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Howard A. Hanson Reservoir

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GREEN AND DUWAMISH RIVERS, AND DUWAMISH
WATERWAY, SEATTLE HARBOR, WASH.

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, UNITED STATES ARMY, DATED FEBRUARY 28, 1949, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON A PRELIMINARY EXAMINATION AND SURVEY OF GREEN AND DUWAMISH RIVERS, WASH., AND A REVIEW OF REPORTS ON DUWAMISH WATERWAY, SEATTLE HARBOR, WASH., AUTHORIZED BY THE FLOOD CONTROL ACT APPROVED ON JUNE 22, 1936, AND THE RIVER AND HARBOR ACT APPROVED ON JULY 24, 1946, AND REQUESTED BY A RESOLUTION OF THE COMMITTEE ON RIVERS AND HARBORS, HOUSE OF REPRESENTATIVES, ADOPTED ON APRIL 18, 1946

July 22, 1949.—Referred to the Committee on Public Works and ordered to be printed, with two illustrations

DEPARTMENT OF THE ARMY,
Washington, D. C., July 20, 1949.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

DEAR MR. SPEAKER: I am transmitting herewith a report dated February 28, 1949, from the Chief of Engineers, United States Army, together with accompanying papers and illustrations, on a preliminary examination and survey of Green and Duwamish Rivers, Wash., and a review of reports on Duwamish waterway, Seattle Harbor, Wash. This investigation was authorized by the Flood Control Act approved on June 22, 1936, and the River and Harbor Act approved on July 24, 1946, and requested by a resolution of the Committee on Rivers and Harbors, House of Representatives, adopted on April 18, 1946.

In accordance with section 1 of Public Law 534, Seventy-eighth Congress, and Public Law 732, Seventy-ninth Congress, copies of the

proposed report were furnished the Governor of the State of Washington and the Secretary of the Interior. Copies of the proposed report were also furnished the Federal Power Commission and the Department of Agriculture for such comments as they desired to make. The views of the State and the Federal agencies are set forth in the enclosed communications, together with the letter to the Bureau of the Budget and the replies to letters from the Federal Power Commission and the Department of the Interior.

The Bureau of the Budget advises that there is no objection to the submission of the report to Congress. However, it also states that in view of certain adverse findings as set forth in the enclosed letter from the Bureau, authorization of the recommended improvement should not be considered to be in accord with the program of the President.

Sincerely yours,

GORDON GRAY,
Secretary of the Army.

LETTER FROM THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington 25, D. C., July 18, 1949.

The honorable the SECRETARY OF THE ARMY

(Through the Budget Officer for the Department of the Army).

MY DEAR MR. SECRETARY: Receipt is acknowledged of Secretary Royall's letter of March 31, 1949, enclosing the proposed report of the Chief of Engineers on Green and Duwamish Rivers, Wash., requested by resolution of the Committee on Rivers and Harbors, House of Representatives, adopted April 18, 1946, and also authorized by the Flood Control Act approved June 22, 1936, and the River and Harbor Act approved July 24, 1946.

The Chief of Engineers recommends construction of the multiple-purpose Eagle Gorge Reservoir project on the Green River in the interests of flood control, fish conservation, pollution abatement, domestic water supply, irrigation, and industrial expansion at an estimated cost of \$18,300,000 subject to the condition that local interests will contribute \$2,000,000 in cash toward the cost of the work. The annual carrying charges are estimated at \$831,658.

In the accompanying reports, it is pointed out that although some information is available on floods dating back to 1891 and stream gaging stations have been maintained in the basin since 1931, accurate and fairly complete data are available for only the December 1946 flood. It is stated that because of the paucity of data regarding stages of floods occurring prior to establishment of stream gaging stations, the known flood history of Green River does not furnish adequate criterion as to the magnitude of the largest flood reasonably to be expected and, therefore, as to the proper amount of flood protection to be provided. Accordingly, the standard project flood used in designing the project was derived by determining the flood that would result if the most critical storm experienced in the general region were to occur over the Green River drainage area at a time when hydrologic conditions were favorable for flood run-off. The total run-off from such a storm is estimated at about 106,000 acre-feet.

The proposed dam would create a reservoir of 106,000 acre-feet, which is more than three times the amount required to control the greatest flood of record.

The major problem involved in construction of the reservoir is the requirement that, in the relocation of the main line of the Northern Pacific Railroad changes in the length and ruling grades must be kept to a minimum. The report states that the railroad can be relocated under the proposed plan without material changes in the line. Development of power was not favorably considered because it is not feasible to increase the height of the dam to provide additional storage for maintaining a conservation pool to supply head for the generation of power due to the problems involved in the railroad relocation and because the season of the year when generating facilities are most needed coincides with the flood period when the reservoir must be kept empty, or emptied as soon as possible if filled by flood waters. Following the end of the flood season, the spring run-off would be stored for release during the dry season in the interest of irrigation, water supply, fisheries, and other uses. It is stated in the report that, while all of these uses are not immediately required, it is reasonable to assume that within the economic life of the project all available storage for use in augmenting the summer low water flow will be required.

The annual benefits from the proposed improvement are estimated at \$893,000 consisting of \$429,000 for prevention of tangible flood damages, \$214,000 from increased returns from agricultural land, \$191,000 from increased return from industrial land, and \$59,000 from fish conservation. The estimated average annual tangible flood damages prevented were computed on the basis of the standard project flood and take into account the anticipated normal increase in population and economic development. The increased returns from change in land use are based on the assumption that 9,600 acres of the 17,600 acres of usable land in the valley bottom will remain in agricultural production and 8,000 acres will be converted to industrial and urban property. The conversion of 9,600 acres to higher priced crops will give an enhancement value to these lands creditable to the proposed project of \$214,000 annually. Based on existing industrial land values and reasonable rates for conversion, the report estimates annual benefits from this source at \$191,000. The report also states that these increased returns of direct benefits to the landowners are sufficiently important to warrant consideration of a substantial local contribution toward the first cost of the project and that the \$2,000,000 contribution offered by local interests is the minimum that will fulfill the requirements of local cooperation. Also, migratory fish life is estimated to benefit to the extent of \$59,000 annually if an adequate summer water supply is assured. The estimated ratio of total benefits to costs is 1.08 to 1.0.

The Secretary of Agriculture advises that construction of the Eagle Gorge Dam on the Green River will not conflict with any present or proposed programs of his Department. The Secretary of the Interior concurs in the recommendation that the reservoir be constructed but considers that disposition of irrigation water releases should be made under the provisions of section 8 of the Flood Control Act approved December 22, 1944. The Chief of Engineers, in his reply of May 17, 1949, to the Secretary of the Interior, agrees with this

proposal. The Federal Power Commission concludes that there are possibilities for the economic development of hydroelectric power in connection with the Eagle Gorge Reservoir project either through (1) a modification in the plan or reservoir operation, (2) an increase in the reservoir capacity by the installation of spillway crest gates, or (3) the transfer of a part of the flood control storage capacity to some future reservoir upstream. The Commission also considers that, should the project be authorized, the feasibility of increasing the reservoir capacity for power purposes and including other provisions in the project for future development of power should be investigated at the time construction plans are being prepared. The Chief of Engineers gives assurance that careful consideration will be given to the recommendations of the Federal Power Commission in the planning and construction of the Eagle Gorge project.

While it would appear that the proposed reservoir would provide a desirable and justified improvement at the Eagle Gorge site on the Green River, I think the report and the comments of the Federal Power Commission raise certain questions as to whether the proposed local contribution represents an equitable division of costs on the basis of the benefits received and as to whether the power-development possibilities of the stream have been adequately explored.

From the information contained in the report, it would appear that because of missing or inaccurate data it has not been possible to make any satisfactory quantitative determinations of flood flows. It would, therefore, seem to follow that, except for the appraisals made after the 1946 flood, estimates of actual flood damages must be only approximations. Despite this lack of basic data the justification for use for design purposes of a standard project flood of a magnitude three times that of the largest flood during the 58-year period of record is not clear. It is also noted that the average annual flood damages that would be prevented by the proposed project are estimated at \$429,000 whereas the total damages in the 1946 flood, which produced the greatest discharge of record, amounted to only \$1,350,000. From the data contained in the report it would appear, therefore, that the possibility of flood damages averaging \$429,000 annually over the estimated 50-year economical life of the project may be remote.

The estimates of benefits also include \$405,000 for land enhancement which, as the reports correctly state, are direct benefits to the landowners warranting a substantial local contribution toward the first cost of the improvement. As these benefits constitute 45 percent of the total amount used in obtaining the benefit-cost ratio of 1.08, I do not believe that the \$2,000,000 proposed in the report, or 10 percent of the total construction cost (\$18,300,000), represents a "substantial" contribution by local interests. On the basis of information contained in the report, the actual monetary profit which will accrue to the landowners from the improvement is of sufficient magnitude to warrant local interests sharing at least equally in the proportional part of the total cost of the work which land enhancement values bear to the total benefits. It would also appear that this is the type of improvement which lends itself well to the creation of a conservancy district to finance and assess the local share of the cost of the project.

It appears that further study is also required to ascertain definitely the economic and engineering feasibility and desirability of power development at the Eagle Gorge site, particularly since power revenues may enhance the justification for the project. These additional

data should be fully developed before submission of the report to Congress, rather than during the stage of preparation of construction plans, in order that the cost, purpose, and benefits from the improvement may be firmly established at the time its authorization is under consideration.

In view of the above, I am authorized by the Director of the Bureau of the Budget to advise you that, while there would be no objection to the submission of the report to Congress, authorization of the recommended improvement on the basis of the amount of the proposed local contribution and in advance of a clarification of the possibilities of the development of electric power at the Eagle Gorge Dam site should not be considered to be in accord with the program of the President.

Sincerely yours,

W. F. McCANDLESS,
Assistant Director, Estimates.

COMMENTS OF THE GOVERNOR OF WASHINGTON

STATE OF WASHINGTON,
EXECUTIVE DEPARTMENT,
Olympia, March 8, 1949.

CHIEF OF ENGINEERS,
United States Army, Washington 25, D. C.

DEAR GENERAL: I received your letter, together with the engineering report covering the preliminary examination for flood control of the Green and Duwamish Rivers in King County, State of Washington.

It is noted that the Board of Engineers, as well as the Chief of Engineers, are favorable to the construction of the Eagle Gorge Dam on the upper Green River, as the best method, to control the damaging floods, which occur with a certain regularity, in the farming section along the lower river. Also, that the improvement at this time of the Duwamish waterway for the purpose of ship or barge navigation is not justified and, therefore, disapproved. The matter of flood control is of greater importance, in this valley, than the enlargement of the lower river for navigation purposes and, therefore, I acquiesce in your decision to give priority to the dam-construction project.

The report shows that the capacity of the reservoir is sufficient to control a flood of 65,000 second-feet, which is almost twice the amount of water recorded in the greatest known flood on this river. This should represent an ample margin to safeguard the valley for an indefinite period, if not for all time.

Since the bed rock at the site of the proposed dam has been thoroughly examined by competent geologists and reported to be favorable for the construction of the required dam, it is believed that no mistake can be made by approving this project to be constructed according to the plans as proposed by the United States Corps of Engineers. As a further approval of the general plan, I need only cite the fact that the State of Washington has now appropriated \$1,500,000 as its contribution and that King County will make available its share, in the amount of \$500,000, as proof of the local interest.

Hoping that further proceedings can now be expedited, I am
Sincerely yours,

ARTHUR B. LANGLEIE, Governor.

COMMENTS OF THE SECRETARY OF THE INTERIOR

DEPARTMENT OF THE INTERIOR,
Washington, D. C., May 5, 1949.

Maj. Gen. LEWIS A. PICK,
Chief of Engineers, Department of the Army.

MY DEAR GENERAL PICK: By letter dated February 21, 1949, (ENGWF) General Crawford transmitted for the information and comments of this Department, copies of a proposed report of the Chief of Engineers on a preliminary examination and survey for flood control of Green and Duwamish Rivers, Wash., and a review of reports on Duwamish waterway, Wash.

The report recommends the construction of a multiple-purpose reservoir at Eagle Gorge on Green River above Palmer, Wash., with a capacity of 106,000 acre-feet. Provision is made for storage for flood control and for augmenting the low water supply of Green River for the preservation of fish life and abatement of pollution. Development of power is not considered feasible. The report recognizes the possible future need for irrigation storage and the possibility of using space in the reservoir for that purpose. No definite provision to that end is made in the report, however, inasmuch as the Bureau of Reclamation has made no specific irrigation proposal for the area and the Bureau's preliminary studies of irrigation possibilities which were made available to the Corps of Engineers indicate that the farmers cannot afford to pay for an over-all irrigation system.

I am pleased to note that during the course of the investigations the regional office of the Fish and Wildlife Service was consulted, and it is the opinion of that Service that fish and wildlife interests have been adequately considered. Important salmon and trout fisheries are maintained by the Green River. These fisheries supply a substantial portion of the commercial catch of Puget Sound, as well as of the high seas; the sports fishery is outstanding. Through the maintenance of a continuous flow of at least 110 second-feet during the period from March to September in accordance with the recommendations of the Fish and Wildlife Service, substantial benefits estimated at \$59,000 annually would accrue in the conservation of fish resources, principally silver salmon, steelhead, and resident trout. Under existing conditions, summer stream flow becomes so small that the fish population suffers considerable losses.

I concur in the recommendations in the report that the reservoir be constructed. However, I cannot agree with the statement in paragraph 73, page 32, as follows: "* * * the use of stored water for irrigation could be provided upon payment of a reasonable fee to the United States under some temporary plan in conjunction with the Washington State Department of Conservation and Development until such time as the region may become organized for irrigation development under the Federal reclamation law." The disposition of irrigation releases from federally constructed reservoirs should not be made under the control of the States, even for a temporary period. Section 8 of the Flood Control Act of December 22, 1944, provides that

dams and reservoirs which are operated by the Secretary of the Army may be utilized for irrigation purposes only in accordance with Federal reclamation laws. Accordingly, I believe that arrangements for the sale of water from the Eagle Gorge Reservoir for irrigation purposes should be made by the Secretary of the Interior through the Bureau of Reclamation. It will be appreciated, therefore, if you will give consideration to the modification of your proposed report to include a provision that any use of Eagle Gorge Reservoir for irrigation will be in accordance with section 8 of the Flood Control Act of December 22, 1944, rather than through the Washington State Department of Conservation and Development.

Opportunity to review the report is appreciated.

Sincerely yours,

J. A. KRUG,
Secretary of the Interior.

LETTER TO THE SECRETARY OF THE INTERIOR

DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, May 17, 1949.

The honorable the SECRETARY OF THE INTERIOR.

DEAR MR. SECRETARY: Reference is made to your letter dated May 5, 1949, commenting on my proposed report on the preliminary examination and survey for flood control of Green and Duwamish Rivers, Wash., and review of reports on Duwamish waterway, Washington.

I am pleased to note your general concurrence in the conclusions and recommendations in my report, with particular reference to construction of a multiple-purpose reservoir at Eagle Gorge on Green River.

The exception taken in your letter to paragraph 73 of the report is noted and concurred in. I agree that possible future sales of water from Eagle Gorge Reservoir for irrigation, whether temporary or permanent, should be made by the Secretary of the Interior through the Bureau of Reclamation, in accordance with section 8 of the Flood Control Act of 1944. I believe, however, that it is unnecessary to change the report itself, inasmuch as the law provides for the above-mentioned disposition of irrigation waters. I am also stating in my letter to the Bureau of the Budget my concurrence in your recommendation in this matter, and am suggesting that our correspondence be made a part of the papers submitted to Congress with the report.

Your cooperation in reviewing and commenting on my report, in accordance with the quadripartite agreement and the Flood Control Act of 1944, is greatly appreciated.

Sincerely yours,

LEWIS A. PICK,
Major General, Chief of Engineers.

LETTER TO THE BUREAU OF THE BUDGET

DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, May 17, 1949.

HON. FRANK PACE, Jr.,
Director, Bureau of the Budget,
Washington, D. C.

DEAR MR. PACE: Reference is made to letter from the Secretary of the Army dated March 31, 1949, forwarding my proposed report and accompanying papers on preliminary examination and survey for flood control of Green and Duwamish Rivers, Wash., and review of reports on Duwamish waterway, Washington.

I am now enclosing, for inclusion with those papers, copies of correspondence with the Secretary of the Interior in accordance with the Flood Control Act of 1944 and the quadripartite agreement for cooperation among executive departments concerned with development of water resources. The Secretary of the Interior, in his letter dated May 5, 1949, agrees with my proposed recommendation for construction of a multiple-purpose reservoir in Eagle Gorge on Green River. I concur in his statement, taken in exception to paragraph 73 of the report, that any future sale of irrigation waters from Eagle Gorge Reservoir should be made by the Secretary of the Interior through the Bureau of Reclamation, in accordance with section 8 of the Flood Control Act approved December 22, 1944, and have so informed the Secretary of the Interior.

It is suggested that this letter and enclosures be made a matter of record for submission to Congress with the report on the Green and Duwamish Rivers.

Sincerely yours,

LEWIS A. PICK,
Major General, Chief of Engineers.

COMMENTS OF THE FEDERAL POWER COMMISSION

FEDERAL POWER COMMISSION,
Washington, June 1, 1949.

Subject: Green and Duwamish Rivers, and Duwamish waterway,
Seattle Harbor, Wash.

Maj. Gen. LEWIS A. PICK,
Chief of Engineers, Department of the Army,
Washington, D. C.

DEAR GENERAL PICK: In response to the request of your office, the Commission makes the following comments on the proposed report of the Chief of Engineers on a preliminary examination and survey of the Green and Duwamish Rivers, and Duwamish waterway, Seattle Harbor, Wash., which was transmitted to the Commission on February 21, 1949, together with the reports of the Board of Engineers for Rivers and Harbors and of the district and division engineers.

Recommended in the reports of your Department is a plan of development of the Green River Basin in the interests of flood control,

fish conservation, pollution abatement, domestic water supply, and irrigation, consisting of the construction of a dam and reservoir at the Eagle Gorge site on Green River. The dam would be of the concrete gravity type with maximum height above stream bed of 230 feet and crest length of about 720 feet. The reservoir would have a gross storage capacity of 106,000 acre-feet below the crest of the uncontrolled spillway. The reservoir outlet would consist of a concrete-lined tunnel through the left abutment, controlled by valves at the downstream end and by an emergency gate at the upstream end. The tunnel would be used for stream diversion during construction of the dam and would be constructed at such an elevation as to permit its emptying the reservoir.

As proposed in the reports, the Eagle Gorge Reservoir would be operated primarily for flood control and would be kept empty during the months of November, December, and January of each year except for temporary impoundments of floodwaters. Filling of the reservoir would begin in February and continue during the spring months. Subsequent releases from storage would be made during the dry summer and fall months for the benefit of water supply, pollution abatement, fish conservation and irrigation. There is no provision for the initial or future generation of power in connection with the project plan.

The reports of your Department conclude that there is no justification for any modification of the existing project for navigation in Duwamish waterway at this time.

The capital cost to the United States of the proposed Eagle Gorge project is estimated in the reports to be \$16,300,000 for construction, and \$80,000 annually for maintenance and operation. In addition local interests would be required to contribute in cash \$2,000,000 toward the cost of the project. The complete project as proposed is estimated in the report to have an evaluated benefit-cost ratio of 1.08 to 1.0.

The Commission staff has reviewed the reports of your Department from the standpoint of determining the possibility of developing hydroelectric power in connection with the project plan. The staff advises that, if the Eagle Gorge project is constructed and operated as now proposed with the reservoir maintained empty from November 1 to February 1 of each year for flood control, the development of power in connection with the project does not appear to be economically feasible. Studies by the staff indicate, however, that the provision of conservation storage capacity in the reservoir for operation throughout the year would make possible the economical development of up to about 65,000 kilowatts of power capacity in the basin. This power might be developed by a single plant located some 14 river-miles downstream from the dam and supplied by a tunnel or pipe line from the dam, or by a power plant at the dam combined with a second plant 14 river-miles downstream and supplied by a canal or pipe line from a diversion dam below the first plant. The conservation storage capacity necessary for such power development might be provided by (1) a modification in the plan of reservoir operation, (2) an increase in the reservoir capacity by the installation of spillway crest gates, or (3) the transfer of a part of the flood control storage capacity to some future reservoir upstream. The staff reports that if power is

developed in connection with the project, either with a power plant at the dam, or at the end of a long conduit, the proposed 20-foot diameter outlet conduit could be utilized for power purposes.

Copies of the staff memorandum discussing the report are transmitted herewith for the information of your Department.

Based on its consideration of the reports of your Department and studies by its own staff, the Commission concludes that there are possibilities for the economic development of hydroelectric power in connection with Eagle Gorge Reservoir project; and further that should the project be authorized, the feasibility of increasing the reservoir capacity for power purposes and including other provisions in the project for the future development of power should be investigated at the time the construction plans are being prepared.

Sincerely yours,

NELSON LEE SMITH, *Chairman.*

GREEN AND DUWAMISH RIVERS, AND DUWAMISH WATERWAY,
SEATTLE HARBOR, WASH.

This memorandum report summarizes the review by the Commission staff of the Corps of Engineers' report on preliminary examination and survey of the Green and Duwamish Rivers, and Duwamish waterway, Seattle Harbor, Wash., including the comments and conclusions contained in the memorandum of the San Francisco regional office, dated May 5, 1949. The report of this preliminary examination and survey was transmitted to the Commission by the Office of the Chief of Engineers with letter, dated February 21, 1949, for comments. The Corps of Engineers' report consists of four parts: the survey report by the district engineer, dated February 11, 1948; the division engineer's report, dated March 5, 1948; the report of the Board of Engineers for Rivers and Harbors, dated January 31, 1949; and the proposed report of the Chief of Engineers.

SUMMARY

The report of the Corps of Engineers was prepared in response to resolution of the Committee on Rivers and Harbors of the House of Representatives, adopted April 18, 1946; and in review of reports on preliminary examination and survey for flood control of Green River, Wash., and Duwamish River, Wash., authorized by the Flood Control Act, approved June 22, 1936; and in review of report on preliminary examination on Duwamish waterway, Washington, authorized by the River and Harbor Act, approved July 24, 1946. The report presents a plan of development of the Green River basin in the interests of flood control, fish conservation, pollution abatement, domestic water supply, and irrigation, consisting of the construction of a dam and reservoir at the Eagle Gorge site on Green River. The report recommends that this plan of development be adopted. The report concludes that there is no justification for any modification of the existing project for navigation in Duwamish waterway at this time.

The staff has reviewed the report of the Corps of Engineers and has studied the possibility of developing power in connection with the Eagle Gorge Reservoir. The staff finds that the proposed schedule of operation of the reservoir in the interest of flood control with the

reservoir to be kept empty for three consecutive months of each year, precludes the initial utilization of the reservoir in the interest of power generation. The staff's studies indicate, however, that the provision of conservation storage capacity in the reservoir for use throughout the year, would permit the economic generation of hydroelectric power in connection with the project. Such storage capacity might be provided by modification of the proposed plan of reservoir operation, by constructing the reservoir with a slightly higher pool level, or by a transfer of a part of the flood-control storage capacity to some future upstream reservoir.

The staff concludes that the feasibility of increasing the reservoir capacity for power purposes and the desirability of making provisions at the project for future power development should be investigated at the definite project stage.

BASIN DESCRIPTION

Green River, Wash., rises in the Cascade Range at an elevation of about 5,000 feet and flows north and west about 60 miles to the junction with the Black River. Below the junction with the Black River it is known as the Duwamish River, which flows north 12 miles and enters Elliott Bay, an arm of Puget Sound, at Seattle. In its upper reaches the river flows with steep slopes through an area characterized by sharply incised valleys and prominent ridges. The river emerges from the hills onto the flood plain just above Auburn and flows about 20 miles to the Black River through a fertile developed valley 2 to 3 miles wide. It continues for about 12 miles in a somewhat narrower valley to Elliott Bay. The section of the river between Auburn and the Black River was formerly known as the White River, but during the 1906 flood the White was diverted through Stuck and Puyallup Rivers and thence to Puget Sound at Tacoma, Wash. This change has been made permanent by construction of a concrete diversion dam. The section of old White River below Auburn is now known as Green River. Duwamish River enters the sound through west waterway, a stretch of about 5 miles which has been improved for navigation. During high water, the east waterway carries part of the discharge. Noticeable tidal effects extend upstream from Elliott Bay to Black River.

The basin, including the Duwamish, has an area of 474 square miles and, exclusive of Seattle, has a population of about 32,000. Seattle, located at the mouth of the river, had a population of 615,000 in 1946. Auburn, with a population of 6,000, and Kent, with 3,000, are the largest towns wholly within the basin. Railroads, highways, and air lines provide transportation for the area. The principal industries are lumbering, coal mining, and agriculture. Green River furnishes important spawning grounds for both commercial and sports fish. The principal spawning areas are in the reach between Auburn and Newaukum Creek and on Big Soos Creek.

Duwamish waterway, the lower section of Duwamish River, is now under improvement for navigation by the United States. There are no existing reservoirs or hydroelectric developments in the basin. The city of Tacoma obtains its principal water supply from Green River at a diversion dam about 3 miles downstream from the Eagle Gorge Dam site. The existing intake works and the upper 0.6 mile

of the diversion conduit have a nominal capacity of 130 cubic feet per second and the pipe line from that point to Tacoma has a nominal capacity of 80 cubic feet per second. Tacoma has a water right for the diversion of 100 cubic feet per second and has filed application with the State for an additional 100 cubic feet per second.

The average annual precipitation varies from about 100 inches along the mountainous north and east rims of the upper basin to about 40 inches in the flat lower basin. Heavy snow packs are characteristic of the mountain areas. About 75 percent of the annual precipitation occurs in the period October to April, and in the summer months there is insufficient moisture for maximum crop production. The length of growing season in the lower valley is about 175 days.

Records of flow of the Green River at Palmer, located about 2 miles downstream from the Eagle Gorge Dam site, are available beginning October 1931. The mean annual run-off from the 231 square miles above this point has been 733,000 acre-feet for the 15-year period of record, varying from a maximum of 1,113,000 acre-feet to a minimum 369,700 acre-feet. The maximum flood of record at this point was that of 1946 with a peak flow 23,200 cubic feet per second. Floods on the Green River generally occur during November through February as a result of intense rainfall augmented by some snow melt. The area subject to damages from inundation is the portion of the valley from Newaukum Creek to Black River, including portions of the towns of Auburn and Kent.

PRIOR REPORTS

Reports prepared by the Corps of Engineers regarding improvement of the Green and Duwamish Rivers in the interest of controlling floods include: (1) House Document No. 286, Seventy-third Congress, second session; and (2) House Document No. 377, Seventy-fourth Congress, second session. Each of these reports recommended a survey to obtain necessary data for the preparation of a plan of improvement for flood control and an estimate of cost.

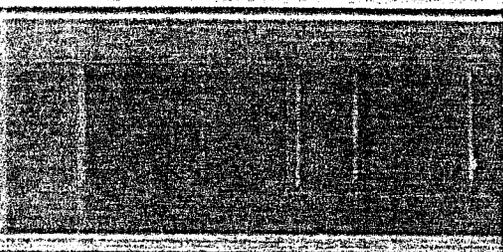
Reports by the Corps of Engineers concerned with the Duwamish waterway include: (1) House Document No. 108, Sixty-eighth Congress, first session; and (2) House Document No. 126, Seventy-first Congress, second session. These two reports contain the recommendations for the existing Federal navigation project for improvement of the waterway.

PLANS OF THE CORPS OF ENGINEERS

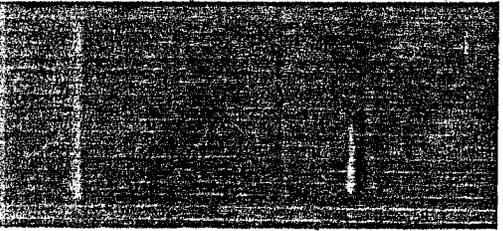
The district engineer investigated several methods for the control of floods in the Green and Duwamish Rivers, including diversion, channel improvement, reservoir storage, and combinations of these methods. As a result of these studies, the Corps of Engineers recommends the construction of a dam and reservoir on the Green River in the vicinity of Eagle Gorge for the primary purpose of flood control with incidental benefits to municipal water supply, irrigation, and other purposes. The location of the proposed project is shown on the attached map¹ of the basin.

The Eagle Gorge Dam, with a tributary drainage area of 225 square miles, would have a maximum height of about 230 feet above

¹ Not printed.



stream bed and a crest length of about 720 feet. As recommended in the report, the dam would be of the concrete gravity type, although it was stated that further investigations might result in the adoption of the concrete-arch type. An uncontrolled overflow spillway in the central section of the dam, with spillway crest at elevation 1,205 feet above mean sea level, would have a design capacity of 145,000 cubic feet per second. The crest of the dam would be at elevation 1,230 feet. The outlet works would consist of a 20-foot diameter concrete-lined tunnel regulated at the downstream end by three 102-inch Howell-Bunger valves and with a 16.5- by 28.5-foot tractor gate and trash racks at the upstream end. The tunnel, with the invert at the intake end at elevation 1,012.5 corresponding to practically zero storage capacity of the reservoir, would be used for stream diversion during construction of the dam.



The reservoir would have a gross storage capacity of 106,000 acre-feet below spillway crest, elevation 1,205, with a corresponding surface area of 1,600 acres. The reservoir area consists mostly of heavily wooded mountain slopes. Two existing power-transmission lines and a telephone line in the reservoir area would have to be relocated, as well as several miles of existing road. It would also be necessary to relocate and reconstruct about 12 miles of the Northern Pacific Railway, the cost of which would be a large proportion of the total cost of the project.

In the interest of flood control, the Corps of Engineers proposes to keep the reservoir empty from November 1 to February 1 each year except for temporary impoundment of floodwaters. Storage of 10,000 acre-feet would be permitted in February and the filling could continue during March, April, May, and June. Subsequent releases could then be made during the dry summer and fall months for the benefit of water supply, pollution abatement, and fish propagation. Controlled flood releases would not exceed 10,000 cubic feet per second.

The total capital cost of the project with 1947 prices is shown in the report to be \$18,300,000, of which local interests would be expected to pay \$2,000,000. The annual carrying charges are shown to be \$823,139 and the annual benefits are shown as \$893,000, indicating a benefit-cost ratio of 1.08.

With respect to hydroelectric power, the report of the district engineer states:

Development of power at the Eagle Gorge site has not been favorably considered because operation of the reservoir for its primary purpose of flood control eliminates the possibility of storage for power when it is most needed. The season of the year when increased generating facilities are needed coincides with the flood period when the reservoir must be kept empty, or emptied as soon as possible if filled by floodwaters, and therefore it is not feasible to combine production of electrical energy with the flood-control project proposed in this report. Because of the problems involved in the railroad relocation, it is not feasible to increase the height of the dam and thereby provide additional storage for maintaining a conservation pool to supply head for the generation of power.

STUDIES BY THE COMMISSION STAFF

The Commission staff, including the San Francisco regional office staff, has reviewed the Corps of Engineers' report from the standpoint of the possibility of developing hydroelectric power in connection with the project plan. The comments of the regional office staff on

the report are contained in a memorandum from that office, dated May 5, 1949.

The staff studies indicate that the development of power in connection with the Eagle Gorge Reservoir project would not be economically feasible under the plan of reservoir operation proposed in the report, whereby the reservoir would be kept empty throughout November, December, and January of each year, for flood-control purposes.

The regional-office staff has made studies of a number of alternative possibilities for the development of firm power on the Green River, which would involve utilizing the proposed Eagle Gorge Reservoir with the capacity shown in the report, in conjunction with a possible future upstream reservoir on the North Fork of Green River with a capacity of 30,000 to 40,000 acre-feet. It was assumed that conservation storage capacity would be maintained in the Eagle Gorge Reservoir throughout the year in exchange for compensatory flood-control storage space to be provided in the upstream reservoir, when needed, in order to provide the degree of flood-control as planned in the report.

The regional staff's studies, based on the incomplete data available, indicate that such coordinated operation of the two reservoirs would possibly permit the economic development on the Green River of up to 65,000 kilowatts of generating capacity with average annual output of about 430,000,000 kilowatt-hours, utilizing a maximum gross head of some 850 feet. This power might be developed either (1) by a single plant located about 14 river-miles downstream from the Eagle Gorge Dam and supplied by a pressure tunnel and pipe line from the reservoir, or (2) by a plant located at the dam, combined with a second plant located 14 river-miles downstream and supplied by a canal or pipe line from a diversion dam below the first plant. An afterbay downstream from the lowermost plant might be required under either plan. Allowances were made in the studies, for water diverted to Tacoma for municipal purposes, which would not be available for power development except for a plant at the Eagle Gorge. Consideration was also given to the requirements of fish life and irrigation.

The Washington staff has considered the possibility of constructing the proposed Eagle Gorge Dam to a greater height than is proposed in the report in order to increase the reservoir capacity in its interest of power development. Sufficient information is not available to the staff to permit adequate study of this possibility. However, it appears that a raise of 20 feet in the pool level, by the installation of crest gates on the dam, could provide approximately 30,000 acre-feet of additional storage capacity without requiring further railroad relocation. This additional storage would possibly permit the development of power in connection with the project without the necessity of constructing a reservoir upstream.

The development of power in connection with the Eagle Gorge project, either with a power plant at the dam or with a power plant connected with the reservoir by a long conduit, could be made by utilizing the proposed 20-foot outlet tunnel at the dam for power purposes. This tunnel would be initially required for stream diversion during construction. Flood-control outlet capacity could be provided by constructing sluices through the spillway section of the dam.

CONCLUSIONS

Based on its review of the Corps of Engineers' report, the Commission staff concludes that, with the project constructed and operated as proposed in the report with the reservoir maintained empty from November 1 to February 1 of each year for flood control, the development of hydroelectric power in connection with the project would not be economically feasible.

The staff concludes further that if conservation storage is provided in the Eagle Gorge Reservoir for use throughout the year, either by modification of the proposed plan of operation, by an increase in the storage capacity of the reservoir, or by a transfer of a portion of the flood-control storage capacity to some possible future upstream reservoir, then the development of up to 65,000 kilowatts of power capacity appears to be justified in connection with the project.

Should the Eagle Gorge Reservoir be authorized, the feasibility of increasing the reservoir capacity for power purposes, possibly by the future installation of crest gates on the dam, and the desirability of including provisions in the project for the future development of power should be restudied at the time construction plans are prepared.

Submitted by:

R. S. ANDERSON,
Senior Engineer.

K. W. ROSS,
Acting Head, Basin and Project Plans Section.

Recommended by:

W. A. LIDDELL,
Acting Chief, Division of River Basins:

Approved by:

E. ROBERT DE LUCCIA,
Chief, Bureau of Power:

LETTER TO THE FEDERAL POWER COMMISSION

DEPARTMENT OF THE ARMY,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, June 23, 1949.

HON. NELSON LEE SMITH,
Chairman, Federal Power Commission,
Washington, D. C.

DEAR MR. SMITH: Reference is made to your letter of June 1, 1949, commenting on my proposed report and accompanying reports on preliminary examination and survey of the Green and Duwamish Rivers, and Duwamish waterway, Washington, transmitted to the Commission on February 21, 1949.

It is noted that the Commission staff concurs with the conclusion that development of power, in connection with the Eagle Gorge Reservoir project as proposed, does not appear to be economically feasible. It is also noted, however, that the Commission believes that there are possibilities for future power development in connection with the project.

You may rest assured, therefore, that the Corps of Engineers will give careful consideration to the recommendations of the Federal Power Commission in regard to provisions for future power develop-

ment in the planning and construction of the Eagle Gorge project, should it be authorized by Congress.

I am forwarding a copy of your letter, and of this reply, to the Bureau of the Budget for its use in reviewing my report.

Sincerely yours,

LEWIS A. PICK,
Major General, Chief of Engineers.

COMMENTS OF THE SECRETARY OF AGRICULTURE

DEPARTMENT OF AGRICULTURE,

Washington, April 28, 1949.

Gen. LEWIS A. PICK,

Chief of Engineers,

Department of the Army.

DEAR GENERAL PICK: In compliance with General Crawford's request of February 21, 1949, the Department of Agriculture has reviewed the proposed report of the Chief of Engineers for the Green and Duwamish Rivers, Wash., as well as the related reports transmitted therewith.

The proposal to construct a dam at Eagle Gorge on the Green River is not in conflict with any present or contemplated programs of the Department.

Sincerely,

CHARLES F. BRANNAN,
Secretary.

REPORT OF THE CHIEF OF ENGINEERS, UNITED STATES ARMY

DEPARTMENT OF THE ARMY,

OFFICE OF THE CHIEF OF ENGINEERS,

Washington, D. C., February 28, 1949.

Subject: Green and Duwamish Rivers, and Duwamish waterway, Seattle Harbor, Wash.

To: The Secretary of the Army.

1. I submit herewith for transmission to Congress the report of the Board of Engineers for Rivers and Harbors in response to resolution of the Committee on Rivers and Harbors of the House of Representatives, adopted April 18, 1946, requesting the Board to review the reports on Duwamish waterway, Seattle Harbor, Wash., submitted in House Documents No. 108, Sixty-eighth Congress, first session, and No. 126, Seventy-first Congress, second session, with a view to determining whether it is advisable to modify the existing project in any way at this time. It also is in review of reports on preliminary examination and survey for flood control of Green River, Wash., and Duwamish River, Wash., authorized by the Flood Control Act approved June 22, 1936; and in review of report on preliminary examination on Duwamish waterway, Washington, authorized by the River and Harbor Act approved July 24, 1946.

2. After full consideration of the reports secured from the district and division engineers, and after affording local interests full opportunity to be heard, the Board recommends flood protection for the

Green and Duwamish Rivers, Wash., by the adoption of the Eagle Gorge project on Green River, Wash., generally in accordance with the plan of the district engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated cost to the United States of \$16,300,000 for construction and \$80,000 annually for maintenance and operation, provided local interests contribute in cash \$2,000,000 toward the cost of the project. Further, the Board recommends that no modification or extension of the existing navigation project for Duwamish waterway, Seattle Harbor, Wash., be made at this time.

3. After due consideration of these reports, I concur in the views and recommendations of the Board.

R. A. WHEELER,
*Lieutenant General,
Chief of Engineers.*

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

DEPARTMENT OF THE ARMY,
BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, D. C., January 31, 1949.

Subject: Green and Duwamish Rivers, and Duwamish waterway,
Seattle Harbor, Wash.

To: The Chief of Engineers, United States Army.

1. This report is in response to the following resolution adopted April 18, 1946:

Resolved by the Committee on Rivers and Harbors of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Duwamish waterway, Seattle Harbor, Washington, submitted in House Documents Numbered 108, Sixty-eighth Congress, first session, and 126, Seventy-first Congress, second session, with a view to determining whether it is advisable to modify the existing project in any way at this time.

It is also in review of reports on preliminary examination and survey for flood control of Green River, Wash., and Duwamish River, Wash., authorized by the Flood Control Act approved June 22, 1936; and in review of report on preliminary examination on Duwamish waterway, Washington, authorized by the River and Harbor Act approved July 24, 1946.

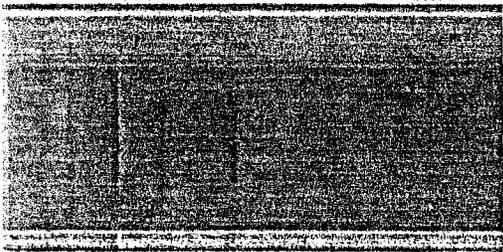
2. Green River, Wash., rises in the Cascade Range at an elevation of about 5,000 feet and flows north and west about 60 miles to the junction of the Black River. Below the junction with the Black River it is known as the Duwamish River, which flows north 12 miles and enters Elliott Bay, an arm of Puget Sound, at Seattle. In its upper reaches the slope of the river is steep, and it flows through an area characterized by sharply incised valleys and prominent ridges. The river breaks out of the hills onto the flood plain just above Auburn and flows about 20 miles to Black River through a fertile developed valley 2 to 3 miles wide. It continues for about 12 miles in a somewhat narrower valley to Elliott Bay. The section of the river between the town of Auburn and Black River was formerly known as the White River, but during the 1906 flood the White was diverted through Stuck and Puyallup Rivers and thence to Puget Sound at Tacoma, Wash. This change has been made permanent by construction of a



concrete diversion dam. The section of old White River below Auburn is now known as Green River. Duwamish River enters the sound through west waterway, a rectified stretch of about 5 miles. During high water the east waterway carries part of the discharge. Noticeable tidal effects extend upstream from Elliott Bay to Black River. The basin, including the Duwamish, has an area of 474 square miles and, exclusive of Seattle, has a population of 32,000. Seattle had a population of 615,000 in 1946. Auburn, with a population of 6,000, and Kent, with 3,000, are the largest towns wholly within the basin. Railroads, highways, and air lines provide transportation for the area. The principal industries are lumbering, coal mining, and agriculture.

3. Duwamish waterway, the lower section of Duwamish River, is under improvement by the United States. The existing navigation project for Duwamish waterway provides for maintenance of the east and west waterways to a depth of 34 feet at mean lower low water, with a width of 750 feet for distances of 6,500 and 5,200 feet, respectively, from the pierhead line in Elliott Bay; for the maintenance of east waterway between the upper end of the 750-foot section and Spokane Street, 34 feet deep, 700 feet long, and 400 feet wide, and of a turning basin, including the head of the east waterway at the junction of the waterways south of the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge, to a depth of 30 feet, after these sections of the waterway have been dredged by local interests to full project dimensions; and for dredging the Duwamish waterway 200 feet wide and 30 feet deep at mean lower low water between the west waterway and First Avenue South, 150 by 20 feet between First and Eighth Avenues South, thence 150 by 15 feet to a point about 1.4 miles above Fourteenth Avenue South Bridge, with a turning basin 600 by 350 feet and 20 feet deep just south of the First Avenue South Bridge, and a turning basin 500 by 250 feet and 15 feet deep and settling basin with a capacity of about 100,000 cubic yards at the upper end of the waterway, a distance of 27,060 feet, or 5.12 miles. The total length of waterways included under the project is about 7.5 miles. Local interests expended \$6,341,000 for new work and maintenance on Duwamish, east, and west waterways. The costs to the United States to June 30, 1948, were \$170,335 for new work and \$413,545 for maintenance, a total of \$583,880. In addition, \$69,333 was expended from contributed funds for new work. No Federal project for flood control on Green or Duwamish Rivers has been authorized. Local interests have constructed dikes and have organized and operated two drainage districts. The two drainage districts have constructed drainage ditches and pumping plants at a total cost of \$53,018. Pile and timber shear walls for bank protection have been constructed in a number of places. Approximately 11.4 miles of private dikes, largely downstream from Kent, have been constructed at an estimated total cost of \$90,000.

4. Floods on the Green River generally occur during November through February as a result of intense rainfall augmented by some snow melt. Discharge records are available only from 1931 when the upstream stream-gaging station near Palmer was installed. The largest floods of record occurred December 9, 1933 and December 11, 1946. The 1946 flood flow was larger in the upstream areas, being 23,200 and 21,900 cubic feet per second at the Palmer and Auburn

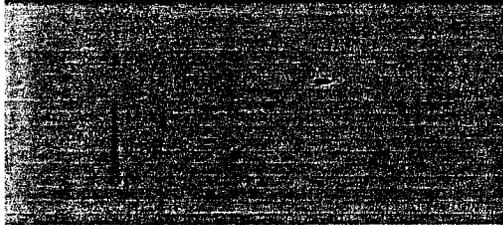


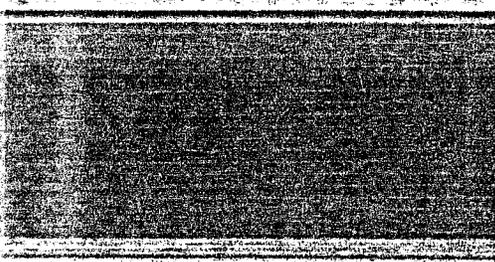
gages, respectively; but the 1933 flood was larger in the lower valley where the greatest damages are incurred, being 21,700 and 24,000 cubic feet per second at Palmer and Auburn, respectively. From a comparison with discharges of record on neighboring streams it has been estimated that a crest discharge of 65,000 cubic feet per second near Auburn might occur, but would be equaled or exceeded only on rare occasions. The area most frequently subject to inundation is the portion of the valley extending downstream from Newaukum Creek to Black River. Portions of the city of Auburn would be flooded only during extremely high floods, but the city of Kent has running water in some of its main streets when the flow exceeds 20,000 cubic feet per second. Downstream from Black River, portions of the valley are flooded to the vicinity of Allentown but this condition is dependent somewhat on tidal stages. The December 1933 flood inundated 13,800 acres and the December 1946 flood 12,000 acres. The gross area subject to inundation from a flood flow of 40,000 cubic feet per second would be approximately 19,000 acres. The area subject to flooding contains a considerable portion of urban property and facilities, agricultural land and improvements, and transportation and service utilities. The tangible damages from the December 1933 and the December 1946 floods are estimated at \$1,750,000 and \$1,350,000, respectively, based on 1947 prices.

5. Local interests stressed the need for flood control in the area downstream from Newaukum Creek to prevent recurrence of flood damages and to attract industries to the area. Any method of control would be satisfactory to the agricultural interests but the fishing interests were opposed to any storage project that might endanger the fish runs on Green River. Approval was expressed for the construction of a flood control dam and reservoir in the vicinity of Eagle Gorge. Local interests have given assurances that, subject to legislative approval, they will participate in the cost of the Eagle Gorge project in the amount of \$2,000,000. Local interests also requested the extension of Duwamish waterway upstream to the vicinity of Black River, to provide a depth of 15 feet, to permit barge navigation to the potential industrial sites adjacent to Duwamish River. Representatives of the Seattle Port Commission and the Seattle Chamber of Commerce, subsequent to the public hearing in the field, indicated that expansion of the industrial area might require a ship channel at some future time, and requested that any present planning take that ultimate development into consideration. No modification of the existing project for Duwamish waterway, other than its extension upstream, has been suggested.

6. The district engineer has investigated the requests of local interests for the extension of Duwamish waterway and concludes that the extension cannot be justified at the present time for either a barge or a ship channel. However, planning for any type of channel rectification in the Duwamish Valley should consider the possible ultimate construction of a deep-water ship channel.

7. The district engineer has investigated several methods for the control of floods in Green and Duwamish River Valleys including diversion, channel improvement, reservoir storage, and by combinations of these methods. He proposes a dam and reservoir in the vicinity of Eagle Gorge as the best plan for development of the basin for the combined purposes of flood control and storage for municipal



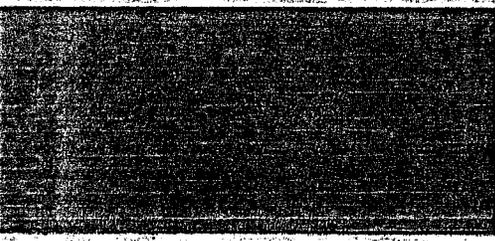


water supply, irrigation, and conservation. The dam with spillway crest at elevation 1,205 would create a reservoir with capacity of 106,000 acre-feet, which is more than three times the amount required to control the greatest flood of record. The project is designed to provide complete protection from the standard project flood by reducing its crest discharge of 65,000 cubic feet per second to the safe capacity of the existing channel below the dam. Reservation of the entire storage will be required from the first of November to the first of March to detain possible flood flows. Following the end of the flood season the spring run-off could be stored for release during the dry season in the interests of water supply for fisheries and municipal uses, irrigation, and abatement of pollution. Development of power is not considered feasible. The cost of the proposed project is estimated at \$18,300,000 and the annual carrying charges at \$823,139. If \$2,000,000 of the first cost of the project is borne by local interests, the total annual carrying charges would be \$831,658 due to the interest rate of 3.5 percent applied to non-Federal costs. The district engineer estimates the total annual benefits at \$893,000, consisting of \$429,000 from prevention of tangible flood damages, \$214,000 from increased returns from protected agricultural land, \$191,000 from increased returns from industrial lands, and \$59,000 from benefits to fish life. The benefit-cost ratio is 1.08 based on total annual benefits and annual carrying charges of \$893,000 and \$823,139, respectively. The district engineer concludes that the construction of a multiple-purpose reservoir project at Eagle Gorge will provide the best plan of development of the Green River basin in the interests of flood control, fish conservation, pollution abatement, domestic water supply, irrigation, and industrial expansion. The project is economically justified in that the annual benefits exceed the annual costs and the local benefits resulting from construction of the project warrant substantial local contribution toward its first cost. He recommends adoption of the Eagle Gorge project substantially as set forth in his report with the first cost estimated at \$18,300,000 for construction and with \$80,000 annually thereafter for operation and maintenance by the United States, subject to a substantial contribution from local interests toward the first cost of its construction. No justification for any modification of the existing project for navigation in Duwamish waterway exists at this time. He therefore recommends that no modification for extension of the existing navigation project for Duwamish waterway be adopted at this time. The division engineer concurs.

8. Local interests were advised of the conclusions of the division engineer and were invited to submit additional information to the Board. Information regarding the urgent need for the proposed improvement was presented by local interests at a meeting before the Board.

VIEWS AND RECOMMENDATIONS OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

9. The Board of Engineers for Rivers and Harbors has reviewed the reports of the district and division engineers and the additional information presented by local interests at a hearing before the Board.



It concurs in general in the views and recommendations of the reporting officers. The proposed dam and reservoir at Eagle Gorge may be used in connection with flood control, municipal water supply, irrigation, and conservation. While not all of these uses are immediately required, it is reasonable to assume that within the economic life of the project all available storage for use in augmenting the summer low-water flow will be required. Considering only the immediate benefits from the project, these benefits exceed the cost and the project is economically justified. The local benefits from land enhancement are of sufficient importance in the opinion of the Board to warrant the requirement of a local contribution of \$2,000,000 toward the cost of the project.

10. The improved channel of Duwamish waterway is adequate in depth and width to accommodate safely present and reasonably prospective commerce. Upstream from this improved section, the river is shallow and winding and is unsuitable for navigation by any type of craft. The land in this unimproved section may be needed for possible future industrial expansion. However, there are no present plans for conversion of this unimproved section to industrial uses. Therefore, there is no need for a barge or ship channel in the waterway at this time.

11. The Board recommends flood protection for the Green and Duwamish Rivers, Wash., by the adoption of the Eagle Gorge project on Green River, Wash., generally in accordance with the plan of the district engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated cost to the United States of \$16,300,000 for construction and \$80,000 annually for maintenance and operation, provided local interests contribute in cash \$2,000,000 toward the cost of the project. Further, the Board recommends that no modification or extension of the existing navigation project for Duwamish waterway, Seattle Harbor, Wash., be made at this time.

For the Board:

R. C. CRAWFORD,
Major General, Chairman.

REPORT OF THE DISTRICT ENGINEER

SYLLABUS

The district engineer finds that recurring floods in the Green River Valley cause substantial flood damage and retard the agricultural and industrial development of the area. After a study of all possible methods of flood control he finds that construction of a concrete dam and reservoir at Eagle Gorge affords the best development of the basin's water resources. This project has least cost, is unanimously desired by local interests, and annual benefits expected are greater than the annual cost of the project. He also finds that local benefits accruing therefrom warrant substantial local participation in the first cost of the project. He therefore recommends adoption of the Eagle Gorge Dam and Reservoir as a Federal project subject to a substantial contribution from local interests toward the first cost of its construction.

The district engineer further finds that extension of Duwamish waterway cannot be combined with river channel improvement for flood control so as to make such work economically feasible. In addition, no need in the interest of navigation can be found at this time for the upstream extension or any other modification of Duwamish waterway. Accordingly the district engineer recommends no modification of the existing river and harbor project for Duwamish waterway.

DEPARTMENT OF THE ARMY,
CORPS OF ENGINEERS,
OFFICE OF THE DISTRICT ENGINEER, SEATTLE DISTRICT,
Seattle, Wash., February 11, 1948.

Subject: Report on preliminary examination and survey for flood control of Green and Duwamish Rivers, Wash., and review of reports on Duwamish waterway, Washington.

To: Division Engineer, North Pacific Division, Corps of Engineers, Portland, Oreg.

I. GENERAL

1. *Authority and scope of report.*—This report is a combined study of the flood-control and navigation problems of Green and Duwamish Rivers, Wash. The Flood Control Act approved June 22, 1936, authorized a preliminary examination and survey for flood control. The report on preliminary examination was submitted by the district engineer December 30, 1937, and after a favorable review by the Board of Engineers for Rivers and Harbors, a survey report was ordered by the Chief of Engineers June 8, 1938.

2. By resolution adopted April 18, 1946, the Committee on Rivers and Harbors, House of Representatives, directed a review of reports on Duwamish waterway, Seattle Harbor. A preliminary examination of Duwamish waterway was authorized also by the River and Harbor Act approved July 24, 1946. Duwamish River and Duwamish waterway form the lower reach of Green River, and in consideration of the scope of the previously authorized flood-control survey, authority was requested to submit one combined report for both navigation and flood control. The Chief of Engineers approved submission of a combined report October 3, 1946.

3. Therefore, this report will consider methods for control of floods in the entire Green and Duwamish river valleys and modifications of the existing navigation project for Duwamish waterway.

4. *Prior reports.*—In addition to the preliminary examination report mentioned in paragraph 1, two other reports in the interest of controlling floods have been made. House Document No. 286, Seventy-third Congress, second session, covers the report on preliminary examination submitted November 10, 1933, and House Document No. 377, Seventy-fourth Congress, second session, covers the report on preliminary examination submitted July 24, 1935. Each of these reports recommended a survey to obtain necessary data for the preparation of a plan of improvement and an estimate of cost.

5. The resolution authorizing the navigation study of Duwamish waterway specifically directed review of the reports published in House Documents No. 108, Sixty-eighth Congress, first session, and 126, Seventy-first Congress, second session. These two reports contain the recommendations for the existing Federal navigation project for improvement of Duwamish waterway. A list of previous navigation reports is given in the appendix.¹

6. *Description of basin.*—Green River lies wholly in King County, Wash. From its source at the crest of the Cascade Mountains in the vicinity of Stampede Pass, the river flows westerly for 40 miles to Auburn, in a narrow drainage basin averaging 8 miles in width. Paralleling Green River to the north is the Cedar River Basin and to the south the White River Basin. At Auburn the river changes

¹ Not printed.

direction and flows north 32 miles to its mouth in Elliott Bay, which forms the principal part of Seattle's salt-water harbor. At its source in the Cascades, the Green River Basin is adjacent to the Yakima River Basin, which drains easterly to Columbia River. On the west, the basin downstream from Auburn is bounded by a ridge, 300 to 400 feet in elevation, the west slope of which drains directly into Puget Sound. The entire drainage basin is shown on the general maps accompanying this report, and the region is also included in the Cedar Lake, Tacoma, and Seattle quadrangle maps published by the United States Geological Survey.

7. *Valley and tributaries.*—Green River Valley is comparatively narrow from its source to Auburn, and in several places the river flows through deep rock gorges. There is little agricultural development upstream from Auburn, but downstream from Auburn the river meanders through a fertile, developed valley 2 to 3 miles wide for about 20 miles to Black River and then continues for 12 miles in a somewhat narrower valley to Elliott Bay.

8. No sizable rivers now flow into Green River. All of its tributaries are small streams joining the river in numerous places, mainly upstream from Auburn. Before 1906, White River joined the Green in the vicinity of Auburn; but during a flood in November of that year, White River was diverted through Stuck River and Puyallup River and thence to Commencement Bay, or Tacoma Harbor. This change has been made permanent by construction of a concrete diversion dam and by channel improvement of Stuck and Puyallup Rivers. Before this diversion the river downstream from Auburn to Black River was known as White River and the area is still locally called White River Valley. The river from its source in the Cascades to Black River is now named Green River.

9. Prior to 1916, the Lake Washington drainage area, which includes Cedar and Sammamish Rivers, had its outlet from the south end of Lake Washington through Black River, which flowed west a short distance to join Green River. The junction of these two rivers formed Duwamish River, which empties into Elliott Bay. In 1916 the level of Lake Washington was lowered and the outlet changed to the Lake Washington ship canal, which reaches Puget Sound through another drainage basin several miles north of Duwamish Valley. Duwamish River, which once was made up of three rivers—the Black, Green, and White—now has no tributaries and is, in fact, merely the lower reach of Green River. Because of the confusion of names, the river will hereinafter be referred to as Green River from its source to Black River, and as Duwamish River from that point to Elliott Bay. The lower portion of Duwamish River has been improved for navigation and is known as Duwamish waterway, east waterway, and west waterway, all as shown on the report map.

10. *Topography.*—Altitudes along the eastern boundary of the basin range from 3,500 feet to 5,750 feet. The Northern Pacific Railway effects a crossing of the Cascade Mountains through Stampede tunnel, adjacent to Stampede Pass (elevation 3,750 feet). Along the northern and southern boundaries of the basin, the altitudes range from over 5,000 feet at the eastern end to about 3,000 feet at a north-and-south line through the vicinity of Kanaskat. Westward of this line, the boundaries are at a much lower elevation, seldom exceeding 1,000 feet and generally below 500 feet. At one point just south of Auburn, the divide is but slightly over 100 feet above sea level. The

upper portion of the basin is characterized by sharply incised valleys and prominent ridges.

11. *Geology.*—Green River is one of the major streams draining the west slope of the Northern Cascade section of the Sierra-Cascade physiographic province. It flows northwesterly across a portion of the Puget Trough section of the Pacific Border province. The Cascades rise to over 5,000 feet near the summit, with ridges forming the valley walls extending in a northwesterly direction to elevation about 4,000 feet at the border of the Puget Trough. The entire basin of the upper Green River above Kanaskat lies within rocks of Miocene age, all volcanic in origin.

12. The Puget Trough section of the Green River Basin may be divided into an eastern and a western half. The soils of the eastern half of the basin range from a sandy to a silty loam and contain large quantities of small boulders and rock fragments. These soils have little agricultural value. The soils of the western half of the basin may be divided into three general divisions as classified in a report, by A. W. Mangum¹ as follows: (a) Puget series, (b) Everett series (c) Buckley loam.

13. The soils of the Puget series have their origin in river deposits and contain a high proportion of silt. The soils so classed are in a belt 2 or 3 miles wide extending from Auburn to Black River and in a narrow strip along the river bottoms from Auburn to Green River Gorge. They are exceptionally well adapted to agriculture. The Everett series, derived from the coarser glacial deposits of sand and gravel, occur on the uplands and produce relatively low crop yields. The Buckley loam, which consists largely of silt and clay, occurs in the vicinity of Enumclaw. It is an impervious soil, but where properly drained is well suited to general farming, and especially to dairying.

14. *Stream-flow records.*—Records of stream flow of Green River are of relatively short duration, being available only from 1931 to date. A recording gage was established by the United States Geological Survey about 2 miles above the Tacoma waterworks diversion dam near Palmer in October 1931, and records of stream flow have been kept to date. The Geological Survey established another recording gage near Auburn in August 1936, and this station has been in continuous operation since that time. A third gage was established in October 1939 near Black Diamond and has records to date. The city of Tacoma has kept a fragmentary record of gage height only at medium and higher stages at its diversion dam since July 1918. Table 1 shows the drainage areas at several points in the basin, and stream-flow data are summarized in table 2.

TABLE 1.—*Drainage areas*

Drainage area above—	Square miles
Green River at proposed dam site.....	225
Green River at gaging station near Palmer.....	231
Green River at diversion dam, Tacoma municipal water supply.....	233
Green River at Kanaskat.....	241
Green River at gaging station near Black Diamond.....	286
Green River at gaging station near Auburn.....	386
Green River at junction with Black River.....	452
Duwamish River at mouth.....	474

¹ Mangum, A. W., Reconnaissance Soil Surveys in the Eastern Part of the Puget Sound Basin: United States Department of Agriculture, Bureau of Soils, 1911.

TABLE 2.—Green River stream-flow data

Station	Drainage area (square miles)	Period of record	Mean discharge (second-feet)												Mean annual run-off (acre-feet)	
			October	November	December	January	February	March	April	May	June	July	August	September		Year
Palmer (near).....	231	Oct. 1, 1931, to Sept. 30, 1946 (16 years)	505	1,272	1,699	1,562	1,037	1,344	1,540	1,481	971	352	173	208	1,012	733,000
Black Diamond (near)†	286	Oct. 1, 1936, to Sept. 30, 1946 (7 years)	426	1,004	1,532	1,218	1,231	1,248	1,537	1,570	969	302	204	281	964	698,000
Auburn (near).....	386	Aug. 1, 1936, to Sept. 30, 1946 (10 years)	398	1,205	1,845	1,616	1,492	1,569	1,928	1,731	1,120	455	258	268	1,155	836,000

† Tabulated mean flows include 85 second-feet diverted by the city of Tacoma for municipal purposes, at a point above Black Diamond and below Palmer gauging station.

† Mean flows are not comparable because of varying periods of record.

15. *Climatology.*—Because the basin ranges in altitude from sea level to over 5,000 feet, marked differences in temperature and precipitation are found throughout the area. Heavy winter snows fall in the higher regions and remain until late spring or early summer. The United States Weather Bureau maintains five stations in the basin, ranging in altitude from sea level at Seattle to 4,000 feet near Stampede. Stations are also maintained in adjacent basins. Recorded data indicate that temperatures in the basin vary from a maximum of 103° to a minimum of -4°, with a mean temperature in the lower valley of about 51° and in the mountain section of about 48°. The length of the growing season (period between killing frosts) in the lower valley is about 175 days.

16. In common with most of the Puget Sound area, the Green River has an abundant yearly precipitation, about 75 percent of which falls during the period from October to April. The summer rainfall is usually insufficient for maximum crop production. Much of the precipitation in the higher elevations occurs in the form of snow, the average annual snowfall at Lester being about 81 inches and in the higher mountains more than 500 inches, whereas at Kent it is but 7.3 inches. Precipitation over the upper reaches of the river system is much greater than over the lower valley. Data as to precipitation in the higher mountains are not available; but at Palmer, elevation 895 feet, the mean annual precipitation for the 22 years of record was 87.45 inches. During the same period the mean annual rainfall at Seattle was 30.91 inches. Climatological data are summarized in tabular form in the appendix.¹

17. *Stream slopes.*—In its upper reaches the river has a rather steep but uniform gradient, averaging 39 feet per mile for the 34 miles downstream from Lester. The steepest section of this portion of the river is in the 6-mile stretch immediately downstream from Kanaskat, in which there is a total drop of 400 feet, or about 66 feet per mile. From a point immediately above Auburn, where the river breaks out of the hills onto the flood plain, down to tidewater the gradient is much less, averaging slightly over 2 feet per mile for the 20 miles between Auburn and Black River.

18. *Channel capacity.*—In its upper and middle reaches Green River occupies a deep and narrow valley, not subject to damaging overflow. From a point 8 miles upstream from Auburn to Elliott Bay the safe channel capacity of the river is approximately 12,000 second-feet. At this stage the banks are nearly full and some backwater occurs in minor tributaries, but there would be no appreciable damage from sustained flows of that amount. During the flood of December 1946, personnel of this office actually observed the effects of a 12,000-second-foot discharge.

19. Noticeable tidal effects extend upstream from Elliott Bay to Black River. A high tide occurring at time of flood prolongs the overflow conditions in the vicinity of Black River, but flooding of the area would take place regardless of the tidal stage because of out-of-bank flows farther upstream which proceed down the main valley lands.

20. *Economic development.*—The economic resources of the Green River Basin fall into four sharply defined geographic zones. In the

¹ Not printed.

mountainous area upstream from Kanaskat the only known major natural resource is timber, and the primary activity is the logging of that timber. About one-half of the timbered area is included in Snoqualmie National Forest, the remainder being privately owned. About 3,000,000,000 board feet of timber remain in the basin, of which about two-thirds is Douglas fir and hemlock. The United States Forest Service estimates that this timber would sustain an annual cut of about 70,000,000 board feet, but the present rate of cutting is considerably above that amount.

21. In the rolling, gravelly area between Kanaskat and Newaukum Creek neither timber nor agricultural crops are produced, but that area is included in a broad belt of coal lands extending from the Sammamish River in the north to the Cowlitz Valley in the south, and there are a number of operating mines in the basin, producing about 175,000 tons of soft coal annually.

22. From Newaukum Creek downstream to the head of Duwamish waterway most of the valley lands are devoted to agriculture. Also in the flood plain are portions of Auburn, most of Kent, several residential towns, and many miles of highways, railroads, and power and telephone lines. Gross value of all real and personal property in the flood plain is estimated to be at least \$45,000,000. This estimate is based on county assessor's records adjusted to present-day values. Despite the frequent flooding, which has always handicapped the agricultural development of the valley, most of the farm units are small and intensively cultivated. Dairy products, berries, and vegetables are the principal source of farm income. The area devoted to agriculture and valley towns is about 17,600 acres from which crops as follows were produced in 1946:¹

Dairy products.....	\$1,404,000
Fruit, berries, and vegetables.....	1,163,000
Bulbs, corms, etc.....	602,000
Poultry.....	561,000
Other.....	281,000
Total (gross farm income).....	4,011,000
Average gross income per acre.....	211

23. The area downstream from the head of Duwamish waterway comprises the principal industrial zone of the city of Seattle. It contains most of Seattle's heavy industry, including a large shipbuilding and repair plant; 2 plants of the Boeing Aircraft Co.; 1 steel rolling mill; 2 flour mills and grain elevators; 1 cement plant; 1 truck and bus manufacturing plant; as well as 9 lumber mills and wood-product plants; 14 foundries; machine shops; and other metal-product plants; 3 marine repair yards; and 20 miscellaneous manufacturing concerns. Most of these establishments have 50 or more employees, and during the recent war many thousands were employed in the shipbuilding and aircraft plants, but these pay rolls have now been greatly reduced.

24. *Population.*—Like other industrial regions, the Seattle area experienced a marked rise in population during the recent war. This population growth has taken place in the cities and towns, whereas the agricultural population has remained substantially constant. Since conclusion of the war the population has continued to increase, but at a much slower rate, and competent observers have predicted

¹ Data furnished by U. S. Department of Agriculture, Bureau of Agricultural Economics.

that shortly the population will continue to increase at a rate somewhat greater than that before the war. The following table indicates the population trend of Seattle since 1930:

	1930	1940	1944 ¹	1946 ²
Seattle (city).....	365,000	268,000	434,000	470,000
Seattle (metropolitan area including Bremerton).....		450,000	570,000	615,000

¹ U. S. Department of Commerce estimate.

² Washington State Census Board estimate (latest available figures).

25. Green and Duwamish River Basins, excluding any part of Seattle, have an estimated 1947 population of 32,000, of whom one-half live within the potential overflow area of the river. The greater part of the basin population is found downstream from Auburn. Kent, having a population of 3,000, and Auburn 6,000, are the largest towns wholly within the basin.

26. *Railroads*.—Four transcontinental railway lines and one local line serve the agricultural section of the basin and have terminals in Seattle. These are the Northern Pacific Railway; Union Pacific Railroad; Great Northern Railway; Chicago, Milwaukee, St. Paul & Pacific Railroad; and the Pacific Coast Railroad. The Northern Pacific Railway main line enters the drainage basin near the headwaters of Green River and stays substantially within the basin until it reaches Seattle. Branch lines join it at Palmer, Kanaskat, and Auburn. The Union Pacific; Great Northern; and Chicago, Milwaukee, St. Paul & Pacific lines serve the lower valley where the population is most dense. A branch of the Milwaukee road extends southward across the basin from Barneston to Enumclaw. The Pacific Coast Railroad Co. operates out of Seattle and serves the Black Diamond coal-mining district. All of these lines pass through the Duwamish Valley, which is thus exceptionally well situated for future rail connections. The lower Duwamish water-front area has adequate connections to these railroads.

27. *Highways*.—Green River Valley is served by two paved State highways extending south from Seattle (U S 99—State 1 and State 5). The latter continues from Auburn to Enumclaw along the southern boundary of the basin and eastward across the Cascade Mountains to eastern Washington as U S 410, State 5. This road is also the main route to the northern side of Mount Ranier National Park. A paved State highway extends across the western part of the basin, connecting Enumclaw and Renton. Several paved State secondary roads in the western part of the basin give cross connections to the State primary highways, and a network of graveled county roads serve local communities as far upstream as Kanaskat. The lower Duwamish Valley lies within the corporate limits of the city of Seattle and the area is served by the city-street system.

28. *Airfields*.—Green and Duwamish River Basins have several airfields within or very near their boundaries. Boeing field, in the south part of Seattle, is built upon reclaimed land of the Duwamish River Valley. The Seattle-Tacoma Airport lies near the west boundary of Green River Basin, on the divide between Green River Valley and Puget Sound. Both of these airfields have long concrete runways and are equipped to accommodate the growing air commerce between

national and foreign cities and the Puget Sound region. In addition to these major airfields there are smaller airfields near Enumclaw and Kent, used for local traffic. Just outside the basin, near Renton, is a large airfield constructed during the war for a nearby (Boeing) aircraft plant.

29. *Fisheries.*—Green River furnishes an important spawning ground for both commercial and sports fish. The principal spawning areas are in the reach between Auburn and Newaukum Creek and in Big Soos Creek, where the State of Washington operates a 25-pond hatchery, the largest one operated by the State. The salmon spawned in these areas contribute substantially to the Puget Sound commercial catch, and the steelhead and trout hatched in the area make Green River one of the best sports-fishing streams in the region. The Washington State Department of Fisheries has estimated that the wholesale value of commercial salmon probably originating in Green River amounted to more than \$400,000 in 1946. Although it is not considered practicable to assign a monetary value to the sports fishing in the stream, the intense interest shown by sports-fishing groups in the progress of this investigation evidences the high recreational value of the fishing grounds.

30. *National reservations.*—About 150 square miles of the eastern part of the basin, or about 33 percent of the total drainage area at the junction with Black River, lies within the Snoqualmie National Forest; and a part of the Muckleshoot Indian Reservation (approximately 240 acres) is located in the southwest corner of the basin, near Auburn.

31. *Tacoma water-supply system.*—The city of Tacoma diverts its principal water supply from Green River by means of headworks located 3 miles upstream from Palmer and 28 miles from Tacoma. The headworks and intake are concrete structures. The diversion dam is a gravity-type structure 148 feet long on the crest, which is 17 feet above the river bed and at an approximate elevation of 895 feet above mean sea level. The intake works, tunnels, and the conduit to a point about 0.6 mile below the dam are designed for a capacity of 130 second-feet, but the pipe line from that point into Tacoma is designed for about 80 second-feet. Tacoma has an existing water right for diversion of 100 second-feet and has filed an application for diversion of an additional 100 second-feet at the present diversion dam. The city has wide discretionary powers, without ownership, over 233 square miles of drainage area above the point of diversion.

32. *Terminal and transfer facilities.*—The navigation aspects of this report are confined to Duwamish waterway as requested in the authorizing resolution. The major terminal and transfer facilities of Duwamish River are located on east and west waterways, but no detailed enumeration of their facilities is included, as the details are not pertinent to this report. Of the total 97 wharves and piers on Seattle Harbor, exclusive of the Lake Washington ship canal, 52 are located on Elliott Bay, 19 on east waterway, 15 on west waterway, 3 on Puget Sound, and 8 on Duwamish waterway. On the east side of Duwamish waterway are six wharves; one of these is operated by the United States as an Army base, one is at the cement plant, one is for unloading tankers, one is used as a marine repair plant, and two are for handling logs. On the west side are two wharves; one is a lumber-handling pier and the other is a ramp used for launching

seaplanes. In addition to these, many small docks and moorings are available for shallower-draft vessels. The terminal and transfer facilities on Duwamish waterway are considered adequate for existing commerce. Additional wharves for deep-draft vessels could be constructed along the waterway or in adjoining slips.

33. *Commerce.*—Separate statistics for commerce on the various waterways of Seattle Harbor are not compiled. The data given in table 3 are for the entire Seattle Harbor and include Lake Washington ship canal traffic. Commerce routed through the Lake Washington ship canal accounted for approximately 14 percent of the vessel traffic and 69 percent of the rafted traffic shown in the table. In 1946, petroleum products represented more than one-half of the total tonnage. Other important items are wheat, coal, gravel and sand, logs and lumber, canned food products, military cargo, and miscellaneous merchandise.

TABLE 3.—Volume of water-borne traffic in Seattle Harbor, for calendar years 1937 to 1946, inclusive

Year	Vessel traffic	Rafted	Total	Year	Vessel traffic	Rafted	Total
	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>		<i>Tons</i>	<i>Tons</i>	<i>Tons</i>
1937.....	6,469,257	1,182,643	7,642,900	1942.....	8,392,444	2,346,698	10,739,142
1938.....	5,372,367	975,233	6,347,600	1943.....	8,687,799	1,672,757	10,360,556
1939.....	5,910,082	1,066,409	6,976,491	1944.....	9,372,363	1,788,780	11,131,143
1940.....	6,235,638	1,526,150	7,761,788	1945.....	8,863,810	1,362,437	10,226,247
1941.....	7,594,308	2,325,404	9,919,712	1946.....	8,256,634	1,389,491	9,646,125

34. Further data on the water-borne commerce for Seattle Harbor are given in the appendix.¹ Imports, largely petroleum products, are transhipped from Seattle to inland distribution centers; and exports of wheat, coal, lumber, and manufactured goods are shipped to domestic, Alaskan, and foreign ports. As shown by table 3, the volume of commerce increased substantially in each of the years 1940, 1941, 1942, 1943, and 1944, and decreased thereafter. Most of the increase noted in the years 1940-44 was military cargo destined to Alaska and the Pacific theater, and the decrease in 1945 and 1946 reflects the sharp reduction in such cargo. It may be reasonably assumed, however, that the substantial increase in population of the Puget Sound area, the presence of new industry, and the postwar commitments of the United States in Alaska and the Pacific will create commerce through Seattle Harbor materially greater than that of 1938-39.

35. *Vessel traffic.*—Data on trips and drafts of vessels, for Seattle Harbor, are given in the appendix.¹ Separate data for Duwamish waterway have not been compiled; however, the small number of deep-water wharves on the waterway indicates that the demand for use of the waterway by deep-draft vessels is not great. With present project dimensions the waterway could handle a much larger volume of commerce than now uses it.

36. *Bridges.*—There are five movable bridges over Duwamish waterway, and four fixed bridges and two footbridges over the river between the head of the waterway and Renton Junction. Between Renton Junction and Green River Gorge, there are 16 additional

¹ Not printed.

bridges. A list of bridges over Duwamish waterway, giving pertinent details, is included in the appendix.¹

37. *Existing project.*—No Federal project for flood control on Green or Duwamish River has ever been adopted. The lower 7½ miles of Duwamish River has been improved by local agencies and the Federal Government to give a navigable waterway having depths varying from 34 feet at Elliott Bay to 15 feet at the head of the waterway, depths being referred to the plane of mean lower low water.

38. The Federal navigation project provides for maintenance of east and west waterways to a depth of 34 feet, with a width of 750 feet for distances of 6,500 and 5,200 feet, respectively, from the pierhead line in Elliott Bay; for the maintenance of east waterway between the upper end of the 750-foot section and Spokane Street, 34 feet deep, 700 feet long, and 400 feet wide, and of a turning basin, including the head of east waterway at the junction of the waterways south of the Chicago, Milwaukee, St. Paul & Pacific Railroad bridge, to a depth of 30 feet, after these sections have all been dredged by local interests to full project dimensions; and for dredging Duwamish waterway 200 feet wide and 30 feet deep between west waterway and First Avenue South, 150 by 20 feet between First and Eighth Avenues South, thence 150 by 15 feet to a point about 1.4 miles above Fourteenth Avenue South Bridge, with a turning basin 600 by 350 feet and 20 feet deep just south of the First Avenue South Bridge, and a turning basin 500 by 250 feet and 15 feet deep and settling basin with a capacity of about 100,000 cubic yards at the upper end of the waterway. The existing project was authorized by the following river and harbor acts:

Act of—	Work authorized	Documents and reports
Mar. 2, 1919.....	Maintenance of east and west waterways 750 feet wide and 34 feet deep, and of Duwamish waterway 20 feet deep and 150 feet wide as far south as the 8th Ave. South bridge.	S. Doc. No. 313, 65th Cong., 3d sess.
Mar. 3, 1925.....	Enlargement of Duwamish waterway.....	H. Doc. No. 108, 68th Cong., 1st sess.
July 3, 1930.....	do.....	H. Doc. No. 126, 71st Cong., 2d sess.
Aug. 30, 1935.....	Maintenance of east waterway between the 750-foot section and Spokane St. and of the turning basin at the junction of east and west waterways.	H. Doc. No. 211, 72d Cong., 1st sess. ¹

¹ Contains latest published maps.

39. Since adoption of the Federal project in 1919 the United States costs up to June 30, 1947, have been \$170,334.74 for new work and \$382,437.13 for maintenance on Duwamish waterway. In addition to these amounts, local interests have contributed \$69,332.64 since 1929 for new work on Duwamish waterway. Prior to this time, local interests had expended a total of \$6,341,000 for new work and maintenance on Duwamish, east and west waterways. The greater part of this sum was spent on the construction of the wide, 34-foot-deep east and west waterways. For many years before adoption of the Federal project the only United States improvement was occasional snag removal under the project for improvement of Puget Sound and its tributary waters.

40. *Other improvements.*—Local interests have constructed dikes and have organized and operated two drainage districts. The county has

¹ Not printed.

constructed roads along the river, and in some places has raised these roads so that they form low dikes. The railroads have placed their main-line tracks on fills well above the floodwater level. In a number of places the county has constructed pile and timber shear walls for bank protection.

41. About 11.4 miles of private dikes, largely downstream from Kent, have been constructed at an estimated total cost of \$90,000, with maintenance costing about \$9,000 annually. These dikes are not continuous, but apparently were constructed wherever the danger from floods appeared most serious or where the individual landowner possessed the necessary capital with which to construct them. No dikes, as such, have been constructed with public funds, although, as just cited, the county has constructed some roads that serve as dikes. Drainage district No. 1, located between Kent and Black River, organized in 1900 and comprising 7,838 acres, has constructed drainage ditches at a total first cost of \$31,846, with maintenance assessments in recent years of \$4,000 annually. Drainage district No. 2, located northwest of Kent along a 3-mile section of the river, organized in 1904 and comprising 515 acres, has constructed drainage ditches and pumping plants at a total first cost of \$21,172, with an average maintenance assessment in recent years of about \$1,950 annually.

42. Costs of county riverbank protection work are not available, but up to \$60,000 a year has been spent on revetments to prevent bank erosion. In 1946 the State of Washington adopted laws increasing the State's participation in the cost of controlling riverbank erosion. King County and the State have now under way a joint program of channel clearing and bank protection at selected locations. The work was started in 1947 and is expected to be completed, in 1948, at a total cost of \$350,000.

43. *Surveys.*—In addition to the reports listed in paragraph 4, the following data were used in connection with the present investigation:

- (a) United States Geological Survey quadrangle maps covering the entire basin (scale 1 to 125,000).
- (b) United States Geological Survey river survey of possible reservoir sites upstream from Auburn.
- (c) Maps of Snoqualmie National Forest, published by the United States Forest Service.
- (d) Map of King County, Wash., prepared by the county engineer.
- (e) Report of an investigation by a board of engineers of the means of controlling floods in the Duwamish-Puyallup Valleys and their tributaries; H. M. Chittenden, major, Corps of Engineers, United States Army, chairman, May 1907.
- (f) Preliminary Report—Green River Flood Detention Reservoir. Unpublished report by Washington State Department of Conservation and Development, July 1, 1936.
- (g) Various reports of the water division of the department of public utilities, city of Tacoma.

(h) Water-Supply Paper 313, published by the United States Geological Survey, entitled "Water Powers of the Cascade Range, Part II, Cowlitz, Nisqually, Puyallup, White, Green, and Cedar Drainage Basins."

(i) Discharge records of various gaging stations of the United States Geological Survey.

(j) Climatological data, published by United States Weather Bureau, Seattle, Wash.

(k) Reconnaissance soil survey of the eastern part of the Puget Sound Basin, Wash., by the Bureau of Soils, United States Department of Agriculture, in cooperation with the State of Washington, dated 1911.

(l) Report entitled "Development of Industrial Sites in Duwamish-Green River Valley for City Planning Commission," by Lars Langloe, consulting engineer, dated September 1946.

(m) Report of the Puget Sound Regional Planning Commission, dated May 1943, entitled "Puget Sound Region, War and Postwar Development."

To supplement the available data used in the compilation of this report, the following surveys and investigations were made by this office:

(n) Topographic survey of the entire flood plain downstream from a point 2 miles above Auburn.

(o) Air photograph, mosaic (scale 1 inch equals approximately 800 feet) of the valley from a point about 3 miles east of Newaukum Creek to the Duwamish waterway.

(p) Soundings of Green and Duwamish Rivers at 500-foot intervals, with probings about every half mile downstream from a point 2 miles above Auburn.

(q) Survey, with subsurface drilling, test-pit excavation, and abutment trenching at proposed dam sites 6 miles upstream from Auburn, and 3 miles upstream from Palmer.

(r) Appraisal of damages resulting from 1933 and 1946 floods.

II. FLOOD CONTROL

44. *Floods*.—Table 4 contains a summary of available data on flows of Green River exceeding 12,000 second-feet near Palmer. Although stream-gaging stations have been maintained in the basin since 1931, accurate and fairly complete records are available for only one flood, that of December 1946. The crest discharge of the 1933 flood near Palmer, previously published as 33,600 second-feet, has recently been revised by the United States Geological Survey on the basis of information obtained subsequent to 1933 and from discharge measurements obtained from recent high flows, to 21,700 second-feet. The flood of November 1892 has previously been reported by this office as having had a range of 40,000 to 50,000 second-feet. A reexamination of all available data indicates that there is insufficient evidence for assigning a quantitative value to this flood but that it appears to have been in the same category as the 1933 flood. The November 1906 and December 1917 floods are estimated to have had magnitudes similar to that of the 1933 flood.

TABLE 4.—Flood flows of Green River near Palmer

Date	Crest discharge		24-hour discharge (second-feet)	3-day runoff (acre-feet)
	Second-feet	Second-feet per square mile		
Nov. 1891 ¹	12,000-20,000			
Nov. 1892 ¹				
Jan. 1903	12,000-20,000			
Nov. 1906 ¹				
Nov. 1909	12,000-20,000			
Nov. 1911	12,000-20,000			
Dec. 18, 1917 ²				
Jan. 22, 1919	12,000-20,000			
Jan. 3, 1921	12,000-20,000			
Dec. 11, 1921	12,000-20,000			
Jan. 7, 1923	12,000-20,000			
Dec. 11, 1924	12,000-20,000			
Nov. 25, 1927	12,000-20,000			
Jan. 13, 1928	12,000-20,000			
Jan. 11, 1932	15,100	65	10,300	39,600
Feb. 26, 1932	17,500	76	14,200	61,100
Nov. 13, 1932	15,000	65	13,350	51,600
Jan. 8, 1933	12,700	55	12,200	52,500
Nov. 4, 1933	12,900	56	10,400	40,500
Dec. 9, 1933	21,700	94	19,000	92,800
Dec. 22, 1933	17,900	77	15,900	84,300
Jan. 23, 1934	14,100	61	11,350	52,600
Oct. 25, 1934	13,250	57	11,500	41,800
Apr. 18, 1938	13,200	57	10,950	43,500
Dec. 3, 1943	14,200	61	11,500	37,100
Jan. 7, 1945	13,600	59	10,200	39,100
Dec. 11, 1946	23,200	100	17,800	75,700

¹ Dates of estimated flows in excess of 12,000 second-feet between 1891 and 1931. This is not a complete list especially during the first part of this period. Data are either missing or too inaccurate for these floods to make a satisfactory quantitative determination of flow.

² Magnitude of December 1933 flood near Auburn.

45. The gaging station near Auburn, in the flood zone, was not established until 1938, and the majority of floods in the basin occurred prior to that year. A study, presented in detail in the appendix,¹ shows that the peak flows near Palmer correlate very well with the peak flows near Auburn. Although the intervening drainage area is considerable, crest discharges at the two stations are approximately the same. This condition may be attributed to intervening valley storage and to differences in topography of the upper and lower river basins that cause marked differences in rainfall intensities. The following tabulation indicates the relation of peak discharges near Palmer, the upper station, and Auburn, the lower station, in the 1933 and 1946 floods.

Station	Peak discharge (second-feet)	
	1933	1946
Palmer	21,700	23,200
Auburn	24,000	21,900

46. *Standard project flood.*—Because of the short period of stream-flow records and the paucity of data regarding stages of floods occurring prior to establishment of stream-gaging stations, the known flood

¹ Not printed.

history of Green River furnishes an inadequate criterion as to the magnitude of the largest flood reasonably to be expected, and therefore as to the proper amount of flood protection to be provided. Accordingly a study has been made to determine the flood that would result if the most critical storm of record in the general region should occur over the Green River drainage area at a time when hydrologic conditions were favorable for flood run-off. The flood so derived is called the "standard project flood." Details of the derivation of the standard project flood are given in the appendix.¹ It is based on the maximum storm of 1906 and indicates that a crest discharge of 65,000 second-feet near Auburn might occur, but would be equaled or exceeded only on rare occasions. The total run-off from the standard project flood, over the above the safe capacity of the present river channel, would be about 106,000 acre-feet.

47. *Extent and character of flooded area.*—The area most frequently subject to inundation is the portion of the valley extending downstream from Newaukum Creek to Black River. Portions of the city of Auburn would be flooded only during extremely high floods, but the city of Kent has running water in some of its main streets when the flow exceeds, 20,000 second-feet. Downstream from Black River portions of the valley are flooded to the vicinity of Allentown. Flooding in this area is dependent somewhat on tidal stages. The floods of December 1917 and December 1933, which were practically of the same magnitude and the highest since the establishment in 1916 of the present stream regimen, inundated 13,800 acres, 11,600 of which were primarily farm land and 2,200 of which were devoted to town sites, brush, and swamp. The December 1946 flood inundated 12,000 acres. The gross area subject to inundation from a flood of 40,000 second-feet would be approximately 19,000 acres.

48. The area subject to flooding contains a considerable portion of urban property and facilities, agricultural land and improvements, and transportation and service utilities. Urban property includes most of the city of Kent, the smaller residential communities of O'Brien, Orillia, Foster, Allentown, and a residential area southwest of Renton. The agricultural land is composed of rich alluvial soil presently adapted to truck and dairy farming. The proximity of the marketing centers of Seattle and Tacoma makes the land especially valuable for truck and dairy farming, and practically no uncleared land remains except small portions having poor drainage. As shown in paragraph 22, the gross farm income in 1946 exceeded \$4,000,000.

49. With a few exceptions, roads in the valley are not raised above the level of the surrounding ground and are therefore subject to overflow in many places. Traffic on the main north-and-south highways becomes blocked with river flows exceeding 20,000 second-feet. The main-line railroad tracks through the valley have been placed on fills and have not been inundated by the floods of record, although these floods have caused localized damage to the fills and to the pile trestles that span openings left in the fills for passage of floodwaters.

50. *Flood damages.*—Field appraisals of damages resulting from the December 1933 and the December 1946 floods have been made by this office. The appraisal of the 1933 flood was made in 1939 and the appraisal of the 1946 flood was undertaken shortly after the floodwaters receded. Flood damages thus determined are believed to well

¹ Not printed.

represent the actual damage suffered in the valley. On the 1947 price basis, tangible damages from these two floods are as follows:

Flood	Peak discharge near Auburn (cubic feet per second)	Damage
December 1933.....	24,000	\$1,750,000
December 1946.....	21,900	1,350,000

The peak discharges were very nearly the same, but the duration of the 1933 flood was greater, causing flooding of a somewhat larger area to a depth of 1 foot or more higher than that of the 1946 flood. Consequently the damage from the 1933 flood is more than that of the 1946 flood.

51. *Improvement desired.*—In connection with the preliminary examination, a public hearing attended by 53 persons was held jointly by the Departments of War and Agriculture in Seattle on November 12, 1937. Local interests stressed the need for flood control in the area downstream from Newaukum Creek and suggested that such control could be effected by diversion, by channel rectification, or by storage.

52. On February 27, 1947, a second public hearing was held to determine the views of local interests in regard to navigation and also to give a summary of the flood-control investigation to date. Navigation problems will be discussed in a later section of this report. Local interests again expressed the great need for flood control to prevent recurrence of the recent flood damages and to attract industries to the area. Any method of control would be satisfactory to the agricultural population of the valley, but the fishing interests were opposed to any storage project that might endanger the fish runs of Green River. Unanimous approval of all those present was voiced for the construction of a flood-control dam and reservoir in the vicinity of Eagle Gorge.

53. *Flood problems and solutions considered.*—As shown previously, the flood damage from Green River is caused by the periodic inundation of valley lands downstream from the city of Auburn. Floods occur during the winter months and are caused by high run-offs resulting from a combination of snow melt and excessive precipitation. Severe floods, which inundate a substantial portion of the valley floor, have occurred in the past at intervals of 8 to 16 years. Less severe floods have taken place at about 2-year intervals. Green River no longer has any important tributaries, and therefore the flood problem is confined to controlling the floods in a single major valley.

54. Control of floods in Green River Valley could be effected by diversion, by channel improvement, or by storage, or by some combination of these means. Studies of each method have been made in sufficient detail to permit approximate estimates of cost to be made, and the relative worth of the methods to be appraised.

55. Diversion of all or a portion of the floodwaters of Green River to the Cedar River could be made through a low divide at Kanaskat; or the Green River could be diverted near Kent and discharged through a tunnel about 2 miles long directly into Puget Sound. Either diver-

sion would be more costly than would either storage or channel improvement, and the diversion to Cedar River would, in addition, require reservation of the entire Cedar River Valley as a floodway, and would thus prohibit any development of that valley.

56. The channel of Green River could be so improved and rectified as to carry within banks any desired flood. As the area to be protected is one where life and highly valuable concentrations of property would be endangered if levees were overtopped, it is essential that the project design flood for channel rectification equal or closely approach the standard project flood. Estimates, therefore, have been prepared for a diked channel of 65,000-second-foot capacity, the standard project flood. To carry floods of this size, a channel right-of-way approximately 700 feet wide, with dikes at least 20 feet high, would be required. The first cost of such a project is estimated to be \$24,000,000. The first cost is greatly in excess of that required for storage, the right-of-way would destroy more than 600 acres of productive farmland and, moreover, it would have no possible multiple-purpose benefits. For these reasons, flood protection by channel rectification alone has not been given further consideration.

57. Three possible locations for storage dams exist in the Green River Basin; one about 6 miles upstream from Auburn, one in a canyon section known as Green River Gorge and one in a deep valley section in the vicinity of Eagle Gorge. Three sites in the gorge were investigated by this office in 1933, in connection with the report printed in House Document No. 286, Seventy-third Congress, second session. That investigation showed the storage available at reasonable cost insufficient adequately to control even a moderate flood; and, furthermore, the reservoir area would include operating and potential coal properties. An analysis of a dam site 6 miles upstream from Auburn disclosed that construction of an earth-fill dam is possible. The estimated cost of a dam and reservoir at this location is \$19,000,000 based on 1947 prices. The United States Fish and Wildlife Service and the Washington State Department of Fisheries have strongly opposed this storage reservoir because the reservoir area includes a substantial part of the salmon-spawning grounds of Green River. The salmon runs of Puget Sound have been declining for many years owing to unrestricted commercial catches in the earlier days and more recently from the encroachment of various industrial and civic developments along the main spawning rivers. To preserve the existing commercial and sport fishery the State of Washington is determined, wherever possible, to keep all remaining spawning areas in their natural condition. The high cost of Auburn storage project and the loss of spawning area which it would cause have eliminated this plan from further consideration.

57a. Studies of possible combinations of storage and channel rectification that would give the desired flood protection to the valley have been made. Results of these studies are graphically shown in figure No. 5 of the appendix¹ so that any combination of storage with its needed corresponding channel rectification may be ascertained. These studies reveal that no possible combination would be as economical as providing the protection by storage alone.

58. *Flood control plan.*—Of the proposed storage sites, the Eagle Gorge site is cheapest in cost and is the only one situated far enough upstream so that it may serve the combined purposes of flood control

¹ Not printed.

and storage for municipal water supply, irrigation, and conservation. The site is suitable for construction of a gravity concrete dam. The site may also be suitable for an arch dam, but further extensive foundation explorations are necessary before a definite decision can be made.

59. *Site description.*—The dam site lies in a narrow rock gorge which presents no unusual foundation or abutment problems for the construction of a concrete gravity dam. An old river channel filled with glacial debris lies back of the right abutment. Subsurface investigation has shown that leakage through that channel would be negligible and could be readily controlled. The reservoir area lies within the Tacoma municipal watershed, in which no economic development other than the Northern Pacific Railway and a few logging camps has taken place. In most places the reservoir walls are heavily wooded mountain slopes. Cost estimates for the plan include relocation of 12 miles of the railroad and realignment of two power transmission lines in the reservoir area.

60. The dam site is near the western extremity of the mountainous portion of the basin, and receives the drainage from an area of 225 square miles. It is within this mountainous section that high rainfall intensities occur during storms and it is also the area that usually contributes melting snow to the flood run-off. The proposed reservoir is therefore located at a place where it can control floodwaters from the principal flood-producing area of the entire drainage basin.

61. *Relocations required.*—The main line of the Northern Pacific Railway traverses the entire reservoir area and its relocation constitutes one of the principal problems involved in the proposed project. Careful field investigations have revealed that the railroad can be so relocated as to pass over a dam having its spillway crest at elevation 1,205 feet without materially increasing the length of the present line or changing its ruling grade.

62. A dam with spillway crest at elevation 1,205 is proposed for construction. Such a dam would create a reservoir with capacity of 106,000 acre-feet, which is more than three times the storage needed to control the greatest flood of record. The proposed storage would give complete protection from the standard project flood by reducing its crest discharge of 65,000 second-feet to the safe capacity of the existing channel.

63. *Geology.*—Eagle Gorge dam site lies within the northern Cascade section of the Sierra-Cascade physiographic province. The present river is apparently flowing in its own stream-cut valley that was modified by local glaciation and by continental glaciation. The valley glaciation broadened and modified the slopes of the lower valley walls, removing the spurs that projected in the valley to give the valley a sinuous course. The first of the continental ice sheets formed a lake within the valley and the marginal drainage from the ice built a large delta into this lake, in the valley of the present North Fork. The river found a new outlet over a low divide into its present valley below the mouth of the North Fork. A tongue of the last continental ice moved up the valley and deposited an end moraine across the valley at the site. Many remnants of lateral moraines remain along the valley walls downstream from the site. Since disappearance of the ice, the river has cut down in the location which was accidentally imparted to it by the topography of the end moraine.

The river at the site is cut through a rock spur that extends from the south valley side. Around the north end of this spur the interglacial channel is now filled with glacial debris consisting of glacial till, dump moraine, stream-deposited gravel, and sand, and about 15 feet of lake silt. The interglacial channel had been eroded along a fault zone to a depth of 100 feet below the existing bedrock floor of the river. Thus the dam site has excellent rock foundation and abutments, but the right reservoir wall has this interglacial channel which may allow some seepage around the rock of the right abutment.

64. The rock at the site consists of Miocene volcanics of tuff and agglomerate with a tuffaceous matrix, with blocks and pebbles of tuff imbedded in it. There are also certain zones of a hard basic andesite. These may be blocks measured in feet or zones measured in hundreds of feet. The exact relationships have not been worked out and the overall structure is not apparent. The rock is soft, but tough and resistant to abrasion and will make an excellent foundation for the proposed dam and appurtenant works.

65. *Dam and control works.*—To provide desirable flow characteristics in the spillway, the dam has been slightly curved in plan. The length along the crest is 700 feet; at the bottom, 100 feet. The ungated spillway has been designed to pass a flood of 145,000 second-feet, the spillway-design flood, assuming that the outlet works had become blocked and that the reservoir was filled to the spillway crest at the beginning of the flood. The derivation of the spillway-design flood is given in the appendix.¹ Flood routings indicate a maximum surcharge of 25 feet in the reservoir to pass the spillway-design flood. The outlet works consist of a 20-foot-diameter concrete-lined tunnel. At its downstream end are three 102-inch Howell-Bunger type regulating valves which will permit passage of bankfull flows during early phases of a storm so that most of the reservoir capacity will remain to store crest flows. At the upstream end of the tunnel is a tractor-type guard gate with an accessory control tower and trashracks. The layout of Eagle Gorge Dam is shown of drawing E-12-7-68 accompanying this report, and further details and discussion are given in the appendix.¹

66. *Multiple-purpose features of Eagle Gorge Dam and Reservoir.*—The proposed dam and reservoir is ideally suited for use in connection with flood control, municipal water supply, irrigation and conservation. All of these uses are not immediately required, but it appears reasonable that within the economic life of the project all available storage for use in augmenting the summer low-water flow will be required. Stream-flow characteristics of Cascade Mountain streams are such that the same reservoir can be used for winter flood control and as a source of storage for summer water uses. In the Green River Basin the flood season extends from November until March, the largest floods occurring in either November or December. Most of the annual precipitation occurs during the winter months, the summer precipitation, from May to October, being very little.

67. *Flood control.*—The use of Eagle Gorge Reservoir for flood control will require reservation of the entire storage from the 1st of November to the 1st of March to detain possible flood flows. Following the end of the flood season, the spring run-off could be stored for release during the dry season in the interest of other uses discussed in the following paragraphs.

¹ Not printed.

68. *Water supply for fisheries.*—Green River fish have considerable importance for both commercial and sports purposes. Under existing conditions, summer stream flow sometimes becomes so small that the fish population, i. e., returning salmon and steelhead, growing fingerlings, and resident trout, suffer substantial mortality. This condition is aggravated by pollution resulting from sewage and industrial water in the valley downstream from Auburn. The Washington State Department of Fisheries and the United States Fish and Wildlife Service have studied the problem in detail, and the Fish and Wildlife Service has estimated the monetary benefits to fish life if the present low flows were augmented. The proposed reservoir has sufficient storage to supply continuously at least 110 second-feet from March until September in the driest year of record without interfering with its use for flood control.

69. *Municipal water supply.*—The city of Tacoma obtains a major portion of its municipal water supply from Green River, the intake structure for the supply line being only 3 miles downstream from the proposed Eagle Gorge Dam. Tacoma acquired the rights to 100 second-feet prior to adoption of the State water code in 1917. On February 7, 1933, the city filed an application with the State supervisor of hydraulics for authority to appropriate an additional 100 second-feet at the city's present diversion dam. Several objections were thereupon filed with the supervisor, and at this date the State has taken no action in the matter. It is understood that the application was filed by the city merely to protect its interests against any appropriation for downstream power development. To divert this additional water will require construction of a second pipe line to Tacoma, a distance of 28 miles. The city also obtains a part of its water supply from wells in the gravelly soil on which part of the city is located. This underground supply has not yet been fully tapped, and water department officials state that the next expansion of the supply system will be by wells. No exact estimate can be made of the time when the maximum permissible withdrawals from the underground system will be reached. From the indefinite data available, it is believed that further diversion for water supply from Green River will not be required for at least another 10 to 20 years.

70. *Irrigation.*—In western Washington, crop production can be materially increased by supplemental irrigation during the dry summer months. Distribution of water to the fields is usually by sprinklers; and wherever possible, water is pumped directly from a river or creek. Nearly 100 permits have been issued by the State of Washington for diversion of water for irrigation in the Green River Valley. This type of irrigation is increasing each year; and if additional water becomes available, it is believed that the practice will become widespread. The valley is relatively narrow and the river has a sinuous course through it so that direct pumping from the river appears practicable for the entire valley.

71. The United States Bureau of Reclamation has made a study of irrigation possibilities in Green River Valley. The results of the study are given in an unpublished report dated June 1944. The report indicates that the farmers cannot afford to pay for an over-all distribution system, and therefore that an irrigation project as ordinarily provided under the Federal reclamation laws cannot be considered. By letter dated April 25, 1947, the regional director, region I, Bureau

of Reclamation, advised that "Although restudy might show a change in the annual benefits to be expected from irrigation, the figures presented in our earlier report represent the closest approximation we can offer at this time."

72. *Allocation of water to various users.*—The storage space in the proposed Eagle Gorge Reservoir can be used for two purposes for which a definite present need exists and for which reasonable estimates of benefits can be made. These two purposes are first, flood control, and second, conservation by providing an augmented low water supply for the preservation of fish life. In addition to these uses, it is believed that at some undetermined time in the future, water which can be stored in the reservoir will be required for municipal water supply, abatement of pollution and irrigation. These last uses are indefinite and are not sufficiently far advanced to permit any reasonable estimate of benefits that might be used for project justification or allocation of cost.

73. The primary purpose of the proposed project is flood control, and the project works can be economically justified by the resulting flood-control and conservation benefits alone. In view of the uncertainties of future water-supply and irrigation requirements, benefits therefrom have not been considered in the project economics, but provision for their ultimate need has been made. At such time as the city of Tacoma may require stored water, it could be made available after determination of a reasonable fee by the Secretary of the Army and in accordance with the policy set forth in section 6 of the Flood Control Act approved December 22, 1944. Similarly the use of stored water for irrigation could be provided upon payment of a reasonable fee to the United States under some temporary plan in conjunction with the Washington State Department of Conservation and Development until such time as the region may become organized for irrigation development under the Federal reclamation law.

74. At present, water rights on Green River are subject to the limitations of natural flows and the priority of other rights. With the storage plan proposed in this report the United States would not be obligated to supply the requirements of any existing water right other than to always release, during periods of low flow, at least the amount of natural inflow into the reservoir.

75. *Power.*—Development of power at the Eagle Gorge site has not been favorably considered because operation of the reservoir for its primary purpose of flood control eliminates the possibility of storage for power when it is most needed. The season of the year when increased generating facilities are needed coincides with the flood period when the reservoir must be kept empty, or emptied as soon as possible if filled by flood waters, and therefore it is not feasible to combine production of electrical energy with the flood-control project proposed in this report. Because of the problems involved in the railroad relocation, it is not feasible to increase the height of the dam and thereby provide additional storage for maintaining a conservation pool to supply head for the generation of power.

76. *Recreational development of the reservoir area.*—No plans for recreational development of the reservoir area are presented. The reservoir lies entirely within the watershed area of the Tacoma municipal water-supply system and it is certain that the city would protest any development that might lead to contamination of the water supply.

Furthermore, the Puget Sound region is well supplied with numerous fresh-water lakes that have permanent pools and that are much more readily accessible to the metropolitan area than would be the Eagle Gorge Reservoir, and it appears, therefore, that recreational facilities at the reservoir are not needed.

77. *Estimate of project first cost.*—Estimates of cost of Eagle Gorge Dam and Reservoir follow. Details of the estimate are given in the appendix.¹ The costs are based on 1947 prices and include overhead, engineering, and contingencies.

Estimate of project first cost:	
Dam and appurtenances.....	\$11,300,000
Relocations.....	6,900,000
Reservoir lands.....	100,000
Total.....	18,300,000

78. *Estimate of project annual charges.*—The annual charges for the proposed dam and reservoir are computed as follows:

Federal investment:	
Total project first cost.....	\$18,300,000
Interest during construction (3 percent of \$18,300,000 for 1½ years).....	823,500
Total, Federal investment.....	19,123,500
Federal annual carrying charges:	
Interest at 3 percent on \$19,123,500.....	573,705
Amortization of investment (50-year life at 3 percent on \$19,123,500).....	169,434
Operation and maintenance.....	80,000
Total, Federal annual carrying charges.....	823,139

If \$2,000,000 of the first cost was borne by local interests, the total annual carrying charge would be \$831,658 owing to the interest rate of 3½ percent applied to non-Federal costs.

79. *Benefits of the flood-control plan.*—Benefits to be realized from the project include prevention of flood damages, increased crop returns from change in land use resulting from removal of the flood threat, prevention of loss of fish life, provision of storage for water supply and irrigation, and aid in industrial expansion. As previously discussed, a monetary value of benefits can be derived only for flood control and benefits to fish life. Intangible flood-control benefits such as preventing loss of life, removing the dangers of isolation and exposure, and eliminating the possible contamination of well-water supplies are very important but cannot be reduced to monetary terms. Contrary to popular opinion, adequate domestic and industrial water supplies in western Washington during the dry season may in the foreseeable future become critical if the present rate of increase in population and economic development continues.

80. *Flood damages prevented.*—On the basis of the appraisal of damages from the floods of 1933 and 1946, both reduced to present-day values, there has been prepared a curve relating river discharge to resulting damage. Another curve, relating damage to frequency of occurrence, was prepared on the basis of stream-flow records of Green River and adjacent streams and of a study of the hydrological characteristics of the basin. Average annual flood damages have been computed from the damage-frequency curve and the annual flood damages that can be prevented by the proposed project amount to

¹ Not printed.

\$429,000. This figure takes into account the anticipated normal increase in population and economic development that would occur if flood control were not provided. The annual flood-damage benefit has been computed on the basis of excluding damage from more than one flood a year as additional damage caused by more than one flood occurring during the same flood season is slight.

81. *Increased returns from change in land use.*—If the lands in the Green River Valley were freed from the threat of recurrent flooding, it is probable that they would be converted at a rapid rate from their present use to the production of higher-value crops and to sites for industrial plants. Soil and climatic conditions in the valley are favorable to the production of truck, berry, and bulb crops, but the landowners are reluctant to make the necessary heavy investment in soil preparation, seed, fertilizer, and equipment required to grow such crops when that investment is liable to heavy damage by floods. The effect of freedom from flooding on land use, and hence on land values, is exemplified in the adjacent Puyallup Valley where climatic and soil conditions are similar to these in the Green Valley, but which is protected from flooding by Mud Mountain Dam. Land values in the Puyallup Valley are generally about 165 percent of those in the Green River Valley.

82. In connection with the appraisals of flood damages, data were assembled on present land use and present farm income. Comparisons were then made with present land use in similar valleys where flooding is not common and an estimate made of the probable future use of Green River Valley lands if flood control were provided. Details of the anticipated change in land use are given in the appendix.¹ Of the 17,600 acres of usable land in the valley bottom it is expected that 9,600 acres will remain in agricultural use and that 8,000 acres will, in the next 50 years, become industrial and urban property. Much of the 9,600 acres of agricultural land will be converted to higher-priced crops, for instance, pasture land to truck crops, thus giving an enhancement benefit creditable to the proposed project. Based on reasonable rates of conversion and farm incomes the net annual benefit from increased crop production is estimated to be \$214,000.

83. Change of 8,000 acres of farm lands in the Green River Valley to industrial use within the economic life of the project has been estimated by a local committee of engineers and industrial real-estate representatives. The estimate appears reasonable in light of Seattle's previous growth and the expected expansion from development of Pacific Northwest hydroelectric power resources. Although flood protection is one of the prime requisites of this conversion, before the land can be so used the river channel must be straightened and new streets, utilities, and bridges must be provided by local interests. Because of these other necessary expenditures all of the anticipated land-enhancement values cannot be credited to flood control. Based on existing industrial land values and reasonable rates of conversion, it is estimated that the annual benefit, which can be credited to flood control, amounts to \$191,000.

84. *Benefit to fish life.*—Studies by the United States Fish and Wildlife Service and the State of Washington Department of Fisheries show that migratory fish life is endangered by inadequate summer

¹ Not printed.

flows. The Fish and Wildlife Service has estimated that an annual benefit of \$59,000 a year may be expected if an adequate summer water supply were assured.

85. *Total annual benefit.*—Tabulated below are the benefits for which monetary values were determined. This total-benefit figure represents only a part of all benefits that may reasonably be expected to accrue from the proposed project.

Summary of benefits:	
Prevention of tangible flood damages.....	\$429, 000
Increased returns from agricultural land.....	214, 000
Increased returns from industrial land.....	191, 000
Fisheries benefit.....	59, 000
Total, annual monetary benefit.....	893, 000

86. The total annual carrying charges of the proposed project have previously been shown to be \$823,139. As the total annual monetary benefit is \$893,000, the ratio of tangible benefits to project costs becomes 1.08 to 1.0, and the project is justified without considering the intangible benefits.

87. *Local cooperation.*—Of the total estimated annual benefits of \$893,000, a substantial portion, or \$405,000, is for increased return from protected land. This increased return is considered to be a direct benefit to present owners of the land and is believed sufficiently important to warrant consideration of a substantial local contribution toward the first cost of the project. The matter of local contribution has been discussed with local interests and assurances have been received from the Department of Conservation and Development of the State of Washington that, subject to legislative approval, it will participate in the cost of the project in the sum of \$2,000,000. This is considered the minimum contribution from local interests that will fulfill the requirements of local cooperation.

III. NAVIGATION

88. *Improvement desired.*—At the public hearing held in Seattle on February 27, 1947, requests were presented for the extension of Duwamish waterway upstream to the vicinity of Black River to provide a depth of 15 feet at mean lower low water, so as to permit barge navigation to the potential industrial sites adjacent to Duwamish River. Improvement to accommodate deep-draft vessels was not suggested at the hearing, but subsequently representatives of the Seattle Port Commission and the Seattle Chamber of Commerce indicated that expansion of the industrial area might require a ship channel at some future time, and requested that any present planning take that ultimate development into consideration. No modification of the existing project for Duwamish waterway, other than its extension, has been suggested.

89. *Difficulties attending navigation.*—The improved channel of Duwamish waterway is adequate in depth and width to accommodate, with safety, present and reasonably prospective commerce. The channel has a good alinement and is not subject to excessive winds or currents. Upstream from the improved section, however, the river is shallow and winding and is unsuitable for navigation by any type of craft.

90. Considerable discussion at the public hearing was devoted to the need for additional industrial sites in the Seattle area. Data were presented showing that the only unoccupied sites were in the vicinity of Duwamish waterway; that at the present rate of industrial expansion these sites would be utilized within the next 3 to 5 years; and that the need for additional industrial land would then be acute. It was stated that future expansion could take place only up the valley of Duwamish River. Adjacent to the river, from the head of Duwamish waterway to Black River, is an area of approximately 1,000 acres of level land, served by all of the railroads reaching Seattle, but subject to flooding, and divided by the meandering river channel into tracts unsuitable in size and shape to industrial use.

91. The conversion of the lower Duwamish River Valley from its present use for farms, residential communities, and a golf course to industrial use will require prevention of periodic flooding and the straightening of the river channel so that an adequate system of roads, railroad spurs, and utilities can be provided. The flood-control project as set forth herein will, if constructed, prevent this periodic flooding. Straightening of the channel could be accomplished by local interests as a necessary part of the work of providing additional land for industrial use, and Federal participation in the cost of such channel work could be justified only if a need for navigation of that channel were shown. At the present time no concrete plans for industrial use of the area are known and, accordingly, no estimate of the potential water-borne commerce to be anticipated from future industries can now be made.

92. *Plan of improvement.*—In view of the uncertainties regarding the amount or kind of commerce that may develop in the future on the lower Duwamish River, no plan for improvement of the river is proposed at this time. The map accompanying this report, however, shows the alinement of a rectified channel which has been proposed by various local interests, and for which a cost estimate has been prepared by this office. The cost estimate, based on 1947 costs, is as follows:

Barge channel, 15 feet deep at mean lower low water, 150-foot bottom width:	
Channel excavation.....	\$7,572,000
Bridge changes.....	1,082,000
Rights-of-way.....	470,000
Total, barge channel.....	9,124,000

To enlarge the barge channel to a ship channel having a depth of 30 feet at mean lower low water and a 200-foot bottom width would involve additional cost as follows:

Channel excavation.....	\$20,210,000
Bridge changes.....	7,190,000
Rights-of-way.....	875,000
Total additional for ship channel.....	28,275,000

93. *Justification of navigation improvement.*—That a barge channel could be justified by barge traffic alone is questionable. Short-haul barge shipments downstream to ships in Elliott Bay would have to compete with truck and rail transshipments. Since the haul is not long, 7 to 10 miles, the rate differential between barge and other types of transportation would not be large. Except for local Puget Sound

traffic and shipments to Alaska, the export cargo from Seattle is handled mainly by ocean-going ships. Because of long distances over the open waters of the Pacific, coastwise barge shipments are not usually feasible. Therefore, the only type of barge traffic that might make use of a waterway would be largely local, and resulting benefits owing to saving in freight rates would be small.

94. That a ship channel could be justified at the present time is out of the question. However, if the area becomes highly developed with industries making large amounts of exports, ship navigation may be very important. Therefore, planning at this time for any type of channel rectification in the Duwamish Valley should consider the possible ultimate construction of a deep-water ship channel. On December 15, 1947, a public hearing was held in Seattle to inform interested persons of the basic findings of the navigation study on Duwamish waterway. When informed that sufficient benefits could not be found to justify extension of the waterway by the Federal Government, local interests had no objection to these findings and offered no additional supporting data to substantiate a navigation improvement at this time.

IV. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

95. *Coordination with other agencies.*—Throughout the course of this survey other interested agencies, both Federal and local, have been advised of the progress of the study and have been called upon for advice and assistance. Such agencies include the Bureau of Reclamation, the United States Fish and Wildlife Service, the United States Department of Agriculture, the State of Washington Department of Fisheries, the Seattle Chamber of Commerce, and the city of Seattle Engineering Department. At the public hearing held on February 27, 1947, various possible plans for providing flood control were discussed. The only plan upon which all interested parties could agree was the storage project at Eagle Gorge. This project supplements the plans of other agencies, particularly the Seattle and King County groups interested in industrial expansion of the Duwamish Valley, and is desired by all interested local agencies, including those of the city, county and State.

96. The Bureau of Reclamation investigations, previously cited, have shown that a Federal reclamation project is not presently warranted, but it is reasonable to assume that if later study should show the need for a Federal irrigation project the available storage in Eagle Gorge would be welcomed. Both the United States Fish and Wildlife Service and the Washington State Department of Fisheries have indicated the desirability of constructing a dam at Eagle Gorge where no harm will be done to spawning areas and where a further benefit to fish life will be realized from increased summer flows. The city of Seattle Board of Public Works and the Seattle Chamber of Commerce have expressed their views that construction of the proposed project is necessary for the protection of agricultural lands and development of additional industrial sites.

97. *Discussion.*—It has been shown herein that the valley of Green River is subject to frequent flooding that results in large damages to existing improvements and inhibits the full development of a potentially rich agricultural and industrial area; that of the various plans

proposed for flood control, only the project for a dam and reservoir at Eagle Gorge can furnish the necessary protection at a cost justified by the resulting benefits and only that project is supported by the various State, county, and local interests. Since part of the project benefits will be derived from increased return from protected land, it has been considered appropriate to ask that local interests give assurances of participation in the initial cost of the project. Such discussions have resulted in receiving assurances that, subject to legislative approval of the State of Washington, local interests will contribute the sum of \$2,000,000 toward the first cost of the project. The proposed Eagle Gorge project will not adversely affect any plan by other Federal or local agencies for the development of agriculture, industry, communications, and fisheries.

98. For convenient reference, there is recapitulated in table 5 the salient features of the project.

TABLE 5.—Eagle Gorge Dam site—pertinent data

Primary use.....	Flood control.
Secondary uses.....	Augmented summer flows, irrigation, water supply.
Drainage area.....	225 square miles.
Mean annual run-off.....	723,960 acre-feet, 60.3 inches a square mile.
Discharge:	
Minimum.....	81 cubic-feet per second.
Mean annual.....	1,000 cubic-feet per second.
Maximum of record near Palmer.....	23,200 cubic-feet per second.
Standard project flood near Auburn.....	65,000 cubic-feet per second.
Spillway design flood (outflow).....	145,000 cubic-feet per second.
Bankfull capacity (Auburn).....	12,000 cubic-feet per second.
Reservoir:	
Pool elevation:	
Minimum.....	1,010 (approximate).
Spillway crest.....	1,205.
Maximum.....	1,230.
Tailwater elevation:	
Minimum.....	1,005 (approximate).
Spillway design flood.....	1,055.
Storage to spillway crest.....	106,000 acre-feet.
Storage converted to inches on drainage area...	8.84 inches.
Spillway: Uncontrolled overflow type with ogee crest. Excavated stilling basin.	
Outlet works: 20-foot concrete-lined tunnel.	
Regulated by 3-102-inch Howell-Bunger valves at downstream end: 16.5-foot by 28.5-foot tractor gate and trash racks at upstream end.	

99. It has been previously explained that the request for an extension of Duwamish waterway was motivated by the desire to create industrial land rather than by the needs of navigation. These industrial lands are important to the community, but it does not appear to be a Federal responsibility to undertake this kind of a land-reclamation project. If at some later time a definite plan for industrial expansion requiring a navigable channel is presented, further consideration of a Federal navigation project would be justified. An important requirement for these potential industrial lands is flood control, and if the flood-control project proposed in this report is adopted, the Federal Government will have made a valuable contribution to the industrial development of the Duwamish Valley.

100. The need for protection of the diminishing fish resources in the Puget Sound area is vital. The fish runs in Green River are an important part of the Puget Sound fishery, and those Green River runs are threatened by pollution resulting from an insufficient water supply in the summer months. The proposed storage plan would provide increased flows of sufficient magnitude to maintain fish life and possibly permit an increase in the present fish population.

101. *Conclusion.*—In view of the foregoing it is concluded that:

(a) The construction of a multiple-purpose reservoir project at Eagle Gorge as outlined in the preceding pages will provide the best plan of development of the Green River Basin in the interests of flood-control, fish conservation, pollution abatement, domestic water supply, irrigation, and industrial expansion.

(b) The project is economically justified in that the annual benefits exceed the annual costs.

(c) Local benefits resulting from construction of the project warrant substantial local contribution toward its first cost.

(d) No justification for any modification of the existing project for navigation in Duwamish waterway exists at this time.

102. *Recommendations.*—I therefore recommend adoption of the Eagle Gorge project substantially as set forth herein, with the first cost estimated at \$18,300,000 for construction and with \$80,000 annually thereafter for operation and maintenance by the United States, subject to a substantial contribution from local interests toward the first cost of its construction.

103. I further recommend that no modification for extension of the existing navigation project for Duwamish waterway be adopted at this time.

L. H. HEWITT,
Colonel, Corps of Engineers,
District Engineer.

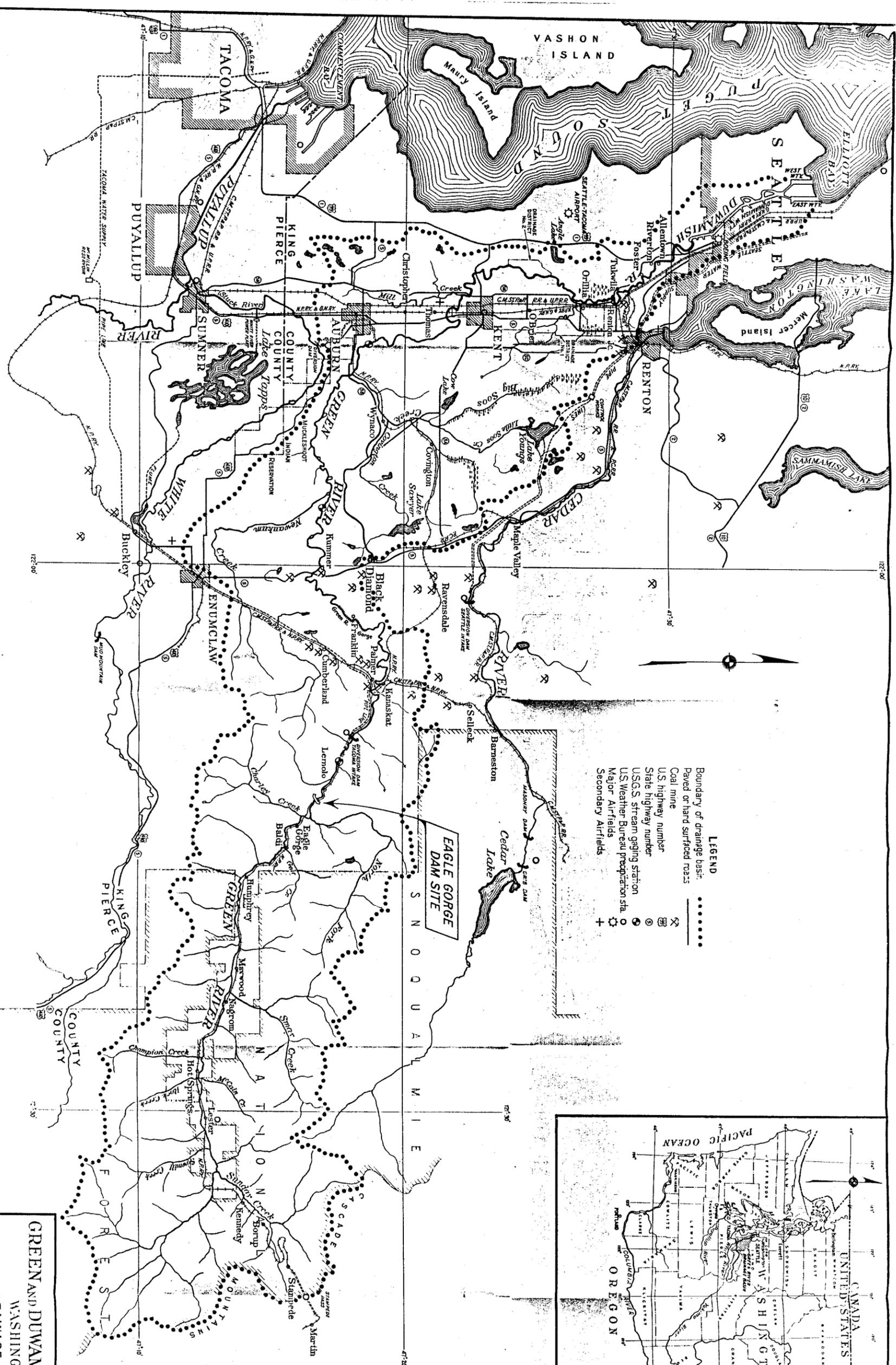
[First endorsement]

OFFICE, DIVISION ENGINEER,
NORTH PACIFIC DIVISION,
CORPS OF ENGINEERS,
Portland, Oreg., March 5, 1948.

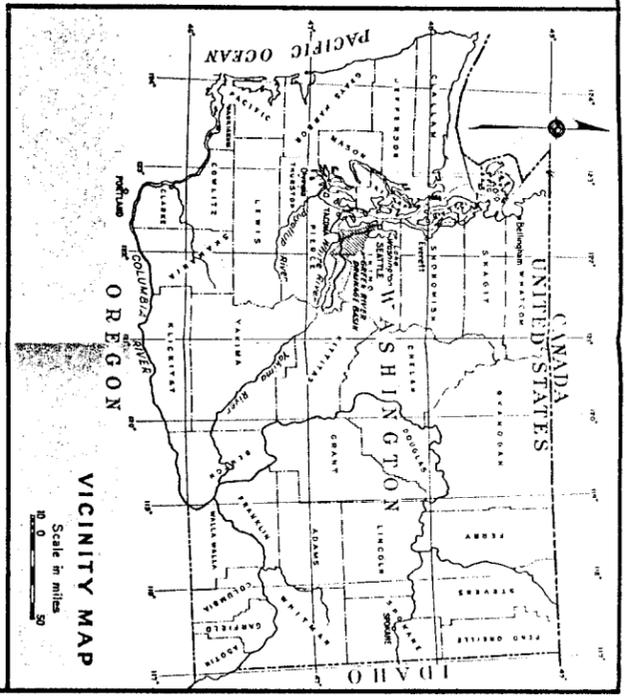
To: The Chief of Engineers, United States Army, Washington, D. C.

I concur in the recommendations of the district engineer that flood control of the Green and Duwamish Rivers be provided substantially as set forth in the report and that no modification or extension of the existing navigation project for Duwamish waterway be adopted at this time.

Theron D. Weaver,
Colonel, Corps of Engineers,
Division Engineer.



- LEGEND**
- Boundary of drainage basin
 - Paved or hard surfaced roads
 - ⊗ Coal mine
 - ⊕ U.S. highway number
 - ⊙ State highway number
 - ⊖ USGS stream gaging station
 - ⊙ USGS stream gaging station
 - ⊙ Major Airfields
 - + Secondary Airfields



**GREEN AND DUWAMISH RIVERS
WASHINGTON
DRAINAGE BASIN**

In 1 sheet
Scale: As shown

Submitted: 11 February 1945
Approved: [Signature]
Chief, Engineering Division
Colonel, Corps of Engineers

Checked by: A.E.M.
16 February 1948

File No. E-12-7-67