JAMES E. STEWART

SKAGIT RIVER
FLOOD REPORTS AND
ASSORTED DOCUMENTS

A CITIZEN CRITICAL REVIEW

WHITEPAPER

By:

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PREFACE

James E. Stewart was an assistant engineer (hydraulic engineer) with the United States Geologic Survey ("USGS"), Water Resources Branch in Tacoma, Washington when he authored his first report on the Skagit River in 1918. ***(Source: Skagit River Flood Report, 8/12/18).*** He left for a few years and was stationed in Hawaii where he was in charge of "water resource investigation". Upon his return he was again assigned to write a report on the historical flooding events on the Skagit River so long as Skagit County would agree to pay for his time. ***(Source: USGS letter to Skagit County 11/16/22)*** Mr. Stewart left USGS for employment with the West Virginia Power and Transmission Company in March 1923, 7 months before his "preliminary" report was completed and given to the Skagit County Commissioners ***(Source: Stewart letter to F.M. Veatch, USGS, 6/1/50)*** in October 1923. ***(Source: Handwritten note contained in USGS files.)***

Mr. Stewarts 1923 report was never published and there is no evidence contained in the USGS files that anyone from USGS ever went into the field to check his flood elevation measurements. In 1946 there was some renewed interest in publishing Mr. Stewarts work. ***(Source: Letter to William Eisenlohr, Jr., Hydraulic Engineer, USGS, Wash. DC from Stewart re Skagit Report, 4/2/46)*** Over the next 15 years, several USGS employees looked at Stewart's work which eventually culminated in the Bodhaine/Stewart Report being published in 1961. ***(Source: Geological Survey Water-Supply Paper 1527, 1961)*** However, based on a letter from Mrs. Stewart, located in the USGS files it is believed that by the time the 1961 report was published, Mr. Stewart had passed away.

In about December, 2002, it became apparent to me that the Corps of Engineers, in their hydraulic analysis was relying entirely on the 1961 Stewart Report to calculate 100 year flood figures for the Skagit River. On January 20, 2003 I wrote a memorandum titled "A Historical Investigation into the Skagit River Flood Levels". Contained within that memorandum were 12 pages concerning the three "Stewart Reports", which raised questions concerning the conclusions, reached by Stewart and USGS. The Corps of Engineers response to those 12 pages of research was two sentences, which stated:

> *"If there are known errors in the derivation of a peak flow, it is necessary to take these up with the USGS as they are in charge of producing this data. Given that an analysis was done in 1918 by USGS, refined in 1923, looked at again and republished in 1961 and is put on the USGS website tells us that these flows are their best estimate."* ***(Source: Seattle District, U.S. Army Corps of Engineers Response To Larry J. Kunzler's Memorandum dated January 20, 2003, Entitled A Historical Investigation Into the Skagit River Flood Levels, 2/21/03)***

At the time this response was written the Corps of Engineers had not reviewed the Stewart Reports, *"I have not read through the "Stewart" reports nor do I plan to unless it is made clear that a methodology used is incorrect."* ***(Source: Memorandum to***

Steve Babcock, Project Manager from Ted Perkins, Hydraulic Engineer, Corp of Engineers, 2/5/03)
Also the Corps statement about the 1918 and 1923 Stewart Reports being published is incorrect. Neither of these two reports was ever "published".

On January 23, 2004, I had the privilege of reviewing and copying the original Stewart documents, including but not limited to Mr. Stewarts "Field Journal" he used to make handwritten notes concerning his measurements during the winter of 1922, contained in USGS files and maintained by the National Archive Records Administration ("NARA"), at the former Sandpoint Naval Air Station, Seattle, Washington. I also reviewed the papers provided by USGS concerning the subsequent work done on the Stewart information used to publish the 1961 Water Supply Paper, the Bodhaine/Stewart report. The original 12 pages contained in my memorandum on January 20, 2003 was used as the foundation for this White Paper. The information was then supplemented with the information I copied from the USGS files at Sandpoint as well as other information obtained from various sources subsequent to that date. An index to the documents copied has been prepared and will be made available to anyone so requesting as well as copies of the documents themselves.

I would like to take this opportunity to thank USGS for not only making the Stewart files available to me but also for paying the .50 cents per page copying charge that the NARA charges citizens for copying documents. That fee to citizens is something that deserves its own investigation but will not be dealt with in this White Paper.

I also would like to thank the U. S. Army, Corps of Engineers, Seattle District, for not only giving me access to their documents but in also providing data needed in the preparation of this paper.

PURPOSE

It is the purpose of this paper, based on the research contained herein, to encourage the major stakeholders (i.e. PSE, SCL, BNSF, Skagit County government), government agencies (i.e. USGS, Corps of Engineers, FEMA, State Dept of Ecology, local governments), elected officials, as well as the citizens of Skagit County, to question the use of the "Stewart data" in determining the flood frequencies on the Skagit River. As this White Paper will show, the historical flood data, gathered by Mr. James E. Stewart is what is driving the determination of any flood project on the Skagit River. Based on the research contained herein, it is believed that his work product is questionable at best and perhaps should not be used at all.

I. THE STEWART REPORTS

A. 1918 REPORT

The main premise of this study was to analyze the Skagit River flood flows for the 1897, 1909 and 1917 floods all of which were "large floods". He concluded that, "**Floods closely approaching these three may be expected on an average of once in ten years**. In addition to these floods there are sure indications of a much greater flood at the Reflector Bar and Sedro Woolley gauging stations and also traditions among the Indians." ***(Stewart Report, 1918, Page 1)***

In his 1918 analysis Mr. Stewart based his conclusions primarily on "flood marks" he located at Reflector Bar[1] which is 47 miles upriver from Concrete (***Stewart Report, 1961, Page 6***) and the Davis Ranch[2] (1.5 miles below Reflector Bar (***Stewart Report, 1918, Page 1***). He also took into consideration flood marks he located at the Skagit River Power Camp near Marblemount, below the Baker River near Concrete (The Dalles[3]) and at Sedro Woolley. He briefly mentioned the Cascade River, Sauk River at Darrington, and the Suiattle River although went into no great detail on those tributaries.

He also talked with a local settler named Mr. Joseph Hart who settled in the Skagit Valley near Sterling (downstream of Sedro Woolley) in 1878 ***(Stewart Report 1918 Page 8)***. Mr. Hart showed Mr. Stewart stains left on trees by previous floods and related stories told to the early settlers by Indians. Stewart wrote that Mr. Hart told him:

> Some of the oldest Indians, judged to be about seventy years of age, told them that when they were small boys a big water came "very quick" and that their tribe did not have time to save their smoked salmon and dried venison; consequently, they nearly starved that winter. Mr. Hart estimated at that time, from the age of the Indians who were able to remember the flood, that this flood must have occurred about sixty years previous to 1879. This makes the date of the flood about 1820 and is confirmed by my study at Reflector Bar and by the young spruce trees which did not have the high-water mark on in 1879. ***(Stewart Report 1918, Pages 8 & 9)***

Mr. Stewart concluded his 1918 report by stating:

[1] See Appendix B.

[2] Ibid.

[3] Ibid

> Due to the limited time on this report errors may be found in the plotting of some of the measurements. Unchecked measurements were also plotted. ***(Stewart Report 1918, Page 11)***

He attached an exhibit to his report, which showed the "estimated" discharge for the three floods at below Baker River (The Dalles) and Sedro Woolley. Those figures are as follows:

YEAR	CONCRETE[4]	SEDRO-WOOLLEY
1897	205,000 cfs	171,000 cfs
1909	185,000 cfs	169,000 cfs
1917	175,000 cfs	157,000 cfs

(Stewart Report 1918, Exhibit J)

Located in the USGS files was a transcription of Mr. Stewart's notes taken on May 2, 1918 while at Reflector Bar which is located one-tenth of a mile below the Diablo Dam. ***(Source: Stewart Report, 1961 Page 8)*** Mr. Stewart was using a hand-held "Seattle levelman's level". He measured the December 29, 1917 high-water mark at "6.15 feet above present water surface." 1909 high-water "8.6 feet above present water surface. He stated, "…it can be assumed that the 1909 flood was 2.5 feet higher than 1917." "Estimated fall in water surface .3 per 100 feet or 1.8 feet." ***(Source: Stewart Notes at Reflector Bar, 5/2/18)***

Mr. Stewart wrote "People who have lived in the Skagit Valley since 1888 say floods of 1897, 1909, 1917 are the only big ones of which 1909 was the largest above Marblemount." In talking about a larger flood event he states, "I think the only flaw in the flood flow of this great flood is the possibility of a log jam or snow slide in the canyon below but in a big flood these obstructions would last such a short time that the great amount of sand seen could not have been deposited." ***(Source: Stewart Notes at Reflector Bar, 5/2/18)***

The statement by Mr. Stewart, "…the only flaw in the flood flow of this great flood is the possibility of a log jam or snow slide in the canyon below…" is significant because it is one of the few documentations that Mr. Stewart realized the possibility of log jams or snow slides as having the possibility of impacting his flood reports. The verbiage that was found in his notes was never repeated in his final work product, and only given one line in the USGS 1961 report which stated, "**Higher stages may also have occurred at other points during other floods as a result of log jams**. ***(Source: Bodhaine/Stewart Report, page 22, 1961)***

Since 1966 I have hiked extensively in the Diablo and Ross Lake canyon areas and have observed tremendous amounts of "flood sand" deposited at the base of numerous

[4] The Dalles

streams and tributaries, as well as major landslide areas to Diablo and Ross lakes (i.e. Creek next to the Diablo Lake boat ramp and Greenpoint Campground in Lake Ross). Surely, any flood events in the pre-dam era, would have carried large amounts of that sand down the valley and just as surely, a lot of it would have been deposited in the Reflector Bar and Davis Ranch area.

Just two final observations concerning the 1918 report. Mr. Stewart stated: "Mrs. Davis states 1897 and 1917 floods just same height, 1 ft over floor in a small bunk house near where they live." ***(Source: Stewart Notes at Reflector Bar, 5/2/18)*** Mrs. Davis was the owner of the Davis Ranch which as previously stated was located 1.5 miles below Reflector Bar. (***Stewart Report, 1918, Page 1***). Also, contained on the front page of the 1918 report is a handwritten note from someone with the initials HEB to GLB (presumed to be G.L. Bodhaine who authored the 1961 report) which states: "Note: I believe all references to 1820 flood in this draft for Sedro Woolley and Concrete are for 1856 flood in later reports." ***(Source: Skagit River Flood Report, 8/12/18)***

The significance of the 1918 report is two fold. First, the figures Mr. Stewart estimated in the table above are considerably lower then in his subsequent work products and will be addressed later in this White Paper. Second, nowhere in either the 1923 report or the 1961 report is this work product even mentioned. This report was given to USGS on August 12, 1918. ***(Source: USGS "Received" stamp on cover page of "Skagit River Flood Report, July 1918)*** That is just 4 years before he began his field measurements for the 1923 report. ***(Source: Stewart Field Journal, 11/24/22)*** No explanation for the discrepancy is ever mentioned by either Mr. Stewart or USGS.

B. 1923 REPORT

1. Preliminary Report

In 1923 Mr. Stewart prepared another report, paid for by Skagit County which consisted of a 28 page Preliminary Report. ***(Source: Preliminary Report – Stage and Volume of Past Floods in Skagit Valley and Advisable Protective Measures Prior to the Construction of Permanent Flood Controlling Works)*** Representatives of Skagit County made arrangements with G.L. Parker, then district engineer of the USGS, Surface Water Branch at Tacoma, to determine the size of the floods. J. E. Stewart was given the assignment of compiling field data and writing a preliminary report, which was completed in 1923 but not published. ***(Floods in the Skagit River Basin Washington by James E. Stewart and G. Lawrence Bodhaine, Geological Survey Water-Supply Paper 1527, (1961) Pg 3)***.

However, as determined by documents obtained in the USGS files, Mr. Stewart left USGS for employment with the West Virginia Power and Transmission Company in March 1923, 7 months before his "preliminary" report was completed and given to the Skagit County Commissioners ***(Source: Stewart letter to F.M. Veatch, USGS, 6/1/50)*** in October 1923. ***(Source: Handwritten note contained in USGS files.)*** As of the writing of this

White Paper it is unclear if the "Preliminary Report" obtained from the USGS files is in fact the one which was presented to the Skagit County Commissioners in October 1923 as that Report has a signature page dated 1/28/29. ***(Source: Preliminary Report – Stage and Volume of Past Floods in Skagit Valley and Advisable Protective Measures Prior to the Construction of Permanent Flood Controlling Works, 1/28/29)***

This report was much more comprehensive then the 1918 report although much of the verbiage from the 1918 report was repeated although not referred to. Mr. Stewart began by stating:

> The results of this study are being formed into a report which will not be completed for some time. The data concerning the volume of the floods, which was the basis of the agreement (*between Skagit County and USGS*) was furnished in August of this year. . . Since the arrival of the first white people, about 1869, there have been six Skagit River floods whose discharge has exceeded 175,000 (cfs) at Sedro Woolley. All of those six floods have occurred since November 15, 1869. (***Stewart Report 1923, Page 1***)

2. Field Notes

The basis for Mr. Stewarts 1923 report was found in his "field notes" taken in the winter on 1922. The first such note was dated September 16, 1922. Mr. Stewart returned to Reflector Bar on 9/15/22. He stated in part:

> "The trip was profitable as faint evidence of the large flood could be traced on the left canyon wall across from where I was. By hand level this was found to be 18.0 feet above water surface of Sept. 15., 18.0 plus 3.3 equals 21.3." "The wave crest of the 1921 flood is about .7 ft below that of 1909 at the 1909 high water mark at Stetattle Creek. The 1921 flood was about .6 or .8 below 1909 flood at the Davis ranch. The 1921 flood came so near that of 1909 in the canyon above Reflector Bar gaging station that they cannot be separated by observation from a distance. The rapid dimming of the 1909 flood marks, the difficulty of finding the early flood mark on the trees where it was bright in 1879, the freshness of the river sand and gravel where the river topped the bank at Reflector Bar, the condition of the Cedar stump at Ruby: all these lead to the assumption that the **great flood** was that of **December 4, 1861**. The old Indian who told Hart and others at Sedro Woolley in 1879 that the flood was when he was a boy either referred to another flood or they did not understand him."
>
> ***(Source: Transcription of Stewart "flood notes" on 9/16/22 by USGS 6/30/23 re Reflector Bar near Marblemount)***

There was a “later note” (unknown when) which stated “Data with measurement of May 2, 1918 makes the crest 15.0 ft. use it in preference.” (**NOTE:** See “flood notes” 5/2/18 for same location.)

The significance of the highlighted text in the above transcription is that this is the only time “the great flood” was determined to be December 4, 1861. In fact, nowhere in any subsequent publication is this flood, great or otherwise, mentioned. What is also significant is the discounting of the statements made by the “old Indian” as in later versions of the Stewart Report, especially in the 1961 version, the “old Indian” is again quoted as being accurate although it is worth noting that in the Preliminary Report delivered to the Skagit County Commissioners, there was no mention of the “old Indian” statements.

Also located in the USGS files was the original “Field Journal” used by Mr. Stewart in the winter of 1922. A transcription of many of his notes is included in this White Paper as Appendix A. A portion of the appendix which provides anecdotal evidence of Mr. Stewarts research, is reprinted here:

Page 23	Leonard Everett says 1897 flood about 9 inches lower than 1909. Says that log jam in The Dalles raised water 10 feet in 2 hours. Considerable distance and slope between 1897 and 1909 and 1921 marks. 1897 1.4 feet higher.
Page 62	Measuring the lengths of rope in Dalles. Found first 100 feet only 95 feet due to shrinkage in rope. Rope probably about okay for the two Dalles sections, as it was graduated while dry but not stretched, while it was used wet and stretched.
Page 69	Checks on rope graduation were made while rope was still stretched across river. It is not certain that these checks are applicable to the lower cross sections also but probably will have to be assumed so.
Page 101	Rockport. Bark and moss point. Possibility 1897 likely wind blown sand. 1.1 feet below this 1921 mark? 1.23 feet below this is 1897 mark. NOTE: Assume 1921 same as 1909. Probably 1909 nail. Ed Presentine says 1897 .5 feet higher then 1909. January 28, 1923. Old Johnny Towne (Indian) said during 1909 flood that when he was a boy he saw river even higher. He is considered to be 70 years old or more so flood would be that of 1856.

(Source: James E. Stewart “Field Journal”, beginning entry November 24, 1922)

The entry on Page 23 is significant because it is now the second time that a “field note” has talked about the influence of log jams on flood flows. A local resident,

"Leonard Everett says 1897 flood about 9 inches lower than 1909. Says that log jam in The Dalles raised water 10 feet in 2 hours." Depending on how you want to read this statement either the 1897 or the 1909 flood had a log jam in The Dalles so much so that it raised flood waters "10 feet in 2 hours". Was the log jam there in the beginning of the flood or near the crest of the flood? We will perhaps never know, but the significance of the entry in the log clearly points to the distinct probability that the Dalles, a somewhat narrow rock canyon, current location of the "Concrete gage", located downstream of the confluence of the Sauk and Baker rivers, both volcanic in nature and thus subject to carrying huge amounts of debris in all kinds of flood flows, would have been subject to log jams in this area. Thus, any historical "flood marks" observed in this canyon, would have been influenced by log jams backing up the water levels. This is especially significant in that the measurements for the 1897, 1909 and 1917 floods were taken approximately 1 mile upstream of The Dalles. ***(Source: Stewart Report 1923)***

Given the fact that the first statement referencing log jams was made at Reflector Bar ***(Source: Stewart Notes at Reflector Bar, 5/2/18)*** and now this statement at the Dalles, both locations which were key to Stewarts computations of flood flows, it raises the distinct possibility if not probability that all of Stewarts research and observations especially on the "great floods" of 1815 and 1856 as well as all other floods for that matter, could have been impacted by the damming of the Skagit River by log jams, landslides, snow slides, ice dams and or volcanic debris flows. None of which was ever referenced in any of the Stewart Reports as having an impact on flood measurements.

The entries at page 62 and 69 are particularly disturbing. Not only are Mr. Stewarts measurements made with a hand held level ***(Sources: Stewart Notes at Reflector Bar, 5/2/18 and Transcription of Stewart "flood notes" on 9/16/22 by USGS 6/30/23 re Reflector Bar near Marblemount)*** but now we find that he was using a 95 foot rope and counting it as 100 feet.

3. Additional Work

The report given to the Skagit County Commissioners was "Preliminary". Documents obtained from USGS strongly suggest that the "1923 Stewart Report" was in fact not finished by Mr. Stewart until at least 1949, if at all. The following statements were written by Mr. Stewart:

> "The field work and part of the office work was accomplished in the four months from the middle of November, 1922, to the middle of March, 1923. In March 1923, the writer resigned from the USGS. But to fulfill the agreement with Skagit County, the office work was continued at every available opportunity until a preliminary report was issued in September, 1923. … After completing the preliminary report, the writer continued the study, as convenient opportunity offered, up to the present time. The work since March, 1923, has been without financial remuneration, but the writer will feel amply repaid if the study and this more complete report result in

> the saving of life and property in Skagit Valley, and a material advance in the science of hydraulics." ***(Source: Stewart "Forward" or "Introduction" section to his 1923 Report, 1/27/43)***

The fact of the matter is that three different versions of the 1923 Stewart Report has been located in USGS and Corp of Engineer files. It is unknown which of the three are Mr. Stewarts work and which one was the work of later USGS employees who "worked" on the report. It is known that "some of the work" was done by Mr. William Eisenlohr, Jr. with the USGS Washington DC office. ***(Source: Floods in the Skagit River Basin Washington by James E. Stewart and G. Lawrence Bodhaine, Geological Survey Water-Supply Paper 1527, (1961) Pg 4)*** It is also possible that the three different versions are drafts that Mr. Stewart submitted to USGS at different times although there was no correspondence to substantiate that.

It is also known that Mr. Stewart felt that additional field work was necessary to justify his findings. He stated in part, "The most important field work is checking the "N" for the slope sections used in The Dalles. This checking of the "N" can be done by Mr. Veach's office alone." ***(Source: Stewart letter to Eisenlohr 4/2/46)*** The "N" he is referring to is the "roughness coefficient" of the Kutter's formula (currently referred to as the "Manning Formula") used by hydrologist to determine flood flows. The more debris and/or sediment in the water or trees and brush along the banks of the river the greater the value of "N". The determination of this value can have a significant impact in the final computation of flood flow analysis. This subject will be dealt with in more detail later in this paper.

Even after Mr. Stewart left the employ of USGS he was still trying to gather data from local residents for his paper. He sent a letter to Frank Davis in which he stated:

> ""I have determined the approximate year of that great flood which reached a gage height of 20.8 at Reflector Bar. … The flood, according to the age of the trees, occurred about 1856." "At The Dalles I found traces of still greater flood or floods. These traces mark the maximum flood or floods in the last few thousand years. I am writing you to ask if you would try to obtain evidence of what gage height the maximum flood at Reflector Bar. By comparison of the floods at The Dalles, I would estimate that this flood reached a gage height of approximately 25 feet at Reflector Bar. Anyway, it must have been somewhere between 23 and 28 feet." ***(Source: Ltr to Frank Davis, Skagit Power Camp, from Stewart 5/5/23)***

On the same day he wrote a memorandum to a Mr. Judd, (presumably an employee of Seattle City Light) in which he stated:

> As you remember, we did a little flood investigation when I was there last September. We accomplished very little as the bark on the trees seemed to be filled with wind-blown sand instead of flood sand." "Since last Sept. I have determined the approximate date of the great flood that I had found traces of at Reflector Bar. This flood occurred about 1856 instead of 1820, as previously estimated." "Since my visit in September I found at

> The Dalles near Concrete that there was a larger flood than the 1856 flood – the flood of Indian tradition that occurred about 1820 may have been the one that reached that state." ***(Source: Memorandum to T.N. Judd, from Stewart, 5/5/23)***

Mr. Stewart was having trouble fitting the 1917 flood into his profiles. He writes another letter to Frank Davis asking him for assistance. He stated:

> "The comparison with the 1917 flood does not work out well and I wonder if you can make any suggestion as to the reason." … "**Readings that I have received may be incorrect**…" … "It may be that at some time an enormous snow slide dammed the canyon between Ruby and Reflector Bar, and then broke loose, such an occurrence would check with the old Indian tradition of a flood about 1820 that came unexpectedly in the night and so quick they hardly escaped (Sedro Woolley Indian tradition). … "If the river should stop rising or fall before the temperature fell or before it stopped raining, it would mean there was a snow slide or jam in the canyon and the water would be down a little later carrying everything before it." ***(Source: Letter to Frank Davis, Davis Ranch, from Stewart, 5/23/23)***

Once again, Mr. Stewart acknowledges the possibility of "snow slides" or "jam" impacting his flood results. Once again, no mention of this in any of the Stewart reports.

Frank Davis answered Mr. Stewart's letter of 5/5/23. Mr. Davis reported that he found:

> "Drift sticks and bark at gulch at 16.3' elevation". … "course wash sand at 19' elevation". … "fine sand, *probably* wash at 22' elevation." "I found no course sand here but there is no doubt about the wash sand at 19." … "Drift at 16.3 does not appear to be very old and was *probably* put there in 1909 though it would seem to be most to high for that." ***(Source: Ltr to Stewart from Frank Davis, Davis Ranch, 5/31/23)***

The measurements were taken with a hand-held level. Davis added a PS to his letter, which stated, "19 is just about the highest point on Reflector Bar flat." ***(Source: Ltr to Stewart from Frank Davis, Davis Ranch, 5/31/23)***

On June 12, 1923 Mr. Stewart solicited the help of local resident, Joseph Hart with whom he had spoke with at length concerning floods in the Sterling area. Mr. Hart responded to Mr. Stewart's letter as follows:

> "The Winter floods previous to the Spring flood of 1894 was about 2 feet higher, but they were never as high or no indications of them being so, excepting the one big flood the Indians tell about. The Winter Floods since that time (1894) were always higher. The more they diked the river close to it, the higher the floods have been." ***(Source: Letter to Stewart from Joe Hart, 6/21/23)***

Joe Hart lived on what is today known as Hart's Island just upstream from Sterling. The island is currently owned by Leonard Halverson.

Mr. Stewart responded to Frank Davis's letter of 7/6/23. He stated that he was at Reflector Bar "last September" in the same "gulch" that Davis made his measurements. However:

> "I determined with a hand level the height of the 1909 and the highest flood. I made them 15.8' and 21.3' which is .5' and .7' respectively lower than your results. … "it would seem as though one of our hand levels was out of adjustment or something else was wrong." ***(Source: Letter to Frank Davis from Stewart, 7/6/23)***

Stewart wanted Davis to have his level checked because Stewart had "no way of checking up my data". … "In case your data proves correct in all points, I will probably want to use it instead of mine. For the time being I am averaging our results." ***(Source: Letter to Frank Davis from Stewart, 7/6/23)***

Mr. Stewart wanted to know if Mr. Davis was:

> "confident that the coarse sand at g. ht. 19 marks the crest of some flood? If it is the crest of a flood … it marks the flood of 1856." … "The fine sand is undoubtedly flood sand, and marks the crest of the maximum flood which occurred about 1814 (within 10 years either way). I got the elevation 21.3 from the faint line on the rock wall opposite the small gulch we both worked in. You can plainly see the mark on the same flood on the rock wall opposite the Thunder Creek gage. I found the flood reached to 20.8 at the Reflector Bar gaging station." ***(Source: Letter to Frank Davis from Stewart, 7/6/23)***

In late August, 1923 Mr. Stewart sends another letter to Mr. T.H. Judd at the "Skagit River Camp. He wrote the following:

> "**The data I have previously furnished you are somewhat in error** as to dates and heights of certain floods. It would be well, therefore, to consider all previous data superseded in reading this letter." "The maximum flood, which has occurred in the last few thousand years, had a discharge of about 120,000 second-feet at Reflector Bar. This estimate of discharge may be in error as much as 20 percent. For engineering purposes it would be necessary to plan on handling 145,000 second-feet at that point, and about 155,000 at the Power Camp." "The flood of December 12, 1921 had a discharge of 63,000 second-feet at Reflector Bar. The estimate of discharge is believed to be within 10 percent of correct. The maximum possible estimate for the 1921 flood would, therefore, be 70,000 second-feet at Reflector Bar and 75,000 second-feet at the Power Camp."
>
> "**The discharges that I have given are therefore in excess of what would be computed by using the mean of waves and surges** (the

USGS method)." For the 1921 flood, I believe Mr. Parker is expecting to publish 57,000 second-feet or 6,000 second-feet less than I have given. There are certain arguments for both systems of computing flood discharges. Personally, I am of the opinion that the true peak discharge would be very nearly a mean of the discharge obtained by the two different methods of obtaining gage heights. ***(Source: Letter to Mr. T.H. Judd from Stewart, 8/22/23)***

Two years pass and there is no evidence anything was done with the 1923 report. In May, 1925, Mr. Stewart advises Mr. G.L. Parker, USGS District Engineer, Tacoma, Washington of the following:

"I regret to say that I have no more of the report ready for typing. My family (including myself) had a protracted siege of the influenza just after I asked you for some information concerning Baker River. In my hydrographic studies for the West Penn Power Company, I have had a chance to go into much more detail than was generally possible for any of us in the Survey. As a result of these studies, I have about come to the conclusion that for many, if not practically all, of the steep sloped streams the Survey records for maximum flood discharge are too low, except where they are based on discharge curves, the upper extensions of which were derived from area and mean velocity curves. "…I consider the trouble to be due to extending the rating table by the continued use of the last difference derived from the rating curve. In some cases, I believe a contributory cause has been the use of .2 or surface velocities with reduction coefficients to mean velocities based on measurements made at much lower stages, and consequent coefficients that are too low. Lastly, I believe that in many cases no account has been taken of the over-flow that occurs when the banks have been topped. However, in allowing for such over-flow I believe there is more danger of over-allowance than under-allowance, due to the fact that in many cases there is dead water, a large coefficient of roughness, and other factors tending to reduce the flow much below the figures for the main channel." ***(Source: Letter to G.L. Parker, District Engineer, USGS, from Stewart, 5/4/25)***

The above verbiage seemed to deal with calculations for all rivers in Washington and not just the Skagit as he later references several other river basins. Later he states:

"I have brought this feature up at this time because I believe that the Skagit River flood discharge at The Dalles can better be determined by an extension of the rating curve with the use of area and mean velocity curves based on the highest convenient .2 and .8 depth measurements than by attempting extreme high flood measurements." … "The highest flood measurements made at The Dalles should be used in checking up the coefficient of roughness that I used in my slope calculations. … One factor that should be remembered in this connection is that the slope

cannot be used for 500 feet or more below The Dalles. This is due to the reduction in velocity head in that stretch of the river for high stages. In fact, for extreme high stages there is an upstream slope for some distance below The Dalles." ***(Source: Letter to G.L. Parker, District Engineer, USGS, from Stewart, 5/4/25)***

The above referenced letter is significant from two aspects. First, it shows us that Mr. Stewart is beginning to question his own work product and second, he realizes that the "coefficient of roughness" or the "N" factor could impact his calculations.

4. 1923 Report Analysis

For purposes of this White Paper all three of the 1923 Stewart Reports are utilized.

Mr. Stewart devoted large portions of his report to "two great floods" (occurring "about" 1815 and 1856 which he justified by his findings at Reflector Bar which as previously stated is located 47 miles above Concrete and is currently referred to as the town of Diablo).

He included in his report the following computations for flood flows at The Dalles (Concrete):

# in order of magnitude	FLOOD EVENT	GAGE HEIGHT	CFS
1	1815	56.6	500,000
2	1856	44.6	350,000
3	1897	38.4	275,000
4	1909	36.4	260,000
5	1921	34.9	240,000
6	1917	33.0	220,000

Included with the table were footnotes which stated:

The stages for floods No.'s 3, 4, and 6 have been **estimated** from flood marks **about one mile upstream**. The stage for flood No. 3 was rather uncertain at the upstream point. The stage for flood No. 1 was determined from the maximum height of flood sand opposite the upper

Dalles gage. The stage for flood No. 2 was determined from its high water mark left on the Canyon wall in The Dalles. (***Stewart Report 1923, Page 4***) (Emphasis added.)

He also included the following computations for flood flows at Sedro-Woolley:

# in order of magnitude	FLOOD EVENT	GAGE HEIGHT	CFS
1	1815	33.5	400,000
2	1856	30.0	300,000
3	1909	26.5	220,000
4	1921	24.3	210,000
5	1917	24.1	195,000
6	1897	24.9	190,000
7	1896	24.8	185,000
8	1906	24.7	180,000

Included with the computations were footnotes which stated:

> See notes for Reflector Bar concerning the accuracy of dates for floods of 1814 (*sic*) and 1856. The stage for flood No. 6 has been obtained by its relation to the stage of flood No. 7 about one fourth mile upstream. The stage discharge relation is shifting. The discharge for all floods except 3, 4, and 5 are based, to a large extent, therefore, on comparative stages at other points. ***(Source: Stewart Report 1923, Page 5)***

The flood flow computations at Sedro-Woolley were somewhat of an enigma for Mr. Stewart as they are for USGS and the Corps of Engineers today. So much so that Mr. Stewart authored a paper titled "Skagit River at Sedro Woolley: Revision 1908-1922". This is a 15 page document that deals with gage height and rating curve corrections to Stewarts previously reported data. Includes such statements as:

> "…possibly staff gage was re-installed in December 1909 at 1.00 ft higher datum than prior to 1909 flood." "1. Prior to 1911 the river flowed around Sterling Bend in a much longer channel than thereafter. Hence the slope past the gage would be less than for the 1921 flood." "2. Choking effect of the NPRR Bridge was greater during the 1909 flood than during later floods because of the greater discharge." *These two* "causes mentioned would make the slope in 1921 much greater than in 1909. Cause #2 would make the difference between 1909 and 1921 floods greater just

above the NPRR embankment than just below it." **NOTE:** NPRR was at the Hwy 9 bridge.

"…no measurements made during the periods November 6, 1908 to August 25, 1910 and September 20, 1919 to November 20, 1922." "…measurements by F.F. Henshaw have been accepted as being as good as other doubtful features of the measurements warrant. These other features are:

1. Measurements made from ferry. Survey experience is that boat measurements are unsatisfactory. 2. Meter rating unknown. 3. Method and accuracy of obtaining width of river unknown.

The flood of December 30, 1917 caused a large low water shift probably due to deposition of large quantities of sand and gravel at the lower end of Sterling Bend cut off. The lower end of Sterling Bend cut off is the location of the break in gradient between the steep valley gradient and the delta gradient. As a consequence when the stream is loaded with material, to its carrying capacity in the upper section, it is forced to deposit at the break in gradient. It is thought that there are several causes entering in the erratic results at Sedro Woolley as follows: 1. Change in stream bed gradient at lower end of Sterling; 2. The river channel on the delta does not have as much carrying capacity as the river down to Sedro Woolley. The water floods the Nookachamps country, in fact creates a vast reservoir. The backwater from the river channel and reservoir undoubtedly affects the rating at the Sedro Woolley station.

(Source: Skagit River Near Sedro Woolley, Revision 1908—1922, 3/13/23)

When comparing the above tables with current USGS and Corps of Engineer documents it is evident that at sometime after the 1921 flood USGS recalculated the gage heights that Stewart was using. It is possible that Stewart was using a different set of datum then is currently in use. The first hint of this appears in a USGS 1950 document which states:

> Measurement No. 76 shows the datum then in use (prior to 1923) to be 8.93 ft higher than USGS datum. Then the 1921 flood was higher than the 1949 by 54.3 – 8.9 -41.7 = 3.7 feet. . ***(Source: Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50)***

In a review of the historical record I was unable to determine exactly when or why this happened although the first indication of the new gage heights shows up in the 1961 Stewart Report which will be discussed later.

It is clear that the Corps of Engineers throughout the last 80 years adopted Stewart's computation of flood levels. However those flood levels are highly questionable. In 1952 the Corps of Engineers while computing flood frequencies wrote the following:

At the time Mr. Stewart made his report no gaging station had been established on Skagit River at The Dalles, near Concrete. His estimate of 240,000 cfs for the crest discharge at this site is a mean of four calculated discharges, one made by contracted opening method and three by slope section. The 1917 and 1909 discharges were **estimated by comparison of stage heights** with that of the 1921 flood. Determination of gage heights of early floods was made from high-water marks. Mr. Stewart **estimates** the discharge of the discharge of the December 1921 flood to have an accuracy within 5 percent; the 1917, 1909, 1856, and 1815 floods, 10 percent; and the 1897 flood, 20 percent at The Dalles. **These values are also subject to question** because of uncertainty of high-water marks, changing channel conditions tending to alter the rating curves such as clearing the bottom valley lands, erosion and deposition, and excessive extension of rating curves. (Emphasis added) ***(Appendix to Report on Survey for Flood Control of Skagit River and Tributaries, Corps of Engineers, 2/21/52, Not For Public Release, Page 17 ¶31)***

Flood records are available in the basin since 1908 but they are not continuous at any single site for the entire period. As described previously, estimates have been made of crest discharges for historical floods occurring in 1815, 1856, 1897, and 1906. However, it was felt that the use of **these flood peaks** not in a continuous series and **of questionable accuracy** would decrease the over-all accuracy of the frequency curve, and so they were omitted from the study. ***(Appendix to Report on Survey for Flood Control of Skagit River and Tributaries, Corps of Engineers, 2/21/52, Not For Public Release, Page 17 ¶33)***

Additionally no verbiage is put forth by Mr. Stewart in his 1923 report as to the discrepancies between his 1918 calculations and his 1922 calculations. They were as follows:

Comparison of 1918 and 1923 Flood Flows Concrete WA.		
Flood year	1918 Report	1923 Report
1897	205,000 cfs	275,000
1909	185,000 cfs	260,000
1917	175,000 cfs	220,000

(Source: 1918 and 1923 Stewart Reports)

5. Tree Staining

Mr. Stewart also discussed much more thoroughly in 1923 then he did in 1918 the local phenomenon of tree staining and his conversations with Joseph Hart. He stated the following:

> The old Indian's statement that the trees were stained by flood water agreed with the opinion of the more accurate thinkers among the settlers. The staining of live cedar bark has also been confirmed by the observations of different people after later floods. In the floods since the coming of the white man, however, only a few trees have been stained. The cause of the staining is not known, but whether a tree will be stained or not probably depends on the condition of the tree, the length of time the tree is immersed and the percentage of the staining material, if any, in the water. … It will be proven later that the flood stains seen in 1879 were from a flood of about 1856. … The story of the flood-stained cedar and spruce trees is practically the same as Mr. Hart, of Sedro Woolley, told it in June, 1918. In 1918, Mr. Hart was in excellent health, and had one of the most accurate memories that it has been the writer's privilege to encounter. ***(Stewart Report, 1923,)***

I think it is pretty clear that "tree staining" is associated only with large flood events. During the 1990 second flood event I was privileged to observe a tree stained in the same manner as described by Mr. Stewart. Art Gadbois residence along Mud Lake Road in Clear Lake has a large spruce tree just outside the back porch which was clearly stained to the height of the flood waters (which were higher then they had ever been in the history of the house being there). The height of the stain lined up exactly with the flood stains on an old cabinet on Mr. Gadbois back porch.

As to the cause of the tree staining I would agree with Mr. Stewart that it is unknown, however, more likely then not, based on research I have done on the volcanoes which impact flood flows on the Skagit, I feel it could be attributable to the very high sulphuric acid content of the streams and tributaries flowing into Baker River from Mt. Baker.

What I find most amazing about this section of the 1923 Stewart Report is that he clearly spent a lot of time with Joseph Hart and was just as clearly impressed with the gentleman. I find it utterly impossible to believe that at no time did Mr. Hart ever mention to Mr. Stewart the real cause of the 1856 flood. You see, Mr. Hart was quoted in a local newspaper in 1896 as saying the following:

> Our fellow townsman, Mr. H.L. Devin, was some years ago engaged in surveying in the upper valley in the vicinity of Baker Lake. Being detained over night in an Indian camp, he was told the history of a great flood. They said that about 60 years ago a great slide had choked up the narrow outlet of the Baker valley and that the water accumulated in the basin thus formed until the whole valley was an immense lake, full 80 feet deep. By this time the imprisoned waters had burst through the dam and in a few hours this great volume of water was precipitated into the Skagit flooding the whole valley. The water marks still plainly visible high up the sides of the Baker

valley and the great variation in those upon the trees as you come down the Skagit would indicate that this was the real cause of that terrible disaster." ***(Reprinted from the Skagit County Times, Serving Sedro and Woolley, Skagit County Washington, Thursday, November 19, 1896.)***

One now has to wonder how Mr. Stewart was able to ascertain the height of the 1856 flood 47 miles upstream of Concrete at Reflector Bar when clearly the majority of the water came from the Baker River. However, Mr. Hart's article does support the premise that the tree stains are caused by large amounts of water coming from the Mt. Baker vicinity. Given the Indian's statement that the water rose "very quick" I think also gives credence to the articles statement concerning the failure of a debris dam bursting.

6. Glacial History

The 1923 Stewart Report spends a lot verbiage on the glacial history of Skagit County. Mr. Stewart attributes the glaciers to forcing the Skagit River above Concrete and pouring "across the Skagit-Suiattle Divide and thence down the Stillaguamish River." But then he states "The Skagit channel from Sauk to Concrete gradually cleared, after the retreat of the Baker glacier, until a high flood in the Skagit over-topped the remaining material and cut a channel for itself. This final step marked the recapture of the Upper Skagit." ***(Source: Stewart Report 1923)***

What Mr. Stewart did not know was that the "large flood on the Skagit" was actually the result of an eruption of Glacier Peak flooding the Sauk River. The White Chuck assemblage Lahar traveled 100 km (62 miles) down Stillaguamish River Valley to Arlington. That eruption changed the flow of the Sauk River near Darrington from the Stillaguamish River to the Skagit River. . ***(Postglacial Volcanic Deposits at Glacier Peak, Washington, and Potential Hazards from Future Eruptions, by James E. Beget, (1982), Open File Report 82-830)*** In fact nowhere in any of the Stewart Reports including the 1961 report does he even recognize Glacier Peak as a volcano. The importance of this observation is that had Mr. Stewart done any research at all on either the Baker River or the Sauk River he would have recognized the strong probability that the flood "marks" he observed could have been influenced by volcanic activity and/or debris dams. There is no indication in any of his written materials that he made any serious attempts at studying the tributaries to the main stem of the Skagit River.

Do I believe that he located many indicators of large floods on the Skagit River. The answer would be an unequivocal yes. But which flood levels or marks or silt in trees would have been caused by actual rain on snow events and which ones would have been caused by debris dams, log jams, or volcanic mud flows is a question that he never attempted to answer.

C. 1961 REPORT

As previously stated the 1923 Stewart Report was unpublished. Thirty eight years later USGS published the Geological Survey Water-Supply Paper 1527 titled *Floods in the Skagit River Basin Washington* by James E. Stewart and G. Lawrence Bodhaine. It is believed that by the time the 1961 report was published Mr. Stewart had passed away. I base that statement in part on the following and in part on the letter from Mrs. Stewart contained in the USGS files forwarding Mr. Stewarts Skagit files to USGS:

> The pertinent data from the report written by J. E. Stewart are included in this report. Interest in the report was revived in 1942 by F. M. Veatch, who succeeded G. L. Parker as district engineer. As a result, some work on it was done in the Washington office during the next few years, chiefly by W. S. Eisenlohr, Jr. In 1949 additional field data were obtained, and work was resumed to evaluate previous data. Most of this report was written by G. L. Bodhaine, Tacoma district. He used the basic data and reports of J. E. Stewart and recent data concerning floods in the Skagit River basin. ***(Stewart Report 1961 Page 4)***

However, several individuals worked on the 1961 report. The last piece of correspondence from Mr. Stewart identified in the USGS files was a letter he wrote in 1950. He wrote in part the following:

> "In April and May 1946 we had some correspondence regarding the possibility of slope measurements below "The Dalles" on Skagit River near Concrete." "…the proposed slope measurements would be made so as to check (using the gaging station rating) the accuracy of the value of "N" used in my 1923 computations for previous large floods at "The Dalles. In March 1923 … I had to leave Tacoma before I had completed the Skagit River Preliminary Flood Report (which contains all of the material previously promised to Skagit County). The most important work not accomplished at that time, due to lack of a gaging station at "The Dalles", was checking the value of "N" used for the slope sections."

Attached to the letter was a memorandum in which Stewart made recommendations for the "slope section". He stated in part,

> "To counteract the uncertainties involved in velocity head gain or loss, it is advisable to take several sections and average the results obtained from them. …In 1922-1923 cross-sections were taken at 618—2,749 and 4,655 feet downstream from the mouth of "The Dalles". It is suggested that for

this important check-work five cross-sections be taken, say about 700—1,700—2,700—3,700 and 4,700 feet downstream from the mouth of "The Dalles". It is important that the first one of these below The Dalles be far enough below so that all of the velocity head gained in The Dalles is lost; i.e. that the water has at least reached its maximum level resulting from the loss in velocity head. Another feature of some importance, although how much is uncertain, is the amount of surging in the stream at the ends of the sections during the crest of the flood. Manifestly the only elevations available, when the flood crest is based on high water marks, is the crest of the surges, whereas what is needed is the mean level of the water at the time of the flood crest. ***(Source: Letter to FM Veatch, District Engineer, USGS, Tacoma, WA from Stewart, 6/1/50)***

On June 1, 1950 Mr. Veatch responded to Mr. Stewart's letter. He stated in part:

"Thank you for your letter of June 1 relative to verification of the value n for the slope-area reach below "The Dalles" on Skagit River near Concrete and for your suggestions for making the determination." ***(Source: Letter to Stewart from Veatch, 6/7/50)***

1. The "N-Factor"

At this point a more thorough discussion of the "N-Factor" is appropriate. The "N-Factor" is a roughness coefficient that's used to determine the hydraulic properties of a cross section of the river. The formula is:

Q=1.49/n(AR^(2/3)S^(1/2))

where

Q is the stream discharge

n is Manning roughness coefficient

A is the channel wetted cross sectional area

R is the hydraulic radius = A/wetted perimeter
S is the water slope

Manning's n for "natural" waterways ranges from 0.015 to 0.050. It could be higher for steep streams with large boulders, and smaller for a very flat sand bed river, but the above range is usually a good starting point. To determine the n value for natural streams takes experience, there are some reference books but most everything was done for the Southeast US and doesn't work for the Northwest. The best way to determine the n value is to find a cross section and measure the area, slope, discharge and back calculate the n value. The n value doesn't have to remain the same for the entire length of the river, it usually changes when the river changes, slope changes, bed material changes etc. ***(Source: Corps of Engineers, Portland District)***

If any specific discharge varies by 5 percent, the corresponding stage could vary significantly depending on the stream slope and geometry. Instantaneous peak discharges presumably would be less accurate. Thus, a potentially significant accuracy problem exists with the basic data. ***(Source: Corps' Engineering Manual EM 1110-2-1416, Page 3-7)***

Unfortunately, Manning's *n* can seldom be calculated directly with a great deal of accuracy. Gage records offer the best source of information from which to calculate *n* for a reach of channel near a gage. . . . Determination of overbank *n* values requires a detailed field inspection, reference to observed flood profiles, use of appropriate technical references, consultation with other hydraulic engineers, and engineering judgment. ***(Source: Corps' Engineering Manual EM 1110-2-1416, Page 3-7)***

The engineer must evaluate the significance of other factors influencing *n*, including bed form changes, channel alignment, cross-sectional area changes, and bank vegetation. Field inspection of the study stream at varying states of flow is imperative for attaining appropriate estimates of *n* for ranges of discharge. It is not beyond reason to expect the hydraulic engineer to walk or float the entire reach of stream to determine friction values. ***(Source: Corps' Engineering Manual EM 1110-2-1416, Page 3-9)***

Important to note at this point is that all of Stewart's "estimates" were before a gage was installed at "The Dalles" and there is no indication that he consulted with other engineers with respect to determining the flood elevation (flood marks of historical floods) estimates. All of his work in the field was never substantiated or observed by other engineers. All subsequent work performed by USGS engineers "assumed" that Stewart's observations were correct.

Conceptually, there are two major features in any reach: the channel and the floodplain. The friction force in the channel stems primarily from the bed sediment grains and bedforms, whereas the friction forces in the floodplain stem primarily from vegetation and, perhaps, structures. Decidedly different values of *n* can be expected for these regions and they should be differentiated. ***(Source: Corps' Engineering Manual EM 1110-2-1416, Appendix D Page D-17)***

The significance of this discussion is that by "tweaking" the "N-Factor" you can alter the estimated flood flows by a substantial amount as will be shown later in this White Paper. Stewart determined the "N-Factor" near Sedro-Woolley as follows:

> "Kutter's "n" (*now referred to as Manning's "n"*) was taken at 0.035 for section 4; 0.04 for section 2, 3, and 5; and 0.050 for sections 1 and 6. Considerable allowance (up to 100%) was made for increased wetted perimeter, when trees, piles, stumps, building, or other obstructions hindered the flow. Slope was taken as the same as found in 1200 feet of river section between bridges. ***(Source: Skagit River Near Sedro Woolley, Revision 1908—1922, 3/13/23)***

However, for "The Dalles", the single most important measurements of flood levels and flow that Mr. Stewart calculated, the location where the Corps of Engineers is currently using to justify its multi-million dollar flood study, the following is known: "In the original computations an n of .033 was assumed for all sections on the basis of computed n's at Sedro Woolley." ***(Source: "Skagit River near Concrete, WA., Verification Study, M.A. Benson, USGS, 8/52)***

2. H.C. Riggs & W. H. Robinson Report

In 1950, two engineers working for USGS, evaluated Stewart's work product and authored a document titled "*Proposed Revision of Skagit River Flood Peaks".* For "The Dalles" area they stated the following:

> "On the basis of a slope-area study made in the reach below the gage for the flood of November 27, 1949[5], it appears that the value of "n" used by Stewart in his 1921 flood flow computation was too low for his upper reach. It was also noted that Stewart did not take into account changes in velocity head in his computations. A recomputation of the 1921 peak by present methods using Stewart's values of A, P, and f, and "N" = .040 for the upper reach and "N" = .033 for the lower reach gives 209,000 cfs." … "I can find no data on which to base an estimate of the percentage of energy recovery for various conditions, but it might be that much of this energy is lost in moving the gravel bottom of the stream." … "The need for revision of the historic flood peaks is supported by the logarithmic extension of the present rating curve. … at those times the overflow area was heavily timbered and would carry little water. In addition, the possibility of a reduction in slope **due to log jams** downstream is to be considered. The recomputed value of 209,000 cfs mentioned above checks this logarithmic extension within 2%. The flood frequency curve shows a sharp offset to the right between recorded and historic floods and **casts further doubt on the published values for the historic floods.** ***(Source: Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50)***

This report is significant because it documents the first time that anyone from USGS ever checked Stewart's work. Twenty-eight years after Stewart's "field work". Nowhere in this or subsequent work products is it documented that anyone ever went into the field and tried to find Stewart's "flood marks" which as previously stated, in the case of "The Dalles" is approximately one mile upstream. ***(Source: Stewart Report 1923, Page 4***) It is the first time that the "N-Factor" is adjusted. It is the first and only time that USGS recognizes the probable impact that log jams can have on flood flows.

For the Sedro-Woolley area Riggs and Robinson wrote in part the following:

> "There was little basis for the original extension of the rating curves at Sedro Woolley. … The extension of the rating curve for the 1921 flood is **based on measurements made during 1922-23**. … The flood of Nov. 28, 1949 reached a stage of 41.7 ft (USGS datum) at Sedro Woolley. Measurement No. 76 shows the datum then in use (prior to 1923) to be 8.93 ft higher than USGS datum. Then the 1921 flood was higher than the 1949 by 54.3 – 8.9 -41.7 = 3.7 feet. … The great difference between the 1897 peak near Concrete and near Sedro Woolley must be due to the extreme sharpness of the peak. ***(Source: Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50)***

The proposed revisions to the flood peaks by Riggs & Robinson are as follows:

[5] The gage in The Dalles was installed in 1924, one year after the last flood "estimated" by Stewart.

Revision for Concrete The Dalles		
Year	Stewart 1923	Revision 1950
1815	500,000	400,000
1856	350,000	280,000
1897	275,000	230,000
1909	260,000	220,000
1921	240,000	210,000
1917	220,000	190,000

Revision for Sedro-Woolley		
Year	Stewart 1923	Revisions 1950
1815	400,000	330,000
1856	300,000	230,000
1896	185,000	170,000
1897	190,000	170,000
1906	180,000	160,000
1909	220,000	190,000
1917	195,000	160,000
1921	210,000	170,000

Needless to say, the above proposed revisions were substantial. The Dalles ranging from 30,000 cfs reduction for the 1917 and 1921 floods to 100,000 cfs for the 1815 flood. Sedro-Woolley reductions in flow ranging from 15,000 cfs for the 1856 flood to 70,000 cfs for the 1815 and 1856 floods. What is important to note is that all of the proposed revisions are based on changing the components of the mathematical equation used to calculate flood flows while still using Stewart's flood elevation marks.

3. F. J. Flynn Report

Two months later another USGS employee named F. J. Flynn wrote a paper further analyzing the Stewart data at Sedro-Woolley. He stated in part:

> "Control conditions are such that an extension of the rating at Sedro Woolley is subject to much greater doubt than the extension of the rating at Concrete. The assumptions made in the analysis by Riggs and Robinson appear generally reasonable and the proposed revisions should be better than the originally published figures. **However, it is possible that the proposed figures for 1909, 1906, 1897, 1896 are still too high."** . . . "This cut-off about a mile downstream from the station cut more than two miles of river channel around the bend. …it appears that the 1909 peak at Sedro Woolley could be as low as 165,000 cfs. If a curve over to left is logical for 1909, it probably should be used for the 1906 flood too, and maybe all the prior floods." ***(Source: Skagit River near Sedro-Woolley, Revision of historic flood peaks, F.J. Flynn, 1/25/51)***

Mr. Flynn was concerned about the impacts of the Sterling Bend cutoff which occurred in the 1911 flood which according to USGS records only carried 66,600 cfs. Stewart included in his "1923" report that this cut-off was "sided by dynamite" which strongly suggest this was not a natural occurrence.

4. M. A. Benson 1921 Flood Report

In May of 1952, Mr. M. A. Benson, another USGS employee made some calculations for the flood of December 13, 1921. He determined that the flood flow for that flood at The Dalles should be 225,000 cfs. He based that determination on using an "N-Factor" of .030 (lower then what Stewart used) and data from the flood of November 27, 1949. The notes on the computation are as follows:

> "Only reach B-C used. Reach A-B is expanding and "n" for that portion of the channel is not well verified. Value of "n" for reach B-C is from verification using data from flood of November 27, 1949. ***(Source: Slope area measurement of Skagit River near Concrete for the flood of December 13, 1921, M. A. Benson, 5/5/52)*** ***Note: See Appendix C.***

In August, 1952, Mr. Benson and presumably Mr. Flynn co-authored a "Verification Study" for the Skagit River near Concrete, Wash. They stated in part:

> The peak discharge of the flood on Nov. 27, 1949 was 153,000 cfs from rating curve extended above 135,000 cfs. The rating is defined at high stages by a series of measurements made in 1932. "The peak discharge for the flood of Dec. 13, 1921 was originally computed by Mr. J. E. Stewart … as 240,000 cfs. … **Using Stewart's values of fall and area and wetted perimeter** of the sections the peak discharge of the flood of Dec. 13, 1921, was recomputed as 209,000 cfs with values of "N" assigned on the basis of those determined for the flood of Nov. 27, 1949. … Stewart's section 1 was about 300 feet upstream from sect. A of the 1949 flood; his section 2 was between sections B and C; and his section 3 was about 700 feet downstream from section D. There appears from the stereo-realist slides to be very little likelihood of much change in conditions in the reach since 1921. … After adjusting the areas for the difference in stage between the two floods, there appears to be practically no change between 1921 and 1949. … The writers believe that there is little basis for using a higher "N" in the upper part of the reach than in the lower part. They feel that an "N" computed for the reach B-C-D is more logical. They also feel that only the reach 2-3 of Stewart's 1921 determination should be used in computing the discharge because reach 1-2 is expanding and the "N" for that reach may be questionable. **Using Stewart's values of Fall**, A and r and the 2-section formula, the writers have computed (unchecked) a discharge of 225,000 cfs using an n of .030 (as determined by the 3-section formula for verification study). In memorandum by Riggs and Robinson dated 11-14-50, there is listed proposed revisions for historic floods. These revisions are based on a straight line extension of the rating curve on log-log paper. However, some of the proposed revised figures actually fall to the left of the straight line extension (those for 1856 and 1897). The writers do not have any data upon which to judge the reasonableness of the straight line extension. However, it should be realized that a wide overflow section many miles downstream from the

> gage could cause the rating to bend to the right. Furthermore, if the discharge for the 1921 is plotted at gage height 47.6 feet and 225,000 cfs it indicates a break to the right. On the basis that the peak for the 1921 flood as computed by Stewart (240,000 cfs) is too high and that the rating now in effect and also in 1921 was the same all the way back to 1815, then the published values for all the historic floods are also a little too high but the highest flood (1815) may be correct. It is felt that the proposed revised figures as listed in the memorandum are too low. After the computation of the 1921 flood is checked, we would favor extending the rating exactly through that point. ***(Source: Skagit River near Concrete, Wash. – Verification Study by F.J. Flynn and M.A. Benson, 8/52)***

The statement, "There appears from the stereo-realist slides to be very little likelihood of much change in conditions in the reach since 1921" would appear to be in direct conflict not only with verbiage contained in this report but with the note contained in the 5/5/52 slope area measurement, "Only reach B-C used. Reach A-B is expanding and "n" for that portion of the channel is not well verified." So based on a "belief" (i.e. an assumption); "without any data in which to judge the reasonableness of the straight line extension; and using Stewart's figures they recomputed the flow to be 225,000 cfs.

It has been documented that more likely than not that the 1856 flood was a debris flood coming out of the Baker River. Since The Dalles is one mile below both the Baker River and the Sauk River, both volcanic in nature, and a very narrow rock canyon as compared to upstream and downstream conditions it is also more likely than not that several log jams occurred in this area. Contained in Stewart's Field Notes is the following notation: *"Leonard Everett says 1897 flood about 9 inches lower than 1909. Says that log jam in the Dalles raised water 10 feet in 2 hours. Considerable distance and slope between 1897 and 1909 and 1921 marks."* Depending on how you want to read the notation either the 1897 flood or the 1909 flood had a major log jam at the Dalles. There is no indication that Benson or anyone else at USGS ever reviewed the Stewart field notes. There also is no indication that Benson or anyone else at USGS ever discussed the possibility that log jams occurred at The Dalles.

5. F. L. Hidaka 1954 Sedro-Woolley Report

In January, 1954, yet another USGS employee, Mr. F.L. Hidaka looked at the Stewart Report and made recommendations for revisions to the flood figures for Sedro-Woolley. There is evidence in the file through later cited documents that he also authored a report for Concrete at The Dalles however that report was not located in the USGS files. Mr. Hidaka stated in part:

> "Measurements 4-10 were used in the definition of the rating tables dated March 17, 1923, which was the only curve which was defined in the upper end before Sterling Bend was cut-off by the river in 1911. A definite change is believed to have taken place after the bend was cut-off causing the rating curve to plot to the right. … Based somewhat on the discharges which were determined for Skagit River near Concrete and upon the elevations of the flood as determined by Stewart, a tentative curve has been drawn. This curve shows less water then obtained at Concrete because of the short duration and the intensity of the flood which due to

channel storage reduced the peak at Sedro Woolley. There is actually no basis for this extension except that it is not believed that the rating curve should break to the right and then back to the left. … On the basis of the tentative curve … new estimates of discharges were made for all the floods which occurred before the Sterling Bend cut-off. … It is believed that the discharge estimates for the 1917 flood is correct and it checks the statement made by Stewart that this flood was remarkable for the length of time that it stayed up high. The discharge obtained for this flood at Concrete was 200,000 cfs while that at Sedro Woolley is 195,000 cfs. Due to the long duration of the flood, the peak discharge for this should be very nearly the same at the two stations because all the channel storage has had an opportunity to fill up and therefore, allowing the peak to proceed down the river without any reductions. The peak for 1921 should be revised on this basis to 200,000 cfs from 210,000 cfs. It is believed that the cutoff of Sterling Bend had enough effect to cause the entire rating to shift to the right and it is on this assumption that the ratings have been extended. ***(Source: Skagit River near Sedro-Woolley, Wash., Proposed revisions of historical flood peaks, F. L. Hidaka, 1/12/54)***

The revisions to the Stewart figures for Sedro-Woolley as proposed by Mr. Hidaka were as follows:

HIDAKA REVISIONS TO SEDRO-WOOLLEY STEWART FIGURES		
YEAR	STEWART 1923	REVISIONS 1954
1815	400,000	370,000
1856	300,000	260,000
1896	185,000	145,000
1897	190,000	145,000
1906	180,000	140,000
1909	220,000	175,000

(Source: Skagit River near Sedro-Woolley, Wash., Proposed revisions of historical flood peaks, F. L. Hidaka, 1/12/54)

The above revisions represented a change of 7.5% to 23.7% in the Stewart figures. There are handwritten notes on the Hidaka report, signed by G.L. Bodhaine on 5/11/54 which changed all of Hidaka's recommended revisions.

6. G.L. Bodhaine, 1954 Memorandum of Review

Finally, thirty one years after the 1923 Stewart Report was begun, in February, 1954, Mr. G.L. Bodhaine, Area Engineer with USGS in Tacoma, began work on the final work product of publishing, for the first time, the Stewart Report. ***(Source: Letter to JVB Wells, Chief, Surface Water Branch, USGS, Washington DC from F.M. Veatch, District Engineer, USGS Tacoma, 3/23/54.)*** In March of 1954, Mr. Bodhaine authored a Memorandum of Review in which he stated in part:

"A decision must be made soon concerning the revision of the flood peaks determined by J.E. Stewart at the gaging stations on Skagit River near Concrete and near Sedro Woolley." **Concrete:** "The 1921 flood peak near Concrete seems to be the logical point through which to extend the rating curve for this station. Benson's computed discharge of 225,000 cfs has been checked and seems to be a reliable figure. A logical extension of the rating curve passes through this point and the 1815 flood peak of 500,000 cfs. … The newly suggested values all differ from those of Stewart by less than 10% so perhaps they should not be revised."

Sedro Woolley: There is no firm basis for extending the rating curve for this gaging station because of dike breakage and the lack of good high water measurements. Measurement 1-10 was made before Sterling Bend was cut off in November 1911. During the next few years considerable changes took place and by 1917 the low water rating had changed by about 3 feet. The effect on the high water rating is unknown because it was not well defined before Sterling Bend was cut off. … Scour is an unknown factor. A small piece of evidence that the river did shift considerably after Sterling Bend was cut of lies in a letter Mr. Veatch received from Mr. Nordmark … in June 1944. Mr. Nordmark stated, "As you know the floor of the river dropped several feet and the water table as measured in wells in the vicinity dropped about 6 feet." *This statement was made in reference to the elimination of Sterling Bend.* … "The writer questions the theory that the peak discharges near Sedro Woolley will always be less than those near Concrete. This factor is dependent upon channel storage, **duration of flood peak,** and intermediate inflow. In November 1949 the peak discharge near Concrete was 154,000 cfs while that near Mt. Vernon was 114,000 cfs which shows quite a reduction. However, in February 1951 the peak discharge near Concrete was 139,000 cfs while that near Mt. Vernon was 144,000 cfs which shows a slight increase. It is not known how many Skagit River floods may have been affected similarly. … The 1951 flood just reached the top of the dikes just downstream from Sedro Woolley but did not break through them. This point, then, should represent main channel flow. These same dikes broke in 1917 and in 1921 so the discharge could easily have increased to 200,000 cfs with little additional change in gage height as is indicated on the rating curve. The writer believes the 1917 and 1921 peak discharges suggested by Stewart to be quite reliable based on the above discussion. … The writer recommends that Stewart's values be used. A maximum change of 10.8% seems small when all of the possible errors are considered. ***(Source: Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)***

The new suggested values assigned to the historical flood flows for Concrete were as follows:

G.L. Bodhaine Flood Flow Curve Figures for Concrete, 1954			
YEAR	STEWART Discharges in cfs	NEW CURVE Discharges in cfs	Percent Difference
1815	500,000	500,000	0
1856	350,000	340,000	2.9
1897	275,000	265,000	3.6
1909	260,000	240,000	7.7
1917	220,000	205,000	6.8
1921	240,000	225,000	6.2

(Source: Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)

The new suggested values assigned to the historical flood flows for Sedro-Woolley were as follows:

G.L. Bodhaine Flood Flow Curve Figures for Sedro-Woolley, 1954			
YEAR	STEWART Discharges in cfs	NEW CURVE Discharges in cfs	Percent Difference
1815	400,000	400,000	0
1856	300,000	290,000	3.3
1896	185,000	165,000	10.8
1897	190,000	170,000	10.5
1906	180,000	165,000	8.3
1909	220,000	200,000	9.1
1917	195,000	195,000	0
1921	210,000	210,000	0

(Source: Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)

What is amazing about Mr. Bodhaine's suggestions is that there was no work product in the files to justify his findings in his memorandum. There was nothing to suggest that he ever traveled to Skagit County at any point in time. There is nothing to suggest that he took into consideration the possibility that Stewart's flood elevation figures were impacted by log jams or other obstructions in the river. In fact, there is nothing that suggest that he even reviewed Stewart's field notes.

What is known is that the Tacoma USGS office was under extreme pressure from their Washington DC office to complete the report. ***(Source: Letter to JVB Wells, Chief, Surface Water Branch, USGS, Washington DC from F.M. Veatch, District Engineer, USGS Tacoma, 3/23/54.)*** What is known is that Mr. Bodhaine only began work on the report in February of 1954 and by May 15, 1954 he had totally disregarded all the suggested flood flows from other USGS hydrologist who had looked at Stewart's work product since 1950 (with the exception of the Benson Report), one as recent as January 1954. ***(Source: Skagit River near Sedro-Woolley, Wash., Proposed revisions of historical flood peaks, F. L. Hidaka, 1/12/54)***

What is strongly suggested is that Mr. Bodhaine, took Benson's 1921 flood calculations which computed a discharge of 225,000 cfs (which has been previously identified as being based on "*a series of measurements made in 1932*" and "*data from the flood of November 27, 1949*" because it "seems to be the logical point through which to extend the rating curve for this station"; accepted the Stewart calculations of the 1815 flood, and then made all the other figures fit his new curve. Admittedly this statement is speculative in nature, however, given the fact that even the Corps of Engineers doesn't use the 1815 or for that matter the 1856 flood events for anything in their calculations, it would appear that Mr. Bodhaine's work product is highly suspect.

In July of 1954, Mr. Bodhaine sent around for review a draft copy of the "Floods in the Skagit River Basin". He attached a cover memorandum. The memorandum had 9 "Notes for reviewers". Among them were:

> (3) We do not have funds (see letter to JVB Wells, dtd July 2) to do any additional work on the flood frequency study. That study is complicated by storage in the reservoirs so perhaps **the most simple study is desirable**; (5) The high-water profile is not very complete but it seemed that some sort of profile should be presented. ***(Source: Cover memorandum attached to a draft of the Stewart/Bodhaine report from GL Bodhaine, 7/2/54)***

Further evidence that the flood flows at Sedro-Woolley were speculative in nature is found in a paper authored by F.J. Flynn in July, 1954, commenting on Mr. Bodhaine's memorandum of 5/13/54. He states in part:

> "The ratings are complicated by lack of definition, building of dikes and breaking and overtopping of dikes and the unknown effect at high stages of the Sterling Bend cut-off made in 1911. The assumptions and analysis made by Mr. Bodhaine **appears reasonable** and we agree with his recommendation to leave unrevised the figures of discharge for historic

flood peaks. ***(Source: Memorandum titled Skagit River at Sedro Woolley, Wash., Historic Flood Peaks, F.J. Flynn, 7/15/54)***

The very next day Mr. Flynn authored another memorandum concerning Bodhaine's work for The Dalles near Concrete. He stated in part:

> "This gives a logical looking curve." . . ."…the gage site and datum should be looked into and corrected if necessary in the compilation report. It appears the "Gage" paragraph of the annual reports 1951 is incorrect." "…it would appear that the flood heights…for the historic floods are at site 200 ft upstream and at same datum used Dec. 10, 1924, to Oct. 27, 1937. (*He suggested that the statement in the report be changed to read)*, "Prior to Dec. 10, 1924, staff gage at site 200 ft upstream at datum 12.7 ft higher." "When we wrote our memorandum of 12/21/45[6] we had no idea of the slopes involved. However from the falls measured in the slope-area determination, the fall between the two gage sites is probably on the order of 0.2 ft. … Even though the error due to neglecting fall between the two gage sites would tend to increase the percentage differences between Stewart's figures and the present curve, no changes in the published figures of discharge are warranted." ***(Source: Skagit River near Concrete, Wash., Historic Flood Peaks, F.J. Flynn, 7/16/54)***

7. 1961 Report Analysis

Seven more years go by and finally, in 1961, the Bodhaine/Stewart Report is published. An interesting table was contained in the report, which is partly reproduced here only to show locations above the mouth of the Skagit River for clarity purposes to reference where Mr. Stewart conducted some of his research:

LOCATION	MILES ABOVE MOUTH
Mouth of Skagit Bay	0.0
Mt. Vernon	10.2
Nookachamps Creek	17.4
Gages near Sedro Woolley	21.1
Day Creek	34.1
Alder Creek	40.2
Birdsview	44.3

[6] The memorandum referenced was not located in the USGS files.

LOCATION	MILES ABOVE MOUTH
Gage near Concrete (Dalles)	52.0
Baker River	55.0
Sauk River	68.7
Gorge Dam	95.2
Reflector Bar	99.8
Diablo Dam	99.9
Ross Dam	103.8
Canadian Border	134

(Source: Stewart Report, 1961 Page 8)

Since the writing of the 1923 Stewart report to the publication of the 1961 report the Skagit River experienced no less than 30 documented flood events (***See Appendix D***). The 1961 report while incorporating much of what Mr. Stewart said in his 1922 report supplemented the information with additional flood information most notably the 1949 and 1951 flood events. Pertinent sections to this memorandum of the 1961 Report follow with specific page number references as well as "Comments" on each section:

GEOLOGY –The Skagit River was blocked not only by this tremendous glacier near its mouth, but also further upstream near the town of Concrete where a large local glacier came down the Baker River Valley. The dam formed by one of the glaciers forced the Skagit River to cross a pass, now occupied by the lower Sauk valley, into the Suiattle River Basin. During a portion of this glacial epoch, while the ice dam held, the entire Skagit River above Concrete poured across the Skagit-Suiattle divide and thence down the Stillaguamish River. The ice dam probably held for many thousands of years and during this time the Skagit-Suiattle pass was rapidly cut down to form a regular river channel. After the glacial epoch, the Skagit River returned to its old lower valley and was able to capture the Suiattle and Sauk Rivers from the Stillaguamish River through the new channel cut through the Skagit-Suiattle divide. … It may be nearly 1,000 feet to bedrock in the old river channel on the Skagit delta. ***(Page 8)***

Comment: Again no mention of the volcanic activity of Glacier Peak or even any mention that Glacier Peak is a volcano.

WINTER FLOODS – A rainfall-runoff study for the Skagit River, based on discharge records at Sedro Woolley and precipitation records in the upper part of the basin, at and near Reflector Bar, was made by J. E. Stewart. This study shows that during the years 1909-23 the average yearly runoff in inches at Sedro Woolley was very nearly equal to the average precipitation at the upper basin sites. This indicates that a much heavier precipitation must have occurred at higher altitudes in order to provide the additional

amount of water lost through evaporation, transpiration, retention, and ground water. For example, the precipitation in November 1909 was 27.7 inches and the runoff was 12.5 inches; in December 1917 the precipitation was 29.8 inches (7.4 inches occurring December 27-29) with a runoff of 14.1 inches; and in December 1921, 12.8 inches of precipitation (10.21 inches occurring December 10-12) ***(Page 10)***

Comment: During the November 21 through 25, 1990 flood event 6 inches of rain fell at Marblemount, 15.5 inches of rain fell at Reflector Bar, 11 inches of rain fell at Glaicer on the Baker River side and 11.3 inches of rain fell at Darrington on the Sauk River. The regulated peaks of 146,000 cfs and 152,000 cfs at Concrete and Mount Vernon respectively would have been 182,000 cfs and 180,000 cfs if left unregulated. **(Flood Summary Report, Nooksack, Skagit and Snohomish River Basins, November 1990 Events, Corps of Engineers, 7/18/91)** The significance of these figures is huge. One has to ask oneself that if Stewart and USGS computations of the 1921 flood are to be believed, how did we end up with only 180,000 cfs unregulated flow with 15.5 inches of rain at Reflector Bar, and Stewart and USGS end up with 240,000 cfs and 225,000 cfs respectfully with only 10.21 inches of rain falling at Reflector Bar?

DURATION OF PEAKS – The duration of the flood peaks in the upper part of Skagit River is an important factor in determining whether the flood will be destructive in the lower reaches. **This may be especially true of the large floods that do not quite reach the stages and discharges of the known great floods**. The peaks of the floods of November 1949 and February 1951 were selected to demonstrate this point. **The peaks would have been considerably higher had there been no storage in the power reservoirs upstream**. ***(Page 11)***

SHORT-DURATION FLOOD OF NOVEMBER 1949 – The flood of November 1949 is a good example of the flattening of a flood crest as it moves downstream. Channel storage had a marked effect on the sharpness of the peak by the time the crest reached Mt. Vernon. The peak discharge of 153,000 cfs near Concrete was reduced to 114,000 near Mt. Vernon. The Sedro Woolley precipitation gage indicates that very little rainfall occurred in the lower part of the basin. ***(Page 11)***

LONG-DURATION FLOOD OF FEBRUARY 1951 – The peak near Concrete lasted many hours longer than the peak of November 1949 although it did not reach as great a discharge. **(T)he duration of the peak reduced the effect of channel storage and that the peak downstream was increased by a large contribution from the low elevations. The large amount of precipitation in the lower reaches of the basin accounts for a part of the increase in peak discharge as the flood progresses downstream.** ***(Page 13)***

EFFECT OF RESERVOIRS – The reservoirs in the upper Skagit River basin have had a material effect on the peak discharge of the river occurring since the dams were constructed. The dam on Baker River (lower Baker) at Concrete was constructed in 1926 and has had an effect on many peak flows in the Skagit River. Diablo Dam was constructed in 1930, and practically all peaks since that date have been reduced somewhat by storage in Diablo Reservoir. The first level in the construction of Ross

Dam was completed in 1940, and all peaks since that date have been affected to some degree by storage in Ross Reservoir. By August 1949, Ross Dam had been raised two more levels and was capable of reducing the peak to a great extent on all but the largest floods at that point. ***(Page 14)***

During the floods of November 1949 and February 1951, Lake Shannon was held at practically a constant level at the time of the peaks, so the Baker River peaks were not appreciably reduced by storage. However, during both floods Diablo and Ross Reservoirs stored large volumes of flow, and the peak discharges on the Skagit River at the gaging station near Concrete were substantially reduced. It has been estimated that the peak flow of the November 1949 flood at the gage near Concrete was reduced by 45,000 cfs owing to storage in the two main-stem reservoirs. This indicates a natural peak discharge of 200,000 cfs near Concrete which probably would have been of disastrous proportions in the lower valley even if the effect of channel storage on the sharp peak was considered. An estimate has been made that the peak discharge of the February 1951 flood at the gage near Concrete was reduced 13,000 cfs by upstream storage. If this flow had not been stored, it probably would have increased the peak at Sedro Woolley and at Mt. Vernon to about 158,000 cfs as a result of the long peak, which also might have proved disastrous to the lower valley. ***(Page 15)***

HISTORY OF FLOODS – The flood of November 1909 was the largest flood on the Skagit River since the coming of the white man in 1878, except for the reach from Cascade River to a short distance below Birdsview where it was surpassed by the flood of November 1897. **Higher stages may also have occurred at other points during other floods as a result of log jams**. … It has been estimated that the natural discharge of the February 27, 1932 flood near Concrete (corrected for effect of upstream storage) would have been about the same as the discharge of the floods of 1896 and 1906 (U.S. Congress, 1933). It has been estimated that the natural discharge of the November 27, 1949 flood near Concrete (corrected for effect of upstream storage) would have been about the same as the discharge of the 1917 flood. ***(Page 22)***

Comment: This highlighted statement is significant and raises further doubt as to the credibility of Stewart's work. First it is an admission by USGS that log jams could have impacted stages of the river which ultimately could have an impact on "observed" flood marks. Second, there were hand-written notes by Mr. Stewart contained in the USGS files which show where he took his measurements and observed "flood marks". It is clear from a reading of those notes that Mr. Stewart determined a height of all the historic floods and then followed them all the way down the Skagit River. The heights of the floods remained constant. This raises the distinct probability that some of Mr. Stewarts "observed flood marks" were assigned to the wrong flood year.

HISTORIC FLOOD DATA –

SKAGIT RIVER NEAR CONCRETE – The floods of 1897 and 1917 have been dated on the assumption that the floods occurred shortly after midnight. The stages for the floods of 1897, 1909, and 1917 **have been estimated from flood marks about 1 mile**

upstream. The stage of the 1897 flood is not as certain as the stages for the other two floods. ***(Page 24)***

Comment: The significance of the highlighted statement is that any debris dam or log jam concentrated in The Dalles would have impacted "flood marks" 1 mile upstream.

SKAGIT RIVER NEAR SEDRO WOOLLEY – The discharges for all floods except those in 1909, 1917, and 1921 are, to a large extent, based on comparative stages and discharges at other points. ***(Page 25)***

FREQUENCY OF FLOODS – Studies made by Benson (1960) and others, indicate that a long record is necessary before a reliable flood-frequency curve can be drawn. In order to come within 10 percent of the correct value 95 percent of the time for a 50-year flood, a length of record of about 110 years is required. In fact, to obtain this accuracy for even a 10-year flood required 90 years of record. However, to come within 25 percent of the correct value 95 percent of the time only about 39 years are required. To obtain this accuracy for a 10-year flood required only 18 years. . . . For this reason historic data have been included whenever possible to lengthen the record. By using certain floods back to 1815, a synthetic 143 record was obtained. ***(Page 53)***

Comment: In order for the highlighted text to be assumed correct one has to assume that the historical data collected was correct. Based on the document review performed in this White Paper and the questions now raised, I would submit that we can no longer make that assumption. We now have gage records for the past 82 years. Surely by using that data we can come very close to the 95 percentile and a lot closer then the 25 percent of the correct value.

FREQUENCY SERIES – Two types of floods series are the partial-duration series, based upon the floods above a selected base discharge without regard to the number of floods that occur in any one year, and the annual-flood series, based upon the highest flood that occurs each year. There are objections to both types. The partial duration series may include floods that are not independent events, that is, the first flood sets the stage of the one closely following. The annual-flood series however, may omit a second independent flood in a year that may be greater than many annual floods of other years. Both series give essentially the same results for recurrence intervals greater than 10 years. . . . The annual-flood series has been used in this study. ***(Page 54)***

Comment: In Skagit County, the back to back floods are referred to as the "double-pump effect". The second flood is almost always larger then the first as was observed in 1990, 1995 (which experienced 5 flood events in 21 days), and 2003 (***See*** Appendix D). What is missing from Mr. Bodhaine's equation is the most important factor, the duration of the flood events. The largest floods, with respect to the lower valley, as discussed in this White Paper, are always the floods of long duration. Surely, somewhere in the flood frequency analysis, that should be factored in.

II. SIGNIFICANCE OF STEWART CALCULATIONS

By this stage of the White Paper it is probably not a surprise that I have arrived at the conclusion that the Stewart calculations are highly questionable at best and overstated at worst. The impacts of using the Stewart figures to calculate flood frequencies and flood flows can best be demonstrated by the table below. The current 100 year flood as computed by the U.S. Army Corps of Engineers is 293,000 cfs without the dams (unregulated), and 221,000 cfs with the dams in place (regulated). Those figures were calculated using the James E. Stewart flood measurements in 1923. Without using those historical flood estimates the 100 year flood drops to 241,000 cfs unregulated, and 182,000 cfs regulated. 182,000 cfs is only 16,000 cfs more then we had at Concrete during the October 2003 flood event the largest flood of record since 1922.

Did the historical flood events happen? Sure they did. But did they happen to the magnitude described by Mr. Stewart and later calculated by USGS? Based on the document review used to write this paper I feel that it is very unlikely.

FLOOD FLOW CFS RECURRENCE LEVELS[7]						
	WITH STEWART		WITHOUT STEWART		WITH STEWART 1918	
Recurrence	Unregulated	Regulated	Unregulated	Regulated	Unregulated	Regulated
10	163,000	124,000	147,000	112,000	153,000	116,000
50	248,000	185,000	210,000	157,000	222,000	165,000
75	274,000	205,000	228,000	171,000	242,000	181,000
100	293,000	221,000	241,000	182,000	257,000	194,000
250	362,000	279,000	288,000	222,000	308,000	237,000
500	423,000	348,000	327,000	269,000	353,000	290,000

(Source: Unregulated columns and Regulated With Stewart column, Corps of Engineers, Seattle District, 2003, all other regulated columns interpolated estimates)

[7] All figures rounded to the nearest 1,000.

III. CONCLUSIONS

Based on the document review contained herein, the Stewart Reports "estimated flood flows" should be discounted for the following reasons:

1. Mr. Stewart originally calculated the 1897, 1909 and 1917 floods as floods that would occur every ten years. ***(Source: Stewart Report, 1918, Page 1)*** The flow of the floods Mr. Stewart calculated for those years has not repeated themselves in the last 83 years.

2. Mr. Stewart often recognized that his work product had room for error and in some instances was just plain wrong. (***Sources: Stewart Report 1918, Page 11; Stewart Notes at Reflector Bar, 5/2/18; James E. Stewart "Field Journal", beginning entry November 24, 1922; Letter to Frank Davis, Davis Ranch, from Stewart, 5/23/23; Letter to Frank Davis from Stewart, 7/6/23; Letter to Mr. T.H. Judd from Stewart, 8/22/23; Skagit River Near Sedro Woolley, Revision 1908—1922, 3/13/23; Letter to FM Veatch, District Engineer, USGS, Tacoma, WA from Stewart, 6/1/50)***

3. The Corps of Engineers has questioned the accuracy of Mr. Stewart's data. ***(Source: Appendix to Report on Survey for Flood Control of Skagit River and Tributaries, Corps of Engineers, 2/21/52, Not For Public Release, Page 17 ¶31)***

4. The discrepancies between calculated flows from Mr. Stewarts 1918 and 1923 Report are never addressed. ***(Source: 1918 and 1923 Stewart Reports; See page 17 of Whitepaper)***

5. No one from USGS was ever able to reproduce Mr. Stewarts flood flows:

CONCRETE FLOOD FLOW CALCULATIONS						
	STEWART		USGS[8]			
Year	1918	1923	Riggs	Benson	Hidaka[9]	Bodhaine
1815		500,000	400,000		?	500,000
1856		350,000	280,000		?	340,000
1897	205,000	275,000	230,000		?	265,000
1909	185,000	260,000	220,000		?	240,000
1917	175,000	220,000	210,000		200,000	205,000
1921		240,000	190,000	225,000	?	225,000

(Sources: Stewart 1918 & 1923 Reports; Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50; Skagit River near Concrete, Wash. – Verification Study by F.J. Flynn and M.A. Benson, 8/52; Skagit River near Sedro-Woolley, Wash., Proposed revisions of historical flood peaks, F. L. Hidaka, 1/12/54; Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)

[8] All USGS calculations are based on Stewart's estimated flood heights.

[9] Given Mr. Hidaka's computations for Sedro-Woolley it is assumed all his flows for Concrete would have been less than Stewart's 1923 calculations.

SEDRO-WOOLLEY FLOOD FLOW CALCULATIONS						
	STEWART		USGS[10]			
Year	1918	1923	Riggs	Benson[11]	Hidaka	Bodhaine
1815		400,000	330,000		370,000	400,000
1856		300,000	230,000		260,000	290,000
1896		185,000	170,000		145,000	165,000
1897	171,000	190,000	170,000		145,000	170,000
1906		180,000	160,000		140,000	165,000
1909	169,000	220,000	190,000		175,000	200,000
1917	157,000	195,000	160,000			195,000
1921		210,000	170,000			210,000

(Sources: Stewart 1918 & 1923 Reports; Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50; Skagit River near Sedro-Woolley, Wash., Proposed revisions of historical flood peaks, F. L. Hidaka, 1/12/54; Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)

6. At no time did Mr. Stewart nor USGS ever take into consideration the log jams which were documented at The Dalles which would have greatly influenced the "flood marks" located by Mr. Stewart. ***(Sources: James E. Stewart "Field Journal", beginning entry November 24, 1922; Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50)***

7. At no time did Mr. Stewart nor USGS take into consideration the fact that both the Sauk River and the Baker River are volcanic in nature and volcanic activity such as debris flows or glacier outburst flows could have impacted the "flood marks" located at "The Dalles". ***(Sources: Stewart 1918 & 1923 Reports; Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50; Skagit River near Concrete, Wash. – Verification Study by F.J. Flynn and M.A. Benson, 8/52; Skagit River near Sedro-Woolley, Wash., Proposed revisions of historical flood peaks, F. L. Hidaka, 1/12/54; Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)***

8. There is absolutely no evidence in the files that anyone from USGS ever verified the "flood marks" obtained by Stewart nor that Stewart himself ever verified the discrepancies between his observations and those of local residents. ***(Sources: Letter to Frank Davis, Davis Ranch, from Stewart, 5/23/23; Ltr to Stewart from Frank Davis, Davis Ranch, 5/31/23; Letter to Frank Davis from Stewart, 7/6/23; Letter to Mr. T.H. Judd from Stewart, 8/22/23)***

9. The Benson 1921 Flood Report which was relied on heavily by Mr. Bodhaine, relied on some undetermined measurements taken in 1932 and the height of the 1949 flood event to calculate the cfs for the 1921 flood event and used an "N-

[10] All USGS calculations are based on Stewart's estimated flood heights.

[11] Mr. Benson did not calculate anything other then the 1921 flood at The Dalles, Concrete, WA.

Factor" lower then Mr. Stewart used which was lower then what other USGS employees used. ***(Source: Skagit River near Concrete, Wash. – Verification Study by F.J. Flynn and M.A. Benson, 8/52; Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50)***

10. Riggs & Robinson calculated the 1949 flood heights at Sedro-Woolley to be 41.7 feet. USGS is currently reporting the flood heights of the 1949 flood at The Dalles at 40.8 feet and a flow of 149,000 cfs at Sedro-Woolley. Mr. Bodhaine used the 1949 flood, as an example of a "short-duration" flood event meaning there was less water at Sedro-Woolley then The Dalles. This discrepancy is not addressed in any of the USGS reports. ***(Sources: Proposed Revision of Skagit River Flood Peaks, H.C. Riggs & W.H. Robinson, 11/16/50; Whitepaper Appendix D; Skagit River Flood Peaks, Memorandum of Review by G. L. Bodhaine, USGS, 5/13/54)***

11. During the November 21 through 25, 1990 flood event 6 inches of rain fell at Marblemount, 15.5 inches of rain fell at Reflector Bar, 11 inches of rain fell at Glacier on the Baker River side and 11.3 inches of rain fell at Darrington on the Sauk River. The regulated peaks of 146,000 cfs and 152,000 cfs at Concrete and Mount Vernon respectively would have been 182,000 cfs and 180,000 cfs if left unregulated. One has to ask that if Stewart and USGS computations of the 1921 flood are to be believed, how did we end up with only 180,000 cfs unregulated flow with 15.5 inches of rain at Reflector Bar, and Stewart and USGS end up with 240,000 cfs and 225,000 cfs respectfully with only 10.21 inches of rain falling at Reflector Bar? ***(Sources: Flood Summary Report, Nooksack, Skagit and Snohomish River Basins, November 1990 Events, Corps of Engineers, 7/18/91; (Stewart/Bodhaine Report, Geological Survey Water-Supply Paper 1527, 1961)***

12. Mr. Stewart used a hand-held level to obtain the heights of all his observed flood-marks, the accuracy of which could not be verified. ***(Source: Letter to Frank Davis from Stewart, 7/6/23)***

13. USGS, specifically Mr. Bodhaine, was under tremendous pressure from their Washington, D.C. office to complete the report. So much so that Mr. Bodhaine even recommended that **the most simple study is desirable.** ***(Sources: Letter to JVB Wells, Chief, Surface Water Branch, USGS, Washington DC from F.M. Veatch, District Engineer, USGS Tacoma, 3/23/54; Cover memorandum attached to a draft of the Stewart/Bodhaine report from GL Bodhaine, 7/2/54)***

What did all the early floods have in common and why did they stop? The answer to the first half of the question is that one man determined how deep the early floods were and based on the document review contained herein, the second half of the answer is strongly suggestive that they never happened to the magnitude that Mr. Stewart said they did. That's why they not only did not repeat themselves once every ten years like Mr. Stewart suggested that they would, but why they also have not repeated themselves in 82 years. Section II "Significance of the Stewart Calculations" shows the impact on flood computations for frequency analysis that Mr. Stewart's work has had on the Skagit River flood control issue. Based on the document review and discussion contained in this Whitepaper, we simply cannot rely on his work product any longer.

APPENDIX A

Larry Kunzler transcribed the following handwritten notes on January 23, 2004 from Mr. James E. Stewart's field journal he used while working in Skagit County in 1922. The field journal consisted mostly of Mr. Stewarts flood elevation measurements taken with a handheld level in the winter of 1922. Mr. Stewart used the notes contained in the journal in preparation of his report delivered to the Skagit County Commissioners in October 1923. The notes transcribed are verbatim the way Mr. Stewart wrote them.

JAMES E. STEWART FIELD JOURNAL
Beginning date November 24, 1922

Page 23 Leonard Everett says 1897 flood about 9 inches lower than 1909. Says that log jam in the Dalles raised water 10 feet in 2 hours. Considerable distance and slope between 1897 and 1909 and 1921 marks. 1897 1.4 feet higher.

Page 24 At Presentine Ferry December 23, 1922. Presentine says Finney Creek had enormous flood in 1897 and changed its course.

Page 62 Measuring the lengths of rope in Dalles. Found first 100 feet only 95 feet due to shrinkage in rope. Rope probably about okay for the two Dalles sections, as it was graduated while dry but not stretched, while it was used wet and stretched.

Page 69 Checks on rope graduation were made while rope was still stretched across river. It is not certain that these checks are applicable to the lower cross sections also but probably will have to be assumed so.

Page 96 **1896 Flood** – Mt. Vernon Herald. Chinook wind started Thursday, November 12, and continued through Friday November 13. Water highest at Mt. Vernon Sunday night November 15. Highest water in the memory of the white man. Many cattle and horses drowned. P.G. Gibbons lost over a million feet of logs. W.A. Sparks lost 100 cord's of bolts. Two big breaks in levees on the west side. One near F.C. Wards place. The other at D. Storrs place. The whole Westside including West Mt. Vernon is a lake. 600 feet of the GNRR track between Burlington and the bridge washed out. One mile of track between Conway and Stanwood turned upside down. Mt. Vernon is not flooded. Dikes raised and kept above flood water.

Page 97 **1897 Flood** – Mt. Vernon Herald. Wednesday morning, November 17 a very warm Chinook wind started, almost a gale by evening. Still in banks Thursday.

Early Friday morning alarm was whistled but water was over levees already. Mt. Vernon flooded. Paper states not as much damage as 1896 flood.

1906 Floods – Mt. Vernon Herald. Flood reached 21½ feet, October 20th p.m. at Mt. Vernon gage. November 15th and 16th big flood. Paper states it was at least 8 inches higher than 1897 (probably due to dikes). GNRR bridge greatly damaged one span at highway bridge carried away. H. Peterson killed running against draw bar.

1909 Floods – Mt. Vernon Herald. Wednesday November 25th Chinook started. Baker River higher than ever known. Railway bridge at Concrete carried away. Paper speaks as though crest were reached about November 25th. Friday, 10 p.m. prior to December 2nd another Chinook started and blew with increasing vigor until Monday – 66 hours. Water still rising at Sedro Tuesday p.m.

Page 98 Hamilton Record says 1909 flood 4 inches higher than 1897 at Hamilton. More damage in 1897 however.

1917 Flood. Slightly over 21 feet, Mt. Vernon gage December 19.

1921 Flood. Stated that 1909 flood 26.4 Mt. Vernon gage and that 1921 flood 1.5 inches lower. Estimate that Puget Sound and Baker River companies lost $50,000, 20 sections of logs.

Page 100 Ed Presentine says 1897 flood 6 inches higher than 1909 at Rockport. Says Indians claim 1897 flood highest on Sauk of all times.

Page 101 Rockport. Bark and moss point. Possibility 1897 likely wind blown sand. 1.1 feet below this 1921 mark? 1.23 feet below this is 1897 mark. NOTE: Assume 1921 same as 1909. Probably 1909 nail. Ed Presentine says 1897 .5 feet higher then 1909.

January 28, 1923. Old Johnny Towne (Indian) said during 1909 flood that when he was a boy he saw river even higher. He is considered to be 70 years old or more so flood would be that of 1856.

Page 106 At Sedro Woolley. 1921 High-water 54.38. 1917 High-water 54.2.

Page 107 Ed Woods brother says 1909 flood highest about 2 a.m. Had fallen some by morning. This does not check with statement by Hart and others.

Page 116-117 December 13, 1922 at Avon. 1921 high-water mark on underside of root[12]. Same mark shows the crest of the waves while the sand in the moss 100.00

[12] It could not be determined if this word was root or roof. If he indeed was at Avon as the field notebook suggest I've got to think that the word was roof as the water in Avon would have been very deep although I admittedly don't understand his computations.

shows crest of standing water. As all of other marks practically are sand in moss we will use that 100.00 – 85.60 = 14.40 for 1921 flood.

Page 122 December 12th & 13th, 1922. Assessor says 1897 flood about 1.1 feet higher than 1896.

Mt. Vernon Argus says water began to recede at 8 a.m., Tuesday, November 30, 1909. Attributed this to breaks in dikes above. Unverified report that water was 2 or 3 feet deep in Olympic Marsh.

1906 flood reached crest at 4 a.m. November 16th 25 feet above low water mark and 1 foot below dikes.

1921 flood 24 feet 10 inches. 2 inches below 1909 at Mt. Vernon late Monday night.

Page 123 Old timers stated that 1897 only time waters reached downtown streets at Mt. Vernon.

Page 127 December 16, 1922 at Sedro Woolley. Hart says 1896 flood at GN embankment across Gages Slough[13] and water at Sedro Woolley dropped nearly 2 feet suddenly during middle of afternoon although it had been rising 8 inches per hour. Was up again by 1 p.m. and finally raised higher then before. 1896 nearly same height as 1917 and not over 2 inches below 1897. 1909 flood 16 inches approximately above 1917 mark in stump. 1921 .075 feet below 1917.

Page 129 Highest upstream dike on Skagit is just above Burlington except the one at Gages Slough. Should see Hart and get more data on big spring flood.

Hart says a temperature of 50° at Sedro Woolley makes a good raise. A temperature of 54° for 48 hours makes a big flood.

Page 131 At Skiyou Ferry, Andersons and Ringhouse barn. 1917 and 1921 high-water practically the same.

At the 3rd and 2nd to last pages from the end of Mr. Stewarts journal there were sort of a list of "things to do". Included in the list were the following:

Get dredge data
Study Baker Lake Storage
Get soundings from USGS
Determine cost of dikes to protect old channel.

[13] Unsure whether he is talking about RR crossing in Burlington or along Highway 20. Given the fact that the "Sterling Dam" was placed along the old dollar road (Highway 20) in 1899 and was higher then the Burlington levees and this was adjacent to Hart's property, I think the Highway 20 location is more accurate. This would explain why he observed the 2 foot drop.

Get flows of tributaries at time of floods.
Determine cost of moving people.
Find out the earliest settlement in Valley.

The last item on the list was the notation “Channel Sterling Bend to Padilla Bay.” Mr. Stewart’s journal was located in a red well file folder with a cover letter from Mr. Stewarts wife stating, “Here are all my husbands papers on the Skagit Report.” Contained in the folder was a carbon copy of the 1922 Robert E. Herzog GNRR report recommending the “Diversion Channel” to Padilla Bay.

APPENDIX B

Description: General view of Reflector Bar. Date: Oct 21, 1954 ***(Source: Seattle City Light.)***

Description: Davis Ranch Date: Mar 29, 1927 ***(Source: Seattle City Light)***

Davis Ranch as it appears today. It's under Gorge Lake where Highway 20 crosses Gorge Lake. Houses on Reflector Bar can be seen in the center background. ***(Source: Picture taken 2/14/04 by Larry Kunzler)***

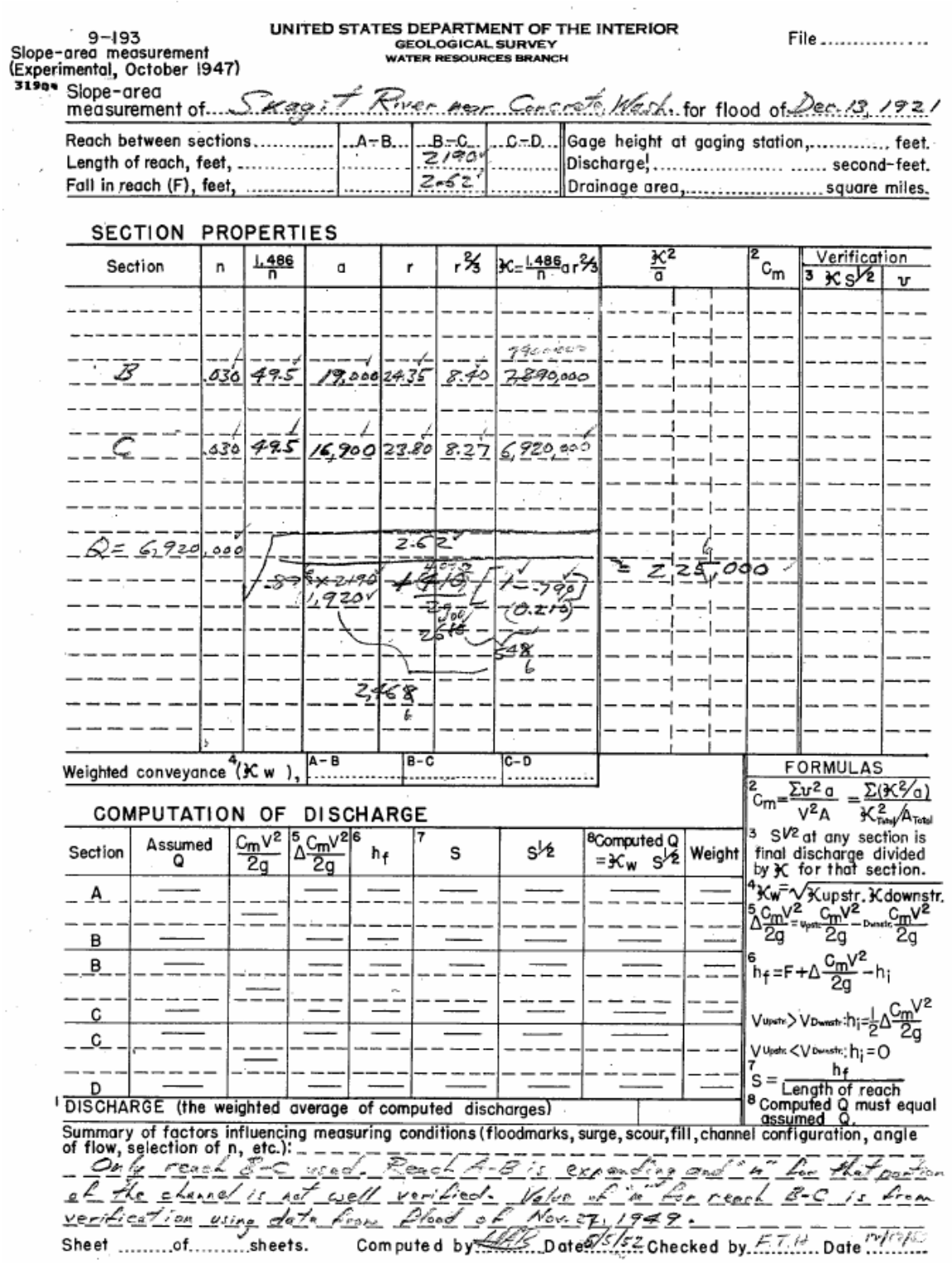
Mouth of The Dalles, Concrete, Wa. Note rock walls on both sides of the canyon and the heavy timber and brush along the banks as well as the increase in the velocity of the river as it is compressed through the canyon. ***(Source: Picture taken by Larry Kunzler, 2/14/04)***

View of The Dalles looking downstream. ***(Source: Picture taken by Larry Kunzler, 2/14/04)***

Example of log jams and woody debris coming from tributary streams and creeks into the Skagit River. ***(Source: Picture taken by Larry Kunzler 2/14/04)***

Log jam on BNSF bridge, 1995 flood event. ***(Source: Corps of Engineers, Seattle District, 1995)***

APPENDIX C



9-193
Slope-area measurement
(Experimental, October 1947)
31904

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

File .....

Slope-area measurement of Skagit River near Concrete Wash. for flood of Dec. 13, 1921

	A–B	B–C	C–D
Reach between sections			
Length of reach, feet		2190'	
Fall in reach (F), feet		2.62'	

Gage height at gaging station, ... feet.
Discharge, ... second-feet.
Drainage area, ... square miles.

SECTION PROPERTIES

Section	n	1.486/n	a	r	$r^{2/3}$	$K = \frac{1.486}{n} a r^{2/3}$	K^2/a	C_m	Verification: $K S^{1/2}$	Verification: v
B	.030	49.5	19,000	24.35	8.40	7,890,000				
C	.030	49.5	16,900	23.80	8.27	6,920,000				
Q = 6,920,000				2.62'			= 2,525,000			

Weighted conveyance $^4(K_w)$, A–B ..... B–C ..... C–D .....

COMPUTATION OF DISCHARGE

Section	Assumed Q	$C_m V^2/2g$	$^5\Delta C_m V^2/2g$	$^6 h_f$	^{7} S	$S^{1/2}$	^{8}Computed Q $= K_w S^{1/2}$	Weight
A								
B								
B								
C								
C								
D								

^{1} DISCHARGE (the weighted average of computed discharges)

FORMULAS

$^2 C_m = \frac{\Sigma v^2 a}{V^2 A} = \frac{\Sigma(K^2/a)}{K^2_{Total}/A_{Total}}$

^{3} $S^{1/2}$ at any section is final discharge divided by K for that section.

$^4 K_w = \sqrt{K_{upstr.} \cdot K_{downstr.}}$

$^5 \Delta\frac{C_m V^2}{2g} = \frac{C_m V^2}{2g}_{Upstr.} - \frac{C_m V^2}{2g}_{Downstr.}$

$^6 h_f = F + \Delta\frac{C_m V^2}{2g} - h_i$

$V_{Upstr.} > V_{Downstr.}: h_i = \frac{1}{2}\Delta\frac{C_m V^2}{2g}$

$V_{Upstr.} < V_{Downstr.}: h_i = 0$

$^7 S = \frac{h_f}{\text{Length of reach}}$

^{8} Computed Q must equal assumed Q.

Summary of factors influencing measuring conditions (floodmarks, surge, scour, fill, channel configuration, angle of flow, selection of n, etc.):

Only reach B–C used. Reach A–B is expanding and "n" for that portion of the channel is not well verified. Value of "n" for reach B–C is from verification using data from flood of Nov. 27, 1949.

Sheet .....of.....sheets. Computed by [illegible] Date 9/5/52 Checked by E.T.H. Date .....

APPENDIX D

HISTORICAL FLOOD FLOWS OF THE SKAGIT RIVER[14]

DATE	C.F.S. CONCRETE	RIVER LEVEL	C.F.S. S-W	C.F.S. M.V.	RIVER LEVEL M.V.[15]
1815	500,000	69.3	400,000	54.56 (Sedro Woolley ("S-W")Gage)	
1856	350,000	57.3	300,000	51.06 (S-W Gage)	
11/16/1896			185,000	45.86 (S-W Gage)	
11/18/1897	275,000	51.1	190,000	45.96 (S-W Gage)	
11/16/06			180,000	180,000[16]	37.00
11/18/08			97,000	N/A	N/A
11/30/09	260,000	49.1	220,000	47.56 (S-W Gage)	
11/21/10			114,000	N/A[17]	N/A
12/30/17	220,000	45.7	195,000	N/A	N/A
12/12/21	240,000	47.6	210,000	140,000[18]	N/A
12/12/24	92,500	32.44	N\A	N/A	N/A
10/16/26	88,900	32.03			
1/12/28	95,500	32.90			
10/9/28	74,300	29.94			
02/27/32	147,000	39.99	157,000	N/A	N/A
11/13/32	116,000		125,000	N/A	N/A
12/22/33	101,000	33.60	110,000	N/A	N/A
01/25/35	131,000	37.90		N/A	N/A
06/19/37	68,300	28.97			
10/28/37	89,600	32.16			
5/29/39	79,600	30.70			
12/2/41	76,300	30.17		65,300	25.99
12/3/43	65,200	28.49			
02/8/45	70,800			59,800	25.77
10/25/46	82,200	31.14		64,900	27.80
10/26/45	102,000	34.00	N/A	94,300	30.25
10/19/47	95,200	32.99	N/A	69,400	28.68
11/28/49	154,000	40.8	149,000	114,000	34.21

[14] . Pool levels are suppose to be at 1592.1 at Ross and 707.9 ft at Upper Baker Reservoir before the simulation begins.

[15]Authors Note: Flood stage is at 28.0 feet.

[16] This figure is incorrect. The levees in 1906 could not have held 180,000 cfs. The figure is a typo contained in the 1965 COE report.

[17]N/A = Not Available.

[18]Extreme difference between Sedro Woolley and Mt. Vernon was due to break in dikes upriver on Burlington side of river. Source: COE report 1/31/25.

DATE	C.F.S. CONCRETE	RIVER LEVEL	C.F.S. S-W	C.F.S. M.V.	RIVER LEVEL M.V.[15]
11/26/50			N/A	68,400	28.19
12/25/50			N/A	74,000	29.08
02/11/51	139,000	38.99	150,000	144,000	36.85
02/1/53	66,000	28.61		65,700	27.76
10/26/55			N/A	84,900	30.69
11/04/55	106,000	34.48	113,000	107,000	33.52
04/30/59	90,700	32.36	92,000	92,300	31.68
11/24/59	89,300	32.17	91,000	91,600	31.58
11/21/60			N/A	70,200	28.51
12/16/60			N/A	70,200	28.51
01/16/61	79,000	30.61	N/A	76,000	29.40
11/20/62	114,000	35.73	N/A	83,200	30.44
10/22/63	73,800	29.80	N/A	N/A	N/A
11/27/63	84,200	31.41	N/A	72,100	28.80
06/22/67	72,300	29.59	N/A	72,000	28.78
10/28/67			N/A	72,700	28.89
01/21/68			N/A	70,900	28.43
06/03/68			N/A	68,800	28.09
01/31/71			N/A	70,300	28.52
07/13/72	91,900	32.54	N/A	80,600	30.07
01/16/74	79,900	30.75	N/A	77,600	29.64
12/4/75	122,000	36.88	N/A	130,000	35.66
12/2/77	70,300	29.27		65,600	27.59
12/19/79	135,000	38.57	N/A	112,000	33.99
12/27/80	148,700	40.19	N/A	114,000	34.16
12/04/82	100,000	33.82	N/A	71,600	28.65
01/05/84	109,000	34.94	N/A	88,200	31.14
01/19/86	93,400	32.75	N/A	72,800	28.84
11/24/86	83,500	31.30	N/A	70,700	28.49
10/16/88	74,100	29.86	N/A	56,700	25.77
11/11/89	119,000	36.39	N/A	88,220	31.14
12/05/89			N/A	95,480	32.39
11/11/90	142,000	40.20	N/A	142,000	36.60
11/24/90	146,000	39.89[19]	196,000[20]	152,000	37.37
11/08/95	143,000	39.45	N/A	89,900	31.62[21]
11/11/95	72,900	29.67	N/A	59,200	26.60

[19] Flooding in Western Washington from 21 to 26 November 1990, COE MFR, 11/29/90

[20] INFO OBTAINED FROM COE 1993 RECON STUDY FAX DATED 3/29/93.

[21] Info obtained from USGS

DATE	C.F.S. CONCRETE	RIVER LEVEL	C.F.S. S-W	C.F.S. M.V.	RIVER LEVEL M.V.[15]
11/14/95	67,700	28.86	N/A	57,100	26.18
11/25/95	63,200	28.11	N/A	61,500	27.03
11/29/95	160,000	41.57	N/A	133,000[22] 141,000[23]	37.32
02/09/96	88,900	32.11	N/A	81,800	29.27
03/20/97	74,740	29.96	N/A	74,980	29.52[24]
11/13/99	101,000	33.80	39.20	78,600	29.88[25]
11/15/01	65,100	28.4	N/A	67,400	28.0[26]
01/08/02	95,600	33.06	38.5	78,700	29.9[27]
06/29/02	63,900	28.23	35.02	58,100	26.25
10/17/03	94,200	33.04		73,400	29.03
10/21/03	166,000[28]	42.21	42.02	129,000	36.19
11/19/03	79,323	30.82	37.31	70,129	28.48

As of November 13, 1999, the Skagit River reached flood stage 66 times since 1900 for an average of once every 1.5 years.

[22] First reported by the COE.

[23] Currently being reported by USGS (10/27/02)

[24] Info obtained from COE Internet Web Site

[25] Info obtained from USGS Internet Web Site

[26] Ibid

[27] Ibid

[28] Sauk River crested 107,000 cfs 18.89, 100 yr flood per USGS 11/10/03 Skagit Flood Control Meeting