WAR DEPARTMENT
United States Engineer Office
Seattle, Washington

July 30, 1940.

Subject: Report on Survey for Flood Control of Skagit River and Tributaries, Washington.

To: The Division Engineer, North Pacific Division, Portland, Oregon.

I. INTRODUCTION

1. Authority. - The following report, with one map, on survey for flood control of Skagit River and its tributaries, Washington, is submitted in compliance with the following acts of Congress:

a. Section 6 of the Act of Congress approved June 22, 1936 (Public, No. 738, 74th Cong., H. R. 8455) provides that:

"The Secretary of War is hereby authorized and directed to cause preliminary examinations and surveys for flood control at the following named localities, and the Secretary of Agriculture is authorized and directed to cause preliminary examinations and surveys for run-off and waterflow retardation and soil erosion prevention on the watersheds of such localities; the cost thereof to be paid from appropriations heretofore or hereafter made for such purposes:

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Skagit River and tributaries, Washington.

* * * * * *"

b. Section 5 of the Act of Congress approved August 28, 1937 (Public, No. 406, 75th Cong., H. R. 7646) provides:

"That section 6 of the Act * * * approved June 22, 1936, is hereby amended by adding to the list of localities at which preliminary examinations and surveys are authorized to be made the following names:

* * * * * *

North and South Forks of the Skagit River from Mount Vernon to Skagit Bay, Washington.

* * * * * *"

Syllabus

The district engineer finds that floods in the Skagit River basin, Washington, cause large damage to urban property, to roads and railroads, and to extensive fertile farm areas; that local interests have expended over $3,000,000 on levees and drains to obtain partial relief from smaller floods but are not protected against the larger floods. He discusses various methods of providing additional flood protection and shows that the most feasible method is by the Avon By-pass project, adopted by the Flood Control Act of 1936, supplemented by top storage for flood control in reservoirs that may, in the future, be provided for power development. He finds that local interests are now unable to provide the required co-operation and that no modification of the physical features of the project will so reduce the cost to local interests as to make it possible for them to supply the required cooperation at this time. He presents a plan for snagging and minor dredging of the river upstream from the by-pass project, in the interests of navigation and flood control, and concludes that the benefits to result from such a project are sufficient to warrant its adoption as a Federal project. He therefore recommends that no modification be made in the existing flood control project, and that a project for snagging and dredging of Skagit River upstream from Sedro-Woolley be adopted, at an estimated annual cost of $10,000, all from Federal funds.

2. The report on preliminary examination was submitted by the district engineer March 29, 1937, and by the division engineer May 7, 1937. The reports were reviewed by the Board of Engineers for Rivers and Harbors under date of June 4, 1937, and on July 29, 1937, the Chief of Engineers directed that a survey be made to include aerial and topographic mapping of the flood plain, and further investigation of the Avon By-pass. A report on progress of survey was submitted January 10, 1938. The present report combines the investigations authorized by the Acts of June 22, 1936, and August 28, 1937.

3. Scope of investigation. - In connection with this report, aerial photographs, scale 1:12,660, of the area downstream from Rockport have been secured and mosaics made. A topographic survey of the area to the north of Skagit River between Burlington and Sedro-Woolley was made to determine whether there was any danger that Skagit River might be diverted to Samish River during flood times.

4. Data available and prior reports. - In the preparation of this report the following reports were available:

Various river and harbor preliminary examination and survey reports.

Report on preliminary examination of Skagit River, Washington, with a view to control of the floods, published as House Document No. 125, Sixty-ninth Congress, 1st session.

Report on Skagit River under the provisions of House Document No. 308, Sixty-ninth Congress, 1st session, and published as House Document No. 187, Seventy-third Congress, 2nd session.

Report on Preliminary Examination of Skagit River and tributaries, with a view to control of its floods, submitted by the district engineer January 30, 1936, in compliance with an Act of Congress approved June 13, 1934 (Public, No. 331, 73rd Cong., H. R. 3363), and returned by the Chief of Engineers June 27, 1936, for any appropriate revision in the light of the policies established by the Flood Control Act of 1936.

Report of March 29, 1937, on Preliminary Examination for Flood Control of Skagit River, submitted in compliance with the Acts of Congress approved June 13, 1934, and June 22, 1936.

Discharge records, both published and unpublished, by the United States Geological Survey.

Reconnaissance soil survey of the eastern part of the Puget Sound basin, Washington. United States Department of Agriculture, Bureau of Soils, 1911.

5. Existing project. - The Flood Control Act of 1936 (Public, No. 738, 74th Cong., H. R. 8455) authorizes a project for the partial control of floods in the lower valley by diversion of part of the flood waters through a bypass to be constructed between the river at Avon and Padilla Bay, together with channel widening and bank revetting between Burlington and Avon, with concrete control works at the head of the bypass and a concrete weir near the outlet, all at an estimated cost of $3,150,100 for construction and $1,832,000 for lands and damages (H. Doc. No. 187, 73rd Cong., 2nd sess.) subject to the provisions that local interests shall provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project, hold and save the United States free from damages due to the construction works; and maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of War. The latest published maps are in the project document.

II. GENERAL DESCRIPTION OF DRAINAGE AREA

6. General description. - Skagit River, the largest stream tributary to Puget Sound, has its source in Canada, 28 miles by river north of the international boundary, and flows southerly and southwesterly for 135 miles to Skagit Bay, an arm of Puget Sound. Skagit basin, comprising 3,140 square miles, touches on the north the basins of Nooksack, Fraser, and Samish Rivers, on the east the basins of streams tributary to Colum-

bia River, and on the south the basins of Stillaguamish and Snohomish Rivers.

7. About 3 miles downstream from Mount Vernon, or 10 miles above the mouth, the river divides and passes through two main and several lesser channels into Skagit Bay. The two main channels, North Fork and South Fork, are navigable for light-draft vessels. At the present time, the North Fork is the one principally used, and unless otherwise noted, its mouth will be considered as the mouth of the river. The tidal effect extends about to the Great Northern Railway bridge, 15.5 miles above the mouth. The tidal range between mean low water and mean high water at the mouth of the river, is 7.7 feet; between mean lower low water and mean higher high water, is 11.5 feet; and the extreme range is about 19 feet.

8. The two largest tributaries of the Skagit are the Sauk and Baker Rivers. Other important tributaries are Cascade River, Thunder Creek and Ruby Creek, all of which head in the higher Cascades.

9. Sauk River enters the Skagit from the south, near the town of Rockport. It is 46 miles long and drains an area of 729 square miles. The Suiattle River is the most important tributary of the Sauk. The Sauk and the Suiattle completely surround Glacier Peak, in Snohomish County, taking all the run-off from its extensive glacial fields.

10. Baker River has its source on the eastern slope of Mount Shuksan, flows southward about 24 miles, passing through Baker and Shannon Lakes (the latter an artificial reservoir created by the power dam of the Puget Sound Power and Light Company) and joins the Skagit at the town of Concrete. The drainage basin of Baker River covers 270 square miles. The river derives a considerable portion of its flow from the glacial fields of Mounts Baker and Shuksan.

11. Altitudes within the Skagit basin range from sea level to 8,000 feet at the crest of the Cascade Range, to 10,750 feet at the summit of Mount Baker, 10,436 feet at Glacier Peak (Snohomish County), 9,038 feet at Mount Shuksan, and 8,894 feet at Glacier Peak (Whatcom County). Part of

the basin upstream from Concrete lies above the timber line and within the zone of perpetual snow and ice.

12. Geology. - The eastern sections of the Skagit drainage area are very rugged and mountainous, much of the higher area being barren rock. All of the higher summits are glacier-clad and stand out in sharp contrast with the flat lowland of the delta section. The intervening lower lands and hills are more rolling and are largely covered with a vast mantle of unconsolidated gravel, sand, and clay left there by the advance and retreat of the great ice sheets of the past.

13. At one time the Suiattle and lower Sauk reached tidewater through the North Fork of the Stillaguamish River. Similarly, the upper 6 miles of South Fork of Sauk River was once the head of the South Fork of the Stillaguamish. The present divide between the Sauk and the North Fork of the Stillaguamish at Darrington is apparently a glacial moraine.

14. Soils. - The "Reconnaissance Soil Survey of the eastern part of the Puget Sound Basin, Washington," prepared by the Bureau of Soils, United States Department of Agriculture, in 1911, lists three principal types of valley soils in the Skagit Basin. In a comparatively narrow strip along the river and its tributaries lies a fine sandy loam soil, generally with good natural drainage. This soil, derived from the finer sand and silt deposited along their banks by the swifter currents of the rivers and their larger tributaries during times of overflow, is well adapted to the growing of nearly all truck, forage and orchard crops.

15. The extensive delta area of the Skagit basin consists of silty clay or silt loam soils, laid down by overflow of the river. The natural drainage of the loam type is, in general, good, although that of the clay type is very poor and artificial drainage is necessary to permit cultivation. Each of these types is extremely productive. Oats, wheat, potatoes, vegetables, and small fruits are extensively grown.

16. The upland areas, lying between the valley and the surrounding hills consist of a gravelly sand loam, derived from the weathering of glac-

ial drift. This soil, because of its excessive natural drainage, is not suited to general farming, but may be made to produce profitable yields by intensive cultivation. Little of the soil of this type in the Skagit basin is under cultivation.

17. Cities and population. - The population within the Skagit basin is about 22,800 (1930 census), 17,300 residing west of Sedro-Woolley, in an area of 170 square miles. East of Sedro-Woolley, area 2,970 square miles, the population is about 5,500, about two persons to the square mile. The six incorporated cities or towns in the basin--all of them below the mouth of the Sauk--have populations as follows:

Burlington	1,407
Concrete	736
Hamilton	252
Lyman	441
Mount Vernon (county seat Skagit County)	3,690
Sedro-Woolley	2,719

18. La Conner, with a population of 549, is located within the broadly defined delta area, although strictly speaking it is just outside of the drainage basin proper. Everett, with a population of 30,567, and Seattle, with a population of 365,583, 38 and 66 miles, respectively, to the southward of Mount Vernon; and Bellingham, with a population of 30,823, 28 miles to the northward, are the principal nearby cities.

19. Railways. - The coast line of the Great Northern Railway between Everett, Washington, and Vancouver, B. C., crosses the western end of the Skagit valley in a north-and-south direction, passing through Mount Vernon and Burlington; and a branch line runs westward from Burlington to Anacortes, and eastward to Rockport, paralleling the river. From Rockport, a railroad, owned and operated by the city of Seattle, continues on up the river to Diablo Dam, a distance of 30 miles.

20. The Northern Pacific Railway between Seattle, Washington, and Vancouver, B. C., also crosses the western end of the valley, passing

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through Sedro-Woolley; a branch line from the Stillaguamish valley extends into Darrington.

21. Highways. - The Pacific Highway crosses the western end of the Skagit valley in a general north-and-south direction, paralleling the Great Northern Railway, passing through Mount Vernon and Burlington. Other paved highways aggregating about 70 miles in length and numerous gravel and improved dirt roads, lie within the basin and lead to outside points.

22. Air fields, lines and facilities. - There are no commercial or municipal airports located in the Skagit River basin. As no regular air routes pass over the basin, there are no emergency landing fields or beacons.

23. National and departmental reservations. - About 2,100 square miles of the Skagit River basin is included within the Mount Baker National Forest. There are no other reservations involved. However, included within the forest area are two recreation areas, two game preserves and a primitive area.

24. Resources and local industries. - Farming is the principal industry of the Skagit basin, followed in importance by lumbering and cement manufacturing. Since 1932, oysters have been grown on the tidelands of Padilla Bay. The delta of the river contains some of the richest and most productive farming land in the State. The uplands are more valuable for forestation than for agriculture.

25. Forest resources. - Based on data furnished by the Northwest Forest Experiment Station, United States Forest Service, in 1938, it is estimated that there is in the Skagit basin 15,725,062 thousand board feet of timber, of which 10,674,833 thousand board feet is within Mount Baker National Forest; the remainder being held in state, county, municipal, or private ownership.

26. In 1931 the daily capacity of logging companies operating within the Skagit basin, amounted to 2,500 thousand board feet. The annual out-

put of logs is believed to be between 250,000 and 300,000 thousand board feet.

27. With the exception of lumber cut at Rockport, Lyman, Mount Vernon, and Sedro-Woolley by mills having a combined daily capacity of about 150 thousand board feet, practically all lumber is cut at tidewater.

28. Agriculture. - Mr. V. J. Valentine, County Agricultural Agent for Skagit County, has estimated that the annual value of farm produce grown in the Skagit River basin is about $9,429,000, itemized as follows:

Grain	$986,000
Vegetables and vegetable seeds	2,183,000
Hay and forage	1,033,000
Fruits and nuts	377,000
Dairy products	3,500,000
Poultry and poultry products	1,250,000
Meat products	100,000
Total	9,429,000

29. It is stated that the Skagit delta produces 90 percent of the cabbage seed, 50 percent of the garden-beet seed, and 30 percent of the turnip and rutabaga seed used in the United States. Two canneries within the basin and three others at nearby points, furnish a market for the fruit and vegetable produce of the valley. Much of the milk produced is shipped as fresh milk to the Puget Sound consuming centers, the remainder being condensed and canned locally.

30. Mineral resources. - The only mineral resources that have been developed are sand, gravel and limestone. A cement mill at Concrete has a daily capacity of 6,000 barrels.

31. The oyster industry. - For a number of years Japanese (Pacific) oysters have been raised successfully on Washington tidelands, notably in Willapa Harbor in southwestern Washington, and in Samish Bay. In 1932 the first planting of oysters was made in Padilla Bay, but from the limited data now available it appears that the industry is not financially successful.

32. Six hydroelectric plants have been constructed in the basin; one on Baker River, two on a small tributary of that stream, one on Newhalem Creek, and two on the upper Skagit River. The Baker River plant, half a mile upstream from the mouth, is owned and operated by the Puget Sound Power and Light Company. Two units of 10,000 kilowatts each are operated under a head varying from 255 feet to 180 feet. An ultimate installation of four 10,000 kilowatt units is contemplated.

33. The Superior Portland Cement Company operates two plants on a creek tributary to Baker River to furnish power for its cement mill at Concrete. The upper plant consists of one 350 kilovolt-ampere unit operating under a head of 74 feet, and the lower plant of three 650 kilovolt-ampere units operating under a head of 420 feet.

34. The city of Seattle has started a series of developments on the upper Skagit River. The first development, on Newhalem Creek, was constructed to furnish power for the building of the Gorge plant and now is connected with the Gorge plant. It consists of one 2,000 kilowatt unit under a head of 500 feet. The Gorge plant, at present, consists of three generators rated at 18,000 kilowatts each under a 270-foot head. The ultimate development calls for six such units, rated at 40,000 kilowatts under a head of 375 feet.

35. The Diablo development of the city of Seattle consists of a constant angle arch dam 389 feet high and a power tunnel 2,000 feet long and 19.5 feet internal diameter leading to the power house. The present power installation is two 60,000 kilowatt generators under a head of 307 feet. The ultimate development calls for two more 60,000 kilowatt units. The Ross Dam (at Ruby Creek) has now been completed to elevation 1380 feet and is being used to store water for the downstream plants. Ultimately Ross Dam will be constructed to about elevation 1725 feet.

36. Bridges. - There are eight bridges in the navigable stretch of the river, details of which are shown in table 1. .

Table 1. - Bridges over Skagit River

Location		Owner	Kind	Purpose for which bridge is used
Miles above mouth	Nearest town			
4	Mount Vernon	Skagit County	Swing	Highway
[1]5.5	Fir	Skagit County	Swing	Highway
10.8	Mount Vernon	Skagit County	Swing	Highway
15.0	Mount Vernon	State of Washington	Swing	Highway
[2]15.2	Mount Vernon	Puget Sound Pulp and Timber Company	Swing	Railway
15.5	Mount Vernon	Great Northern Railway Company	Swing	Railway
21.8	Sedro-Woolley	Northern Pacific Railway Company	Swing	Railway
22.0	Sedro-Woolley	Skagit County	Swing	Highway

[1]Above mouth of South Fork; all other mileages are above mouth of North Fork.

[2]This bridge is now partially dismantled.

37. Navigation. - Skagit River is navigable to Marblemount, 78 miles above the mouth. None of the tributaries are navigable. Present navigation upstream from Mount Vernon is limited to the towing of logs by small boats, but regular freight service is maintained between Mount Vernon and Seattle, via the North Fork. Logs dumped in or adjacent to South Fork are towed to salt water via that branch. The existing project, adopted by the River and Harbor Act of June 25, 1910, provides for a low-water channel in the South Fork between Skagit Bay and deep water in the river by the construction of a training dike at the mouth of the river, regulating dikes and a mattress sill at the head of the North Fork, and sills to close subsidiary channels in the delta.

38. The mattress sill at the head of North Fork, the dikes closing off subsidiary sloughs, and the training dike at the mouth of South Fork, were completed in 1911. The expected results were not, however, secured and the controlling depth over the bar at the mouth of South Fork does not exceed 1-1/2 feet at mean lower low water. Further work is held in abeyance awaiting the required local cooperation for work on a bar on the South Fork just below the head of the forks.

39. The larger part of the flow of Skagit River was formerly carried by the South Fork, but it now discharges through the North Fork, so that freight boats plying on the Skagit River have ceased to use the South Fork because of shallows therein and use the North Fork. The mattress sill across the North Fork was intended to throw more water down the South Fork, but apparently did not do so or at least was not effective in improving depths in it; consequently, the sill was partially removed to facilitate navigation in the North Fork.

40. Temperatures. - The mean temperature of the Puget Sound country ranges from 38° in midwinter to 60° in summer. The average is from 33° to 43° in midwinter and from 50° to 74° in midsummer. From table 2 it will be noted that the range of temperature in the Skagit basin is from -1° to 99° in the lower portion, and from -11° to 109° in the foothills, with a mean annual temperature of about 48° to 50°.

Table 2. - Meteorological data for stations in or near Skagit River basin. (Compiled from reports of United States Weather Bureau to December 31, 1936.)

Station	Elevation above mean sea level	Temperature: No. of yrs. obs.	Temperature: Maximum	Temperature: Mean annual	Temperature: Minimum	Temperature: Length of growing season	Precipitation: No. of yrs. obs.	Precipitation: Mean annual precipitation	Precipitation: Average annual snowfall
	feet		F°	F°	F°	days		inches	inches
Mount Baker Lodge	4200	7	91	39.9	-11	105	12	110.32	499.7
Diablo Dam	892	8	106	47.7	-10	213	10	63.62	79.6
Baker Lake	670	-	-	-	-	-	8	102.88	58.1
Gorge Power Plant	505	24	109	49.3	-4	208	29	75.36	80.82
Darrington	500	19	105	48.3	-11	154	20	77.54	41.4
Concrete	243	25	106	50.5	-1	206	24	61.50	31.5
Anacortes	60	33	95	50.4	7	232	46	27.14	5.83
Sedro-Woolley	48	43	99	50.3	-1	184	43	46.58	8.7

41. <u>Precipitation.</u> - The amount of precipitation is unequally distributed seasonally, there being a "wet" season beginning in October or November, and extending to March or April, or occasionally as late as May. On the average, about 80 percent of the annual precipitation occurs during the wet season.

42. The mean annual precipitation in the mountainous portion of the Skagit basin exceeds 100 inches, decreasing to about 30 inches or even less in the lowlands. November, December, and January are the months with greatest precipitation; June, July, and August are the driest. On the summits and higher slopes, the greater part of the winter precipitation is in the form of snow, which, at elevations between 5,000 and 10,000 feet, probably exceeds 500 inches annually, decreasing to less than 12 inches near the coast. (See table 2.)

43. <u>Gaging stations and stream-flow records.</u> - The United States Geological Survey has gathered stream-flow data at 24 gaging stations on the Skagit River and tributaries for varying lengths of time from 1908

to the present. House Document No. 187, Seventy-third Congress, second session, presents a summary of all of these data to September 30, 1931. Table 3, following, summarizes the available discharge data to date for such of the gaging stations as are particularly pertinent to flood control problems.

Table 3. - Summary of stream-flow data, Skagit River and tributaries

Station	Drainage area	Length of record	Mean discharge in second-feet												
	Square miles	Years	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Year
Skagit River below Ruby Creek	978	[1]31	1,641	2,099	2,024	1,740	1,638	1,679	3,568	7,723	8,876	4,731	2,103	1,406	3,275
Skagit River near Concrete[2]	2,700	15	10,052	12,317	13,607	12,536	10,045	10,550	15,695	25,628	28,341	17,762	9,117	7,144	14,419
Skagit River near Sedro-Woolley	2,970	16	10,700	16,400	16,300	13,500	12,000	10,300	13,900	23,900	31,600	23,200	12,200	9,160	16,200
Cascade River at Marblemount	180	11	666	792	713	698	564	618	1,013	1,641	2,099	1,519	815	589	979
Sauk River near Sauk	714	12	2,407	3,894	4,059	4,043	3,184	3,235	4,224	6,658	8,321	5,317	2,453	1,860	4,141
Baker River below Anderson Creek	164	18	1,830	1,750	1,810	1,520	1,400	1,110	1,710	2,850	3,590	2,990	1,800	1,490	1,990

[1]Eleven years of record and 20 years of reliable estimate.
[2]Corrected for effect of storage regulation in Shannon and Diablo reservoirs.

44. Floods. - Skagit River, in common with other rivers similarly located on the western slope of the Cascade Range, is liable to severe floods which at times cause great damage. The whole of the Pacific Northwest is subject to a peculiar warm, moist wind blowing off the ocean, usually from the southwest, known as a "chinook." The chinook induces heavy precipitation and melts with great rapidity the accumulated snow lying on the generally rough and precipitous areas, augmenting the local downstream run-off and producing short but high crest floods.

45. A flood is liable to occur at almost any season of the year. For example, in the year 1896 there was a flood in January, one in June, and one in November. A chinook will usually cause a rise in the lower river about 36 hours after it begins to blow, the amount of the rise depending upon the velocity, temperature and duration of the wind, the intensity and amount of precipitation, and the amount and character of snow in the mountains. The highest floods usually occur in November and December when the winds carry a large amount of moisture, causing excessive precipitation, and when the snow in the mountains is loose and porous.

46. The first white people settled in the valley about 1869. High-water marks since then have been recorded from time to time, with increasing accuracy. Prior to that time the record of floods depends upon testimony and tradition of the Indians, upon certain direct and indirect evidence of high-water marks and upon flood records elsewhere. Gaging stations have been established only since 1908 and the records therefrom are not, in general, continuous for any particular station.

47. In 1923, Mr. J. E. Stewart, of the United States Geological Survey, collected data for, and partially completed, a report on Skagit River, jointly for his department and for Skagit County. Mr. Stewart's report contained flood data and information on the climate and geology of the valley. He made a careful study and analysis of all data and evidence available and reached the conclusion that "a flood about 1815 was nearly a maximum, but there had been prior to that time several floods approxi-

mately as large." The 1815 flood had, he believes, about twice the discharge of the floods of 1909, 1917 and 1921, and he also found evidence of a flood in 1856 about one and one-half times as great as those recent floods. The following data, with the exception of those for the 1932 and 1935 floods, are taken from Mr. Stewart's report.

List of major floods

About 1815: Maximum flood.

1856: Next highest and higher than any since settlement of the valley.

December 14, 1879; 1880; 1882; November 3, 1883; October 30, 1887; May 27, 1894: No specific record.

November 16, 1896: Highest, up to then, since settlement of the valley and probably since 1856.

November 19, 1897: Everywhere higher than that of 1896. Especially high from Cascade River to below Birdsview. In general in this section of the river the 1897 peak has not been exceeded since the settlement of the valley. This flood rose with remarkable suddenness due to a very warm chinook and heavy rain. Both stopped suddenly after about 36 hours. The Cascade, Sauk, and Baker were very high and caused a high peak in the Skagit near the mouth of each stream, but due to sudden starting and stopping of flood conditions the peaks were rapidly reduced by storage in traveling down the Skagit.

November 16, 1906: Exceeded that of 1897 in the diked district, due to recent construction of dikes. Elsewhere lower.

November 30, 1909: Exceeded all previous since settlement, and exceeded all subsequent (up to 1923) floods above the Cascade River and below Birdsview to the sea, except where log jams affected the 1897 and 1921 floods.

December 30, 1917: Remarkable for length rather than peak height. Comparable in height to 1896 and 1906. Damage on the delta was due partly to the long period of overflow after the dikes had been broken.

December 13, 1921: Nearly as great as 1909.

February 27-28, 1932: Estimated natural discharge (corrected for effect of upstream storage) at The Dalles about the same as the discharge of the 1896 and 1906 floods. Measured discharge at The Dalles 35,000 second-feet less than estimated natural discharge. Occurred later in winter season than usual.

January 25, 1935: Somewhat lower than flood of February 1932.

48. Flood discharges as determined by Mr. Stewart, together with data on the floods of February 1932 and January 1935, are shown in table 4.

Table 4. - Flood discharges of Skagit River.

Date	Skagit River at Reflector Bar (drainage area 1,100 sq. miles.): Crest discharge		Skagit River at The Dalles (drainage area 2,700 sq. miles.) Crest discharge		Skagit River at Sedro-Woolley (drainage area 2,970 sq. mi.) Crest discharge	
	Total	Per sq.mile	Total	Per sq.mile	Total	Per sq. mile
	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1815	115,000	105	500,000	185	400,000	135
1856	95,000	86	350,000	130	300,000	101
Nov. 16, 1896	—	—	—	—	185,000	62
Nov. 19, 1897	48,000	44	275,000	102	190,000	64
Nov. 16, 1906	—	—	—	—	180,000	61
Nov. 30, 1909	70,000	64	260,000	96	220,000	74
Dec. 30, 1917	43,000	39	220,000	81	195,000	66
Dec. 12, 1921	[1]63,000	57	240,000	89	210,000	71
Feb. 27, 1932	[2]45,000	39	[4]147,000	54	—	—
Feb. 27, 1932	[3]47,400	41	[5]182,000	67	—	—
Jan. 25, 1935	[2]30,300	26	[4]131,000	49	—	—

[1]United States Geological Survey Water Supply Paper No. 552 reports this as 58,000.

[2]Measured discharge below Gorge power plant (drainage area 1,160 square miles).

[3]Estimated discharge corrected for storage in Diablo reservoir.

[4]Measured.

[5]Estimated natural, corrected for effect of upstream storage.

49. The discharge of the 1921 flood at Mount Vernon (drainage area 3,062 square miles) was determined by Mr. Stewart as approximately 190,000 second-feet, of which 140,000 second-feet was carried by the river channel below a break in the dikes just above the Great Northern Railway bridge. It will be noted that for this flood the crest discharge is given as 240,000 second-feet at The Dalles; 210,000 second-feet at Sedro-Woolley, and 190,000 second-feet at Mount Vernon. This decrease in peak discharge as the floods advance downstream is due to storage in the river channel and overflow areas.

50. Between 1921 and 1932 conditions of the Skagit River were materially modified by the construction of two power reservoirs: One in Baker

River (Shannon Lake) with a usable capacity of about 132,000 acre-feet, and one on the upper Skagit River (Diablo reservoir) with a total capacity of 90,000 acre-feet. Although the reservoirs were constructed solely for power development, their normal operation was such that the beginning of the winter flood season found both reservoirs well drawn down and with a considerable amount of storage capacity available. Thus, although it occurred late in the winter season, the crest discharge of the February 1932 flood at The Dalles was measured as 147,000 second-feet, with a run-off during the 3 days of highest discharge of 602,000 acre-feet. It has been estimated that, if Shannon and Diablo reservoirs had not been in operation, the crest discharge at The Dalles would have been about 182,000 second-feet, with a corresponding 3-day run-off of 706,000 acre-feet.

51. In general, floods in the Skagit basin are of short duration. Occasionally two or more crests occur a few days apart. Tables 5 to 11, which show daily discharges through flood periods at the more important stations within the basin, illustrate these points.

Table 5. - Daily flood discharges of Skagit River below Ruby Creek (drainage area 978 square miles)

Date	Estimated discharge	Date	Estimated discharge	Date	Recorded discharge	Date	Estimated discharge	Date	Estimated discharge
1909	Sec.-ft.	1917	Sec.-ft.	1921	Sec.-ft.	1932	Sec.-ft.	1935	Sec.-ft.
Nov. 22	3,980	Dec. 27	2,120	Dec. 9	1,910	Feb. 24	890	Jan. 23	2,100
23	15,200	28	4,500	10	3,770	25	1,740	24	5,210
24	14,300	*29	21,200	11	12,400	26	11,400	25	14,000
25	8,820	30	19,000	*12	29,200	*27	27,500	26	18,200
26	6,160	31	18,300	13	24,200	28	23,600	27	14,700
27	4,720	1918		14	13,000	29	14,900	28	11,700
28	8,470	Jan. 1	24,300	15	8,600	Mar. 1	9,690	29	9,660
*29	28,400	2	19,400	16	6,580	2	7,270	30	8,250
30	25,700	3	14,000	17	5,470	3	5,710	31	7,560
Dec. 1	12,900	4	11,000	18	4,630	4	4,910	Feb. 1	7,690
2	8,610	5	8,900	19	3,800	5	4,380	2	10,200
3	6,150	6	8,110	20	3,180	6	3,890	3	10,600
4	4,670	7	7,800	21	3,070	7	3,500	4	9,840
Crest	54,000		33,500		45,700		32,000		-

Crest occurred on date indicated by *.

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Table 6. - Daily flood discharges of Skagit River at Newhalem and Reflector Bar

Skagit River at Newhalem; Drainage area, 1160 square miles		Skagit River at Reflector Bar; Drainage area, 1100 square miles				Skagit River at Newhalem; Drainage area, 1160 square miles					
Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge[1]	Date	Discharge[1]
1909	Sec.-ft.	1917	Sec.-ft.	1921	Sec.-ft.	1921	Sec.-ft.	1932	Sec.-ft.	1935	Sec.-ft.
Nov. 22	5,680	Dec. 27	2,720	Dec. 9	2,460	Dec. 9	2,860	Feb. 24	2,070	Jan. 23	3,220
23	21,700	28	5,780	10	5,420	10	8,350	25	2,950	24	9,280
24	20,400	*29	27,200	11	16,200	11	28,200	26	8,510	*25	24,200
25	12,600	30	24,400	*12	38,000	*12	42,400	*27	31,900	26	24,800
26	8,800	31	23,500	13	30,200	13	28,600	28	32,100	27	19,200
27	6,750	1918	-	14	16,700	14	18,700	29	19,500	28	14,300
28	12,100	Jan. 1	31,200	15	11,300	15	12,600	Mar. 1	13,000	29	11,600
*29	40,500	2	24,900	16	8,680	16	10,300	2	9,040	30	10,200
30	36,700	3	17,900	17	7,200	17	7,600	3	7,140	31	9,330
Dec. 1	18,400	4	14,100	18	6,300	18	6,190	4	6,320	Feb. 1	9,680
2	12,300	5	11,400	19	4,900	19	5,380	5	6,300	2	13,400
3	8,790	6	10,400	20	4,200	20	4,780	6	5,060	3	13,200
4	6,670	7	10,000	21	4,000	21	4,380	7	4,580	4	12,000
Crest	76,500		43,000		58,000		60,000		45,000		30,300

Crest occurred on date indicated by *
[1] Affected by storage in Diablo Reservoir.

Table 7. – Daily flood discharges of Skagit River at The Dalles and near Sedro-Woolley

Skagit River near Sedro-Woolley, Drainage area, 2,970 square miles						Skagit River at The Dalles, Drainage area, 2,700 square miles			
Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge[1]	Date	Discharge[1]
1909	Sec.-ft.	1917	Sec.-ft.	1921	Sec.-ft.	1932	Sec.-ft.	1935	Sec.-ft.
Nov. 22	20,600	Dec. 27	28,200	Dec. 9	14,100	Feb. 24	7,500	Jan. 23	34,000
23	68,500	28	60,400	10	21,500	25	14,100	24	78,000
24	102,000	29	87,800	11	56,200	26	[2]69,400	*25	120,000
25	49,400	*30	155,000	12	111,000	*27	[2]129,000	26	95,000
26	28,800	31	87,000	*13	188,000	28	[2]105,000	27	65,300
27	21,700	1918		14	125,000	29	59,300	28	49,900
28	31,500	Jan. 1	119,000	15	95,000	Mar. 1	40,400	29	40,800
29	118,000	2	95,000	16	37,000	2	31,700	30	36,400
*30	198,000	3	65,800	17	29,300	3	24,100	31	32,700
Dec. 1	93,600	4	60,200	18	24,800	4	20,700	Feb. 1	33,600
2	53,100	5	52,000	19	19,700	5	23,700	2	43,900
3	37,000	6	42,500	20	19,700	6	21,900	3	42,200
4	30,400	7	53,500	21	17,300	7	18,400	4	36,100
Crest	220,000		195,000		210,000		147,000		131,000

Crest occurred on date indicated by *

[1] Affected by storage in Shannon and Diablo Reservoirs.

[2] When corrected for effect of upstream storage regulation, these data would be:
Feb. 26   97,000
27   160,000 (crest 182,000)
28   99,000

Table 8. - Daily flood discharges of Cascade River at or near Marblemount

Cascade River near Marblemount Drainage area, 148 square miles		Cascade River at Marblemount Drainage area, 180 square miles			
Date	Discharge	Date	Discharge	Date	Discharge
1909	Sec.-ft.	1932	Sec.-ft.	1935	Sec.-ft.
Nov. 22	2,880	Feb. 24	390	Jan. 23	2,260
23	7,870	25	1,030	24	5,820
24	4,840	26	8,300	25	8,550
25	2,500	27	9,250	26	6,560
26	1,900	28	4,530	27	3,940
27	1,420	29	2,490	28	3,000
28	9,790	Mar. 1	1,880	29	2,470
29	31,700	2	1,500	30	2,240
30	8,590	3	1,250	31	2,030
Dec. 1	3,890	4	1,120	Feb. 1	2,290
2	2,360	5	1,150	2	3,210
3	1,740	6	1,020	3	2,720
4	1,380	7	875	4	2,240
		Crest:			
		Feb. 26	12,900		

Table 9. - Daily flood discharges of Sauk River above Whitechuck River
(drainage area, 152 square miles)

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
1917	Sec.-ft.	1921	Sec.-ft.	1932	Sec.-ft.	1935	Sec.-ft.
Dec.27	6,020	Dec. 9	1,230	Feb.24	450	Jan.23	3,760
28	8,000	10	3,980	25	2,370	24	9,820
*29	17,400	11	10,300	*26	14,600	*25	12,700
30	7,810	*12	16,700	27	11,700	26	7,640
31	7,950	13	8,860	28	6,380	27	4,390
1918		14	4,420	29	3,560	28	3,340
Jan. 1	7,380	15	3,060	Mar. 1	2,440	29	2,750
2	4,420	16	2,390	2	1,860	30	2,400
3	3,770	17	1,970	3	1,560	31	2,200
4	4,110	18	1,650	4	1,440	Feb. 1	2,200
5	3,770	19	1,360	5	2,220	2	2,680
6	3,520	20	1,210	6	1,730	3	2,610
7	3,280	21	1,120	7	1,390	4	2,270
Crest	21,000		23,000		20,000		13,200

Crest occurred on date indicated by *

Table 10. - Daily flood discharges of Sauk River at Darrington and near Sauk

Sauk River at Darrington Drainage area, 293 square miles				Sauk River near Sauk Drainage area, 714 square miles			
Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
1921	Sec.-ft.	1932	Sec.-ft.	1932	Sec.-ft.	1935	Sec.-ft.
Dec. 9	4,080	Feb. 24	1,150	Feb. 24	(1)	Jan. 23	14,500
10	11,700	25	4,830	25	(1)	24	36,300
11	19,400	*26	25,000	*26	51,400	25	46,300
*12	27,000	27	17,500	27	44,500	26	31,200
13	14,000	28	10,600	28	23,600	27	18,000
14	5,530	29	5,970	29	12,700	28	13,000
15	3,960	Mar. 1	3,970	Mar. 1	8,900	29	10,700
16	3,270	2	3,030	2	7,240	30	9,640
17	2,800	3	2,550	3	5,900	31	8,630
18	2,360	4	2,280	4	5,400	Feb. 1	8,630
19	1,950	5	5,050	5	7,900	2	10,700
20	1,700	6	3,200	6	6,900	3	10,300
21	1,590	7	2,280	7	5,530	4	8,960
Crest	36,000		36,000		68,500		(1)

Crest occurred on date indicated by *

[1] Data not available.

Table 11. - Daily flood discharges of Baker River below Anderson Creek
(Drainage area, 184 square miles)

Date	Discharge	Date	Discharge
1917	Second-feet	1921	Second-feet
Dec. 12	1,010	Nov. 25	1,770
13	1,940	26	1,980
14	5,410	27	4,440
15	5,240	28	3,060
16	11,400	29	2,380
17	6,660	30	2,910
18	11,400	Dec. 1	3,140
19	8,760	2	2,500
20	3,980	3	1,970
21	2,710	4	1,620
22	2,340	5	1,440
23	1,840	6	1,490
24	1,540	7	1,400
25	1,410	8	1,360
26	1,840	9	1,820
27	6,360	10	6,030
28	12,900	11	14,600
*29	27,400	*12	19,600
30	16,800	13	13,000
31	19,200	14	4,240
1918		15	(1)
Jan. 1	20,200	16	(1)
2	15,200	17	(1)
3	12,200	18	(1)
4	13,100	19	(1)
5	13,500	20	(1)
6	9,050	21	1,160
7	9,240	22	1,070
8	7,260	23	1,000
9	4,160	24	935
10	2,850	25	879
Crest	36,800		23,600

Crest occurred on date indicated by *
[1] Data not available.

52. Table 12 condenses flood-flow data of the Skagit River system. In each case the discharge of the tributaries is given for the day preceding the maximum discharge at Sedro-Woolley or at The Dalles. It will be seen that the tributaries of the Skagit River show markedly different rates of discharge. Thus Skagit River below Ruby Creek, which drains 33 percent of the area tributary to the river at Sedro-Woolley, contributes less than 16 percent of the flood discharge at Sedro-Woolley; whereas Cascade River near Marblemount, draining only 5 percent of the area, contributed in 1909, 16 percent of the discharge.

Table 12. - Contribution of tributaries to [illegible] discharge of Skagit River

Item	Station: Skagit River near Sedro-Woolley	Skagit River at The Dalles	Skagit River below Ruby Creek	Cascade River at Marblemount	Cascade River near Marblemount	Sauk River near Sauk	Sauk River at Darrington	Sauk River above Whitechuck River	Baker River below Anderson Creek
Drainage area:									
Square miles	2,970	2,700	978	180	148	714	293	152	184
Percent of area at Sedro-Woolley	100.0	90.9	32.9	6.1	5.0	24.0	9.9	5.1	6.2
Percent of area at The Dalles	110.0	100.0	36.2	6.7	5.5	26.4	10.9	5.6	6.8
Mean discharge April 1914 - March 1931:									
Second-feet	15,600	14,400	3,150	-	870	4,200	2,020	1,100	1,970
Percent of discharge at Sedro-Woolley	100.0	92.3	20.2	-	5.6	26.9	12.9	7.1	12.6
Percent of discharge at The Dalles	108.3	100.0	21.9	-	6.0	29.2	14.0	7.6	13.7
Second-feet per square mile	5.3	5.3	3.2	-	5.9	5.9	6.9	7.2	10.7
Crest discharge in second-feet:									
November 1909	220,000	260,000	[1]54,000	-	-	-	-	-	-
December 1917	195,000	220,000	[1]33,500	-	-	-	36,000	21,000	36,800
December 1921	210,000	240,000	45,700	-	-	-	36,000	23,000	23,600
February 1932 (measured)	[1]135,000	147,000	[1]32,000	12,900	-	68,300	36,000	20,000	-
February 1932 (corrected for storage)	[1]160,000	[1]182,000	(2)	(2)	-	(2)	(2)	(2)	-
Maximum 24-hour discharge in second-feet:									
November 1909	198,000	-	[1]28,400	-	31,700	-	-	-	-
December 1917	155,000	-	[1]21,200	-	-	-	-	17,400	27,400
December 1921	188,000	-	29,200	-	-	-	27,000	16,700	19,600
February 1932 (measured)	-	129,000	27,500	8,300	-	51,400	25,000	14,600	-
February 1932 (corrected for storage)	-	[1]160,000	(2)	(2)	-	(2)	(2)	(2)	-
Percent of discharge at Sedro-Woolley:									
November 1909	100.0	-	14.3	-	16.0	-	-	-	-
December 1917	100.0	-	13.7	-	-	-	-	11.2	17.7
December 1921	100.0	-	15.5	-	-	-	14.4	8.9	10.4
Percent of discharge at The Dalles:									
February 1932 (measured)	-	100.0	21.3	6.4	-	39.8	19.4	11.3	-
February 1932 (corrected for storage)	-	100.0	17.2	5.2	-	32.1	15.6	9.1	-
Highest 3-day run-off in acre-feet:									
November 1909	812,200	-	[1]132,900	-	99,300	-	-	-	-
December 1917	715,900	-	[1]116,000	-	-	-	-	65,900	125,700
December 1921	840,800	-	131,700	-	-	-	119,800	71,100	93,600
February 1932 (measured)	-	601,600	130,900	43,800	-	237,000	105,300	64,800	-
February 1932 (corrected for storage)	-	[1]705,900	(2)	(2)	-	(2)	(2)	(2)	-

[1]Estimated.
[2]No upstream storage.

53. Table 13 gives flood run-off in terms of inches of run-off from the watersheds.

Table 13. - Flood run-off in inches

Station	Drainage area	3-day run-off, depth in inches				
	Square miles	Nov. 1909	Dec. 1917	Dec. 1921	Feb. 1932 (measured)	Feb. 1932 (corrected for storage)
Skagit River near Sedro-Woolley	2,970	5.13	4.52	5.31	-	-
Skagit River at The Dalles	2,700	-	-	-	4.18	4.90
Skagit River below Ruby Creek	978	[1]2.55	[1]2.22	2.52	2.51	(2)
Cascade River at Marblemount	180	-	-	-	4.56	(2)
Cascade River near Marblemount	148	12.58	-	-	-	-
Sauk River near Sauk	714	-	-	-	6.22	(2)
Sauk River at Darrington	293	-	-	7.67	6.74	(2)
Sauk River above Whitechuck River	152	-	8.13	8.77	7.99	(2)
Baker River below Anderson Creek	184	-	12.81	9.54	-	-

[1]Estimated.
[2]No upstream storage.

54. Probable future floods. - Natural evidence at Reflector Bar indicated that the flood of 1815 was nearly a maximum, but that there had been, prior to that time, several floods approximately as large. The discharge of that flood at The Dalles (500,000 second-feet) is equivalent to a discharge of 185 second-feet a square mile from the entire tributary area. No flood of actual record in the Puget Sound region has approached such a rate of discharge for so large a drainage area; and it is probable that such floods will occur only at extremely long intervals. Table 4 shows that floods in excess of 180,000 second-feet, at Sedro-Woolley, have occurred six times since 1896, or on an average of once in 7 years. Such floods may be expected to occur in the future with about the same frequency, with materially larger floods, such as that of 1856, occurring at much longer intervals.

III. FLOODED AREA

55. Extent and character. - The area subject to inundation by major floods of the Skagit River comprises about 75,000 acres, most of which is improved and cultivated land. Of this amount, 70,000 acres lie west of Sedro-Woolley, including practically all of the area lying west of the Great Northern Railway between Milltown and Blanchard, about 35,000 acres of which are, at ordinary river stages, tributary to Samish River, Joe Leary Slough and other sloughs of Padilla Bay. About 45,000 acres of the flooded area have been inclosed by dikes (see paragraph 68), which offer some protection against inundation, so that the entire 75,000 acres would probably not be flooded during any ordinary flood. Included in the flood plain are portions of the towns of Hamilton, Lyman, Sedro-Woolley, Burlington, and Mount Vernon, as well as about 35 miles of railroad grade and 80 or more miles of State and county roads.

56. Land values. - Using data abstracted from the Fifteenth Census of the United States, it is estimated that there are, in the overflow area, about 1,000 farms, embracing an area of 53,000 acres and valued, with

buildings and equipment, at $16,000,000. Buildings and farm machinery represent $5,000,000 of the value, thus leaving $11,000,000 as the value of 53,000 acres, or an average of $208 an acre. About 22,000 acres of the farm land is uncleared or in pasture, and is subject to little damage by inundation. Assuming an average value for this non-crop land of $100 an acre, there would remain a valuation for crop land of $8,800,000, or $284 an acre, and a total valuation of $13,800,000 for crop land, buildings and equipment, all of which are liable to more or less damage at times of flood. The values given are as determined in 1930 and are probably higher than present-day prices.

57. No data are available as to the valuation or costs of town property, road and railroad grades, etc., or other non-farm areas subject to flood damage.

58. Flood damages. - Although the damage caused by floods in the Skagit basin has been large, it is difficult to evaluate because of the lack of data. Lack of proper flood control will have a retarding effect on a higher development in the basin in future years, or if it be more highly developed without the flood control protection, an increase in the annual flood damage losses will result. The estimates of damages given in the succeeding paragraphs were prepared by various local agencies, no check being made by this office.

59. The spring flood of 1894, which destroyed crops valued at $1,500,000, prompted the settlers to extend their system of dikes. The flood of 1897 washed out the roadbed of the Great Northern Railway between Burlington and Sedro-Woolley, flooded part of Mount Vernon, and caused a heavy loss of livestock and property above Concrete. The flood of 1906 caused a loss of $250,000. The discharge at Sedro-Woolley during the 1897 flood was slightly greater than for the flood of 1906, so the damages resulting from the 1897 flood were probably on the order of $300,000. The flood of 1909 caused damages conservatively estimated at $1,500,000. It ruined many farms, destroyed several hundred head of livestock and washed

out many miles of dikes and drainage ditches. The Great Northern Railway embankment between Burlington and Mount Vernon was washed away and serious damage done to the State highway. That part of Mount Vernon west of the river was entirely flooded.

60. The flood of 1917 caused a loss estimated at $500,000. It destroyed the roadbeds of the Great Northern Railway and of the Pacific Northwest Traction Company (tracks now removed) between Mount Vernon and Burlington, seriously interrupting the communication of the region for 2 weeks. Extensive damage was also done to the dikes.

61. The 1921 flood caused a tangible loss of over $600,000, the greatest damage being inflicted upon the land and crops, roads and bridges, ditches and dikes and the logging industry.

62. The tangible damages due to the February 1932 flood of the Skagit River are estimated to have been about $600,000. This amount does not include such intangible damages as the loss of trade on account of the disruption of business and the crippling of transportation and communication. The chief damages suffered were, in round numbers: To farm lands, improvements and crops, $500,000; to railways, $46,000; to public roads and bridges, $36,000; and to dikes, $14,000.

63. A minor flood in December 1933 did damage to land and improvements in the upper valley to the extent of about $50,000. At the same time abnormally high tides breached sea dikes and flooded parts of the delta area with salt water. It is estimated that the damage from this source (which is not considered flood damage) was approximately $200,000. (See paragraph 69 for costs of repairs and betterments made by the Civil Works Administration and the Washington Emergency Relief Administration.)

64. No data are available as to the damage resulting from the flood of January 1935, but by comparison of flood heights with the 1932 and 1933 floods, it is believed that the damage from the 1935 flood was about $100,000, chiefly in erosion of land.

65. Summary. - A summary of the reported flood losses is given in table 14. This record is incomplete and based on very meager data for the earlier floods, but serves as a guide in deriving an estimate of annual flood losses.

Table 14. - Summary of known flood losses

Year	Estimated loss	Crest discharge at Sedro-Woolley
		Second-feet
1894	$1,500,000	No record
1896 (Jan.)	No record	(1)
1896 (June)	No record	(1)
1896 (Nov.)	No record	185,000
1897	300,000	190,000
1906	250,000	180,000
1908	No record	[2]92,600
1909	1,500,000	220,000
1914	No record	[2]104,000
1917	500,000	195,000
1921	500,000	210,000
1932 (Feb.)	600,000	[3]147,000
1932 (Nov.)	No record	[3]116,000
1933	50,000	[3]101,000
1935	100,000	[3]131,000
Total	$5,300,000	
Average, 1894-1936 (42 years)	126,000	
Say	130,000	

[1]Probably over 100,000 second-feet.

[2]24-hour discharge.

[3]At The Dalles.

66. The incomplete estimate of $130,000 gives no consideration to losses resulting from lesser, unlisted, floods that occurred during the period, to the unrecorded damages for some of the floods listed in table 14, to the probable increase in damages that would occur now or in the future for floods of the same magnitude, nor to the damages that would result from a flood like that of 1856. With these facts in mind and considering, further, that no allowance has been made for intangible damages, it is believed that the average annual flood losses from floods equal to or less than that of 1856 will amount to $220,000.

IV. WORK DONE BY LOCAL INTERESTS

67. Existing flood control works. - The only existing works for control of Skagit River floods consist of dikes and drainage ditches. Three reservoirs, constructed and operated in the interest of power development, furnish incidental storage for detention of flood waters, and an extensive system of bank revetment, built with Works Progress Administration funds under the engineering supervision of this office, protects the points at which bank erosion has been most severe.

68. Dikes and diking districts. - Downstream from Sedro-Woolley are 16 diking districts, organized and operating under the laws of the State of Washington, and embracing a total area of approximately 45,000 acres. They have expended on the construction and maintenance of dikes, to 1938, a total of about $2,020,000, or $45 an acre. In addition to the area inclosed by district dikes there are about 1,000 acres diked by individual landholders, but the costs of these dikes are not available. Much of the diked land south of Samish River lies outside of the Skagit River basin proper, but overflow waters of the Skagit occasionally cover the area. Over 30 percent of the existing dikes are designed to protect the area from inundation by salt water. No accurate separation of costs between salt and fresh-water dikes is possible; but in general the river dikes are of heavier section and more costly construction than the sea dikes, so that the total cost of river dikes, both district and private, has probably been between one and one-quarter and one and three-quarter million dollars.

69. Following the abnormally high tides of December 1933, about 60 miles of dikes, chiefly along the sea front, were repaired and strengthened with Civil Works Administration and Washington Emergency Relief Administration funds at a cost of $161,203.14, the construction work being under supervision of this office.

70. Table 15 summarizes data pertaining to the 16 diking districts of the Skagit River delta.

Table 15. - Diking districts, Skagit County

District	Date organ-ized	Acres in district (1934)	Estimated value of land: Total[1]	Estimated value of land: Per acre	Recent annual assessments for diking per acre: 1931	1932	1933	1934	1935	1936	1937	Total levies to 1937, inclusive: Per acre	Total levies to 1937, inclusive: Total
No. 1 -----	1897	8,268	$1,571,000	$190	-	$0.63	$0.42	$0.63	$0.63	$0.63	$0.63	$39.15	$323,687
No. 2 -----	1897	2,632	573,000	220	$0.76	1.52	1.52	1.52	2.85	2.79	1.93	83.21	219,000
No. 3 -----	1897	6,366	1,814,000	280	-	0.63	0.79	0.79	1.57	1.57	1.57	65.35	416,048
No. [2]4 -----	-	1,579	249,000	160	-	0.16	0.38	0.32	0.34	0.46	0.38	12.93	20,418
No. [2]5 -----	1897	2,825	643,000	230	1.00	1.00	1.50	2.00	1.50	1.77	1.80	64.25	181,501
No. [2]8 -----	1897	631	70,000	110	0.32	0.48	0.48	2.53	2.54	2.54	1.90	22.69	14,317
No. [2]9 -----	1897	1,419	320,000	230	-	-	0.21	-	-	-	-	14.01	19,883
No. [2]12 -----	1897	13,380	2,503,000	190	0.08	0.81	0.86	0.82	0.82	0.83	0.84	26.67	356,840
No. 13 -----	[3]1897	1,869	338,000	180	0.80	1.40	1.20	1.79	2.00	2.80	1.40	66.96	125,154
No. 15 -----	1903	885	120,000	140	0.45	0.51	1.02	1.00	1.50	1.00	1.00	71.00	62,832
No. 16 -----	1904	407	78,000	190	2.31	1.47	1.22	1.23	1.47	1.23	1.72	70.28	28,603
No. 17 -----	1910	1,263	428,000	340	3.56	5.17	5.15	1.19	1.19	0.95	0.95	142.96	180,557
No. 18 -----	1918	576	253,000	440	0.97	2.92	0.56	1.56	1.65	1.46	0.77	51.22	29,500
No. [2]19 -----	1919	1,960	442,000	230	0.03	0.26	0.61	1.02	1.02	1.02	1.02	14.12	27,685
No. 20 -----	1919	537	24,000	50	-	0.93	-	3.50	2.80	1.90	1.86	45.33	24,350
No. 21 -----	1922	391	176,000	450	0.58	0.90	1.23	1.79	1.28	1.01	0.90	25.09	9,812
Total or average ---		44,988	9,602,000	[4]213								44.91	2,020,304

[1]Based on 1937 assessment.
[2]Either wholly or partially outside of Skagit River drainage area, but area affected by overflow from the Skagit River.
[3]Reorganized in 1929.
[4]Local apprai ser of Federal Land Bank estimates average value as $195 an acre.

71. The fact that Skagit River floods still inflict large damages in the delta area indicates that these dikes do not furnish adequate flood protection. Built without a comprehensive and coordinated plan, many of the dikes are poorly designed and improperly located. In an effort to inclose as much land as possible the dikes have been placed close to the riverbank with little or no consideration given to alinement, river sections, or other elements entering into the proper design of such a system. As a result frequent breaks, due to overtopping and to undermining of riverbanks and dikes, have occurred.

72. Drainage and drainage districts. - Supplementing the protection afforded by the diking districts are drainage ditches constructed by 12 drainage districts, also organized and operating under state law. Data concerning these districts are summarized in table 16.

Table 16. - Drainage districts, Skagit County

District	Date organized	Acres in district (1934)	Estimated value of land: Total	Estimated value of land: Per acre	Recent annual assessments for drainage per acre: 1931	1932	1933	1934	1935	1936	1937	Total levies to 1937, inclusive: Per acre	Total levies to 1937, inclusive: Total
No. 14 -----	1900	9,453	$1,096,000	$120	$0.42	$0.53	$0.53	$0.53	$0.53	$0.58	$0.58	$24.86	$235,032
No. 15 -----	1906	9,452	1,372,000	150	0.31	0.31	0.56	0.99	1.12	0.99	1.45	21.49	203,102
No. 16 -----	[1]1906	2,874	649,000	230	0.82	0.82	0.82	1.00	1.00	1.00	1.00	19.21	55,202
No. 17 -----	1909	4,987	648,000	130	0.60	1.20	1.29	1.40	1.40	3.19	3.23	43.73	218,085
No. 18 -----	1910	1,575	220,000	140	0.51	0.51	0.51	0.51	0.63	0.63	0.63	17.04	26,835
No. 19 -----	1922	6,508	1,337,000	210	[2]5.51	3.19	-	0.23	0.73	0.73	0.59	40.40	262,895
No. [3]20 -----	1920	537	28,000	50	-	0.09	-	0.75	0.19	0.40	0.93	8.53	4,580
No. 21 -----	1922	547	104,000	190	3.39	3.53	1.28	-	-	-	-	39.30	21,495
No. 22 -----	1928	1,134	197,000	170	1.97	1.45	0.98	1.05	0.65	1.46	1.68	13.64	15,473
No. 23 -----	1933	306	-	-	-	-	-	8.56	-	-	-	8.56	2,618
No. [4]13 -----	1928	1,837	332,000	180	1.20	1.80	0.80	0.80	0.60	0.80	0.80	11.13	20,437
No. [5]16 -----	1928	318	71,000	220	4.72	3.15	2.41	3.77	3.77	2.20	1.57	29.31	9,322
Total or average ---		39,528	5,884,000	150								27.20	1,075,076

[1]Reorganized in 1934.
[2]Mainly for retirement of bonds.
[3]Drainage improvement district within Diking District No. 20.
[4]Drainage improvement district within Diking District No. 13.
[5]Drainage improvement district within Diking District No. 16.

73. Including all works done by the Civil Works Administration, by the Works Progress Administration, by diking and drainage districts and by individuals, the total expenditures for the reclamation and protection of the lands have been over $3,600,000. In addition there is provided by tax levy in Skagit County a fund known as the "River Improvement Fund" to be used for minor work of river protection and for collection of hydrographic and other data. This levy is limited by state law to one mill on the dollar per annum. Data are not at hand as to the total expenditures under this fund, but for the years 1932 to 1934, inclusive, the fund provided $1,678 for river protection and $575 for cooperation in maintenance of the gaging station at The Dalles. The work done by Mr. Stewart was also paid for from this fund.

74. Works Progress Administration projects. - A Works Progress Administration project for the revetting of banks at points of erosion between Hamilton and Burlington, sponsored by Skagit County, was completed in May 1938, under the engineering supervision of this office. In this project 22,102 linear feet of revetment (190,751 square yards) was completed at a cost of $269,349. About 12 percent of the funds expended was furnished by the sponsoring agency.

75. Some work (under the Works Progress Administration and supervision of this office) has been done on the upper Skagit and the Sauk Rivers. On the upper Skagit above Hamilton, 36 miles of snagging was completed in February 1939. The total cost was $41,221 of which about 5 percent was furnished by the sponsoring agency. On the Sauk River near Darrington, 12 miles of snagging and 750 linear feet (3,333 square yards) of brush revetment were completed in March 1939. The total cost of the Sauk River work was $42,032 of which about 4 percent was furnished by the sponsoring agency.

76. Detention reservoirs. - There are three power reservoirs in the Skagit River system: Shannon Lake on Baker River, and Diablo reservoir and Ross Lake on the upper Skagit River. As pointed out in paragraph 50, Shannon and Diablo reservoirs were effective in reducing the crest of the 1932 flood,

although no provision had been made for flood storage in the reservoirs. Diablo Dam is now used principally to create head for the Diablo power plant of the city of Seattle and to provide daily pondage, Ross Dam furnishing practically all storage for the city's downstream power plants. Ross Dam was completed to elevation 1365 feet in 1939 and a timber bulkhead to elevation 1380 has since been added, giving a total storage capacity of 100,000 acre-feet.

V. PROPOSED MEASURES OF RELIEF

77. Desires of local interests. - At a joint public hearing held by the Departments of War and Agriculture on March 2, 1937, in connection with the preliminary examination, county officials stated that the county's financial position was such that it would be impossible at that time for the county to furnish the local cooperation required for the construction of the Avon By-pass as authorized under the existing project. The consensus of opinion was that the by-pass was not wanted but that dredging in the lower river channel and bank revetment to prevent erosion of land was necessary. One speaker suggested revetment to prevent erosion and the construction of a flood control reservoir on Sauk River in lieu of the construction of the Avon By-pass.

78. Protective measures considered. - Four plans for reducing flood damage in the Skagit basin have been considered: Storage of flood waters, diversion of flood waters, modification of the existing diking system, and channel improvement.

79. Storage. - Reference has already been made to the existing reservoirs on the river system. Although these reservoirs might, under normal power operation, furnish incidental flood control storage, such use cannot be assured for future floods. Numerous undeveloped power sites exist in the Skagit basin (see H. Doc. 187, 73rd Cong., 2nd sess., p. 76 et seq.) but of the sites only four (including the Ruby site, now partially developed by Ross Dam) combine favorable dam sites with sufficient storage

capacity to make them effective as flood control reservoirs. These four are the Ross (Ruby) site on the upper Skagit River, the Cascade site on the Cascade River, the lower Sauk site on the Sauk River, and the Baker Lake site on the upper Baker River.

80. Ross site. - This site, just below the mouth of Ruby Creek and at the upstream limit of backwater from Diablo Dam, is now under development by the city of Seattle. The dam is at present constructed to elevation 1365 feet on foundations capable of supporting a dam to elevation 1500 feet. The city plans to raise the dam to 1500 feet as soon as the need for power warrants such additional height. At the higher elevation the dam will store about 500,000 acre-feet. The ultimate development, as now planned by the city, will include a dam to elevation 1725 feet, providing about 3,000,000 acre-feet of storage of which 300,000 acre-feet will be reserved for flood control, and a power plant with a capacity of 360,000 kilowatts.

81. Table 12 shows that the run-off at the dam site for the 3 days of maximum flow during the floods of 1909, 1917, 1921, and 1933 was, respectively, 133,000 acre-feet, 116,000 acre-feet, 132,000 acre-feet, and 131,000 acre-feet. It appears, therefore, that the proposed reservation of 300,000 acre-feet for flood control will absorb the entire flood run-off at the dam site for an ordinary flood, and probably would retain the 3-day run-off from a flood like the one of 1815.

82. Cascade site. - The dam site for this project is located on the Cascade River about 8 miles above its mouth, where the drainage area is 148 square miles. Records of flood flow at the dam site are limited to the major flood of November 1909. The mean discharge for the day of greatest flow (November 29) was 31,700 second-feet, or 16 percent of the discharge at Sedro-Woolley, and the run-off for the three highest days was 99,300 acre-feet. As elsewhere in the basin the flood of 1909 was the highest since records have been kept, it may be assumed that the storage of 100,000 acre-feet would absorb the flood run-off of the Cascade River

during ordinary floods, and that the storage of 200,000 acre-feet would effectively detain the flow of such a flood as the one of 1815. To provide storage of 100,000 acre-feet a concrete arch dam 360 feet high above the foundation would be required. A dam to provide 200,000 acre-feet is considered infeasible.

83. Investigations have revealed that a dam creating a total storage of 104,000 acre-feet might be justified for power development if there were a demand for the power. Under such a plan there could be reserved for flood storage, during the winter season, about 32,000 acre-feet without materially affecting the cost or quantity of the available power. In addition to the controlled storage there would be temporary storage of about 15,000 acre-feet above the spillway crest which would be effective in reducing the flood crest.

84. So far as known to this office, no agency has under consideration plans for development of this project. As the reservoir site lies almost entirely within the national forest, any power development would be under the jurisdiction of the Federal Power Commission and therefore appropriate reservation in the interest of flood control could be made.

85. Sauk site. - The dam site for this project is located on Sauk River about 7 miles above its mouth, where the drainage area is 714 square miles. The natural low water surface elevation is 280 feet. The possible forebay elevation is limited to approximately elevation 500 feet by the height of the ridge on the left bank at the dam site and also by the height of the divide between the Sauk and Stillaguamish River basins at the upper end of the reservoir near Darrington. The low elevation of this divide suggests the possibility of diverting a portion of the flood flow into the North Fork of the Stillaguamish. (See paragraph 95.)

86. From a study of flood flow records on the Sauk River it is estimated that a storage capacity of about 270,000 acre-feet would be required to detain the 3-day run-off during floods of the size of those of 1909, 1917, and 1921. For a flood such as the one of 1815 probably about 500,000

acre-feet would be necessary. A reservoir of 270,000 acre-feet capacity could be provided by a dam to elevation 455 feet, and a reservoir of 500,000 acre-feet capacity by a dam to elevation 490 feet.

87. If the project were constructed in the combined interest of power and flood control about 200,000 acre-feet (between elevations 498 feet and 475 feet) could be reserved for flood storage. If such storage were reserved the year round the cost to flood control would be the entire additional expense of creating the top 200,000 acre-feet. If, however, the flood storage were reserved only during November, December, January, and February of each year (the normal flood period), power production would be reduced only slightly below the production possible by using the entire storage for power development. On such a basis it would appear that flood control could properly be charged with only the value of the potential power thus lost.

88. So far as known, no power development at this site is planned by any agency. A small portion of the reservoir site lies within the Mount Baker National Forest, and since storage regulation would affect navigation on the main stream, it is believed that this project when developed should be under license from the Federal Power Commission.

89. **Upper Baker site.** - The dam site for this project is located on Baker River about 12 miles above its mouth and 8 miles downstream from Baker Lake at a point where the drainage area is 184 square miles. Flood discharge records at the site are available for the floods of 1917 and 1921. Of these two, the 1917 flood was much the more severe, reaching a crest discharge of 36,800 second-feet, and having a 3-day run-off of 125,700 acre-feet. The crest flow represented a discharge of 200 second-feet a square mile, and the average discharge over the 3-day period, a discharge of 115 second-feet a square mile. This rate of discharge is so large, as compared with other streams of the Puget Sound area, as to suggest that the 1917 flood must have been nearly as large as any of recent years. It is assumed, therefore, that a storage of 130,000 acre-feet would adequately control any

but the most severe floods on the Baker River. A dam about 280 feet high (foundation to walkway) would be required to create 130,000 acre-feet of storage.

90. If the site were developed as a power project, it would be possible to reserve about 40,000 acre-feet of storage for flood control during the winter months at no material sacrifice of power output. Such a storage could absorb about one-half of the maximum day's run-off of the 1917 flood.

91. Preliminary investigations of the power project have been made by the Puget Sound Power and Light Company, but since the site is located within the national forest, a license for its development must be secured from the Federal Power Commission.

92. Reservoir combination. - Mr. Stewart estimated that the diked channel below Sedro-Woolley carried 140,000 second-feet during the 1921 flood. This estimate is subject to considerable uncertainty, however, and it is believed that the existing channel could not safely carry for long more than 100,000 second-feet. Studies have been made of the possibility of limiting the discharge to this figure by storage of flood waters in the proposed reservoirs. These studies, which are based on 24-hour average flows and which, therefore, give only approximate results, lead to the following conclusions:

a. With storage for flood control only, no two of the proposed reservoirs could have been so operated as to reduce the discharge at Sedro-Woolley during the 1921 flood, and probably during the 1909 flood, to 100,000 second-feet. Storage of the total input to Sauk, Ruby, and Baker reservoirs during the maximum day of the 1921 flood could have reduced the discharge at Sedro-Woolley to about 90,000 second-feet. In the absence of discharge data for the 1921 flood, the further reduction in discharge that could be effected by storage in Cascade reservoir cannot be determined.

b. With storage for combined power and flood control, using the flood control reservations outlined in the preceding paragraphs, and allowing enough discharge through the turbines to satisfy the ordinary needs of power generation, regulation of Sauk, Ruby, and Baker reservoirs could have reduced the discharge of the 1921 flood at Sedro-Woolley to about 99,000 second-feet. It is believed that the use of top storage in Cascade reservoir could have reduced the 99,000 second-feet to about 88,000 second-feet, thus making an over-all reduction of 100,000 second-feet. Approximately the same reduction could have been made in the 1856 flood by similar use of top storage in the four proposed reservoirs. If it is assumed that the 1856 flood could be reduced by 80,000 second-feet, the discharge of that flood at Sedro-Woolley would be reduced from 300,000 second-feet to 220,000 second-feet, which is the measured crest discharge of the 1909 flood and the figure used in designing the Avon By-pass (see paragraph 97). Thus, a flood approximately as large as that of 1856 could be so controlled as to cause no overflow in the delta area by combining use of top storage in the four proposed reservoirs with the operation of the proposed Avon By-pass.

93. Preliminary cost estimates, made in connection with power studies of the Skagit River, show costs of the proposed flood storage as follows:

Reservoir	Storage acre-feet	Approximate cost
Cascade	100,000	$4,500,000
Sauk	270,000	7,250,000
Upper Baker	130,000	4,500,000

94. Ruby reservoir, now licensed as a power development, is not available for flood storage alone and accordingly, costs for that reservoir are not shown. It is obvious that the costs of the other reservoirs, for flood storage alone, cannot be justified by the resulting reduction in flood damages.

95. Diversion. - As pointed out in paragraph 85, diversion of part

of the flood flows of the Sauk River might be made to the North Fork of the Stillaguamish River near Darrington. Such a diversion would very materially reduce the flood heights through the Skagit River delta area, but would add to the already serious flood threat in the Stillaguamish basin. No further consideration, therefore, should be given to such diversion.

96. Two possible routes exist by which a portion of the flood waters might be diverted from the lower Skagit basin; one, 9.6 miles long, to divert just upstream from Burlington and discharge into Padilla Bay by way of Joe Leary Slough; and the other to divert at Avon, downstream from Burlington, and also to discharge into Padilla Bay. The latter route, 5.6 miles long, is referred to herein as the Avon By-pass. The area protected by either by-pass is identical, about 65,000 acres, or 93 percent of the area flooded west of Sedro-Woolley.

97. The maximum discharge of actual record, at Sedro-Woolley, was 220,000 second-feet (November 30, 1909). It is estimated that the existing river channel and dikes are adequate to carry safely a flow of 100,000 second-feet, thus leaving 120,000 second-feet to be carried by the by-pass during a flood of the magnitude of the one of 1909.

98. The Avon By-pass, together with necessary channel improvement and revetment of the portion of the river between the high ground upstream from Burlington and the point of diversion, is the project adopted by the Flood Control Act of 1936.

99. The opposition of local interests to the construction of the Avon By-pass, as expressed at the public hearing (see par. 77), is caused largely by the desire of these interests to avoid or reduce the very heavy contribution required of them under the adopted project. It is probably utterly impossible for them at the present time to make the required contribution and it may continue to be impossible for many years to come unless the required contribution is lowered by act of Congress. It is possible that a detailed survey of the proposed by-pass and a reappraisal of the required right-of-way would show that the right-of-way costs could

be reduced slightly from those stated in the authorization, but such reduction would be too small to alter the ability of local interests to make the required contribution.

100. Modification of existing diking system. - In its natural condition Skagit River, during flood periods, overflowed its banks and inundated a large portion of the delta. The flood waters reached Puget Sound not alone through the river channels proper, but also through the many sloughs and small drainage channels, and by passing directly across the flats. The existing dikes hold the river partially in bounds, although during severe floods the dikes frequently fail by "boils" before being overtopped. A system of dikes proportioned to carry the entire flood flow at a surface elevation approximating that obtaining under natural conditions would include within the waterway so much valuable agricultural land as to be prohibitive in cost.

101. A system of dikes proportioned to carry the entire flood flow within the lateral limits of the natural river channel and at velocities below the point of scour would require high and expensive dikes, and in addition, the raising of all bridges in the improved section and the construction of an expensive drop or series of drops at or near tidewater. The latter would probably also involve the construction of navigation locks.

102. Channel improvement. - Instead of creating the additional waterway required for passage of the flood waters by dikes alone it would be possible, and more economical, to combine dikes and channel improvement to provide the necessary cross-sectional area. This scheme would involve the construction of a protection dike on the right bank of the river from the high ground above Burlington to a point just upstream from the Great Northern Railway bridge. No dike is provided for the left bank along this stretch, as it is desirable to utilize this Nookachamps Creek area for storage at the higher river stages. This storage is valuable in that it reduces the flood crests past the Great Northern Railway bridge. The existing diked channel below the Great Northern bridge has an estimated

maximum capacity of 140,000 second-feet, but the channel would not carry this discharge for long, as the dike material would soon become water-soaked and fail. To provide for a discharge of 220,000 second-feet (the greatest of actual record) below this point it would be necessary to enlarge the channel and to use the dredged material for the construction of adequate dikes.

103. It is estimated that a channel from Sedro-Woolley to Skagit Bay via the North Fork of Skagit River, adequate to carry safely a discharge of 220,000 second-feet, would require the excavation of approximately 56,000,000 cubic yards of material, and the acquisition of about 3,000 acres of agricultural land for right-of-way.

104. Erosion prevention. - It was suggested at the hearing in connection with the preliminary examination that one large item of flood damage—the erosion of land—might be reduced or eliminated by the revetment of banks at points of erosion or by elimination of some of the lands at which erosion is most severe. Velocities in the tidal section, that is the section downstream from near Sedro-Woolley, are so low that little bank erosion occurs even during flood seasons. Upstream from Sedro-Woolley, however, erosion has been severe in the past, and may be expected to continue unless remedial measures are undertaken.

105. The Works Progress Administration project (par. 74) has resulted in revetment of lands at a few critical points between Burlington and Hamilton and the removal of snags from the river, and will reduce erosion losses through that stretch of the river. Other points of erosion will, however, develop in the future as the force of the current is diverted by lodged snags, and from other causes, and it may be assumed that complete prevention of erosion will require revetment of practically the entire river from Hamilton to Sedro-Woolley. A comparison of maps made in 1907, 1911, 1930, and 1937 shows a total of 670 acres eroded in 30 years. Some of this land will, with time, again become usable, but taking no credit for any land that may resume a useful status, and giving the

lost land a high value of $300 an acre, there would be indicated a total loss from erosion from Hamilton to Sedro-Woolley, of $201,000, or an average of $6,700 a year.

106. The average annual damage from erosion would pay for the revetment of not more than 900 feet of riverbank and it is extremely doubtful that the revetment of 900 feet a year, even if it could be made at the proper place, would prevent all erosion.

107. An unknown but large amount of the erosion could be prevented by the periodic removal of the snags that lodge on the river bottom. Such removal would not only aid in preventing future flood damage but would be of material benefit to navigation on that portion of the river. Under the existing project for Puget Sound and its tributary waters, Washington, snagging is now done from Sedro-Woolley to the river mouth. At Sedro-Woolley the river has cut itself a new channel under the railroad bridge and left a dry channel under the swing span of the bridge, so that the snag boat is unable to get upstream from Sedro-Woolley. Above the railroad bridge some snags are removed by blasting, but this method is slow and expensive. If a derrick scow and towboat, capable of passing under the railroad bridge, could be rented when needed, it would be possible not only to keep the river free from snags but also to do urgently needed dredging at several bars that now obstruct the passage of logs and towboats during the low water season.

108. It is impossible to appraise accurately the benefits that would result from snagging the river channel. It is believed that the presence of snags and drift greatly accelerates bank erosion, and it is certain that navigation is seriously handicapped by lodged snags. As pointed out in paragraph 105 complete prevention of bank erosion would effect a saving of about $6,700 a year. The value of rafted logs transported on the Skagit River averages about $790,000 a year, the great bulk of the commerce originating upstream from Sedro-Woolley, and moving to sawmills on Puget Sound. It would appear that the combined benefits to bank

protection and to navigation of periodic snagging and a limited amount of dredging would amount to at least $10,000 annually.

109. Irrigation. - Irrigation is now practiced in the Skagit basin only to a limited extent, but throughout western Washington irrigation by overhead sprinklers, to supplement the low rainfall of the growing season, is becoming increasingly common. It is probable that in the Skagit basin many farms will install irrigation facilities in the next few years. The low water flow of the river is, however, sufficient to meet any foreseeable irrigation demand without storage and without detriment to other uses of the river.

110. Pollution, recreation, etc. - So far as is known to this office, no serious pollution problem has ever existed in the Skagit basin. During flood seasons the river leaves its banks and reaches tidewater by flowing overland across farm and barnyards. During such times the overflow waters probably find their way into the wells of the valley and carry a certain amount of pollution into them. Opposition to the construction of the Avon By-pass has been voiced by the oyster industry of Padilla Bay on the ground that the by-pass would discharge polluted water onto the oyster beds. In view of the fact that the by-pass would carry water only about 1 year in 5, and then for only 2 or 3 days, and that these same flood waters, under present conditions, reach Padilla Bay after flowing over land, it appears that the fears of the oyster growers are without foundation. Nevertheless, the estimated costs of the by-pass, as given in the authorizing act, are believed sufficient to permit the channel to be swung to the south of the oyster beds and to provide a training wall between the outlet and the oyster beds and thus to remove the objections of the oyster growers.

111. Neither the proposed Avon By-pass nor the proposed snagging upstream from Sedro-Woolley will have any material effect on the fish life of the river or the migrant waterfowl that feed along the margins of Skagit Bay, nor on the use of the river for recreational purposes.

112. Measures for run-off and waterflow retardation and soil erosion

prevention. - The Department of Agriculture has not completed its survey of Skagit River, and therefore, the measures to be proposed for run-off and waterflow retardation and soil erosion prevention are not yet known. Under date of July 18, 1940, the director, Pacific Northwest Forest and Range Experiment Station, states "Any program that is initiated by our Department would complement whatever measures are taken * * * for the control of floods on this stream."

VI. DISCUSSION, CONCLUSION, AND RECOMMENDATION

113. Discussion. - The project authorized by the Flood Control Act of 1936, i.e., the construction of Avon By-pass and the revetment of banks between Burlington and the point of diversion, appears to offer the greatest measure of relief from flood damage at the lowest aggregate cost. That project would afford protection to the area downstream from Sedro Woolley from a flood discharge of 220,000 second-feet, but would not reduce flood damage in the area upstream from Sedro-Woolley nor protect against such a flood as the one of 1856. As pointed out in paragraph 99 the local cooperation required for the construction of the Avon By-pass is considered by the local interests to be too great to be met under present conditions.

114. The proposed Sauk reservoir, if operated solely for flood control, would offer a large measure of protection from lesser floods throughout the whole area downstream from the dam site, but would probably effect little diminution in damage caused by larger floods. The cost of providing such storage would be materially greater than the cost of the Avon By-pass and the resulting benefits downstream from Sedro-Woolley very much less.

115. Reservation, for flood control during the winter months, of top storage in future power reservoirs could probably be made at a cost amply justified by the resulting benefits. Such storage alone would not offer adequate protection to the delta area, but if it were made the second step

in a program of which the Avon By-pass were the first step, even a flood such as that of 1856 would be carried safely through the delta lands. The Avon By-pass could be constructed whenever funds were made available, but provision of flood storage in the reservoirs cannot be economically secured until power development at those sites is undertaken at some indefinite future time.

116. Flood protection by means of dikes or channel improvement, or by a combination thereof, could be secured only at prohibitive initial and maintenance costs.

117. There appears to be reasonable possibility that partial protection against erosion of valuable agricultural land, and material aid to navigation on the river upstream from Sedro-Woolley, could be secured at a cost of $10,000 annually and that such a cost would be justified by the resulting benefits.

118. Conclusion. - In view of the foregoing it is concluded that the only feasible method of providing flood control for the area downstream from Sedro-Woolley is by the Avon By-pass, augmented by reservation of top storage in future power reservoirs, but that there is no possibility that the required local cooperation for the by-pass can be secured at present and only a remote possibility that any of the proposed power reservoirs, excepting Ross reservoir, will be built in any foreseeable future. Partial protection from bank erosion between Hamilton and Sedro-Woolley, and material aid to navigation through the same stretch, is possible by snagging and dredging at an estimated annual cost of $10,000. Because of the importance of this snagging to navigation, it is concluded that the work might well be done as a Federal project.

119. Recommendation. - I therefore recommend that no modification be made in the existing project for flood control of Skagit River, and that a project for snagging and dredging of Skagit River upstream from Sedro-Woolley be adopted, at an estimated annual cost of $10,000, all from Federal funds.

2 Incl.:
Map (E-6-6-2) tracing and 14 prints (separate roll)
Appendix (15 copies)

B. C. Dunn,
Colonel, Corps of Engineers,
District Engineer.