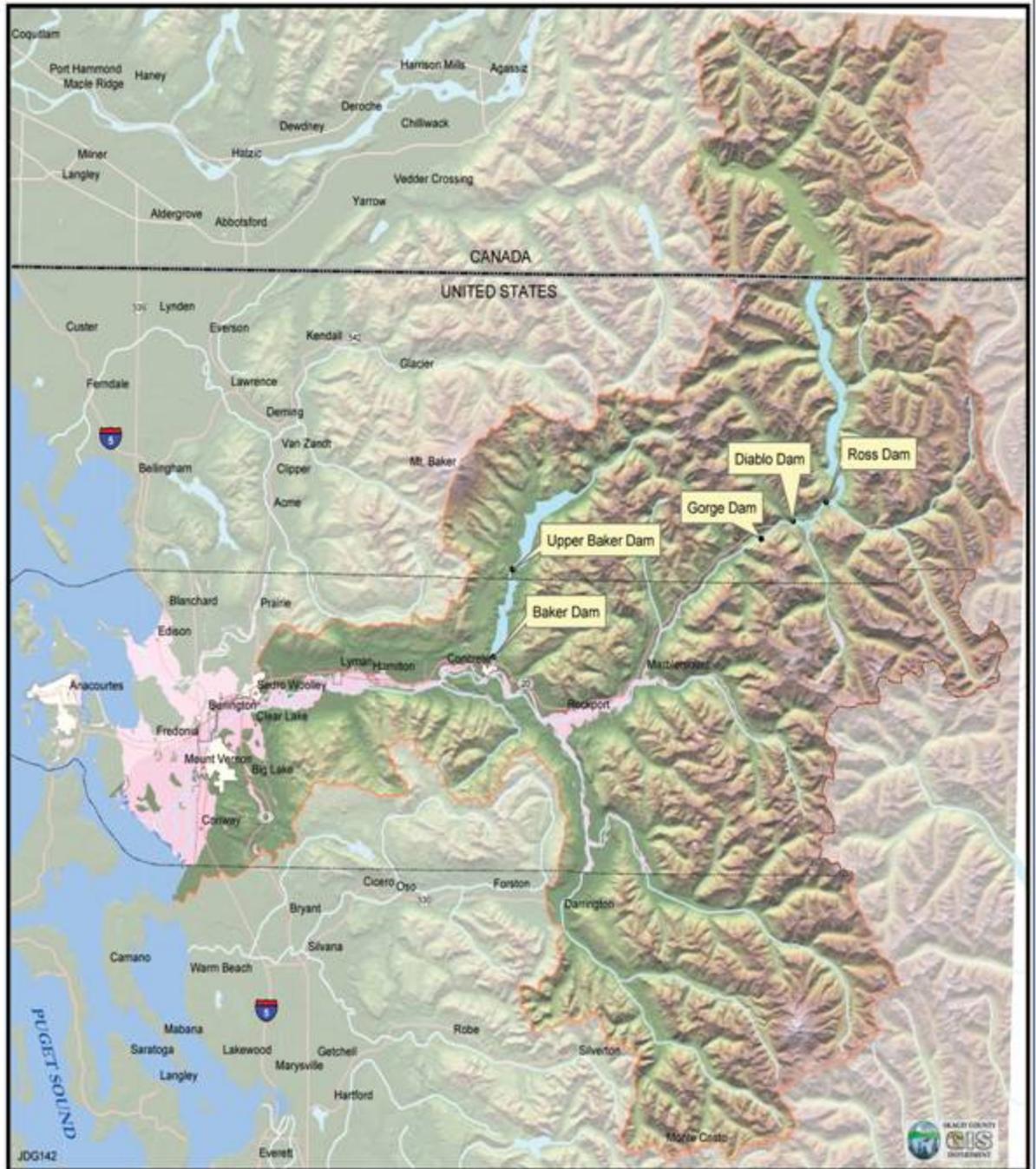
Ross Dam



Lower Baker Dam



Map Printed: June 5, 2003



An aerial photograph of a river winding through a forested area. A bridge crosses the river on the left side. A red circle highlights a small structure on the riverbank, identified as a current gage. The surrounding landscape includes dense green forests and some open fields with scattered buildings.

Current gage at the Dalles

Flow= 9,980 cfs

GH= 16.47 ft

on 2006-04-27

2006/04/27 9:05 am

An aerial photograph showing a large concrete dam structure in the center, with a green steel truss bridge extending from the right side of the dam across a wide river. The surrounding area is densely forested with green trees. The water in the river is a clear, light blue-green color. The dam has a long, low profile with a central spillway. The bridge is a long, narrow structure with a complex truss design.

The Dalles

Flow= 8,000 cfs

GH= 15.74 ft

on 2006-08-27

27/08/2006

The 1.8-ft gage datum discrepancy

The USGS stated in its November 5, 2008 letter,

“...the gage datum of Stewart’s historical HWM elevations was likely to be 142.7 ft NGVD’29 and not 140.9 ft.” (142.7 – 140.9 = 1.8 ft)

The 1.8-ft gage datum discrepancy

- Stewart's surveyed 1921 HWM at upper Dalles gage is El. 175.75 (gage height **34.86** + gage datum El. 140.89)
- USGS published 1921 HWM at current Dalles gage is El. 177.6 (gage height 34.86 + gage datum El. 130.00 + gage datum difference 12.69, or $34.86 + 12.69 = 47.55$, say **47.6**)
- 1.8 ft is the difference between USGS published and Stewart's surveyed 1921 HWM elevations

USGS Estimated Peak Stages and Discharges of Skagit River near Concrete for Four Historical Floods (Drainage Area = 2,700 sq. mi.)

Flood	Gage Height at Current Gage* as Published in 1961 (ft)	Gage Height** Estimated by Stewart in 1923*** (ft)	Discharge Estimated by Stewart in 1923*** (cfs)	Discharge Revised by USGS in 2007**** (cfs)
1897	51.1	38.4	275,000	265,000
1909	49.1	36.4	260,000	245,000
1917	45.7	33.0	220,000	210,000
1921	47.6	34.9	240,000	228,000

* Current gage datum El. 130.00 (NGVD29) at RM 54.15.

** At the Upper Dalles gage installed by Stewart for his flood investigation during the winter of 1922-23. Gage Datum El. 140.89 surveyed by Stewart (Stewart's survey notes, pp. 86-87).

*** These unpublished 1923 estimates by James Stewart were documented in the 1961 U.S. Geological Survey Water Supply Paper (WSP) 1527 (USGS 1961).

**** Revised due to Manning's "n" verification in Scientific Investigations Report 2007-5159 (USGS 2007)

The 1.8-ft gage datum discrepancy

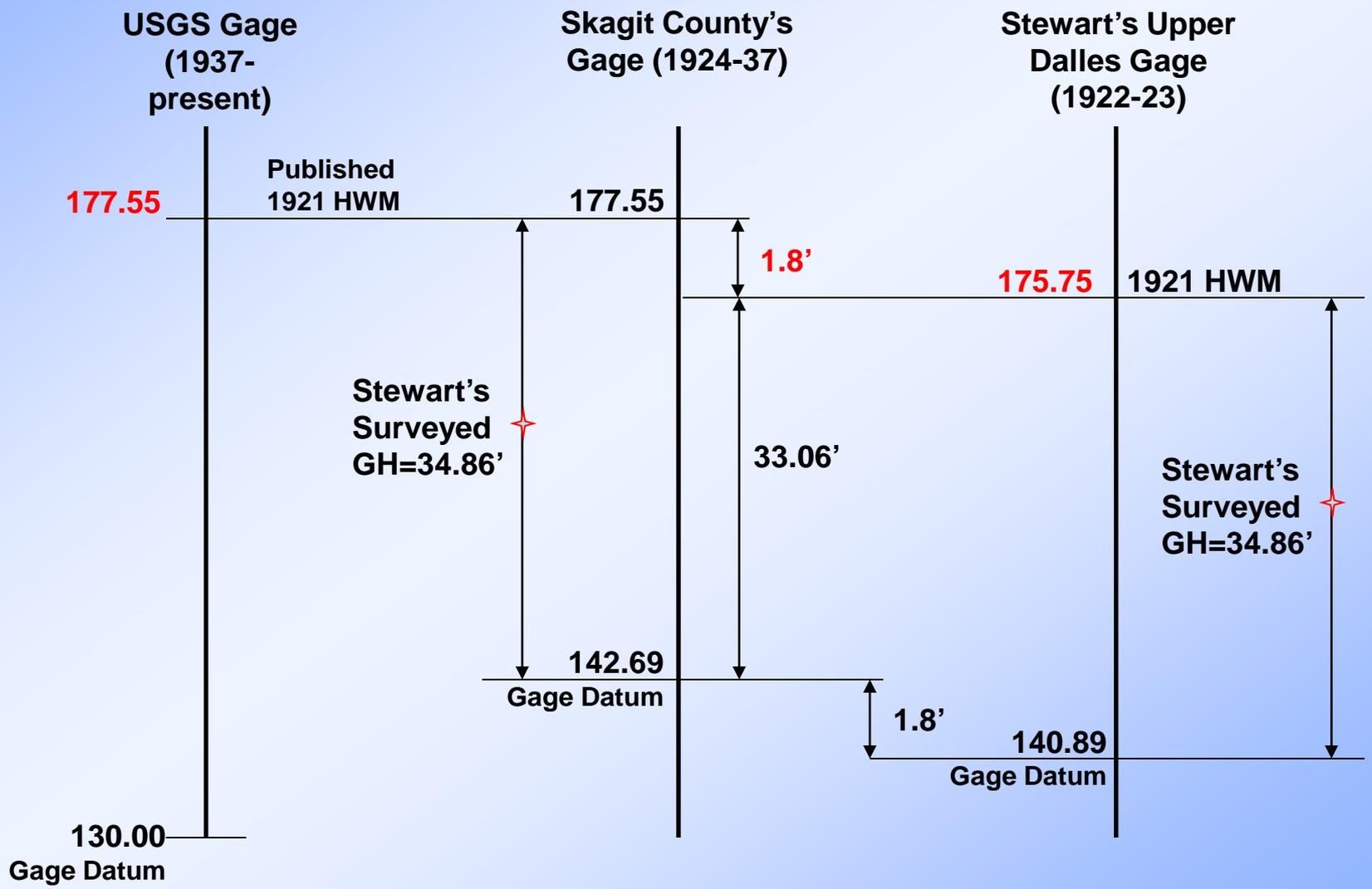
- Skagit County operated a gage at upper Dalles in 1924 – 37, with gage datum El. 142.69
- 12.69 ft is the gage datum difference between County's old gage and USGS current Dalles gage
- USGS has a record of this 12.69 ft datum conversion between County's old gage and USGS current Dalles gage

The 1.8-ft gage datum discrepancy

- 1.8 ft is the gage datum difference between Stewart's upper Dalles gage and County's old gage
- USGS looked for but could not find any record of the 1.8 ft datum conversion between Stewart's upper Dalles gage and County's old gage
- USGS' November 5, 2008 letter provides records that appear to show both Stewart's and County's gages were on same datum, though inconclusive



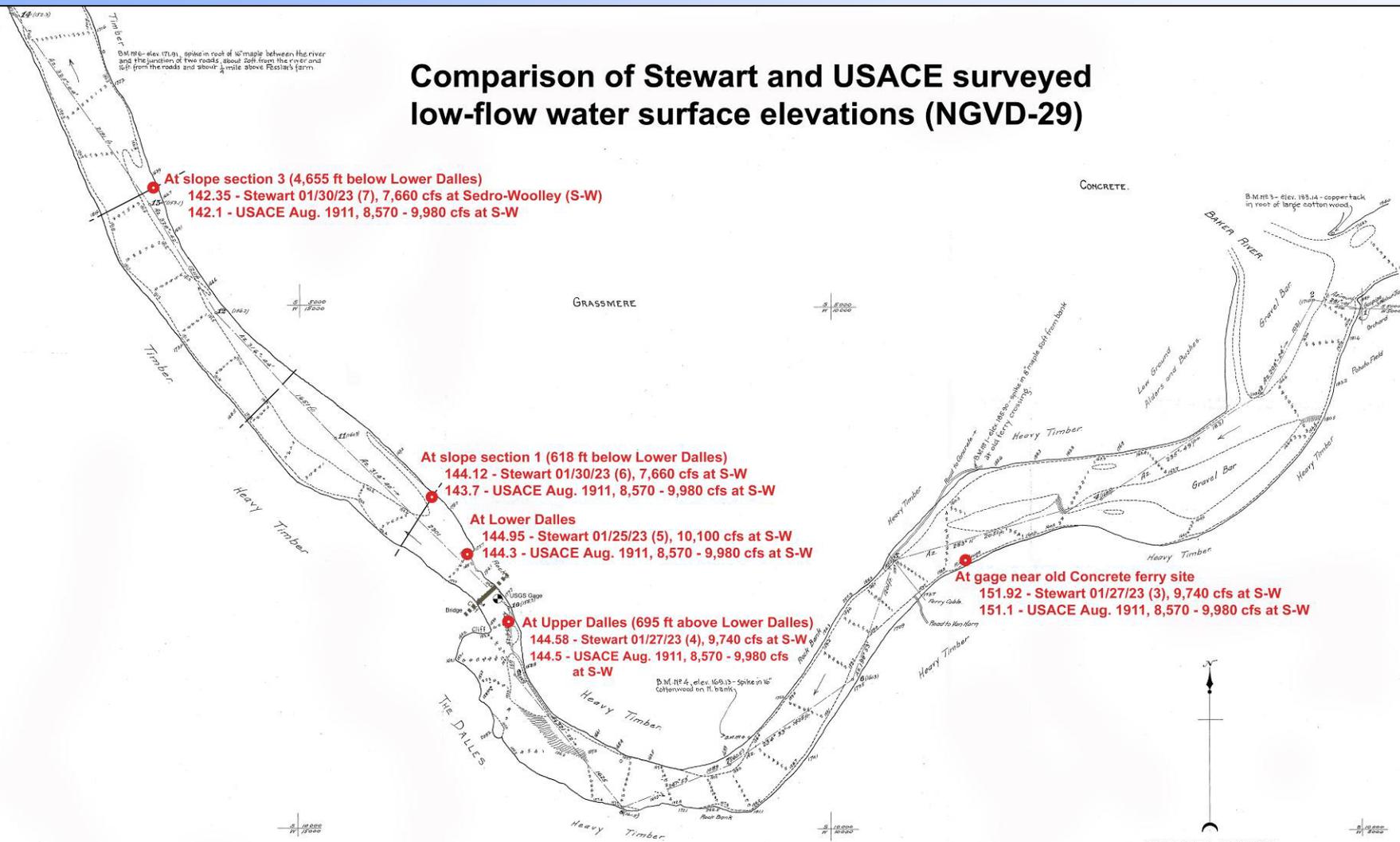
The 1.8-ft gage datum discrepancy



The 1.8-ft gage datum discrepancy

- The USGS stated that “...the gage datum of Stewart’s historical HWM elevations was likely to be 142.7 ft NGVD’29 and not 140.9 ft.”
- If this USGS statement were correct, all of Stewart’s surveyed elevations would have been 1.8 ft too low, including *low-flow water surface elevations*

Comparison of Stewart and USACE surveyed low-flow water surface elevations (NGVD-29)



At slope section 3 (4,655 ft below Lower Dalles)
 142.35 - Stewart 01/30/23 (7), 7,660 cfs at S-W
 142.1 - USACE Aug. 1911, 8,570 - 9,980 cfs at S-W

At slope section 1 (618 ft below Lower Dalles)
 144.12 - Stewart 01/30/23 (6), 7,660 cfs at S-W
 143.7 - USACE Aug. 1911, 8,570 - 9,980 cfs at S-W

At Lower Dalles
 144.95 - Stewart 01/25/23 (5), 10,100 cfs at S-W
 144.3 - USACE Aug. 1911, 8,570 - 9,980 cfs at S-W

At Upper Dalles (695 ft above Lower Dalles)
 144.58 - Stewart 01/27/23 (4), 9,740 cfs at S-W
 144.5 - USACE Aug. 1911, 8,570 - 9,980 cfs at S-W

At gage near old Concrete ferry site
 151.92 - Stewart 01/27/23 (3), 9,740 cfs at S-W
 151.1 - USACE Aug. 1911, 8,570 - 9,980 cfs at S-W

Notes

- (1) Stewart survey datum based on MSL (approximately same as NGVD-29)
- (2) USACE survey datum based on extreme low water of Puget Sound (-8.93 ft converting to NGVD-29). Assuming survey in this area conducted Aug. 24-30, 1911.
- (3) Stewart's survey notes, p. 84
- (4) Stewart's survey notes, p. 86
- (5) Stewart's survey notes, p. 84
- (6) Stewart's survey notes, p. 64
- (7) Stewart's survey notes, p. 64

LEGEND

- High Water Line
- Extreme Low Water
- Traverse Line
- Elevations of Stations, plus Elevations on Banks
- Roads
- Riffles

SKAGIT RIVER.
 FROM BAKER RIVER TO SEDRO-WOOLLEY, W.N.
 Surveyed under the direction of Major J. B. Cavanaugh,
 Corps of Engineers, U.S. Army,
 W.T. Preston, Assistant Engineer.
 Aug 24 to Sept 19, 1911.
 Scale 1/100ft. to the inch

Surveyed by W.F. Flynn, Junior Engineer.

Animals are based on the true azimuth of Sta 117 near Sedro-Woolley. Distances were obtained by the stadia method. Elevations are referred to extreme low water of Puget Sound. Soundings are expressed in feet below extreme low water of Skagit River. Wildcat local elevations are indicated by extreme low water of

Comparison of low-flow water surface elevations surveyed by Stewart and others using NGVD-29 datum



Stewart 1922–23 Survey					Difference Between Stewart and Other Surveys (ft)	
Location	Based on 140.89 Datum	Based on 142.69 Datum	USACE 1911 Survey*	Recent Survey	Based on 140.89 Datum	Based on 142.69 Datum
Near old Concrete Ferry Site	151.92 (01/27/23 – Stewart notes, p. 84, flow 9,740 cfs at Sedro-Woolley)	153.72 (01/27/23 – Stewart notes, p. 84, flow 9,740 cfs at Sedro-Woolley)	151.1 (8,570–9,980 cfs at Sedro-Woolley)	152.1 (Skagit County 04/28/08 – 9,420 cfs at Mt. Vernon and 7,680 cfs at Concrete, surveyed 152.32/150.84 at LB Pt. # 1365/1366)	0.82 and –0.18	2.62 and 1.62
Upper Dalles Gage	144.58 (01/27/23 – Stewart's Notes, p. 86, flow 9,740 cfs at Sedro-Woolley)	146.38 (01/27/23 – Stewart's Notes, p. 86, flow 9,740 cfs at Sedro-Woolley)	144.5 (8,570–9,980 cfs at Sedro-Woolley)		0.08	1.88
	147.55 (12/23/22 – Stewart's Notes, p. 34, 6.66+140.89, flow 14,200 cfs at Sedro-Woolley)	149.35 (12/23/22 – Stewart's Notes, p. 34, 6.66+140.89, flow 14,200 cfs at Sedro-Woolley)		147.4 (PIE 9/30/04 – flow 13,300 cfs at Mt. Vernon and 12,500 cfs at Concrete)	0.15	1.95
Lower Dalles Gage	144.95 (01/25/23 – Stewart's notes, p. 54, 3.91+141.04, flow 10,100 cfs at Sedro-Woolley)	146.75 (01/25/23 – Stewart's notes, p. 54, 3.91+141.04, flow 10,100 cfs at Sedro-Woolley)	144.3 (8,570–9,980 cfs at Sedro-Woolley)		0.65	2.45
Upper Slope Section	144.12 (01/30/23 – Stewart's notes, p. 64, flow 7,660 cfs at Sedro-Woolley)	145.92 (01/30/23 – Stewart's notes, p. 64, flow 7,660 cfs at Sedro-Woolley)	143.7 (8,570–9,980 cfs at Sedro-Woolley)		0.42	2.22
Lower Slope Section	142.35 (01/30/23 – Stewart's notes, p. 64, flow 7,660 cfs at Sedro-Woolley)	144.15 (01/30/23 – Stewart's notes, p. 64, flow 7,660 cfs at Sedro-Woolley)	142.1 (8,570–9,980 cfs at Sedro-Woolley)		0.25	2.05
				Range of Difference =	–0.18 to 0.82	1.62 to 2.62

* Elevations based on extreme low water of Puget Sound were adjusted by –8.93 ft to NGVD-29 (see USGS 1961, p. 52, “Gage” description). The Skagit River survey was conducted between August 24 and September 19, 1911 by USACE from Baker River to Sedro-Woolley (see the title and notes of the original USACE surveyed map on lower right corner of Figure 4). We assume the survey in Concrete area was conducted in August 1911 for conservatism, as the Sedro-Woolley gage data indicate that the Skagit River flows in August 1911 were lower than those in September 1911.

Comparison of 1921 HWMs independent of datum difference

Location	Stewart 1922–23 Surveyed Elevation (ft) Based on 140.89 Gage Datum at Upper Dalles 1921 HWM*	Low-Flow Water Level**	Relative Gage Height (ft) 1921 HWM Above Low-Flow Water Level	Similar Low-Flow Water Level (NGVD-29) Surveyed by Other**	Converted 1921 HWM Elevation (NGVD-29) Not Associated w/ Stewart's Gage Datum	Difference between Stewart's and Converted 1921 HWM Elevations (ft)
Near old Concrete Ferry Site	182.58 ^a	151.92	30.66	152.1 (Skagit County, 2008)	182.76	-0.18
Upper Dalles Gage	175.75 ^b	144.58	31.17	144.5 (USACE, 1911)	175.67	0.08
	175.18 ^c	147.55	27.63	147.4 (PIE, 2004)	175.03	0.15
Lower Dalles Gage	171.04 ^d	144.95	26.09	144.3 (USACE, 1911)	170.39	0.65
Range of Difference =						-0.18 to 0.65

*See Figure 5 for Stewart's HWM elevations

**See Table 2 for Stewart's and others' low-flow water surface elevations

Notes:

- a. 182.58 = 32.0 (gage height) + 150.58 (gage datum), Stewart's survey notes, p. 85
- b. 175.75 = 34.86 (gage height) + 140.89 (gage datum), Stewart's survey notes, p. 87
- c. 175.18 = 34.29 (gage height) + 140.89 (gage datum), Stewart's survey notes, p. 87
- d. 171.04 = 30.0 (gage height) + 141.04 (gage datum), Stewart's survey notes, pp. 54-55 & p. 67

At Upper Dalles

146.47 (4/27/06)

1921 HW 175.03

gh 27.63

147.4 (9/30/04)

1921 HW 175.67 not 177.6 published by USGS

gh 31.17

144.5 (Aug. 1911)

Date

flow (cfs) c/MV or SW

Aug. 1911 =	8,570/9,980 @ SW
1/27/23 =	9,740 @ SW
9/30/04 =	12,500 / 13,300
12/23/22 =	14,200 @ SW

2006/04/27 9:05 am

Conclusions

- Stewart's surveyed elevations are based on MSL, consistent with the use of NGVD-29 datum
- There is no evidence that Stewart's gage datum was incorrectly surveyed (by 1.8 ft too low as the USGS statement suggested)
- USGS published 1921 HWM El. 177.6 is based on an incorrect 12.69 ft gage datum difference, which does not include the 1.8 ft datum difference between Stewart's gage and County's gage
- USGS should have used the corrected 10.89 ft gage datum difference ($= 12.69 - 1.8$)



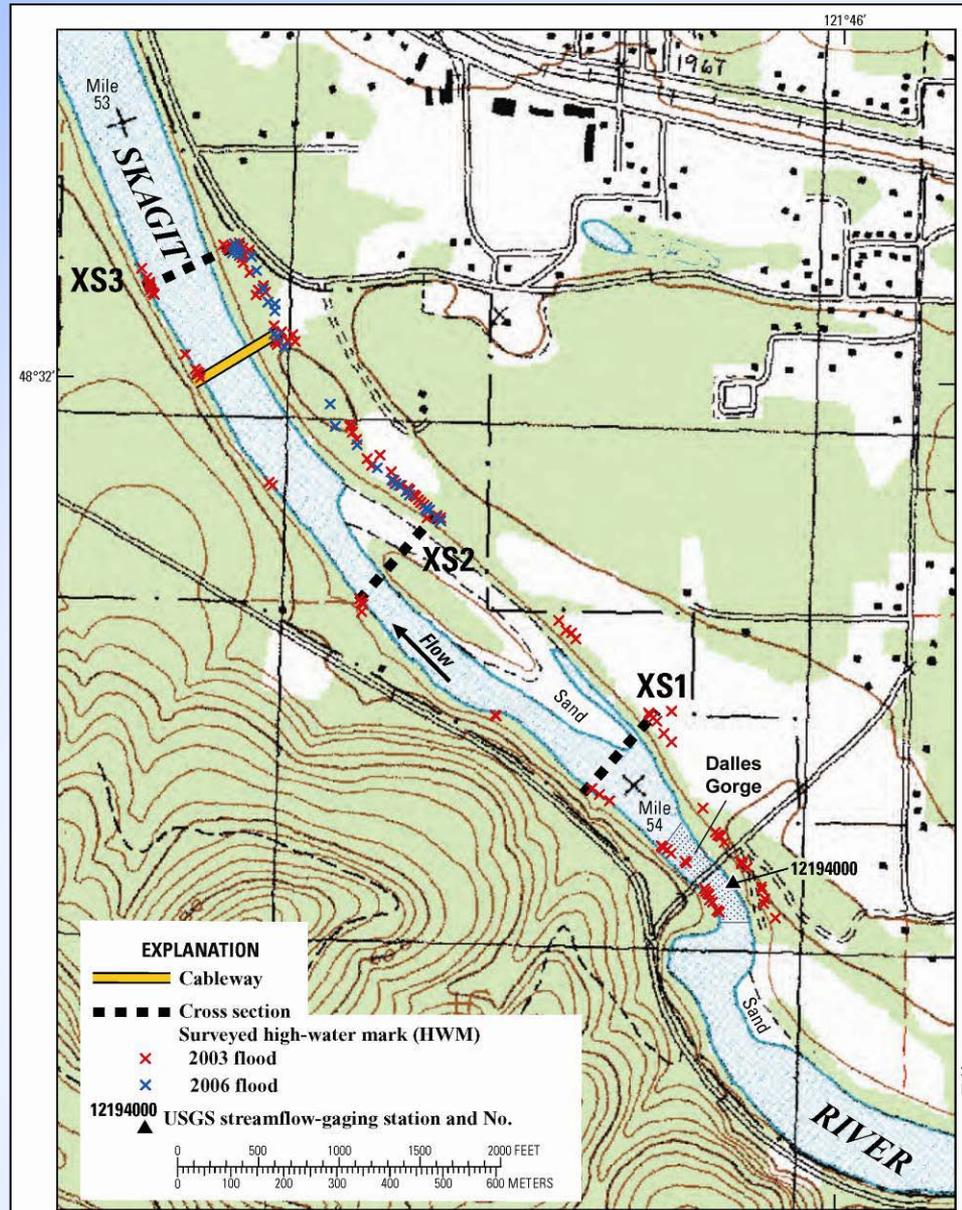
Historical flood peak discharges of Skagit River near Concrete

(Estimate of 1921 peak discharge using HEC-RAS model)

Peak Discharge (cfs)			
Flood	1923 Estimated by Stewart	2007 Revised by USGS	2008 Estimated by PI Engineering
1897	275,000	265,000	181,200
1909	260,000	245,000	179,000
1917	220,000	210,000	158,700
1921	240,000	228,000	169,700

Review of Stewart's Slope-Area Computations

Topographic map of the slope-area measurement reach on the Skagit River near Concrete showing the three cross sections (XS1, XS2, and XS3), the streamflow-gaging station, and HWMs from the 2003 flood and the 2006 flood surveyed by the U.S. Geological Survey (source of data: Scientific Investigation Report 2007-5159, USGS)







Slope sections below the Dalles
Flow= 9,980 cfs
GH= 16.47 ft
on 2006-04-27

2006/04/27 9:08 am



Slope sections below the Dalles

Flow= 8,000 cfs

GH= 15.74 ft

on 2006-08-27

27/08/2006

Slope-section hydraulic parameters and 1921 flood peak discharges computed by Stewart

Slope-Area Reach	Mean Flow Area (sq. ft)	Mean Hydraulic Radius (ft)	Water Surface Fall (ft)	Reach Length (ft)	Slope of Hydraulic Grade Line	Manning's "n" Value	Computed 1921 Peak Discharge (cfs)
XS1-XS2	18,500	26.1	2.11	1,860	0.00113	0.033	244,000
XS2-XS3	18,000	24.2	2.62	2,190	0.00120	0.033	234,000
XS1-XS3	18,200	25.1	4.73	4,050	0.00117	0.033	240,000

Note: Flow area = 18,000, 19,000, and 16,900 for XS1, XS2, and XS3, respectively

Uniform or Non-uniform Flow?

- Stewart's slope-area computations are based on *uniform flow*, ignoring velocity head difference between sections
- The flow in the slope-section reaches, XS1-XS2, XS2,-XS3, and XS1-XS3 are non-uniform flow, or *gradually varied flow*, as velocity varies from section to section
- Therefore, the velocity head variation between sections need to be included in the computations

Slope-Area Calculations

□ Manning's Equation: $Q = 1.486/n AR^{2/3} S^{1/2}$

where Q = discharge in ft^3/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:

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



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

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

h_v = velocity head at the respective section; h_f = 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 or deceleration in a contracting or expanding reach,

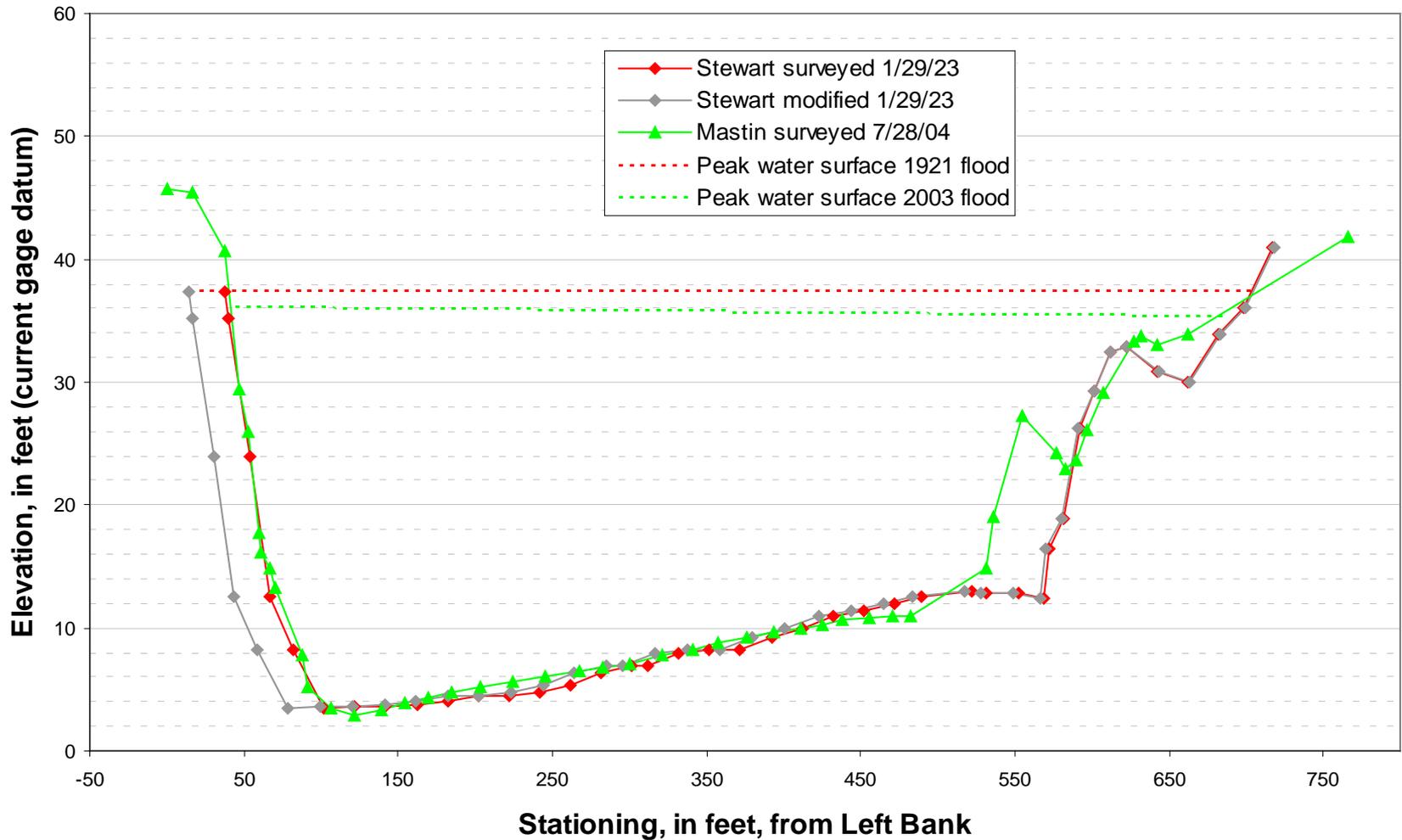
and k = a coefficient, 0.5 for expanding reach and zero for contracting reaches.

Survey Rope Stretched?

**Stewart made an assumption
after he surveyed XS3 section
that his survey rope
had stretched without verification**



Slope Section XS3 – Skagit River near Concrete, WA



HWM at XS1?

**The HWM at XS1
used in Stewart's slope-area computations
was unsupported by Stewart's or County's
surveyed HWMs**



Summary of 1921 HWMs (Lower Dalles to XS2) (surveyed 3/7-8/1923 by Skagit County staff under Stewart's direction, unless noted otherwise)

Station (ft)	HWM (ft)	Elevation (NGVD-29)	Above Current Gage* Datum (ft)
0+00	30.00**	171.04	41.04
5+25	29.68	170.72	40.72
8+65	29.06***	170.10	40.10
9+85	30.37	171.41	41.41
15+25	28.62	169.66	39.66
20+90	28.40	169.44	39.44
24+70	28.97	170.01	40.01

Notes:

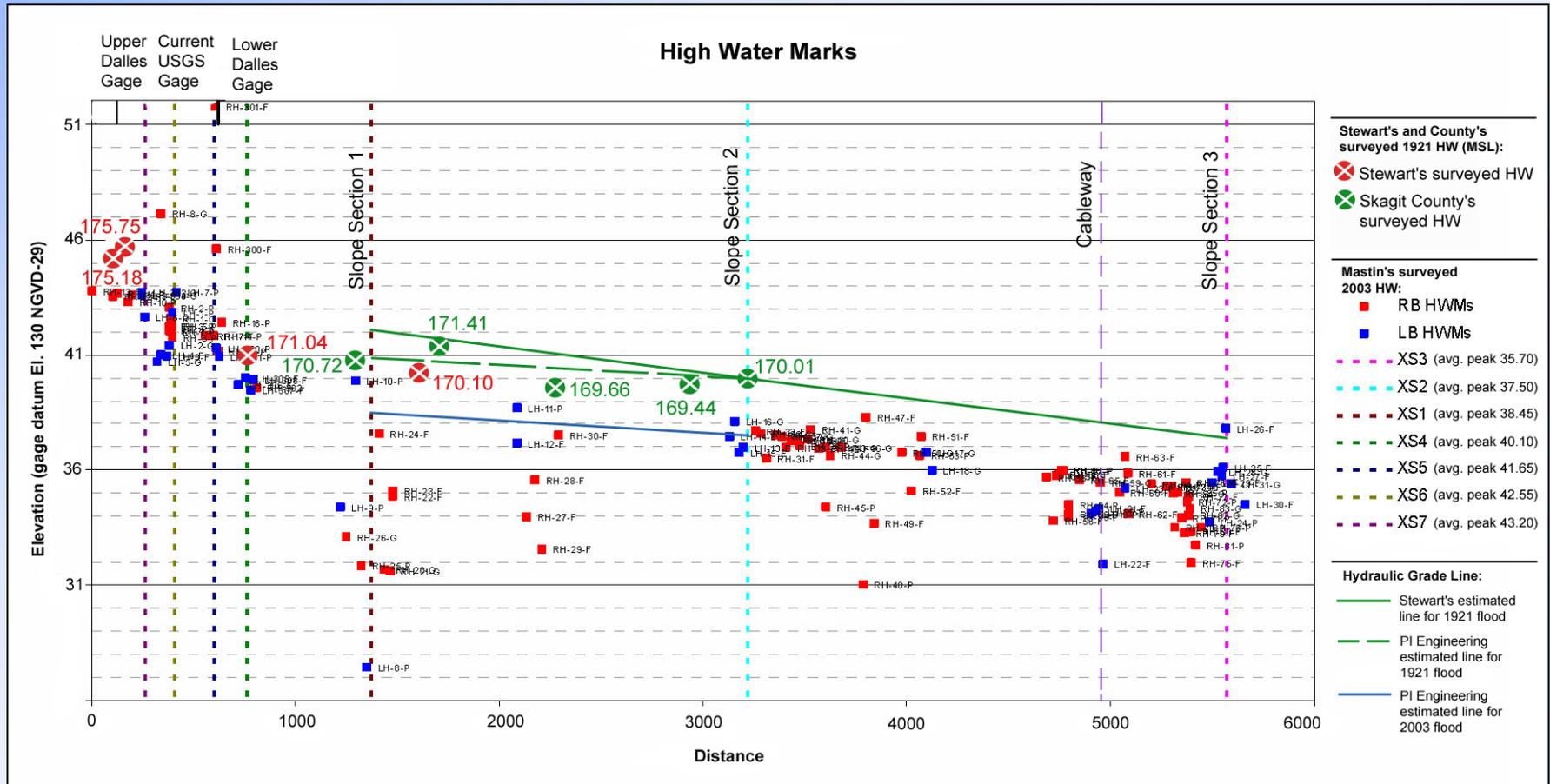
*Current gage datum El. 130.00 above NGVD-29

**Also surveyed by Stewart 1/25-30/1923 (see Stewart's survey notes, pp. 54-55)

***Only surveyed by Stewart 1/25-30/1923 (see Stewart's survey notes, p. 64, "170.10 1921 HW" at 865' below lower Dalles gage)



1921 and 2003 flood high water marks surveyed by Stewart (in 1922-23) and USGS (in summer 2004)

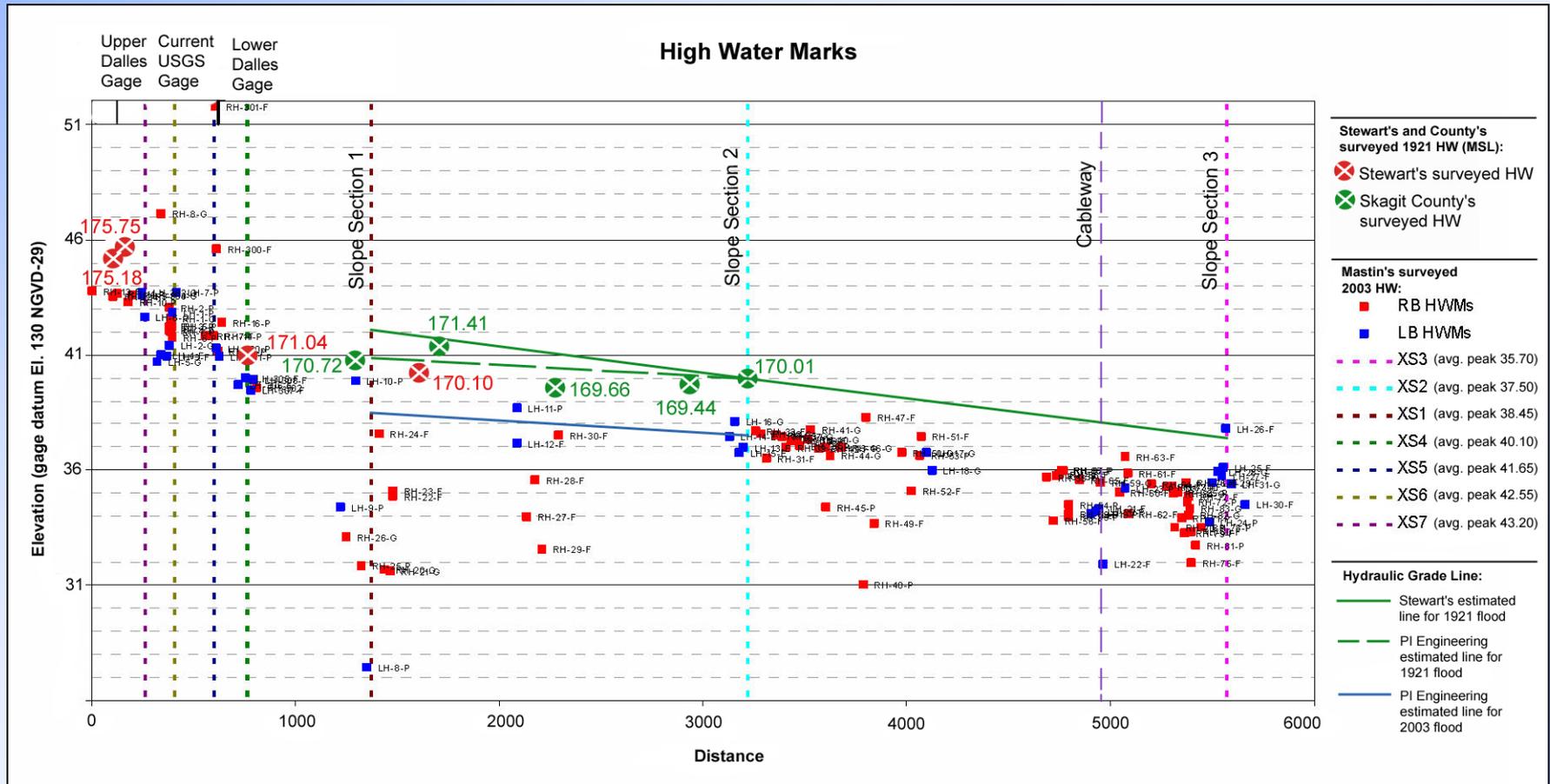


Surge Effects?

Stewart stated his HWMs were at
crest of surges
and suggested his HWMs be adjusted for
the amount of surging
in order to obtain the *flood crest levels*
for more accurate discharge computaions



1921 and 2003 flood high water marks surveyed by Stewart (in 1922-23) and USGS (in summer 2004)



Indication of surging for 2003 flood at slope sections

Slope-section	Highest HWM (ft)*	USGS-estimated Peak Water Level (ft)*	Indication of Surging (ft)
XS1	39.87	38.45	1.4
XS2	38.08	37.50	0.6
XS3	37.79	35.70	2.1

* Source of data: USGS-provided spreadsheet – Concrete_03_SAM.xls

**Reevaluation of 1921 Flood Peak Discharge
Using Slope-Area Method
with corrections discussed above**

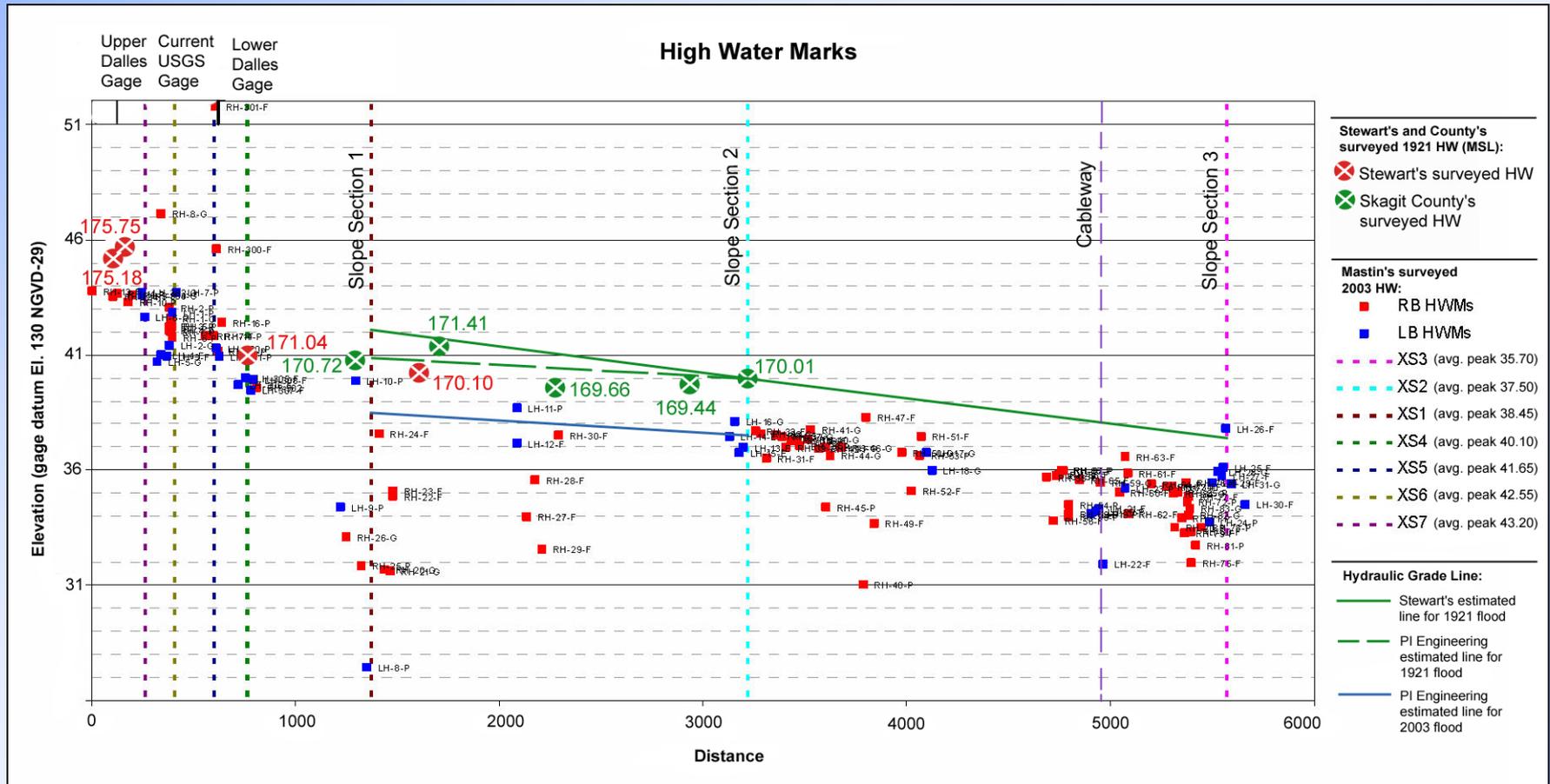
Summary of 1921 flood peak estimates using slope-area method and Stewart-surveyed data



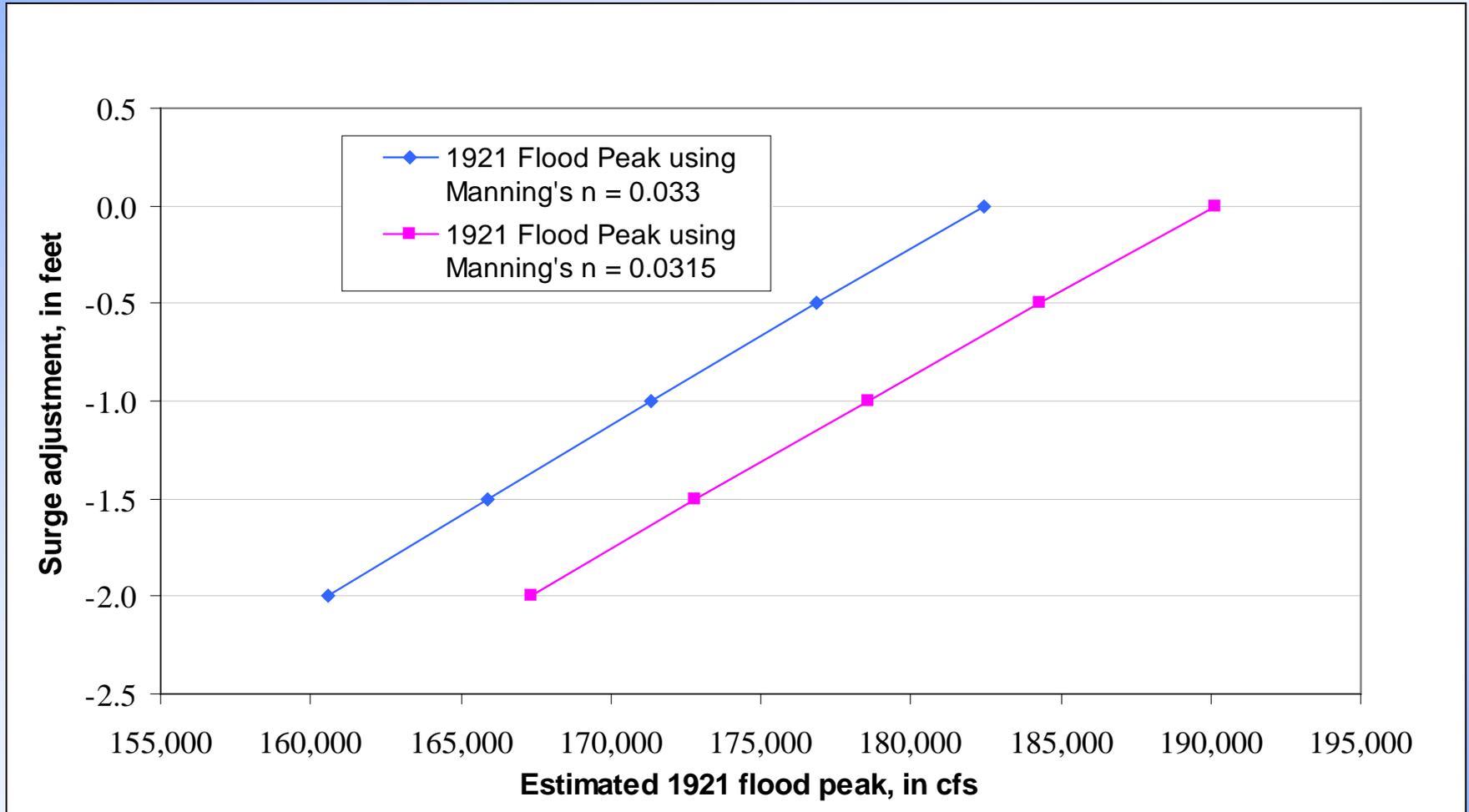
	Surge Adjustment (ft)	Manning's "n" value	Reach XS1-XS2	Reach XS2-XS3	Reach XS1-XS3	Average
	0.0	0.0330	163,600	198,000	185,800	182,467
	-0.5	0.0330	158,300	192,100	180,100	176,833
	-1.0	0.0330	153,200	186,300	174,500	171,333
	-1.5	0.0330	148,100	180,500	169,000	165,867
	-2.0	0.0330	143,300	174,800	163,600	160,567
	0.0	0.0315	172,000	205,000	193,500	190,167
	-0.5	0.0315	166,400	199,000	187,600	184,333
	-1.0	0.0315	161,000	193,000	181,800	178,600
	-1.5	0.0315	155,500	186,900	176,100	172,833
	-2.0	0.0315	150,500	181,100	170,400	167,333
Stewart's original estimates (1923)	0.0	0.0330	244,000	234,000	240,000	240,000
USGS revised estimate (2007)	0.0	0.0315	N/A	228,000	N/A	228,000



1921 and 2003 flood high water marks surveyed by Stewart (in 1922-23) and USGS (in summer 2004)



Estimated 1921 flood peak vs. surge adjustment using slope-area method



Conclusions of Reevaluation

Using Slope-Area Method

- Stewart's estimated 1921 flood peak discharge of 240,000 cfs is too high
- USGS-revised 1921 flood peak discharge of 228,000 cfs is high, too
- Using a conservative 0.5-ft surge adjustment, the slope-area method returns an estimate of 177,000 to 184,000 cfs for 1921 flood peak discharge

Reevaluation of 1921 Flood Peak Discharge Using Stage-Discharge Rating

current gage rating has been stable

for high flows

for over 80 years

An aerial photograph showing a green truss bridge crossing a river. The river is surrounded by dense green forest. The bridge is a long, narrow structure with a complex truss design. The water in the river is a deep green color. The forest is thick and covers the surrounding hillsides.

The Dalles

Flow= 8,000 cfs

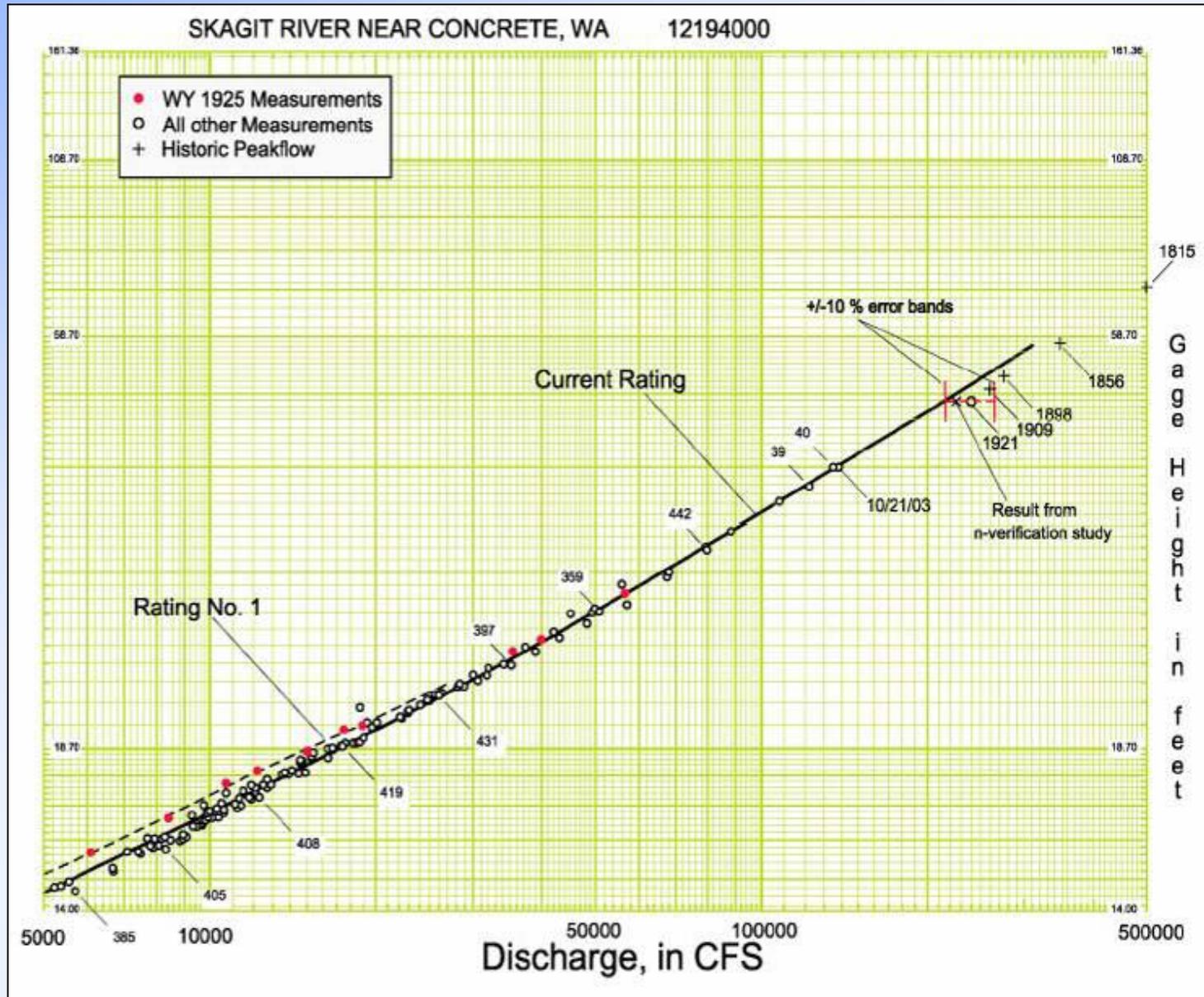
GH= 15.74 ft

on 2006-08-27

27/08/2006

Stage-discharge Rating Curve for the Skagit River near Concrete

(Provided by USGS, May 2004)

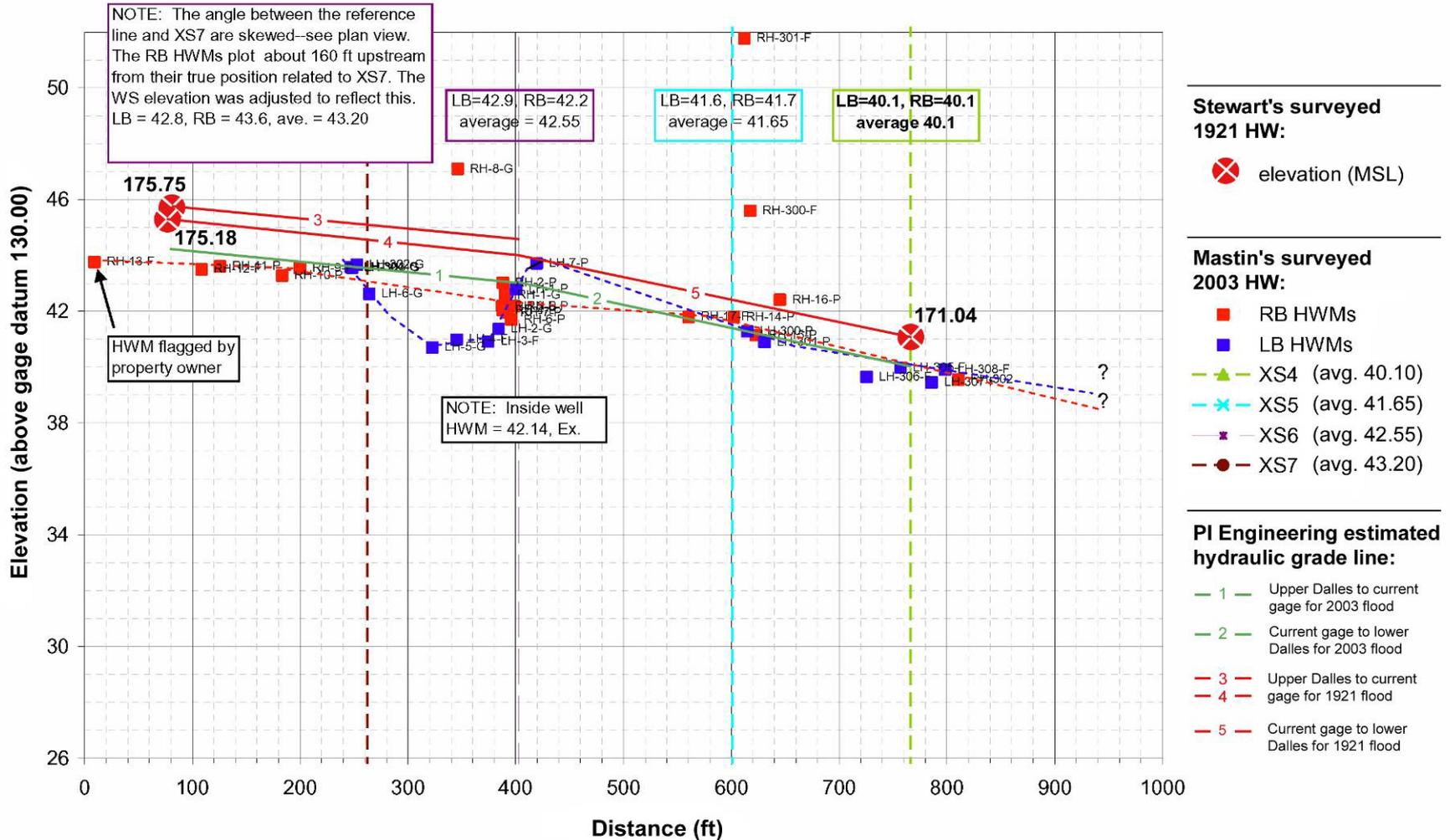




1921 and 2003 HWMs in the Dalles gorge

(original source of data: USGS-provided spreadsheet – Concrete_03_SAM.xls)

High Water Marks





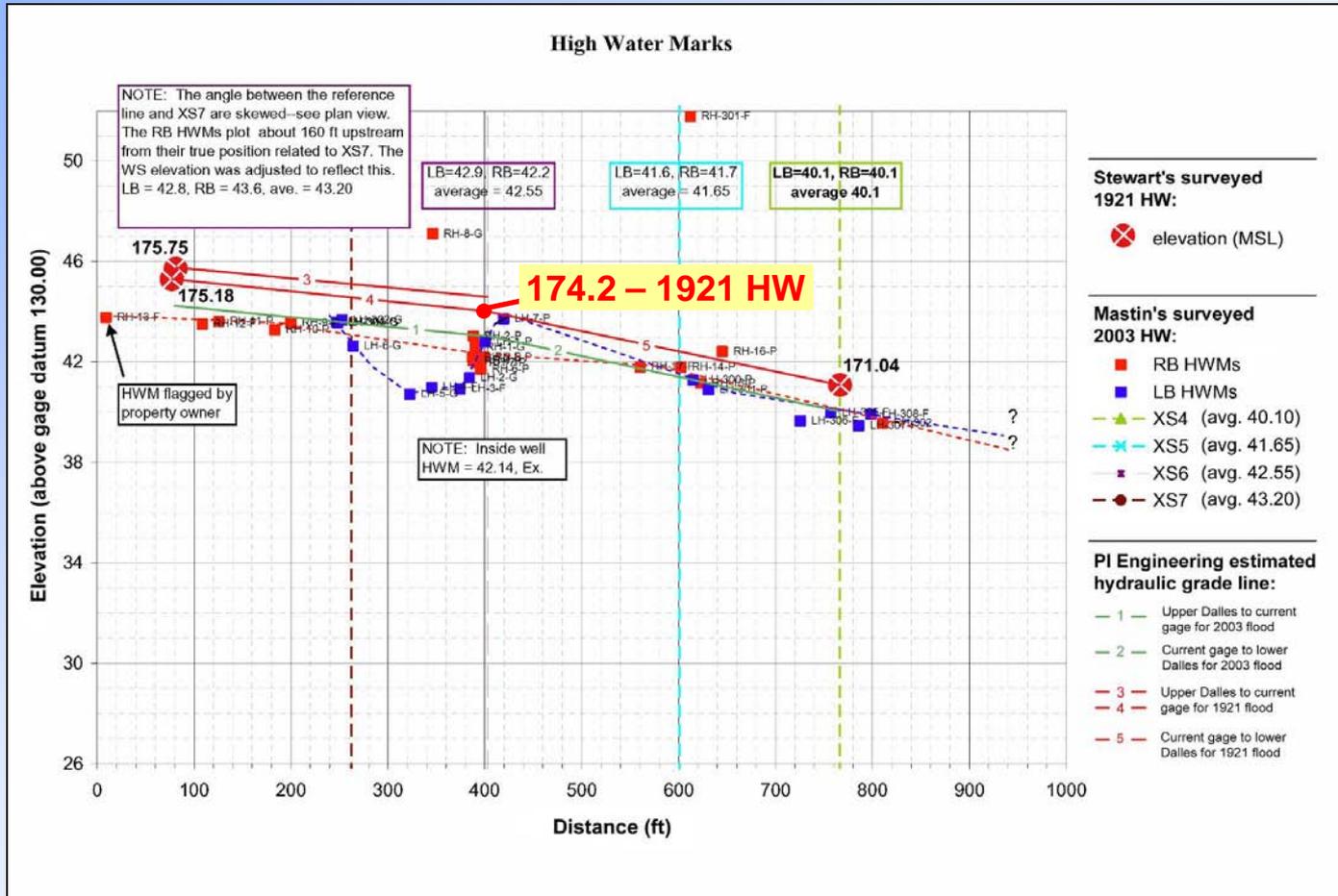
Transferring of Stewart's HWMs to current gage site

Stewart-surveyed 1921 HWM (MSL)		Estimated Water Surface Drop (ft) to current gage	PI Engineering – Estimated 1921 HWM (MSL) at current gage
Upper Dalles	175.75	1.18	174.57
	175.18	1.18	174.00
Lower Dalles	171.04	-2.96	174.00
			Average = 174.19 (or 174.2)



1921 and 2003 HWMs in the Dalles gorge

(original source of data: USGS-provided spreadsheet – Concrete_03_SAM.xls)



Amount of surging

2003 flood at the current gage site

2003 HWM (gh, ft)

Outside well 43.021 & 43.715

Inside well 42.14

Difference (amount of surging) 0.9 & 1.6

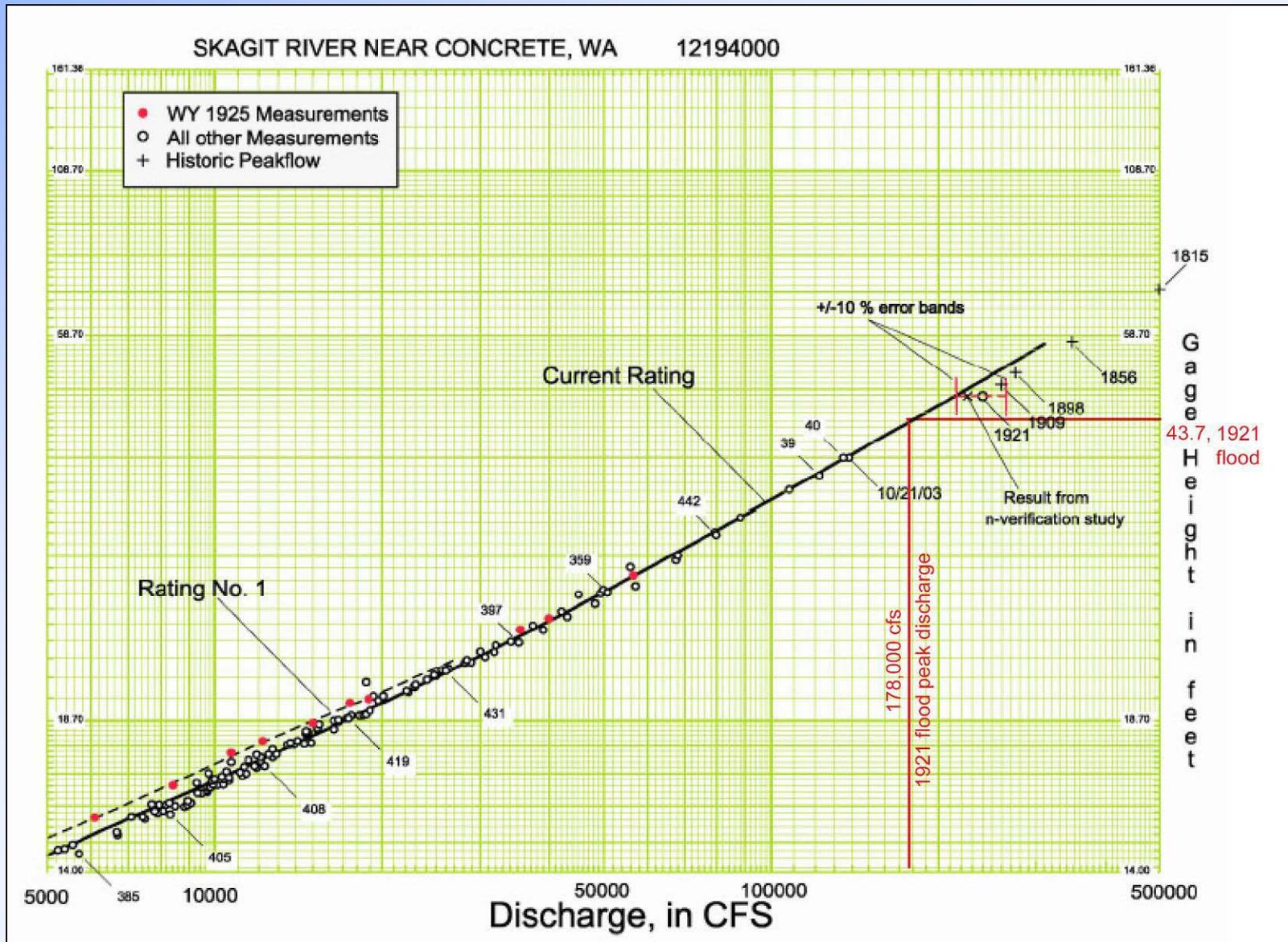
Determination of 1921 HWM inside gage well

1921 HWM outside well	174.2
Using 2003 flood amount of surging	0.9 ~ 1.6
	<hr/>
1921 HWM inside well	173.3 ~ 172.6

Using conservative 0.5 ft surge → 1921 HWM inside well 173.7
 (or 43.7 above 130.00)

Stage-discharge Rating Curve for the Skagit River near Concrete

(provided by USGS, May 2004)



Conclusions of Reevaluation

Using Stage-Discharge Rating Method

- Stewart's estimated 1921 flood peak discharge of 240,000 cfs is too high
- USGS-revised 1921 flood peak discharge of 228,000 cfs is high, too
- Using a conservative 0.5-ft surge adjustment, the stage-discharge rating method returns an estimate of 178,000 cfs for 1921 flood peak discharge

At Concrete

- Extension of hydraulic model and comparison to Stewart-surveyed 1921 high water marks
- Forensic investigation of houses built prior to 1921 to determine if they had previously been flooded

22/

Levits at Concrete

BS	HT	FS	Elev
.40	230.91		230.51
		5.34	225.17
1.31	215.64		214.33
		5.30	209.03
7.45	214.79		214.32
		0.47	214.32
2.96	217.28		204.76
		12.92	204.76
1.72	206.38		193.65
		12.73	193.65
0.91	194.56		182.13
		12.33	182.13
4.40	186.63		184.55
		2.08	184.55

23/

Nov 28

See pages 18 and 30 also

Measured down 11.24' from this point on freight car to rail below (about 300 ft below depot)

Ground surface 7.9 ft below line of sight at this point. Note that zero level for old channel cell low pt EIV 210 ft

1921 flood mark of Wolff's Residence

(Mc Daniels near Washington Cement plant can give 1909 flood)

Leonard Everett says 1897 flood about 9" lower than 1909, says that log jam in Dalles raised water 10 ft in 2 hrs. He says 1897 about highest midnight 1909 after midnight possibly 12:30 1921 highest about 1 am considerable distance and slope between 1897 and 1909 in Ks. Est mark at 0.25 ft below 1897 18 ft higher than 1909 and 34 ft higher than 1921 Found line at 1909 Hgt 2.0' above 1921 at Washington Cement plant machine shop

TP

Dec 21 1922	10.5	20.5
	4.7	9.4

11.2 rod 4.6 top 15.8
10.00
4.7
3.0
64
1921 Hgt

These are relative figures with historical stumps and Washington Cement Plant. The gages are a combination of 5' height and 6' diameter.

Fig is wrong primary see by Hbm half at page 141 See 3/24/23 Sec bottom of page 18 for true comparison of 1909 and 1921



Old Wolfe Residence

Crofoot

PARCELS OWNED
BY L.E. WOLFE
1921

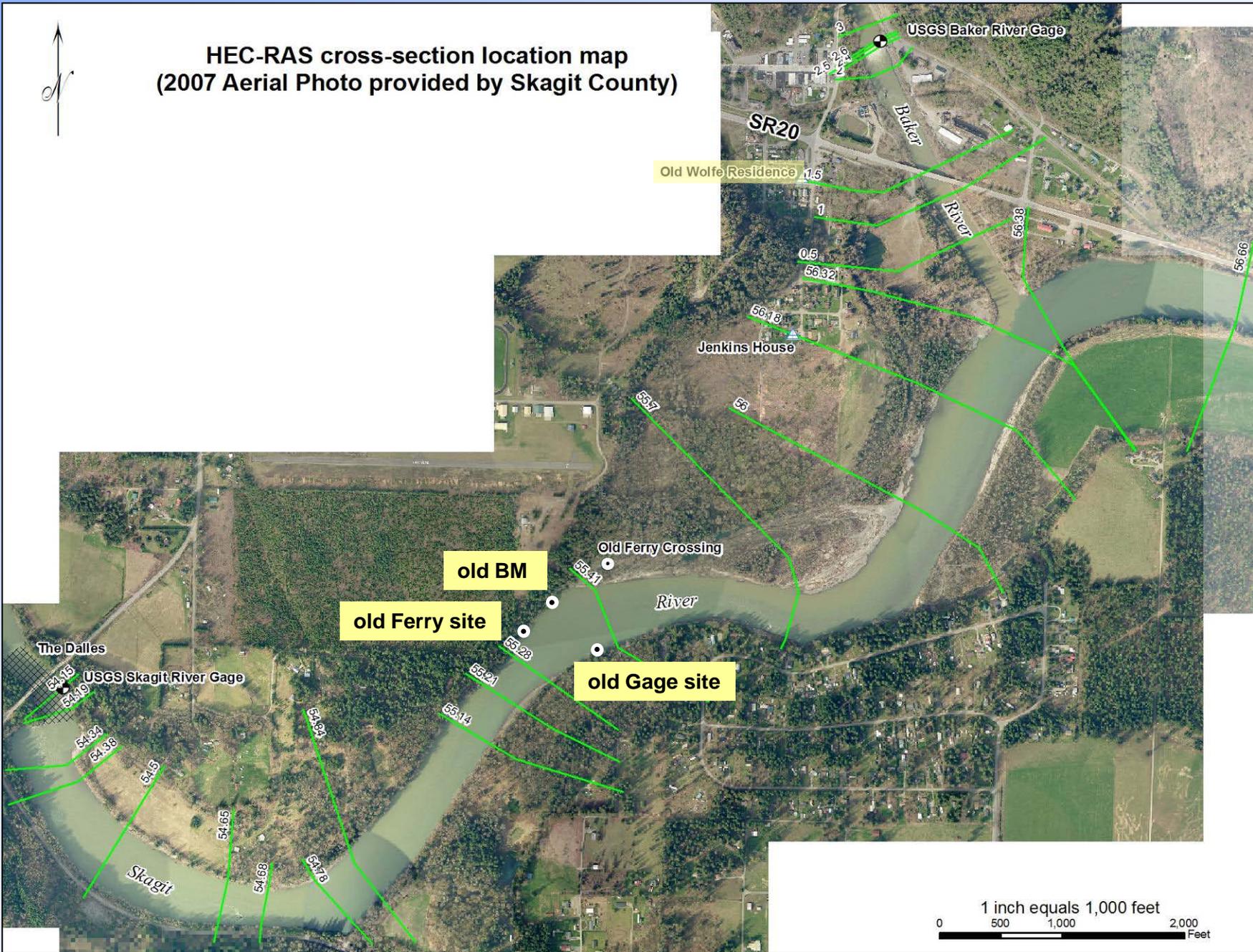
SOURCES

- 1) 1921 Real Property Tax Roll And Assessment, State Archives, Bellingham
- 2) Skagit County on-line Assessor Database
- 3) Assessor Parcel Map Section 11 Township 35 Range 08

Research conducted by
Josef Knuzler and Cuel Martin
30 MAY 08

off map
P70613

HEC-RAS cross-section location map (2007 Aerial Photo provided by Skagit County)



October 2003 Flood

Jenkins House at 7752 South Dillard

(Photo provided by Allen Jenkins)





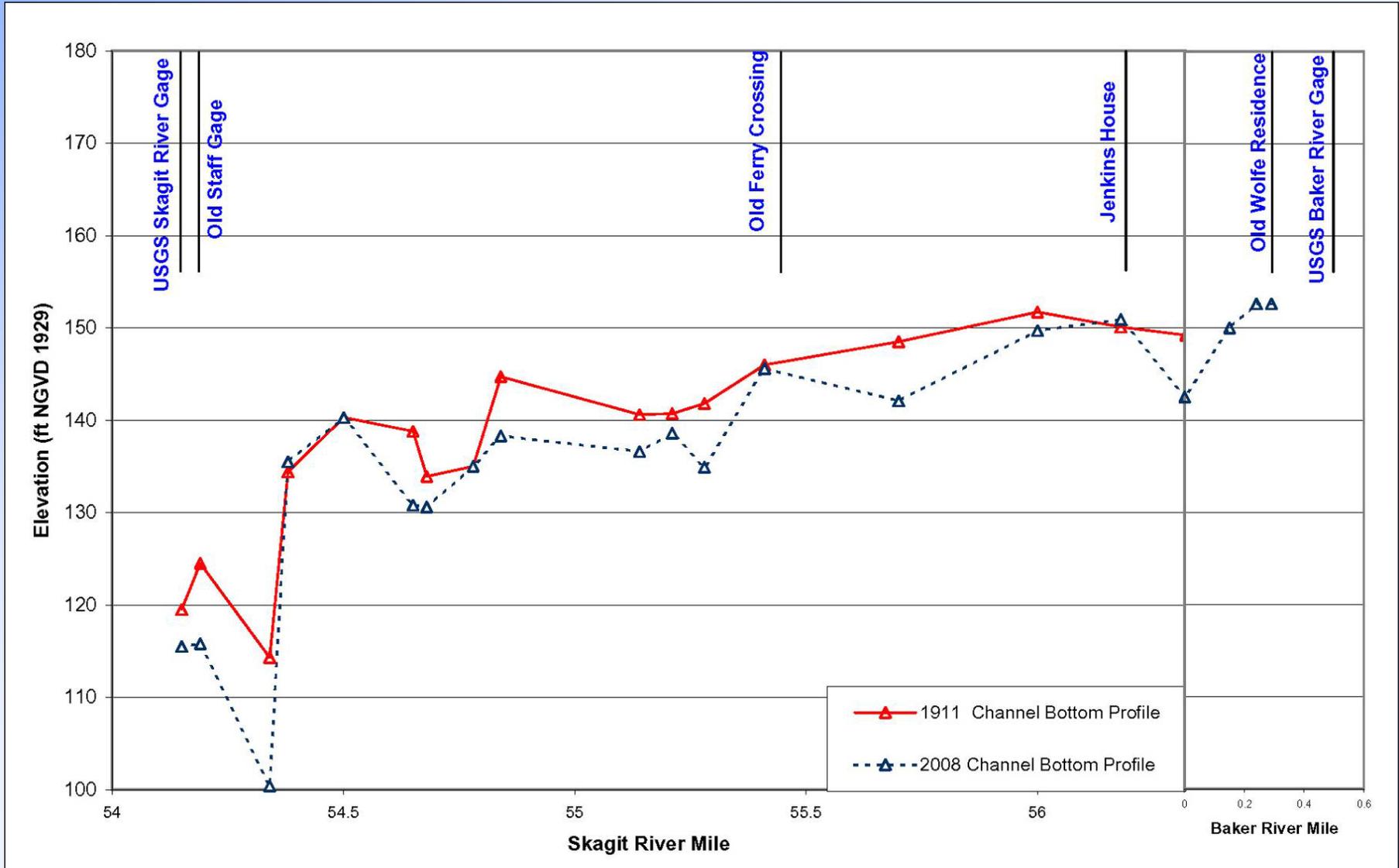
Comparison of Modeled and Observed 2003 Flood Elevations (NGVD-29)

Date of Flood	Time	Skagit River Flow* (cfs)	Baker River Flow** (cfs)	High Water Mark Location	Source of Data	Observed (ft)	Modeled (ft)	Difference (ft) btw. Modeled and observed flood elev.
21-Oct-03	6:15 AM	165,655	4,647	Baker River gage	USGS gage record	183.49	183.70	0.21
21-Oct-03	6:30 AM	164,169	4,655	Baker River gage	USGS gage record	183.48	183.50	0.02
21-Oct-03	7:15 AM	162,602	4,710	Baker River gage	USGS gage record	183.32	183.29	-0.03
21-Oct-03	7:30 AM	162,342	4,747	Baker River gage	USGS gage record	183.22	183.25	0.03
21-Oct-03	9:30 AM	150,956	4,822	Baker River gage	USGS gage record	181.77	181.70	-0.07
21-Oct-03	9:45 AM	151,538	4,822	Baker River gage	USGS gage record	181.54	181.78	0.24
21-Oct-03	6:15 AM	165,655	4,647	Jenkins House	Resident provided photo	182.75	182.78	0.03
21-Oct-03	6:30 AM	164,169	4,655	Jenkins House	Resident provided photo	182.75	182.57	-0.18
21-Oct-03	9:30 AM	150,956	4,822	Jenkins House	Resident provided photo	181.15	180.74	-0.41
21-Oct-03	9:45 AM	151,538	4,822	Jenkins House	Resident provided photo	181.15	180.82	-0.33
21-Oct-03	6:15 AM	165,655	4,647	Old staff gage at the Dalles	USGS 2004 survey	173.30	173.39	0.09
21-Oct-03	6:30 AM	164,169	4,655	Old staff gage at the Dalles	USGS 2004 survey	173.30	173.21	-0.09

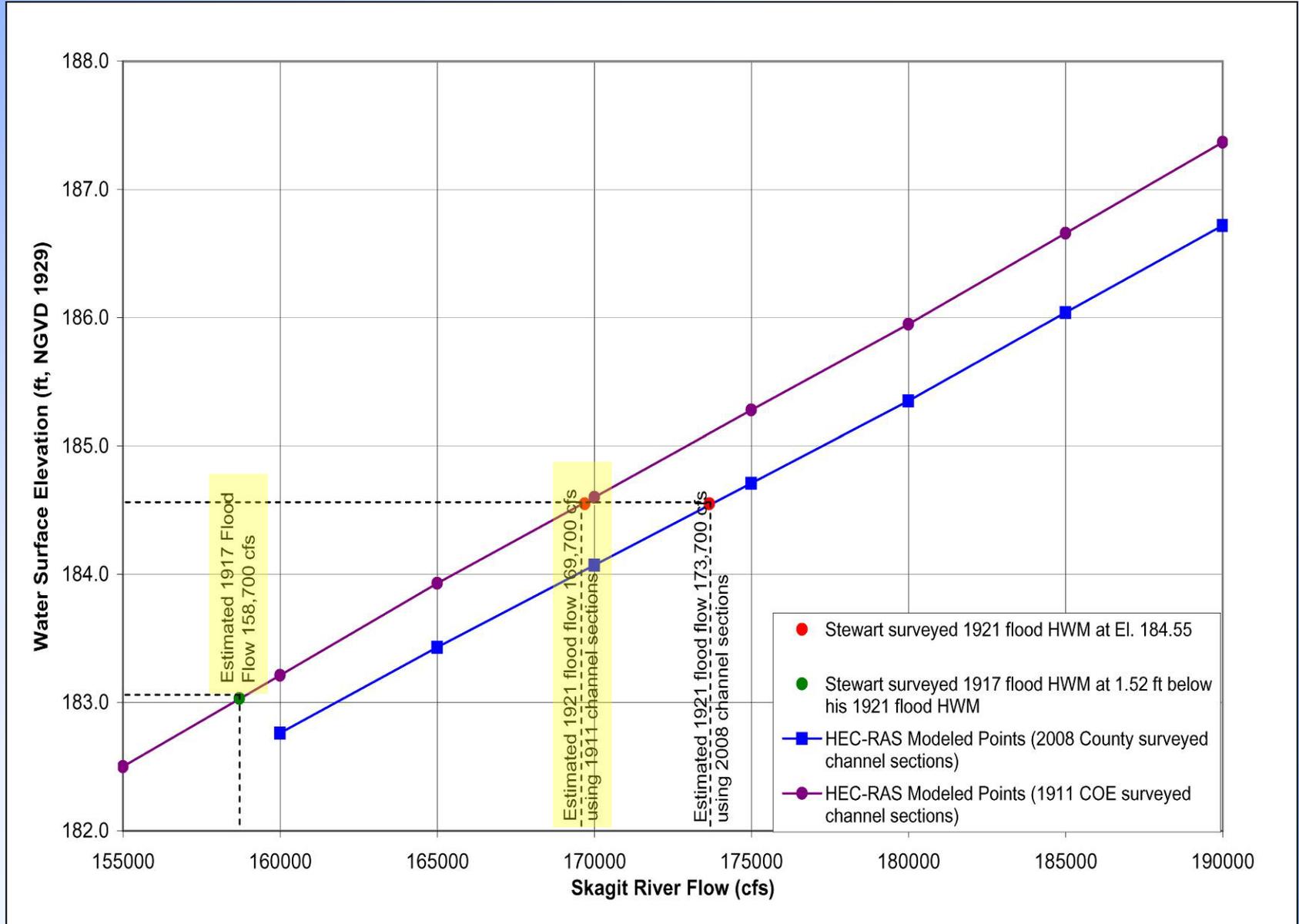
*USGS provided flow data (15-minute interval) at the Skagit River gage near Concrete

**PSE provided hourly flow data (interpolated for 15-minute interval) below Lower Baker Dam and powerhouse

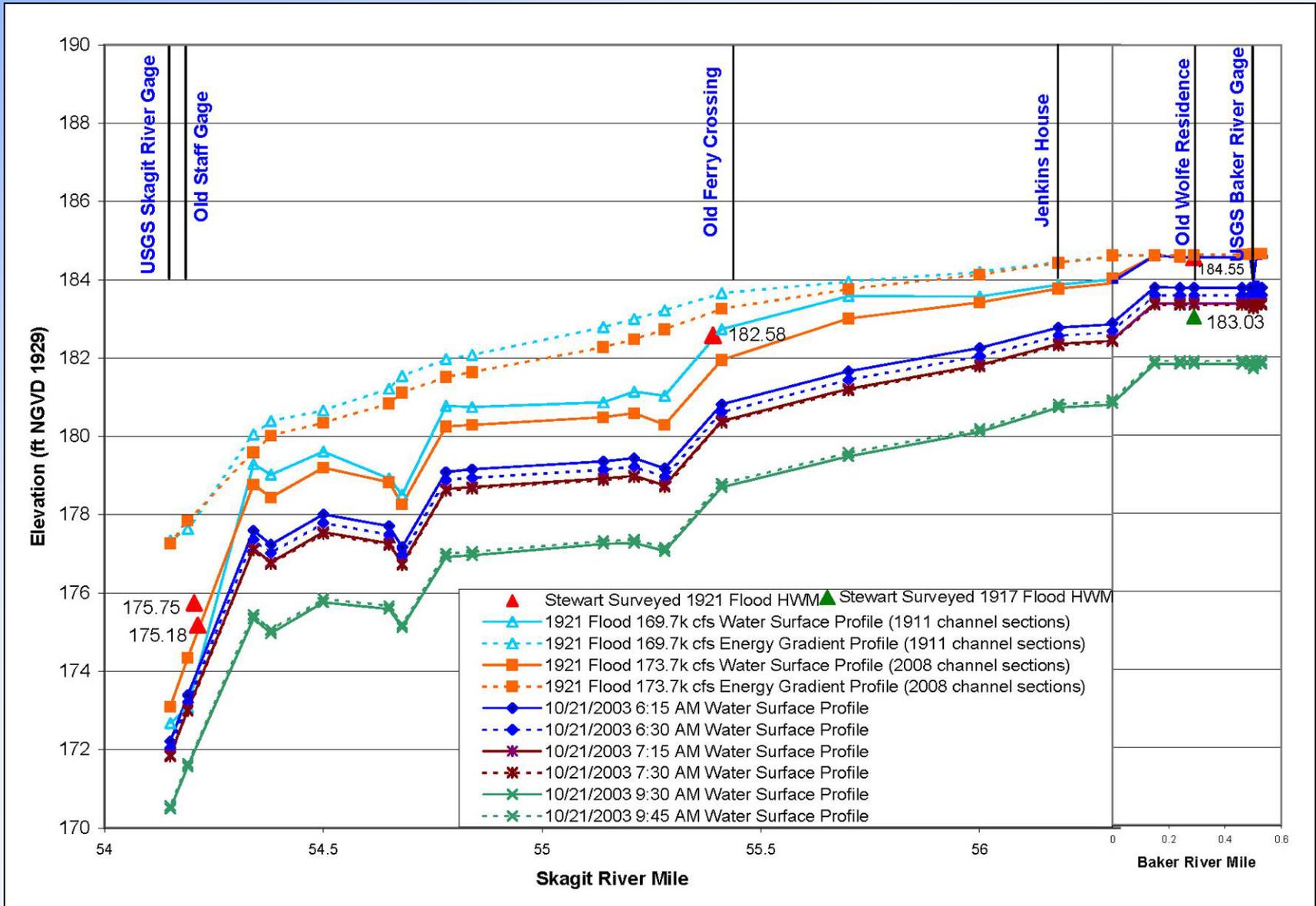
Comparison of 1911 and 2008 Surveyed Skagit River Channel Bottom Profiles in Concrete Reach



Flood Stage-Discharge Curve at Wolfe Residence in Concrete



HEC-RAS Modeled Flood Profiles in Concrete Reach of the Skagit and Baker Rivers



Conclusions of Reevaluation

Using HEC-RAS Modeling Method

- Stewart's estimated 1921 flood peak discharge of 240,000 cfs is too high
- USGS-revised 1921 flood peak discharge of 228,000 cfs is high, too
- Using Stewart's HWMs at Wolfe residence and old ferry landing site, the HEC-RAS modeling method results in an estimate of 169,700 cfs for 1921 flood peak discharge



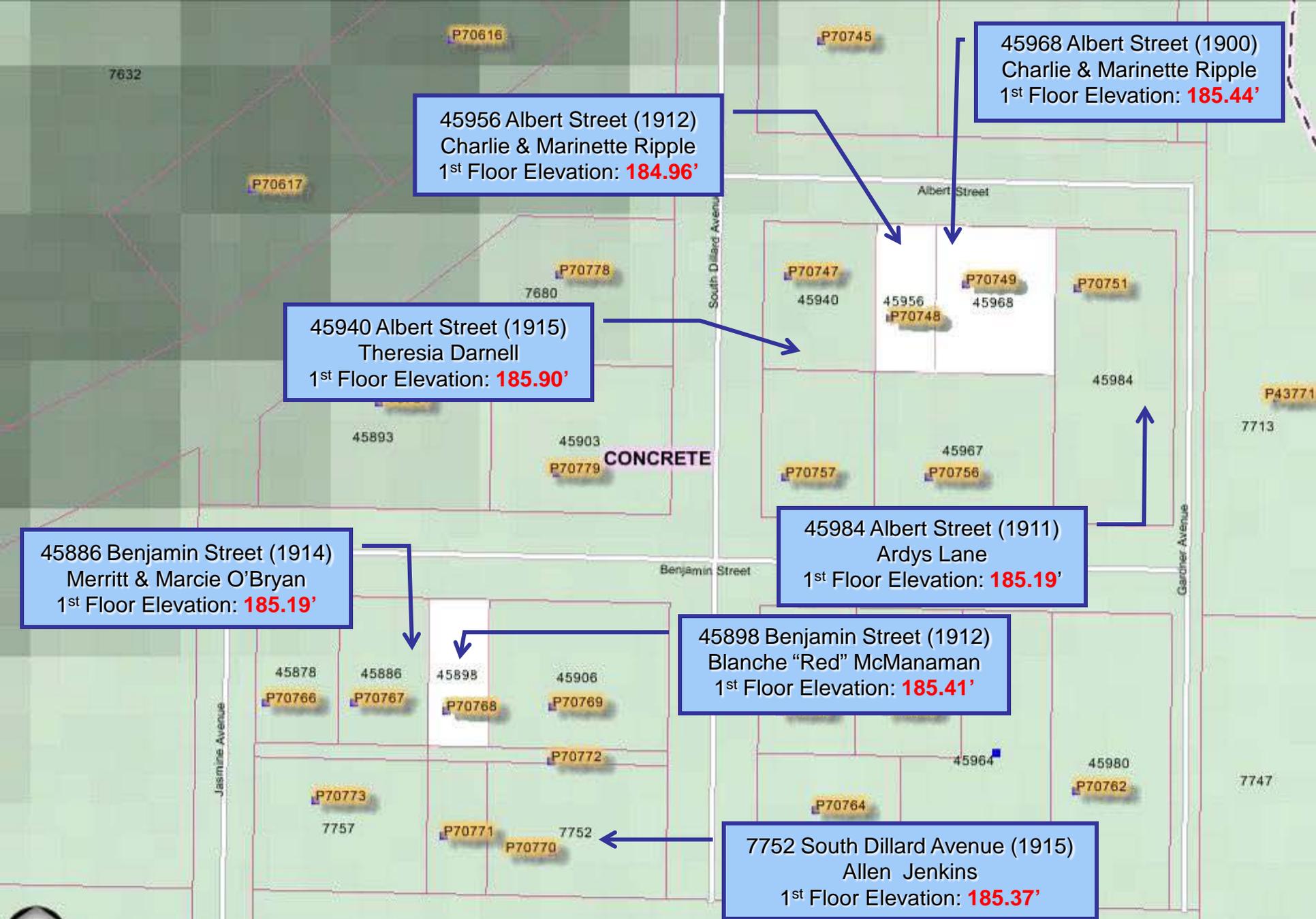
Historical flood peak discharges of Skagit River near Concrete

(Estimate of 1921 peak discharge using HEC-RAS model)

Peak Discharge (cfs)			
Flood	1923 Estimated by Stewart	2007 Revised by USGS	2008 Estimated by PI Engineering
1897	275,000	265,000	181,200
1909	260,000	245,000	179,000
1917	220,000	210,000	158,700
1921	240,000	228,000	169,700

Conclusions of Reevaluation

- Using slope-area method, the estimated 1921 flood peak discharge is 177,000 - 184,000 cfs
- Using stage-discharge rating method, the estimated 1921 flood peak discharge is 178,000 cfs
- Using HEC-RAS modeling method, the estimated 1921 flood peak discharge is 169,700 cfs (the best scientific method and result)



Crofoot Parcels and First Floor Elevations (2008 surveyed by County)

Ripple House #1, parcel #70749



Ripple House #1,
45968 Albert Street,
Crofoot Addition, Concrete

Ripple House #1 with exterior
siding removed for inspection of
interior wall cavity.
First floor elevation 185.51



Ripple House #2, parcel #P70748

First Floor Elevation 184.96. Annotated photo showing exterior siding removed for inspection of interior wall cavity



**HEC-RAS modeled 1921
(240,000 cfs)**

**HEC-RAS modeled 1917
(220,000 cfs)**

**Stewart-Surveyed 1921
High Water Mark,
Crofoot's Addition**

**45956 Albert Street, Concrete, WA
2nd Ripple House, Built 1912**

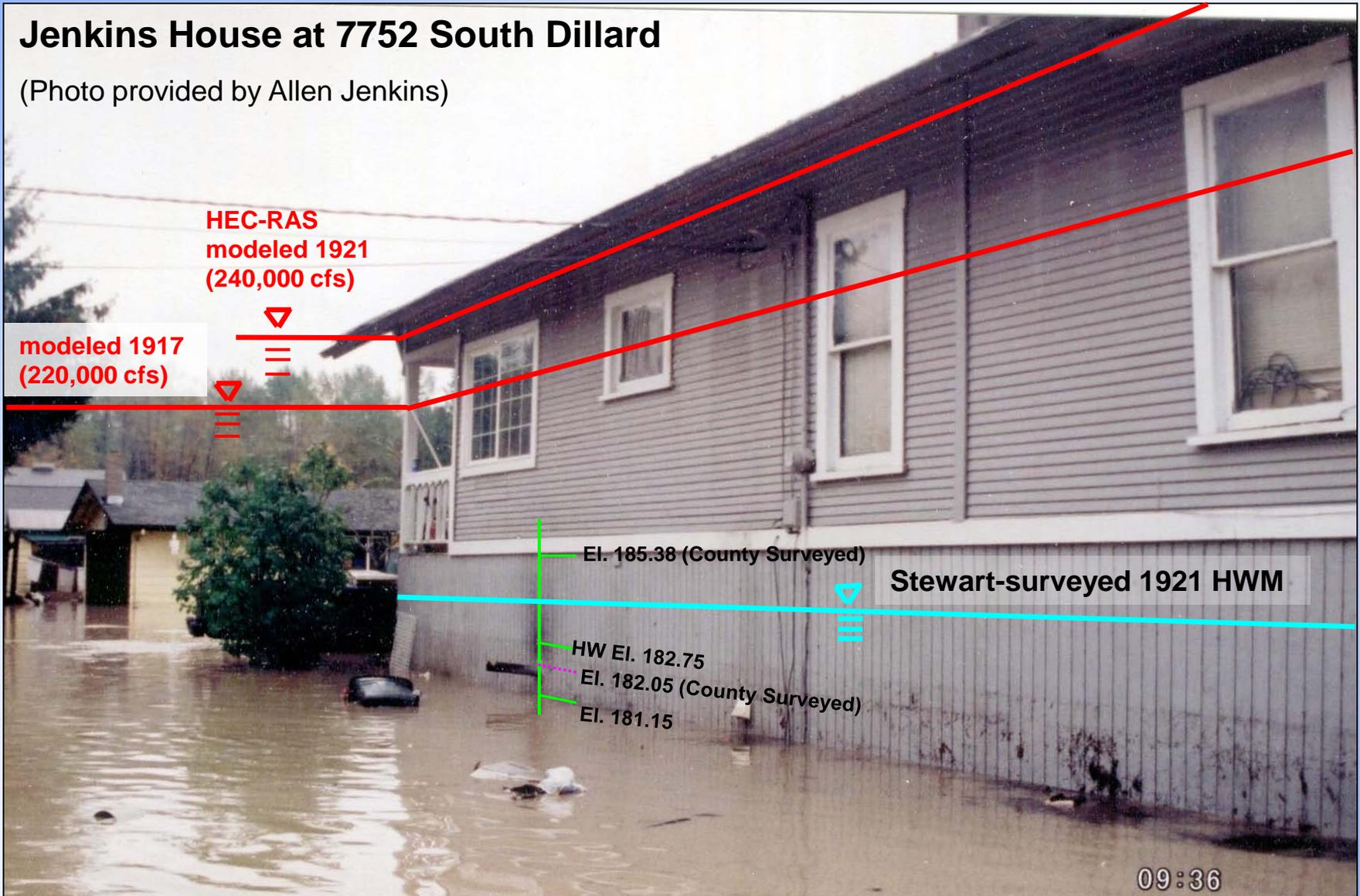
04/03/2008 12:08

First Floor elevation 184.96

October 2003 Flood

Jenkins House at 7752 South Dillard

(Photo provided by Allen Jenkins)



HEC-RAS
modeled 1921
(240,000 cfs)

modeled 1917
(220,000 cfs)

El. 185.38 (County Surveyed)

Stewart-surveyed 1921 HWM

HW El. 182.75

El. 182.05 (County Surveyed)

El. 181.15

09:36

At Hamilton—

- “Smith” house – constructed in 1908
 - Survived floods of 1909, 1917, and 1921
- Stewart-surveyed high water marks (based on citizen interviews in 1922), and additional information documenting the 1909 flood in County records

Nov 27 1922

At Hamilton

	1273	1273	00.00	MS
TP	1068	19.05	436	8.34
			2.27	16.78
	294	96.84	93.70	GN rail
TP	421	98.65	2.40	94.44
			3.03	95.62
				1917 HW
TP			4.95	93.70
	3.40	97.18		
TP			4.49	92.61
	5.87	98.48		
			1.59	96.89

MS

10 AM

RP

nail in 14" maple in river edge at old levee

Nov 28

in front of Hamilton Depot. SElev from USGS Bulletin 670?

GN rail

.55 above = 1909 HW
.84 above = 1921 HW

at AJ Jacobin cigar store. Bldg may have settled 100% in 1897
95.55
96.17 = 1909
95.62
96.17 = 1921

95.62
80.11 = 1919 HW above stage 1/2 hr

96.17
80.11 = 1909 HW above stage 1/2 hr

96.46
80.11 = 1921 HW above stage 1/2 hr

R.P. described above

96.89
16.78
80.11 ELEV of US NOV 27

Magrus Miller says 1897 flood came to door knob of James Smiths drug store (more drug store raised since then) Hinge across from Hamilton may have 1897 mark

Historical Flood Marks in Lyman-Hamilton Area



Aerial Photo of Hamilton Area



2003 Flood in Hamilton

Photo showing WS El. 98-100, 145,000 cfs
Flood Peak WS El. 99-101, 165,000 cfs at 9:30 am
(photo taken by Skagit County on Oct. 21, 2003, 2:40 pm)



“Smith” House, built in 1908, Hamilton WA



Smith House in Hamilton during Oct. 21, 2003 Flood

Photo showing WS El. 100, 145,000 cfs (2:40 pm)

Flood peak WS El. 101, 165,000 cfs (9:30 am)



Smith House in Hamilton, undated photograph of the 1909, 1917, or 1921 flood event (Hamilton Museum archives)

First Floor El. 100.83

Water Surface El. 98 (+) shown in the photo



Hamilton Results

- Max historical flood discharge since 1908 at the Smith House was no more than 188,000 cfs
- Historical flood discharges for the 1909, 1917, and 1921 events based on Stewart's HWMs at Jacobin Cigar Store appear much less than 188,000 cfs

2003 Flood in Hamilton

Photo showing WS El. 98-100, 145,000 cfs

Flood Peak WS El. 99-101, 165,000 cfs at 9:30 am

(photo taken by Skagit County on Oct. 21, 2003, 2:20 pm)



**Old Jacobin
Cigar Store
Location**



**Smith
House**

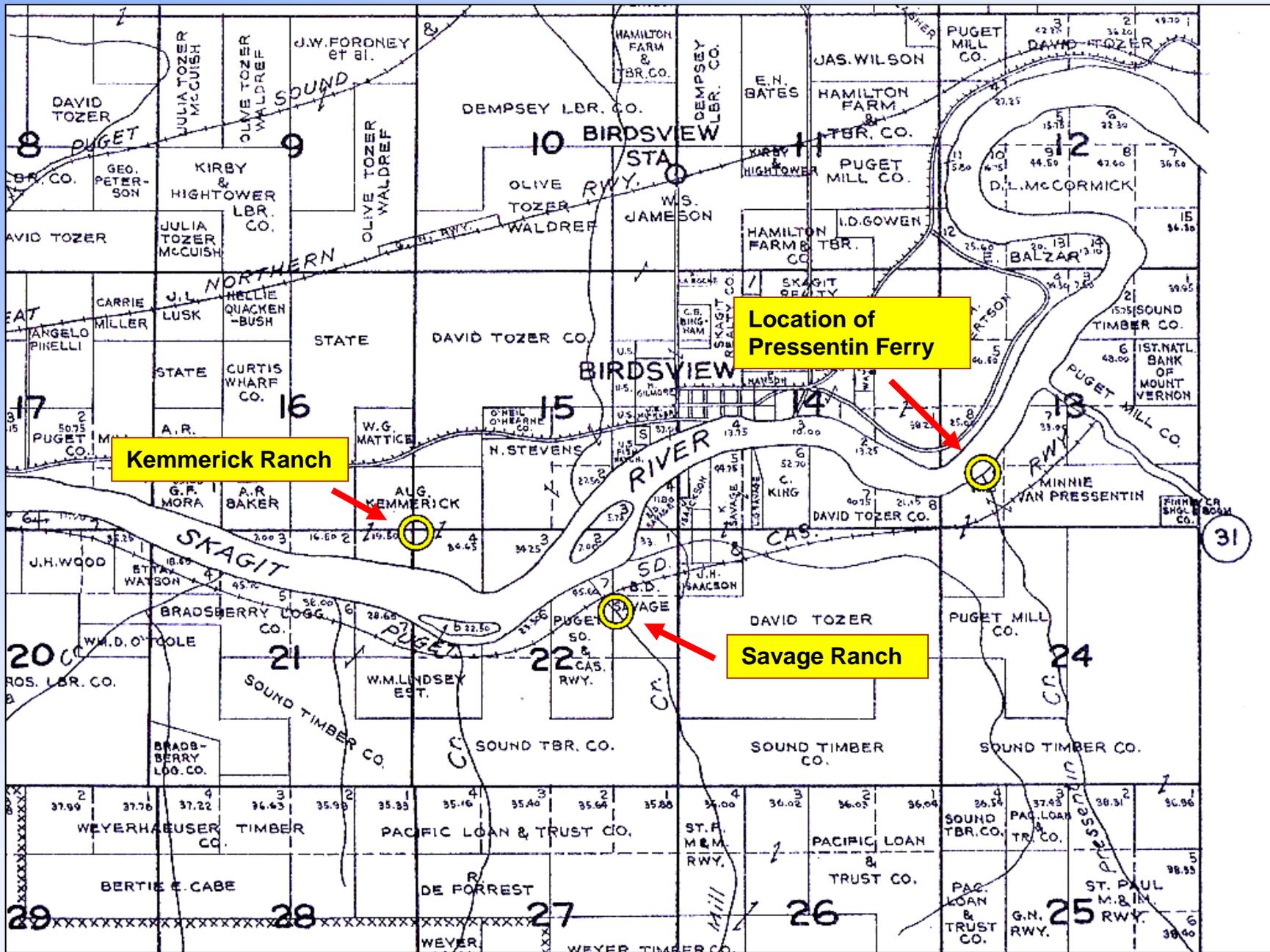
Smith House, built in 1908, Hamilton WA



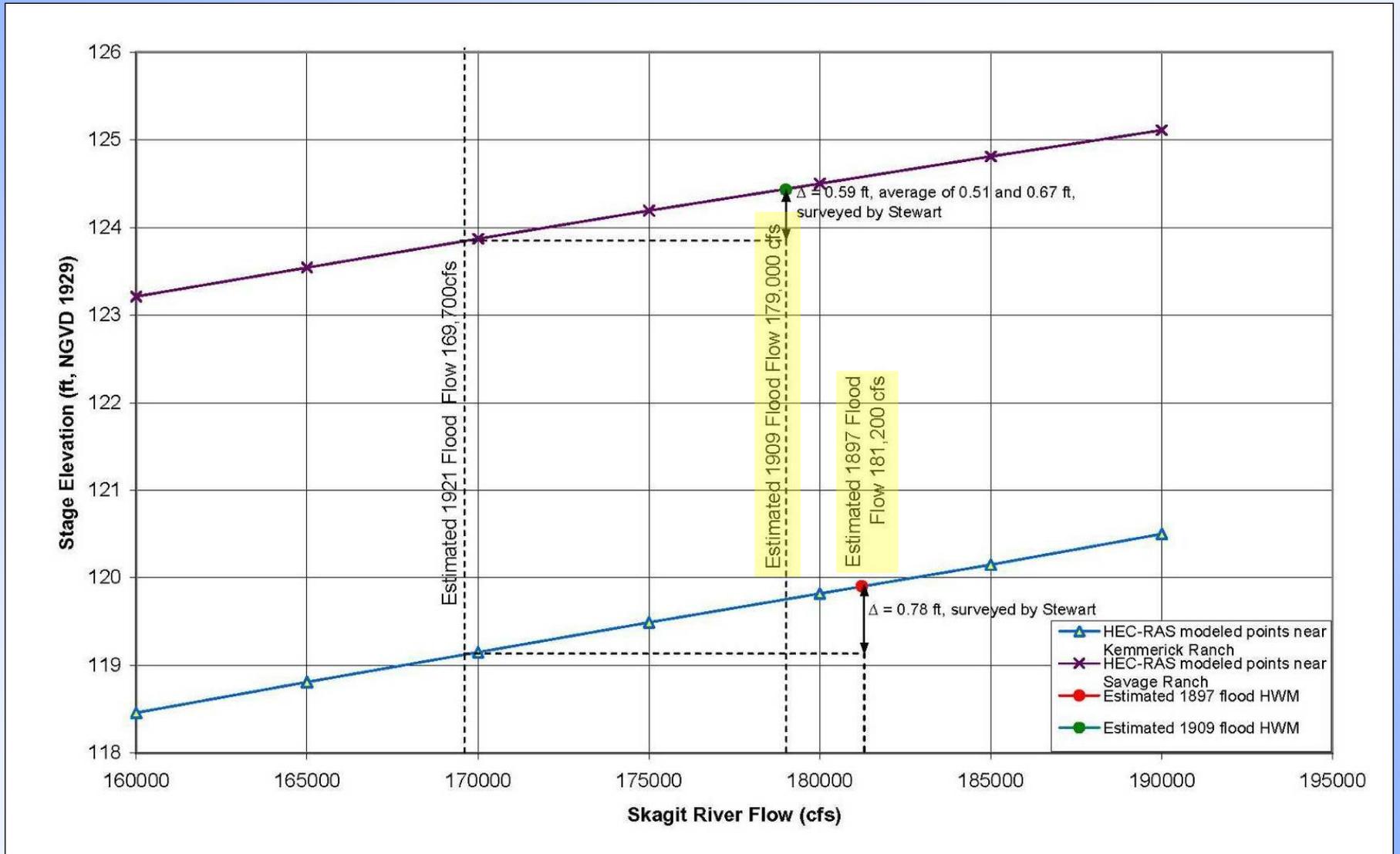
“Smith” House, built in 1908, Hamilton WA







Flood Stage-Discharge Curves at Kemmerick and Savage Ranches near Birdsvie

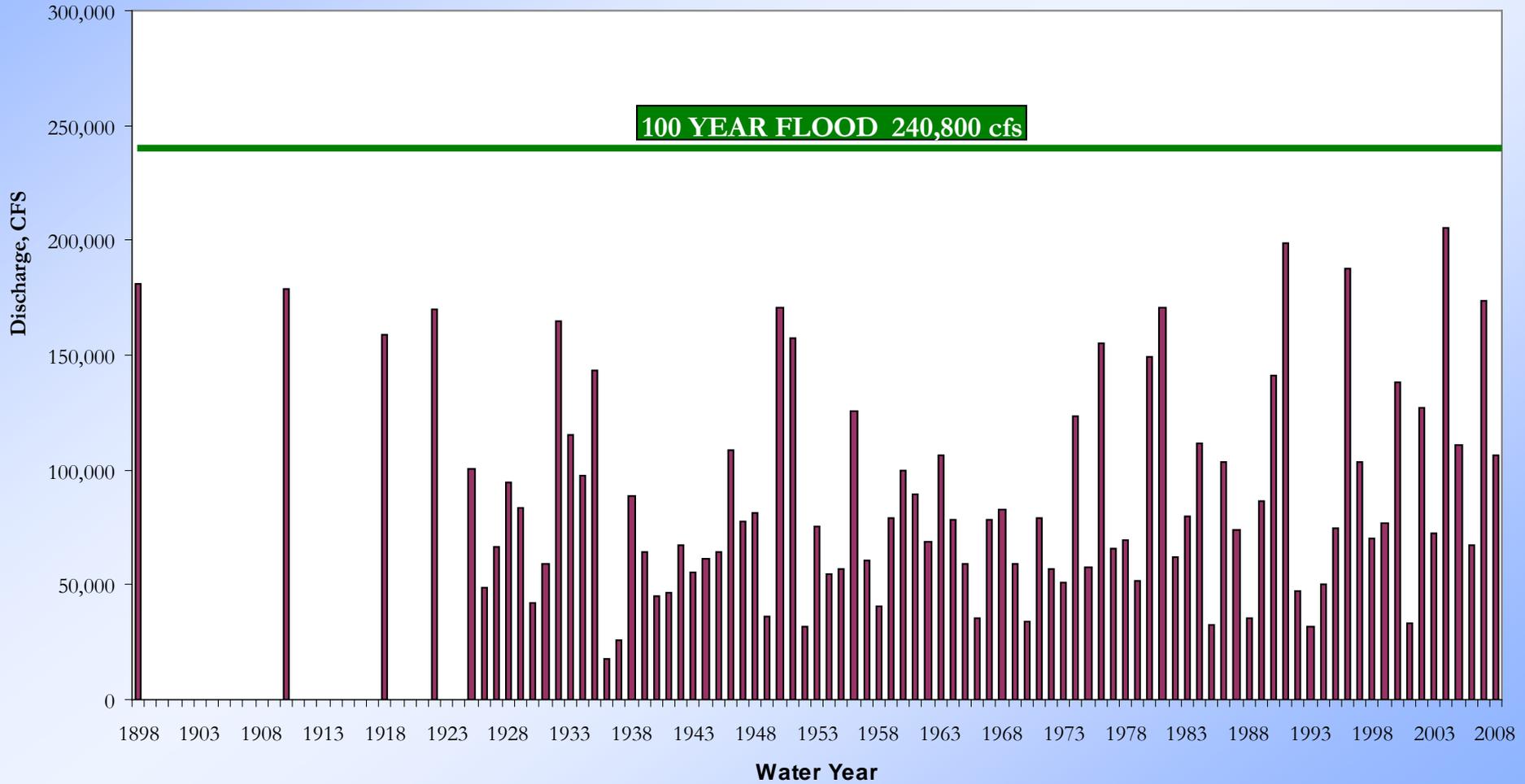


Estimated Peak Discharges of Skagit River near Concrete for Four Historical Floods (Drainage Area = 2,700 sq. mi.)

Flood	Discharge Estimated by Stewart in 1923 (cfs)	Discharge Revised by USGS in 2007 (cfs)	Discharge Modeled by PIE in 2008 (cfs)
1897	275,000	265,000	181,200
1909	260,000	245,000	179,000
1917	220,000	210,000	158,700
1921	240,000	228,000	169,700

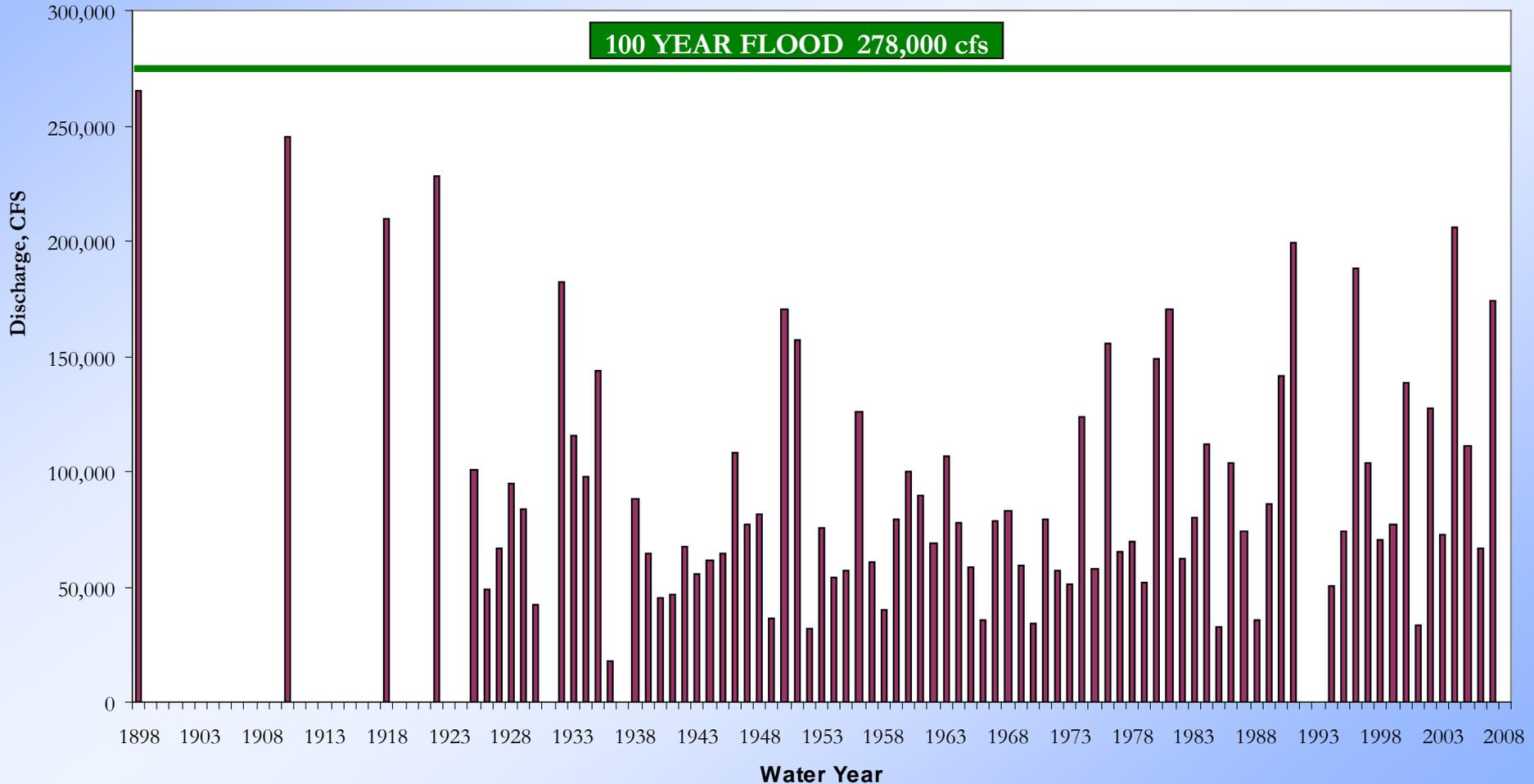


SKAGIT RIVER WINTER UNREGULATED ANNUAL PEAK DISCHARGES (PIE) Water Year 1898 to 2008 - USGS Gage near Concrete, WA





SKAGIT RIVER WINTER UNREGULATED ANNUAL PEAK DISCHARGES (COE) Water Year 1898 to 2008 - USGS Gage near Concrete, WA



FEMA 100-Year Flood Hydrographs at Sedro Woolley (with existing flood storage)

