75TH CONGRESS, 3d Session } HOUSE OF REPRESENTATIVES { DOCUMENT No. 704

COLUMBIA AND SNAKE RIVERS, OREG., WASH., AND IDAHO

LETTER

FROM

THE SECRETARY OF WAR

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, UNITED STATES ARMY, DATED MAY 26, 1938, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON REEXAMINATION OF COLUMBIA AND SNAKE RIVERS, OREG., WASH., AND IDAHO, AUTHORIZED BY SECTION 6 OF THE RIVER AND HARBOR ACT APPROVED AUGUST 30, 1935, AND REQUESTED BY RESOLUTIONS OF THE COMMITTEE ON COMMERCE, UNITED STATES SENATE, ADOPTED MAY 21, 1938, AUGUST 21, 1935, AND JUNE 10, 1936

JUNE 13, 1938.—Referred to the Committee on Rivers and Harbors and ordered to be printed with four illustrations

WAR DEPARTMENT,
Washington, D. C., June 7, 1938.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

DEAR MR. SPEAKER: I am transmitting herewith a report dated May 26, 1938, from the Chief of Engineers, United States Army, on reexamination of Columbia and Snake Rivers, Oreg., Wash., and Idaho, authorized by section 6 of the River and Harbor Act approved August 30, 1935, and requested by resolutions of the Committee on Commerce, United States Senate, adopted May 21, 1938, August 21, 1935, and June 10, 1936, together with accompanying papers and illustrations.

Sincerely yours,

HARRY H. WOODRING,
Secretary of War.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, D. C., May 26, 1938.

Subject: Report on reexamination of Columbia and Snake Rivers, Oreg., Wash., and Idaho.
To: The Secretary of War.

1. I submit, for transmission to Congress, my report, with accompanying papers and illustrations, on additional investigations made under authority of section 6 of the River and Harbor Act approved August 30, 1935, which provides that the surveys authorized pursuant to section 1 of the River and Harbor Act of January 21, 1927, and House Document No. 308, Sixty-ninth Congress, shall be supplemented by such additional study or investigation as the Chief of Engineers finds necessary to take into account important changes in economic factors as they occur, and additional stream-flow records, or other factual data. It is also in response to the following resolution, adopted May 21, 1938:

Resolved by the Committee on Commerce of the United States Senate, That the Chief of Engineers is hereby requested in reviewing reports on the Columbia and Snake Rivers, Washington, Oregon, and Idaho, in accordance with resolutions previously adopted by this committee, to consider the indirect benefits that would accrue to the general public from improvement of the waterways in question, including relief of unemployment.

Included is the report of the Board of Engineers for Rivers and Harbors in response to resolutions of the Committee on Commerce of the United States Senate, adopted August 21, 1935, requesting review of report on Columbia River, Wash. and Oreg., submitted in House Document No. 103, Seventy-third Congress, first session, with a view to determining if the pool to be formed by the Bonneville Dam renders advisable further improvement of the river in the vicinity of The Dalles; and adopted June 10, 1936, requesting review of report on Snake River, Idaho and Wash., submitted in House Document No. 127, Fifty-sixth Congress, second session, and subsequent reports, with a view to determining whether any modification is advisable in the existing project up to Lewiston, Idaho, at the present time.

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 that the plan presented for the coordinated improvement of the Columbia and Snake Rivers from The Dalles to Lewiston, Idaho, by the construction of four locks and dams on each stream supplemented by open-river improvement between the pools of the proposed dams on the Snake, be adopted; the construction of the various elements of this plan to be initiated at such time and prosecuted at such rate as the Congress may direct.

3. I have given due consideration to these reports. Extension of the low-cost water transportation to Lewiston and the lowered cost of irrigating certain benchlands made possible by the improvement would confer immediate and important benefits to the region affected. But the transportation savings and the benefits from irrigation are insufficient to justify the large cost of the improvement at this time, even with generous allowance for the rate of development of the region. Considering the large blocks of power to be made available to this region from the Bonneville and Grand Coulee projects and the estimated power market for the near future, it is difficult to credit any benefits to the large quantities of hydroelectric power which can be generated at the proposed dams. For this reason I am unable to recommend the adoption now of this project by Congress in the sense that appropriations will thereafter be at once justified to commence the development.

4. Subject to the foregoing, comments, I concur in the views of the Board of Engineers for Rivers and Harbors expressed in its report.

5. I consider these reports to be most valuable documents in the forward planning of the water resources of the Nation, and I have no doubt that this very promising section of the country will eventually justify the prosecution of the project. Furthermore, the indirect and intangible benefits, coupled with the tangible benefits, may be found sufficient to warrant construction of elements of the project for relief of unemployment. For these reasons some action by Congress at this time would be advantageous which recognizes the virtue of this project and gives it such stamp of approval as would make it a basis for modifying the existing projects and as would provide an overall plan for coordinating the improvements in this part of the Valley of the Columbia River which may be undertaken by local agencies or by States or be selected for relief employment. The approval of the plan by Congress would also afford reasonable assurance that the Federal Government would participate in carrying the project to completion when conditions warrant.

6. I therefore recommend that the general plans presented herein for the initial and ultimate development of the Columbia and Snake Rivers between the pool of the Bonneville Dam and Lewiston, Idaho, be accepted by the Congress as a general guide for future development of the waterway in the combined interests of navigation, irrigation, and the development of hydroelectric power, and that the Congress authorize from time to time such portions of the plan as it wishes to initiate, revised as may be needed at the time to meet changing conditions.

J. L. SCHLEY,
Major General.
Chief of Engineers.

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

WAR DEPARTMENT,
BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, D. C., February 8, 1938.

Subject: Columbia and Snake Rivers, Oreg., Wash., and Idaho.
To: The Chief of Engineers, United States Army.

1. This report is in response to the following resolutions:

Resolved by the Committee on Commerce of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under section 3 of the River and Harbor Act of June 13, 1902, is hereby requested to review the report on Columbia River, Washington and Oregon, submitted in House Document Numbered 103, Seventy-third Congress, first session, with a view to determining if the pool to be formed by the Bonneville Dam renders advisable further improvement of the river in the vicinity of The Dalles, adopted August 21, 1935.

And

Resolved by the Committee on Commerce of the United States Senate, That the Board of Engineers for Rivers and Harbors, created under section 3 of the River

Montana, northern Idaho, and elsewhere in the region. The basin is served by four main transcontinental railways and numerous branch lines. Improved highways connect the principal towns of the basin and reach practically all major tonnage-producing areas. The transfer of freight to the waterways under consideration, however, is in many places handicapped by the canyonlike nature of the river valleys. Except where main highways cross or parallel the streams, routes to the river landings usually consist of unimproved dirt roads on extremely steep gradients. Waterborne commerce is now limited chiefly to down-bound shipments of wheat from a new terminal warehouse at The Dalles, and the ferrying of sacked grain across the Snake River at various points above Riparia. Commerce on the waterways in 1934, the last year preceding interruption of through navigation to lower Columbia River points by construction activities at Bonneville, totaled 23,408 tons through The Dalles-Celilo Canal, 3,758 tons on the Columbia above Celilo, and 13,003 tons on the Snake. Some increase in commerce above The Dalles is anticipated on completion of the open-channel work now in progress.

6. In House Document No. 103, Seventy-third Congress, now under review, general plans were presented for the most effective improvement of the Columbia River for navigation and the prosecution of such improvement in combination with the development of power, control of floods, and irrigation. The comprehensive plan included dams for power and navigation at four sites on the main stream between Vancouver and the mouth of the Snake; and dams for power, with provision for the installation of navigation facilities if later found advisable, and for the possible reservation of a part of the developed power for irrigation purposes, at six sites between the mouth of the Snake and the head of Grand Coulee, Wash. Subsequent to the submission of these reports the proposed Rock Island site above the mouth of the Snake has been developed by private power interests; the Bonneville Dam, the farthest downstream of the proposed power and navigation developments, is now nearing completion; and the Grand Coulee Dam is being constructed by the United States in the combined interests of power development and irrigation. Large blocks of power will be made available at the two Federal dams, and the Grand Coulee project is expected to provide ultimately for the irrigation of approximately 1,200,000 acres of land in the western part of the Columbia Plateau. When completed to the full height proposed for the ultimate development, the Grand Coulee Dam will impound 5,000,000 acre-feet of usable storage. Preliminary studies indicate that operation of this storage in the interest of power at and below the dam would increase the minimum flow of the Columbia River at The Dalles to over 70,000 cubic feet per second and raise the minimum low-water stage between Celilo and the mouth of the Snake by approximately 2 feet, but would not appreciably affect existing high velocities through the rapids. In a report submitted to Congress April 28, 1936, general plans were presented for improvement of the Snake River by the construction of a series of 10 locks and dams to provide slack-water navigation from the mouth to Lewiston. The Chief of Engineers concurred with the Board of Engineers for Rivers and Harbors in the view that the high cost of this improvement would not be warranted until slack-water navigation on the middle Columbia had been extended to the mouth of the Snake by the construction of additional locks and dams above

Bonneville; and that consideration of the latter would be warranted after the Bonneville Dam and related improvements had been placed in operation, the marketability of power further developed, due experience had in the operation of the work for the passage of migratory fish, and the value of the new navigation facilities demonstrated.

7. Local interests in general request the adoption at this time of a comprehensive plan for development of the Columbia and Snake Rivers between The Dalles and Lewiston by the construction of a series of locks and dams to permit the economical operation of modern inland water carriers over this reach. One group requests that priority be given the proposed Umatilla Dam, and another suggests a single high dam at The Dalles in lieu of the several heretofore proposed for development of the middle Columbia River. Most of the interested organizations, however, propose that design, location, and priorities of construction be left to the Department. The proponents claim that the improvement would afford large annual savings in freight rates. Fishery interests strongly oppose the suggested high dam at The Dalles and request that construction of the lower dams be held in abeyance until the effect of the Bonneville and Grand Coulee projects on the fishing industry is determined.

8. The plans heretofore presented for the comprehensive development of the Columbia and Snake Rivers have been restudied by the division engineer in the light of changed conditions and the more accurate basic data which have since become available, supplemented by topographical, hydraulic, and aerial surveys made in connection with the present examination. Consideration has also been given the proposed high dam at The Dalles. For the latter the division engineer proposes a dam with maximum height of 680 feet and normal pool elevation of 540 feet above mean sea level, which would create a lake of 1,210 square miles extending to the Rock Island Dam on the Columbia and to a point 10 miles above Riparia on the Snake. Its cost, exclusive of facilities for navigation and fishery interests, would probably exceed $800,000,000, nearly half of which represents flowage rights and damages resulting from the inundation of 74,000 acres of irrigated lands, 425 miles of railways, 300 miles of improved highway, 180 miles of primary transmission line, and the homes and business establishments of some 10,000 people, including the communities of Arlington, Umatilla, Wallula, Burbank, Pasco, and Kennewick. With a maximum pool drawdown of 50 feet resulting in useful storage behind the dam of 33,000,000 acre-feet, and assuming the existence of 5,000,000 acre-feet of storage at Grand Coulee and of the 1,500,000 acre-feet already definitely planned for the Flathead project on the Clark Fork of the Columbia, the primary power available at the dam would total 3,840,000 kilowatts. The total prime power which could be made available through construction of the high dam at The Dalles and in addition at those low dams heretofore proposed for the upper Columbia (exclusive of Grand Coulee) is estimated at 4,921,000 kilowatts. The total cost per installed kilowatt (67 percent load factor) under this set-up is estimated at roughly $130. For purposes of comparison the division engineer has presented an alternate scheme of improvement in which the single high dam is replaced by a series of low dams between The Dalles and Rock Island, with stream flow regulated by additional headwater storage above Grand Coulee. Utilizing only a part of the desirable headwater storage apparently available, he finds that

5,147,000 kilowatts of additional prime power could be obtained at an average cost per installed kilowatt, including cost of headwater storage, amounting to less than 75 percent of the cost of additional power obtained under the high-dam scheme. The foregoing comparison does not take into consideration the large blocks of additional power which would be available on the tributaries above Grand Coulee under the headwater storage plan, or the flood-control benefits of the added storage in many upstream areas. Other disadvantages of the high dam include the destruction of railways, highways, and developed farm lands, and the concentration of an extremely large block of power at one site. The headwater storage plan is susceptible of progressive development with growth of the power market, whereas the high-dam plan would entail an enormous initial investment with deficit operation for the long period which would probably be required for the development of a market sufficient to absorb the power. The division engineer concludes that the coordinated development of the Columbia between The Dalles and the mouth of the Snake in the combined interest of navigation, power, and irrigation should be based on a series of relatively low dams without storage provisions.

9. In appendix A[1] of his report the division engineer presents a scheme for the ultimate improvement of the Columbia and lower Snake Rivers by the construction of a series of dams and locks to provide slack-water navigation from the head of the Bonneville pool to Lewiston. For the Columbia River section he proposes four dams instead of the three heretofore considered, substituting a lower dam at the John Day site and an additional dam at Arlington to avoid the excessive flowage damages, estimated at $37,000,000, resulting from the high John Day Dam. The four dams now proposed would be located, respectively, at miles 193, 217, 243, and 292 above the Pacific Ocean. The maximum operating heads would range from 48 to 76 feet, the continuous power available at minimum flow from 114,000 to 181,000 kilowatts, and the power installation (for estimating purposes) from 385,000 to 517,000 kilowatts. Designs and estimates are based upon provision of adequate fishways and navigation locks 56 feet wide, 360 feet long, and 9 feet deep. The estimated total costs with generating facilities range from $49,470,000 for the Umatilla Dam to $59,250,000 for the Arlington Dam. Omission of generating equipment, but with provision for its future installation, would reduce the foregoing initial costs by roughly 50 percent.

10. The division engineer believes that the advisability of providing a ship channel instead of a barge channel in the Columbia River above The Dalles should be considered as a future possibility. The proposed pools will have adequate depths except at the heads of those behind The Dalles and Arlington Dams, where increased depths are obtainable by excavation and provisions for keeping pool elevations above normal at low flows. Barge locks can be constructed with a view to possible conversion to ship locks in the future. He points out, however, that currents near the upper ends of the proposed pools will be too swift for the safe navigation of ocean-going vessels for between 1 and 2 months of the average year.

11. For the ultimate development of the Snake River below Lewiston the division engineer has prepared plans for a complete slack-water improvement with a series of 10 locks and dams. While such

[1] Not printed. See plate A at end of document.

an extensive development may be feasible in the far-distant future, he believes that planning at the present time may for all practical purposes be limited to slack-watering only those stretches which cannot be made navigable by open-river methods at reasonable cost. He therefore proposes the construction of four locks and dams at sites 4, 57, 93, and 135 miles above the mouth, supplemented by open-channel improvement to provide a minimum depth of 5 feet over a bottom width of 150 feet outside the pools. Navigation and fishway facilities would be similar to those proposed for the four middle Columbia River dams. The slack-water pools, totaling 60 miles in length, would drown out the more steep and hazardous sections where commercial navigation is now impracticable. The 81.4 miles of open river remaining between the mouth and Lewiston would have an average slope of 2.4 feet per mile, with maximum velocities of 8 miles per hour at low water and 9 miles per hour at medium stages. Through navigation would be possible with boats of adequate power during 10 months of the average year, and would be blocked by ice or floods during the remaining 2 months. Power could be generated at the lowest three dams, although at relatively high cost due to excessive reductions in head during high water. The total initial cost is estimated at $47,000,000 with power installations totaling 155,000 kilowatts, and $28,000,000 without power facilities. The division engineer presents this improvement, plus the four locks and dams proposed for complete canalization of the middle Columbia, as the best coordinated plan of improvement of the Columbia and Snake Rivers between The Dalles and Lewiston.

12. The division engineer states that the coordinated improvement described above would benefit navigation, irrigation, and power interests. Some degree of flood control could be effected through use of storage in the upper levels of pools, but this method of operation would either conflict with power use or entail increased costs, and is not justified by the relatively slight value of additional flood control on the lower Columbia. Excluding commodities not generally susceptible of water movement, the division engineer finds that somewhat less than 3,000,000 tons of grain, petroleum products, flour, and miscellaneous items now moving between tidewater and the interior could obtain joint rail-water rates under current Interstate Commerce Commission practices over a satisfactory shallow-draft navigation improvement to Lewiston. He believes that not more than half the present tonnage would actually be diverted to the waterway, since other factors than costs enter into the method of transportation adopted by the shipper, but assumes that the total tonnage will double over a period of 50 years, provided the proposed ship channel be constructed to The Dalles; industries are developed along this channel due to the availability of large blocks of hydroelectric power, and additional areas are placed under irrigation to meet the demands of a population increased through industrial expansion along the coast. He further believes that an average of 1,000,000 tons per year of iron ore, limestone, silica, clays, and other minerals will eventually move via the waterway between the tributary area and the electro-metallurgical and electro-chemical industries to be established along the lower Columbia. The improvement is credited with unit savings based upon comparison of existing rail rates to tidewater and prospective joint rail-water rates after improvement; or where greater savings

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would result, on the difference between existing rail rates and a combination of trucking costs to the waterway plus an assumed water rate of 5 mills per ton-mile. The total savings in transportation costs anticipated by the division engineer for improvements extended to Lewiston or various points below are as follows:

Improvement to—	Miles from Portland	Potential tonnage	Unit savings	Total savings	Increment savings	Summation
The Dalles	97	1,158,330	$0.28	$324,332		
Umatilla	197	1,855,225	.69	1,280,105	$955,773	$955,773
Pasco	234	2,052,735	.75	1,539,551	259,446	1,215,219
Riparia	299	2,132,310	.84	1,791,140	251,589	1,466,808
Lewiston	372	3,132,310	.93	2,913,048	1,121,908	2,588,716

A total of 448,000 acres of benchlands bordering the lower Snake and the Columbia River above Arlington are susceptible of irrigation by pumping when justified by economic conditions. Construction of the proposed Arlington and Umatilla and the lower of the Snake River Dams would reduce the estimated annual costs for pumpage to these areas by $210,000, $145,000, and $220,000, respectively. The total navigation and irrigation benefits discussed above amount to only 15 percent of the estimated total annual carrying charges for the coordinated improvement. As no other major interest is materially affected, the remaining charges must be covered, if at all, by the value of the power generated. Annual costs thus chargeable to power are indicated below:

Improvement to—	Miles from Portland	Total installed capacity (kilowatts)	First cost	Annual cost	Annual navigation benefits	Annual irrigation benefits	Annual costs chargeable to power	
							Total	Per kilowatt
Umatilla	197	1,317,000	$177,000,000	$9,000,000	$955,000	$210,000	$7,835,000	$5.95
Pasco	234	1,702,000	229,500,000	11,700,000	1,215,000	355,000	10,130,000	5.95
Riparia	299	1,807,000	257,900,000	13,200,000	1,465,000	575,000	11,160,000	6.20
Lewiston	372	1,857,000	268,700,000	14,000,000	2,590,000	575,000	10,835,000	5.85

The division engineer points out that actual power costs will probably exceed those indicated above by about 30 percent due to the development of power-plant structures in smaller steps than assumed in his report.

13. The division engineer concludes that further improvement of the Columbia River from The Dalles to the mouth of the Snake and of the latter stream below Lewiston should be considered a single project; that this potential trade route between tidewater and the interior of the Pacific Northwest cannot be made usable over its entire length by open-river improvement at reasonable cost; that construction of a high dam at The Dalles is neither advisable nor advantageous; and that the best coordinated improvement comprises a series of four locks and dams on each stream, with supplemental channel improvement on the Snake between the pools formed by the dams, all as outlined above; that the direct navigation and irrigation benefits to the general public are not commensurate with the cost of the coordinated improvement, and that it cannot now be safely assumed that sufficient power can be sold from the dams within the next 50 years to assure economic justification for the development in view of the large blocks of power available at Grand Coulee and Bonneville, although such a possibility exists; and that provision of low-cost water transportation between tidewater and the interior, which he considers more or less essential to success of the Federal projects already under way in the basin, will promote the economic security and future development of agriculture and industry in the Pacific Northwest, with indirect benefits which may be sufficient to warrant the initiation of construction work at the present time. He believes, however, that decision as to whether work should be started at this time, without waiting for further development of the power market, must be left to the Congress, and recommends that the coordinated plan presented by him for further improvement of the Columbia between The Dalles and the mouth of the Snake, and of the Snake below Lewiston, Idaho, be approved as a basis for modification of the existing projects for these waterways when such action appears to be justified, but that no modification in these projects be made at the present time.

14. Local interests were advised of the nature of the division engineer's conclusions and invited to present additional information to the Board. At their request a hearing was held in Washington, D. C., at which proponents of the improvement and their Representatives in Congress presented voluminous data in support of the need for immediate prosecution of the coordinated plan of improvement proposed by the division engineer. They stated that each year of delay in completion of a suitable navigation channel to Lewiston compounds the losses in the marketing of products of the farm, forest, and mine sustained by reason of noncompetitive freight rates, and prevents any marketing of the lower grades of those products. They believe that low-cost water transportation would not only stimulate and enhance present restricted production, but would release lower-grade commodities, increase the regional and national wealth, reduce unemployment in measurable degree, and go far toward the permanent relief of distressed agricultural and other economic activities. The proponents emphasized their conviction that indirect benefits, though not evaluated by the division engineer, would far outweigh direct benefits which can only be predicated on present activity retarded by the very conditions that are sought to be improved. They urged the approval and immediate adoption of the coordinated plan presented by the division engineer as being the one that will produce the greatest benefit to the regional and national public.

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

15. Under the provisions of House Document No. 308, Sixty-ninth Congress, which was enacted into law with modifications in section 1 of the River and Harbor Act approved January 21, 1927, the Department made comprehensive surveys of the Columbia and Snake Rivers and their tributaries with a view to the formulation of effective integrated plans for the utilization of the water resources of these basins for purposes of navigation in combination with the development of potential water power, the control of floods, and the needs of irrigation. The comprehensive plan for the main stem of the

Columbia, published in House Document 103, Seventy-third Congress, included dams for power and navigation at four sites on the main stream between Vancouver and the mouth of the Snake; and at six sites between the mouth of the Snake and the head of Grand Coulee, Wash., dams for power alone, with provision for the installation of navigation facilities if later found advisable, and for the possible reservation of a part of the developed power for irrigation purposes. Subsequent to the submission of this report the proposed Rock Island site above the mouth of the Snake has been developed by private power interests; the Bonneville Dam, the farthest downstream of the proposed power and navigation developments, is now nearing completion as a Federal undertaking; and the Grand Coulee Dam is being constructed by the United States in the combined interests of power development and irrigation. Plans were presented for complete canalization of the lower Snake by the construction of a series of locks and dams with provision for future development of power, none of which has as yet been built by either Federal or private interests.

16. The division engineer has restudied the problems of water use in the Columbia and Snake basins in the light of changed conditions. Operation of the high Grand Coulee Dam for power development would increase the minimum low-water flow and stage of the river below, but would not be of material benefit to open-river navigation above The Dalles since the critical high velocities through the rapids sections would not be appreciably affected. He finds the most suitable plan for the ultimate improvement of the 2 streams between the Bonneville Dam and Lewiston, Idaho, to be a series of 4 locks and dams for complete canalization of the middle Columbia between the head of the Bonneville pool and the mouth of the Snake, and a series of 10 locks and dams for complete canalization of the Snake from its mouth to Lewiston. As a logical first step toward the ultimate development, he presents a coordinated plan providing for the 4 locks and dams on the middle Columbia and 4 of the 10 locks and dams proposed for the final development of the Snake, the reaches of that stream between the pools of the 4 dams proposed for the initial step to be improved by open-river methods until such time as the remaining dams can be justified by the increased demands of navigation and growth in the power market.[1] He points out that construction, if undertaken, would necessarily extend over a considerable period of years and that the locks and dams should be built in the order which will best meet the most pressing need of water-borne commerce—the establishment of through navigation to Snake River points. He accordingly finds that the Umatilla Dam and the 4 dams proposed for the Snake River should be constructed before undertaking slack-water improvement of the Columbia below Umatilla, where a fairly adequate channel already exists. The Board of Engineers for Rivers and Harbors concurs in the view that the foregoing plans constitute a satisfactory comprehensive and integrated program for the initial and ultimate development of the Columbia and Snake Rivers between Bonneville and Lewiston, Idaho, and that further planning and investigation are neither required nor warranted. The definite savings in transportation costs and to irrigation now in prospect are not in themselves commensurate with the cost of the coordinate improvement, and the large blocks of power susceptible of development at the proposed dams cannot be disposed of advantageously until the output of the Bonneville and Grand Coulee projects has been absorbed. While the immediate tangible benefits are incommensurate with the carrying charges of the undertaking, the Board nevertheless recognizes that the proposed coordinated improvement would stimulate development of the natural resources of a large area in the Pacific Northwest and convey to that region, and to the Nation as a whole, indirect and intangible benefits of sufficient importance to warrant the initiation of construction work in the near future. The Board therefore recommends that the plan presented herein for the coordinated improvement of the Columbia and Snake Rivers from The Dalles to Lewiston, Idaho, by the construction of 4 locks and dams on each stream supplemented by open-river improvement between the pools of the proposed dams on the Snake, be adopted; the construction of the various elements of this plan to be initiated at such time and prosecuted at such rate as the Congress may direct.

[1] See Plate A at end of document.

For the Board:

M. C. Tyler,
Brigadier General, Corps of Engineers,
Senior Member.

REPORT OF THE DIVISION ENGINEER

SYLLABUS

The division engineer reports that further improvement of the Columbia River between The Dalles and the mouth of the Snake River, and of the latter stream below Lewiston, Idaho, should be considered as a single project. It will be necessary to resort to locks and dams in order to provide an adequate channel above Umatilla, or to provide navigation facilities more adequate than the present 7-foot channel below Umatilla.

Construction of a high dam at The Dalles is considered neither advisable nor advantageous. The best coordinated plan of improvement consists in a series of four dams on each stream with supplemental channel improvement on the Snake River between the pools formed by the dams. Adequate provision should be made at all dams for passage of fish, future delivery of water for irrigation, and, where feasible to do so, for future development of hydroelectric power. Provisions for flood control cannot be made at costs commensurate with benefits.

The estimated total cost of the proposed improvement without power facilities is $138,000,000, not including interest during construction. The direct benefits in connection with navigation and/or irrigation that would accrue to the general public from the improvement are not commensurate with its cost, but it appears that the project will eventually be self-liquidating through the sale of surplus power from the proposed dams. Indirect benefits from the proposed improvement, in connection with increased development of agriculture and industry in the Pacific Northwest, are large and may be sufficient to warrant starting construction at this time without waiting for further development of the power market. Whether such a step in advance should be taken appears to be a question which must be left to the wisdom of Congress.

The division engineer recommends that no modification be made in the existing projects for the waterways in question at this time, but that the coordinated plan submitted in this report be approved as a basis for modifying the existing project when such action is considered justified.

WAR DEPARTMENT,
OFFICE OF THE DIVISION ENGINEER,
NORTH PACIFIC DIVISION,
Portland, Oreg., June 30, 1937.

Subject: Review of the reports on Columbia and Snake Rivers, Oreg., Wash., and Idaho.
To: The Chief of Engineers, United States Army.

CHAPTER I. INTRODUCTION

1. *Authority.*—The report herein has been prepared and is submitted under authority of the following acts of Congress:

(*a*) Section 6 of the River and Harbor Act, approved August 30, 1935, authorizing the Chief of Engineers to supplement the surveys made under the provisions of House Document No. 308, Sixty-ninth Congress, first session, by such additional studies as he finds necessary to take into consideration changed conditions.

(*b*) Resolution by the Committee on Commerce, United States Senate, adopted August 21, 1935, requesting a review of the report on the Columbia River, Oreg. and Wash., submitted in House Document No. 103, Seventy-third Congress, first session, with a view to determining if the pool to be formed by the Bonneville Dam renders advisable further improvement of the river in the vicinity of The Dalles.

(*c*) Resolution by the Committee on Commerce, United States Senate, adopted June 10, 1936, requesting a review of the report on the Snake River, Idaho and Wash., submitted in House Document No. 127, Fifty-sixth Congress, second session, and subsequent reports, with a view to determining whether any modification is advisable in the existing project up to Lewiston, Idaho, at the present time.

2. *Previous reports.*—The Columbia River report under review was prepared under the provisions of House Document No. 308, Sixty-ninth Congress, first session, and, amongst other things, outlined a plan for a series of 10 dams between tidewater and the international boundary for the coordinated development of the main stream in the combined interest of navigation, flood control, irrigation, and power.

3. The Snake River report under review was a preliminary examination and survey report and was favorable to limited open-channel improvements between Riparia, Wash., and Lewiston, Idaho.

4. Since the submission of the foregoing reports further studies have been made, under various authorizations, with a view to determining the advisability of additional open-river or slack-water improvements on the Columbia and Snake Rivers. In the River and Harbor Act approved August 30, 1935, further open-river improvements on the Columbia River to provide a 7-foot channel, over suitable widths, from Celilo to Wallula, was authorized. In a report submitted by the division engineer under date of June 24, 1935, the advisability of improving open-river conditions or providing slack-water improvements between Umatilla on the Columbia River and Lewiston on the Snake River were investigated. The latter report was unfavorable to further improvements at that time, but recommended that when such improvements became warranted they be undertaken by the construction of a lock and dam at Umatilla Rapids, with a pool elevation of 310.5, and the provision of a series of 10 locks and dams on the Snake River.

5. *Changed conditions.*—On the Columbia River, development of the coordinated plan outlined in House Document No. 103, Seventy-third Congress, first session, has already commenced. Private interests have developed the Rock Island site set up therein as a power project and the Federal Government is now engaged, under its Public Works program, in the development of the farthest downstream site, at Bonneville, in the combined interest of navigation and power, and in the development of the farthest upstream site, at Grand Coulee, in the combined interest of irrigation and power. Due to engineering and economic advantages the normal pool of the Bonneville project is being constructed to an elevation of +72 mean sea level instead of +54 as recommended for the farthest downstream site in the report on the Columbia River under review. This higher pool level affects entrance conditions at the lower end of the existing Dalles-Celilo Canal, encroaches on the potential head available at the proposed Dalles dam site, the second upstream dam of the series, and adds 18 feet to the depth of water in which that dam will be constructed. Completion of the Grand Coulee high dam will eventually make available about 5,000,000 acre-feet of usable storage which, if operated in the combined interest of irrigation and power use, will increase existing low-water discharges below this project with a resultant beneficial effect on downstream power developments and open-channel depths.

6. Since former reports were submitted, extensive channel improvements are being made in the stretch of the Columbia between the Dalles-Celilo Canal and Umatilla, and new river equipment has been built for operation on the Columbia to Umatilla and possibly Pasco on the Snake. Much additional hydraulic and hydrographic data relating to open-river or lock and dam plans of improvement have also been obtained.

7. *Scope of present report.*—The report contained herein has been prepared with a view to determining (*a*) the effect of the foregoing changed conditions on existing navigation projects on the Columbia River above The Dalles and (*b*) the most practicable method of obtaining through commercial navigation to Snake River points under a coordinated plan for eventual complete slackwater improvements from the head of the Bonneville pool to Lewiston, Idaho, on the Snake River. The latter objective required reconsideration of the alternate plans of improvement, developed in the Columbia River report under review, in the light of changed conditions and more accurate basic data, and included consideration of a possible high dam at The Dalles site with a normal pool elevation of 540 mean sea level and a usable storage capacity of some 33,000,000 acre-feet that has been seriously advocated by certain interests and has been the subject of much discussion.

8. The field work undertaken in connection with the present investigations included accurate topographic and hydrographic surveys of The Dalles dam site which were not available; a topographic and hydrographic survey of The Dalles-Celilo Canal and a topographic survey of Five Mile Rapids on a scale of 1:1,000; a topographic survey of The Dalles pool to elevation 258 mean sea level on a scale of 1:10,000; and an aerial photographic survey of the projected Dalles pool to elevation 540 mean sea level on a map scale of approximately 1:16,000. Field data obtained recently in connection with other surveys have been available for reasonably accurate computation of backwater curves. Estimates for flowage and the necessary railway and highway revisions have been based upon available maps supplemented by the aerial photographs and field reconnaissance.

9. *Organization.*—This report and the related engineering and economic studies were prepared in the office of Col. T. M. Robins, division engineer, under the supervision of C. I. Grimm, head engineer. R. E. Mackenzie, engineer, was in direct charge of preparation of the engineering appendix, and F. Kochis, engineer, was in direct charge of the economic studies. Estimates of tonnage were prepared by Fred R. Brown, associate statistician. Field surveys were made by the second Portland district, Lt. Col. C. F. Williams, district engineer. Allen Darr, engineer, was in direct charge of topographic and hydrographic surveys. G. W. Shoemaker, associate engineer, in direct charge of aerial mapping, and Senior Engineer B. E. Torpen furnished valuable data based on a reconnaissance and study of headwater storage.

10. *Acknowledgments.*—Cooperation by the following agencies is acknowledged:

United States Army Air Service, which made the aerial photographs used for preparation of aerial maps.

United States Bureau of Reclamation for information relating to irrigation projects in the Columbia River watershed.

United States Geological Survey for stream flow data.

Department of Lands, Victoria, British Columbia, for information relating to Columbia River and tributaries in Canada.

CHAPTER II. GENERAL DESCRIPTION

11. *Drainage area.*—The Columbia and Snake Rivers drain an area approximately 259,000 square miles in extent. The Columbia River, with a length of 1,200 miles, rises in British Columbia and flows first northward and then southward, crossing the international boundary in northeastern Washington, to its confluence with the Snake River, its major tributary. After being augmented by the Snake the Columbia turns westward, flowing along the Oregon-Washington boundary to its outlet into the Pacific Ocean. The Snake River, 1,036 miles in length, has its source in western Wyoming and joins the Columbia River 325 miles above the mouth of the latter stream. Other important tributaries entering the Columbia River above the mouth of the Snake are the Kootenai River, Clark Fork, Spokane River, Okanogan River, and the Chelan and Yakima Rivers. The important tributaries of the Columbia below the Snake are the Umatilla, John Day, Deschutes, and the Willamette Rivers in Oregon, and Klickitat, White Salmon, Lewis, and Cowlitz Rivers in Washington. The Columbia River drainage basin is shown on plate I, accompanying this report.

12. *River sections under consideration.*—The stretch of the rivers under primary consideration in this report are the 133-mile section of the Columbia between The Dalles, Oreg., and the mouth of the Snake, and the 140-mile section of the latter stream from its mouth to Lewiston, Idaho. The streams in these reaches are bordered by high, rolling, semiarid plateaus. In general, both river valleys are narrow and gorge conditions predominate. However, near the mouth of the Snake and along certain sections of the Columbia the river valleys widen, and developed bench and bottom lands, some under irrigation, are found supporting small communities.

13. The fall at low water in the 140-mile reach of the Snake River from Lewiston to the mouth is 393 feet, or averages approximately 2.8 feet per mile. About 75 percent of this drop occurs through 56 rapids which have a combined length of 45 miles and low-water slopes varying from 3 to 12 feet per mile. The fall at low water in the 123-mile stretch of the Columbia River between the mouth of the Snake and Celilo is 185 feet, or approximately 1.5 feet per mile. About 50 percent of this drop occurs through 21 rapids which have a combined length of 20 miles and low-water slopes varying from 2 to 10 feet per mile. In the next 10 miles of its course the Columbia River drops an additional 80 feet through Celilo Falls and Ten and Five Mile Rapids.

14. The minimum low-water discharge of the Snake at Riparia is 10,600 cubic feet per second, while the minimum discharge of the Columbia at The Dalles is about 35,000 cubic feet per second. The maximum flood of record on both streams occurred in 1894, when the discharge of the lower Snake was estimated at 409,000 cubic feet per second and the discharge of the Columbia at The Dalles was estimated at 1,170,000 cubic feet per second. Low-water stage on the Snake usually occurs during August or September while the minimum flow on the Columbia occurs between December and February when both rivers are often closed by ice. Major freshets, caused by the melting of snow, occur during the period May to July on both streams. Winter freshets may occur on both streams as a result of heavy rainfall, but peak floods on the lower Columbia are a result of combined summer floods from the Snake and upper Columbia Rivers.

15. *Tributary area.*—The area considered tributary to the Columbia and Snake Rivers between The Dalles and Lewiston consists of 90 counties in Oregon, Washington, Idaho, and Montana which, with Portland as a terminal and the provision of a satisfactory shallow-draft channel to Lewiston, could obtain joint rail-water rates under the Interstate Commerce Commission ruling set forth in *Ex parte 96*. This tributary area, which includes 54 percent of the gross area of these four States and 34 percent of their population, is indicated on plate I. Pertinent population data relating to the tributary area are summarized in the following table. The subdivisions are determined by the shortest distance over present transportation routes to the available river transfer points.

Area tributary to the Columbia and Snake Rivers	Number of counties	Area (square miles)	Population statistics					
			Percent increase			Population, 1930	Density per square mile	Percent urban
			1900 to 1910	1910 to 1920	1920 to 1930			
At The Dalles	8	18,381	+122	+28	+15	132,165	7.2	32
The Dalles to Umatilla	29	75,786	+71	+34	+1	289,308	3.8	25
Umatilla to Pasco	30	65,821	+76	+13	+1	318,349	4.9	30
Pasco to Riparia	15	34,213	+55	+14	−2	334,873	9.8	61
Riparia to Lewiston	8	16,847	+44	−2	−1	97,145	5.8	24
Total	90	211,048	+67	+18	+1	1,171,840	5.6	37

16. The communities in the tributary area having a population of 10,000 or over, and their rate of growth during the past decade, are

shown in the following table. There are 20 other communities in the area having a population between 5,000 and 10,000.

Community	Population, 1930	Percent increase	Community	Population, 1930	Percent increase
Spokane, Wash	115,514	+10.6	Walla Walla, Wash	15,976	+3.1
Butte, Mont	39,532	−5.0	Missoula, Mont	14,657	+15.7
Great Falls, Mont	28,822	+19.5	Anaconda, Mont	12,494	+7.1
Yakima, Wash	22,101	+19.2	Helena, Mont	11,803	−1.9
Boise, Idaho	21,544	+0.7	Wenatchee, Wash	11,627	+83.9

During the period 1920 to 1930 the rural population decreased approximately 4 percent, to 732,710.

17. The principal pursuits in the tributary area are farming, lumbering, and mining. Grain, largely wheat, is raised under dry-farming methods on the high, rolling plateaus bordering the lower Snake and Columbia Rivers. Some 3,450,000 acres of land in the area are under irrigation, the principal crops being hay, fruits, vegetables, and specialty crops. The principal irrigation developments are located in central Washington, southern Idaho, and western Montana. Lumbering activity is extensive in northeastern Washington, northern Idaho, western Montana, and is also carried on in other sections of the region where large tracts of timber, mainly ponderosa and other species of pine, are available. Copper, lead, zinc, phosphate rock, and other metallic and nonmetallic minerals are mined in the region. The principal mining districts are located in the Coeur d'Alene area of northern Idaho, and in the Butte-Anaconda area in Montana. Deposits of other minerals such as iron, limestone, magnesites, clays, and silica, are known to exist in the region, but, in general, information as to their extent or quality is lacking. The area adjacent to the Snake River between Lewiston, Idaho, and Homestead, Oreg., which is practically without transportation facilities, is known to be highly mineralized but, as yet, development work has been limited, perhaps due to the lack of transportation facilities.

18. Based upon production data, upon analysis of traffic movements and upon information submitted by local interests, the total present commerce moving between the tributary area and tidewater is estimated as follows:

Commodity	Tributary area					
	To The Dalles	The Dalles to Umatilla	Umatilla to Pasco	Pasco to Riparia	Riparia to Lewiston	Total
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
West-bound:						
Grain	132,070	382,200	732,710	177,600	610,060	2,034,640
Fruit	117,575	5,700	6,050		1,300	130,625
Lumber	20,600	11,500	5,100	8,500	10,000	55,700
Canned goods	25,000	4,500	12,200	1,200	1,200	44,100
Flour	20,000	79,750	43,600	63,400	6,000	212,750
Wool	1,810	10,020	930	20	570	13,350
Potatoes	5,000	8,750	1,920			15,670
Lead				32,800		32,800
Livestock	10,720	46,300	480	1,050	3,710	62,260
Hay		20,000	28,000	3,000	4,000	55,000
Paper				10,000		10,000
Subtotal	332,775	568,720	830,990	297,570	636,840	2,666,895
East-bound:						
Petroleum products	28,420	104,270	77,160	76,130	55,920	341,900
Sugar	2,750	5,040	6,650	8,770	4,840	28,050
Salt	1,370	5,200	3,310	4,330	2,420	16,630
Fertilizer	400	50	550	250		1,250
Building materials	2,750	10,440	3,510	9,400	2,880	28,980
Iron and steel	1,370	5,270	3,330	4,810	2,480	17,260
Groceries	2,900	10,460	6,940	10,220	5,040	35,560
General merchandise	8,200	30,080	19,990	26,260	14,550	99,080
Autos	1,370	5,150	3,330	4,810	2,480	17,140
Subtotal	49,530	175,960	124,770	144,980	90,610	585,850
Grand total	382,305	744,680	955,760	442,550	727,450	3,252,745

19. *Transportation facilities.*—The major transportation routes serving the area are shown on plate I. Transcontinental rail lines, consisting of the Great Northern, the Northern Pacific, and the Chicago, Milwaukee & St. Paul Railways, enter the Columbia Basin via Montana and northern Idaho, pass through Spokane, and continue on to Seattle on tidewater. The Union Pacific System enters through the valley of the Snake, leaves the bank of the Snake River at Huntington, Oreg., strikes the Columbia River at Umatilla, and follows the south bank of that stream to Portland. The Spokane, Portland & Seattle Railway, a branch of the Northern Pacific, runs from Spokane to Portland, parallels the north bank of the Columbia from Pasco to Vancouver. Numerous feeders extend from the railroads into the wheat-producing areas and branch lines of the Northern Pacific and Union Pacific traverse the Yakima Valley. There are no railroads along the south bank of the Snake between Riparia and Lewiston and above the latter point there are no railroads along the river for a distance of 165 miles. This stretch includes the well-known Snake River Canyon.

20. An improved highway net connects the main communities in the area and improved roads reach practically all of the major tonnage-producing areas. Through highway facilities between northern and southern Idaho are limited to a single improved road extending from Lewiston to Weiser. With the exception of localities where the main highways cross or parallel the Columbia and Snake, the routes to the river landings consist of unimproved dirt roads on steep gradients.

21. Rail, highway, and water distances from the tributary area to the nearest tidewater point and to The Dalles are summarized in the following table:

Community	To Portland			To The Dalles			To nearest river terminal below Lewiston			
	Rail	Highway	Water	Rail	Highway	Water	Via rail	Terminal	Via truck	Terminal
The Dalles, Oreg	87	93	97							
Yakima, Wash	[1] 163	[1] 158		222	102		90	Pasco	86	Pasco.
Condon, Oreg	185	185		98	92		45	Arlington	38	Arlington.
Umatilla, Oreg	186	192	197	99	99	100				
Wallula, Wash	213	219	222	126	126	125				
Pendleton, Oreg	218	233		132	140		42	Umatilla	41	Umatilla.
Pasco, Wash	230	235	234	136	142	137				
Walla Walla, Wash.	244	250		157	157		31	Wallula	31	Wallula.
Bend, Oreg	252	198		165	144		165	The Dalles	144	The Dalles.
Magellon, Wash	261	316	277	174	223	180				
Riparia, Wash	284	311	299	197	218	202				
Central Ferry, Wash.	298	315	314	212	222	217				
Spokane, Wash	[1] 309	[1] 324		284	293		109	Magellon	94	Central Ferry.
Baker, Oreg	344	338		258	245		168	Umatilla	146	Umatilla.
Lewiston, Idaho	356	347	372	269	254	275				
Weiser, Idaho	415	400		328	307		239	Umatilla	208	Do.
Wallace, Idaho	[1] 429	[1] 410		361	378		187	Magellon	183	Central Ferry.
Grangeville, Idaho.	433	426		346	333		77	Lewiston	79	Lewiston.
Boise, Idaho	494	477		407	384		318	Umatilla	285	Umatilla.
Missoula, Mont	[1] 547	(2)		520	(2)		346	Magellon	(2)	(2).
Polson, Mont	[1] 564	(2)		531	(2)		397	Pasco	(2)	(2).
Butte, Mont	[1] 666	(2)		625	(2)		451	Magellon	(2)	(2).
American Falls, Idaho.	692	706		605	613		516	Umatilla	514	Umatilla.
Great Falls, Mont	[1] 636	(2)		795	(2)		621	Magellon	(2)	(2).
Lewistown, Mont	[1] 917	(2)		876	(2)		702	do	(2)	(2).

[1] To Seattle.
[2] Trucking not pertinent.

CHAPTER III. EXISTING PROJECTS

22. *Columbia River.*—Between the communities of The Dalles and Celilo, the existing project provides for open-river improvements through Three Mile Rapids and for the construction of an 8.5-mile lateral canal, with one tandem and three single lift locks, between the foot of Five Mile Rapids and the head of Celilo Falls on the Oregon side. The canal has a controlling depth of 8 feet over a bottom width of 65 feet, while the locks have usable widths varying from 45 to 50 feet, usable lengths of 265 feet, and controlling depths over the sills of 7 feet. The lift through the locks at low water totals 82 feet. The existing project above Celilo provides for an open-river channel 7 feet deep and 150 feet wide from Celilo to Wallula and a similar channel with no prescribed depth or width from Wallula to the mouth of the Snake.

23. The Dalles-Celilo Canal was completed in 1913 and its construction cost to date has been approximately $4,670,000. Maintenance and operation charges on the canal during recent years have averaged about $57,000 per annum. The open-river project above Celilo was adopted in 1935 and work on the project as far upstream as Umatilla is now under way under two separate contracts. The work contracted for is 30 percent completed and project dimensions as far upstream as Umatilla are expected to be obtained by 1938. The first cost of the completed improvement above Celilo is estimated at $1,415,000, while the cost of maintenance after completion is estimated at $50,000 per annum. The total cost of the existing projects to June 30, 1936, has been as follows:

Project	The Dalles-Celilo Canal	Open-river channel above Celilo	Total
First cost	$4, 669, 092. 33	$101, 916. 20	$4, 771, 008. 53
Annual maintenance and operation	564, 696. 97		564. 696. 97
Total	5, 233, 789. 30	101, 916. 20	5, 335, 705. 50

24. *Snake River.*—The existing project on the Snake River provides for open-river improvements to obtain a 5-foot depth in the existing channel to Riparia (mile 68); thence a channel of the same depth and generally 60 feet wide to Lewiston (mile 140); and for the removal of boulders and rock points between Pittsburg Landing (mile 218) and Johnsons Bar (mile 230). No increase in depth above Lewiston was contemplated. Work on the existing project was suspended in 1917 due to lack of traffic. Some work above Lewiston was done in the past year and the project is now 85 percent completed. The latest revised estimate of first cost is $317,500, while annual maintenance charges after completion are estimated at $10,500. The total cost of the existing project to June 30, 1936, excluding $85,000 of contributed funds, was as follows:

New work	$150, 052. 26
Maintenance	167, 683. 98
Total	317, 736. 24

25. *Channel conditions upon completion of work in progress.*—Natural channel depths below Bonneville and through the Bonneville pool, after completion of the Bonneville dam, will vary from a minimum of 9 feet below the dam to a minimum of 30 feet above the dam. The Chief of Engineers in a report dated March 30, 1936, has recommended the construction of a ship channel 27 feet deep and 300 feet wide, from Vancouver, the head of existing deep-draft navigation, to Bonneville.

26. The Bonneville pool, by raising the existing low-water stage at the lower end of the Dalles-Celilo Canal approximately 26 feet, will raise the low-water surface at the intermediate sill of the tandem locks, located at the lower end of the canal, to within 3 feet of the sill elevation. At a stage of 300,000 second-feet, which is exceeded 22 percent of the time, a depth of 8 feet will be made available over the intermediate sill. The Dalles-Celilo Canal drowns out at a stage of 17 feet above low water at Celilo, which corresponds to a flow of approximately 650,000 cubic feet per second. A flow of 650,000 cubic feet per second may be expected, as an average, about 9 days during the year. Completion of the open-river work now in progress will provide a channel 7 feet deep and 150 feet wide from the head of the Dalles-Celilo Canal to Umatilla. Present channel velocities through the rapids in this section of the river, during low and medium stages, average about 5 to 6 miles an hour and for short distances approach 8 to 10 miles an hour. Average velocities tend to increase with increase in stage, while maximum velocities tend to decrease. The open-river improvements now under way will have no material effect on the foregoing velocities.

27. Channel conditions on the Columbia River between Umatilla and the mouth of the Snake are reasonably satisfactory except for Umatilla and Homly Rapids. At the former, safe navigation is limited to medium and high stages due to a tortuous channel, narrow widths, and high velocities. Umatilla Rapids has a length of about 14,000 feet and a fall averaging approximately 6.3 feet per mile. The width of the existing channel through the most critical sections is limited to about 100 feet. Low and medium stage velocities are in the order of 10 miles an hour and depths, in general, are adequate. Homly Rapids, immediately below the mouth of the Snake River, has a length of about 9,000 feet and an average slope of over 5.3 feet per mile. Navigation through this stretch of the river is limited by lack of depth, narrow channels, and high velocities. The controlling depth is about 4 feet over a 60-foot width and low water velocities through the most critical sections average about 7 miles per hour. The following table is presented to indicate actual and relative difficulty of navigating the rapids under consideration:

Stage at Umatilla [1]					+0.3		+4.0		+10.0	
Discharge (cubic feet per second)					48,000		105,000		230,000	
Time exceeded (percent)					99.5		57		24	
Rapid	Miles above mouth	Length (feet)	Fall (feet, low water)	Slope (feet per mile, low water)	Velocity (miles per hour)		Velocity (miles per hour)		Velocity (miles per hour)	
					Average	Maximum	Average	Maximum	Average	Maximum
John Day	215.7	12,170	8.1	3.52	5.5	6.5	4.0	7.5	6.2	7.8
Indian	219.7	2,800	2.1	3.96	3.0	3.0	3.7	6.5	8.2	9.6
Squally Hook	222.9	4,230	6.3	7.88	3.7	6.0	4.3	7.5	6.4	7.2
Rock Creek	227.9	2,640	4.0	8.00	3.5	7.5	5.8	9.8	4.8	4.8
Four o'Clock	232.4	1,320	2.7	10.80	4.6	6.0	4.8	8.0	5.7	6.3
Blalock	234.0	6,860	3.0	2.31	--------	6.8	4.0	--------	--------	--------
Owyhee	238.4	7,920	7.4	4.93	--------	--------	4.3	7.3	--------	8.7
Canoe Encampment	264.0	7,550	5.8	4.06	4.0	4.5	4.6	7.0	7.4	7.8
Devils Bend	284.2	8,440	9.8	6.12	4.5	6.6	3.4	5.4	6.5	7.0
Umatilla	291.6	13,710	16.3	6.27	10+	--------	10.0	--------	6.7	--------
Homly	317.5	8,980	9.1	5.35	6.8	--------	7.8	--------	6.7	--------

[1] 0 of gage at elevation, 247.71.

NOTE.—Velocities estimated from surface float measurements made in 1936 except for Umatilla and Homly Rapids where estimates are based upon 1915, 1930, and 1931 measurements of velocity of drifting boat.

28. On the Snake River the work undertaken has failed to provide a navigation channel adequate for competition with land transportation. The controlling depth to Riparia at extreme low water is less than 1 foot over a width of about 30 feet, and similar channel conditions prevail as far upstream as Lewiston. Low-water velocities through the Snake River rapids average about 4 or 5 miles per hour, and through the critical sections reach a maximum of about 8 miles per hour. During medium and high stages mean velocities increase, while maximum velocities tend to decrease.

29. *Effect of future upstream storage on existing projects.*—Upstream storage developments on the Columbia and Snake Rivers in the interest of power or irrigation use will, in general, tend to increase low-water flows through the river sections under consideration. Preliminary studies indicate that operation of the 5,000,000 acre-feet of usable storage behind the proposed Grand Coulee high dam, in the interest of power at and below this site, would increase the present minimum flow at The Dalles to over 70,000 cubic feet per second. This increase would raise the minimum low-water stage between Celilo and the mouth of the Snake by approximately 2 feet but would have no appreciable effect on existing high velocities through the rapids sections. During the high-water season the Grand Coulee Reservoir will usually be filled before the flood peak occurs, unless it is provided with a very large flood-control outlet capacity. The base of the dam now being constructed will include a part of the proposed outlets and others will be installed at higher levels. Based on studies made in this office, it is estimated that a total outlet capacity of 350,000 cubic feet per second will be necessary for material reduction of flood crests as high as 900,000 cubic feet per second on the middle Columbia. In the interest of power below, reduction of the crests of floods of this magnitude will have great value ultimately.

30. The irrigation season in the Columbia Basin corresponds, in general, with the period of high run-off. Accordingly, if future irrigation developments are undertaken by diversion from natural stream flow or by seasonal storage of flood waters, return flow during the low-water period may tend to raise low water stages. However, if cyclic storage is undertaken for irrigation purposes, as is now being done on the upper Snake River where during low run-off years only return flow and release for power requirements are allowed to pass downstream, present low water discharges may be expected to be decreased.

31. Future upstream storage developments on the Columbia and Snake Rivers in the interest of power use will tend to iron out seasonal fluctuations in flow with a resultant beneficial effect on navigation.

32. *Existing commerce.*—Present water-borne commerce on the sections of the rivers under consideration is confined mainly to downbound shipments of wheat originating at the terminal warehouse located at the lower end of The Dalles-Celilo Canal and to transfer of grains, mostly wheat, from the south bank of the Snake River, between Riparia and Couse Creek, to the railroad terminals on the north bank. The latter movement is principally ferriage but at times hauls as long as 20 miles may be made. There is no through movement of commerce between the Snake and the Columbia Rivers. Between Lewiston and Johnsons Bar on the Snake River some passengers and freight are moved to local mines and farms by high-powered, shallow-draft launches. The commerce during past years over the river sections under consideration has been as follows:

Year	The Dalles-Celilo Canal		Columbia River from Celilo to mouth of Snake		Snake River, mouth to Johnsons Bar		
	Tons	Value	Tons	Value	Tons	Value	Passengers
1931	987	$74,100	449	$43,724	26,577	$652,327	825
1932	408	11,702	--------	--------	9,797	269,463	807
1933	15,640	425,734	--------	--------	17,922	489,789	664
1934	23,408	792,337	3,758	114,684	13,003	419,181	1,044
1935 [1]	3,631	120,006	650	22,382	8,895	345,539	693

[1] Through navigation to lower Columbia River interfered with by construction activities at Bonneville.

33. *Type of river craft.*—The boat used for the movement of the foregoing commerce on the Columbia River is owned by the Shaver Transportation Co. The vessel is a wooden-hull, stern-wheel steamer with a 500-horsepower power plant, a maximum cargo capacity of about 200 tons, and a loaded draft of 4½ feet. The railroad company owns and operates the river boat used for the transfer of grain on the Snake River. This latter vessel is powered by a 700-horsepower high-pressure steam engine, has a cargo capacity of 200 tons, and draws 5 feet fully loaded. The shallow-draft launches operating above Lewiston on the Snake River are powered by two 125-horsepower engines and draw about 3½ feet with a load of from 12 to 14 tons.

34. Plans are under way for more complete utilization of the Columbia River upon completion of the work now in progress. The Shaver Transportation Co. proposes to extend their operations upstream to Umatilla, using towed barges if feasible. The Inland Navigation Co., a new concern on the rivers now operating between tidewater and The Dalles, proposes to extend operations to Umatilla and possibly points upstream. The present equipment of the latter organization consists of a steel-hull, tunnel-bottom, twin-screw, packet boat, and two rented barges. The vessel is powered by two 650-horsepower engines and has a loaded draft of about 7 feet. Its cargo capacity is about 1,000 tons of bulk petroleum products upstream and 800 tons of bulk or sacked grain downstream. If economical, barge tows are contemplated below Umatilla. Another organization has also recently completed the construction of a twin-screw, 400-horsepower, Diesel-driven tug, which is now operating between tidewater and Attalia, above Umatilla. The tug carries no pay load but draws a barge with a cargo capacity of 1,000 tons of petroleum products.

35. *Terminal facilities.*—The port district of The Dalles has constructed a combined deep-draft and river-boat terminal capable of handling some 200,000 tons of cargo annually. The wharf is 1,100 feet long and 125 feet wide, and on it are located two transit sheds, each with a floor area of 42,780 square feet. The dock is equipped with marine elevators and plans are under way to provide adequate rail and highway connections and additional facilities for the unloading of petroleum products. The Inland Navigation Co. has constructed oil-storage tanks having a capacity of 1,300,000 gallons at The Dalles. The only transfer facilities on the Columbia River above The Dalles consist of a covered transit shed constructed by local interests, adjacent to The Dalles-Celilo Canal, and a small transfer and freight house on wheels at Umatilla. It is understood that the Inland Navigation Co. has acquired land in the vicinity of Wallula for a future oil terminal.

36. On the Snake River below Lewiston there are no terminals other than a few warehouses on the south bank of the river above Riparia where there is no railroad. River terminal facilities at Lewiston consist of two warehouses and elevators for handling bulk grain. Three railroad warehouses could be adapted for river shipments. The river-bank warehouses below Lewiston handle sacked grain, and transfer to boat for movement to the railroad on the opposite shore requires chuting to the boat.

37. *Bridges.*—The following bridges cross the Columbia River between The Dalles and the Rock Island project and the Snake between the mouth and Lewiston:

COLUMBIA RIVER

Miles above mouth	Nearest town	Purpose	Owner	Type	Number of spans	Clearance above low water	Width of channel opening	Remarks
						Feet	*Feet*	
191	Big Eddy, Oreg.	Highway	The Dalles Bridge Co.	Swing	5	[1] 15	[1] 65	Under construction
198	Celilo, Oreg.	Railroad	Oregon Trunk R. R.	do	9	58	95	
323	Kennewick, Wash.	do	Oregon-Washington Railroad & Navigation Co.	do	8	32.75	113.25	
339	Pasco, Wash.	do	Northern Pacific Ry. Co.	do	13	39.5	98.5	
340	Pasco and Kennewick.	Highway	State of Washington.	Fixed	5	75.2	420	Tolls.
424	Beverly, Wash.	Railroad	Chicago, Milwaukee & St. Paul Ry.	do	15	67	255	
432	Ellensburg, Wash.	Highway	State of Washington.	do	7	{73 46	[2] 210 [3] 510	

SNAKE RIVER

0.5	Burbank, Wash.	Railroad	Northern Pacific Ry. Co.	Swing	7	36	150	
2	Perry, Wash.	Highway	Walla Walla and Franklin Counties, Wash.	Fixed	9	72.5	172	
60	Riparia, Wash.	Railroad	Oregon-Washington Railroad & Navigation Co.	do	5	210	235	
68	do	do	do	Swing	4	31.5	158	
84	Central Ferry	Highway	State of Washington.	Fixed	8	70	250	
142	Lewiston, Idaho	do	Lewiston-Concord Bridge Co.	do	7	73	136	

[1] Clearance over and through The Dalles-Celilo Canal.
[2] Side spans.
[3] Center spans.

CHAPTER IV. DESIRES OF LOCAL INTERESTS

38. *Hearings.*—In connection with the present studies, hearings were held at The Dalles on December 15, 1936, and at Lewiston on February 16, 1937, in order that local interests could express their views and opinions. Transcripts [1] of the hearings accompany this report.

39. *Improvement desired.*—Local interests, in general, desire the adoption of a comprehensive plan for the coordinated development of the Columbia and the Snake Rivers, from The Dalles, Oreg., to Lewiston, Idaho, in the interest of navigation by a series of locks and dams. With the exception of two organizations, no specific project is listed for priority. The Wallula Gateway Club desires the construction of the Umatilla project as the first step of a coordinated development, while the Multnomah Civic Club proposes the construction of a 478-foot dam at The Dalles for the development of the middle Columbia River.

40. The fishery interests, in general, do not oppose the adoption of a comprehensive plan of improvement, but desire that further developments on the Columbia and Snake be held in abeyance until the effect of Bonneville and Grand Coulee on the fishing industry is determined. Fishery interests are strongly opposed to the construction of the very high dam at The Dalles.

[1] Not printed.

41. *Benefits from improvements.*—Local interests are of the opinion that the improvements proposed, when completed, would result in a material reduction in existing freight rates between the interior area and tidewater. The resultant average annual savings in freight rates, over the amortization period, creditable to the proposed improvements are estimated by local interests as follows:

Item	Tons per annum	Annual savings	
		Total	Per ton
Existing commerce:			
Grain products	2,293,600	$3,837,259	$1.67
Other commodities	6,500,000	13,000,000	2.00
Potential commerce	8,793,600	16,837,259	1.92
All commodities	4,411,400	8,450,000	1.92
Total	13,205,000	25,287,259	1.92

42. The foregoing estimate of annual navigation benefits by local interests includes practically all tonnage moving in and out of the tributary area irrespective of its origin, its destination, or the route traveled. Accordingly, the unit and total savings are much greater than estimated by this office.

CHAPTER V. HIGH DAM AT THE DALLES VERSUS HEADWATER STORAGE

43. *General.*—In accordance with the desire of some local interests, the feasibility of developing the midreach of the Columbia River by the construction of a high-storage dam at The Dalles site has been investigated. The plan of development considered contemplates the construction of a dam with a maximum height of about 680 feet and a normal pool elevation of 540 above mean sea level, backing water up to the tailwater elevation of the Rock Island dam on the Columbia and 10 miles above Riparia on the Snake River. With a drawdown of 50 feet, the usable storage behind The Dalles high dam would amount to approximately 33,000,000 acre-feet. In order to arrive at the relative cost and economies of the high dam as compared with a series of low dams through the stretch of the river under consideration, the cost of power developments based upon the low dam series with headwater storage has been compared with the cost of power developments with the proposed storage located at The Dalles.

44. *The Dalles Dam to elevation 540.*—Construction of a high dam at The Dalles with a normal pool elevation at 540 would create a lake approximately 775,000 acres (1,210 square miles) in extent, as shown on plate VIII.[1] The reservoir would inundate some 74,000 acres of developed irrigated lands and approximately the same irrigable area. In addition, 425 miles of railroad, 300 miles of improved highways, and about 180 miles of primary transmission lines would require relocation or reconstruction. A population of some 10,000 people, and their improvements, would have to be moved from the reservoir area. The principal communities affected would be Arlington, Umatilla, Wallula, Burbank, Pasco, and Kennewick.

45. A preliminary design and cost estimate for The Dalles high dam, excluding navigation and fish facilities, is given in appendix A.[2]

[1] Not printed.
[2] Only Plates I, II and IV of this appendix printed.

The facilities required for navigation and fishery interests at a dam of this height are unprecedented, and their costs have not been included in the various plans used for comparative purposes as they may be omitted from such a comparison without material error. A summary estimate of The Dalles dam to elevation 540, including an item for engineering and contingencies, is given in the following table:

Reservoirs and damages	$346,000,000
River diversion	5,500,000
Main dam	230,000,000
Power facilities (5,700,000 kilowatts)	220,000,000
Buildings, grounds, and miscellaneous	2,500,000
Total	804,000,000

46. *Storage requirements and availability.*—The 4-year period, May 1, 1928, to April 30, 1932, which is the driest of record, has been used in estimating the relation between storage and stream flow. Plate V[1] shows the hydrographs for this period at three important stations—Kettle Falls on the upper Columbia, Riparia on the Snake, and The Dalles on the lower Columbia. On the same plate are diagrams showing the relation between storage and stream flow for these three stations and also for Trail, British Columbia, on the main river, and Metaline Falls, on the Clark Fork. The break of the curve in the flow storage diagram, which represents approximately the amount required for annual regulation, is a good indicator of the most economical upper limit of storage for power regulation, as further storage does not produce commensurate increase in sustained flow. The diagrams indicate that the practical limit of storage is 20,300,000 acre-feet for the area above Kettle Falls, of which 16,500,000 acre-feet would be required for regulation of the area above Trail, British Columbia, and 3,800,000 acre-feet for the Clark Fork.

47. For the Snake River above Riparia the upper limit of economical storage as indicated by the flow-storage diagram is 6,600,000 acre-feet. Similar studies of the Spokane River indicate that 1,000,000 acre-feet of storage is desirable. The sum of these amounts of headwater storage is 27,900,000 acre-feet required for regulation of practically all the watershed above the junction of the Columbia and Snake Rivers.

48. The flow-storage diagram for The Dalles indicates that 27,000,000 acre-feet of storage, producing a minimum flow of 130,000 second-feet, is desirable if located at this point. Storage at The Dalles may be regarded as an alternative to the headwater storage plan.

49. The Clark Fork Basin, which comprises 40 percent of the drainage area above Kettle Falls, contains favorable sites for large volumes of storage. The 3,800,000 acre-feet indicated as desirable above Metaline Falls would result in a regulated flow of 16,000 second-feet during the 4-year period of study. There is little doubt that the required storage and much more is available.

50. The low-water elevation of Lake Pend Oreille, the principal storage site on the Clark Fork, is elevation 2,049, and the area about 80,000 acres. Regulation to elevation 2,067, resulting in 1,610,000 acre-feet of storage, can be effected without extensive flowage damages,

[1] Not printed.

and it is physically possible to add 100 feet to the lake level, creating 20,000,000 acre-feet of storage. This would drown out the town of Sand Point (population 3,300), which would be affected little if any by regulation to elevation 2,067. The Clark Fork below Z Canyon flows for 14 miles through Canadian territory and has a fall of over 400 feet in this section. The 3,800,000 acre-feet of storage will increase the minimum flow from 5,000 to 16,000 second-feet and will be of great value to power developments on the Canadian as well as the American section of the river.

51. Storage of Columbia River headwaters in Canada is a very important consideration. Discussion of some of the major aspects and possibilities is therefore presented, although due to limited data such discussion must be preliminary. The amount indicated as desirable for control of the Canadian area by the flow-storage diagram is 16,500,000 acre-feet. The total watershed area at Trail, British Columbia, is 34,000 square miles, of which 19,000 square miles are in the Kootenai watershed. The principal storage site on the Kootenai River is Kootenai Lake, which fluctuates under present conditions approximately between elevations 1,746 and 1,764, and has an area of about 109,000 acres at low stages. It appears feasible to construct at the outlet of the lake a dam to create the storage required for annual regulation (about 8,000,000 acre-feet) or even a greater amount.

52. Developments within the area that would be flooded by Kootenai storage are, in general, limited, and this site offers opportunity for a large volume of cheap storage. Raising the level of the lake to elevation 1,764 would permanently inundate at the south end of the lake about 50,000 acres of reclaimed land, part of which is in the United States. Higher levels will, of course, involve more flowage in the United States. The Kootenai River from the lake to the Columbia has a fall of 360 feet, concentrated in a distance of 20 miles, and is now an important power stream, with four plants having a combined capacity of 173,000 kilowatts. Further regulation of the river by storage in Kootenai Lake is therefore of great value to power developments on this section of the river which is located entirely in Canada.

53. The Arrow Lakes have a maximum rise and fall of 36 feet from the low-water elevation of about 1,382 to the maximum high-water level of about 1,418. The lakes have an area of about 100,000 acres and storage capacity between minimum and maximum levels of approximately 3,600,000 acre-feet. It is physically possible by damming the lakes at the outlet at Castlegar to provide storage for complete annual regulation. However, the town of Revelstoke, which is situated on the main line Canadian Pacific Railroad at elevation 1,425, and other railroads and developments probably limit, as a practical proposition, the maximum lake level to about 1,418, the elevation of maximum high water, which would provide 3,600,000 acre-feet of storage. From the outlet of Arrow Lakes to the Canadian border the river has a fall of about 80 feet in 37 miles to back water from the Grand Coulee project, and therefore the regulation of Arrow Lakes has relatively little value for development of power in Canada.

54. The 1,000,000 acre-feet of storage on the Spokane River indicated by flow-storage studies to be desirable is easily obtainable, as it is quite definitely known that 2,000,000 acre-feet of storage is available at reasonable cost on Coeur d'Alene Lake and its tributaries.

55. Preliminary studies indicate that on the headwaters of the Salmon and Clearwater Rivers, the two major tributaries of the Snake River, there is available about 7,000,000 acre-feet of storage. The Snake River below Milner has two storage sites which have estimated capacities of 1,000,000 and 500,000 acre-feet. Above Milner the many storage sites must be utilized primarily for irrigation, and have not been considered for regulation below Milner. The 6,600,000 acre-feet of storage indicated as the upper limit of economic storage is apparently obtainable on the Salmon and Clearwater Rivers at relatively low cost, as the headwater areas of these streams are practically undeveloped. The minimum flow at Riparia would be increased from 10,600 to 29,000 second-feet by 6,600,000 acre-feet of storage used for that purpose.

56. Based on the foregoing, the following tentative plan of regulation for power by headwater storage on the upper Columbia and tributaries is set up. Of the 20,300,000 acre-feet of storage theoretically required for regulation of the area above Kettle Falls, 5,000,000 acre-feet is now definitely proposed at Grand Coulee, and 1,140,000 acre-feet is now definitely proposed at Flathead Lake in Clark Fork Basin for the power plant under construction at Polson, with provision to increase to 1,500,000 acre-feet. These units have therefore been considered as furnishing the first regulation, leaving 13,800,000 acre-feet to be developed for control of the area above Kettle Falls. The Clark Fork will require 2,300,000 acre-feet of storage in addition to that proposed for Flathead Lake. Since storage at Grand Coulee is more effective for regulation than if located above Trail, British Columbia, the amount indicated for that station may be reduced to 11,500,000 acre-feet and subdivided into 8,000,000 acre-feet on Kootenai Lake and 3,500,000 acre-feet on the Arrow Lakes, since storage on Kootenai appears to be cheaper and more valuable than in Arrow Lakes. The provision of these volumes of storage and 1,000,000 acre-feet on the Spokane River would result in a sustained flow at Grand Coulee of about 78,500 second-feet.

57. A definite plan of headwater regulation for the lower Snake River has not been set up, as regulation of the upper Columbia as outlined affords a basis for comparison with The Dalles storage plan. The existence of extensive power developments and the prospective development at Grand Coulee favors the creation of storage on the upper Columbia and tributaries rather than on the lower Snake and tributaries.

58. Consideration of the flow-storage diagrams alone for the columbia at The Dalles indicates that the upper limit of economical storage is 27,000,000 acre-feet. However, considering both flow and head, a draw-down of 50 feet from a normal pool elevation 540 resulting in a useful storage of 33,000,000 acre-feet in addition to the 6,500,000 acre-feet definitely proposed for the Grand Coulee and Flathead Lake gives the maximum amount of prime power for a normal pool elevation of 540, and is therefore set up herein as the most feasible plan for this project.

59. The amounts and locations of storage as just discussed are theoretically desirable for annual regulation. For cyclic regulation much greater amounts are required. In practice the amounts would be determined on the basis of the cost and value of the storage at the various headwater sites, considering power and flood-control values

that could be developed on the tributaries, and other considerations. They would necessarily vary from the theoretical amounts set up. The profile of the Columbia River and main tributaries, plate II, shows that any increase in minimum flow of the tributaries resulting from headwater storage has a large drop before reaching the main stream. Storage on the Columbia would not take advantage of this fall.

60. The above mentioned storage requirements are for power regulation alone. Storage for irrigation, which is also an important factor, can be provided by either developing other sites or by combining the two uses and constructing higher dams. The latter scheme, where feasible, will give lower costs per acre-foot of power storage.

61. To obtain the large volume of headwater storage indicated as ultimately desirable, many practical difficulties would have to be overcome in obtaining flowage rights, and provision of storage in Canada in large amounts would involve agreements between the United States and Canadian Governments. The alternate plan of creating a large reservoir at The Dalles involves extraordinary difficulties with regard to raising of the pool, as discussed hereinbefore. The practical difficulties involved in headwater storage will undoubtedly be far less than those involved in creating a large reservoir on the Columbia River at The Dalles, as has been proposed.

62. *Comparison of headwater-storage plan with storage at The Dalles.*—For comparing plans involving headwater storage with a downstream-storage plan such as has been proposed at The Dalles, various methods have been studied. Apparently the simplest and most direct method is to set up alternate plans of improvement for the Columbia and Snake Rivers, one including the high dam at The Dalles as the principal storage project and the other with dams of moderate height on the main streams and headwater storage as the principal source of regulation. Cost of power per kilowatt of installed capacity may be used as the principal yardstick, as the greater part of the value of such a project is in the power. Other benefits must be considered when they differ materially in the two plans. In the comparison that follows only the primary power has been considered, and the estimates of the cost of power facilities have been made for installations based upon a 67-percent load factor. All costs except navigation facilities and fishways are charged to power. While these assumptions are not proposed as final, they are believed to afford a fair comparison. Grand Coulee as now proposed has been omitted from both plans in the comparison, as it is the same in both plans. However, the headwater-storage plan increases the regulated flow at Grand Coulee Dam and the additional power therefrom is included in the headwater-storage plan. The increase in firm power at Bonneville has not been considered, as it will be practically the same for both plans, due to physical limitations on ultimate installed capacity. The estimates indicate that the installed cost of power developed by the headwater-storage plan is definitely less than that developed by concentrating storage and power at The Dalles.

63. The estimates that follow do not include the cost of navigation facilities, fishways, interest during construction, or carrying charges, which will be discussed later. A credit has been allowed the high-dam plan for the elimination of four navigation dams on the lower Snake River. The installed capacity under each plan is approximately the

same, so that the two schemes are comparable as to power absorption. No credit has been allowed the headwater-storage plan for the power developed on the tributaries or above Grand Coulee on the main stream.

TABLE 1.—*Cost of power for high-dam plan*

	Acre-feet
Storage:	
At Grand Coulee	5,000,000
At Flathead Lake	1,500,000
At The Dalles (50-foot draw-down from 540)	33,000,000
Total	39,500,000

Site	Minimum regulated flow (cubic feet per second)	Head at minimum flow	Prime (kilowatts)	Installed kilowatts at 67 percent load factor	Cost: Dam and reservoir (in millions)	Cost: Power facilities (in millions)	Cost: Total (in millions)	Cost: Per kilowatt installed
Foster Creek	42,900	162	471,000	706,000	$22.25	$31.80	$54.05	$76.60
Chelan	44,500	90	272,000	408,000	21.00	22.00	43.00	105.30
Rocky Reach	46,500	57	180,000	270,000	21.90	19.50	41.40	153.20
				60,000 installed				
Rock Island	47,400	49	158,000	236,000			26.25	111.20
The Dalles	137,000	414	3,840,000	5,700,000	584.00	220.00	804.00	141.00
Total		772	4,921,000	7,320,000			968.70	132.30
Credit for elimination of Snake River navigation dams							27.13	
Total							941.57	128.60

TABLE 2.—*Cost of power, headwater-storage plan*

	Acre-feet
Storage:	
On Spokane River	1,000,000
At Grand Coulee Dam	5,000,000
Above Grand Coulee Dam, including 1,500,000 acre-feet at Flathead Lake	15,300,000
Total	21,300,000

Site	Minimum regulated flow (cubic feet per second)	Head at minimum flow	Prime (kilowatts)	Installed kilowatts at 67 percent load factor	Cost: Dam and reservoir (in millions)	Cost: Power facilities (in millions)	Cost: Total (in millions)	Cost: Per kilowatt installed
Grand Coulee	[1] 35,600	315	760,000	1,135,000		$37.40	$37.40	$33.00
Foster Creek	78,500	156	829,000	1,244,000	$22.25	57.20	79.45	63.70
Chelan	80,100	85	461,000	691,000	21.00	38.70	59.70	86.40
Rocky Reach	82,100	53	287,000	430,000	21.90	33.20	55.10	128.00
				60,000 installed				
Rock Island	83,000	45	254,000	381,000			39.50	103.30
Priest Rapids	83,000	129	729,000	1,090,000	37.55	57.80	95.35	87.45
Umatilla Rapids	114,000	51	395,000	595,000	17.03	43.10	60.13	101.00
Arlington	114,000	48	371,000	560,000	29.60	36.10	65.70	117.30
John Day	115,000	58	452,000	680,000	21.70	45.55	67.25	98.90
The Dalles	118,000	76	609,000	893,000	17.80	55.10	72.90	81.70
Total		1,016	5,147,000	7,699,000			632.48	82.15

[1] Increased minimum flow produced by 14,800,000 acre-feet of storage in addition to that definitely proposed at Grand Coulee Dam and Flathead Lake.

64. The construction cost of the power contained in the headwater-storage plan, neglecting the cost of storage, is $46.45 per kilowatt less than that contained in The Dalles high-dam plan. The product of

the difference in cost per kilowatt for the two plans and the installed capacity of the headwater-storage plan is $357,618,000, which is the amount that can be expended for headwater storage with power investment costs equal in the two plans. The headwater-storage plan requires 14,800,000 acre-feet of storage in addition to that now definitely proposed for Grand Coulee and Flathead Lake. The definitely proposed storage is not charged against either plan. The low-dam plan could therefore pay $24.15 per acre-foot for the 14,800,000 acre-feet of storage.

65. It is estimated from available data which is preliminary that storage on the Canadian section of the river and on the Clark Fork is obtainable under present conditions of development at a cost not to exceed $5 per acre-foot. The large lakes—Kootenay, Arrow, Pend Oreille, and Priest Lake—can provide large amounts of storage at low cost. It has been estimated that storage on Priest Lake would cost about $1 per acre-foot. A large portion of the headwater-storage cost can probably be charged to power developed on the tributaries. For example, at Flathead Lake and on the headwaters of the Spokane River studies that have been made indicate that the full cost of storage can be carried by the local power and flood control benefits when there is a market for the power. Using $5 per acre-foot, which is considered as a high charge to the Columbia River projects for headwater storage, the power from a series of low dams on the main river can be developed at a cost of $91.80 per kilowatt as compared with a cost of $128.60 for power developed with the high-dam plan.

66. It is pertinent also to compare the cost of power developed by the high-dam plan with the cost of power developed from a series of low dams without headwater storage, other than at Grand Coulee and Flathead Lake. Table 3 shows that on the same basis as the first two estimates power could be developed at a cost of $106.90 per kilowatt, $21.70 less than that developed by the high-dam plan. The installed capacity under this plan would be over 4,000,000 kilowatts, which is more than half of the capacity of the other two plans. This plan could be coordinated with any future headwater-storage plan.

TABLE 3.—*Cost of power, low-dam plan with limited headwater storage*

	Acre-feet
Storage:	
At Grand Coulee	5,000,000
At Flathead Lake	1,500,000
Total	6,500,000

Site	Minimum regulated flow (cubic feet per second)	Head at minimum flow	Prime (kilowatts)	Installed kilowatts at 67 percent load factor	Cost			
					Dam and reservoir (in millions)	Power facilities (in millions)	Total (in millions)	Per kilowatt installed
Foster Creek	42,900	162	471,000	706,000	$22.25	$31.80	$54.05	$76.60
Chelan	44,500	90	272,000	408,000	21.00	22.00	43.00	105.30
Rocky Reach	46,500	57	180,000	270,000	21.90	19.50	41.40	153.20
				60,000 installed				
Rock Island	47,400	49	158,000	236,000	----------	----------	26.25	111.20
Priest Rapids	47,400	131	421,000	631,000	37.55	32.80	70.35	111.40
Umatilla Rapids	79,000	52	273,000	420,000	17.03	30.40	47.43	112.80
Arlington	79,000	48	257,000	403,000	29.60	25.80	55.40	138.30
John Day	80,000	59	320,000	480,000	21.70	32.20	53.90	112.20
The Dalles	83,000	76	428,000	658,000	17.80	40.50	58.30	88.60
Total	----------	724	2,780,000	4,209,000	----------	----------	450.08	106.90

67. *Advantages and disadvantages of storage at The Dalles.*—Substitution of The Dalles high dam for five power plants and nine navigation dams and locks of the headwater-storage plan would reduce operating costs and tend to decrease the difference in the cost of power as developed by the two plans. Reduction in the operating costs of dams and locks, while not chargeable to power, would be a saving for the project as a whole. Offsetting this saving is the increased cost of pool maintenance required by the 50-foot draw-down of the high dam. The draw-down area would in many localities be marshy, with many pools left by the receding water which would require annual treatment to prevent the breeding of mosquitoes. The elimination of unsanitary conditions in the areas exposed by draw-down caused by sewage from the towns along the pool would require special construction.

68. Under the high-dam plan there will be available over 6,000,000 kilowatts of firm power at The Dalles and Bonneville located on the definitely proposed ship channel, while under the low-dam plan this will amount to about 1,300,000 kilowatts. The firm power available with the regulation proposed at the Columbia River dams, including Grand Coulee, is approximately 9,000,000 kilowatts. Use of Columbia River power for electrochemical and electrometallurgical purposes will undoubtedly be an important factor, and where raw materials can be supplied most economically by ships, location on a ship channel is a great advantage. However, there are vast mineral resources in the regions surrounding and eastward of the Columbia River that will probably supply, to a great extent, industries using Columbia River power, and for these industries locations on the river farther inland will be equal to or more advantageous than a location at or below The Dalles. In many instances it will even be advantageous to utilize the power at the mines. A great deal of cheap hydro power is available on streams near the Pacific coast for supplying ordinary requirements in the coastal area. Giving consideration to the foregoing and recognizing that only a part of the power will be used for heavy power-consuming industries, the advantage in concentrating more power at The Dalles and Bonneville than provided in the low-dam plan is very doubtful.

69. Navigation would be benefited by the high-dam plan because of the deeper water, lower velocities, and fewer lockages. The lower velocities would, if other conditions were equal, permit larger tows of barges, and reduction of the time required for passage through locks would permit speedier operation. This advantage would, however, be offset by the higher cost of terminals designed to operate on a lake having a 50-foot fluctuation in level and the prevalence of rough water on the large lake formed by the high dam. These terminals would extend farther into the lake than those built for the pools included in the headwater-storage plan, and would require machinery capable of loading and unloading barges more than 50 feet below the main floor of the terminal. Facilities for passing navigation at The Dalles high dam involve great cost and unprecedented design.

70. It may be concluded that the advantages and disadvantages in regard to power and navigation discussed above approximately balance each other. There are then the following items included under disadvantages of the high-dam plan which are not balanced by advantages. Step development of the headwater-storage plan

can provide power as required by the market, with the result that carrying charges would be low as compared with those for The Dalles high dam where an enormous investment would have to be carried while a market for the power developed.

71. The high-dam plan destroys many miles of highways and railroads as well as large areas of valuable irrigated land, irrigable lands, and other developments. In contrast to this, the headwater-storage plan can provide storage on the large headwater lakes and relatively undeveloped areas where the damages to property will be small compared to those involved in The Dalles high-dam plan.

72. There are practical difficulties in obtaining such a large sum of money for a single project. Uncertainty as to the ability of the power market to absorb the great amount of power in a reasonable time makes the investment in this project of speculative nature. In contrast, the headwater-storage plan, being developed by steps as required by the demand for power, reduces to a minimum the uncertainties as to the power market.

73. The headwater-storage plan by increasing the minimum flow of tributaries permits the development of power which would not be available from an equal amount of storage at The Dalles. Also, headwater storage will, in many areas, provide flood control which is needed in addition to power.

74. If Columbia River commercial and sport salmon fishing is to be preserved, adequate facilities to insure the passage of fish over the dams must be provided. The Dalles high dam would, it is believed, be an insurmountable object to the migration of fish and would destroy upstream salmon fishing. Hatcheries and facilities for taking all of the fish from the river below the dam would be necessary to preserve salmon fishing below.

CHAPTER VI. PLANS OF IMPROVEMENT CONSIDERED

75. *General.*—Pursuant to the discussion in the preceding chapter' the plan presented herein for the coordinated development of the Columbia River, between The Dalles and the mouth of the Snake, in the combined interest of navigation, power, and irrigation is based upon a series of relatively low dams without storage provisions. The installed power capacities at the sites under consideration, as shown on plans in appendix A,[1] are based upon unregulated flow with approximately the same ratio of installation to continuous power as is proposed for the complete development at Bonneville. Power output characteristics of the projects are given in the same appendix. In estimating power values at these projects no consideration has been given to that added by regulatory effect of storage behind the Grand Coulee high dam, nor from other headwater-storage developments, since any net benefits accruing from such regulation to the plants below would not obtain at any site until power installations using nearly all the unregulated flow were required there, and are partially creditable to such storage developments. When headwater storage is developed, adequate space is available at all sites for additional power facilities, and approximate estimates for same have been made for the comparative

[1] Not printed.

estimates of paragraph 63. Cost estimates in paragraph 82 are based upon preliminary designs as shown in appendix A[1] and present price levels. The designs and cost estimates are based upon provision of adequate fishways and navigation locks 56 by 360 feet in the clear, with a controlling depth of 9 feet.

76. Although plans and estimates have been prepared, and are submitted in appendix A,[1] for complete slackwater development of the Snake River from its mouth to Lewiston, and such extensive development may be feasible in the far distant future, it is believed that for all practical purposes planning at this time may be limited to provision of locks and dams only in those stretches of the waterway which cannot be made navigable by open-river methods at reasonable cost. Accordingly the coordinated plan presented herein for improvement of the Snake River does not provide definitely for 6 of the 10 locks and dams needed for complete slack-water development. Designs and cost estimates for the proposed Snake River dams are based upon provision of adequate fishways and navigation locks 56 by 360 feet in the clear with 9 feet over the sills at low water.

77. Due to the raising of the water-surface elevation at the lower entrance of The Dalles-Celilo Canal by the Bonneville pool, designs and estimates have been prepared for desirable improvements of the lower tandem lock in this canal in the interest of through navigation on the Columbia with the existing authorized projects. To make such through navigation practicable, The Dalles-Celilo Canal must be maintained in a satisfactory operating condition until such time as the proposed Dalles Dam is constructed.

78. *Rectification of The Dalles-Celilo Canal.*—The improvements proposed consist of lowering the intermediate sill and floor of the present tandem lock, thus accomplishing the total lift in a single lockage varying from 44 feet at extreme low water to 14 feet at a 650,000 cubic-foot-per-second stage, when canal operation ceases. The first cost of the foregoing work, as detailed in appendix A,[1] is estimated at $84,000. The foregoing change in structure would reduce present annual maintenance and operation charges approximately $2,500. The new work should be carried out before January 1, 1938, prior to the raising of the Bonneville pool.

79. *Alternate plans considered for John Day.*—Two alternate plans of improvement have been considered for the stretch of the Columbia River lying between the head of The Dalles pool and the Umatilla Dam site. One scheme contemplates the construction of a single dam at the John Day site to elevation 258, as proposed in the report under review, while an alternate plan proposes two dams, one at John Day to elevation 210 and the other at Arlington to elevation 258. The two-dam plan has been developed with a view to reducing the excessive flowage damages involved in the single-dam plan, estimated at about $37,000,000, including the business district of the town of Arlington, valued at $3,800,000. The power available under either plan of development would not be materially different. Comparative cost estimates, including interest during construction, both for a plan which

[1] Not printed.

initially excludes generating facilities and one including them, are summarized as follows:

Plan of development	Plan with power facilities		Plan without power facilities (first cost)
	Installed capacity (kilowatts)	First cost	
Single-dam scheme, John Day to elevation 258	806,000	$110,000,000	$66,000,000
2-dam scheme:			
John Day to elevation 210	400,000	56,000,000	29,500,000
Arlington to elevation 258	400,000	63,000,000	36,500,000
Total	800,000	119,000,000	66,000,000

80. With step development of this stretch of the river, the two-dam scheme would decrease the initial investment by some $36,500,000 but increase the construction cost of a development of 800,000 kilowatts by some $9,000,000. With interest at 3.5 percent and taking into consideration increased maintenance and operation charges of the two-dam scheme over the single-dam scheme, it is estimated that this reduced initial investment would result in a reduced initial annual cost of some $1,230,000. As the latter figure would, with interest at 3.5 percent, accumulate to $9,000,000, the difference between the ultimate cost of the two alternate schemes, in approximately 7 years, the two-dam plan is the most economical if the second dam is not required before the end of a 7-year period. Taking into consideration the large block of power that could be made available by the low John Day dam, the two-dam scheme is the most economical from the standpoint of power and the most practical.

81. *Columbia River development.*—Pursuant to the foregoing, the coordinated plan of improvement proposed for the Columbia River contemplates the construction of four combined navigation-power dams between The Dalles and the mouth of the Snake River. Detailed descriptive information relating to the proposed projects, their layouts, and estimates of cost are given in appendix A.[1] A profile of the proposed developments is given on plate VI,[1] and pertinent data relating to them are summarized in the following table:

Project	The Dalles	John Day	Arlington	Umatilla
River mileage	193	217	243	292
Normal pool elevation (mean sea level)	150	210	258	310.5
Pool area (acres)	11,500	13,220	34,310	16,800
Miles railway affected	33	69	72	38
Miles highway affected	7	8	26	2
Minimum tailwater elevation (mean sea level)	74	151	210	258
Maximum head (feet)	76	59	48	52.5
Minimum flow (cubic feet per second)	35,000	35,000	35,000	35,000
Continuous power at minimum flow (kilowatts)	181,000	140,000	114,000	125,000
Power installation-kilowatt (for estimating)	517,000	400,000	400,000	385,000

82. The estimated first and annual cost of the foregoing developments are given in the following tables. Estimates are based on construction of a complete powerhouse skeleton substructure in the initial major cofferdam to permit the installation of power units as needed by the use of stop-log cofferdams only. Actually depending

[1] Not printed. For plate VI, see plate A at end of document.

upon the prospective power market at the time of construction, it would probably be desirable to construct a skeleton substructure for a lesser number of units as done at Bonneville. This procedure would add somewhat to the over-all construction costs as estimated but decrease carrying charges.

Project	The Dalles, elevation 150	John Day, elevation 210	Arlington, elevation 258	Umatilla, elevation 310.5	Grand total
			First cost		
Reservoir and flowage	$5,700,000	$11,200,000	$17,700,000	$7,500,000	$42,100,000
Cofferdams and pumping	2,200,000	4,000,000	4,300,000	1,660,000	12,160,000
Main dam	9,400,000	6,000,000	7,100,000	7,370,000	29,870,000
Power plant	31,900,000	26,800,000	25,800,000	27,900,000	112,400,000
Navigation facilities	2,500,000	2,000,000	1,350,000	2,040,000	7,890,000
Fish facilities	2,500,000	2,500,000	2,500,000	2,500,000	10,000,000
Building, grounds, etc	500,000	500,000	500,000	500,000	2,000,000
Grand total	54,700,000	53,000,000	59,250,000	49,470,000	216,420,000
			Annual cost		
Interest at 3½ percent	1,920,000	1,860,000	2,080,000	1,730,000	7,590,000
Amortization at 0.763 percent	420,000	405,000	450,000	375,000	1,650,000
Replacement at 0.50 percent	275,000	265,000	295,000	250,000	1,085,000
Maintenance and operation	395,000	325,000	325,000	315,000	1,360,000
Grand total	3,010,000	2,855,000	3,150,000	2,670,000	11,685,000

83. The initial cost of the foregoing projects without generating facilities including interest during construction and based upon step development, is estimated as shown in the following table. The initial steps include a number of power intake structures in the interest of future power and make possible future extension of these facilities.

Project	Pool elevation	First cost	Annual cost		Total annual cost
			Interest and amortization	Maintenance, operation, and replacement	
The Dalles	150	$23,000,000	$980,000	$190,000	$1,170,000
John Day	210	29,500,000	1,260,000	225,000	1,485,000
Arlington	258	36,500,000	1,560,000	260,000	1,820,000
Umatilla	310.5	23,700,000	1,010,000	195,000	1,205,000
Total		112,700,000	4,810,000	870,000	5,680,000

84. *Plans for Columbia River Ship Channel.*—Although it does not appear advisable at the present time to base plans and estimates upon a ship channel in the Columbia River above The Dalles, it is important that this be considered as a future possibility. The proposed pools have adequate depth for a ship channel to Umatilla except at the upper ends of the pools formed by The Dalles and Arlington dams, where increased depths are obtainable by excavation and provisions for holding the pools above normal at low flows. Barge locks can be constructed with a view to possible conversion in the future, or it may be found advisable to provide ship locks when the projects are constructed.

85. Ship navigation at the upper ends of pools, including the Bonneville pool, will be impractical or hazardous at high flow due to swift currents. It is not likely that ships can operate at flows over 500,000

cubic feet per second which prevail about 1 month of the average year, and the safe limit may be as low as 400,000 cubic feet per second, which is exceeded about 50 days of the average year.

86. *Snake River.*—The coordinated plan of improvement proposed for the stretch of the Snake River between the mouth and Lewiston, shown on plate VII,[1] consists of a series of four locks and dams supplemented by open-channel work to obtain a controlling depth of 6 feet at a flow of 15,000 cubic feet per second over a bottom width of 150 feet with a depth of 5 feet during extreme low water (10,600 cubic feet per second). Construction of the four locks and dams would require the revision of approximately 22 miles of railroad along the river bank. The four locks and dams are so located as to improve river sections that cannot be adequately improved by open-river methods. Detailed cost estimates for the locks and dams, excluding power, are given in appendix A.[1] Power installations at three of the foregoing dam sites might be feasible when warranted by market conditions. Due to the reduction of head at these sites during flood periods, power facilities would be expensive. A résumé of the estimated cost of the foregoing developments, including interest during construction and power facilities at the three farthest downstream dams, is summarized as follows:

Item	Section (mile to mile)	Head	Installed capacity (kilowatts) [1]	Estimated first cost	Estimated annual cost		
					Interest and amortization	Maintenance and operation and replacement	Total
Open-channel work	0–4	------	----------	$165,000	$7,000	$5,000	$12,000
Dam No. 1	4–33	68	45,000	15,910,000	680,000	155,000	835,000
Open-channel work	33–57	------	----------	2,295,000	98,000	100,000	198,000
Dam No. 4	57–70	45	60,000	12,505,000	536,000	150,000	686,000
Total to Riparia	70	------	105,000	30,875,000	1,321,000	410,000	1,731,000
Open-channel work	70–93	------	----------	470,000	20,000	50,000	70,000
Dam No. 7	93–106	37	50,000	10,765,000	460,000	130,000	590,000
Open-channel work	106–135	------	----------	409,000	17,000	40,000	57,000
Dam No. 10	135–141	33	----------	4,265,000	181,000	50,000	231,000
Total to Lewiston	141	------	155,000	46,784,000	1,999,000	680,000	2,679,000

[1] Installed capacity is twice continuous kilowatts available at minimum flow of 10,600 cubic feet per second except at dam No. 1 where 5,000 cubic feet per second required for irrigation pumping.

87. As shown in detail in appendix A,[2] the cost of the four foregoing locks and dams, excluding power facilities but including interest during construction, is estimated as follows:

Lock and dam	First cost	Annual cost		
		Interest and amortization at 3½ percent	Maintenance and operation and replacement	Total annual cost
Dam No. 1	$11,860,000	$506,000	$90,000	$596,000
Dam No. 4	6,500,000	278,000	60,000	338,000
Dam No. 7	5,265,000	225,000	55,000	280,000
Dam No. 10	4,265,000	183,000	50,000	233,000
Total	27,890,000	1,192,000	255,000	1,447,000

[1] Not printed. For plate VII, see plate A at end of document.
[2] Not printed.

88. *Channel conditions after improvement.*—Completion of the coordinated improvements outlined herein for the Columbia and Snake Rivers would make available a satisfactory 9-foot navigable channel on the Columbia River to the mouth of the Snake and a channel on the latter stream 5 feet deep at extreme low water from its mouth to Lewiston. Depths on the Snake River would be 6 feet or over for approximately 95 percent of the time. The proposed locks and dams on the Snake would provide slack water over a distance of 60 miles in which the average slope of the river is 3.4 feet per mile and drown out the more steep and hazardous sections where commercial navigation is at present not feasible because of inadequate depths, a narrow channel, and high velocities, leaving 81.4 miles of open river, from the mouth to Lewiston, having an average slope of 2.4 feet per mile. The latter slope is about half that of the 71-mile stretch on the upper Rhine, which has a project depth of 6½ feet for 18,000 cubic feet per second and carries a large tonnage. The proposed open-channel work on the Snake would greatly improve navigable conditions by providing reasonable depths and a wider channel, but would not materially affect velocities through the rapids in these sections. The swifter rapids, having velocities of over 6 miles per hour, have a combined length of nearly 10 miles, with maximum velocities for short distances of about 8 miles per hour at low water and 9 miles per hour at medium stages.

89. With boats of adequate power, through navigation over the stretches of river under consideration would be possible at all times except when the rivers were blocked by ice or when velocities were too high during floods. The navigation season is accordingly estimated as 11 months during the average year for the Columbia and 10 months for the Snake.

CHAPTER VII. BENEFITS CREDITABLE TO COORDINATED PLAN

90. *General.*—The interests that would be directly benefited by improvement in accordance with the coordinated plan presented herein are navigation, irrigation, and power development. While some degree of flood control could be effected by the use of storage in the upper levels of the proposed pools, this method of operation would either conflict with power use or involve increased cost of structures and flowage, and is not warranted by the small value of additional flood control on the lower Columbia River. Indirect benefits, which cannot be reduced to dollars and cents, would accrue to the general public in large measure from the provision of low-cost water transportation and cheap power throughout a vast hinterland containing large agricultural and industrial resources only partially developed.

91. *Navigation benefits.*—The present commerce considered available for movement over the rivers, if improved, consists of existing traffic moving between tidewater and the interior, as outlined in paragraph 18, with the exception of fresh fruits and vegetables, livestock, paper, general merchandise, and automobiles. The latter commodities are not considered as adaptable to economical water movement, due either to their character or to the fact that they move in small lots. The remaining tonnage available for water movement, amounting to 2,843,080 tons, consists of 70 percent grain, 12 percent petroleum products, 8 percent flour, and 10 percent miscellaneous tonnage. Approximately 85 percent of the present available tonnage is out-bound.

92. Since other factors than costs enter into the method of transportation adopted by the shipper, it cannot be expected that more than 50 percent of the present tonnage that could move at a saving over an improved waterway would so move. However, it is reasonable to assume that this tonnage will double over a period of 50 years. Such increased river traffic is predicated upon the ship channel to be constructed to The Dalles, upon industrial developments along this channel due to availability in that locality of large blocks of cheap hydroelectric power, and upon further irrigation developments in the tributary area to furnish the additional foodstuffs required by a population increased through industrial expansion along the coast.

93. The electrometallurgical and electrochemical industries that will locate in the lower Columbia River area will require large quantities of raw materials such as iron ore, limestone, silica, clays, magnesites, and phosphates. These raw materials, as well as other valuable minerals, are to be had in the area tributary to Snake River points. Although the deposits in this area are as yet not fully explored and developed, it is believed that they would be mined and used extensively if they could be shipped out by river from Lewiston. The average volume of this prospective traffic for the Snake River, over a long period of time, is estimated at 1,000,000 tons per year.

94. Estimates of the savings in transportation costs from the proposed improvement of the several stretches of the waterways in question have been made, based upon comparison between present rail rates to tidewater and prospective joint rail-water and/or truck-water rates after improvement, and are summarized in the following table:

Improvement to—	Miles from Portland	Potential tonnage	Unit savings	Total savings	Increment savings	Summation
The Dalles	97	1,158,330	$0.28	$324,332		
Umatilla	197	1,855,225	.69	1,280,105	$955,773	$955,773
Pasco	234	2,052,735	.75	1,539,551	259,446	1,215,219
Riparia	299	2,132,310	.84	1,791,140	251,589	1,466,808
Lewiston	372	3,132,310	.93	2,913,048	1,121,908	2,588,716

With the exception of the grain tonnage within economical trucking distance of the rivers, the above savings represent the difference between existing rail rates and joint rail-water rates computed in accordance with Interstate Commerce Commission rulings set forth in *Ex parte 96*. The grain tonnage within practical trucking distance of the rivers, which varies from about 50 to 100 miles, could, with the improvements proposed, move more economically by truck and water than on a joint rail-water rate. Accordingly, savings on this grain tonnage were based upon comparison between existing rail rates and probable future water rates plus present trucking costs, on the assumption that either a private or cooperative water transportation agency would make such service available to the farmers. The probable future water rate was taken as 5 mills per ton-mile. Handling and terminal differentials were taken into account.

95. *Future irrigation benefits.*—Along both sides of the lower Columbia River between Arlington and the mouth of the Snake are found arable benchlands from 250 to about 750 feet above river elevation. These lands, totaling 378,000 acres and with an annual water requirement of about 3.85 acre-feet per acre, are susceptible to irrigation from the Columbia River when justified by economic conditions. Construction of the Arlington and Umatilla Dams, as outlined herein, would, when development of these lands takes place, reduce the average pumping lift to the lands by some 45 feet with a resultant reduction in the first cost of pumping equipment and in annual electrical energy requirements. The savings in first cost of pumping equipment creditable to the Arlington Dam has been estimated at $700,000 and for the Umatilla Dam at $490,000. The annual savings in electrical energy, based upon a cost of 2 mills per kilowatt-hour and a pumping efficiency of 67 percent has been estimated at $127,000 and $85,000, respectively. Accordingly, the total annual irrigation benefits creditable to the proposed Arlington and Umatilla projects, with annual charges excluding energy estimated at 12 percent of the first cost, is considered as $210,000 and $145,000, respectively.

96. Approximately 70,000 acres of arable lands, susceptible to irrigation from the river, are also found along both banks of the lower Snake about 250 feet above normal river elevation. When these lands become economical of development, they could be irrigated, by pumps direct-connected to turbines, by pumping through a head of about 175 feet from the pool of the proposed Five Mile Rapids Dam (dam No. 1) on the Snake River. The first cost of installation is estimated the same, whether pumping is done with electrical energy from normal river elevation or by direct-connected turbines from the pool of the proposed dam. However, with a power rate of 2 mills per kilowatt-hour, which might eventually be obtained from other sources, pumping from the pool of the proposed dam would result in an annual savings in electrical energy of approximately $220,000 per annum due to elimination of energy requirements.

97. *Cost chargeable to power.*—As navigation and irrigation benefits can carry only about 15 percent of the total estimated annual cost of the coordinated plan, the remaining charges must be carried by power values as no other major interest is materially affected by the proposed improvements. The following table indicates by reaches the portion of the annual costs that can be carried by navigation and irrigation, as outlined hereinbefore, and the remaining cost that must be carried by power:

Improvement to—	Miles from Portland	Total installed capacity (kilowatts)	First cost	Annual cost	Annual navigation benefits	Annual irrigation benefits	Annual costs chargeable to power	
							Total	Per kilowatt
Umatilla	197	1,317,000	$177,000,000	$9,000,000	$955,000	$210,000	$7,835,000	$5.95
Pasco	234	1,702,000	229,500,000	11,700,000	1,215,000	355,000	10,130,000	5.95
Riparia	299	1,807,000	257,900,000	13,200,000	1,465,000	575,000	11,160,000	6.20
Lewiston	372	1,857,000	268,700,000	14,000,000	2,590,000	575,000	10,835,000	5.85

98. From the foregoing table it may be noted that the annual cost of power, based upon single-stage construction of the powerhouse skeleton structure at each project and excluding carrying charges during the load-building period, would average approximately $6 per kilowatt of installed capacity for the coordinated plan. Actually the cost of power would probably be about $8 per year per kilowatt

of installed capacity due to development of power plant structures in smaller steps which will increase somewhat the over-all construction cost and to some accumulation of carrying charges during the load-building period.

CHAPTER VIII. CONCLUSIONS AND RECOMMENDATIONS

99. *Conclusions.*—On account of the importance of through commercial navigation between tidewater and the interior of the Pacific Northwest, further improvement of the Columbia River from The Dalles to the mouth of the Snake River, and of the latter stream below Lewiston, Idaho, should be considered as a single project. This potential trade route cannot be made usable over its entire length by open-river improvement at a reasonable cost. It will be necessary to resort to locks and dams to secure an adequate channel above Umatilla, or to provide facilities more adequate than the present 7-foot channel below Umatilla.

100. Construction of a high dam at The Dalles, to create a pool extending up the Snake River and the Columbia River above the mouth of the Snake, is considered neither advisable nor advantageous. The best coordinated plan of improvement consists in a series of four locks and dams on each stream with supplemental channel improvement on the Snake River between the pools formed by the dams, as outlined in this report. Provisions should be made for passage of fish, future delivery of water for irrigation and, where it is feasible to do so, for future development of hydroelectric power. Provisions for flood control cannot be made at costs commensurate with benefits.

101. The estimated cost of complete improvement under the plan outlined above, without power facilities, is $138,000,000, not including interest during construction. Construction, if undertaken, would necessarily extend over a considerable period of years and the locks and dams should be built in that order which will meet best the most pressing need of water-borne commerce—establishment of through navigation to Snake River points. Accordingly, the Umatilla Dam and the four proposed dams on the Snake River should be constructed before undertaking slackwater improvement of the Columbia River below Umatilla where a fairly adequate channel already exists. The estimated cost of the Umatilla dam, without power facilities, is $22,700,000. The proposed Snake River improvement, without power facilities, will cost about $30,200,000. These estimates do not include interest during construction.

102. The direct navigation and irrigation benefits that would accrue to the general public from the proposed improvements are not commensurate with its cost, but it is possible that sufficient surplus power from the dams can be sold within the next 50 years to make the improvement economically sound. It is not safe to assume now, however, that this can be done, on account of uncertainty as to how long it will take the market to absorb the very large blocks of power which the Grand Coulee and Bonneville projects are capable of producing.

103. Provision of low-cost water transportation between tidewater and the interior will promote the economic security and future development of agriculture and industry in the Pacific Northwest, and is more or less essential to the success of the Federal projects already

undertaken with a view to construction and utilization of water resources in the Columbia Basin. The indirect benefits to be expected from the improvements proposed in this report are, therefore, very material and may well be sufficient to warrant starting construction work at this time without waiting for further development of the power market. Whether such a step in advance should be taken appears to be a question which must be left to the wisdom of Congress.

104. *Recommendations.*—It is recommended that the coordinated plan outlined in this report for further improvement of the Columbia River between The Dalles and the mouth of the Snake River, and of the Snake River below Lewiston, Idaho, be approved as a basis for modification of the existing projects for these waterways when such action appears to be justified, but that no modification in the existing projects be made at this time.

THOMAS M. ROBINS,
Colonel, Corps of Engineers,
Division Engineer.