United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Reston, VA 20192

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In Reply Refer To:
Mail Stop 409
#2006547-DO

OCT 26 2006

Mr. Daniel O'Donnell
Post Office Box 532
LaConner, Washington 98257

Dear Mr. O'Donnell:

In a letter dated September 11, 2006, Representative Rick Larsen requested that the U.S. Geological Survey (USGS) review the report by Mr. Larry Kunzler titled, "James E. Stewart Skagit River Flood Reports and Assorted Documents, A Citizen Critical Review Whitepaper." Representative Larsen notes that local residents and Skagit County area selected officials requested that we examine four data points that they believe to be inaccurate. In addition, Representative Larsen requested we review and comment on pages 48-69 of Mr. Kunzler's report.

In response to Representative Larsen's request, we have reviewed and commented on Mr. Kunzler's report. Our comments are enclosed. If you have any questions, please contact Dr. Cynthia Barton, Director of the USGS Washington Water Science Center, directly at (253) 552-1602.

Sincerely,

Matthew C. Larsen

Matthew C. Larsen
Chief Scientist for Hydrology

Enclosure

Copy to: Honorable Rick Larsen
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USGS:Water:SBlanchard:kmlong:5032:10-11-06:#2006547-DO

Enclosure

INTRODUCTION

In a letter dated September 11, 2006, Representative Rick Larsen requested that the U.S. Geological Survey (USGS) review the report by Mr. Larry Kunzler titled, "James E. Stewart Skagit River Flood Reports and Assorted Documents, A Citizen Critical Review Whitepaper." Representative Larsen notes that local residents and Skagit County area elected officials requested that we examine four data points that they believe to be inaccurate. In addition, Representative Larsen requested we review and comment on pages 48-69 of Mr. Kunzler's report.

This document first provides a summary of the work related to the four data points. From Mr. Kunzler's white paper, the four points in question must be the discharges of the four historical floods of 1897, 1909, 1917, and 1921 at the USGS streamgage, Skagit River near Concrete (Station Number 12194000). These four data points are important because the flood frequency at the Skagit River near Concrete streamgage is the principal design criterion for the current flood study of the Skagit River being conducted by the U.S. Army Corps of Engineers and they are the four highest discharges used in calculating the flood frequency. This streamgaging station was chosen to be the focal point of the hydrologic analysis because of its long record of annual peak discharges, its position in the basin below all the major tributaries to the Skagit River, and its hydraulically stable rating due to the stable bedrock control of the Dalles Gorge. The best way to describe the current position of the USGS on the four historical floods is to outline the history of how these discharges were determined and verified.

This document then provides comments and responses to Mr. Kunzler's rebuttals in the numbered conclusions section on pages 48-69 of the white paper. The USGS Washington Water Science Center originally responded to Mr. Kunzler's numbered conclusions in June 2004, and the most recent version of Mr. Kunzler's white paper on pages 48-69 contains those USGS responses and Mr. Kunzler's rebuttal to those responses. It should also be noted that the validity of the USGS flood data called into question by Mr. Kunzler has been reviewed and accepted by the U.S. Army Corps of Engineers and the Federal Emergency Management Agency (FEMA).

THE FOUR DATA POINTS

The 1918 Report by James Stewart

James Stewart first investigated the Skagit River Basin flood characteristics in 1918 as a USGS employee from the Tacoma, Washington, office. An unpublished, draft report, "Skagit River Flood Report," (1918) by J.E. Stewart outlines his preliminary findings at the time. This is an unofficial draft of a report. It was included in the archives of the USGS as a working document when authored by Stewart. Like drafts of all scientific reports, it is subject to change and revisions. It is a draft and should not be interpreted as final. Stewart discussed at length his findings at the Skagit River at Reflector Bar above Marblemount, about 44 river miles upstream of Concrete where a streamgaging station had been in operation since 1908. A cabin nearby at the Davis Ranch had experienced the 1897, 1909, and 1917 floods and provided a record of the high-water marks (HWMs) for each of the floods. Based on the gage height of the 1909 flood determined from marks on the canyon walls, the height of a drift log below the gage, and the stage-discharge relationship (rating or rating curve) at the site, Stewart calculated the peak discharge of 58,800 cubic feet per second (cfs) for the 1909 flood. From the relative difference in HWMs in the cabin, he determined the peak discharges for the 1897 and 1917 floods. It was also here that Stewart found evidence for a larger flood estimated at 95,000 cfs that preceded settlement in the area which started in 1873. Stewart does not explicitly describe how discharge was determined; it is presumed that it was determined from extension of the current rating, which was defined by 23 discharge measurements by 1918. The highest direct current-meter measurement was 22,300 cfs. The last paragraph of the report states, "...the lower portion of the rating curves is only valuable to give a general shape to the curve and to be used as a starting point." The peak discharge for the 1909 flood was later revised to 70,000 cfs (Stewart and Bohdaine, 1961, p. 38).

In his 1918 report, Stewart also notes that he found an 1897 and a 1909 HWM in Concrete, but at the time there had been no discharge measurements available to establish a stage-discharge relationship. Although the 1918 report does not say how Stewart determined the discharge, a memo by Stewart in 1919 concerning a proposed station on the Skagit River near Concrete shows that the maximum discharge of 275,000 cfs for the 1820 flood was "based on the estimated combined flow of the tributaries, and the flow at Sedro Woolley." It suggests that a rudimentary stage-discharge relationship was constructed by comparing discharges and gage heights at the Skagit River at Sedro Woolley with gage heights on the Skagit River near Concrete (at the Dalles). One would presume that Stewart's discharge determinations for the Skagit River near Concrete for the 1897 flood (205,000 cfs), the 1909 flood (185,000 cfs), and the 1917 flood (175,000 cfs) were calculated with this preliminary rating. Without discharge measurements to more precisely define a relationship between stage and discharge, Stewart did what he could to make the best estimate of the peak discharges at Concrete. We do not know of any example when the USGS has used this method to calculate peak discharge. Also of interest from Stewart's 1918 field work is the discovery of evidence for a larger, earlier flood prior to the first white settlements in the area, and how the evidence for the historic floods could be found throughout the Skagit River Basin.

Skagit Basin Field Work, 1922-23

Stewart revisited the Skagit Valley in late 1922 to continue his study of flooding in the basin. In December of 1921, a large flood occurred on the Skagit River, and a year later Stewart surveyed the HWMs from the 1921 flood when they were still clearly evident "determined within one or two tenths of a foot" (Stewarts unpublished 1923 report, "Stage and Volume of Past Floods in Skagit Valley and Advisable Protective Measures Prior to the Construction of Permanent Flood Controlling Works"). Stewart collected extensive field data in the vicinity of Concrete, uncovered flood evidence of historic floods, established a streamgage on the Skagit near Concrete, and made the first calculation of the discharge of the 1921 flood.

Stewart found substantial evidence of the relative magnitude of the four historic floods from HWMs. Published gage heights at the current gage datum are 51.1 ft. (1897 peak), 49.1 ft. (1909 peak), 45.7 ft. (1917 peak), and 47.6 ft. (1921 peak). Downstream from the streamgage where there is no question of whether the marks are more representative of flooding on the Baker River or flooding of the Skagit River, Stewart found several sets of HWMs that could only represent the water surface of the Skagit River. However, the river was probably not confined within the main stream banks, and because the relationship of discharge and stage downstream will not be the same as at the Concrete streamgage, relative HWM differences between floods would not necessarily be the same as differences in stages at the gage. In the town of Hamilton, at River Mile (RM) 40 (gage is at RM 54.15), Stewart found a 1917 HWM 0.55 feet below a 1909 HWM and 0.84 feet below a 1921 HWM (p. 14, field book). At Kemerick Ranch (about RM 45), Stewart found HWMs that showed the 1897 peak was about the same as the 1909 peak and 0.8 feet above the 1921 peak (p. 27, field book). At Savage Ranch across from Old Birdsviews School (about RM 46), Stewart's notes show the 1909 flood to be 0.51 and 0.67 feet higher than the 1921 flood and the 1917 flood to be 0.68 feet below the 1921 flood (p. 27, field book). At Pressentin Ferry (assumed to be at the mouth of Pressentin Creek and existing boat ramp, RM 47), the notes show an 1897 HWM 2.8 feet above an "approx." 1921 HWM (p. 25, field book). Stewart was fully qualified and experienced in location and measurement of HWMs from recent and past flooding. It is unlikely that he would have made significant errors in stage estimates for these past floods based on interpretation of physical field evidence.

At the streamgage, Skagit River near Concrete and upstream of the gage, Stewart found and documented the gage heights for the four historic floods and found further evidence for the relative magnitude. He originally leveled in the elevation of a 1921 HWM in a maple tree at an elevation of 47.0 feet (corrected to current gage datum) (p. 59, field book) and later found a nearby mark 0.6 ft higher (p. 75, field book) to give the published gage height of 47.6 feet. Near this same location at the Dalles Cabin, Stewart found several sand bars and leveled in elevations (shots). He notes that, "These shots on sandbar show 1909 at least 1.3 [feet] above 1921 while levels [for] 1909 1.3 [feet] above 1921 at Concrete." (p. 58, field book). At the Washington Cement Plant's machine shop, Stewart found a 1909 mark 2.0 feet higher than a 1921 mark (p. 23, field book). On page 18, Stewart has levels at McDaniel's residence, noted to be east of Washington Cement Plant and above the Baker River, showing a 1909 HWM 1.27 feet above a 1921 HWM. The elevation difference of the sand bars near the streamgage provided evidence that the elevation differences between HWMs found near the confluence of the Baker River and the Skagit are similar to the differences at the streamgage. Also near the confluence, Stewart notes (p. 22, field book) that an 1897 HWM on a stump found by Magnus Miller near the Old Baker Highway Bridge was 3.6 feet higher than a 1921 HWM. Stewart ran levels from a 1921 HWM at Wolf's residence to the streamgage and calculated a gage height of 46.7 (current gage datum) (p. 30, 33, field book) and found a 1917 HWM that was 1.52 feet below the 1921 HWM (p. 19, field book). It is unknown where Wolf's residence is in relation to the gage other than the clue that the 1921 HWMs closely agree with 1921 HWMs at the gage and the fact that the survey notes show it took only 12 leveling turning points (turning points are generally not more than about 400 feet apart and in steep forested terrain they would likely be much closer together) to get from the Wolf HWMs to the gage. At Robertson's Ranch (RM 58.5) about 2 miles above the confluence of the Skagit and Baker Rivers, L. Robertson marked the 1909, 1917, and 1921 floods with knife cuts on siding board on his barn (p. 2, field book). This kind of record of flood HWM is considered among the best historical flood data. The 1909 peak was 1.83 feet above the 1917 peak water surface and 0.29 feet above the 1921 peak.

Besides the evidence for the four historic peaks since 1897, Stewart found a "distinct" high water line nine feet above the 1921 HWM at the Concrete streamgage location. He dated this flood by dating a grove of even-aged fir trees on the sand bar immediately above the gage. The date corresponds with a great flood that predates white settlement in the Basin, but left a stain on trees that was still visible by the early settlers until about the turn of the century.

During this period Stewart made a field survey of the high-water profile from the 1921 flood including channel cross sections at the entrance to the gorge near the Skagit River near Concrete streamgage and at three locations downstream of the gorge. With this information, Stewart made a calculation of the peak discharge by the contracted-opening method using water-surface elevation and the entrance cross-section geometry. Stewart also used the downstream cross-section information and water-surface profile to compute a peak discharge using the slope-area method. He averaged the results to calculate a peak discharge of 240,000 cfs for the 1921 flood. Although they are commonly used to indirectly estimate the peak discharges, slope-area calculations are sensitive to the roughness coefficient (n-value) that is chosen, a somewhat subjective procedure based on comparison with channel reaches with a known roughness coefficient or based on an additive procedure of determining a base coefficient value and then adding to the value for various roughness elements that may be present in the reach (Dalrymple and Benson, 1967). Stewart used an n-value computed from a discharge of 40,200 cfs at Skagit River at Sedro Woolley. Without any direct current-meter measurements greater than 10,700 cfs up to the end of 1924, a logarithmic extension of a stage-discharge rating would not be a reliable method to calculate discharge beyond about 25,000 cfs. Stewart's indirect calculations of the 1921 peak flow provided the best calculation of the peak discharge and defined the upper end of the stage-discharge rating which could then be used to accurately calculate the 1897, 1909, and 1917 peak discharges. The indirect method used by Stewart is nearly the same as the indirect method used by the USGS today to calculate peak discharges when no current-meter measurements are available for discharges in the high range of flows.

The 1940's to Early 1960's

During this period, a verification study of Stewart's slope-area calculation was made and a compilation of Stewart's work was published in a USGS Water Supply Paper 1527, "Floods in the Skagit River Basin Washington" (Stewart and Bodhaine, 1961).

On November 27, 1949, a peak discharge of 153,000 cfs occurred on the Skagit River near Concrete. The discharge was determined by extending the rating beyond the highest current-meter measurement of 135,000 cfs that was made in 1932. The USGS saw the opportunity to check Stewart's slope-area calculation by conducting an *n*-verification study, where n refers to Manning's "*n*". Manning's *n* is the roughness coefficient in the slope-area calculation. The verification was made by back-calculating the *n*-value given the discharge and other hydraulic information compiled from surveys in the field. Four cross sections were surveyed in the general vicinity of the three cross sections Stewart used for his slope-area calculation. The *n*-values determined by H.C. Riggs and W. H. Robinson of the USGS for the upstream, middle, and downstream reaches were 0.040, 0.0276, and 0.0325, respectively. They recalculated the 1921 peak discharge as 209,000 cfs using an *n*-value of 0.040 for Stewart's upstream reach and 0.033 for Stewart's downstream reach. There was some concern over using the upstream reach with a large expansion. Expanding reaches are generally avoided if possible because the energy loss due to expansion must be estimated in the hydraulic calculations. Riggs and Robinson used the standard USGS procedure of applying a 0.5 coefficient of energy loss (Dalrymple and Benson, 1967, p. 3) in their computation for this reach.

Later, in years 1951-52, F.J. Flynn and M.A. Benson of the USGS revised Riggs and Robinson's analysis by eliminating the upper reach because (1) of the question about energy loss due to expansion, (2) of the poorly defined right-bank water-surface profile in this reach, and (3) there was no visual evidence in the reach to explain why the first reach should be rougher than the other reaches. Flynn and Benson computed an *n*-value of 0.0305 for the remainder of the reaches. They recomputed the 1921 peak discharge to be 225,000 cfs using only Stewart's downstream reach and an *n*-value of 0.030. All of these computations of discharge are standard hydraulic practice in which the assumptions and field conditions used to document peak discharge can be interpreted somewhat differently by experienced engineers. All values reported by any USGS employee are within the uncertainty of the flood discharge measurements.

In 1961, G. L. Bodhaine of the USGS compiled data from Stewart's previous reports, his field data, and work by W. S. Eisenlohr, Jr., of the USGS done in the 1940s, into Water Supply Paper 1527. Bodhaine agreed with Flynn and Benson on their analysis of the *n*- verification study of the 1949 flood, but did not revise Stewart's peak discharge calculation because it was only 6.2 percent different than the original value. The USGS policy to revise previously published data is to revise only if the revised discharge is reliable and more than 10 percent different than the original discharge. Again, this is because values about +/-10 percent are considered within the uncertainty of flood measurements. The stage and discharge values published in Water Supply Paper 1527 agree with Stewart's data in his 1923 report as shown in table 1 except for:

- The stage of the 1917 flood, which is 2.2 feet higher;
- The discharge for the 1897 flood, which is 5,000 cfs greater; and
- The discharge for the 1815 flood which is 20,000 cfs greater.

Table 1. - Historical peak discharges and stages for the Skagit River near Concrete as published in the USGS Water Supply Paper 1527, p. 50.

Year when peak occurred	Gage Height (at current gage datum, feet)	Discharge (cfs)
1815	69.3	500,000
1856	57.3	350,000
1897	51.3	275,000
1909	49.1	260,000
1917	45.7	220,000
1921	47.6	240,000

Recent Years, 2003 to present

In recent years, the U.S. Army Corps of Engineers has been developing a flood damage reduction study, and Skagit County and city governments are planning large-scale capital improvement projects to reduce flood impacts. Because of these activities and the importance of the flood records of the Skagit River near Concrete in the design flood analysis, the computation of the flood discharges and flood frequency at Skagit River near Concrete have come under much scrutiny. Peak discharges for the 1815 and 1856 historical floods were downgraded to estimates in the USGS peak-flow files, and consequently, are not used in the flood frequency analysis because the dates of the peak stages of these floods could not be validated and the evidence of the peak stages was limited.

On October 21, 2003, a large flood occurred in the Skagit River basin. The Skagit River near Concrete peaked at 166,000 cfs, the largest peak since 1921. The peak was computed using logarithmic extension of the current stage-discharge rating for the station and verified with a current-meter measurement at 138, 000 cfs made hours after the river crested. This provided another opportunity to verify the *n*-value by a survey of the water-surface profile, and unlike the 1949 *n*-verification, three cross sections were surveyed as close as possible to the locations of cross sections used by Stewart. The water-surface profile on both banks was surveyed 9 months after the October 2003 flood and the 2003 water-surface profiles defined. Two profiles were used to delineate the slope of the water surface thought to bracket a plausible range of possible water-surface slopes. As in 1949, HWMs at the most upstream cross section were difficult to locate. Using only the lower two cross sections, and the 2003 peak discharge, *n*-values were back calculated to be 0.024 and 0.032 for the two profiles. Recalculating the discharge of the 1921 flood with these two *n*-values results in bracketing discharges of 266,000 and 215,000 cfs which were 10.8 percent greater and 10.4 percent less than the published value of 240,000 cfs. The average of the two values is 240,500 cfs (Mastin and Kresch, 2005) and is believed to again verify the original value of the 1921 flood.

This is the second *n*-verification by the USGS of the Stewart indirect measurement of the 1921 peak discharge. Both *n*-verifications supported the original calculation of the 1921 discharge. Although this latest *n*-verification indicates a possible range of plus or minus 11 percent from the published discharge, the average value is almost exactly the same as Stewart's calculation. It is the opinion of the USGS that the stage of the 1921 flood was well defined and accurate, and the calculation of discharge at 240,000 cfs is rated in the range of good to fair with a range of error of +/-10-15 percent. The three other historic floods in 1897, 1909, and 1917 have less well-defined stages, but there was good evidence that the relative height of the floods at Skagit River near Concrete, as published in Water Supply Paper 1527, when compared to one another and the 1921 flood are correct. (NOTE: Water Supply Paper 1527 has an error on p. 28, near the bottom of fifth paragraph where it states that the "flood of 1897 was found to be 3.6 feet higher than the flood of 1909 at Concrete." It should read, "...3.6 feet higher than the flood of 1921...'). The best calculations of these discharges are based on the stage-discharge rating that includes the 1921 indirect measurement of peak discharge. Because the stage determinations of these older floods are less reliable than the 1921 flood, the accuracy of the discharge of these floods is somewhat less than the accuracy of the 1921 flood.

RESPONSE TO COMMENTS ON PAGES 48-69 OF MR. KUNLER'S WHITE PAPER, UPDATED JULY 11, 2006

1) In the rebuttal by Mr. Kunzler, he stated that the USGS misstated the value of the historical floods originally computed by Stewart and cited the values from his 1918 draft report. The discharge values in the 1918 report were believed to be estimated from a rating developed by comparison of discharge and gage height values at Sedro Woolley. At the time the values were estimated, there were no discharge measurements to establish a reliable stage-discharge rating, nor any hydraulic computations to make reasonable calculations of the peak discharge. Again, the 1918 report is a preliminary draft of Stewart's early work, and subject to review and revision as appropriate. Stewart's 1918 draft report presented rough estimates of the flood discharge, or a starting point for further investigation. By the time Stewart presented his discharges in the 1923 report, a gage had been established, current-meter discharge measurements had been made, an indirect hydraulic calculation of peak flow had also been made, and a good stage-discharge rating had been developed. Prior to the 1923 report, there were no reliable calculations of discharge; the USGS considers Stewart's 1923 data as his original calculations.

   Mr. Kunzler also noted the fact that the magnitude of the historical floods has not been repeated since 1921. This may be unusual; however, this pattern is also shown in the annual peak flow series in other large rivers in the Pacific Northwest (fig. 1) where the largest floods in a long record appear to have occurred near the turn of the century, and lower annual peaks appear to have occurred since that time.

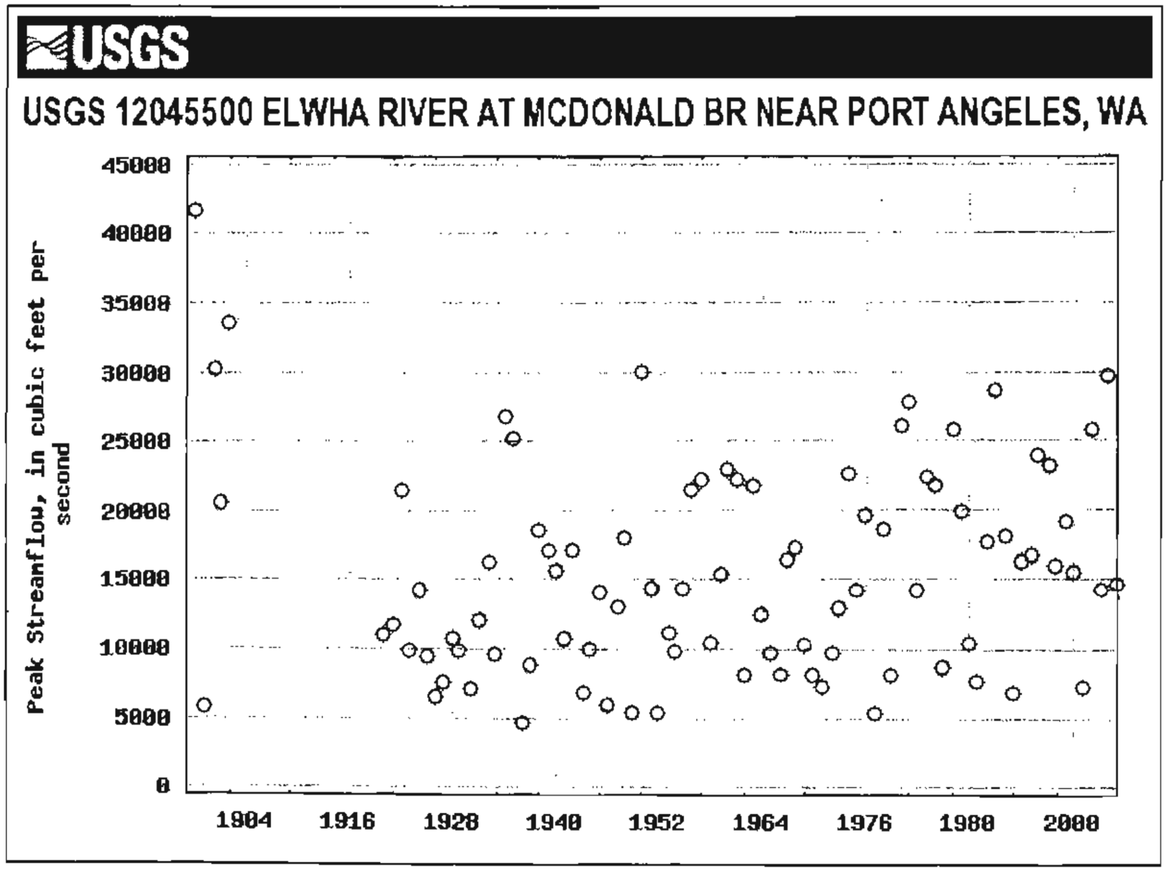

Figure 1a. Annual peak discharges recorded at the Elwha River at McDonalds Bridge near Port Angeles, Washington. The Elwha River has not been regulated for flood control.

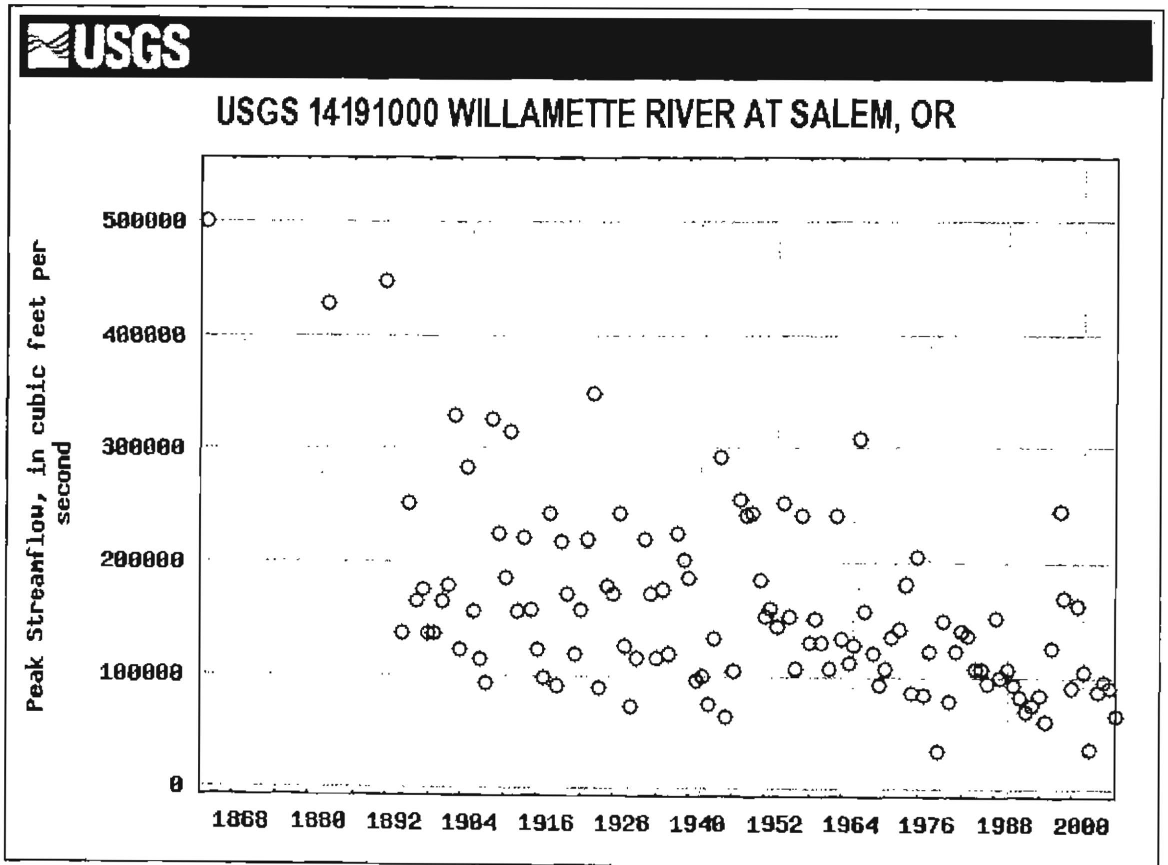

Figure 1b. Annual peak discharges recorded at Willamette River at Salem, Oregon. The Willamette River at Salem has been regulated beginning in 1941.

2) Mr. Kunzler's rebuttal brings up the sensitivity of the roughness coefficient in the discharge calculations and states that a USGS hydrologist is indifferent to differences of 30,000 cfs. Mr. Kunzler is correct in noting that the roughness coefficient is sensitive to the calculation's outcome. The coefficient is not something that can be directly measured in the field. It is rare to have the opportunity and resources to verify the roughness coefficient in an indirect discharge computation. In the case of Stewart's indirect, there have been two *n*-verification studies. We have suggested the error of the 1921 peak discharge calculation is +/-10 to 15 percent and the most accurate value we can compute is 240,000 cfs plus or minus 24,000 to 36,000 cfs. This does not imply we are unconcerned about 30,000 cfs. Flood scientists are faced with the task of measuring and documenting violent and dangerous flows. This is done with the best available methods, and uncertainty is a fundamental part of hydrology, science, and engineering. We feel the best value to use in the annual time series of peak flow for flood frequency analysis is 240,000 cfs for the 1921 flood discharge, and it would be improper to use a lesser value even though it may lie within the error range.

   Mr. Kunzler is also concerned that no one went to the field or reviewed Stewart's methodology and his "estimated ratings." Stewart's work was checked in the 1940s by Eisenlohr, Jr., and in the 1950s by Riggs, Robinson, Flynn, Benson, and Bodhaine. In 2004, it was checked by Mastin and Kresch. Field data and office computations are checked for math errors, but it is rare to go to the field and resurvey HWMs or channel geometry unless a substantial error was discovered. No substantial error was found with Stewart's field work. Estimated ratings of flow calculations are subjective. Stewart assigned an accuracy of 5 percent to the 1921 flood and 10-20 percent to the other three historic floods on the Skagit River near Concrete. Based on the results of the last verification study, an accuracy of 10 to 15 percent would probably be more reasonable for the 1921 peak flow calculation and 15-25 percent for the other historical floods. Stewart's work was well within the standards of accepted flood hydraulic engineering today.

3) Mr. Kunzler implies the Corps of Engineers has rejected Stewart's work in a 1924 public meeting and questioned the data in a 1952 report. In the 1924 meeting minutes, Colonel Barden said "The information that was collected by Mr. Stewart and given in his report to the committee was excellent...but that data was necessarily more or less inaccurate." The fact that Stewart's work was described as excellent followed by the comment that "data was more or less inaccurate," makes it difficult to interpret Colonel Barden's comments out of the context in which they were spoken. In the 1952 report, the values the Corps brings into question are the error estimates, not discharge values themselves. In our recent conversations with the U.S. Army Corps of Engineers, they have stated they accept our calculations of the four historic peak discharges on the Skagit River as the best available data.

4) Mr. Kunzler denies Stewart's reports are drafts and states that information in the drafts has been used in the published reports. While it is the policy of the USGS to not release draft or provisional reports to the general public, information contained in drafts and provisional reports is included in the final reports. As described earlier, the discharges for the four historical floods on the Skagit River near Concrete in the 1918 draft were only rough estimates of the discharge before any current-meter measurements or hydraulic analysis were available. As data became available, the discharges were revised.

5) Mr. Kunzler's rebuttal states the discharges of the historical floods at the Skagit River near Concrete are too high based on extending a linear relationship of increased discharge with stage for recent peak flows with the 2003 peak flow. Mr. Kunzler has in effect constructed a stage-discharge rating. Most ratings generally use a logarithmic relationship and use measurements to define the rating. Mr. Kunzler's results are about the same as those from plotting the historic discharges on a straight-line extension of the current stage-discharge rating for the station (fig. 2). Our previous response of June 7, 2004, to Mr. Kunzler stated the 1921 peak discharge calculation lies about 10 percent to the right of the current rating with a straight-line extension. Does this mean that the 1921 indirect calculation is wrong? Not necessarily; the stage-discharge relationship could have changed over time (that is, channel conditions could be different now than when Stewart made his measurements), or the relationship could change as the flow increases. We suspect the influence of vegetation on the sand bar located downstream from the gage

on the stage readings for high flows has changed over time. An aerial photo from 1937 shows a barren sand bar, and sequential photos over time after 1937 show increasing tree growth until today where a dense thicket of alders, maples, and cottonwoods inhabit the island. The island becomes inundated during high flows as it did during the October 2003 flood. If the sand bar was bare in 1921, we would expect the resistance to flow during a large flood to be less than it is today for a similar flow. If this were the case, the same discharge would have a lower gage height at the gage. This may be part of the reason the historical peak discharges plot to the right of the straight-line extension of the current rating.

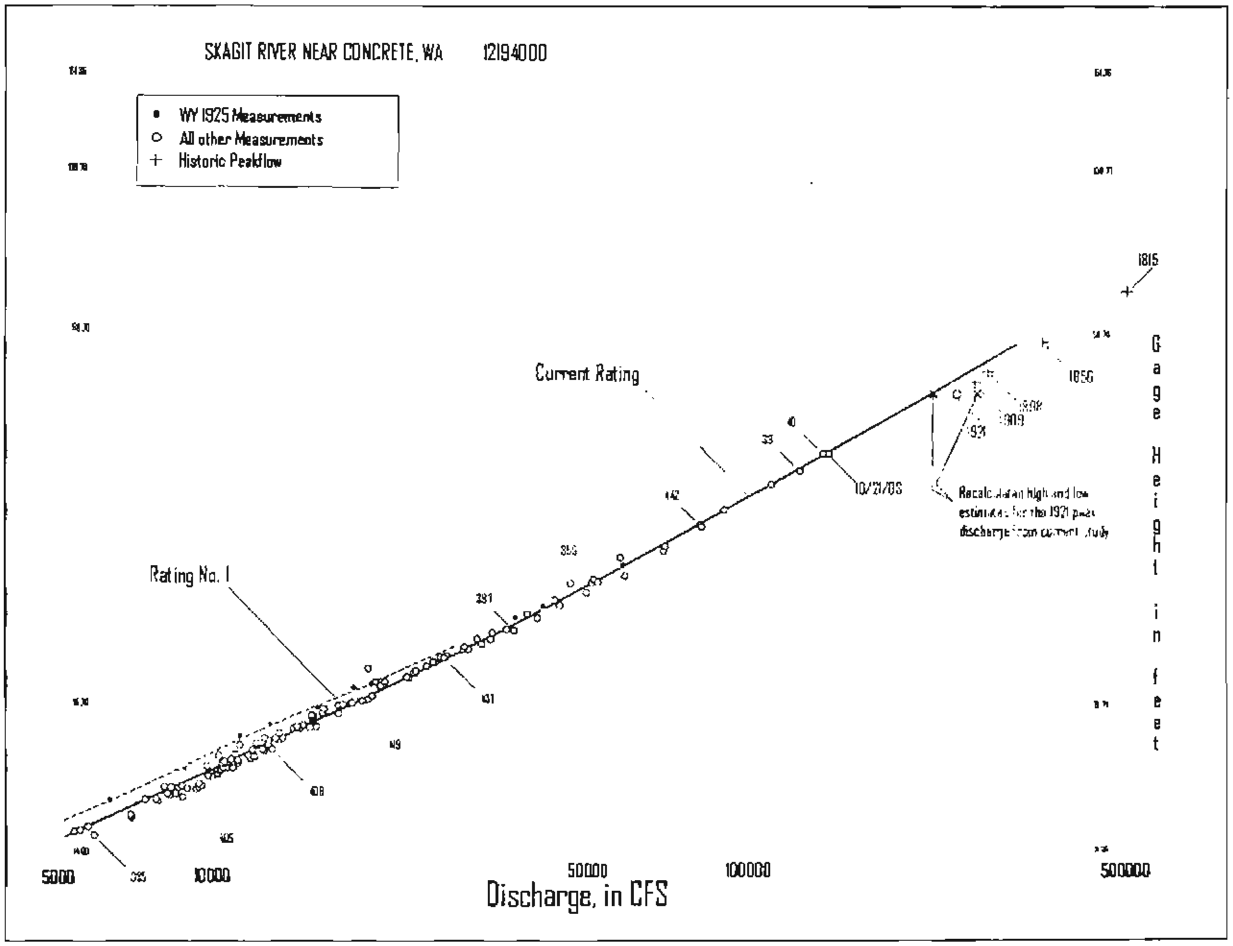

Figure 2. Current stage-discharge rating and rating number one for Skagit River near Concrete, Washington, streamgage with the four historic peak discharges and the recalculated high and low estimates for the 1921 peak discharge. (from Mastin and Kresch, 2005, figure 10).

6) Mr. Kunzler's rebuttal suggests the historical flood marks were the result of floods due to log jams, and thus, they have skewed the flood frequencies. There is no doubt log jams are a natural process that occurs in the Skagit Basin especially in the smaller tributaries. We are currently investigating a peak-of-record flood on Bacon Creek below

Oates Creek near Marblemount that we suspect is an outburst flood from a temporary log jam. An indicator of a possible outburst flood when no hard field evidence or witnesses to debris jams are available is a regional comparison of the calculation of the peak flow in terms of peak cfs per square mile of drainage area (unit peak discharge). At Bacon Creek the unit peak discharge was much larger than nearby streamgages during the October 2003 flood. If an outburst flood from a log jam caused a localized flood downstream of the log jam, then we would expect to see an unusually high unit peak discharge value when compared with other streamgages in the basin. We do not have hard evidence of a debris jam causing any of the historic floods and we do not see abnormalities in the unit peak discharge computed for the historic floods.

7) Mr. Kunzler's rebuttal suggests the historic flooding on the Skagit River may have been due to glacier outburst floods, earthquakes, landslides, or flooding after large forest fires and these were never considered by Stewart. In our original response it was reported that Dr. Kevin Scott, a USGS volcanologist who has studied the volcanoes in the Skagit Basin, does not believe the lahars generated from Mt. Baker or Glacier Peak could have caused the magnitude of flooding suggested by the HWMs. In addition, if the large floods on the Skagit River were due to one of these processes that occurred in the past, there is no reason it will not occur again in the future, and therefore, they should not be removed from the annual series of peak flows.

Mr. Kunzler goes on to doubt the evidence of the even-aged fir trees on the sand bar upstream of the Skagit River near Concrete streamgage as an indicator of the timing of the 1856 flood. The USGS does not suggest this is a precise indicator of the date and because of this it has downgraded the 1856 flood to an estimate in the USGS Peak-Flow File. Mr. Kunzler also doubts Stewart's remark that the highest floods since the arrival of the white men have not covered this bar to a depth of more than two feet. A group of USGS flood scientists dug a soil pit near the down stream end of this sand bar in May 2006, and ran levels to the surface of the pit. It was at an elevation of 39.0 feet (gage datum). The 2003 flood had a gage height of 42.14 feet, the 1921 gage height was 47.6 feet, and the 1856 flood was estimated at 57.3 feet. It should be noted the sand bar varies in elevation by several feet, the highest elevations are near the river and the lowest elevations are on the North side where the bar intersects with the steep slope. The 2003 flood did not show any evidence of clearing the vegetation on the sand bar at a water depth of about 3 feet at the pit nor did it clear away the trees at a water depth of 8.5 feet in 1921. However, one could imagine that at a water depth of 18 feet, the stream power might have the capacity to strip the sand bar bare. Stewart's method to determine the date the 1856 flood by dating the even-age forest grove on the sand bar is certainly plausible and ingenious, but is only estimation and not an "undoubted explanation" as he describes it. This technique of flood dating has been used in other flood studies (Sigafoos, 1964; and Yanosky and Jarrett, 2002).

8) In Mr. Kunzler's rebuttal, he is concerned with the discrepancy of HWMs in Stewart's notebook and why these discrepancies are never addressed by anyone. In any flood study there will be discrepancies in the HWMs, and this is a constant concern. Even closely spaced HWMs may be different from each other by a foot or more. As a flood recedes, it can create HWMs at lower elevations than the peak water-surface. Experienced flood hydrologists know this and account for it in their interpretation of water-surface profiles. Additionally, it is common for there to be surging and waves with flooding, and this will also cause unequal HWMs. It is the experienced flood hydrologist that must sort these out. Today's practice in a field survey of the water-surface profile in a slope-area computation is to grade an HWM as excellent, good, fair, or poor and to briefly describe it. When the HWM waters surface profile is drawn after the field data are collected, the hydrologist uses his or her judgment to draw the profile through the trend of the HWMs while weighting the quality and type of each HWM. The problem is more pronounced when trying to trace historic floods based on people's recollection and poor quality HWMs. A person's recollection is often a good starting point, but physical data like tree scars, staining, and sediment deposits used by Stewart should take the prominent role.

   The descriptions of the HWMs found by Stewart are recounted in the second and third paragraphs in the section above titled "Skagit Basin Field Work, 1922-23." The descriptions were taken directly from Stewart's field notes and provide a trail of evidence of how Stewart came to the final gage heights he used to determine the magnitude of the historic peak discharges for the Skagit River near Concrete. The observations and notes have discrepancies. This is expected as work and refinement progresses from field notes to drafts to reports. The 1921 HWMs, however, were clearly defined at the gage and the preponderance of evidence for the relative size of the floods provides reasonable assurance Stewart correctly ordered the magnitude of the other three historic floods.

9) Mr. Kunzler's rebuttal implies the Manning's *n* was based on the reviewer's assumptions and asks why is it so low when the U.S. Army Corps of Engineers is using a Manning's *n* of 0.040 in their model. This *n*-value is significantly less than the U.S. Army Corps of Engineers *n*-value because the model reach used by the U.S. Army Corps of Engineers is much longer than the reach chosen for the USGS slope-area computations, and it contains turns and other irregularities that increase roughness. The USGS slope-area computations purposely avoided these types of features. A simple comparison of *n* is not applicable because it does not apply to the same stretch of river. [Initially, Stewart assumed the *n* value would be the same as that determined in Sedro Woolley. As it turns out, this was a reasonable assumption. Because of the importance of the *n*-value in the calculation of peak discharge in a slope-area indirect method, the USGS performed an *n*-verification study and back-calculated *n* from channel geometry and a known peak discharge from 1949. There was some debate about how the *n* value was calculated from that initial *n*-verification study so again in 2004 another *n*-verification analysis was completed. This last *n*-verification showed that the *n*-values fell in the range from 0.024 to 0.032--the average *n*-value resulted in a calculated discharge for the 1921 peak essentially the same as the discharge calculated by Stewart.]

Mr. Kunzler states a 1937 aerial photo shows the island that exists now below the Dalles did not exist in 1921 and the river was clearly wider downstream than it is today. The same aerial photo was used by Mastin and Kresch (2005, p. 11 and 12) along with a 2001 aerial photo to show precisely the opposite. The photo shows the island (or sand bar at medium to low stages) has almost identical shape today as in did in 1937, but the vegetation is quite different. In 1937 the island/sand bar is bare with no vegetation resulting in less resistance and a lower *n*- value. In 2001 the island/sand bar has a dense alder/maple/cottonwood forest which results in more resistance during high flows and a higher *n*-value. The 1937 aerial photo does not indicate much about the conditions of the island/bar in 1921, but channel cross sections in 2004 located at the same locations (+/- 10 feet) as those surveyed in 1923 show the island did exist in 1923 and the cross sections have changed very little over this time interval. This is another indicator of the stability of the rating for the streamgage just upstream.

10) The rebuttal states the USGS uses bureaucratic non-speak in responding to a discrepancy described by Mr. Kunzler. We may be misunderstanding the issue; however, the 1949 flood was used by Bodhaine as an example of a short duration flood that shows the reduction in the flood peak discharges on the Skagit as the flood moves downstream of Concrete. Using the figures Mr. Kunzler supplies, the peak discharge near Concrete is 154,000 cfs, 149,000 cfs at Sedro Woolley, and 114,000 cfs at Mt. Vernon. From these figures, the peaks are decreasing downstream. We do not understand where the discrepancy in the peak discharges lies.

11) The rebuttal to our response to the question of why rainfall is not well-correlated with the historic peak discharges asks why the USGS has not done any scientific research into this issue. Water available for runoff (WAR) is dependent on many factors other than the 4-day rainfall total Mr. Kunzler uses to make his point. WAR is dependent on the moisture capacity of the soil, existing moisture in the soil, rainfall intensity, snow, snow condition, storm intensity and duration, movement directions, and temperature. As in many of the Cascade watersheds, a large portion of the Skagit Basin lies in a transition zone where precipitation may be snow or rain. When freezing elevations are low, the potential for flooding in the near future is low no matter how much rain is being collected at low-elevation rain gages.

Analysis of the correlation between Diablo rainfall and peak discharge since 1990 using the information provided by Mr. Kunzler in his White Paper table of "4-day rainfall in Skagit River Basin," yields a coefficient of correlation, R^2, of 0.0158 indicating little correlation (fig. 3). Mr. Kunzler states that based on the relationship between rainfall and discharge from the data in his table, the Stewart measurements are over-estimated. The relationship between rainfall and discharge is poor and should not be used to discount calculated discharges based on-site specific hydraulic data.

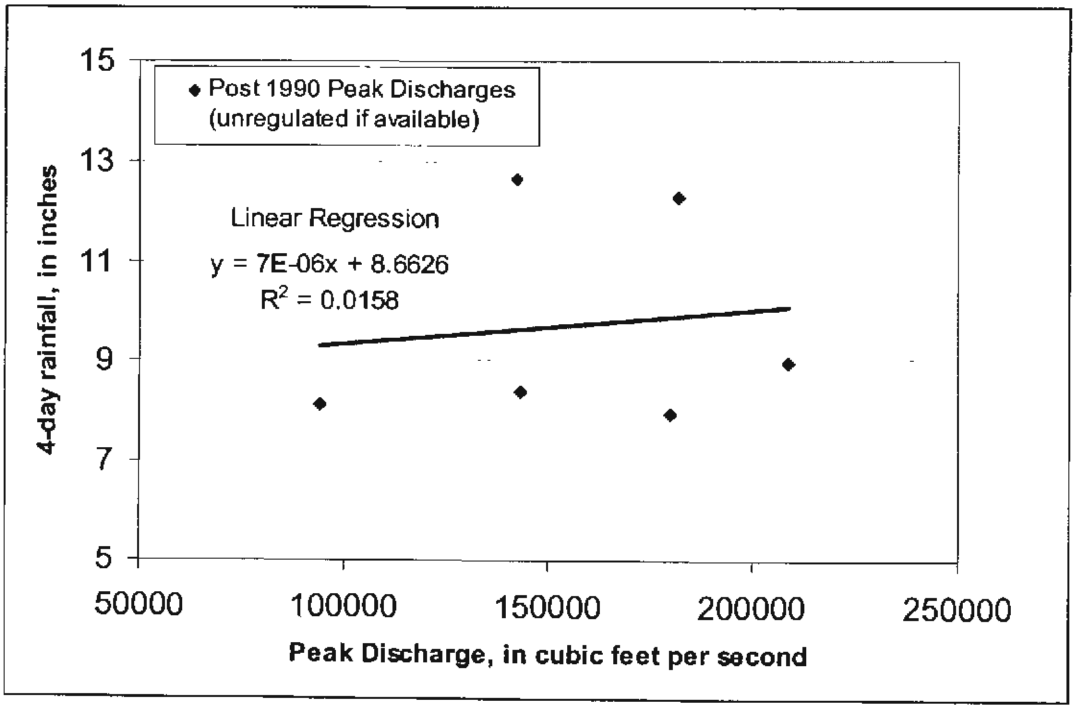

Figure 3. Post 1990 Peak Discharges on Skagit River near Concrete versus 4-day rainfall totals at Diablo, Washington.

12) In Mr. Kunzler's rebuttal he suggests Stewart's data should not be used at all because some of the data could be in error by as much as 25 percent or more. This idea of ignoring historical floods because there is some uncertainty in the value goes against the general ethics and guidelines of the scientific community on flood frequency analysis. Most agencies in the United States follow the procedures prescribed by the Interagency Committee on Water Data (1982) in their "Guidelines for determining flood flow frequency: Bulletin 17-B." On page 5 of the Bulletin it states:

> "Historic flood information should be obtained and documented whenever possible, particularly where the systematic record is relatively short. Use of historic data assures that estimates fit community experience and improves the frequency determinations."

The National Research Council (1988) recommends using historical and paleoflood data stressing that as much information as possible about floods needs to be used for evaluation of the risk. Many other researchers (Tomlinson and others, 2004; England and others, 2003; National Research Council, 1999; Stedinger and others, 1993; Bras, 1990; Kite,, 1988) have used historic data in flood frequency analysis and explain the advantages of using such data.

13) Mr. Kunzler's rebuttal quotes Dr. Jarrett's (USGS) comment about some of the short comings of Stewart's work. Dr. Jarrett's overall review of Stewart's historical flood studies (memo of Feb. 15, 2005) was very complimentary;

shortcomings were few and relatively minor. It is agreed that more could have been done by Stewart and it is puzzling why no photographs were taken. Often there is more work that can be done in any investigation, but resources and time rarely allow it. Mr. Stewart used the tools of his time to investigate and calculate discharges and was ahead of his time in applying paleohydrology techniques to date the floods. He knew the *n*-value in his calculation of the 1921 peak discharge at the Dalles was questionable and advises the USGS District Engineer in 1925 to complete an *n*-verification study. Two *n*-verification studies were completed and both validate the *n*-value selected by Mr. Stewart. The USGS considers Mr. Stewart's work to be of the high quality required for USGS hydrologic investigations and publications. We are pleased so much good work has been done by the USGS over a long period of time to understand flood frequency in the Skagit basin.

14) Mr. Kunzler reports on the flooding of two houses in Hamilton located on the Skagit River about 14 river miles below the Skagit River near Concrete streamgage. From Mr. Kunzler's account of the flood levels in the houses that were constructed in 1902 and 1908, the 1990 flood (146,000 cfs) and the 1995 flood (160,000 cfs) were significantly larger than the 1909 flood (260,000 cfs) and the 1921 flood (240,000 cfs). We cannot explain how this could have occurred except that it is contrary to Mr. Kunzler's own previous contention that the 1909 and 1921 floods should be lower than reported but well above the 1995 flood. This claim is contrary to the clear evidence of flood marks and hydraulic analysis of the 1921 flood, the analysis made by Pacific International Engineering hired by Skagit County, and all other flood analyses of which we are aware. The information provided by Mr. Kunzler does not agree with evidence elsewhere and it is difficult, therefore, to reconcile without further investigation.

USGS CONCLUDING REMARKS

While one must respect Mr. Kunzler's passion and the efforts he has put into arguing his point that the four historical floods should be eliminated because of possible inaccuracies in the data, it would be wrong to eliminate the data from the flood frequency analysis. There is good evidence these floods were large floods and occurred at or near the time they were reported to have occurred. The stage of the 1921 flood is precisely known and the computation of discharge is as good as can be done today. The discharge has been confirmed with two separate *n*-verification studies. While the other historical floods have not been verified as rigorously as the 1921 flood, the stage-discharge rating has been established for the range of discharge of these historical floods, and the published relative magnitude of the floods is reasonable in light of the preponderance of the HWM information. One could debate the exact stage for these floods, but allowing for some uncertainty in the stage, the published discharge is thought to be within a reasonable range of uncertainty. We know all discharge information contains uncertainty; even a good direct measurement with a current meter is generally thought to be within five percent of the true value. The scientific community, by consensus, recommends the inclusion of historical data whenever possible (see references cited for response to number 12). The USGS has decided to downgrade the two oldest floods published by Stewart and Bodhaine as estimates and the

U.S. Army Corps of Engineers is not using them in the flood frequency analysis. The dates for the occurrence of these floods and their stage are not as well defined as the other four historical floods and that is why they were downgraded to estimates.

There is little more that could be done at this point to verify data collected nearly a century ago, except possibly a paleoflood study which would look at past flood sedimentation or tree scarring evidence as paleostage indicators. Because paleoflood studies rely on interpretation of natural sediment deposits and documentation of similar sediment in other locations, there is greater uncertainty in these studies than in normal flood investigations. The benefit of accepting greater uncertainty is the extension of flood records back into the geological past and identification of floods far greater than recorded by humans. This type of study might support or refute the two historical flood estimates or perhaps find evidence of even older and larger floods. When trying to calculate the flood frequency of the 100- or 500-year flood, the consensus of the scientific hydrology community is that historical flood data is valuable and usually improves calculations of flood risk. The Skagit River is a flood-producing alluvial system. It has been the pathway for frequent and large floods in the past, and will do so in the future.

The USGS is committed to providing the best scientific information possible so that the public, policy makers, and emergency management officials can make informed decisions to prepare for flood hazards and reduce losses from future floods.

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