CHAPTER III.—DISCUSSION

I. NAVIGATION

1346. The Columbia River from its mouth to Portland is being improved under the existing project to permit navigation by nearly all of the largest ships, and no further consideration is given in this report to improvement of this section of the river. Terminal facilities from the entrance of the river to Vancouver are extensive and adequate for the present commerce and will be provided for future commerce.

1347. The present condition of the river from Vancouver to The Dalles will permit boats of fairly high power and of 7-foot draft to navigate as far as The Dalles. Boats with a draft of not over 5 feet can operate above The Dalles to the foot of Homly Rapids, 6 miles below the mouth of the Snake River. Above the foot of Homly Rapids the draft cannot exceed 4 feet at low water. The condition of river as to slopes and rapids is shown on plate 35.

1348. The principal obstacles to navigation are the swift currents in the numerous rapids between Warrendale and the mouth of Snake River. The first difficult place to navigate is the stretch in Columbia River Gorge, just above Bonneville, where currents of from 7 to 10 miles per hour are encountered during low water and 15 miles per hour during high freshets. The second difficult place is at Three Mile Rapids, about 1½ miles above The Dalles. Here there is easy navigation at low water, but the difficulties increase as the river rises. The current at low water is very slight but at ordinary freshet stages there are swift currents, boils, and eddies, which make navigation difficult even for self-propelled boats of fairly high power. The Dalles-Celilo Canal overcomes the rapids between Three Mile Rapids and the head of Celilo Falls. The depth on the lock sills, 7 feet, permits drafts up to about 6 feet through the canal.

1349. Above Celilo Falls to the mouth of Snake River, a distance of about 124 miles, there are 16 rapids, some of which have currents up to 10 miles per hour at low water. Navigation during the low-water condition is probably more difficult than during the high stages on account of the shallow water in the rapids. The controlling depth in this stretch of river is 6 feet to foot of Homly Rapids and 4½ feet in this rapid. Above Homly Rapids a draft of 6 feet can be carried to the mouth of Snake River.

1350. The river is usually closed by ice in the wintertime for a period lasting from a few days to as much as 2 months. During some winters the river is free of ice but this is unusual. The summer freshets close the two canals (Cascades Canal and The Dalles-Celilo Canal) when a stage of 42 feet on lower gage at Cascades Canal is reached. Navigation is then suspended for periods varying from a few days to 6 weeks. About 60 percent of the freshets are high enough to close the canals. Due to ice and freshets a navigation season of more than 10 months cannot be depended upon above Vancouver.

1351. Until the advent (in 1882) of the railroad on the left bank the river was the only highway. It was first navigated by canoes and batteaux, operated by the fur traders and later by flat boats which sailed upstreams and drifted down. In 1850 navigation by steamboats began below Bonneville and the next year saw steamboats on the river between the Cascades and The Dalles. In 1858 the first steamboat was constructed above Celilo Falls and operated to Priest Rapids on the Columbia and to Lewiston on Snake River.

1352. During the mining excitement in the Clearwater River region, from 1861 to 1864, the steamboats did an enormous business for the times. A number of steamboats were built, but the mining excitement soon subsided and business for the boats fell off rapidly. The first railroad was completed along the river to Pasco in 1882. The railroad company owned or controlled all of the boats on the river above Astoria. Shortly after 1882 the river traffic ceased above Vancouver and nearly all commerce was handled by the railroads.

1353. From 1882 to 1905 there was little or no commerce on the river above Celilo. Several efforts were made to revive the river commerce but they failed, mostly through lack of patronage. There were no large communities on the river and all of the agricultural production was some distance away with no improved roads. The railroad along the river had feeder lines into the interior and carried all of the traffic from points off the river. The boat companies which attempted to revive the water-borne commerce were small concerns, had few boats, and did not give frequent or regular service, so that the shipper could not depend on prompt service. With the exception of a few small wharves, there were no water terminals and there were no physical connections with the railroads on the river above Vancouver. Freight was received and delivered on the river banks, a method of handling which often resulted in losses by storms and by rising water.

1354. A boat line was started in 1905 and an attempt made by local interests to revive water-borne commerce. There was then only one railroad (on left or south bank) paralleling the river from the ocean to Snake River. After the boat line had begun business, a second railroad was completed from Portland to Pasco on the right bank of the river. The boat line (the first to attempt revival of water transportation above Celilo Falls since 1894) suspended operations in 1912 due to lack of patronage and there was no further boat service on the Columbia above Celilo until 1915, when The Dalles-Celilo Canal was opened to navigation. Another company bought the three boats and other equipment owned by the first concern and operated between Portland and Lewiston until December 1917. It then suspended regular service above The Dalles, stating that boat service was discontinued due to lack of patronage. Occasional trips were made until 1920. There has been no boat service on the river above The Dalles since that date. The condition of the river above Celilo, since the completion of the existing project in 1918, is much better than it was when the river commerce was at its height during the period from 1858 to 1864.

1355. Regular boat service below The Dalles was discontinued in 1923, due also to lack of patronage. Since then two attempts have been made to operate boats to The Dalles, but neither venture was profitable, and at present there is no boat service above Vancouver, except in connection with the paper mill located at Camas, Wash., about 14 miles above Vancouver.

1356. From the foregoing, it would appear that the principal cause of the failure of attempts to establish boat service on the river above Portland has been the lack of patronage. This was due in part to the fact that there were no adequate water terminals and the boat service was not frequent enough to insure quick and regular delivery. The principal cargoes were general merchandise upstream and some farm products downstream. The bulk of the commerce handled was general merchandise, which commanded a high freight rate. Wheat was not carried in large quantities by the companies which operated after 1915. The wheat-growing sections are located at some distance from the river and require long hauls to the river bank. There are no wheat warehouses on the river, and no place for storage except in the open on the river banks. The railroads have feeder lines into the wheat-growing sections from the main lines along the river and numerous warehouses are located at convenient points along the railroads. These warehouses are owned and operated by grain and milling companies, who buy the wheat from the producers delivered at the warehouse, and mill much of it en route to destination, which, under the "milling in transit" privilege, gives a low railroad rate for the milled product.

1357. The average haul from the farm to railroad shipping points is about 8 miles. It is estimated that for those counties contiguous to the Columbia between the mouth of Snake River and tidewater, the average haul from the farm to the nearest proposed water terminal would be about 30 miles. This 30-mile truck haul increases the actual cost of river transportation to the farmer by about $1.56 per ton. The transportation costs by rail corresponding to the 30-mile truck haul would be about $0.96 a ton, i.e., an 8-mile truck haul and a 22-mile rail haul to a point on the railroad corresponding to the river terminal. This makes a net difference of 60 cents per ton to be added to the water costs in order to make them comparable with the rail rates. If the additional 60 cents per ton be added to the water rate, the apparent savings due to water transportation under open river conditions are so reduced as to leave little inducement for the shipper to change from the railroad.

1358. A boat company, to handle large quantities of wheat, must provide facilities equal to those on the railroads. This would require greater capital than boat operators in the past apparently have been able to command. Even with the proper warehouse facilities at convenient boat landings, it is doubtful if boat operators could expect to compete profitably, under the existing methods of handling wheat from the producer to the consumer, without purchasing the wheat.

1359. In estimating the economic value of the various conditions of river improvement outlined in this report, the railroad tonnage originating and terminating in the counties contiguous to the portion of the river affected by the improvements was determined. The railroad freight in and out of these counties for the year 1928–29 amounted to a total of 1,956,292 tons. Of this total 1,563,585 tons were downstream or westbound, and 392,707 tons were upstream or eastbound. About 60 percent of the downstream traffic was wheat. It was assumed that river freight would be of the same general character as the railroad freight and in about the same proportion as to eastbound and westbound tonnage. The cost estimates for river freight therefore assume that the upstream traffic would be 25 percent of the downstream traffic and that wheat would comprise about 50 percent of the total cargo handled.

1360. In considering the benefits to shippers from navigation improvements, a comparison is made between water costs and existing rail rates between various terminals. So much of the comparison as applies to handling freight between water terminals indicates that there is a saving in favor of the navigation costs. However, this does not include the additional trucking charge which must be paid by the shipper in order to get his freight to the river terminal.

1361. *Possible methods of improving river for navigation.*—The following methods for improving Columbia River for navigation are considered:

(*a*) Removal of shoals and rocks to improve open-river channel.
(*b*) Construction of lateral canals around difficult stretches.
(*c*) Construction of dams creating a series of pools.

The first method is suitable where slopes are moderate and where there is a sufficient low-water flow to provide the required channel depth and width for the prospective navigation. Columbia River, with a flow of about 50,000 second-feet at low water, can supply a sufficient quantity of water for an almost unlimited commerce. An open-river channel avoids delays in lockages and is to be preferred if the slope is not so great as to cause strong currents. Columbia River is tidal to Warrendale, but above Warrendale the numerous falls and rapids limit open-river work to clearing the existing channels of obstructions and constructing regulation works. Where the slope is excessive, the channel through the rapids cannot be deepened without lowering the pool and increasing the slope above the rapids.

1362. Local interests desire a straight channel 7 feet deep and 100 feet wide at low water. Under the existing project, completed in 1918, the channels have been cleared of the most dangerous obstructions. The present channel depth is not less than 7 feet except at Homly Rapids (about 6 miles below the mouth of the Snake River), which has a low-water depth of 4½ feet, and on a few gravel shoals where the controlling depth is 6 feet. The width of the existing channel is greater than 100 feet except at Homly Rapids, where it is less than 100 feet. Navigation can be made easier and less hazardous if the existing channels are straightened by the further removal of rock pinnacles and projecting ledges, not contemplated in the existing project. Clearing and straightening the present channel in a number of short stretches of river would permit navigation at night, which is not now possible. No great increase in depth can be made in the existing channels without affecting the regimen of the stream. It is thought that a depth of 7 feet through the gravel shoals between Vancouver and the mouth of the Snake River, except at Homly Rapids, may be secured without difficulty. At Homly Rapids it would be difficult to secure more than 5 to 6 feet. The cost of the work required to straighten the channels by the removal of rock pinnacles and projecting ledges in the channel between Warrendale and the mouth of Snake River is estimated at $556,200. The work contemplated under this estimate would make navigation easier and safer but it would not decrease the current which exists in the channels. A depth of 9 feet is believed desirable for successful barge navigation, but securing of this depth by open-river methods in the Columbia River is impracticable at some points.

1363. *Types of craft.*—Paragraphs 476 to 493 of this report contain a study of the various types of craft suitable for Columbia River conditions. The opinion of nearly all of the steamboat captains familiar with navigation conditions on the Columbia above Warrendale, expressed in interviews and replies to questionnaires, was that barge navigation for that portion of the river in its present condition is physically impracticable even though at favorable stages, it is possible. The principal obstacle to barge navigation is the narrow twisting channel through the rapids. The currents are swift at many places, which would make handling of barges extremely difficult. The straightening of the channel and the removal of the more dangerous rocks would not decrease the currents but would permit a limited use of barges. On account of the swift currents fleets of barges cannot be used unless fleets are broken up at the foot of the rapids, barges taken through singly, and fleets re-formed above the rapids.

1364. However, it is the opinion of this office that the packet boat or self-propelled freight boat of the Columbia River type is the most economical type of boat for the open river. Estimates of the cost of operating self-propelled boats, under present open-river conditions, indicate that if such boats could obtain sufficient tonnage they could handle freight at an average cost of $0.021 per ton-mile, including all expenses, terminals, etc., or $0.004 per ton-mile under the existing rail rates.

1365. Further improvement by removing obstructive rocks and shoals, and by deepening and straightening the channel, as under condition (*b*), would decrease hazards to navigation, but the swift currents would remain. It is estimated, however, that the actual cost of operating boats, with further open-river improvement, would be about 10 percent less than under the present conditions, due to the saving of time in navigating the rapids at low water and the ability to navigate the river at night in places where it is not now possible to do so.

1366. Investigation of the history of the various companies which have engaged in river transportation to points above the Cascades Gorge leads to the conclusion that while the use of packet boats or self-propelled boats has been practicable, insofar as the physical conditions of the river are concerned, the companies have been unable to obtain sufficient tonnage to make such operation profitable, due mostly to their inability to secure shipments from points at some distance from the river.

1367. Local interests claim that open-river improvements as outlined above will result in a much greater use of the river and will induce boat companies of greater financial strength than those which have operated in the past to establish themselves on the river. This appears to be a reasonable view. The extent to which the river would be used under the improvements proposed is difficult to estimate.

1368. In a recent traffic survey, made under the direction of the Columbia Valley Association, promises were obtained by them from prospective shippers for 400,000 tons annually of miscellaneous freight, in the event a boat line was put in operation. This is more tonnage than has ever been handled on the river by boat companies which have operated in the past. The maximum tonnage of record was for the year 1908, in which 54,953 tons passed between Portland and The Dalles through the Cascades Canal, and this was due in part to railroad construction on the right bank of the river.

1369. The estimate of 400,000 tons contemplated additional navigation improvement for the Snake, as well as the Columbia, and includes tonnage tributary to Lewiston. About 300,000 tons was estimated for the counties contiguous to the Columbia below the mouth of Snake River. In view of the small net savings which would accrue to the shipper, it is the opinion of this office that 100,000 tons is the maximum tonnage which could be diverted to the river from these counties. If 100,000 tons could be transported annually, there would be an apparent gross saving of $70,000 per year to the shippers. The annual interest, depreciation, operation, and maintenance on the improvements is, however, estimated at $55,000, which would leave a net saving of $15,000 annually. This saving would continue only until such time as high dams for power might be built, so that if power dams should be constructed in the near future the cost of the open-river improvements would not be economically justified.

1370. As has been pointed out above, the failures of past attempts to establish navigation on the river above Warrendale have been due to lack of patronage rather than to physical features of the channel. There is no means of insuring that the proposed open-river improvements will result in continued use of the river, or that a large tonnage would be handled.

1371. Slack-water navigation may be secured by a lateral canal paralleling the river, but this method limits the volume of commerce unless the canals are unusually large. Due to the steep slope of the river and swift currents, a lateral canal, with locks at various points, would be required for the entire length of the Columbia River between Bonneville and the mouth of the Snake in order to obtain slack-water navigation. The cost of a continuous lateral canal would be prohibitive on account of the enormous quantities of rock excavation and number of locks involved, and also on account of the necessity of moving railroads and highways where they would interfere with canal construction.

1372. Short lateral canals, however, might be constructed around the worst obstructions only. Such partial improvement would leave long stretches of open river with moderate currents except during the freshet period. The two principal obstacles are the swift currents through the section of the river between Warrendale and the head of Cascades Rapids, and the section from the foot of Three Mile Rapids to the foot of The Dalles-Celilo Canal. Lateral canals at the Cascades and around Three Mile Rapids would give easy navigation to the head of Celilo Falls.

1373. From Warrendale to the head of Cascades Gorge, a lateral canal on the right bank about 7 miles in length would be required. Its cost is estimated at $21,190,000. An extension of The Dalles-Celilo Canal between the foot of Three Mile Rapids and the lower entrance of The Dalles-Celilo Canal, a distance of about 2½ miles, would be necessary, at an estimated cost of about $2,000,000. These two canals would eliminate the worst obstructions to navigation in the river. While strong currents would still be encountered at numerous points above Celilo, these currents are not so swift as those in Cascades Gorge and Three Mile Rapids, and would be less serious obstacles to navigation. The cost of constructing lateral canals around each of the minor rapids above Celilo Falls would be great and the resulting benefits would not be sufficient to warrant their installation.

1374. With the lateral canals through Columbia Gorge and around Three Mile Rapids, and further open river improvement above Celilo, barge navigation would be feasible as far as Homly Rapids, a distance of about 318 miles from the mouth of the Columbia. The cost of these two canals and the probable amount of open river work required is estimated at $23,515,000. There would still be some current at all stages of the river. During extreme freshets the river would be unnavigable. The cost of operating boats would be less than under open river improvements, without such canals, but would be more than for slack-water conditions. It is estimated in paragraphs 550 and 556 of this report that freight could be transported at a cost of $0.021 per ton-mile, including terminal charges and cost of handling freight between inland destination and the river, if the river were improved by the additional short lateral canals at Cascades Gorge and at Three Mile Rapids and some open river work from Celilo Canal to Snake River. It has also been estimated that as a result of the comparatively low transportation cost, 200,000 tons of freight per year might be diverted to the river. On such a basis the savings over existing freight rates would amount to $160,000 a year. However, the interest, depreciation, and maintenance upon the improvement (two lateral canals and open river work) are estimated to be $1,025,600 annually. It is apparent that in view of the prospective commerce, construction of lateral canals is not economically justified at the present time.

1375. The projects for power include five plans (A to E) (see plate 49) which canalize the river between Warrendale and the mouth of the Snake by creating a series of pools. Under each plan the elevation of the pool created by the upper dam is 330 feet above sea level. A pool at elevation 330 would extend upstream to a point 15 miles above the mouth of Snake River on the Columbia, and to the head of Five Mile Rapids, 6 miles upstream on Snake River. In addition to the five plans mentioned above, a plan including a dam at Wallula was considered. The Wallula Dam would have a pool elevation of 550, which would extend upstream to the foot of the Rock Island Dam, now under construction, 129 miles above the mouth of Snake River, and together with Rock Island Dam would give slack-water to about Wenatchee, Wash., 142 miles above the mouth of Snake River. On Snake River the pool (elevation 550) would extend up the river approximately to Central Ferry, a distance of about 86 miles above the mouth of Snake River.

1376. The cost of the navigation features (locks and approaches) through the dams varies from $13,500,000 to $34,800,000. The preferred plan for power is plan D (see pl. 49 p. 1545), navigation features of which have an estimated cost of $14,600,000. Under plan D slack-water navigation would be possible above Warrendale to a point about 15 miles above the Snake River on the Columbia and up the Snake for a distance of about 6 miles to the head of Five Mile Rapids.

1377. All the plans involving dams for power provide a series of successive pools at low water. Each dam would create a pool extending from its crest to the foot of the next dam upstream, under low water conditions. The narrow rocky gorge in which the Columbia flows throughout most of its course permits little storage capacity to be developed by dams of moderate height. Some storage effect is obtained in the case of the higher dams, but this is not sufficient to take care of the excess water of the larger freshets.

1378. During high water, the currents in upper end of the pools created by the dams would be almost as great as those which now exist in the open river. However, the channel would be deep and straight and there would be no hazards to navigation other than the swift currents. Further regulation of the river by means of storage in the upper reaches would, of course, reduce these currents. The average freshet which occurs annually during the 3-month period from May to July, would rarely block navigation for a longer period than 30 days annually. Ice conditions in the winter months might block navigation for a period averaging 1 month annually. Under the various plans for power dams, slack-water navigation would be possible for 10 months of the year.

1379. A few high dams are believed preferable to a greater number of low dams, insofar as navigation is concerned, as there would be deeper channels and fewer delays due to breaking up of fleets of barges in going through the locks. For slack-water conditions barges with tow boats are believed to be the most economical type of craft.

1380. In case of high dams for power, boats could not pass the dam sites during the construction of the dams so that provision would have to be made to pass freight over the dam site. This could be done by means of a portage railway around the dam site. Freight transfer facilities would have to be provided at each terminus of the portage railroad. The cost of transferring freight over the dam site would have to be charged to the cost of the dams. However, there is no navigation at the present time on the portion of the river in which the dams would be built. This cost of passing freight by the site during construction would be contingent upon the amount of traffic which might develop prior to the construction of the dams. An estimate has been made of the possible savings in freight costs which might result under slack-water conditions created by the plans having the upper pool elevation at 330. If, due to the lower rates, about one third, or 600,000 tons of freight, originating along the river below the mouth of Snake and now carried by the two railroads paralleling the river could be diverted to the river, it is estimated that it could be carried for $0.016 per ton-mile and cover all costs, boats, terminals, etc. This would represent a difference of $0.009 per ton-mile, or $1,080,000 for 600,000 tons annually hauled an average distance of 200 miles, below the present cost of transporting this tonnage by rail between the various terminals considered. The annual cost due to the navigation features only of the power dams required for handling this traffic is estimated at $884,000. This, deducted from the difference between rail and water costs, gives $196,000 as the probable annual net savings which might result from slack-water navigation.

1381. The series of power dams which include a high dam at Wallula carrying the upper pool to elevation 550 would be much more favorable to navigation than those which stop at elevation 330. However, the economic benefits to navigation would be so small when compared to the enormous cost of this plan that they could not be considered as materially affecting the question of whether or not the project should be built. The construction of Wallula Dam would have to be justified on its merits as a power development alone. In view of the fact that the Wallula project is unlikely to be developed for many years to come, if ever, a more detailed consideration of the navigation features involved has not been presented. Detailed cost estimates of the dams for power are given in the power section of this report.

1382. In view of the limited amount of prospective commerce, which might be expected under the present state of development of the country through which the Columbia flows, the expenditure of the large amounts of money which would be required for the construction of dams for navigation alone does not appear to be economically justified. Future development may, of course, create a greater need for river transportation. However, further improvement of other methods of transportation may alter the present basis for comparison. It is believed of little value to attempt to make, too far in advance, detailed estimates relative to future transportation needs.

II. POWER

1383. The possibility of full utilization of the Columbia River below the mouth of Snake River for power production is graphically illustrated in plate 49, page 1545. This plate shows approximate location of all sites described in this report. Also it shows five major series or combinations of projects from the mouth of the Snake to tidewater at Warrendale.

1384. The distance between the mouth of the Snake and the mouth of the Columbia is 324 miles. Only the upper 184 miles of this section, extending from the mouth of the Snake to Warrendale, is suitable for power developments, since Warrendale, which is located 140 miles from the ocean, is at the practical upper limit of tidal influence during the low-water period. For 123 miles, from the mouth of the Snake to Celilo, the river has a roughly uniform slope. In the 11-mile section between Celilo and the foot of Three Mile Rapids, just above The Dalles, it drops 82 feet at low water. At the foot of Three Mile Rapids it enters a virtual pool which extends for about 43 miles to the head of Cascades Rapids. At Cascades Rapids the river drops 25 feet in less than 2,000 feet, and in the next 7 miles to Warrendale it has an additional drop of 12 feet. These two distinct falls in the river have fairly well fixed the location of the power dams at The Dalles and Cascades Rapids. For the rest of the river, where dam sites are numerous, factors other than natural fall influence the location of power dams.

1385. Disregarding for the present the Wallula site, an elevation of 330 has been set as the upper limit to which the low-water level should be raised for any project constructed below the mouth of Snake. By not exceeding the 330 level, expensive damages to property would be avoided. With an upper controlled level of 330, and 4 feet as mean low water elevation at Warrendale, the total available fall would be 326 feet between the mouth of the Snake and Warrendale.

1386. "Firm power" has been determined for unregulated flow which has occurred 99.3 percent of the time in the 17-year period 1913–30. At The Dalles this flow is 55,000 second-feet. The only tributary between Warrendale and the mouth of the Snake materially adding to the flow of the Columbia is Deschutes River, which enters the Columbia 15 miles above The Dalles. Disregarding the effect of the smaller streams, the flow of 55,000 second-feet has been used in the power computations to determine "firm power" for sites below mouth of the Deschutes and 50,000 second-feet for sites between mouth of the Deschutes and mouth of the Snake. It is assumed that during the rare and brief occasions, totaling only 44 days in 17 years, when the natural flow drops below these rates that the shortage can be made up from the pondage back of the dams. (Compare par. 620.)

1387. The effect of storage has been considered where storage reservoirs have been proposed below the mouth of the Snake, but no benefit from possible storage above the mouth of the Snake has been included in the computations of power output at sites on the lower river. The increase in firm-power output for the comprehensive plan of development has been computed (see par. 1412), but the cost of the additional installation has not been estimated.

1388. The following sites on the main stream have been investigated and, with the exception of Wind Mountain, explored by drilling in order to determine their feasibility for dam construction:

Site:	*Distance in miles above mouth of Columbia*
Homly Rapids	318
Wallula power site	313
Umatilla Rapids	292
Canoe Encampment Rapids	264
Arlington power site	242.5
Blalock Rapids	234
Four O'Clock Rapids	232
Squally Hook Rapids	222.5
John Day Rapids	216
Biggs Rapids	207
Five Mile Rapids	193.5
Big Eddy	192
Three Mile Rapids	190
Wind Mountain	155
Cascades Rapids	147
Bonneville	143
Warrendale	140

1389. Of these 17 sites 12 have been eliminated because of not economically fitting into the general scheme of developing power between mouth of Snake and tidewater or on account of foundation difficulties.

1390. The remaining five sites, Umatilla, Arlington, John Day, The Dalles, and Warrendale, have been given a closer study in order to determine the best plan of development. The following tabulation gives these five major sites and the proposed elevation of pool levels to which head-water at the dams would be controlled by means of crest gates. At all of these sites, except Warrendale, pool levels would remain the same at high-water stages as at low water. At Warrendale the topographic conditions permit an increase in pool level without material damage to property.

Site:	*Elevation of controlled pool level*
Umatilla	330
Arlington	258 or 330
John Day	258 or 330
The Dalles	150 or 183 or 330
Warrendale	54

1391. The following combinations of these five sites have been considered in arriving at conclusions as to the comprehensive plan of development. The tabulation gives the controlled pool levels and head interpreted as the difference between upper and lower pool levels at low water. Graphically these series are represented on plate 49, page 1545.

Series	Site	Upper pool level	Head in feet	
			Each site	Total series
A	Umatilla	330	72	
	John Day	258	108	
	The Dalles	150	96	
	Warrendale	54	50	326
B	Umatilla	330	72	
	Arlington	258	75	
	The Dalles	183	129	
	Warrendale	54	50	326
C	Arlington	330	147	
	The Dalles	183	129	
	Warrendale	54	50	326
D	The Dalles	330	276	
	Warrendale	54	50	326
E	John Day	330	180	
	The Dalles	150	96	
	Warrendale	54	50	326

1392. As mentioned above, 12 sites were eliminated from further investigation as not economically fitting into any general scheme of development. However, of these 12 sites, one, the Wallula site, is more outstanding than the rest and while not included in the general scheme of development, merits more detailed consideration, especially since there appears to be no dam site which can be effectively developed for power purposes above Wallula between elevation 330 and elevation 405, the foot of Priest Rapids. The Wallula site holds not only great power possibilities for the site itself, but also would add substantially to the power output at each site below on account of the large storage reservoir created by a dam in the Wallula Gorge. The storage available in the Wallula Reservoir if built to an elevation of 550, tailwater level at the Rock Island plant, 140 miles above, would raise low-water flows downstream nearly 50 percent and would add to firm-power production in like proportion for all the projects investigated between Umatilla and tidewater.

1393. A dam at Wallula can be built with entire safety to great height on account of the excellent character of foundation rock. However, the reservoir above it would destroy properties of large present value and of greater potential value. These properties comprise the cities of Pasco and Kennewick, a network of railroads and highways centered at Pasco and large areas of irrigated and irrigable lands. The destruction of these properties has been considered such a serious detriment that a project at Wallula proposed to raise the low-water level above elevation 330 has not been considered as economically justified. A pool level to elevation 330 or less would have little value from a power point of view and would not fit into the proposed plans.

1394. *Effect of location on power output and cost.*—Of the five sites—Umatilla, Arlington, John Day, The Dalles-Celilo section, and Cascades Rapids-Warrendale section—the first four all have rock of a character satisfactory for the support of high masonry dams. At Umatilla, Arlington, and John Day, the rock in the river channel and on the shores is found at reasonable depth. The river at these three sites flows in a channel which changes in general appearance but slightly for several miles. The location chosen for dam and power house at each of these sites may not necessarily be the best and most economical. It is possible that a more detailed investigation may prove another location to offer greater advantage and economy. However, a change in the exact location at the site farther upstream or downstream, up to a mile or even more, would not materially affect the estimate or influence the power output since general conditions remain essentially the same. At these three sites, unwatering and diversion for construction, although expensive, should not involve any unusual problems, as rock is found in the river channel at reasonable depth below low-water levels.

1395. In the Celilo to The Dalles and Cascades Rapids to Warrendale sections of the river, on the other hand, conditions at the site are such that a comparatively accurate location is necessary in order to gain the most benefit from the development.

1396. In the section of the Columbia between Celilo and The Dalles, that portion of the river which lies between the head of Five Mile Rapids and the foot of Three Mile Rapids, a distance of about 4 miles, presents the most favorable condition for development. Here, in the main channel, the depth to rock is very great, about 150 feet below water surface at low-water stages. Some unprecedented construction methods would have to be resorted to in order to unwater the stream and to permit the construction of the main dam in the dry. A method to overcome the difficulty at this point has been worked out and the details of this part of the work are described in paragraph 787.

1397. The total fall in the river between Celilo and the foot of Three Mile Rapids, a distance of 11 miles, is 82 feet. Of the several sites in this reach, each has such distinct features and would show such difference in cost that a location within comparatively narrow limits has been necessary in order to determine the best development. Three sites have been investigated, 1 at head of Five Mile Rapids, 1 at Big Eddy Island, and 1 at Three Mile Rapids. The difference in power output between these three sites is small. The unwatering of the main channel and river diversion are also essentially the same for the three sites, possibly somewhat more difficult at Five Miles Rapids. The deciding factor in choosing the final location has been cost of construction. For the Five Mile Rapids site a canal about 8,000 feet in length and costly power-house construction, not duplicated at the other locations, have eliminated that location. The chief difference between the Big Eddy Island and the Three Mile Rapids locations lies in the cost of the dam outside of the main-channel section. The general elevation at Three Mile Rapids is lower than at the plateau downstream from Big Eddy where the main structures in the Big Eddy Island location would be built, resulting in a greater cost for the dam on account of greater height. The investigation of sites in The Dalles-Celilo section of the Columbia thus determined the location of the main dam between Big Eddy Island and the Oregon shore, with the power house on the Washington shore parallel with the stream and downstream from Big Eddy Island.

1398. In the section of the river from the head of Cascades Rapids to tidewater, a distance of 7 miles, solid rock has not been encountered at resonable depth. The foundation material in most of this section is sand, gravel, and boulders, intermixed with Eagle Creek formation, and no really uniform formation is found except at Warrendale.

1399. Three sites for dams have offered themselves for this section: At head of Cascades Rapids; at Bonneville; and at Warrendale.

1400. It would probably be feasible to locate a dam at the head of Cascades Rapids. Two plans for developing the head created by the dam and the natural fall at Cascades Rapids have been investigated. One, the Cascades Rapids plan, would have a power house located at the foot of the present Cascade Locks. Such development would have serious drawbacks. With the power house near the dam, the head would be insufficient for effective power production during much of the flood season, and for much of the balance of the year the plant would be able to produce only a fraction of its capacity at low water, unless an unreasonable number of units were installed. Thus a plant at this place could be serviceable as only a producer of secondary power in a larger power system.

1401. The other plan, with a dam at the head of Cascades Rapids and the power house farther downstream on the Washington side at a point where the head would not be seriously affected by tailwater rising more rapidly than headwater levels, would require the construction of a canal in the slide material on the Washington shore along the Columbia Gorge. The character of the material through which the canal would be excavated is such that much difficulty and very great, and unforeseen expense might be involved in its construction and maintenance. Moreover, the integrity of the diversion dam above the rapids is dependent on the permanency of the rock bottom at the rapids. The river bed may be partly on debris of slide material but is probably mostly in Eagle Creek formation, the character of which changes from hard to soft in a short distance, and severe erosion in the river bed would jeopardize the safety of the dam.

1402. The Bonneville plan with the main dam at Boat Rock and power house at lower end of Bradford Island would have the advantage of having the dam founded on rock. The depth to bedrock is 140 feet below low water, and the river in this section is restricted in width, which conditions present serious construction problems and may necessitate relatively heavy expenditure.

1403. In this section of the river, there remains further the Warrendale site. Here rock has not been struck by the exploration drilling. Sand and gravel deposits overlie the bedrock to great depth and the entire structure must be founded on that formation. A design has been made for this site consisting of a concrete overflow dam with extensive aprons, both upstream and downstream. The difference between the elevation of the water above and below the dam is 50 feet at low river stage, and 35 feet at high floods.

1404. All of the plans for development of the site between Cascades Rapids and Warrendale have undesirable features. A very detailed and careful investigation beyond the scope of this report to determine definitely the feasibility of any one of the plans here discussed would be required. However, from such data as are available this office is of the opinion that the Warrendale development is the most desirable in this reach of the river.

1405. *Discharge duration.*—Records of flow of the Columbia River at The Dalles have been kept since 1878. A study of the hydrographs shows that the earlier years of the time since 1878 carried greater flow than the more recent years. The lowest flows on record have occurred within the last few years. For this reason it has been thought advisable not to base estimated power production on the full period of time since 1878, but to base power studies on the period of 17 years, from April 1, 1913, to March 31, 1930.

1406. The low water flows adopted for power computations are shown in paragraph 612. To determine spillway capacities the greatest flood on record, that of June 6, 1894, with a crest of 1,170,000 second-feet, has been adopted. With all spillway gates open a flood of that magnitude would pass any of the proposed dams without raising the water level. A flood exceeding that of 1894 by 25 percent would pass the spillway with 3 additional feet of depth over the crest. A flood 50 percent greater than that of 1894 would raise the pool level about 8 feet at the dam over that of controlled level. This would still be 2 feet below the relocated railroad tracks. A flood of such magnitude would probably cause some damage to the railroads farther upstream, to operating bridges and gates, but would not endanger main structures. In fact, these structures would probably be safer under conditions of extreme floods than they would be at intermediate stages of river flow.

1407. *Load factor.*—The lowest load factor for any one plant here considered has been assumed at 50 percent. Load factor is interpreted as the relation between the average yearly load and the peak load for the year. Power demand both for domestic and industrial use ordinarily is higher during the winter months than in the summer, resulting in the peak being reached at time of low water rather than the time of high stages of the river. However, it has been considered on the side of safety to assume that the peak would occur at any time during the entire year. The number of units necessary to carry peak loads during a flood of 800,000 second-feet was determined. (See par. 612.) For installations not affected by storage a number of units would always be idle during the low water season as the installation was fixed by flood flows. It is not improbable that a final study of the load factor and time of occurrence of the yearly peak loads would indicate that a less number of units would be required for flood stages. As the cost of one unit with its hydraulic and electric equipment, power house, sub- and superstructures, and intake structure is comparatively great, a considerable saving would be effected for each unit thus eliminated.

1408. *Effect of variable head.*—In all the projects herein discussed, except Warrendale, large crest gates control the pool level, keeping it constant except for draw-down in the storage schemes. An increase in flow would then result in dropping off of effective head as tail-water levels rise. While for the higher head plants, the loss in head is 15 to 20 percent, the loss will become as great as 50 percent for some of the plants with a head of about 100 feet at low water. With such variations in head, water-wheel capacities would drop off sharply, and a reduction in output would result. This has been considered when determining the number of units to be installed.

1409. The greatest economy for such cases would be to install different types of units, some to operate at their highest efficiency at low water and at higher heads with resulting reduction in efficiency for the lower heads. Additional units would be installed and go into operation at their highest efficiency as the head decreases. A somewhat smaller number of units would then result.

1410. Another way of saving some cost would be to install smaller generators on such a number of units as would operate only at times of high water and low head, when the capacity of the turbines is reduced.

1411. The purpose of these suggestions is to indicate that refinements resulting from a more detailed study of the particular conditions prevailing at each site may result in lower estimates of construction costs.

1412. *Effect of storage in the upper Columbia.*—If a total storage of about 26,000,000 acre-feet above the mouth of the Snake were available (see par. 571), the output of any project below the mouth of the Snake would benefit correspondingly. In the comprehensive plan of development as here presented, the output 100 percent of the time at The Dalles project would be increased by 540,000 kilowatts and at Warrendale by 90,000 kilowatts.

1413. *Cost of transmission.*—The unit transmission cost increases with distance. For the purpose of the estimate the center of power consumption for generation below the mouth of the Snake is taken at Portland, Oreg. The site nearest to Portland is Warrendale, which is 40 miles away. Umatilla, the site farthest upstream, is 190 miles from Portland. The Dalles site, which is capable of large power production, is 90 miles distant. These differences in distance from point of generation to center of consumption materially influence the cost of power at the receiving end when cost of transmission is added to cost at the site.

1414. The cost of transmitting power is here taken from plate 113.[2] Tabulations showing costs of transmission when power is delivered at Portland, Oreg., as load center are given in paragraphs 639 to 920.

1415. To assume that all the power is to be transmitted to Portland from each site may be ultra-conservative as there is a possibility of industries being located at the place of generation. Industries locating at the power site, would be more probable for The Dalles development than for the other sites, as The Dalles, although a city of small size (about 6,000 inhabitants), is already established as a center in a territory of great possibilities. For comparison, however, the estimated cost of power for all of the sites has been based on the assumption that the generated power would be delivered in Portland.

1416. *Revision of railroads and highways.*—Both banks of Columbia River and some of the streams tributary to the Columbia between Vancouver, Wash., and the mouth of Snake are traversed by railroads and highways that would be in part submerged by backwater from proposed dams in Columbia River.

1417. The Vancouver division of the Spokane, Portland & Seattle Railway traverses the north bank, and the main line of the Oregon-Washington Railroad & Navigation Co., a subsidiary of the Union Pacific System, traverses the south bank. These railroads are single track except about 22 miles of the Union Pacific near The Dalles, Oreg., which is double track. Connecting with these main lines at several points are branch lines. The main lines generally were built at the bases of high rock cliffs, on the slopes near high water level in Columbia River. Revision to a higher elevation would in many places locate the proposed lines in the cliffs where construction would be much heavier than that of the existing lines. Solid rock cuts would be of large dimensions, and many tunnels and viaducts would be required to carry the lines through points and over ravines.

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[2] Not printed.

1418. It is assumed that construction of dams in Columbia River and the attendant developments would increase the transportation business and create a need for higher class railroads with double tracks and heavy structures. While the first reconstruction may be single track, yet the roadbed, tunnels, and viaducts may be built to double-track width more cheaply during the first period of construction than they could be built to single-track width and widened after the track is in operation. The cost of double-track construction would be much greater than that of single track. The estimates of revisions have been made on the assumption that the proposed new lines will be equivalent in class and dimensions of roadbed and material to the existing lines, and that the extra cost of better classes and larger dimensions will be borne by the companies demanding them. It is assumed that the increase in transportation business which may be expected from the construction of dams would net the railroads a sufficient increase in earnings to enable them to meet these extra costs.

1419. There are no modern highways on the north bank of Columbia River that would be affected by construction of dams in the Columbia. The Evergreen Highway, of modern construction, is well above backwater elevations. Such roads as will be submerged are of little value. On the south bank the Columbia River Highway, of modern construction, would be rebuilt where the existing grade is below the backwater elevations or within the proposed right-of-way of the railroads. The proposed construction is estimated as of the same classes and dimensions as the existing highway. It is assumed that the extra costs of better classes and larger dimensions will be met by the State of Oregon.

1420. *Power market.*—As stated in paragraph 645, the estimates have been based on the assumption that 50 percent of the increase in power market in the Pacific Northwest would be absorbed by any project constructed on the Columbia River below mouth of Snake. For comparison graphs have been prepared, plates[2] 95 to 100, inclusive, showing the cost of power if all or 100 percent of this power market was absorbed by any one project built in this section.

1421. Of course, in actual practice the projects would be put into operation in succession, each after the previously constructed project has been loaded to full capacity. A study of the increase in power demand, paragraph 1025, shows the tendency of the load to increase at a fairly uniform percentage rate from year to year. As the load grows the annual increments become larger. Thus a project which would be brought into operation in, say 1950, would become loaded to ultimate capacity at a more rapid rate than if the same project was first generating power in 1940. The carrying charges for this project would thus become less were it built as second or third in a series of developments than if it were built as an initial project in the same series. However, to facilitate the direct comparison of the projects, the calculation of the carrying charges on each has been computed, when making the estimates and preparing the graphs, as though it were to be put into operation in 1940.

1422. *Secondary power.*—The quantity of secondary power which can be produced will be greater in a series without seasonal storage. However, it would not be out of reason to assume that any development on Columbia River would be made part of a "super-power" system, whose network would embrace all of the Pacific Northwest.

[2] Not printed.

In such cases part of the secondary power would approach in value that of "firm power" at times when other streams in the territory are forced to operate at fractional capacity on account of water shortage. Conversely, at the time of the year, usually early summer, when during flood season for the Columbia, any plant on that stream would be handicapped on account of serious reduction in effective head, an interconnection with other generating plants might enable them to fill in the power shortage occurring at Columbia River plants.

1423. The amount of available secondary power has been shown under "General data" in the description of each project included in series A and D.

1424. *Cost of power.*—Factors affecting the cost of hydroelectric power for the projects discussed in this report are: construction costs, cost of transmission, damage to property, interest, magnitude of power output as determined from stream flow, storage and physical conditions at the site, load factor, and the absorption of power by the power market.

1425. Of the five series herein compared, the first two, or series A and B, comprise low head dams with pools too small for seasonal storage. The last three, series C, D, and E, contain storage reservoirs which would be beneficial, not only to the individual projects themselves, but also to any project in the river below. In the comprehensive plan of development, series D, the available storage behind The Dalles Dam with pool elevation 330 is 4,625,000 acre-feet in the upper 40 feet.

1426. The following tabulation gives the cost in mills per kilowatt-hour at the site and delivered in Portland, Oreg., or at an equal distance from the site. It assumes an installation capable of developing the firm power at a 50 percent load factor. It also assumes that the market to be supplied will absorb 50 percent of the increase of load estimated for the Pacific Northwest.

Series	Project	Elevation of controlled pool level	Total cost in millions of dollars		Firm power in thousands of kilowatts	Cost in mills per kilowatt-hour, 50 percent load factor and 50 percent power market			
			4 percent money	6 percent money		4 percent money		6 percent money	
						At the site	At Portland	At the site	At Portland
A	Warrendale	54	58.8	61.7	200	2.20	2.53	3.05	3.47
	The Dalles	150	88.5	93.4	375	1.89	2.29	2.57	3.08
	John Day	258	109.9	116.6	385	2.12	2.56	2.98	3.55
	Umatilla	330	60.1	63.0	250	1.77	2.45	2.47	3.34
	Total series		317.3	334.7	1,210	1.99	2.38	2.76	3.26
B	Warrendale	54	58.8	61.7	200	2.20	2.53	3.05	3.47
	The Dalles	183	115.9	123.7	500	1.75	2.15	2.46	2.97
	Arlington	258	71.5	75.3	250	2.11	2.61	2.96	3.59
	Umatilla	330	60.1	63.0	250	1.77	2.45	2.47	3.34
	Total series		306.3	323.7	1,200	1.90	2.30	2.66	3.17
C	Warrendale	54	64.9	68.1	230	2.15	2.48	2.96	3.38
	The Dalles	183	132.3	141.8	600	1.68	2.08	2.30	2.87
	Arlington	330	178.1	193.9	685	1.92	2.42	2.76	3.39
	Total series		375.3	403.8	1,515	1.86	2.24	2.64	3.13
D	Warrendale	54	67.0	70.4	240	2.14	2.47	2.95	3.37
	The Dalles	330	344.5	397.0	1,450	1.55	1.95	2.49	3.00
	Total series		411.5	467.4	1,690	1.64	1.99	2.56	3.01
E	Warrendale	54	64.9	68.1	230	2.15	2.48	2.96	3.38
	The Dalles	150	103.5	109.6	460	1.81	2.21	2.46	2.97
	John Day	330	197.0	216.2	875	1.62	2.06	2.38	2.95
	Total series		365.4	393.9	1,565	1.75	2.11	2.49	2.96

1427. Plates[2] 95 to 100, inclusive, show the effect of 50 to 100 percent of the estimated growth of the power market being supplied by any one project; the effect of 4 and 6 percent money, and of load factors varying from 50 to 100 percent.

1428. *Comprehensive plan of development.*—From the above tabulation (par. 1426), it will be noted that series D and E produce power at about the same kilowatt-hours cost. Series D, however, produces 125,000 kilowatts more than series E, due to the greater storage available at The Dalles site. The difference in the kilowatt-hour cost between these two series is not sufficient to be conclusive in favor of either scheme. A more detailed investigation may vary the figures.

1429. The two series involving smaller projects and consequently less individual cost would be better adapted to step development. The entire head in the river between the mouth of Snake and tidewater could, of course, be utilized at low water, but a serious loss in head would result at high stages. There would be no seasonal storage effect and consequently less power would be produced than in the three series with storage reservoirs. This explains the higher unit cost of power production for these lower head developments as shown in the table.

1430. Construction costs for any of the sites are high and constitute a serious handicap, which is unavoidable in dealing with a river as large as the Columbia.

1431. The choice lies between step development with smaller initial cost and single development with greatly increased initial cost, but with greater power output at smaller unit cost. The Columbia River offers the greatest opportunity in the United States for developing hydroelectric power. Its enormous power potentialities when fully realized would change the economic aspect of the whole Pacific Northwest. Judging from this background, the unprecedented size of power development on the Columbia River is merely a measure of the extraordinary benefits which may accrue therefrom.

1432. A study of the power market leads to the conclusion that large blocks of power will be required within the next few decades. From an economic and national point of view it is the opinion of this office that series D, a development at The Dalles to 330 and at Warrendale to elevation 54, which produces the largest amount of power at a low unit cost, is the most desirable scheme of development on the Columbia River between the mouth of the Snake and tidewater.

III. FLOOD CONTROL

1433. Below the mouth of the Snake, flood damage occurs during the Columbia River annual freshets and is caused mainly by the overflow of lowlands adjacent to the stream along the lower 120 miles of its course; that is, below the mouth of Sandy River, which enters the Columbia on the Oregon side about 14 miles above Vancouver, Wash. Above the mouth of Sandy River little arable land is subject to overflow except during freshets of unusual heights.

1434. The valley of the Columbia below the Sandy contains about 266 square miles of arable lands below the crest elevation of the flood of 1894. About 226 square miles of this area are below the crest elevation of ordinary floods. These arable lands are scattered in

[2] Not printed.

small parcels. A total of about 119 square miles of the area subject to overflow is now protected against ordinary floods by levees.

1435. Flooding of the low lands begins when the Columbia is discharging approximately 600,000 second-feet at The Dalles, Oreg. This stage is reached about once every 2 years. Small damage results from floods of 600,000 to 700,000 second-feet. A flood of over 700,000 second-feet may be expected to occur once in 3 years. The flood of 1894, the highest of record, had a discharge of 1,160,000 second-feet at The Dalles. It caused a large amount of damage. Subsequent moving of the railroads and construction of some levees to an elevation about the crest elevation of this flood has eliminated much of the source of damage from future floods of this height. A flood equivalent to that of 1894 may be expected to occur once in 400 years. A slightly greater flood may be expected to occur once in 1,000 years.

1436. The flood discharge of Columbia River occurs once a year during the 3 months period of May to July. The duration of the floods has varied from 10 to 60 days. The rise is gradual, seldom exceeding 1 foot a day, hence there is ample time to remove livestock and equipment to higher levels. Comparatively little property loss occurs. While little accurate information is available as to the actual losses it is estimated that over a period of years the average damage from all sources will not exceed $150,000 per year.

1437. *General measures for flood control.*—The measures generally applicable to control of floods are:

1. Installation of retarding basins, or storage reservoirs.
2. Diversion of flood flows.
3. Channel improvements.
4. Protection of the flooded areas by levees.

The application of these measures to Columbia River is considered from the viewport of whether the costs involved are justified by the savings affected in preventing flood damage.

1438. *Installation of retarding basins or storage reservoirs.*—Table 68 shows the amount of storage which would have been required to take care of the floods in excess of 600,000, 700,000, 800,000, and 900,000 second-feet, respectively. To take care of the excess flow above 600,000 second-feet for the highest flood of record, 28,278,000 acre-feet of storage would have been required.

1439. There are no natural storage sites on Columbia River below Pasco suitable for flood control purposes. It is possible that storage for flood control might be provided in the various lakes in the upper Columbia, Clarks Fork, and Kootenai Basins. However, the regulation of the flow from storage in the upper part of the stream would be difficult and the costs involved would not be justified by savings in probable flood damages. The use of retarding basins and storage reservoirs is not considered an economical way of dealing with Columbia River floods. However, some incidental benefit to flood control would accrue from the regulation of the flow resulting from the ultimate power and irrigation development both above and below the mouth of the Snake. It is estimated that this ultimate irrigation and power development will decrease the average daily flow during May by 143,000 second-feet; during June by 88,000 second-feet; and during July by 34,000 second-feet. Table 69 shows the effect that this decrease would have had upon the frequency and duration of flood flows for the period of record. By comparison with table 68, which shows the size and duration of past flood discharges, it will be noted that floods in excess of 600,000 second-feet would have occurred 15 times in place of 27 times, and that floods with discharges in excess of 700,000 second-feet would have occurred 5 times instead of 13. The number of occurrences of discharges in excess of 800,000 second-feet would have occurred 3 times instead of 4. Discharges, in excess of 900,000 second-feet, would have occurred once instead of twice, as formerly. In each of the above cases, the duration of the floods would also have been decreased.

1440. *Diversion of flood waters.*—Columbia River flows in a generally rocky channel normal to two mountain ranges. The area affected by floods lies in the section between the ranges. The physical conditions are such that there is no practicable procedure by which diversion of the flood waters could be accomplished.

1441. *Channel improvements.*—The improved channel of that portion of the river along which the greater part of the flooded areas is situated has a minimum depth of 30 feet and a minimum width of 500 feet. The project authorized July 3, 1930, provides for a channel 35 feet deep and 500 feet wide. The completion of the project will increase the area of the cross section by about 2,500 square feet. However, this project also includes construction of spur dikes to contract the flow. The effect of the dikes about offsets the effect of the additional channel area in so far as flood heights are concerned. The cost of obtaining a sufficient channel depth to provide for flood flows is so great that it is not considered as a practical method of flood control for Columbia River.

TABLE NO. 68.—*Columbia River at The Dalles, Oreg., flood discharges in excess of 600,000 second-feet and storage required to regulate flood discharges*

[Period of record, 1878–1930 (53 years)]

Date	Maximum discharge average per 24 hours	Storage required in acre-feet to take care of flow above discharges given, and number of days flow exceeded these discharges							
		900,000 second-feet		800,000 second-feet		700,000 second-feet		600,000 second-feet	
		Days	Acre-feet	Days	Acre-feet	Days	Acre feet	Days	Acre-feet
June 1879	643,000							25	1,146,000
July 1880	914,000	5	102,000	18	2,794,000	42	8,892,000	57	18,232,000
June 1882	883,000			15	1,820,000	21	5,426,000	35	10,794,000
June 1884	698,000							30	2,944,000
June 1886	673,000							15	1,242,000
June 1887	896,000			17	1,784,000	38	7,034,000	49	15,860,000
May 1890	633,000							14	608,000
June 1892	607,000							2	28,000
June 1893	679,000							17	1,114,000
June 1894	1,160,000	23	502,000	32	11,982,000	39	19,032,000	52	28,278,000
June 1896	785,000					28	2,818,000	46	10,058,000
May 1897	780,000					16	1,444,000	23	5,338,000
June 1898	649,000							14	926,000
June 1899	787,000					17	1,162,000	36	6,582,000
June 1901	662,000							10	798,000
June 1902	644,000							6	332,000
June 1903	787,000					15	1,816,000	29	6,260,000
May 1904	629,000							5	124,000
June 1908	653,000							9	554,000
June 1909	675,000							16	1,208,000
June 1913	759,000					15	1,304,000	30	5,826,000
July 1916	727,000					7	182,000	29	4,008,000
June 1917	727,000					4	140,000	33	3,718,000
June 1921	773,000					13	1,060,000	31	5,744,000
June 1922	677,000							15	1,106,000
June 1927	690,000							21	2,510,000
May 1928	766,000					7	646,000	16	3,154,000
27 floods		28 days over 900,000 second-feet ½ day a year		82 days over 800,000 second-feet 1½ days a year		262 days over 700,000 second-feet 5 days a year		665 days over 600,000 second-feet 12½ days a year	

TABLE NO. 69.—*Effect that future regulation would have had upon Columbia River flood discharges of record in excess of 600,000 second-feet at The Dalles, Oreg.*

[Period of record, 1878–1930. Also see table no. 68]

Date	Maximum discharge average for 24 hours corrected for future regulation	Additional storage required in acre-feet to take care of flow above discharges given, and number of days flow would have exceeded these discharges							
		900,000 second-feet		800,000 second-feet		700,000 second-feet		600,000 second-feet	
		Days	Acre-feet	Days	Acre-feet	Days	Acre-feet	Days	Acre-feet
June 1879	[1]								
July 1880	880,000			14	1,310,000	29	5,118,000	45	13,060,000
June 1882	795,000					16	2,190,000	24	5,968,000
June 1884	610,000							1	20,000
June 1886	[1]							0	
June 1887	808,000			1	16,000	21	2,276,000	43	9,200,000
May 1890	[1]							0	
June 1892	[1]							0	
June 1893	[1]							0	
June 1894	1,072,000	14	3,136,000	23	6,674,000	32	12,200,000	45	19,994,000
July 1896	744,000					11	520,000	32	5,290,000
May 1897	651,000							10	560,000
June 1898	[1]							0	
June 1899	690,000							26	2,824,000
June 1901	[1]							0	
June 1902	[1]							0	
June 1903	699,000							18	2,234,000
May 1904	[1]							0	
June 1908	[1]							0	
June 1909	[1]							0	
June 1913	671,000							17	1,692,000
July 1916	693,000							16	1,618,000
June 1917	639,000							7	298,000
June 1921	685,000							13	1,368,000
June 1922	[1]							0	
June 1927	602,000							1	16,000
May 1928	623,000							7	328,000
15 floods		14 days over 900,000 second-feet ¼ day a year		38 days over 800,000 second-feet ¾ day a year		109 days over 700,000 second-feet 2 days a year		305 days over 600,000 second-feet 6 days a year	

[1] Less than 600,000.

1442. *Levees and embankments.*—A large portion of the areas affected by floods has been protected by levees and embankments. In general, the increase in value of the lands has justified the construction costs of these levees. The use of levees and embankments appears to be the only practical method of protection against floods for the areas on Columbia River.

1443. In paragraphs 1088 to 1094 it is assumed that the damages for which estimates have been made must have occurred in those sections where the levee heights were little above ordinary flood elevations. No flood has occurred during the period for which the estimates were available, which would have overtopped the levees built to 2 feet above the 1894 flood crest. The cost of raising all existing levees which are not now up to 2 feet above the uncontracted 1894 flood crest, and of reconstructing on safe ground certain levee sections now threatened by bank erosion, is estimated at $1,665,000 (par. 1105). This would provide ample protection for a flood of 1,020,000 second-feet, if the effect of channel contraction, due to protective works and improvements for navigation, is taken into consideration. A flood of this magnitude might occur once in 50 years. The interest at 6 percent on the cost of construction would amount to $99,900. As the probable flood damage amounts to $150,000 a year, the expenditure of $1,665,000 for levee raising and reconstruction appears economically justified.

1444. The cost of raising all existing levees up to an elevation 4 feet above a contracted flood equivalent to that of 1894, and reconstructing those sections of levee now threatened by bank erosion, is estimated at $6,705,000 (par. 1105). The annual interest on this amount is $402,300. The damage that might be done by such a flood probably would be great, though the probability of its occurrence is small—about once in 400 years. In view of the estimated annual damage of $150,000 a year, which includes the probable damages from all floods reduced to an annual basis, the expenditure of this amount is believed to be economically unjustified.

1445. Plate 120 contains a list of the unprotected arable areas and indicates that about 23 square miles of these areas might be protected profitably in the future. There is little demand at present for the extension of the existing diking districts. Private interests will undoubtedly undertake the diking of the additional areas whenever there appears to be economic justification. The problems of flood control are local and are not of the nature to warrant the United States' undertaking levee construction. Neither private owners of land, organized districts, nor municipalities, having for their purpose flood-protective measures along lower Columbia River, have called upon the United States to assume part of the costs.

1446. There is a small amount of damage due to bank erosion by river currents, steamer wash, and wave action. Bank erosion is greatest during flood periods but appears to be no more than would be normally expected, in maintenance of levees. Much of the damage from bank erosion is due to the fact that in some localities the levees have been located too close to the bank line. There have been some requests for Government aid in preventing this type of damage. It has been suggested that spur dikes be constructed, levees be faced with riprap, and that gently sloping beaches be built to break the wave action. In general, the cost of the protective works proposed is more than the loss incurred by lack of such protection. Any levees constructed in the future should be located a sufficient distance from the bank line to insure their safety from erosion. In view of the strictly local nature of such damages and of the limited area involved, expenditure of Government funds, for prevention of bank erosion, appears to be unjustified.

IV. IRRIGATION

1. GENERAL

1447. Of the 1,335,000 acres of irrigable land in Columbia Basin below the mouth of the Snake, about 277,000 acres are now irrigated and about 72,000 acres additional unirrigated are included in existing constructed projects. Irrigation developments in the main have taken place in the arid and semiarid portions of the basin, characterized climatically by long, hot, dry summers, in which agricultural production, unaided by irrigation, is ordinarily impossible and always uncertain. With irrigation, lands formerly nonproductive, or producing only in favorable years, were brought to produce heavy yields every year. Such yields are often one third to one half greater than the yields obtained on favorably situated unirrigated lands of the humid portions of the basin. In spite of the certainty and quantity of crop yields, some irrigation developments have experienced financial difficulties, as pointed out in preceding paragraphs. These troubles, however, have been in large part due to adverse factors avoidable by the exercise of care in engineering studies, by careful financing, and by the devotion of increased attention to methods of settlement. Other troubles, such as overproduction and the consequent drop in prices, are apparently unavoidable.

2. PROBABLE RATE OF IRRIGATION DEVELOPMENT

1448. Estimates of future needs for agricultural lands in Oregon, Washington, and Idaho have been made in paragraphs 1318 to 1384. These estimates are based on assumptions as to increase in population, use of land, use of products, and yields. Due consideration is given present and probable future trends for these elements. It has been determined that if observed trends of population, consumption, yields, and acreages continue, about 890,000 acres of new agricultural land will be required in the three States by 1940, 620,000 acres additional by 1950, and 650,000 acres additional in the succeeding decade which marks the end of the period for which the population study was made. The additional acreage required by 1960 represents an average annual increase of about 70,000 acres. The above figures are based on yields which might be derived from irrigated lands, as it is believed that, due to the certainty and abundance of such yields, and also to the lack of desirable new lands in unirrigated sections, future agricultural development will include irrigation. Yields from other than irrigated lands would be smaller and consequently the figures for additional agricultural land would be larger if based upon such yields. Using the States of Washington and Oregon and the period 1900 to 1920 as a basis in estimating future settlement for irrigable land, and bearing in mind also the increase of the population of the United States and of the basic agricultural market, it is believed that upon the return of agricultural prosperty additional irrigable land for the States of Washington and Oregon could be settled at the rate of 50,000 acres per year. This may be divided over several localities or concentrated in any one section of the two States as economics may dictate.

1449. While it is estimated that there will be a market for the products of an additional 70,000 acres per year for the next 30 years the probable rate of settlement is only 50,000 acres per year, hence the rate of settlement apparently is the limiting factor in the development of additional irrigated lands in the areas considered.

1450. The history of irrigation settlement throughout the entire West shows that for the majority of the irrigation projects a part, generally between 10 and 20 percent, has remained unsettled. A study[34] of the rate of settlement on Government irrigation projects shows that, while 100 percent settlement is rarely attained, for the average project 70 percent of the irrigable acreage for which water could be supplied was settled at the end of the first 15 years after the beginning of construction work.

1451. Factors retarding settlement may be divided into two general classes, namely, incorrect estimation of physical characteristics and in-

[34] Economics of Land Reclamation, Ray P. Teele (1927).

sufficient attention to the economics of the development. The most important factors included in the first class are inclusion of undesirable lands in the irrigable area and incorrect estimation of the water-supply and irrigation requirement. In the second class are the failure to properly estimate the total costs of irrigation construction, including carrying charges during the settlement period, and the failure to determine the feasibility of the project with relation to demand for its products. It is believed that many of these unfavorable factors can be avoided in the future.

1452. Marginal lands in all projects considered in this report have been eliminated and an adequate water supply provided. Due consideration has been given to the probable demand for additional agricultural development.

1453. If the rate of settlement of 50,000 acres per year stated above would apply to any one area exclusively, then the largest area considered in this report, 103,000 acres, would be colonized in less than 3 years. It is not likely, however, that concentration of settlement could be secured for any one of the comparatively small projects considered to the exclusion of all others. Settlement for any project will probably extend over a longer period of years, and it is believed that it would not be safe to allow a period of less than 10 years for the settlement of any of the tracts considered.

3. DETERMINATION OF PUMPING LIFTS

1454. The areas considered in this report are so situated with relation to the elevation of Columbia River that gravity irrigation is not feasible. The only feasible method of irrigation is by pumping. The allowable cost of irrigating by pumping, and consequently the maximum economic lift, are based on the net return from agricultural effort available for payment of irrigation costs. Determination of the maximum lift fixes the upper boundary of an area. In an endeavor to include all lands that might ultimately be considered irrigable by pumping from Columbia River, upper limits of projects were determined by lifts based on maximum probable returns that might be reasonably expected for the areas considered.

1455. Studies for the pumping areas contemplate construction of a power dam with a backwater elevation of 330 feet above sea level in the section of the Columbia between Arlington and the mouth of Snake River. The reservoir formed would drown out a part of the lands within normal reach of pumping from the main river. These lands, however, are in the main, rough and sandy and their loss is more than compensated for by the inclusion of better lands at higher elevations which can be reached from elevation 330. Fixing of the backwater elevation below 330 feet, by the construction of a lower dam, would result in a shifting downward of the pumping area, and an increased unit cost of pumping due to the inclusion of lands with larger water requirement.

1456. Production costs and returns have been determined by a study of costs and returns from existing irrigated lands. Consideration was given various plans of land utilization. The plan believed most suitable to the areas considered, under probable conditions of market demands, assumes that the farm will be stocked with dairy and meat animals, and that the feed produced on the farm will be fed to livestock. Economical utilization of land is believed to be as follows:

	Percent of the farm
Acreage in hay	32
Acreage in fruit	2
Acreage in grain	28
Acreage in truck, root crops, and forage	17
Acreage in pasture	21

1457. Net returns from irrigated lands that may be considered applicable to pumping costs are determined by the deduction from gross returns of costs of production exclusive of irrigation costs.

1458. The costs of irrigation by pumping include charges for electrical energy consumed, interest, depreciation, and amortization on the cost of irrigation works, and operation and maintenance of the irrigation system. A summary of those irrigation costs is given below, expressed in terms of cost per acre-foot for each foot of lift.

Electrical energy at 1 mill per kilowatt-hour [35]	$0.00153
Interest at 4 percent (plant cost, $0.06375)	.00255
Depreciation at 1.783 percent (plant cost, $0.06375)	.0011365
Amortization at 1.783 percent (plant cost, $0.06375)	.0011365
Operation and maintenance	.0008
Total cost of irrigation by pumping per acre-foot per foot of lift	.007153

1459. Application of the above cost to net returns available for irrigation costs fixes the probable maximum economic lift for the type of farm adopted. Lifts are estimated for the three major soil types found in the areas considered, sandy loam, medium and fine sandy, and coarse sandy soils. Maximum lifts determined are 710 feet for the sandy loam soils, 470 feet for the medium and fine sandy, and 380 feet for the coarse sandy. Variations are due to the different water requirements of the three types of soil.

4. IRRIGABLE AREAS

1460. A study of the lands which might be irrigated from Columbia River below the mouth of the Snake discloses five principal areas—Cold Springs, Horse Heaven, Willow Creek, Arlington, and Roosevelt—totaling 378,060 acres of irrigable land. Irrigation plans for the five pumping areas are shown on plate 127. Plants are located at favorable points on Columbia River at elevation 330, water being lifted through a pressure pipe line to the elevation desired. Two of the five areas named are considered in three divisions each, making a total of nine pumping units. In some cases topographic features prevented the use of the maximum economic lift. In other cases boundaries were determined by subdivision of large areas into units at different elevations served by separate pipe lines, thereby reducing unit construction and equipment costs and amount of electrical energy consumed.

1461. Only the better lands of the various tracts are included in the proposed projects. Marginal lands that are undesirable on account of roughness, steepness, or unsatisfactory soil conditions are excluded. Such lands are those having slopes greater than 15 percent and those excessively sandy, hummocky, or rocky.

5. IRRIGATION REQUIREMENTS

1462. The annual gross irrigation requirement is estimated to be from 3.3 to 6.2 acre-feet per acre, variation being due mainly to soil

[35] Use of secondary power assumed; see par. 1170.

conditions. The total diversion requirement for the 378,060 acres considered is estimated to be about 1,464,000 acre-feet per year, with an allowance of 15 percent loss in conduits, all conduits of 50 second-feet or more capacity to be lined. This water is used during the months March to October, inclusive. The maximum use occurs in June. The total diversion for all areas during this month would be about 4,900 second-feet, about 1 percent of the average flow at The Dalles during June. The annual freshet of the Columbia occurs during the period May to July, hence the maximum irrigation demand coincides with the period when the greatest volume of water is available. The greatest diversion in proportion to flow occurs in September, when 2,250 second-feet are required, representing about 2 percent of the flow at The Dalles during that month.

6. CONSTRUCTION COSTS

1463. Estimates of construction costs for the various areas are based on engineering estimates and unit costs as stated in paragraphs 1274 to 1308. Total costs are made up of engineering costs, interest during construction and interest during the settlement period. The construction period is estimated to be 3 years for all projects. The settlement period is assumed to be 10 years for each project. However, additional figures are given for costs which would result if projects were settled at the rate of 50,000 acres a year. A preparation period of 2 years is allowed after construction during which no payments of principal or interest on construction costs are made. Interest for the above items is compounded at 4 percent.

1464. Annual charges are made up of (1) interest at 4 percent of total cost; (2) depreciation at 1.783 percent of total cost, based on 30 years life; and (3) operation and maintenance of irrigation works at $2 per acre plus the cost of elecrical energy used.

1465. Acreages, unit construction costs and annual charges are shown in tabulation below:

Irrigable areas, Columbia Basin below mouth of the Snake, areas, construction costs and annual charges

	Irrigable area	Estimated construction cost per acre	Total cost (per acre)		Annual irrigation charges (per acre)		Components of annual charges per acre, 10-year settlement period		
			10-year settlement period	Settlement rate 50,000 acres per year	10-year settlement period	Settlement rate 50,000 acres per year	Interest	Depreciation	Operation and maintenance [1]
	Acres								
1. Cold Springs area	50,000	$115.92	$159.50	$135.60	$15.35	$13.97	$6.38	$2.84	$6.13
2. Horse Heaven area, division A	28,500	100 25	138.00	117.25	11.50	10.30	5.52	2.46	3.52
3. Horse Heaven area, division B	47,500	100.62	138.40	117.70	12.41	11.21	5.54	2.47	4.40
4. Horse Heaven area, division C	66,000	111.14	152.90	122.53	14.63	13.45	6.12	2.72	5.79
5. Willow Creek area, division A	37,940	99.80	137.30	116.72	12.58	11.39	5.49	2.45	4.64
6. Willow Creek area, division B	103,770	93.00	127.95	113.03	12.46	11.60	5.12	2.28	5.06
7. Willow Creek area, division C	31,350	110.15	151.54	128.82	14.39	13.08	6.06	2.70	5.63
8. Arlington area	11,500	90.18	124.07	105.47	11.89	10.83	4.96	2.20	4.73
9. Roosevelt area	1,500	80.24	113.37	96.40	9.49	8.50	4.53	2.04	2.92
Total	378,060	[2] 102.60	[2] 141.00	[2] 120.00	[2] 13.30	[2] 12.15	[2] 5.65	[2] 2.52	[2] 5.13

[1] Cost of electrical energy plus $2.

[2] Weighted average.

1466. As stated above, the only method of irrigating these areas from Columbia River is by pumping. Alternate gravity water supplies from tributary streams have been suggested for Horse Heaven, Willow Creek and Arlington areas. It has been pointed out that there is not sufficient water available from Klickitat and Cispus Rivers to irrigate the entire Horse Heaven area as proposed under the gravity project. More than 140,000 acres, the area for which an adequate water supply from Klickitat River is available, lies outside the area considered in this report as a pumping project. It is assumed, therefore, that there is no conflict in this area between gravity irrigation from Klickitat and Cispus Rivers and pumping from Columbia River. Irrigation of Willow Creek and Arlington areas by gravity from John Day River is considered in detail in a separate report by this office. A comparison of the costs under the gravity plan with those under pumping, as outlined in this report (paragraphs 1292 to 1308) shows the latter to be the cheaper method for irrigation of this area. For purposes of comparison, the principal-cost features of the two plans, based on a 50,000-acre-per-year rate of settlement are summarized below.

	Gravity area, John Day project	Pumping areas			
		Willow Creek			Arlington
		A	B	C	
Estimated construction cost per acre	$185.00	$99.80	$93.00	$110.15	$90.18
Total cost per acre	237.50	116.72	113.03	128.82	105.47
Annual charges:					
Interest at 4 percent	9.50	4.67	4.52	5.15	4.22
Depreciation at 1.78 percent	4.24	2.08	2.02	2.30	1.88
Operation and maintenance	2.25	4.64	5.06	5.63	4.73
Total annual charges	15.99	11.39	11.60	13.08	10.83

7. ECONOMIC FEASIBILITY

1467. It is assumed that, in order to classify an irrigation project as feasible, returns from agricultural effort must be large enough to cover farming costs and maintenance, operation and depreciation of irrigation works and, in addition, a fair return on the investment of the farmer.

1468. The cost of irrigation features for projects considered, based on a 10-year settlement period, has been found to vary from $110 to $159 per acre, with a weighted average cost for the nine projects of $141 per acre. Additional investment required of the settler covers land value, buildings, working capital, and preparation of the land, including clearing, fencing, leveling and ditching. It is estimated that these items will total about $161 per acre. Thus, the total investment on which agricultural operation should show a return is $302 per acre. Considering 6 percent a fair return, $18.12 per acre per year would have to be realized from the net return for this item alone.

1469. Annual charges covering depreciation (30 years life), operation and maintenance of irrigation works are estimated to vary from $4.89 to $8.97 for the nine projects, the weighted average being $7.65 per acre.

1470. The total of the above two items (interest and annual charges), $25.77, is the amount by which the average annual gross returns per acre must exceed costs of production other than profits and water costs to render irrigation development economically feasible for the projects considered.

1471. Net returns from irrigated farms vary widely. This variation is due to a number of factors, some of the most important being prices received for products, cost of labor and supplies used in production, soil conditions, and farm management, including preparation of the land, use of irrigation water, and crop selection. Average net returns for all farms of the Northwest are undoubtedly less than the $25.77 set forth above. Under present market conditions it is doubtful if this return could be secured from many of even the best farms. However, net returns for a group of dairy farms in Idaho have exceeded this figure, as described in paragraphs 1176 to 1182 above. Similar returns have been shown in other districts. A recent study[36] of irrigation in California states that a reasonable net return from alfalfa production in California would be $25 per acre, which amount would be applicable to the payment of interest on the investment, irrigation water, and additional profits.

1472. It is believed that under favorable conditions returns from irrigable areas considered herein may justify the maximum expenditure indicated. Such conditions include fair prices, reasonable production costs, careful selection and preparation of the land, timely and wise use of irrigation water and proper selection and rotation of crops. Under present conditions it would probably be unwise to develop any of the areas considered. When demand and costs are such that satisfactory net returns can be secured, development will be economically feasible. Before development of any area is approved further detailed study must be made, especially with respect to soil conditions.

1473. If the average annual cost of electrical energy for the acreage considered, $3.13 per acre, is capitalized at 6 percent and added to the estimated construction cost, $102.60 per acre exclusive of interest, the total, $155, is comparable to similar costs for gravity projects. It is believed that this will compare favorably with the cost on many existing gravity projects and is as low or lower than the cost of many proposed projects.

V. COMBINED FEATURES

1474. The power developments, outlined in the power section of the report, have been estimated on a basis of the entire cost of the project being justified by the probable returns from power alone; that is, they are not contingent upon the navigation, irrigation, or flood-control features for their economic feasibility. However, the irrigation and navigation features, and to some extent the flood-control features, are contingent upon the development of power.

1475. The power dams, by creating a series of pools, make slack-water navigation possible. Inasmuch as these power dams are in themselves economically feasible from a power point of view, it is unnecessary to charge a part of their cost to navigation. Navigation between the mouth of the Snake and head of tidewater is not of sufficient importance to justify the large expenditure involved in the con-

[36] Bulletin No. 34, Division of Water Resources, State of California.

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