

struction of dams in the interest of navigation alone. The economic benefits of the dams to navigation, however, are believed to be sufficient to justify, in the interests of navigation, the construction of the locks through the dams.

1476. The proposed power developments will provide cheap secondary power necessary for the irrigation projects. The higher portions of irrigable areas along the Columbia River are the more desirable. Areas closer to the river have sandy soils and are less fertile than the higher areas. By creating a pool above the dam and thus raising the elevation of the water above normal river heights, more of the desirable higher areas have been brought into pumping range. The irrigation developments described are based upon the prior construction of power dams, and their feasibility is contingent upon the development of cheap power.

1477. While the problem of flood control is solved most economically by the use of levees to protect the areas subject to flood, some incidental benefits to low lands in the tidal section would accrue from future regulation resulting from power and irrigation developments above. Table 23-B shows the extent to which this future regulation would have reduced the frequency and duration of flood flows for the period of record. For example, floods in excess of 600,000 second-feet, which occurred 27 times for a total of 665 days, would have occurred but 17 times over a period of 348 days if the total ultimate regulation had been in effect during the period of record.

1478. While the regulation of the flow for power and irrigation uses would decrease the effect of floods on low lands in the tidal section, the effect that this regulation would have upon the navigation channel in the tidal section and upon the channel across the bar at the mouth of the Columbia is difficult to determine. High flood discharges scour the channel across the bar, but they also cause shoaling in the channel from the sea to Vancouver and Portland. Regulation of the flow by reducing flood heights would probably benefit the river channel from Vancouver and Portland to the mouth and adversely affect the channel across the bar at the mouth. Increasing of the low flows, which occur during the wintertime, when, due to storms, deterioration of the channel across the bar is most rapid, might assist in maintaining the channel.

1479. While the effects of future regulation cannot be determined accurately in advance, it is believed that the methods now used in maintaining the existing channel can be applied successfully to overcome adverse effects of regulation, if any.

CHAPTER IV.—COMPREHENSIVE PLAN

1480. The principal features of the comprehensive plan believed to offer the most effective development of the Columbia below the mouth of the Snake for the purposes of power, navigation, irrigation, and flood control may be summarized as follows (see pl. 128):

1481. *From mouth to Warrendale.*—In the section of the river between its mouth and Warrendale the river is tidal. Under the existing project navigation is amply provided for. There are no power sites in this section, and no power development is contemplated under the comprehensive plan. There are numerous small parcels of low lands subject to inundation when the Columbia has

its annual rise. Some of these areas are protected by levees and are cultivated. Levee construction is believed to be the most practical method of protecting the low lands from floods and rendering them suitable for crop production. The construction of new levees for the land not at present protected and the additional construction work outlined as desirable for increasing levee heights on the partially protected areas are believed to be matters wholly of private concern. Their protection will have no effect on navigation, and it is not a matter of general public interest. There are no areas along this section of the river for which irrigation can be considered necessary at this time.

1482. *Warrendale to mouth of Snake*.—Above Warrendale, the head of tidewater, the character of the river changes, and between Warrendale and the mouth of Snake River the development of power will benefit navigation, irrigation, and, to some extent, flood control. Two power dams are proposed for this section. One at Warrendale would have a head of 50 feet, and would back water to The Dalles, the site of the next dam. The estimated cost of the power development features at Warrendale is \$67,000,000. This dam would provide slack-water navigation for the section of the river between Warrendale and The Dalles. The cost of the navigation locks through the above dam is estimated at \$3,100,000. There are no irrigable areas along the river between Warrendale and The Dalles of sufficient size to warrant their inclusion in any comprehensive plan. There are no appreciable areas inundated by floods. The total cost of the combined power and navigation features of the Warrendale development is estimated at \$70,100,000.

1483. The second dam, The Dalles development, would be located at Big Eddy, a point about 3 miles east of The Dalles, Oreg. It would have a head of 275 feet and would create a pool extending to a point in the Columbia River about 15 miles above the mouth of the Snake, and to the foot of Five Mile Rapids in Snake River. The estimated cost of the power development, including the dam and power features, is \$340,000,000. This dam would provide slack-water navigation past the mouth of Snake River. The cost of navigation locks through the dam is estimated at \$11,500,000. By raising the water level to elevation 330, the proposed pool elevation, and by providing cheap power for pumping this power development would render the ultimate irrigation of 378,000 acres possible. These areas, with their acreages and estimated costs of irrigation features, are:

Project	10-year settlement period		
	Area (acres)	Total cost per acre	Total cost
Cold Springs area.....	50,000	\$159.50	\$7,975,000
Horse Heaven area:			
Div. A.....	28,500	138.00	3,933,000
Div. B.....	47,500	138.40	6,574,000
Div. C.....	66,000	152.90	10,091,000
Willow Creek area:			
Div. A.....	37,940	137.30	5,209,000
Div. B.....	103,770	127.95	13,270,000
Div. C.....	31,350	151.54	4,751,000
Arlington area.....	11,500	124.07	1,427,000
Roosevelt area.....	1,500	113.37	170,000
Total and average.....	378,060	141.00	53,400,000

1484. There are no appreciable areas inundated by floods between The Dalles and the mouth of Snake River. The combined cost of the power, navigation, and irrigation developments for the section of the river between The Dalles and the mouth of Snake River is estimated at \$404,900,000.

1485. The total cost of the above comprehensive plan for development of Columbia River below the mouth of Snake River, comprising a power dam at The Dalles, a power dam at Warrendale, the navigation features for passing craft through each dam, and the ultimate irrigation of 378,000 acres, is estimated at \$475,000,000.

CHAPTER V.—CONCLUSIONS AND RECOMMENDATIONS

I. CONCLUSIONS

1486. Columbia River below Warrendale, the head of tidewater, offers no opportunity for improvement by power, flood control, or irrigation developments. Navigation between Portland and Vancouver and the sea is amply provided for under the existing project.

1487. Between Warrendale and the mouth of Snake River there are a number of sites at which power development would benefit navigation, irrigation, and to some extent flood control.

1488. The most desirable combination of sites for a comprehensive plan of development comprises The Dalles site, with a dam with pool at elevation 330 feet above sea level, and the Warrendale site, with a dam with pool at elevation 54 feet above sea level.

1489. Navigation features to pass craft through the power dams proposed in the report are economically justified and should be provided.

1490. The irrigable areas listed in paragraph 1483 above can best be irrigated by pumping from Columbia River. The economic feasibility of irrigating these areas is dependent upon the development of cheap power, the creation of a pool at elevation 330 as contemplated under The Dalles power development, and the return of favorable agricultural conditions. Under present conditions the projects cannot be developed profitably.

1491. Flood control is not of sufficient importance to be included as a major factor in the development of Columbia River below the mouth of Snake River. Some of the areas affected can be economically protected by new levees or by raising existing levees.

1492. In view of the importance of obtaining an accurate record of the flow of the Columbia below the mouth of Snake River, for properly designing any development for power, irrigation, navigation, or flood control, a base stream gaging station should be established on Yakima River near its mouth, and the base stream gaging stations at the following locations should be continued:

Columbia at Vernita, Wash.
 Snake at Riparia, Wash.
 Umatilla at Umatilla, Oreg.
 John Day at McDonald, Oreg.
 Deschutes at Moody, Oreg.
 Columbia at The Dalles, Oreg.
 Klickitat at Pitt, Wash.
 Hood River at Powerdale, Oreg.
 White Salmon at Husum, Wash.
 Sandy near Bull Run, Oreg.

Willamette at Salem, Oreg.
 Lewis near Ariel, Wash.
 East Fork Lewis near Heisson, Wash.
 Cowlitz at Castle Rock, Wash.

1493. Navigation between the sea and points upstream as far as Portland and Vancouver, whether viewed from the standpoint of prior use, invested capital, or potential benefit to the general public, is the most important use of the Columbia River. The effect of future regulation of the flow above the head of tidewater upon the channel in the tide water section and upon the channel across the bar at the mouth of the Columbia cannot be determined definitely prior to such regulation. However, sufficient flow for the needs of sea-going navigation should be provided at all times. Works planned for the upper reaches of the river must be subservient to such need of navigation.

II. RECOMMENDATIONS

1494. It is recommended that future development of Columbia River below the mouth of the Snake be based upon the comprehensive plan stated in chapter IV above, comprising a power dam at The Dalles site with its pool at elevation 330, a power dam at Warrendale with its pool at elevation, 54, the navigation features for passing craft through these dams, and the irrigation, at such time in the future when it may become economically justified, of 378,000 acres by pumping from the pool created by The Dalles power dam.

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Major, Corps of Engineers, District Engineer.

APPENDIX A

Appendix A of this report is not printed. Its contents are as follows:

Map no. 1.—A compilation of topographic maps of a large portion of the watershed of the Columbia River below the mouth of the Snake, partly on a scale of 1:62,500 and partly 1:125,000.

Map no. 2.—A river plan, or topographic map of the Columbia River below the mouth of the Snake in 67 sheets, scale 2 inches equals 1 mile. This map shows the river itself and contours with various intervals from 20 to 100 feet covering the banks on either side up to an elevation above that affected by any proposed works.

Map no. 3.—A profile of the Columbia River below the mouth of the Snake in 8 sheets, horizontal scale 2 inches equals 1 mile, vertical scale 1 inch equals 20 feet.

Map no. 4.—A map of the Columbia River from Celilo Falls to Snake River in 21 sheets scale 1:10,000. This map is without contours and shows little detail above the high-water mark but shows numerous soundings on lines 500 to 1,000 feet apart.

Map no. 1 is not suitable for reproduction but can be seen by interested parties at the office of the Chief of Engineers, Washington, D.C.; the division engineer, Pacific division, San Francisco, Calif.; or the district engineer, Portland, Oreg. Maps nos. 2, 3, and 4, being of purely technical interest, have not been printed, but blueprints may be purchased at cost from the district engineer, Portland, Oreg.