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SKAGIT RIVER, WASH.

LETTER

FROM

THE SECRETARY OF WAR

TRANSMITTING

WITH A LETTER FROM THE CHIEF OF ENGINEERS, REPORT ON PRELIMINARY EXAMINATION OF SKAGIT RIVER, WASH., WITH A VIEW TO CONTROL OF THE FLOODS

DECEMBER 12, 1925.—Referred to the Committee on Flood Control and ordered to be printed.

WAR DEPARTMENT,
Washington, December 7, 1925.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

MY DEAR MR. SPEAKER: I am transmitting herewith a letter from the Chief of Engineers, United States Army, of the 4th instant, together with report of Col. W. J. Barden, Corps of Engineers, dated January 31, 1925, on preliminary examination of Skagit River, Wash., authorized by the flood control act of May 31, 1924.

Sincerely yours,

DWIGHT F. DAVIS,
Secretary of War.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, December 4, 1925.

Subject: Preliminary examination of Skagit River, Wash.
To: The Secretary of War.

1. There is submitted herewith, for transmission to Congress, report dated January 31, 1925, by Col. W. J. Barden, Corps of Engineers, on preliminary examination of Skagit River, Wash., authorized by the flood control act of May 31, 1924.

2. The Skagit River rises in British Columbia and flows south and west through the State of Washington into Skagit Bay, an arm of Puget Sound. Its drainage area is about 3,100 square miles. In its upper and middle reaches it flows through mountainous or hilly country which is sparsely populated and in which the principal activity is lumbering. Near the town of Sedro Woolley, about 25 miles above its mouth, it enters a flat and fertile plain. The lower 9½ miles have been improved for navigation by the Federal Government by the provision of dikes and other works, and a limited amount of snagging and dredging has also been undertaken.

3. The river is subject to heavy floods, of which the most serious of record have occurred in November and December, but which may occur at any season on account of the action of warm southwest winds in melting the snow on the high mountains in which the river has its source. Examination of alluvial deposits and other evidence point to the occurrence of floods about 1815 and about 1856, with discharges, near the present site of Sedro Woolley, of about 400,000 and about 300,000 second-feet, respectively. Since 1896 there have been six floods whose discharges at this point exceeded 180,000 second-feet, two of which had a volume of 210,000 second-feet or more. Local interests desire Federal assistance in the control of these floods.

4. The district engineer, who is also the division engineer, reports that the principal flood problem is encountered in the flat valley and delta country at and below Sedro Woolley. This section contains three towns with a combined population of over 8,000. The area is devoted to agriculture and the production of dairy products, the annual value of which is in the neighborhood of $7,500,000. To protect their land from floods, local interests have organized themselves into a number of independent drainage and diking districts, which are reported to have expended to date about $1,800,000 in protective works, in addition to amounts spent by individuals. The works have in many cases been badly designed, particularly as regards the location of the main levees along the river, which have been placed too close together, thereby unduly restricting the floodway. As a result, the channel below Sedro Woolley will probably not carry in excess of 140,000 second-feet without a breach in the levees. If it did carry a much greater volume than this, the result would be to endanger a railroad bridge between Mount Vernon and Burlington, which if carried away would in turn probably cause the destruction of two other bridges below it. The solution of the problem therefore involves either holding the flood volume below about 140,000 second-feet, or modifying the bridges and protective works so that a larger amount can safely be carried.

5. In the opinion of the district engineer, at long intervals of time there are likely to be floods with a volume of 300,000 second-feet or over, but he considers that the expense of protective works designed for these would probably be prohibitive. Floods of 210,000 to 220,000 second-feet may be expected about once every 25 years, and it is for these that additional works, if undertaken at all, should be designed. He discusses three methods for guarding against them: By detention reservoirs in the upper valley; by an increase in the carrying capacity in the lower river, either by dikes or by channel improvement; by a diversion channel.

6. The district engineer thinks it unlikely that detention reservoirs designed and operated solely for flood prevention would be justified, in view of their expense. Some relief might be afforded by dams and reservoirs created in connection with hydroelectric development. Two such dams are now being constructed in the upper valley, and others will probably be built later. It is possible that arrangements might be made with the power companies whereby they would permit the use for flood-prevention purposes of a certain amount of their reservoir capacity. In addition to artificial reservoirs, there is a beneficial effect from the natural storage of low-lying lands not protected from floods. This is especially noticeable in the vicinity of Nookachamps Creek, between Sedro Woolley and Mount Vernon, where there is an unprotected area of 10 square miles, the effect of the natural storage of which is to reduce the volume of high floods by about 20,000 second-feet. The district engineer thinks it undesirable that the natural storage, at this and other points, should be reduced by further reclamation works, unless arrangements are made fo flooding the areas during high freshets.

7. Modification of the levees to provide a complete solution of the problem would probably require the moving back of the entire main line levee on one side or the other of the river, a quite expensive undertaking. Supplementary levees behind the main ones have been suggested, but the district engineer doubts their utility. He also considers impracticable a solution by means of channel enlargement except as this might be undertaken to a limited extent in connection with further levee construction.

8. It would be possible to divert the river at some point below Sedro Woolley through an artificial channel running west into Padilla Bay. The district engineer considers four alternative routes for such a channel, but in advance of a survey is unable to pass definitely on their relative merits.

9. The district engineer concludes that, while a diversion channel appears to offer the most satisfactory solution, it is impracticable without a survey to determine what method or combination of methods would give the best results. In view of the probable cost of any complete scheme, and of the localization of benefits, he does not feel that the Federal Government is justified in undertaking or cooperating in protective works. He believes however that a survey is justified, at an estimated cost of $20,000.

10. This report has been referred, as required by law, to the Board of Engineers for Rivers and Harbors, and attention is invited to its report herewith. The board agrees with the district engineer as to the desirability of a survey, but feels that the locality should meet half its cost.

11. After due consideration of the above-mentioned reports, I concur in the views of the Board of Engineers for Rivers and Harbors. The area on the lower Skagit affected by floods is some 75,000 acres, and it is claimed that the average annual loss by floods in past years has been about $150,000. Navigation or other general interests are but little affected. I am not prepared at this time to pass on the advisability of the Government assisting in the construction of protective works, but I feel that the complexity of the problem and the failure of the locality to devise a satisfactory plan for itself or to coordinate with the various works heretofore undertaken, render it

advisable for the United States to make a survey. Due, however, to the localization of the benefits and the considerable cost of the survey, it is proper that those concerned should meet part of such cost. I therefore report that a survey is advisable, with a view to preparing plans and estimates of cost for the prevention and control of floods in the Skagit River, Wash., at an estimated cost of $20,000, provided that local interests contribute 50 per cent of this amount, or $10,000.

H. TAYLOR,
Major General, Chief of Engineers.

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

SYLLABUS

The Board of Engineers for Rivers and Harbors recommends a survey, with a view to preparing plans and estimates of cost for the prevention and control of floods in the Skagit River, Wash., at an estimated cost of $20,000, provided local interests contribute $10,000 to the cost of the survey.

(Second Indorsement)

BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, D. C., February 26, 1925.

To the CHIEF OF ENGINEERS, UNITED STATES ARMY:

1. The following is in review of the report on preliminary examination of Skagit River, Wash., authorized by the flood control act of May 31, 1924.

2. The Skagit River rises in British Columbia and flows south and west for 125 miles into Skagit Bay, an arm of Puget Sound. It is under improvement by the Federal Government under a project providing for the improvement of the lower 9½ miles of the navigable channel by dikes and other works; also, under the general project for "Puget Sound and its tributary waters," a limited amount of snagging and dredging has been undertaken in the Skagit. Local interests now request Federal assistance in controlling the river's floods.

3. The drainage area of the Skagit is about 3,100 square miles, principally in the United States. Its largest tributaries are the Sauk, Baker, and Cascade Rivers, with drainage areas, respectively, of 715, of 270, and of 222 square miles. The sources of these rivers are in the Cascade Mountains. From its head to near the town of Sedro Woolley the Skagit flows through mountainous or hilly country, generally heavily timbered and sparsely populated. The drainage area above Sedro Woolley is 2,970 square miles, or about 95 per cent of the total. From this point the river flows to Skagit Bay through a flat and fertile plain. About 9 miles above the mouth it assumes a delta formation and enters the bay by several mouths, of which the principal ones are the North and South Forks.

4. The district engineer, who is also the division engineer, reports that the principal flood problem is concerned with this lower stretch of the river between Sedro Woolley and the mouth. The territory along the river and in the delta has a present annual production of 120,000 tons of oats, hay and straw, potatoes, and general farm

products, valued at about three and one-half million dollars. There is also a considerable production of dairy products, the annual value of the condensed-milk output being about $4,000,000. The principal communities are Mount Vernon, 11 miles above the mouth of the river, Sedro Woolley, 25 miles, and Burlington, the latter lying to the north of the river about midway between the first two. The combined population of these three is over 8,000.

5. Above Sedro Woolley there are several small communities along the river, the most important being Lyman, Hamilton, and Concrete. The latter, at the mouth of the Baker River, 58 miles above the mouth of the Skagit, is the center of a cement industry. Otherwise, the principal activity in the upper valley is lumbering.

6. The river is subject to floods of considerable intensity. The most serious ones of record have been in the months of November and December. Floods are, however, likely to occur at any season, due to the action of intermittent warm southwest winds, known as "chinooks," which cause a rapid melting of the snow on the high mountains in the upper valley. Examination of alluvial deposits, the testimony and traditions of the original Indian inhabitants, and other evidence point to floods having occurred about 1815 and about 1856 considerably in excess of anything subsequently recorded. Since 1896 there have been six floods of considerable intensity and a number of minor ones. The following gives the best available data or estimates as to height and discharge of these floods near Sedro Woolley:

All of this verbiage came directly from the 1923 unpublished Stewart Report.

Date	Gauge height, feet	Discharge (cubic feet per second)	Date	Gauge height, feet	Discharge (cubic feet per second)
About 1815	33.5	400,000	Nov. 16, 1906	24.7	180,000
About 1856	30.0	300,000	Nov. 30, 1909	26.5	220,000
Nov. 16, 1896	24.8	185,000	Dec. 30, 1917	24.1	195,000
Nov. 19, 1897	24.9	190,000	Dec. 13, 1921	24.3	210,000

7. The lower stretch of the river has been diked and leveed by local interests, operating through a number of independent drainage districts and diking districts. The expenditures of these districts to date are said to have been over $1,800,000, and including other works undertaken by individuals it is likely that the total amount spent by the locality for flood control exceeds $2,000,000. The works undertaken are not well coordinated, and were frequently badly designed in that the levees, to protect as much land as possible, were placed too close to the river on both sides, thus unduly restricting the channel. A flood volume exceeding about 140,000 second-feet below Sedro Woolley is likely to cause a breach in the levees. A volume in excess of this, if retained in the floodway by higher levees, would endanger the bridge of the Great Northern Railway, which crosses the river about 18 miles above its mouth between Mount Vernon and Burlington. If this bridge were carried away, it would probably result in the destruction of two other bridges just below it, one used by the Pacific Northwest Traction Co. and the other a highway bridge. The problem therefore reduces either to holding the flood volume below this amount of about 140,000

second-feet or to modifying levees, bridges, and other works so that a greater flow can safely be passed.

8. From a consideration of past records, and from theoretical computations, the district engineer is of the opinion that maximum floods are likely to occur at long intervals with a volume of 300,000 second-feet or more. He considers that works designed for security against such floods would probably be of prohibitive cost. Floods of from 210,000 to 220,000 second-feet may be expected about once every 25 years, two having occurred in the past 16 years. In his opinion, measures of relief, if found practicable at a reasonable cost, should be designed for floods of this size. He considers three means for relief:

(*a*) Detention reservoirs in the upper valley.
(*b*) Increase in the carrying capacity of the lower river, either by dikes or by channel improvement.
(*c*) A diversion channel.

9. As regards detention reservoirs, the district engineer thinks it unlikely that the cost of works designed for this purpose alone would be justified by the benefits. He considers possible, however, that flood control might be combined with hydroelectric development. Based on an investigation several years ago by the Geological Survey, power developments are in progress at two points in the upper valley, one on the Baker River, the other on the Skagit above the mouth of Cascade Creek. Modification in the design of either of these projects for the purpose of including flood control features might result in complications, due either to the flooding of land in Canada, to the flooding of land in a national forest of the United States, to increased cost of the work, or to reduction of the pondage available for power purposes. It is, however, possible that arrangements might be made with one or the other of the power companies in charge of the present developments whereby for a money consideration they would modify their plans so as to provide for the impounding of a certain amount of flood water. It is also likely that there will be other power developments in the upper valley which may also involve flood control possibilities and whereby conditions may to some extent be further ameliorated.

10. The natural storage of low-lying lands in the valley has a beneficial effect in reducing floods in the lower river. The district engineer thinks it undesirable further to restrict this natural storage by levees unless arrangements are made for flooding such protected areas during high freshets. This applies especially to an area of about 10 square miles adjoining Nookachamps Creek, between Sedro Woolley and Mount Vernon, which it has been proposed to reclaim. The present effect of this natural storage is to reduce the flood volume at Mount Vernon by some 20,000 second-feet below that at Sedro Woolley.

11. As regards levees and channel enlargement, the present capacity of the floodway below the Great Northern Railroad bridge, about 140,000 second-feet, might be slightly increased by minor changes in the levee system, but satisfactory results could probably be obtained only by reconstruction of one or the other of the two main levees for practically its entire length. This would be quite expensive. Emergency levees behind the present system have been suggested, but the district engineer doubts their utility. A solution by channel

improvement alone he considers impracticable, on account of the cost of digging and maintaining the channel and the difficulty of disposing of dredged material. A limited amount of channel improvement might, however, be found desirable in connection with further levee construction, together with the removal of drift and the clearing of brush in certain localities.

12. Diversion of the river would be possible at some point below Sedro Woolley, the diversion channel to run generally west into Padilla Bay. The district engineer discusses briefly four alternative routes, but is unable to give a definite opinion as to their merits in advance of a survey. Any of them would be quite expensive.

13. The district engineer concludes that, with the information now available, it is impossible to determine what method or combination of methods would give the most satisfactory relief from floods. He is inclined to think that a diversion channel might offer the best solution, but feels that careful study should also be given to other methods. Turning to the importance of the problem, he points out that the benefits would accrue to local interests substantially in the following order: Owners of flooded land, towns along the river, the Great Northern Railway, the Pacific Northwest Traction Co., Skagit County, the State of Washington, the Puget Sound & Baker River Railway, and the Puget Sound & Cascade Railway. The effect of any of the proposed works on navigation would be slight. The interest of the Federal Government is therefore confined to its general concern for the safety and prosperity of any of its citizens and for the conservation of the country's resources. The district engineer considers that, since the benefits would be principally local, the United States would not be justified in actually undertaking any works for flood protection, either alone or in cooperation with local interests. He does, however, consider that it is justified in making a survey to develop a comprehensive plan, at an estimated cost of $20,000. He recommends that such a survey be undertaken.

14. This is a case involving an area of about 75,000 acres and a population of perhaps 10,000, whose average annual loss from floods in the past is estimated to have been in the neighborhood of $150,000. It involves also the safety of the bridges and rights of way of several railroad lines, including a branch line of one transcontinental railroad. The situation has arisen, common in the United States, of a number of works for flood control constructed by local interests at considerable expense, but without general coordination and without proper design and forethought. As a result, the lower valley of the Skagit is susceptible to considerable damage in times of high flood, and will continue to be unless and until the entire problem is subjected to an expert and disinterested study, and properly designed and probably quite expensive works are installed. The board is not convinced that the interest of the United States is sufficient to justify it in meeting any of the cost of such works, but believes that there is sufficient national interest so that the Government may properly make a study and recommend a solution, particularly since it is probably the best qualified agency to undertake such a study. Due, however, to the considerable cost of the survey and to the localization of benefits, the board feels that it is proper to demand a 50 per cent cooperation in the cost thereof. It therefore recommends that a survey be au-

thorized, at an estimated cost of $20,000, with a view to preparing plans and estimates of cost for the prevention and control of floods in the Skagit River, Wash., provided that local interests contribute $10,000 to the cost of the survey.

For the board:

EDGAR JADWIN,
Brigadier General, Corps of Engineers,
Senior Member of the Board.

PRELIMINARY EXAMINATION OF SKAGIT RIVER, WASH.

SYLLABUS

The Skagit River is subject to severe floods which cause great damage, chiefly to the rich farm lands and communities of the delta below Sedro Woolley.

Local interests have spent large sums in the construction of dikes (levees) but in the absence of any properly coordinated plans these have in general been located too close to the banks and therefore do not provide adequate capacity for large flood flows. In such floods the dikes break and the delta is flooded, causing damages estimated by local interests at from $500,000 to $1,500,000.

Insufficient data are available to permit of the determination of the best plans for flood relief. The cost of protection against floods of maximum size would be prohibitive and protection against floods of moderate size would be expensive. To secure this by dikes alone or in combination with channel enlargement would require reconstruction of the present system of dikes from above the Great Northern Railway bridge to the mouths of both forks. A diversion channel or by-pass to Padilla Bay might be found feasible. The cost of detention reservoirs for flood protection alone would probably be excessive, but there is a possibility that some degree of relief might be secured at reasonable cost by arrangements for storage of flood waters in reservoirs under contemplation in connection with power projects.

The benefits of any improvement would appear to be almost wholly to local, railroad, county, and State interests. Navigation interests are small and can be provided for at comparatively small costs under the existing project, slightly modified. The interest of the General Government is indirect only but it appears to be the best agency to secure cooperation between the various interests directly involved.

The district engineer concludes that the United States should not undertake any works of improvement for flood relief either alone or in conjunction with local interests, but that it should cooperate to the extent of securing data and preparing plans and estimates of costs and recommends a survey for that purpose.

WAR DEPARTMENT.
UNITED STATES ENGINEER OFFICE,
Seattle, Wash., January 31, 1925.

Subject: Preliminary examination of Skagit River, Wash., with a view to control of the floods.

To: The Chief of Engineers, United States Army.

1. In compliance with section 1 of the act of May 31, 1924, "Authorizing preliminary examination and surveys of sundry streams with a view to the control of their floods" and instructions contained in the department letter [1] of June 21, 1924, the following report, with maps in three sheets [1] is submitted on a preliminary examination of Skagit River, Wash.

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[1] Not printed.

2. *General description.*—The following description of the Skagit Basin is quoted from Water Supply Paper No. 419, published in 1916 by the United States Geological Survey:

Skagit River, the largest stream tributary to Puget Sound, rises in Beaver Lake, British Columbia, 20 miles north of the Canadian line, and flows southwestward 125 miles to its mouth near Mount Vernon, Skagit County, Wash. Below Mount Vernon it passes by several channels through its delta into Skagit Bay, an arm of the sound.

Its basin comprises 3,100 square miles on the western slope of the Cascade Mountains, touching the crest for 130 miles, measured along the divide, or 90 miles in a straight line, extending from Indian Pass northward along the eastern boundaries of Snohomish, Skagit, and Whatcom Counties to the Canadian line, thence northward 20 miles into British Columbia, where it reaches Fraser River basin.

Altitudes within this area range from sea level to about 7,000 feet on the Cascade divide and to more than 11,000 feet at the summit of Mount Baker, the highest peak in this basin. Other mountains whose slopes are drained by the Skagit are Glacier Peak and Mount Shuksan. Roughly speaking, the greater part of this area that is above an altitude of 1,000 feet—approximately 2,500 square miles—is in the Washington and Snoqualmie National Forests. Above the timber line and within the zone of perpetual snow much of the surface is barren rock. On Mount Baker and Glacier Peak there are many glaciers, which furnish the most permanent water supply of the river. Below an elevation of about 4,000 feet the area is in general timbered with Douglas fir and hemlock, which are smaller and less abundant with increase in altitude. Some of the heaviest stands of Douglas fir are found on the lower stretches of this area. Cedar also is abundant.

The prevailing soil on the higher elevations is coarse glacial gravel, but there are many pockets of loam in the valleys, and the deposits of limestone and clay at the mouth of Baker River are notable, as they furnish materials for the Portland cement factories there. Underbrush and litter are thick on the lower levels and along the stream courses, become thinner up the slopes, and die out before they reach the timber line.

The greater part of this area is snow covered to a depth of 2 to 10 feet in winter and to much greater depths on the higher slopes and peaks. As on all streams in the Puget Sound region, the minimum stages of the streams are reached in September and October, when freezing nights cut off the snow water from the higher slopes and the drought still prevails in the valleys and low areas. A second low stage comes in February, when the streams in the higher courses are ice locked and when all precipitation is held back in the form of snow.

The two largest tributaries of Skagit River are Sauk and Baker Rivers. Thunder Creek, Ruby Creek, and Cascade River are also large, as they head in the high Cascades.

Sauk River, the largest of the tributaries, drains 731 square miles, mostly in the northeastern part of Snohomish County, and enters the Skagit approximately at the head of navigation near the town of Rockport. From its mouth to its most distant source at Indian Pass the river is about 50 miles long. Glacier Peak, 10,436 feet above sea level, is the highest peak in this area. A large part of the basin is above the timber line and much of it is in the zone of perpetual ice and snow.

Baker River, the tributary second in importance, heads at Hannegan Pass, on the eastern slope of Mount Shuksan, and flows southward about 25 miles, passing through Baker Lake, on the southeastern slope of Mount Baker, to its junction with the Skagit, 58 miles above the mouth of that river, at Concrete, Wash. The basin of this stream comprises 295 square miles, is very mountainous and rugged, and is chiefly in Whatcom County, within the Washington National Forest. Like the Sauk, this river drains much surface within the zone of perpetual ice and snow, and is fed by the glacial fields of Mounts Baker and Shuksan.

3. The lower river is affected by the tide to the Great Northern Railway bridge, about 17 miles above the mouth. The extreme tidal range at the mouth is 20.5 feet; the range between mean lower low water and mean higher high water is 11.4 feet.

4. *Previous examinations and surveys.*—No previous examination of this river with a view to the control of floods has been made. Examinations and surveys with a view to improvement for navigation have been made as follows:

(*a*) Examination, February 11, 1875. Page 791, Annual Report Chief of Engineers, 1875. Favorable for improvement by removal of snags, log jams, and some bank protection at an estimated cost of $15,000.

(*b*) Examination, July 14, 1881. Page 2603, Annual Report Chief of Engineers, 1881. Favorable for construction of snagboat at an estimated cost of $15,000 and $10,000 per year for operation for snagging on this and other streams entering Puget Sound.

(*c*) Preliminary examination, November 8, 1890. (H. Ex. Doc. No. 38, 51st Cong., 2d sess.) Unfavorable except for more efficient removal of snags.

(*d*) Survey Skagit River from mouth to the town of Sedro, Wash., ordered by river and harbor act of June 3, 1896. Report dated December 11, 1897. (H. Doc. No. 204, 55th Cong., 2d sess.) Unfavorable.

(*e*) Preliminary examination and survey Skagit River, Wash., up to Sedro Woolley ordered by river and harbor act of March 2, 1907. Reports on preliminary examination dated April 15, 1907, and on survey dated March 31 and November 3, 1908. (H. Doc. No. 1188, 60th Cong., 2d sess.) Favorable for securing a reliable channel of entrance through the delta at the mouth by construction of a training dike and cutting off subsidiary channels and by construction of regulating dikes and a mattress sill at head of North Fork at an estimated cost of $100,000.

(*f*) Preliminary examination and survey Skagit River, Wash., from Sedro-Woolley to Baker ordered by river and harbor act of June 25, 1910. Reports on preliminary examination dated November 5, 1910, and on survey dated February 29, 1912. (H. Doc. No. 909, 62d Cong., 2d sess.) Unfavorable.

(*g*) Preliminary examination and survey Skagit River, Wash., ordered by river and harbor act of July 25, 1912. Report on preliminary examination dated December 6, 1912, and on survey dated January 26, 1914. (H. Doc. No. 935, 63d Cong., 2d sess.) Favorable for improvement of Skagit City Bar by combined dredging operations and training walls at not to exceed $30,000.

(*h*) Report of Board of Engineers for Rivers and Harbors dated December 26, 1919, and related report by district engineer dated March 10, 1919, on previous report (*g*) as required by river and harbor act of March 2, 1919. (H. Doc. No. 591, 66th Cong., 2d sess.) Favorable for same work, but at an estimated cost of $45,000 and with local cooperation to the extent of assuming all claims for damages.

(*i*) Preliminary examination, Skagit River, Wash., ordered by river and harbor act of September 22, 1922. Report dated February 9, 1924. Favorable for small amount of dredging to be done under general project for Puget Sound and tributary waters. Not published.

5. Discharge and other data of value in connection with a study of plans for flood control are found in United States Geological Survey Water Supply Papers and in an uncompleted report on Skagit River floods prepared by Mr. J. B. Stewart, of the United States Geological

Survey, jointly for that bureau and Skagit County, a copy [1] of which has been furnished this office.

6. *Improvement for navigation.*—(*a*) *Original conditions.*—In its original condition extensive shoals at the mouths of both the North and South Forks prevented access from Skagit Bay to the river channels except on tides. Inside the mouths ample depths were in general available to the forks. The least depth was at the Skagit City Bar about 6 miles from the mouth of the South Fork. In the early days what was known as the Old Main River was the principal channel. When first officially examined in 1875 the river was much obstructed by snags and at and above the forks navigation was completely blocked by two large timber jams or rafts. After the removal of these rafts in 1877–1879, mainly by the efforts of the early settlers, the river was navigable for boats of about 3 feet draft at most stages to Avon, 14 miles above the mouth, and during ordinary high water to the Sauk River, 69 miles from the mouth. During extreme high water boats occasionally ascended the river as far as "The Portage" (about 88½ miles).

(*b*) *Previous projects.*—The removal of snags and other obstructions in this river was first undertaken in 1880 under an appropriation of $2,500 made by the act of June 14, 1880. Since 1882 this work has been continued by the snagboat maintained and operated under the general appropriation for the improvement of Puget Sound and tributary waters. The boat is equipped with a clamshell bucket and has done a limited amount of dredging in connection with its main work of removing obstructions.

(*c*) *Existing project.*—The existing project, based on report printed in House Document No. 1188, Sixtieth Congress, second session, was adopted by the river and harbor act of June 25, 1910, and provides for a low-water channel in the South Fork between Skagit Bay (Saratoga Passage) 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 closing subsidiary channels in the delta at an estimated cost of $100,000. The estimated annual cost of maintenance is $5,000. The act of March 2, 1919, authorized a project for increasing the depth at Skagit City Bar by dredging and the construction of training dikes subject to certain conditions of local cooperation which have not been complied with.

(*d*) *Work done and present conditions.*—The mattress sill at the head of North Fork, the dikes closing off subsidiary sloughs, and the training dike at the mouth of the South Fork were completed in 1911 with the exception that the latter dike, on account of increased cost of the work over the estimate, is 5,500 feet shorter than the project length of 16,000 feet. Since completion minor repairs have been made to the dikes as required, and they are in general in good condition. The expenditures to December 31, 1924, have been $99,829.80 for new work and $18,676.10 for maintenance, a total of $118,505.90. These figures do not include the cost of the removal of snags and other obstructions under the general appropriation for the improvement of Puget Sound and tributary waters. The expected results in the way of increased depth have not been secured and the controlling depth over the bar at the mouth of the South Fork does not exceed 1½

[1] Not printed.

feet at mean lower low water. It also appears that some deterioration has taken place in the depths in the South Fork at points above the mouth, chiefly at Skagit City Bar, and as a result the freight boats running to Mount Vernon have for several years past used the North Fork. The sill at the head of the latter has recently been partially removed to facilitate the use of this fork.

7. *Past and present commerce.*—The commerce for 1923 was as follows:

Commodity	Tons	Value	Commodity	Tons	Value
Canned milk	12,116	$2,059,720	Fuel oil	3,304	$30,736
Butter	262	222,700	Sand and gravel	21,000	18,901
Eggs	267	115,878	Miscellaneous	11,462	3,058,555
Hay, grain, and vegetables	7,100	284,000			
Floated logs	376,613	2,259,678	Total	432,829	8,064,523
Lumber and shingles	705	14,355			

8. Prior to the advent of the railroads into this valley in about 1890 the river afforded practically the only means of communication with the outside world. Since that time the number of passengers carried by boat has steadily decreased from about 12,000 in 1892 to 33 in 1922. The percentage of the commerce carried by boats has largely decreased but the total amounts have increased, the average for the last five years having been 67,750 tons per year. Of this amount, however, 30,000 tons were sand and gravel, most of which was dredged near Riverside and hauled down the river to Mount Vernon.

9. The only company now operating freight boats on a regular schedule is the Skagit River Navigation Co. This company operates one boat regularly between Seattle and Mount Vernon, making three trips a week, the times of arriving and departing from the Skagit River being variable according to the stage of the tide. A second boat is put on the river in the fall of the year when the grain and hay shipments are heavy. These vessels are stern-wheel freighters of 477 and 638 gross tons, drawing 2½ feet light and about 7 feet when loaded. No freight boats now go above Mount Vernon.

10. The bulk of the water-borne traffic has always been the floating or rafting of logs. This reached a maximum of 674,492 tons in 1918 and the average for the five years prior to 1923 was approximately 480,000 tons. In recent years most of these logs have been brought in by rail by the Puget Sound & Baker River Railway, which traverses the upper Skagit Valley to near Hamilton (41 miles above the mouth) and thence back into the timbered hills, and dumped into the river about five miles above Mount Vernon. There they have been rafted and then towed down the South Fork and across Skagit Bay to Utsaladdy where deep-draft towboats took them to the various mills on Puget Sound. Recently, however, this company, on account of the difficulties of navigating the river, has extended its terminus to Similk Bay, near Deception Pass, and is no longer using the Skagit River. The English Logging Co. is the only one operating on the river at the present time. It dumps its logs into Tom Moore's Slough near the mouth of the South Fork from which place they are towed to Utsaladdy.

11. *Prospective commerce.*—The total tonnage will be less in the future than in recent years due to the closing down of the operations on this river of the Puget Sound & Baker River Railway Co. The tonnage carried by the freight boats may, however, be expected to increase at a moderate rate, especially if somewhat better boat service is provided. Navigation is now hampered by lack of depth at low tide on the bar and at a few shoal spots in the river. Boats are obliged to run on the tides and this tends to disarrange their schedules. A slight increase of depth at the mouth and over a few short shoals in the river which would permit navigation at stages of tide somewhat above the lowest would be beneficial.

12. *Bridges.*—The lower river is crossed by eight bridges as shown by the following table:

No.	Miles above mouth	Owner	Distance to nearest town (miles)	Character	Horizontal clearance (feet)	Vertical clearance at high water (feet)	Cross-sectional water area at flood stages (square feet)
1	(NF) 3½	Skagit Co.	Conway, ¼	Swing	80	7	10,450
2	(SF) 5½	do	Conway, 5½	do	115	10	9,950
3	12¾	do	Mount Vernon, 0	do	109	6	19,740
4	17	do	Mount Vernon, 1	do	100	10	21,300
5	17¼	Pac. NW. Tr. Co.	do	do	98	8	21,800
6	17¾	G. N. R. R.	Mount Vernon, 1¼	do	80	12	19,000
7	25	N. P. R. R.	Sedro-Woolley, 1	do	91	10	[1]
8	25¼	Skagit Co.	Sedro-Woolley, ¼	do	100	13	25,600

[1] Not measured.

13. *Towns.*—Mount Vernon, about 11 miles above the mouth, and Sedro Woolley, about 14 miles farther upstream, each with a population of some 3,500 are the largest towns in the valley. Mount Vernon is the county seat of Skagit County, and is the center of an extensive agricultural and dairying community. Other towns lying in the valley and subject to damage by floods are as follows: Burlington, population 1,360, about 3½ miles north of Mount Vernon; Lyman, population 500, about 8 miles by road above Sedro Woolley; Hamilton, population 500, about 3 miles above Lyman; Concrete, population 900, about 31 miles above Sedro Woolley; Conway, Fir, and Milltown, small settlements, each of about 100 inhabitants, located on the South Fork of the river below Mount Vernon.

14. *Railways.*—The Great Northern Railway traverses the district north and south through Mount Vernon, and the Northern Pacific runs in the same direction through Sedro Woolley. A branch of the former runs west from Burlington to Anacortes and east up the Skagit River to Rockport. The Puget Sound & Cascade River Railroad is being constructed from Mount Vernon up the south side of the river to Finney Creek. It will probably be extended farther up the valley. It and the Puget Sound & Baker River Railway referred to in paragraph 10 are, under the State law, common carriers, but are operated almost exclusively for the transportation of logs.

15. *Resources and local industries.*—The Skagit River delta contains some of the richest farming land in the State. The average

yearly production of oats is given as approximately 50,000 tons; of hay, 30,000 tons; of potatoes, 12,000 tons; of straw, 18,000 tons; of general farm products, 10,000 tons; or a total of 120,000 tons of coarse farm products with an estimated value of $3,400,000 at present prices. In addition there is the production of vegetable seed which amounts in value to over $200,000 per annum and is increasing. It is said that the valley grows 80 per cent of the cabbage seed produced in the entire United States.

16. The delta is also a good dairying country and there are two large condensing plants at Mount Vernon and one at Burlington, the annual value of the product being approximately $4,000,000.

17. All of this tonnage comes from a territory within a radius of about 10 miles from Mount Vernon. Commodities are generally trucked to the shipping centers of Mount Vernon, Sedro Woolley, Burlington, and other small towns, Mount Vernon being the principal point from which shipments by water are made.

18. There is still a large amount of timber in and tributary to the Skagit Valley. The annual lumber shipments are given as approximately 300,000,000 feet board measure (approximately 500,000 tons).

19. *Floods.*—The Skagit River, in common with other rivers similarly located in this section, is subject to severe floods which frequently 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, which is known as the chinook. Such a wind, with accompanying precipitation, as it strikes the cooler temperature of the mountains, may occur at any time of the year and may be felt by a large or small extent of territory at the same time. A "chinook" striking a snow field causes the snow to melt with abnormal rapidity. The conditions surrounding the source of the Skagit are therefore such that a flood is liable to occur at almost any time. For example, in the year 1896, there was a flood in January 22 feet high near Mount Vernon; one in June, 20 feet high; and one in November of 24 feet. A "chinook" will usually cause a marked rise in the lower river about 36 hours after it begins to blow, the amount of the rise depending upon the precipitation, the intensity and warmth of the wind, and the amount of fresh snow on the mountains. The highest floods usually occur in November and December.

20. The first white people arrived in this valley about 1869. High water marks since then have been recorded from time to time, with increasing accuracy, of course, in later years. Prior to that time the records of floods depend upon testimony and traditions of the Indians, upon certain direct and indirect evidence of high-water marks and upon flood records elsewhere. Gauges have been established and regularly read and actual discharge measurements taken only since about 1908, and these are not in general complete over any extended periods. Mr. Stewart 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 approximately as large. This latter fact was determined at Reflector Bar, where alternate layers of flood sand and charcoal were found. The flood sand could have been deposited only by floods approximating the maximum size; while the charcoal could have been left only by forest fires which occurred during the time intervening between maximum floods." These maximum floods

had, he believes, about twice the discharge of recent floods and he also found evidence of a flood in 1856 about one and one-half times as great. The following data are taken from his report:

LIST OF 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.

November 16, 1896: Highest since settlement of thevalley and probably since 1856.

November 19, 1897: Everywhere nigher than tnat 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 subsequent floods above the Cascade 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 flood producing a great deal of overflow after the dikes had been broken.

December 13, 1921: Nearly as great as 1909.

21. Flood heights and peak discharges as determined by Mr. Stewart are shown in the following tables:

Skagit River at Reflector Bar.—Twenty-two and five-tenths miles above Marblemount and 4.5 miles below Ruby Creek. Above the main tributaries, Cascade, Sauk, and Baker. Drainage area, 1,100 square miles.

Date	Gauge height (feet)	Discharge (cubic feet per second)	Discharge in second-feet per square mile	Accuracy (per cent)
Unknown	21	120,000	109	20
About 1815	20.5	115,000	105	20
About 1856	18.5	95,000	88	15
Nov. 18, 1897	12.5	48,000	44	10
Nov. 29, 1909	15.4	70,000	64	10
Dec. 29, 1917	12.5	43,000	39	10
Dec. 12, 1921	14.5	63,000	57	10

Skagit River at The Dalles.—Two miles below the Baker River and 56 miles above the mouth. Drainage area, 2,700 square miles.

Date	Gauge height upper Dalles gauge (feet)	Discharge in cubic feet per second	Discharge in second-feet per square mile	Accuracy (per cent)
About 1815	56.6	500,000	189	10
About 1856	44.6	350,000	135	10
Nov. 19, 1897	38.4	275,000	106	15
Nov. 30, 1909	36.4	260,000	98	10
Dec. 30, 1917	33.0	220,000	81	10
Dec. 13, 1921	34.9	240,000	91	5

Skagit River near Sedro Woolley.—Twenty-five miles above the mouth. Drainage area 2,970 square miles.

Date	Gauge height (feet)	Discharge cubic feet per second	Discharge in second-feet per square mile	Accuracy (per cent)
About 1815	33.5	400,000	134	15
About 1856	30.0	300,000	101	15
Nov. 16, 1896	24.8	185,000	62	15
Nov. 19, 1897	24.9	190,000	64	15
Nov. 16, 1906	24.7	180,000	61	15
Nov. 30, 1909	26.5	220,000	74	10
Dec. 30, 1917	24.1	195,000	66	10
Dec. 13, 1921	24.3	210,000	71	10

Skagit River, at Mount Vernon.—Eleven miles above the mouth. Drainage area 3,062 square miles. At Mount Vernon the discharge of the 1921 flood was the only one determined, and this was unsatisfactory, due to breaking dikes, bridge obstructions, small slope, etc. The discharge in the river channel proper, below the break in the dikes just above the Great Northern Railroad bridge, was 140,000 cubic feet per second (accuracy within 20 per cent), and the total discharge was roughly estimated at 190,000 cubic feet per second.

22. It will be noted that for the 1921 flood the discharge at The Dalles is given as 240,000 cubic feet per second; at Sedro Woolley, 210,000 cubic feet per second; and at Mount Vernon, 190,000 cubic feet per second. This decrease in peak discharge as the floods advance down the river is due to the overflow of the banks. The overflow district acts as a storage basin and cuts down the peak, but increases the length of the flood.

23. The extreme low water discharge at Sedro Woolley is about 2,830 cubic feet per second and the mean yearly discharge about 16,400 cubic feet per second.

24. The determination of the discharge of the large floods prior to the settlement of the valley is necessarily of less accuracy than that of the later floods. Mr. Weston E. Fuller (Trans. A. S. C. E. Vol. LXXVII, p. 628) has determined a relation between the flood to be expected in a series of years and the average yearly flood of the form $Q = Q\ (Ave)\ (1 + 0.8 \log T)$ or as shown in the following table:

Time in years:	Ratio of largest flood to average yearly flood
10	1.80
25	2.12
100	2.60
500	3.16

The average flood (24 hours) at Sedro Woolley for the 14 years, 1908–1919 and 1921–22, was approximately 101,600 cubic feet per second. Applying these ratios to this figure a flood of about 183,000 cubic feet per second might be expected every 10 years; one of 215,000 cubic feet per second every 25 years; one of 264,000 every 100 years; and one of 321,000 cubic feet per second every 500 years. Peak discharges would exceed these figures by probably 15 per cent. Higher ratios have been found in certain cases, and it is stated (p. 92, Relief from Floods, Alvord & Burdick) that the Miami flood peak discharge at Dayton, Ohio, in 1913, was 4.92 times the average annual flood peaks.

25. The maximum rate of run-off per square mile in that flood at Miami town (3,937 square miles drainage area) was 98 cubic feet

per second (p. 60, Part IV, Technical Reports, Miami conservancy district). That rate applied to the 2,970 square miles above Sedro Woolley would give a flood of 291,060 cubic feet per second. The works carried out by the Miami conservancy district were designed to protect against a flood 40 per cent greater than that of 1913.

26. *Flood discharge of tributaries.*—The discharge data on the tributaries in general cover short periods only:

(*a*) *Cascade River.*—The Cascade River enters the Skagit at Marblemount. A gaging station was maintained from March, 1909 to April, 1913, about 8 miles above the mouth. The drainage area is about 222 square miles. The maximum discharge (24-hour period) was 31,700 cubic feet per second on November 29, 1909; the minimum, 212 cubic feet per second; and the mean for the period, 1,237 cubic feet per second.

(*b*) *Sauk River.*—The drainage area of the Sauk River is about 715 square miles. The Suiattle River which empties into it about 12 miles above the mouth has a drainage area of about 213 square miles. Gaging stations were established on the Sauk below the Suiattle and in the Suiattle but were maintained for such short periods that the records are of little value. A station has been maintained on the Sauk at Darrington, 23 miles above its mouth, with drainage area of 293 square miles, from June, 1914 to date. The maximum discharge (peak) was 36,000 cubic feet per second on December 29, 1917 and December 12, 1921; the minimum 340 and the mean 2,180.

(*c*) *Baker River.*—At the mouth of the Baker River at Concrete, drainage area 270 square miles, a gaging station was maintained from September, 1910 to March, 1915. At 11 miles above Concrete and just below Anderson Creek a station has been maintained from September, 1910 to date, drainage area 184 square miles. A conversion factor has been established between discharges at these stations, and applying this factor to readings at Anderson Creek, the maximum discharge (peak) at Concrete was 43,000 cubic feet per second on December 29, 1917, and 27,600 on December 12, 1921.

27. *Relative discharge from different sections.*—It will be noted from the tables, in paragraph 21, that the flood discharge in second feet per square mile for the upper Skagit Valley above the main tributaries is less than for the major portion of the watershed as measured at The Dalles and Sedro Woolley. The same is true for mean annual discharge. This is unusual. The discharge per square mile for the other portions of the watershed, and particularly of the tributaries that head in the mountains, must necessarily be far more than for the upper valley. The following table shows the conditions for the small flood of November, 1910 (the only year in which records exist for all five of the stations listed):

Station	Drainage area (square miles)	Discharge (24 hours) cubic feet per second	Discharge second feet per square mile
Upper Skagit, 1 mile above Goodell Creek	1,150	20,100	19
Cascade	222	10,800	50
Sauk, above Clear Creek	259	22,600	85
Baker, at mouth	270	17,400	65
Sedro Woolley	2,970	89,100	30

The maximum discharge of record for each of these areas is as follows:

Station	Date	Discharge	Discharge in second-feet per square mile
Upper Skagit	Nov. 29, 1909	[1] 63,500	55.2
Cascade	do	[1] 31,700	142.6
Sauk, at Darrington (drainage area 293 square miles)	Dec. 29, 1917 Dec. 12, 1921	[1] 36,000	122.3
Baker, at mouth	Dec. 29, 1917	[1] 43,000	158.0
Sedro-Woolley	Nov. 30, 1909	[2] 220,000	74.0

[1] Peak. [2] 24 hours.

28. *Existing dikes.*—The upper valley is generally narrow, with little low and. Near Sedro Woolley the hills recede and the valley widens into the delta, comprising an area of approximately 100 square miles of highly cultivated and valuable farming land. It is here that the greatest damage from floods occurs, though the towns in the upper valley are liable to damage from the larger floods. Below Sedro Woolley the channels have been generally diked (leveed) but the work has been done at various times by individuals and by some 16 different diking districts organized under the State law. Nearly one and one-half million dollars have been expended by these districts in the construction and maintenance of the dikes. In the absence, however, of any well studied or properly coordinated plans they have in many cases been improperly designed and located, the distance apart varying from 680 feet to over 1,200 feet along the main river above the forks. In general, in an effort to inclose as much land as possible, they have been placed close to the river bank without reference to the area required for the passage of flood waters. As a result frequent breaks have occurred due both to overtopping and undermining river bank and dikes.

29. The channel is also unduly restricted by the bridges above Mount Vernon, particularly at the Great Northern Railway bridge which is located immediately below a right-angled bend.

30. The existing dikes and diking districts are shown on sheets 2 and 3 of the accompanying map,[1] and additional data concerning them are given in the following table:

No.	Date organized	Area (acres)	Houses in district	Population	Estimated value of land		Amounts expended for diking		Annual assessments per acre		
					Total	Per acre	Total to 1923	Per acre	1921	1922	1923
1	1897	8,268	348	1,392	$2,388,775	$289	$256,878.56	$31.07	1.69	2.53	1.28
2	1897	2,632	86	344	734,386	280	146,562.52	55.69	.95	1.90	1.90
3	1897	6,408	667	2,668	3,686,086	279	318,082.30	49.64	1.58	4.49	2.18
4	------	1,584	50	200	344,100	218	14,946.82	9.44	.77	.64	.51
5	1897	2,828	22	88	580,915	206	124,778.01	44.12	3.20	3.19	3.19
8	1897	631	5	20	137,415	218	5,016.03	7.94	.79	.79	1.10
9	1897	1,419	15	60	358,760	253	19,582.58	13.80	------	.50	.25
12	1897	13,392	335	1,340	3,314,345	248	214,224.21	16.00	.21	.83	.83
13	1897	1,840	35	140	474,430	258	68,921.00	37.46	.42	2.17	2.17
15	1903	890	9	36	111,575	126	39,167.79	44.01	3.99	4.44	4.20
16	1904	438	16	64	97,315	223	17,158.71	39.17	1.24	2.25	2.30
17	1910	1,263	69	276	308,190	243	119,292.07	94.45	3.97	4.27	4.29
18	1918	576	6	24	108,545	186	15,939.42	27.67	3.02	3.41	4.87
19	1919	1,960	79	316	443,360	227	12,691.27	6.48	.80	.98	1.15
20	1919	537	18	72	62,045	116	11,270.33	20.99	1.90	1.87	1.87
21	1922	391	7	28	70,600	180	1,961.68	5.02	------	3.10	1.92
Total	------	45,057	1,767	7,068	13,216,842	------	1,386,473.30	------	------	------	------

[1] Not printed.

31. *Drainage districts.*—Supplementing the protection to the delta lands furnished by the diking districts, drainage districts have been organized for the purpose of providing the necessary drainage for the lower portions of the delta. These ditches are shown on the map and the following table gives data concerning the districts:

Name of district	Organized	Acres in district	Total levies to 1923, inclusive	Outstanding indebtedness in warrants	Bonds	Annual assessment per acre	
						1922	1923
Olympia Marsh	1900	9,474	$163,410.68	$33.12		0.48	0.43
Beaver Marsh	1906	9,455	100,530.48	12,643.56		.15	.99
Bow-Edison	1908	2,465	24,162.81	2,295.74		.47	.70
Mount Vernon-Conway	1909	5,003	114,125.98	199.61		1.60	1.40
Edison-Blanchard	1910	1,574	15,225.63	30.93		.32	.32
Avon-Fredonia	1922	6,590	17,967.98	1,254.04	$140,000.00	.91	2.73
Nookachamps	1920	537	2,876.19	59.72		.94	.94
Beaver Lake	1922	547	1,461.21	82.25	12,000.00		2.68
Total		35,645	439,760.96	16,578.97	152,000.00		

32. Including the amounts spent by individuals the total expenditures by local interests for the protection and reclamation of these lands may be conservatively estimated at $2,000,000.

33. In addition, following the flood of 1921 a levy of 1 mill on the assessed valuation of Skagit County was placed to provide for a fund in accordance with State law, known as the river improvement fund, to be used for the purpose of investigation of the flood problem by competent engineers, the collection of necessary additional hydrographic data and the preparation of plans for relief. Mr. J. E. Stewart, at that time with the United States Geological Survey, was employed to make a preliminary investigation and a copy of his report is inclosed. For the purpose of securing accurate stream flow records a very complete gauging station has been constructed at The Dalles in collaboration with the United States Geological Survey, which, on account of its excellent location, will give better records of flood flows than have hitherto been available. Some minor works of improvement have also been carried out. (Par. 55.) The total expenditures from this fund to date have been nearly $10,000.

34. *Flood damages.*—The following statement concerning flood damages is quoted from Mr. Willis's paper (par. 37):

> In answering this, I will quote in considerable detail from a report made two years ago by Mr. J. W. Collins, secretary of the Mount Vernon Commercial Club.
>
> Mr. Collins says: "The spring flood of 1894, although it did not cause as much destruction by washing and breakage as some of the fall freshets, probably cost as much as any of the others. The complete destruction of the year's crops caused a loss of approximately $1,500,000. This flood impressed upon the settlers the necessity of protection against the spring freshets, and from this time on the system of dikes was greatly increased and extended in its scope.
>
> "The flood of 1897 washed out the Great Northern Railway embankment at Sterling Bend between Burlington and Sedro-Woolley and cost the company a large sum in replacements and repairs. The southern part of Mount Vernon was also flooded, and the county courthouse was converted into a refuge for the flood sufferers. The district above Concrete suffered more severely in this flood than in any since that date. Several hundred head of cattle were lost and a number of houses, barns, and outbuildings were washed away in this vicinity alone.
>
> "The flood of 1906, while not as disastrous as that of 1897, caused a loss in stock and property of $250,000.

"The 1909 flood caused irreparable damage to farms in some localities by covering them with sand and gravel in some instances, and in others by washing them completely away. There were lost in this flood more than 300 head of horses and cattle, 600 head of sheep, 4,000 tons of hay, a large quantity of oats, and untold quantities of straw and other valuable farm products. The Great Northern Railway embankment from Mount Vernon to Burlington was completely destroyed and serious damage done to the right of way of the State highway. The dike on the west side of the river above Mount Vernon was broken and the entire town of Mount Vernon west of the river was flooded, causing a large property damage. As an indication of the heavy loss in washouts of dikes and drainage ditches, the following figures showing expenses of three dike districts in the county are significant:

	District 1	District 3	District 12
1909	$3,449.10	$12,086.34	No tax.
1910	37,000.96	17,153.06	$18,860.40
1911	9,218.36	13,913.80	4,184.02

"Considering the fact that there are 21 districts in the county, the above figures will show a very heavy loss from this source alone; $1,500,000 would not be an excessive estimate of the damage done by this flood.

"The flood of 1917 likewise washed out the Great Northern Railway embankment from above Mount Vernon to Burlington; also the right of way of the Pacific Northwest Traction Co. between the same points. It seriously threatened the town of Burlington. For a period of nearly two weeks communication with Mount Vernon and near-by towns was by steamer alone. This flood caused extensive damage to the dikes, although not so widespread as the flood of 1909. The loss in dollars and cents was approximately $500,000."

Mr. Collins, in his report, while he gives many very valuable details of the kind of damage, gives only a lump sum for the total estimated damages. So far as I have been able to learn there has been only one detailed estimate of damages caused by any of our floods. That was made by Mr. H. L. Devin, of Sedro Woolley, directly after the 1921 flood. This flood was nearly as great in discharge as that of 1909, but the damage was probably considerably less. Very few losses in this or any flood are matters of actual record.

In the case of one town, however, we have a definite item. To repair the damages done by the 1921 flood to the streets, sewers, and crossings cost the city of Burlington $7,102.74.

The cost to repair the roads and bridges of the county after a flood has not heretofore been segregated from the regular road and bridge expense. The county always holds the funds for roads and bridges in reserve until after the usual flood period. If a flood occurs, these funds are used to repair the damages. If no flood occurs, the funds are used for the customary improvements and extension. In this way, it has happened that the expenses for roads and bridges has not increased materially following floods. Improvements and extensions have merely been postponed while the money went to repair flood damages.

Hence it comes about that the estimates prepared by Mr. Devin in January, 1922, are the most accurate now obtainable. Mr. Devin spent three weeks collecting data for these estimates, and the only item that he considers a real estimate is that on "Damages to land and future crops" which he has placed at less than half the figures put upon it by the farmers consulted.

Following are Mr. Devin's figures for the flood damage in 1921:

Public roads and bridges	$75,000
Buildings	30,000
Loss of logs and bolts	105,000
Merchandise and personal property	45,000
Dikes, ditches, and drain tile	100,000
Crops, harvested and unharvested	30,000
Live stock	5,000
Damage, land and future crops	100,000
Loss of wages	15,000
Total	505,000

There are also intangible losses. Among these are many thousand dollars in loss of trade to merchants, either through the sudden cutting off of transportation or through the crippling of the customers' ability to buy.

The total losses from all floods in the past 50 years have been enormous; yet as the valley becomes more highly developed each succeeding flood is likely to be more disastrous than the last. The damage to the present valley of such a flood as that of 1820, which had nearly double the discharge of 1909, or of a flood like that of 1856, which was 40 per cent greater than that of 1909, can hardly be conceived.

35. Exact determination of flood losses is difficult. That above given for the 1921 flood is evidently more accurate than that for previous floods. It apparently does not include the damage to the Great Northern Railroad nor to the Pacific Northwest Traction Co., nor does it attempt to estimate intangible losses due to interruption and disruption of business.

36. While the losses are large, it does not seem probable that the average annual loss for the past 25 years has exceeded $125,000, or at most $150,000. These figures will give an approximate basis for considering the feasibility of plans for flood control. Such works are for insurance, and the annual cost must not exceed the probable losses if no insurance were carried.

37. *Views of local interests.*—For the purpose of securing the desires and views of local interests, a public hearing was held at Mount Vernon on November 26, 1924, at which some 70 people were present. A copy of the minutes of the hearing accompanies this report.[1] The papers [1] presented by Mr. H. L. Willis, chairman of the Skagit River Improvement Committee, and by Mr. R. E. L. Knapp, county engineer, Skagit County, clearly present the situation from the local viewpoint, and attention is invited thereto. Very briefly it may be stated as follows: That this valley suffers very heavy losses from floods at more or less regular intervals; that the people have spent more than a million and a quarter of dollars in the construction and maintenance of dikes and have recently undertaken at considerable expense the collection of discharge and other data necessary for the preparation of a comprehensive scheme of flood relief; that in view of the recognized difficulty and magnitude of the work necessary for flood relief they desire that the United States should undertake it; and that while they are unable to make any exact statement as to the amount of cooperation that they will furnish, they think that the work they have already done and are doing should be considered as evidence that they will contribute to the full extent of their ability.

38. *Interested parties.*—The parties at interest and that might be expected to contribute in greater or less degree to the cost of any measures for flood relief are:

First. The owners of the lands subject to overflow. Their interest is direct and vital.

Second. The towns along or near the river. Their interest is direct so far as they may be subject to actual flood damage and interruption of business in time of floods; indirect in that their prosperity is largely dependent upon that of the owners of the flooded lands.

Third. The Great Northern Railway. This road has a very direct interest due to the actual damage to its tracks and roadbed, the danger of its bridge being destroyed, and loss of business due to interruption of service.

Fourth. The Pacific Northwest Traction Co. The bridge of this company would very likely be destroyed if the Great Northern bridge were carried away.

[1] Not printed.

Its tracks and roadbed are damaged by floods and its business is interrupted and suffers accordingly.

Fifth. The Puget Sound & Baker River Railroad. A portion of the track of this company lies within the area subject to floods.

Sixth. The Puget Sound & Cascade Railroad. This is a new road. It closely follows the river bank for considerable distances and might be damaged to some extent in large floods.

Seventh. Skagit County. The direct interest of the county is probably limited to possible damage to county roads and bridges. Indirectly it is vitally interested since the greater part of its population is located in the delta.

Eighth. The State of Washington. The State has a direct interest in so far as possible damage to its roads and bridge is concerned, and is indirectly interested in so far as its prosperity is dependent upon that of the units of which it is composed.

Ninth. The United States Government. Such interest as the Government has is somewhat remote, but will be referred to later.

39. *Measure of relief to be considered.*—The maximum discharge that can be safely carried under existing conditions through and below the Great Northern Railroad bridge probably does not exceed 140,000 cubic feet per second. (Par. 21.) Any flood of greater discharge at that point will probably result in a break of the dikes above or, if these have been so strengthened as to carry a larger discharge, the dikes below will break. The Great Northern bridge will also be endangered and if destroyed would probably also carry away the Pacific Northwest Traction Co. and the Pacific Highway bridges.

40. Consideration of plans for flood relief must be largely based upon what the interested parties can afford to or may be willing to expend for relief. Maximum floods occurring at long intervals may carry 300,000 cubic feet per second or more. (Par. 21.) Absolute security against floods would require works to provide for such a discharge and the cost of these is believed to be prohibitive.

41. Floods of 210,000 to 220,000 cubic feet per second at Sedro Woolley may be expected to occur about every 25 years (two have occurred in the last 16 years), and measures undertaken for relief should, if possible within reasonable limits of cost, be designed for a discharge of that magnitude.

42. *Possible methods of flood relief.*—Possible methods of relief from floods that should be considered include the following, either singly or in combination:

a. Flood prevention by reservoirs or detention basins, including natural river valley storage.
b. Flood protection by:
  (1) Dikes (levees)—
    (a) A revision or reconstruction of present system.
    (b) A system of emergency dikes built back of the present ones or for protection of special localities.
  (2) Channel improvement—
    (a) Straightening and enlarging present channel by widening and deepening, with possible bank protection.
    (b) Removal of drift and possible construction of drift barriers. Clearing banks of timber and underbrush.
c. Flood diversion by construction of an outlet or relief channel.

43. *Flood prevention.*—The cost of flood prevention by the construction of reservoirs or of detention or retarding basins for that purpose alone is usually very great and is in general not feasible except where the property interests are of great value and where great loss of life may be involved. It is not believed that flood pre-

vention could be secured for the Skagit in this manner within reasonable limits of cost.

44. While the methods of using a reservoir for power purposes and for flood prevention are in general directly opposed, it is possible in some cases to make one reservoir serve both purposes, though necessarily at an increased expense, which must be borne by the secondary object to be served.

45. Investigations of sites for power development in the Skagit Basin have been made by the United States Geological Survey (Profile Surveys in 1915 in Skagit River Basin, Wash., Water Supply Paper 419), by power companies, and by the city of Seattle. As a result two locations have been selected and power developments are now in progress at both, viz, the upper Skagit Valley and the Baker River.

46. *Baker River development.*—The Puget Sound Power & Light Co. is now engaged in the development of a power project on the lower Baker River a short distance above the mouth. The Federal Power Commission has not assumed jurisdiction over this work. The essential features of this plant are:

Concrete dam with crest elevation of 393 and spillway gates giving pool elevation of 405; tail-water elevation, 180.

Tunnel to power house. Initial installation two 20,000 horsepower units, to which two more will be added later.

Usable storage with draw down to a elevation 320, approximately 50,000 acre-feet, which is expected to give a regulated discharge, equivalent to 1,400 cubic feet per second, for 100 per cent of the time. Extreme low water flow about 600 cubic feet per second.

As the mean annual flow of the Baker River is about 2,520 cubic feet per second, the regulation to only 1,400 cubic feet per second as given by this dam can not be expected to give any relief from floods. The reservoir will almost certainly be full in time of large floods. It is impracticable to raise the dam, as work is already in progress and the company would not in any case be willing to do this, as it would extend the pool beyond the boundary of the Washington National Forest and thus bring the development within the jurisdiction of the Federal Power Commission.

47. Plans for future development contemplate a dam just above the forest boundary located at about elevation 425 with pool elevation of 694 or 30 feet above Baker Lake. This would give a 74,000 acre-feet storage with draw-down to about elevation 624. It will probably be 5 to 10 years before this development is started. While this reservoir would give a greater regulated discharge than the lower one and the mean annual discharge at this point is less (2,090 cubic feet per second), it is unlikely that any material flood relief would be secured by the ordinary operation for power purposes. However, barring a possible question as to suitable foundation on one side of the valley, the height of this dam could be increased within reasonable limits so as to provide a certain fixed reserve for flood prevention, and as this development will come under the Federal Power Commission this could be required if found desirable, and upon proper compensation being paid by those desiring flood relief.

48. *Upper Skagit development.*—The city of Seattle has started a development on the upper Skagit at what is known as the "Gorge" site, about 18½ miles above the Cascade River and 9½ miles below Ruby Creek. This includes a low diversion dam, tunnel 11,000 feet

long and power house with two 37,500 horsepower generating units. No storage is now provided.

49. The ultimate development contemplated (dependent upon Federal Power Commission license not yet secured) is to have an installed capacity of about 555,000 horsepower. It will include a 240-foot concrete dam at the Gorge site and an additional tunnel and further power house installation. At Ruby Creek a high dam is to be constructed with a 3-mile tunnel to the Ruby power house at Stetattle Creek (Reflector Bar). The Gorge Dam will have a crest elevation of 880 feet and will pool the water to the Ruby power house, a distance of about 4 miles. The capacity of this reservoir will be small, about 6,000 acre-feet. The Ruby Creek Dam will have an ultimate elevation of 1,600 feet, carrying the pool to the Canadian border, a distance of about 23 miles along the reservoir. The usable draw-down to elevation 1,350 would be 1,300,000 acre-feet. Initial construction, however, may be to elevation 1,450 only, which is estimated to give a regulated flow of 1,800 cubic feet per second or that sufficient for the Gorge Creek plant. The mean annual discharge at Ruby Creek is about 3,533 cubic feet per second so that the initial construction could not be expected to give any flood relief. Although the reservoir when the dam is raised to elevation 1,600 would utilize nearly the entire river discharge in average years and give some relief from normal floods it is not believed that any assured relief in time of the larger floods would be given. To insure this, it would be necessary to raise the dam still higher, which might involve international complications as the pool would then be extended into Canada, or else to make arrangements with the city by which a certain portion of the reservoir capacity would be held intact for flood prevention. The latter would necessarily involve some possibility of loss of power storage.

50. The peak discharge at Ruby Creek in the 1921 flood was 45,700 cubic feet per second (29,200 cubic feet per second for 24 hours) and on the Baker at Anderson Creek 23,600 cubic feet per second (19,600 cubic feet per second for 24 hours). At Sedro Woolley it was 210,000 cubic feet per second. The information now available as to the two proposed dams indicates that by raising them a relatively small amount above the height contemplated for power development alone sufficient storage could be provided to take practically the entire 24-hour discharge in such a flood and that the cost might not be excessive. If this were done a very material reduction in the flood crests at Sedro Woolley and below would be secured, but it is improbable that this reduction would be sufficient in the case of floods such as those of 1909, 1917, and 1921 to permit the peak to be carried in safety by the present levees.

51. It is probable that other suitable locations for reservoir or power dams may be later developed, particularly on the Cascade and Sauk Rivers.

52. *Natural valley storage.*—It appears undesirable to impose any further restrictions upon the natural valley storage by the construction of additional dikes unless arrangements be made by means of spillways and gates to utilize these areas as reservoirs in times of large floods. This has particular application to an area on the south bank adjoining the Nookachamps Creek which it has been proposed to protect by dikes. This area, approximately 10 square miles in

extent, when flooded to an average depth of 7 feet has a reservoir capacity of about 45,000 acre-feet. This is sufficient to absorb a discharge of some 22,000 cubic feet per second for 24 hours or double that amount for 12 hours and accounts for the smaller flood discharge at Mount Vernon than at Sedro Woolley. (Par. 22.)

53. *Flood protection.*—The natural river channels at bank-full stage have a capacity that probably does not exceed one-third of the maximum flood discharge. With the existing dike system, as previously stated, the capacity is possibly about 140,000 cubic feet per second. Some increase of capacity could probably be secured by raising and strengthening these dikes. While their distance apart is quite irregular, it is believed that any scheme of partial revision of location would be unsatisfactory and that to secure any material increase of capacity and certainly in order to provide for floods such as those of 1909 and 1921, nothing less than reconstruction of one or both dikes for practically the entire length of the system would be sufficient. Should such reconstruction be undertaken, some reduction in length might perhaps be secured by closing off some of the delta sloughs. It is clear that such a plan would be very expensive. A system of emergency dikes back of the present ones has been suggested, but it is doubtful whether this would be found to be feasible. Dikes for the protection of certain localities might very possibly be made a part of a plan that did not provide for complete protection of the entire valley.

54. Improvement by channel enlargement alone is considered impracticable on account of the cost, impossibility of disposing of the excavated material, and tendency of the channel to fill. A moderate enlargement mainly by widening above the low-water plane and combined with the use of the excavated material for the construction of dikes might be found feasible. Raising or lengthening bridges, or both, will probably form an essential part of any scheme of dike reconstruction or channel enlargement. Some bank protection might also be found necessary.

55. Removal of drift and construction of drift barriers in certain localities would have some beneficial effect. Some work of this character has already been undertaken by local interests. A limited amount of clearing of timber and underbrush from the banks would probably have some effect in increasing velocities of flood flow.

56. *Flood diversion.*—Below Sedro Woolley the river changes its general westerly course to one nearly south. At this point the distance to Padilla Bay is somewhat less than that to Skagit Bay, and a large portion of the flood overflows before the construction of dikes, as well as of those occurring afterwards due to the breaking of dikes in this vicinity, have been into Padilla Bay through the Samish River, Joe Leary slough, and Indian and Telegraph sloughs. Artificial diversion channels would naturally follow the same general routes, and might be located as follows:

First. From the river above Burlington northwesterly to Samish River.
Second. From just above the Great Northern Railroad bridge to Joe Leary slough.
Third. From just above the Great Northern Railroad bridge to Indian and Telegraph sloughs.
Fourth. From Avon to Indian and Telegraph sloughs.

The first plan appears to offer no special advantages over the other three. The second location would be somewhat longer than the third, but a single levee only would be required along the full length of Bayview Ridge. The fourth would be the shortest in distance, but since the outlet would be located in the contracted section in the river which begins just above the Great Northern bridge, this plan would require enlargement of the river channel and relocation of at least one of the levees in that portion of the river.

57. It is impossible with the information now available to determine what method or combination of methods would best solve the flood relief problem of this valley. Careful study must be given to the feasibility and cost of a reconstruction of the diking system with dikes properly located and combined with channel enlargement at least to the extent of providing sufficient material for the dikes. The local situation is such as to indicate that the construction of a diversion channel might offer the best solution of the problem. There is an excellent prospect that some relief may be secured through the reservation for flood prevention of a certain portion of the capacity of prospective power dam reservoirs. While relief by detention reservoirs would probably be prohibitive in cost some study should be given that plan. The short duration of the floods on this river renders relief by impounding or detention of flood waters particularly applicable. For a comprehensive study of the entire problem, complete topographic and hydrographic surveys of the lower valley and additional data as to discharge are required. When these have been secured many different plans and combinations of plans must be worked out in considerable detail before a decision could be reached as to the best plan to be adopted, or indeed to determine whether any plan can be devised at a cost which is warranted by the benefits to be secured.

58. *Special or local benefits and general or national benefits.*—In paragraph 38 a list was given of the interests concerned in securing measures for flood relief. The benefits of any improvement would probably accrue to the special or local interests substantially in the following order: Owners of land subject to overflow, the towns along the river, the Great Northern Railway, the Pacific Northwest Traction Co., Skagit County, the State of Washington, the Puget Sound & Baker River Railway, and the Puget Sound & Cascade Railway. The measure of such benefits and the amount of cooperation in the cost of any improvement that should or would be furnished is largely dependent upon the plan of improvement that might be undertaken, its cost and the amount of protection that would be furnished. No direct statement of willingness to contribute has been received except as contained in the paper submitted at the hearing by Mr. Willis for the Skagit River Improvement Committee to the effect that the people of this valley could be depended upon to give their full measure of support to any practicable scheme which would require cooperation.

59. It is believed that the general or national benefits from such an improvement would be insufficient to justify the United States in undertaking it. The only direct Federal interest would be in case the plan adopted should be such as would improve the navigable capacity of the river, but the amount of navigation is small and the needs thereof can be provided at comparatively small cost under

the present project if slightly modified. Indirectly the Federal Government is interested to the extent that the prosperity of the country as a whole is dependent upon that of its units. It is also interested to the extent of seeing that any plan that may be undertaken for flood relief is one which is in harmony with the use of the water resources of the region for the development of power, for navigation, and for such other purposes as may properly be related to or coordinated therewith. Also it is probably the agency that is best able to secure cooperation between the various interests that would be benefited by any improvement and which should bear the cost thereof. Furthermore, recent legislation apparently indicates a tendency toward a policy of somewhat liberal assistance by the United States in matters of flood control, at least to the extent of making the required surveys and plans therefor.

60. *Recommendation.*—In view of the above it is my opinion that the Federal interests involved in the proposed improvement of the Skagit River, Wash., with a view to the control of its floods and the national benefits which might result therefrom are insufficient to justify the United States in undertaking such work, either alone or in conjunction with local interests, but that they are sufficient to justify cooperation by the United States to the extent of securing the necessary data for the preparation of adequate plans and of formulating such plans and the estimates of cost of carrying them out. I therefore recommend that a survey for this purpose be authorized.

W. J. BARDEN,
Colonel, Corps of Engineers, District Engineer.