

386. Several mills for the production of vegetable oils from copra (dried coconut), flaxseed (par. 205), and soybeans have become of importance. Their materials are generally imported, although some domestic flaxseed is used. Copra ranks first as to bulk among the imports of Portland, Oreg. An important byproduct of the vegetable-oil industry is meal, used as a stock feed. A large part of the oil is taken by local paint and soap factories, while the balance is shipped to other paint and soap factories and to margarine manufacturers throughout the Nation.

387. There are several small leather and rubber manufacturers making saddles and harness, shoes, trunks and valises, belting, leather novelties, rubber buttons, half-soles and other products. Only a few inadequate tanneries exist, most of the leather being brought from the East. Steps are now being taken to establish a tannic-acid plant to utilize the hemlock waste from paper mills.

388. Other industries include gas manufacturing, printing and publishing, baking and candy making, coffee and spice roasting and grinding, and ice manufacturing. Manufacture of all agricultural and live stock products have been discussed under Agriculture, Stockraising and Related Industries, paragraphs 177 to 278.

B. NAVIGATION

(A) GENERAL

389. The entrance of the Columbia River was discovered by Captain Gray, who, in command of the American ship *Columbia* (83 feet long; 212 tons), on May 11, 1792, sailed into the river and bestowed the name of his vessel on the stream. Prior to that date it was spoken of as the "Oregon" or "River of the West", but there was no definite information regarding it and it was little known except to the Indian tribes.

390. In October 1792 Capt. George Vancouver of the British Royal Navy, learning of the Columbia from Captain Gray, sent one of his ships, the *Chatham*, in command of Lt. W. R. Broughton, into the Columbia River. Lieutenant Broughton explored the river from the entrance to a point near Washougal, Wash., or about 120 miles from the mouth. (See *Voyage of Discovery to the North Pacific and Round the World* by Capt. George Vancouver, London, printed 1798).

391. The overland expedition of Lewis and Clark reached the mouth of the river late in 1805, and spent the winter of 1805-6 on the coast a short distance south of the entrance to the stream. Trappers and traders, mostly of the Hudson's Bay Co., were the first white settlers; later, colonists came to make their permanent homes in the so-called "Oregon country", which originally embraced all of the territory of the present States of Oregon, Washington, and Idaho, and portions of Wyoming and Montana.

392. The first white persons to navigate the Columbia River or traverse any part of the upper Columbia River were members of a party of the Northwest Fur Co. under David Thompson, astronomer and surveyor of the company. They started from Canada in 1810 and wintered in the vicinity of the headwaters of the Columbia near

the fifty-second parallel. In the spring of 1811 they built boats in the vicinity of Kettle Falls, and they arrived at the present site of Astoria at the mouth of the Columbia on July 15, 1811. (See David Thompson, *Pathfinder, and the Columbia River*, by T. C. Elliott, member of Oregon Historical Society.)

393. Jurisdiction over the "Oregon country" was the subject of political difference with Great Britain, and between 1843 and 1846 there was much negotiation as to the boundary west of the Rocky Mountains, resulting finally in the treaty of 1846, which defined its northernmost limit as it exists today, viz., the forty-ninth parallel of north latitude. Prior to 1846 the region was, in part, jointly occupied by the United States and Great Britain. The discovery of the river entrance by Captain Gray, as noted above, was an important factor in fixing the northern boundary as defined by terms of the treaty of 1846.

394. While the early colonists in the lower basin arrived, mainly, by overland "Oregon Trail" route, the basin's early agricultural and commercial development was due very largely to the navigation facilities afforded by the Columbia and its tributaries. These transportation facilities, particularly as afforded by the river's tidal reach, remain today one of the most important factors in the economic welfare of large portions of Oregon, Washington, and Idaho, which, topographically, are directly tributary to the lower reaches of the stream.

395. The first steamship to enter the river was the Hudson's Bay Co.'s steamer *Beaver*, a small side-wheel vessel 101 feet long; 109 tons. It was built in England in 1835 and entered the Columbia on March 19, 1836. This vessel was also the first steamship to navigate the Pacific Ocean. The first American steam vessel to enter the river from the sea was the *Caroline*, in June 1850.

396. Vessels of about 20-foot draft could navigate the river entrance in its unimproved condition, though the vast expanse of the ocean bar at the river's mouth, together with the shifting nature of the channels crossing it, gained for the locality much ill fame in shipping circles throughout the world. Vessels of about 15-foot draft could ascend the river, prior to any improvement, to the vicinity of St. Helens, Oreg., but lightering of cargoes was often necessary to carry this draft to Vancouver, Wash., or to Portland, Oreg., on the Willamette River.

397. The Hudson's Bay Post was established at Vancouver in 1821, and Vancouver was the head of navigation for sea-going craft. The head of navigation for ocean-going vessels on the Columbia River is still Vancouver, Wash., at a distance of 104.5 miles from the ocean; and on the Columbia and Willamette Rivers it is Portland, Oreg., located on the Willamette River, about 6 miles from its confluence with the Columbia. The tidal effect extends to Warrendale, Oreg., about 35.5 miles above Vancouver. The river has not been improved above Vancouver for sea-going craft. Warrendale is at the foot of the gorge of Columbia River, known as "The Cascades." Above Warrendale the river is obstructed by falls and rapids, and navigation is limited to light-draft river craft.

398. The first river-type steamer to ply the stream, a side-wheel vessel 90 feet in length, was named the *Columbia*. She was built at Astoria, Oreg., and made her trial trip on July 3, 1850. The river steamer *Lot Whitcomb*, also a side-wheel vessel, 160 feet long, was

under construction at Milwaukie, on the Willamette River, at that time, and was put into service shortly afterward. These two pioneer river steamers plied between Astoria and Vancouver on the Columbia, and to Oregon City, on the Willamette. Freight between river points on these first vessels was \$25 per ton, and fare was \$25 per passenger.

399. The earliest portages around the Cascades Rapids were made by the use of wagons. In 1859 a tramway was built. In 1862 a steam railway was built along the Washington shore from the foot to the head of the Cascades. A steam portage railway was also built on the Oregon side.

400. The first steamer to navigate the river between the head of Cascade Rapids and The Dalles was the *James P. Flint*, a small, propeller-driven vessel built below the rapids and hauled up over them in 1851. It was used between the Cascades and the town of The Dalles, in connection with the portage road around the rapids in the gorge between Bonneville and the head of the Cascades Rapids. Other early river steamers on the river between the head of the Cascades Rapids and The Dalles were the *Mary*, a small, side-wheel vessel, built in 1853; the *Hassalo*, a stern-wheel boat, 153 feet long, built in 1857; and the *Idaho*, a side-wheel boat, 147 feet long, built in 1860. All of these four vessels plied between the head of Cascades Rapids and The Dalles, connecting with the upper end of the portage roads around Cascades Rapids. The portage railroad operated until shortly after the completion of the railroad from Portland to Wallula, in 1882, when the boat service above the Cascades was discontinued.

401. The construction of the Cascades Canal began in 1878, but the canal was not opened to navigation until November 6, 1896. During the construction of the Cascades Canal the portage railroad on the left bank of the river was in use until completion of the railroad on the left bank in 1882. In 1891 the State of Oregon constructed a portage railroad on the Oregon shore from the head to the foot of the main rapids, with its lower terminus just below the present entrance of the Cascades Canal. This portage railroad discontinued operations when the canal was opened to navigation in 1896. The State portage railroad was used in connection with two boats owned and operated by local interests at The Dalles, Oreg. They had one boat above the portage running as far as The Dalles and one boat operating below the portage. (See Lewis and Dryden, Marine History of Northwest.)

402. Owing to the obstructions to navigation between the foot of Three Mile Rapids (about $1\frac{1}{2}$ miles above the town of The Dalles) and Celilo, the head of navigation was at The Dalles, and freight and passengers were transferred by means of wagons over a wagon road constructed between The Dalles and Celilo. This wagon road did not follow the river bank but went inland a few miles and returned to the river about 1 mile above Celilo Falls. It was used until about 1862, when a portage railroad was built between The Dalles and Celilo. The railroad followed the left bank of the river to the town of Celilo, located about 1 mile above Celilo Falls, where freight was transferred to boats. In 1882 this portage railroad became a part of the main line of the railroad between Portland, Oreg., and Wallula, Wash. (the present Union Pacific Railroad), and regular boat service above Celilo Falls was discontinued shortly thereafter, though some boats remained on the Snake River, operating above the railroad crossing at Riparia.

403. The first steamer on the river above Celilo Falls was the *Colonel Wright*, which was built at Celilo in 1858, and made her first trip in 1859. Due to gold discoveries on the Salmon River in Idaho, in 1862, the next few years witnessed the greatest era of steamboat activity on the river above Celilo, and 10 or 12 boats were in operation. In 1864, the steamers carried 36,000 passengers to and from the Idaho mining regions on the Clearwater and Salmon Rivers. The boats ran regularly as far as Lewiston; occasional trips were made on the Clearwater and on the Snake above Lewiston. Navigation declined rapidly from 1866 to 1870, and during the high-water periods most of the boats were taken to lower river points. Soon after completion of the railroad between Wallula and Portland, in 1882, navigation above Celilo Falls practically ceased.

404. An effort was made during the years 1891-94 to revive navigation on the Columbia above Celilo. A railway was built on the Washington shore from the foot of Five Mile Rapids to the head of Celilo Falls. The steamer *Fred K. Billings* was built (or rebuilt) at Pasco, but the vessel was wrecked on her first trip down the river. The operating company went into the hands of a receiver and the plan was not revived.

405. In 1905 the Oregon State Portage Railway was completed between Big Eddy and Celilo, and in 1910 was extended downstream to The Dalles. Two steamers were built above Celilo to operate in connection with the portage railway, and one was built at Portland to operate below the portage railway. These steamers ceased running in the fall of 1912, owing to lack of patronage. From the last-named date to 1915 there was no commerce on the river between Celilo and mouth of Snake River, although two small steamers were used on the Columbia between the mouth of the Snake and Priest Rapids. Steamers on the Snake River continued to operate between Riparia and Lewiston, transferring wheat from the south side of the river, where there was no railroad, to the railroad on the north side.

406. The Dalles-Celilo Canal was opened to traffic on May 5, 1915, and another attempt was made to revive navigation on the river above Celilo. It was unsuccessful from a financial standpoint and boat operations were discontinued in 1917. Since then there has been no regular service on the river above The Dalles, Oreg.

407. The opening of the canal at the Cascades in 1896 was followed by a fairly large increase in navigation of the section of the river between Portland and The Dalles. Navigation of this section declined after the completion in 1908 of the Spokane, Portland & Seattle Railway along the north bank from Kennewick to Vancouver, Wash., but revived somewhat upon the completion of The Dalles-Celilo Canal in May 1915. Navigation of the section of the river between the Cascades Canal and The Dalles continued until June 1923, when regular boat service was discontinued on account of lack of business. Several attempts have since been made to revive commerce and navigation of the river above Portland as far as The Dalles, but have been unsuccessful, due it is said to lack of patronage. Nearly all of the tonnage now handled through the Cascades Canal consists of rafted logs.

408. The failure of the boat lines which have attempted to operate on the river above Vancouver during recent years is said to have been due partly to the completion of highways on both sides of the river

and partly to the lack of fixed rates for rail and water transportation. The highways permit truck lines to operate from points away from the river and to make direct delivery to the consignee. This affects railroad traffic as well as that which might otherwise be handled by boat lines. The absence of fixed rates by State and interstate commissions in the past made it possible for the railroads to reduce rates at will for a sufficient length of time to force boats from the river, whenever a steamer company attempted to establish service.

409. Against the rapid decline of navigation on the upper reaches of the river is contrasted the marked increase in traffic on the lower 100 miles between the mouth of the Willamette and the sea. This lower section has been improved to meet the needs of the rapidly expanding deep-water commerce of Portland, Oreg., located on the Willamette about 12 miles above its confluence with the Columbia. Local river traffic below the mouth of the Willamette, with the exception of rafted logs, has shown a marked decline since the completion of the railroad along the left bank of the river to Astoria, Oreg., in 1896, and the later completion of improved highways on both sides of the river below Vancouver.

(B) PREVIOUS INVESTIGATIONS AND REPORTS

410. The Columbia River, from its mouth to the international boundary has been the subject of many examinations and reports. The following is a list of the more important examinations and reports, including those upon which the existing projects are based.

411. *Mouth of Columbia River*.—Report of January 24, 1903. Report by Board of Engineers, United States Army, Annual Report of 1903, page 2275. This report recommended the existing project which provides for a channel 40 feet deep in the entrance, and for the north and south jetties.

412. *Columbia and lower Willamette Rivers below Vancouver*.—House Document No. 195, Seventieth Congress, first session. Channel 35 feet deep and 500 feet wide, Portland to the sea. Rivers and Harbors Committee No. 6, Seventieth Congress, first session; modifications of cooperative requirements mouth of Willamette to Vancouver.

413. *Vancouver to The Dalles*.—There is no existing project for this section of river, except for the stretch between Bonneville and the head of Cascades Rapids. A survey report for this stretch of river was made under date of November 29, 1922. The report was unfavorable and was not published. This report includes provision for a lateral navigation canal and consideration of development of power. There are a number of printed reports on the canal at the Cascades. The principal report is contained in Senate Executive Document No. 72, Fifty-first Congress, second session; also in Annual Report of 1891, page 3343.

414. *The Dalles to head of Celilo Falls*.—There are a number of reports on this section of river. The existing project, The Dalles-Celilo Canal is based on a survey report published in Annual Report, Chief of Engineers of 1904, page 3473. This section of river is also considered for power in a survey report under date of November 29, 1922, Columbia River, Celilo Falls to Snake River. This report was unfavorable and has not been published.

415. *Celilo Falls to mouth of Snake River.*—This section of river was until 1907 reported on under the caption of "Upper Columbia and Snake Rivers." The existing project which was completed in 1918 is contained in House Document No. 440, Fifty-ninth Congress, second session. The survey of November 29, 1922, resulted in an unfavorable and unpublished report for improvement by locks and dams, and for consideration of any proposition by local interests for the development of power.

(C) EXISTING PROJECTS—WORK DONE AND PRESENT CONDITIONS OF RIVER

416. The Columbia River below the mouth of Snake River is divided by physical characteristics and by existing projects for improvement into seven sections, as shown in the following tabulation:

	Dis- tance	Fall	Currents	Remarks
	Miles	Feet		
1. Mouth of Columbia.....			Tidal.....	Improved for sea-going vessels; 2 jetties at mouth; 46 feet controlling depth.
2. Mouth to Vancouver.....	104.5	5.6	do.....	Improved, 25 feet; Vancouver to mouth of Willamette River; 30 feet below mouth of Willamette.
3. Vancouver to Warrendale....	35.5	7.0	Moderate current...	Tidal, unimproved; 8-foot channel.
4. Warrendale to head of Cascades.	7.0	37.0	Rapids.....	Cascades Canal and Locks; open river improvement to Bonneville, 4½ miles.
5. Head of Cascades to The Dalles.	41.0	4.0	Moderate current...	Natural 8-foot channel; no project for improvement.
6. The Dalles to head of Celilo Falls.	12.0	82.0	Rapids.....	Dalles-Celilo Canal and Locks.
7. Head of Celilo Falls to Snake River.	124.0	185.0	Swift, with rapids...	Open-river improvement.

See also plate 35.

The section of river from mouth of Snake River to International Boundary is reported upon by the Seattle (Wash.) district.

The stretch of river from Pacific Ocean to mouth of Snake River is covered in this section of the report.

417. A full description of previous projects and those now in force for the improvement of the river and the amounts expended are given in the annual reports of the Chief of Engineers. The following extracts were taken from the above-mentioned reports:

Columbia River at mouth.—Prior to improvement there were from one to three channels across the bar and these varied from time to time both in location and depth. Depths were from 19 to 21 feet at mean lower low water. The channels over the bar shifted between Cape Disappointment on the north and Point Adams on the south, a distance of about 6 miles. The existing project provides for a channel across the bar 40 feet deep at mean lower low water and of suitable width (not less than ½ mile), to be secured by dredging and by converging rubble mound jetties, the south jetty being about 7 miles long and the north jetty 2½ miles long. The opening between the outer ends of the jetties is about 2 miles wide. This improvement, which was completed in 1918, resulted in a depth of 46 to 48 feet at mean lower low water for a width of 3,500 feet, and a depth

of 40 feet over a width of about 8,000 feet. The improvement has made it possible for the largest vessels operating on the Pacific coast to enter and leave at any stage of tide and in any weather, except during the most severe storms. A draft of 35 feet is practicable at mean lower low water under ordinary conditions.

418. *Mouth to Vancouver.*—The channel between the mouth and Vancouver was obstructed by numerous sand bars, in which were comparatively narrow channels with depths varying from 10 to 15 feet at low water. The existing project provides for a channel 35 feet deep and 500 feet wide in Columbia River from its mouth to mouth of Willamette River (99.5 miles) and 25 feet deep and 300 feet wide from the Willamette River to Vancouver, Wash., 5 miles. This project was adopted in 1930 and is a modification of a 30-foot project which was completed, as far as depth was concerned, several years ago, but dike work was not completed until 1930. The deepening of the channel to 35 feet is in progress and will be completed in 1932. The effect of the improvement has been to permit greatly increased draft and has enabled sea-going vessels to operate on regular schedules. Vessels now arrive and depart from Portland at all hours. In June 1930 a draft of 29 feet could be carried throughout the year at low tide, and by taking advantage of the tide 30 to 31 feet could be carried.

419. *Vancouver to Warrendale.*—There is no existing project for the improvement of this stretch of river as the natural depth is sufficient for river craft up to a draft of 8 feet at low tide throughout the year. This section of river is tidal, although the tidal effect is not noticeable except at extreme low water. At Warrendale, Oreg., where a gage has been read for a number of years, there is a tide of about 4 inches at low stages of river. There is, however, no reversal of current above a point a few miles upstream from St. Helens. The natural channel depth, except for some sand bars, is sufficient for light-draft ocean-going craft as far as Warrendale.

420. *Warrendale to head of Cascades.*—This section of river includes about 7 miles of the river where it passes through the Cascade Range. There is a fall at low water of 25 feet in the upper one half mile and a total of about 37 to the head of tidal influence at Warrendale. The fall of 25 feet in the upper 2,500 feet of the gorge effectually barred upstream navigation at any stage of river and the lower 4 miles was unsafe, due to obstructing rock ledges and boulders. The controlling depth was 5 feet in the main channel of the rapids. The foot of the lower rapids above Warrendale was the head of navigation, and freight was transferred around the obstruction, at first by teams and later by a steam railroad, until the opening of the Cascades Canal, in 1896.

421. The existing project provides for a canal with one lock around the upper Cascades Rapids and open river improvement below the canal. The canal has a length of 3,000 feet and a clear width of 90 feet. The lock is located at the lower end of the canal and has two chambers in flight. There are no dams in the canal. The lock chambers have a clear width of 90 feet and a usable length of 462 feet. The project depth over upper miter sill is 8 feet, but during the record low water of 1930 there was only 5½ feet on the sill. The canal can operate to a stage of 43 feet at the lower entrance and 32 feet at the upper entrance. The canal is then closed to navigation until the river recedes to the navigable stage. The canal is also closed by ice during some of the winter months. Ice conditions sufficient to close

the canal do not occur every winter. This improvement, which when completed permitted boats to ascend the rapids below the canal and through the canal as far as The Dalles, resulted in greatly reduced freight rates.

422. *Cascades to The Dalles.*—From the head of the Cascades to the foot of Three Mile Rapids, about $1\frac{1}{2}$ miles above The Dalles, there is no project for improvement and no improvement will be needed for river craft.

423. *The Dalles to Celilo.*—From the foot of Three Mile Rapids to the head of Celilo Falls, a distance of about 10 miles, there is, first, Three Mile Rapids, which has a length of one half mile; then, a narrow rocky gorge about 1 mile in length to the foot of Five Mile Rapids. From the foot of Five Mile Rapids to head of Celilo Falls the river is unnavigable and The Dalles-Celilo Canal was constructed between these two points.

424. The Dalles-Celilo Canal is about 8.6 miles in length and has a total fall of 81 feet at low water. There are five locks in the canal: Tandem Locks (two locks in flight) at the lower entrance, with a combined lift of 70 feet at low water; Five Mile Lock, $1\frac{1}{2}$ miles above the lower entrance, with a lift of 12 to 16 feet, depending on the stage of river; Ten Mile Lock, 5.2 miles above the lower entrance (this lock is used to regulate the level of the water in the canal during freshets and is not used at low water); and Celilo Lock, about one half mile below the upper entrance of the canal. (This lock is used at all stages of river above 4 feet at upper entrance to the canal). Ten Mile Lock has a clear width of 50 feet and all of the other locks have a clear width of 45 feet. The usable length of all of the locks is 265 feet. The depth on lock sills is 7 feet at average low water, but during an unusually low-water season, such as that of 1930, the depth on the entrance sills is somewhat less than 7 feet for a short period. The canal trunk has a bottom width of 65 feet with side slopes of 4 vertical to 1 horizontal in rock excavation and 1 vertical to 2 horizontal in concrete-lined sections. The depth in the canal trunk is 8 feet at low water. The normal river freshets at the lower end of the canal reach a stage of about 45 feet. The highest flood (1894) reached a stage of about 70 feet above low water. At the upper entrance of the canal the stage during normal freshets is about 18 feet and the maximum stage about 33 feet. The canal is designed to operate to a stage of 18 feet in the upper pool, and is drowned out when the river rises above that stage. The improvement in this stretch of river has made continuous navigation possible to points on the Columbia as far as Priest Rapids, 397 miles above the mouth of the river, except during the high-water periods and when closed by ice.

425. *Celilo Falls to mouth of Snake River.*—This section of river was navigable for light-draft boats at all stages of the river in its unimproved state. The controlling depth was about 3 feet and channels were crooked and obstructed by boulders and projecting ledges. The improvement work under previous and existing projects has consisted of open-channel work and of removal of rock pinnacles and other obstructions in the existing channels without general increase of depth. The principal obstruction to navigation is now the swift currents in the rapids. The controlling depth is generally greater than 6 feet, except through Hornly Rapids, 5 miles below the mouth of Snake River. Here the river is divided into several channels and the navigation channel has a controlling depth of $4\frac{1}{2}$ feet.

426. The channels are generally wide but in a number of places are crooked through the rocky reefs. There are only a few gravel shoals in this stretch of river. The rapids generally occur where rocky reefs cross the river bed. Straightening and deepening of the channels through the reefs, while possible, is costly, and no method of open river improvement can reduce the current in the rapids sufficiently to make easy navigation at all stages of river. The improvement of this stretch of river has, however, made navigation much less hazardous than formerly, and has permitted deeper draft to be carried at low water, but much more open-river work will be necessary to clear and straighten the channels for other than self-propelled boats of high power.

427. With the completion of The Dalles-Celilo Canal in 1915 the head of continuous navigation was moved upstream about 200 miles to the foot of Priest Rapids, a distance of 397 miles from the ocean. Priest Rapids has a fall of about 62 feet in 9 miles and is unnavigable except at moderate high stages and then not without danger.

428. The Columbia River from the mouth of the Snake to the foot of Priest Rapids has a fairly slight slope and there are no serious obstructions to navigation. This stretch of river, which has no project for improvement, is included in the report of the Seattle, Wash., district.

(D) LOW WATER, FRESHETS, ICE CONDITIONS, ETC., AFFECTING
NAVIGATION

429. *Low water.*—The plane of low water for the river from Vancouver to the upper end of the estuary at the mouth is low water at low tide, and in the estuary, the mean of the lower low tides. The existing project provides for a 35-foot depth at low water so that low-water conditions do not affect navigation below Vancouver. The adopted plane of reference for low water in the river between Vancouver and Warrendale is zero on the gage at Vancouver, but the river in December 1929 fell 1.4 feet below the zero of the gage. The depth over the shoals is, however, sufficient, even at the lowest stage of river, for river steamers. The adopted low water plane between Bonneville and The Dalles is a reading of 96.0 on the upper gage at the Cascades Canal, and this plane was used to determine the elevation of the lock sills. The river has, however, fallen as low as elevation 93.2 on the gage which limits the draft of boats to somewhat less than 5.0 feet during extreme low-water stages. The lowest stages of river usually occur during the winter months when the river is ordinarily affected by ice jams. In the winter of 1930-31, with no ice or freezing weather, there was, for a few days only, a depth of 5.2 feet over the upper sill of the upper lock, and for 15 days the depth was only 6.0 feet on the upper lock sill. From November 1, 1930, to March 2, 1931, except for a few days, the depth on the upper sill was less than 7 feet.

430. Between the head of the Cascades Canal and the foot of The Dalles-Celilo Canal, the natural channel is wide and deep, and navigation would not be affected during the low-water season.

431. The adopted plane of low water for The Dalles-Celilo Canal is a reading of elevation 89.0 on the Celilo gage. This gives 7 feet on the lock sills. The stage at Celilo rarely falls below elevation 89.0. For

the lower entrance of the canal the adopted low-water plane is a reading of 8.0 on the lower gage which gives 8 feet on the lower sill, but the river fell below this stage in the winter of 1930-31, and for a few days there was only 5.8 feet on the lower sill. The low water of 1930-31 was, however, the lowest of record in the length of duration and may not occur again for a number of years.

432. From Celilo to the mouth of Snake River, the adopted low-water plane is 0.8 on Umatilla gage, but for a short period during the winter of 1930-31 the river fell to zero on the gage. Soundings taken in January and February 1931 with the Umatilla gage reading about zero indicate that there are three places in this stretch of river where the controlling depth is somewhat less than 7 feet. At Homly Rapids, 6 miles below the mouth of the Snake River, the depth is only $4\frac{1}{2}$ feet at low water.

433. *Freshets*.—Below Warrendale the annual freshets do not seriously interfere with navigation. The mean velocity in the Columbia River below Vancouver is about 3.5 miles per hour, with a flood of 625,000 second-feet. The maximum surface velocities during ordinary flood stages is about 5 miles per hour. The velocities above Vancouver to Warrendale are somewhat higher than those below Vancouver, but do not seriously affect navigation. Between Warrendale and the foot of the Cascades Canal, the maximum surface velocity in the channel in the gorge below the canal is about 8 miles per hour at low water. The current in the gorge decreases as the river rises to about a 10- or 12-foot stage and becomes less than the low water velocity, but as the river rises above a 10- to 12-foot stage the current increases until at flood stage a velocity as high as 15 miles per hour is reached. This limits navigation during high freshets to high-powered boats.

434. The Cascades Canal was designed to operate up to a 38-foot stage of river at the lower entrance, but can be operated to a 42-foot stage. Freshets above a 42-foot stage close the canal to navigation until the river recedes to that stage. This delay to navigation does not occur every year but when it does occur may continue from a few days to a month.

435. Between the head of the Cascades Canal and the foot of Three Mile Rapids, a distance of about 43 miles, there is a rather quiet pool with a very flat slope and there is no high velocity at any stage.

436. At Three Mile Rapids, about 1 mile below the lower entrance to The Dalles-Celilo Canal, during low water, the river flows through a narrow rocky gorge. This part of the channel has been widened to give a width of 250 feet at low water. The depth is 10 feet where the channel has been deepened along the shores and from 100 to 180 feet deep in the center of the gorge. The current is light at low water but increases with the river stage. During high water, the river rises above the rocky shelf on each side of the channel, and whirls, eddies, and waves render navigation in Three Mile Rapids very difficult.

437. The Dalles-Celilo Canal was designed to operate to the same high-water stage as the Cascades Canal and extreme high water would delay navigation at both canals to the same extent. Steamboats have navigated Three Mile Rapids to almost the limiting stage for The Dalles-Celilo Canal without mishap, but navigation through Three Mile Rapids at flood stage is hazardous, even for self-propelled boats of fairly high power.

438. From the head of Celilo Falls to the mouth of Snake River the current is strong at low stages, and is generally less at moderate and high stages of river. At low water the maximum velocity is about 10 miles per hour in this stretch of river. Boats which can ascend the river (through the Cascades and The Dalles-Celilo Canal) would have no difficulty above the Celilo Canal as the velocities are no greater for corresponding stages of the river above Celilo than they are in the rapids below the Cascades Canal.

439. *Ice.*—During some winter seasons the river is free of ice but there is generally some ice in the river every winter. Occasionally the river has been filled with ice down to its mouth, and navigation by ocean-going ships below Vancouver has been interfered with. Above Vancouver, ice conditions are sometimes very severe and close the river to navigation for a month or two. A delay of 1 month annually can be expected for the river above Vancouver. The Cascades Canal and The Dalles-Celilo Canal are sometimes closed by ice when the river itself is not entirely closed to navigation.

440. *Winds.*—The prevailing wind in the summertime from March to October is upstream and assists upstream navigation when it is not strong enough to cause high waves. It delays downstream navigation when it is sufficient to cause rough water and boats have often tied up on that account. It also affects boats going through the Celilo Canal, but as the upstream wind usually subsides in the evening, boats can go through The Dalles-Celilo Canal in the evening and early morning. With an upstream wind it was not uncommon for the boats going upstream to use a sail to assist them in stemming the rapids below the Cascades Canal. Downstream winds affect upstream navigation, if they are very strong. There have been times when boats could not pass through the gorge of the Cascades going upstream when the downstream wind was blowing. Barges were sailed upstream in the early days and sails were lowered into the water to assist them going downstream.

441. *Fog.*—At times there is much fog in the river below Warrendale but it does not greatly interfere with navigation. Above Warrendale there are occasional fogs but they do not affect navigation seriously.

442. Summing up the difficulties of navigation it may be stated that a loss of 1 month by freshets and 1 month by ice may be expected annually, leaving a navigation season of 10 months. Delays, if any, by upstream winds occur from March to September, and by downstream winds from November to March; such delays are, however, not serious.

(E) TERMINAL FACILITIES

443. *Mouth to Vancouver.*—The river from its mouth to the upper limits of the city of Portland and Vancouver is well equipped with water terminals and facilities for handling every kind of freight for sea-going and inland vessels. There are extensive public terminals at Astoria, Longview, St. Helens, Portland, and Vancouver, and several public terminals at smaller towns along the lower river. A full description of the water terminals from Vancouver to the seas is given in Port Series No. 11, a revised copy of which is now ready for the printer. (See also annual reports published by the port of Portland, port of Vancouver, port of Longview, and port of Astoria.)

444. *Vancouver to mouth of Snake River.*—There are no large water terminals on the river above Vancouver, Wash., and there are no industries above Vancouver requiring large water terminals. Camas, Wash., a town of 2,500 population, located 14 miles above Vancouver on a channel of the Columbia, known as Camas or Washougal Slough, is the site of a large paper mill, the chief industry of the town. The only water terminal is a wharf with about 500 feet frontage on the slough. This wharf is owned and used by the paper company and is physically connected with the railroad (Spokane, Portland & Seattle) along the north bank of the river. There are no public terminals or other wharves at Camas.

445. Above Camas there are at present no water terminals remaining on the river. A few wharves were built, probably 30 years ago, on the river between Camas and The Dalles, and these, when they became unserviceable, were not replaced. At Hood River and The Dalles wharf boats were used to handle the freight. They were taken down river when traffic was suspended about 10 years ago.

446. Between The Dalles and the mouth of Snake River, there was one small water terminal with incline track and a warehouse on wheels, located at Umatilla, Oreg. The track remains but the warehouse has been removed. Pasco, on the left bank, 4 miles above the mouth of Snake River, has a small wharf, which has been unserviceable since 1920. Kennewick, opposite Pasco, has an inclined wharf constructed and used about the same time as the wharf at Pasco. It also is unserviceable.

447. No special type of water terminal can be recommended prior to the installation of a water transportation system. It is believed that wharves should be used as far as The Dalles, Oreg. Such wharves should be provided with storage warehouses, and if the traffic develops, should be provided with mechanical facilities for loading and unloading cargoes, especially where wheat will be shipped in large quantities, either in bulk or sacked. If water-borne commerce should be revived, it is probable that for some time to come The Dalles would be the terminal for the greater part of the tonnage between Vancouver and The Dalles.

448. There are large wheat-raising areas on both sides of the river between Celilo and the mouth of Snake River. In the event of any extensive commerce on this section of the river, it would be necessary to develop a few central water terminals. The possible locations for such terminals would be at Biggs, Arlington, Boardman, Umatilla, and Wallula, on the south bank, and at Maryhill, Roosevelt, and Paterson, on the north bank. Small freight shelters would serve at other points until business increased sufficiently to warrant greater development. Pasco and Kennewick, 4 miles above the mouth of the Snake, would be the natural locations for water terminals to serve the large farming sections in areas adjacent to them.

(F) COMMERCE

449. From the date of discovery of the river, May 11, 1792, until the present day, the head of commerce and navigation for sea-going vessels entering the Columbia River has been Portland, Oreg., located on the Willamette River a few miles above its confluence with

the Columbia, and Vancouver, Wash., located on the north bank of the Columbia 104.5 miles from its mouth. The local commerce of the river was carried in small boats, principally flatboats or bateaux. Sea-going sailing vessels occasionally entered the river and ascended to Vancouver on the Columbia and to Oregon City on the Willamette.

450. Shortly after 1836 the population of the Oregon country began to increase and with it the commerce of the river below Portland. In 1847 the population was from 4,000 to 5,000 and was located mostly in the Willamette Valley. The Columbia River and the Willamette River were the only highways for commerce. On the Columbia there was some river traffic below The Dalles, even in the early days. At The Dalles transfer was made from wagon to boats, then down the Columbia, to the Cowlitz River, and up the Cowlitz about 34 miles to what is now known as Toledo, where a portage was made by pack trains or wagons through the Chehalis Valley to Olympia on Puget Sound. The principal commerce at that time consisted of supplies, household goods, and furs. The water-borne commerce of the river increased with the increase of population. The gold rush of 1849 had a beneficial effect on the commerce of the Columbia as California was the principal market for Oregon farm products.

451. Until 1850 there were no river steamboats on the Columbia or the Willamette Rivers. In 1850 two river steamboats were built, one at Astoria on the Columbia, and one at Milwaukie on the Willamette. These boats operated between Astoria and Vancouver on the Columbia and to Portland and Oregon City on the Willamette River. These were followed in rapid succession by others. As the population grew the demands on water transportation were increased, for there were no improved roads; in fact, until 1916, there was no continuous road down the river from Portland to Astoria and up the river to The Dalles.

452. Prior to 1896 there was no railroad along the Columbia River below Goble, Oreg., 26 miles below the mouth of the Willamette, where the Northern Pacific Railroad crossed the river by ferry to Kalama, and went north up the Cowlitz River Valley to Puget Sound. After the completion of the railroad to Astoria, local river traffic gradually fell off. At the present time the principal traffic is log rafts, but some signs of a revival of river transportation are appearing.

453. Ocean-borne commerce increased rapidly after 1850 and today the Columbia River is one of the principal shipping ports of the United States. The ocean commerce increased from a comparatively few tons annually in 1850 to 7,096,332 tons in 1929.

454. The following is a comparative statement of commerce over the Columbia River bar for the years 1925-29, inclusive.

Year	Freight		Passen- gers
	Tons	Value	
1925	5,235,882	\$268,146,344	20,195
1926	6,297,683	315,139,879	16,253
1927	6,711,020	318,624,554	18,904
1928	6,966,340	338,306,192	13,903
1929	7,096,332	349,457,300	15,324

455. The following is a comparative statement of the inland river traffic on the Columbia River below Vancouver, Wash., for the years 1925-29, inclusive.

Year	Freight ¹		Rafted logs and piling		Passen- gers
	Tons	Value	Tons	Value	
1925	2,421,359	\$42,056,366	2,290,055	\$21,623,870	90,288
1926	2,345,923	41,776,935	2,324,075	18,563,030	87,351
1927	2,331,859	40,914,764	5,436,540	22,058,049	71,009
1928	2,013,775	45,236,888	5,737,846	33,137,327	68,655
1929	2,221,885	37,548,052	6,529,543	26,244,712	61,357

¹ Exclusive of rafted logs and piling.

456. Complete commercial statistics for Columbia River below Vancouver covering a long period of years may be found in the annual reports of the Chief of Engineers.

457. Prior to 1851 the commerce of the river below Vancouver was carried in small boats and was mainly downstream. It consisted mostly of household goods and supplies of the immigrants.

458. *Vancouver to The Dalles.*—One large steamer was constructed above the Cascades in 1853 and a second in 1857 to run in connection with a portage road around the Cascades. The commerce of the river above the Cascades was at its height from 1860 to 1866. From 1866 to 1870 navigation of the Columbia declined rapidly with the decline of excitement in mining. No statistics were collected for the years 1884-91, inclusive; however, the commerce of the river during the period was evidently very small, due to the completion in 1882 of the Oregon Railroad & Navigation Co.'s railroad from Wallula to Portland, Oreg., which practically suspended the river commerce above Portland. The river traffic as far as The Dalles was revived in September 1892 by the Oregon State Portage Railroad, which was constructed by the State of Oregon to portage freight around the Cascades Rapids until the completion of the Cascades Canal.

459. In the early days freight and passengers were transferred around the Cascades on a wooden tramway (constructed in 1851) and around The Dalles to the head of Celilo Falls by teams. Later (1860-62) steam railroads were constructed from the foot of the gorge to the head of the Cascades Rapids, and from the town of The Dalles to the head of Celilo Falls. These portage railroads were discontinued upon the completion of the railroad along the left bank to Portland in 1882. A portage railroad constructed by the State of Oregon around the Cascades Rapids in 1891 was used until the completion of the Cascades Canal in 1896.

460. The following tabulation shows the commerce on that portion of the Columbia River affected by the Cascades Canal. The tabulation shows all of the commerce of which there is a record.

*Commerce of the Columbia River above Portland, Oreg., passing through the
Cascades Canal*

	Tonnage up and down	Passengers up and down	Remarks
1864	21, 834		
1875-76	25, 339	9, 365	No statistics available.
1876	65, 975	No record	
1880-81	27, 000	No record	
1881-82	17, 000	No record	
1883	57, 000	No record	
1884-91			No statistics available.
1892	9, 724	6, 071	Oregon State Portage R. R. began operating around Cascades Rapids.
1893	8, 712	6, 949	Carried by Oregon State Portage R. R.
1894	6, 276	6, 261	Do.
1895	8, 122	10, 675	Do.
1896	2, 630	3, 371	To Nov. 5, 1896, carried by Oregon State Portage R. R.
<i>Fiscal years</i>			
1896-97	8, 134	5, 886	Cascades Canal opened Nov. 5, 1895.
1898	18, 119	20, 327	
1899	16, 699	23, 908	
1900	17, 710	30, 639	
1901	22, 425	34, 762	
1902	19, 709	52, 720	
1903	36, 181	50, 821	
1904	31, 967	76, 971	
1905	35, 165	64, 403	Oregon State Portage R. R. from the foot of Five Mile Rapids to Celilo revived navigation on the river above The Dalles, Oreg.
1906	46, 882	133, 073	
1907	53, 770	89, 239	
1908	54, 953	86, 615	
1909	34, 168	70, 482	
1910	32, 794	93, 369	Beginning of hired labor work on The Dalles- Celilo Canal.
1911	38, 063	95, 810	
1912	41, 778	84, 925	Open River Transportation Co., which had steamers above Celilo, suspended operations Oct. 31, 1912.
<i>Calendar years</i>			
1914	43, 904	74, 291	
1915	42, 477	103, 380	The Dalles-Celilo Canal opened May 5, 1915. Navigation above The Dalles resumed.
1916	37, 280	44, 509	
1917	40, 135	38, 387	
1918	25, 733	17, 040	
1919	20, 721	8, 602	
1920	16, 557	8, 544	
1921	5, 334	4, 523	
1922	15, 518	8, 113	
1923	5, 484	2, 275	Regular boat service to The Dalles was discon- tinued in 1923.
1924	678	None	
1925	803	264	
1926	461	5, 584	
1927	2, 762	878	Regular boat service resumed to The Dalles in September 1927.
1928	17, 665	1, 301	
1929	476	930	Boat service discontinued.
1930	1, 819	895	

‡ Prior to 1920 no log rafts were taken through the canal; the tonnage shown above since 1919 does not include rafted logs.

461. Most of the tonnage was bound upstream and much of it went as far as Lewiston, Idaho, the head of navigation on the Snake (about 141 miles above its mouth). After the completion of the railroad from Portland to Riparia, Wash., in 1882, and later to Spokane, navigation and commerce on the Columbia River above Celilo practically ceased. Only a few boats remained on the river above Celilo Falls, and they were taken to the Snake River to operate between its mouth and Lewiston as feeders for the railroads which crossed the Snake River at its mouth, and at Riparia, 67 miles above the mouth.

462. The following is a statement of the commerce above Celilo Falls insofar as the records are available:

Calendar year	Tons	Remarks
1858		First steamer built above Celilo Falls.
1858-63		No record.
1864	2, 183	Over the river from Celilo to Lewiston.
1875	18, 230	
1879	65, 975	
1880-1904		No record.
1905	3, 058	Carried by Oregon State Portage R.R. from Celilo to foot of Five Mile Rapids.
1906	5, 630	Do.
1907	7, 776	Do.
1908	4, 319	Do.
1909	8, 421	Do.
1910 ¹	13, 530	Carried by Oregon State Portage R.R. from Celilo to The Dalles.
1911	16, 411	Do.
1912	7, 241	Carried by Oregon State Portage R.R. from Celilo to The Dalles, to November 3, 1912.
1913	0	No commerce.
1914	0	Do.
1915	8, 394	May 5 (opening The Dalles-Celilo Canal) to December 15, 1915.
1916	8, 681	March 9-December 20, 1916.
1917	5, 308	March 3-December 15 (regular boat service discontinued)
1918	61	4 trips as far as Arlington.
1919	463	2 trips to Lewiston in June 1920.
1920	1, 204	May 28-July 14 (boat service discontinued).
1921	0	No commerce.
1922	127	Small boats.
1923	0	No commerce.
1924	7	Small boats.
1925	75	Special trip of boat.
1926	0	No commerce.
1927	0	Do.
1928	0	Do.
1929	0	Do.
1930	0	Do.
Total	174, 127	

¹ The Oregon State Portage R.R. was extended from the foot of Five Mile Rapids to The Dalles in 1910.

Of the upstream freight carried on this section of river in 1915 and 1917 about one half the quantity went up Snake River, but there was very little downstream freight that originated on Snake River. In 1916, 5,254 tons of freight, mostly general merchandise, passed through The Dalles-Celilo Canal. The downstream freight amounted to 3,430 tons, of which about three fourths consisted of grain and flour.

463. In March 1931 a shipment of 225 tons of paper products from the paper mills at Camas, Wash., was shipped by barge up to The Dalles and from that point the shipments were distributed by truck. Although the experiment was considered a success, only one trip was made because the railroad company immediately reduced the freight rate on paper products to the boat rate.

464. In June 1931 a shipment of about 1,400,000 grain sacks, comprising about 525 tons, consigned to the Farmer's National Grain Corporation, was taken from Portland, Oreg., by river steamer to points on the upper Columbia River, separate trips being made to Big Eddy, Umatilla, and Wallula, Wash. As a result the railway rate on grain sacks from Portland to Pendleton was reduced from 51 to 42½ cents per hundred pounds.

465. In July 1931 an attempt was made to move wheat from The Dalles to Portland by steamer. The steamer *Cowlitz* on the first trip, loaded with 100 tons of sacked wheat, encountered a heavy head wind, overturned, and sank at a point about 5 miles below The Dalles.

The *Cowlitz*, it may be stated, is a very shallow-draft boat, and it is not probable that the accident would have happened to a craft drawing more water. Efforts are also being made to establish a boat service to carry wheat from the Columbia above Celilo to Portland.

(G) LOCAL COOPERATION IN RIVER IMPROVEMENT

466. The local interests represented by the port of Portland, the port of Vancouver, Wash., and the port of Astoria, have assisted in the improvement of the river below Vancouver.

467. The port of Portland and the port of Astoria have contributed \$500,000 toward the improvement of the entrance to the Columbia River to date. On the Columbia and Willamette Rivers below Portland, the port of Portland has cooperated in the improvement work by dredging and construction of dikes under the previous and existing projects, at a cost of approximately \$6,000,000, and is required under the existing project to improve and maintain the channel in the Willamette River and to assist in the work of improving and maintaining the channel in the Columbia River below the mouth of the Willamette River, by loaning to the United States, for a total of not exceeding 6 dredge months annually, hydraulic pipeline dredges, without charge other than operating costs.

468. The port of Vancouver has contributed about \$27,000 under previous projects for the improvement of the Columbia from Vancouver to the mouth of the Willamette River and has contributed about \$82,000 under the existing project. It has a balance of about \$31,000 to pay to complete the required cooperation.

469. There is no project for the improvement of the section of the river from Vancouver to The Dalles except between Warrendale and the head of Cascades Rapids. Although no local cooperation was required by law, the State of Oregon contributed a portage railroad at the Cascades Rapids to portage freight around the rapids during the last 5 years of the canal construction work.

470. For the improvement of the river between The Dalles and Celilo, the State of Oregon furnished the canal right of way free of cost to the United States and constructed and operated a portage railroad to transfer freight around the obstruction to navigation during the 10-year period that the canal was under construction.

471. For the improvement of the river between the head of Celilo Falls and the mouth of Snake River no local cooperation was required by law, but the State of Washington contributed \$25,000 toward the existing project.

(H) VIEWS OF LOCAL INTERESTS FOR FURTHER IMPROVEMENT OF THE RIVER FOR NAVIGATION

472. *Mouth to Vancouver.*—Local interests representing Portland desired a depth of 35 feet from the entrance of the river to Portland and this was provided for in the existing project adopted by the River and Harbor Act of 1930. The local interests at Vancouver, with the existing project depth of 25 feet from the Willamette River to Vancouver, desire an increase to 30 feet. This increase can be secured by dredging and will no doubt be provided when justified by commerce.

473. For the river above Vancouver the local interests desire a channel 7 feet deep and 100 feet wide at low water to the mouth of the Snake River. The present channel depth between Vancouver and Celilo exceeds 7 feet at extreme low water. From Celilo to the Snake River there is now a depth of 7 feet, except in three places. Two of these places have a controlling depth of 6 feet over gravel shoals and could be increased to 7 feet, but the third place, Homly Rapids (about 6 miles below the mouth of Snake River) has a controlling depth of only $4\frac{1}{2}$ feet over a bottom composed of gravel, boulders, and rocky reefs, so that a depth of 7 feet would be difficult to secure. The depth at Homly Rapids could probably be increased somewhat by closing secondary channels and deepening present navigation channel or by developing one of the secondary channels as a navigation channel.

(I) EFFECT OF DESIRED IMPROVEMENT

474. The effect of the improvement desired by local interests for the river below Portland and Vancouver will permit vessels of increased draft to enter the river and ascend it to Portland and Vancouver. At the present time a draft of 29 feet at low tide can be carried in the river to Portland throughout the year, and by taking advantage of the tide 30 to 31 feet can be carried. With a depth of 35 feet in the project channel the draft can be increased to permit all but a few of the deepest draft ships to enter the river. The increase in depth of the channel from 25 to 30 feet at low water between the mouth of the Willamette River and Vancouver will allow vessels with drafts up to about 28 feet to dock at Vancouver.

475. A channel depth of 7 feet above Vancouver will permit drafts up to 5 feet at low water and to about 7 feet (the depth on lock sills in The Dalles-Celilo Canal) at higher stages of river; such drafts can, however, be carried most of the time with the present condition of the channels above Vancouver. Further improvement of the channel by open-river methods will not greatly lessen the present cost of operating river craft as it will not reduce the currents in the rapids. It will, however, lessen the dangers to navigation by removing projecting rock ledges and by straightening existing channels or developing new channels, and will make navigation somewhat easier than under the present condition of the channels. It will also permit boats to navigate this section of river at night, which cannot now be done without considerable risk.

(J) RIVER CRAFT—TYPES USED AND SUITABLE

476. From the Pacific ocean to Portland, Oreg., a distance of 112 miles, the river has been used for sea-going craft of all descriptions, both sail and power, as well as river craft. The existing project for improvement will permit the use of ships of practically unlimited ocean tonnage.

477. Above Vancouver, Wash. (about 5 miles above the mouth of the Willamette), only river craft have used the river, as there are no industries above Vancouver to furnish cargoes for sea-going craft. Light-draft sea-going boats could now navigate the river as far as Warrendale, 36 miles above Vancouver.

478. Above The Dalles only river craft have been used. The strong currents limit navigation to rather high power self-propelled boats. A type of stern-wheel packet steamboat known as the "Columbia River" type was developed on the Columbia and Willamette Rivers. This is a stern-wheel boat; hull generally 150 to 200 feet in length, with 30- to 34-foot beam, and 6- to 8-foot depth of hold; two long stroke reciprocating steam engines, and one locomotive type boiler. This type of boat is very efficient for swift-water navigation and was used almost entirely on the Columbia River above Portland. At first several side-wheel steamers were used on the river below Bonneville and between the head of the rapids and The Dalles, before the Cascades Canal was in operation, but these were replaced with the stern-wheel type. A few small screw-propeller boats were also used on the river above Portland. During the past few years, small twin-screw gasoline or diesel-tow boats have been used with success on the river from Warrendale to The Dalles. These boats are used mostly for towing logs.

479. Owing to the swift currents above Warrendale, barges are not generally used above Vancouver, Wash. They were used to a limited extent between Portland and Bonneville and above the Cascades Gorge to The Dalles in the early days when there was a portage railroad from Bonneville to the head of the Cascades Gorge. The use of tow barges was discontinued upon the completion of the Cascade Canal in 1896. They were not used for commerce on the Columbia River above The Dalles at any time in the history of the river, but some flat boats were used in the early days above Celilo, and were sailed upstream and drifted downstream.

480. The proper type of craft to use on a waterway depends upon physical characteristics of the waterway. The size and power depend upon the kind of cargo to be carried. To give prompt, efficient, and economical service, the craft should have sufficient power to handle its load without loss of time.

481. The principal downstream commerce, if developed, on the Columbia River, would be wheat. This commodity, if carried in bulk, would require a special type of boat. Barges with holds properly covered could be used and the wheat, either sacked or in bulk, could be loaded into the hold by gravity, and removed by elevators. The other commodities likely to be shipped are wool, some garden truck, and fruit. The last two items should be carried in fast-moving craft to prevent deterioration, or the boats should be provided with refrigeration. Most of the fruit is now shipped by rail to inland and Atlantic points, though some fruit is sent to Portland by rail for shipment to west coast and European ports. The upstream commerce would be general merchandise, petroleum products, and lumber. General merchandise going upstream would be comparatively small in quantity. The petroleum products, such as fuel oil and gasoline would have to be carried in barrels, if the carriers are to be used for general cargoes, unless special tow barges were used for oils and gasoline. Merchandise should be carried in steel-box containers, in order to protect it from the weather and from theft.

482. There are two general methods of transportation for waterborne freight—that using the self-propelled boat or barge, and that using the towboat with a fleet of barges. Two types of towboats are in general use—one, the stern wheel, Mississippi and Columbia River

type, and the other, the twin-screw tunnel type. The stern-wheel type generally permits of lighter draft for high-powered boats than the propeller type. The maximum size of any one type is fixed by the usable size of the locks through which the craft must pass, and by the minimum navigable depth of the channel.

483. On the Columbia River above Vancouver, there are two canals. The first is the Cascades Canal, $42\frac{1}{2}$ miles above Vancouver, and the second, The Dalles-Celilo Canal, $87\frac{1}{2}$ miles above Vancouver. The Cascades Canal has lock chambers 90 feet wide by 462 feet long with 8-foot depth over the sills at ordinary low water and $5\frac{1}{2}$ feet at extreme low stages. The Dalles-Celilo Canal has lock chambers 45 feet in width by 265 feet in length, with $7\frac{1}{2}$ -foot depth over sills at ordinary low stages; somewhat less at extreme low water. These dimensions govern the size of the craft which may ply the Columbia to points above these canals.

484. The maximum economical size of a fleet of barges with towboat is dependent upon the power of the towboat, number of lockages necessary at each lock, time lost in breaking and making up tows before and after lockages, swiftness of the current, minimum width of channel, and curvature of bends.

485. Were it not for the swift water in the rapids below the Cascades Canal, fleets of barges could be taken as far as The Dalles, for the river is tidal below Warrendale, and has a very flat slope between the head of Cascades Rapids and The Dalles, leaving only about 5 miles of the 84 miles from Vancouver to The Dalles, where navigation is difficult. During middle stages of river, boats of moderate horsepower can stem the current, but during higher freshet stages, and during very low stages, it takes a high-powered boat (without a tow) to stem the current below the Cascades. Most of the steamers used on the river above Vancouver had about 500 horsepower, but a few boats had as much as 1,000 horsepower. Barge navigation to points above Warrendale would require powerful towboats or cables to get the barges over the swiftest places between Warrendale and the lower entrance to the Cascades Canal. An experimental trip was made March 30, 1931, taking a barge 130 by 36 by 8 feet loaded with 225 tons of paper, and with a draft of 3 feet, from Camas to The Dalles. One stern-wheel steam towboat of 300 horsepower, and one 165-horsepower Diesel towboat, were used, and the two towboats could not take the barge through the Summit Rapids. The barge was pulled over the rapids after a delay of 2 hours by using a cable fastened to the shore. The stage of river was 5 feet above adopted low water in upper pool of Cascades Canal.

486. The lock chambers of the Cascades Canal are large enough for five ordinary sized barges and one towboat. The usual size of barges on the lower Columbia River is about 35 feet by 120 feet, but narrower and slightly longer barges would probably be more suitable for towing through the rapids. It is doubtful if more than one barge at a time could be towed from Bonneville to the Cascades Canal, so that the size of the locks does not affect the size of tows upstream. Going downstream a full tow of five barges could be taken into the lock, but it is questionable whether such a tow could be handled through the rapids except at moderate stages of the river, without danger of breaking up the fleet.

487. Tow barges, if used for navigation of the river above The Dalles, should be of shallow draft and have less beam than barges for the river below The Dalles, as the controlling depth in the channel above the Celilo Canal, at low water, does not exceed 6 feet. Such barges should have an easy rake for towing, since there is a large amount of wave action in the rapids, especially when strong winds are blowing in the open river. Only one barge at a time can be locked through The Dalles-Celilo Canal, unless its beam over all is less than 22 feet, then it is possible to pass through two barges abreast, with a towboat behind. A few barges have been taken through The Dalles-Celilo Canal with the towboat behind and pushing one barge.

488. While the Columbia River stern wheel type of steamboat described above is very efficient, as far as navigation is concerned, it is not an economical type of freight carrier, as all freight must be handled by the boat's crew and is carried on the main deck, which is already occupied by propelling engines, boilers, mess rooms for crew, and fuel bunkers, leaving but little space for freight. The size of stern-wheel boat formerly used on the upper river is from 150 to 170 feet in length between perpendiculars, 30 to 40 feet in width, and has 5- to 7-foot depth of hold. The usual sized upriver boat had a draft of not over 5 feet and carried from 200 to 250 tons of freight. The largest boat used on the river above Portland could not carry more than 400 tons fully loaded to about 5 feet. It had a length of about 200 feet, a beam of 38 feet, and a hold 6 feet in depth.

489. A packet boat with passenger accommodations, recently launched, is equipped with a Diesel engine of 500 horsepower and has a speed of about 14 miles per hour in still water. Her semi-tunnel stern and rudder system makes the boat easy to handle. She has a length of 160 feet, 30-foot beam, and is 10 feet 6 inches in depth amidships. Her draft is about 4 feet light and 6 feet loaded. She carries 425 tons of freight and has accommodations for 75 passengers. This is said to be the first departure from the Columbia River type in 50 years. The boat is equipped with a freight elevator to elevate freight to the deck level.

490. A boat similar to the boat described in the preceding paragraph, but without passenger accommodations, is believed to be a very suitable type for freight services only on the Columbia River above Portland. The freight-carrying capacity of the boat described could be increased to 500 tons if no passenger accommodations were provided. Such a boat could be arranged for hauling all kinds of freight and could be unloaded and loaded mechanically through hatches in the roof of the deck house.

491. Packet boats of smaller size would, however, be required for small consignments, for passengers and for way business. All bulk freight and large shipments of commodities would go by freight boats. With the present condition of river as to currents it is doubtful if fleets of tow barges could be economically used, but single barges might be used at times when river conditions are favorable.

492. The port of Astoria (in 1915) made a study of possibilities of making water shipments, especially of wheat, from the Columbia and Snake Rivers above Celilo to Astoria, and as a result it was decided that barges could not be used economically above Bonneville (2½ miles above Warrendale), and the port made plans to use high-powered freight boats of the Columbia River type above Bonneville and to

transfer the wheat to barges at Bonneville, below which point fleets of barges could be towed to Astoria. The plans were not carried out because the terminal rail rate to Astoria was made the same as that to Portland in which case boats would get nothing for the 100-mile haul from Portland to Astoria.

493. The port of Portland made a study of the physical possibilities affecting commercial navigation of the upper Columbia and Snake Rivers, which covered a period of 2 years (1929-31) and as a result of the survey concluded that on account of the strong currents barges could not be economically used on the river above Bonneville, and that a stern-wheel packet steamboat of the Columbia River type of 500 tons freight capacity would be the most suitable. The type of boat selected would have a length of about 210 feet and a beam of about 36 feet, with a long-stroke reciprocating steam engine of 1,000 horsepower.

(K) POSSIBILITIES OF FURTHER IMPROVEMENT OF THE COLUMBIA RIVER
IN THE INTERESTS OF COMMERCE AND NAVIGATION

494. *Mouth to Vancouver.*—From the Pacific Ocean to the mouth of the Willamette, the Columbia River has been improved for ocean navigation of practically unlimited tonnage. From the mouth of the Willamette to Vancouver, Wash., a distance of 5 miles, the channel depth at low water is now 25 feet and will, no doubt, be increased to 30, and later to 35 feet, as soon as required by navigation.

495. *Vancouver to Warrendale.*—From Vancouver to Warrendale, a distance of about 35.5 miles, the existing channel is adequate for river craft of drafts up to 8 feet and until industries that require ocean-going craft are established above Vancouver, no further improvement is needed. As this section is tidal and has very little slope, the existing channel can be deepened by dredging.

496. *Warrendale to Head of Cascades.*—From Warrendale to the head of the Cascades Rapids, a distance of about 7 miles, the river bed is obstructed by falls and rapids and at low water the fall is approximately 37 feet, of which about 25 feet is concentrated in the main rapids and is overcome by means of the Cascades Canal. Below the canal the fall is concentrated in two places, at low water, and though the depth of water is sufficient for river craft, navigation is difficult at all stages of river on account of strong currents.

497. Owing to the narrow gorge through which the river flows from below the main falls to Bonneville, the dimensions of the river channel through the gorge cannot be increased sufficiently to give moderate current velocities at all stages of river without a great quantity of excavation and excessive cost. The low-water flow of the Columbia at The Dalles is about 50,000 second-feet. The usual freshet flow is about 600,000 second-feet with a maximum flood flow of about 1,200,000 second-feet. The gorge is from 400 to 700 feet in width at low water and has steep side slopes. The area of the channel does not increase very fast as the river rises, hence high velocities result.

498. Canalization by means of a dam at the lower end of the gorge would reduce the velocities at low stages but would not greatly reduce the velocities at high stages. A lateral canal is the only method that would provide slack water throughout the year. It would be difficult to construct a lateral canal along the left bank of the river, as the

mountain slopes, which are of loose and unstable material, extend into the river bed. A railroad and a highway parallel the high-water line. A lateral canal could be more easily constructed on the right bank of the river. To do this, it would be necessary to move the railroad and the State highway which occupy the river bank. Such a canal would have a total length of 7½ miles, including about 4 miles of open channel below the lower lock. Two locks would be necessary, a lock at the upper entrance to lock boats down into the canal as the river rises and a lock at the lower end. The upper lock would have a lift of about 45 feet and the lower lock about 40 feet.

499. The following is an approximate estimate of the cost of a lateral canal on the right bank following closely the high-water line through the gorge from the river above the main rapids to Hamilton's Slough and via the slough (which would have to be deepened) to the mouth of the slough into the river at a point about opposite Warrendale. The canal would have a bottom width of 100 feet and a depth of 10 feet at low water, side slopes of one vertical on one and one half horizontal, and a total length of 7½ miles, including about 4 miles of open channel in Hamilton's Slough. Sufficient power could be developed at the lower lock to operate the canal by using the canal as a headrace.

Dry excavation, 12,000,000 cubic yards, at \$1	\$12, 000, 000
Dredging, 2,500,000 cubic yards, at 30 cents	750, 000
Concrete lining, 150,000 cubic yards, at \$12	1, 800, 000
Riprap, 200,000 cubic yards, at \$2	400, 000
Upper lock	1, 800, 000
Lower lock	1, 800, 000
Upper entrance to canal	200, 000
Buildings	50, 000
Power house	50, 000
Changing location of railroad	200, 000
Changing location of highway	70, 000
Lands, damages, etc.	70, 000
Miscellaneous	2, 000, 000
Total	21, 190, 000

500. The above estimate, which is a revision of the estimate in report of 1922, is for a waterway skirting the hill in the right bank of the river. This hill is apparently debris from a gigantic landslide from the mountains on the north side of the river. The general level of the top of the hill is from 250 to 300 feet above the low-water surface of the river. The whole mass is said to be moving toward the river, but no serious movement has taken place along the highway and the railroad on the river bank. A canal straight through the hill would be shorter but would cost much more on account of the greater quantities of excavation.

501. The existing channel in the gorge below the Cascades could be improved somewhat by widening the channel in Summit Rapids and by removing pinnacles of the reef which crosses the river at Summit Rapids. Only a very limited increase of channel dimensions could be made without lowering the water surface pool above Summit Rapids. Lowering the water surface in the pool between the head of Summit Rapids and the lower entrance to the Cascades Canal would lessen the depth of water over the lower lock sill. The project depth over the sill is 8 feet at adopted low water but the river frequently falls below this plane. During the 3 months from the end of November 1930 to the end of February 1931 the depth on

the lower lock sill was less than 8 feet. For about 1 week of this period the depth was less than 6½ feet with a minimum of 6.1 feet for 1 day. The period from September 1930 to March 1931 was one of the driest of record. The widening of the navigation channel through Summit Rapids would have to be so limited that the effect would not be very beneficial to low-water navigation.

502. High-water navigation would be benefited somewhat by the removal of a portion of Sheridans Point on the right bank of the river, about 1 mile below the foot of Cascades Rapids, where a rocky point projects far enough beyond the general shore line to create rapids and very swift currents. Here the current is so strong at stages of river above 38 feet on the lower gage at the Cascades Canal as to prevent all but the most powerful boats on the river from passing the point.

503. The following is an estimate of the cost of the removal of points of reef and projecting ledges and obstructive rocks in the channel below the Cascades Canal to Bonneville:

3,000 cubic yards subaqueous rock at \$12 per cubic yard.....	\$36, 000
5,000 cubic yards dry rock excavation at \$3 per cubic yard along river bank.....	15, 000
Total.....	51, 000

504. *Cascades to Three Mile Rapids.*—From the head of the Cascades Canal to the foot of Three Mile Rapids, a distance of 43 miles, the existing channel is wide and deep and no improvement would be required for river craft. There are, however, several pinnacles, rocks or reefs, not directly in the channel but a menace to navigation in foggy weather. These could be removed to a safe depth by blasting, if found necessary.

505. *Foot of Three Mile Rapids to The Dalles-Celilo Canal.*—Between the foot of The Dalles-Celilo Canal and the foot of Three Mile Rapids the river flows through a narrow rocky gorge nearly 2 miles in length with almost perpendicular side walls. The lower three quarters of a mile of the gorge is known as Three Mile Rapids. At low water the fall through the gorge is about 1 foot. At ordinary freshet stages the fall is about 5 feet and mostly concentrated at the lower end of the gorge. During the higher freshet stages the river overflows its banks at Three Mile Rapids. From the foot of Three Mile Rapids to the lower entrance of The Dalles-Celilo Canal sufficient rock excavation was made along the sides of the gorge to give a channel 250 feet wide and 10 feet deep at the narrowest point. This work made navigation somewhat safer than formerly but did not reduce the current at medium and high stages of river. The present channel below the lower entrance to the Celilo Canal flows between nearly perpendicular rock walls and is fairly straight and deep and not less than 250 feet wide from the lower entrance of the canal for a distance of about 1 mile. It then makes a reverse curve into the head of Three Mile Rapids. This condition is caused by an apparent offset in the channel at the lower end of the rocky gorge. The reverse curve makes navigation very difficult during freshets.

506. To give slack water from the lower entrance of The Dalles-Celilo Canal to the foot of Three Mile Rapids, an extension of The Dalles-Celilo Canal downstream for a distance of approximately 12,000 feet would be required. For about 1,000 feet just below the lower

entrance of the present canal construction of a canal extension would be difficult on account of the steep slopes close to the river. Highway and railroad construction would be expensive. Below this section the construction would not be difficult.

507. Based on the cost of the present canal and locks, it is estimated that the cost of this extension of The Dalles-Celilo Canal would be about \$2,000,000, including rights of way, moving railroads, and making some change in the highway along the river bank. No field surveys for this estimate have been made.

508. Some relief could be afforded navigation during high water by straightening the existing channel through Three Mile Rapids. This would require the removal of a large quantity of rock along the left bank at the head of Three Mile Rapids. If removed down to an elevation of 5 feet above the low-water plane, boats could pass over the excavated portion of the shore line at about a 15-foot stage of river, giving a channel of 600 feet at that stage. The present low water channel width is 250 feet. The cost of this work would be approximately \$180,000 (for excavation of 120,000 cubic yards of rock to elevation 5 feet above low water at \$1.50 per cubic yard).

509. The removal of a portion of the rocky bench on the left bank down to an elevation 5 feet above the plane of low water as outlined above would remove the reverse curve in the channel and leave only a slight curve not detrimental to navigation and would also reduce the current to some extent, during high stages of river, so that boats could navigate Three Mile Rapids during periods when the canals are open to navigation.

510. *Foot of Five Mile Rapids to head of Celilo Falls.*—The Dalles-Celilo Canal, which extends from the foot of Five Mile Rapids, 3½ miles above the town of The Dalles, to the head of Celilo Falls, has made navigation possible over this stretch of river at freshet stages below about a 20-foot stage at Celilo, Oreg. Freshets above a 20-foot stage, which are likely to occur every year, in the early summer months close the canal from 1 day to a month. This canal was designed to operate in connection with the Cascades Canal, which is also closed by freshets at a stage corresponding to a 20-foot stage at the head of Celilo Falls. No further provision for navigation need be made in this stretch of river until navigation conditions change at the Cascades.

511. *Celilo Falls to mouth of Snake River.*—The present condition of channels in this stretch of 124 miles of river indicates a controlling depth of 6 feet at low water, except at Homly Rapids (6 miles below the mouth of Snake River), where the low-water depth is only 4½ feet over pinnacles of reef rock, large boulders and gravel. Improvement of this section of river began in the year 1872, was suspended in 1880, and resumed under the existing project in 1908. The work consisted of removal of dangerous boulders, rock pinnacles, and ledges of rock projecting into the channels. The existing project which was completed in 1918 did not provide for additional depth or width in the existing channels. The results secured were greater safety for boats and an increase of draft at low water. Soundings taken in February 1931 at a very low stage of river and good weather conditions with no ice in the river, show that the controlling depth at low water is 6 feet up to Homly Rapids, where the depth is 4½ feet at low water.

512. Local interests have expressed a desire for a straight, open river channel 7 feet deep and 100 feet wide from Vancouver to the

mouth of Snake River, except at Homly Rapids. They also claim that, since many years must elapse before the river is canalized, the existing channels should be improved to make navigation safe and easy.

513. The present condition of the channel in the shoals and rapids from Celilo Falls to Snake River, is shown by the following tabulation:

Locality	Miles above Celilo Falls	Controlling depth at low water	Width of channel at this depth	Length of shoal less than 7-foot depth	Velocity of current low water	Remarks
		<i>Feet</i>	<i>Feet</i>	<i>Feet</i>	<i>Miles per hour</i>	
Biggs Rapids.....	6½	6	300	500	5	Gravel shoal.
John Day Rapids.....	16	6	175	-----	7	Rock pinnacles to be removed.
Indian Rapids.....	19	10	150	-----	6	Crooked.
Squally Hook Rapids..	22	7	100-200	-----	7	Some rock pinnacles to be removed and channel straightened.
Rock Creek.....	27	8	100	-----	8	Channel should be straightened.
Four O'Clock Shoal....	32	6	300	600	4	Gravel shoal.
Owyhee Rapids.....	38-40	7	200	-----	6	Gravel shoal. Some rock pinnacles should be removed to straighten channel.
Cance Encampment Rapids.	64	8	200	-----	6	Channel should be straightened.
Devils Bend.....	85	7½	200	-----	7	Rock pinnacles. Channel should be straightened.
Umatilla Rapids.....	91	6	200	300	10	Do.
Bull Run Shoal.....	109½	6	300	500	5	Gravel.
Homly Rapids.....	117	4½	60	2,000	7	Rock pinnacles. Gravel.

514. The improvement of the existing channel to give a depth of 7 feet over a width of 100 feet in all places, except Homly Rapids, would not require much work, as there are only 5 localities below Homly Rapids with less than 7 feet, but straightening the channels so that barges could be towed through the rapids would require a large amount of work.

515. The following estimate is for a channel 7 feet deep at low water over a width of 100 feet, fairly straight through the shoals and rapids.

Biggs Rapids: The shoalest water is at the head and foot of the rapids and the bed is probably all gravel. Closing the slough along the right bank would probably relieve the shoaling at the head of this rapid.

Closing slough in right bank with loose rock dike:

3,000 cubic yards stone, at \$5 per cubic yard..... \$15,000
2,000 cubic yards gravel dredging, at \$1 cubic yard.. 2,000

\$17,000

Lower John Day Rapids:

500 cubic yards subaqueous rock, at \$10..... 5,000

Removal of several high points of reef would straighten the channel which now has a sharp turn at its lower end.

Middle John Day Rapids:

3,000 cubic yards dry rock excavation, at \$2 per cubic yard..... \$6,000

500 cubic yards subaqueous rock, at \$10 per cubic yard..... 5,000

11,000

Upper John Day Rapids:

1,500 cubic yards subaqueous rock excavation, at \$10.... 15,000

Total for John Day Rapids..... 31,000

Indian Rapids:		
300 cubic yards subaqueous rock, at \$12 per cubic yard-----		\$3, 600
Squally Hook Rapids:		
2,000 cubic yards subaqueous rock, at \$10 per cubic yard-----		20, 000
Rock Creek Rapids:		
1,000 cubic yards subaqueous rock, at \$10 per cubic yard-----		10, 000
Four O'Clock Rapids shoal:		
4,000 cubic yards gravel excavation, at \$1 per cubic yard-----		4, 000
Owyhee Rapids:		
300 cubic yards removal of rock pinnacles, at \$12-----	\$3, 600	
400 cubic yards subaqueous rock pinnacles, at \$10-----	4, 000	
		<u>7, 600</u>
Canoe Encampment Rapids (bottom studded with pinnacles):		
1,000 cubic yards subaqueous rock pinnacles, at \$10-----		10, 000
Devils Bend Rapids:		
1,500 cubic yards subaqueous rock pinnacles, at \$10-----		15, 000
Umatilla Rapids:		
Lower rapids, main channel:		
3,000 cubic yards subaqueous rock, at \$10-----	\$30, 000	
Middle rapids:		
1,000 cubic yards subaqueous rock pinnacles, at \$10-----	10, 000	
Upper rapids, opening channel close to Oregon shore:		
4,000 cubic yards subaqueous rock, at \$10-----	40, 000	
Total, Umatilla Rapids-----		<u>80, 000</u>
Homly Rapids (closing secondary channels):		
10,000 cubic yards piling, loose rock, dikes, at \$4-----	\$40, 000	
1,000 cubic yards subaqueous rock pinnacles, at \$10-----	10, 000	
2,000 cubic yards gravel, at \$1-----	2, 000	
		<u>52, 000</u>
Isolated reef points (not specifically mentioned):		
1,000 cubic yards subaqueous rock removal, at \$10-----		10, 000
Removal of gravel shoals (not specifically mentioned):		
5,000 cubic yards, at \$1-----		5, 000
Engineering and surveys-----		60, 000
Total-----		<u>325, 200</u>

516. The following is a summary of the estimates for 7-foot open river channel from Vancouver to Snake River:

Vancouver to The Dalles-----	\$51, 000
The Dalles to foot of The Dalles-Celilo Canal widening channel in Three Mile Rapids-----	180, 000
Celilo to Snake River:	
Biggs Rapids-----	\$17, 000
John Day Rapids (3 pitches)-----	31, 000
Indian Rapids-----	3, 600
Squally Hook Rapids-----	20, 000
Rock Creek Rapids-----	10, 000
Four O'Clock Rapids shoal-----	4, 000
Owyhee Rapids-----	7, 600
Canoe Encampment Rapids-----	10, 000
Devils Bend Rapids-----	15, 000
Umatilla Rapids (3 pitches)-----	80, 000
Homly Rapids-----	52, 000
Reef Points, not specifically mentioned-----	10, 000
Gravel Shoals, not specifically mentioned-----	5, 000
Engineering and surveying-----	60, 000
Total-----	<u>325, 200</u>
Total-----	<u>556, 200</u>

517. The removal of rock pinnacles in the existing channels, together with the removal of rocky ledges, which now project into these channels, would eliminate all sharp turns and give a fairly straight channel through the rapids. This would make navigation

by self-propelled boats much easier and safer and would also make it possible to tow single barges by the use of powerful towboats. This improvement would not decrease the strength of the current but would remove, at least to some extent, dangerous eddies and whirls which make navigation difficult, and would permit navigation at night, which is not now possible at some of the rapids. The towing of barges is mainly a question of power and if sufficient towboat power cannot be provided, the straighter channels would permit the use of cables in assisting boats in the swift currents.

518. A lateral canal from Warrendale to the head of the Cascades Gorge, a distance of about 7 miles, would give slack water through the gorge and give continuous navigation throughout the year, except when the river is closed by ice. The cost of such a canal (100 feet wide and 10 feet deep), with necessary locks, is estimated at \$21,190,000. (See par. 499). Such a canal would give easy navigation to the foot of Three Mile Rapids at all stages of river. To overcome the difficulties to navigation through Three Mile Rapids under the present conditions of river, The Dalles-Celilo Canal would have to be extended downstream for a distance of 2½ miles. The estimated cost of this extension is \$2,000,000. (See par. 507.) This extension would permit easy navigation to the head of Celilo Falls. Adding the estimated cost of the lateral canal at Cascades (\$21,190,000), and the estimated cost of the extension of The Dalles-Celilo Canal (\$2,000,000), to the estimated cost of the open-river improvement, Celilo Falls to Snake River (\$325,000), the total cost would be as follows:

Lateral Canal at Cascades.....	\$21, 190, 000
Extension downstream of The Dalles-Celilo Canal.....	2, 000, 000
Removal of dangerous rocks to straighten channel, Celilo Falls to Snake River.....	325, 000
Total.....	23, 515, 000

519. A series of low dams for navigation would be beneficial for low-water conditions, but would not greatly assist navigation during freshets. The power developed by means of such dams would be small and of no great commercial value.

520. The cost estimates of high dams for combined navigation, power, irrigation, and flood control is treated in the power section of the report. The following paragraphs cover the extent to which proposed high dams will improve the river for navigation in the section of river between Warrendale and Snake River.

521. In its existing condition there are a number of rapids and shoals in the river which make navigation difficult. With a dam at Warrendale, one just above The Dalles, and possibly one or more above that point, arranged so that the raised water levels produced by each dam will extend to the next dam upstream, all rapids and shoals will be submerged, channel areas will be increased, and the velocity of current reduced at all stages of the river. The reduction of current velocity will be large just above the dams and for a considerable distance upstream, but there will be less effect as the upper end of raised water levels is approached. And, in case the channel is comparatively deep and narrow at any point near the upper end of the reservoir, the currents may be considerable during high stages of the river, even after the dam has been constructed.

522. An examination of the channel conditions between Warrendale and the mouth of Snake River indicates that the most critical sections for current velocities, after the construction of the dams, are to be found between Warrendale and the upper end of Cascades Rapids. Any craft which can navigate this section of the river will have no difficulty between the Cascades and the mouth of Snake River.

523. The construction of a power dam at Warrendale with crest at elevation 54 will raise the low-water level in the river at the upper end of Cascades Canal 12 feet or more above existing low-water level. It will submerge Cascades Rapids and all rapids and shallow areas in the river between Cascades Locks and the dam. Rock pinnacles, bars, and similar obstructions near the main navigation channel will, generally, be covered by a depth of water greater than the draft of river boats and barges, even at low-water stages. At The Dalles and Three Mile Rapids the water level will be raised 5 to 6 feet at low water. The velocity of the current will be reduced at all points affected by the raised water levels, but the amount of reduction will grow less as the distance upstream from the dam increases. Transportation of freight in barges will be practicable for a large portion of the year.

524. In the case of a dam at Warrendale, it would be desirable, although not absolutely essential, to improve certain sections of the river between Warrendale and head of Cascades Rapids where the existing channel is narrow and velocities high in order to obtain the greatest benefit to navigation from the construction of the dam. At locations such as Sheridans Point and Cascades Rapids the raised water levels produced by the dam will not reduce the velocity of the current during freshet periods sufficiently for easy navigation. A study of velocities at a number of sections indicates that the critical points for navigation will be at the bridge below Cascades Locks at Sheridans Point, and at Cascades Rapids. At the upper end of Cascades Rapids the channel is wide but rather shallow, and because of its elevation the increase in depth of water caused by the dam will not be great. The current here will be rather swift even with a flow not greater than 200,000 or 300,000 second-feet. Slightly less velocities will be encountered at Sheridans Point. The channel will also be somewhat deficient in width at the highway bridge across the river below the Cascades Canal and in the vicinity of Summit Rapids. The current conditions can be improved at all of these points by removing obstructions above existing low-water level and cutting back the shores on one or both sides to such an extent that the channel cross section will be fairly uniform. Removal of obstructions and widening of the channel will be advisable at Cascades Rapids, at the highway bridge, at Sheridans Point, and for some distance above and below Sheridans Point. At the latter point the Washington shore should be cut back from 150 to 200 feet, and considerable cutting should be done on the opposite shore just west of the point. The total estimated cost for this work is \$1,500,000.

525. *Velocities of current.*—Plate 36² shows the average flow duration at Cascades Locks for the 17-year period ending April 1, 1930. The mean average flow is 225,000 second-feet or less for 9 months of each year, and 430,000 second-feet or less for 11 months.

526. Plate 37² shows the estimated mean velocity for various rates of flow between 100,000 and 600,000 second-feet at four of the most

² Not printed.

critical sections of the river between the Warrendale dam site and Cascades Locks, with dam installed. In computing the values from which to plot the curves, the enlarged areas obtained by widening and clearing out the channel have been used, except at the highway bridge section, where the natural section was taken. Some increase in cross section could be made at this point, with a consequent improvement in current velocities. Plate 38² shows the duration of various mean velocities at the four critical sections used on plate 37.²

527. These plates indicate that with a dam at Warrendale and the river improved as previously described, the velocity of current at the swiftest location between the dam and Warrendale will not exceed 5.8 feet per second or 4 miles per hour during 9 months of the year, and will not be greater than 8.8 feet per second or 6 miles per hour for practically 11 months of the year at the worst point. Velocities of the magnitude shown on the plates will occur for only a short distance at any of the points. In the remainder of the river they will be less than at the points selected.

528. The velocities given are mean velocities obtained by dividing the given flow by the area of cross section below the water level at that stage of the river. The probable surface velocities will be from 10 to 12 percent greater than these. However, it is not likely that the current will have equal velocity for the full width of the channel, and an experienced navigator will select the route offering easiest passage.

529. On plate 39² a comparison is shown between velocities with the river in its existing unregulated condition, and the reduced velocities which will result from the construction of the dam and improvement of the channel. Two sections at Sheridans Point have been taken. The currents are reduced by more than 50 percent for the greater part of the year at these sections.

530. *Time during which currents will permit barge navigation.*—Transportation by means of barges is practicable in currents up to 6 miles per hour, and possible when the current considerably exceeds this velocity. This study shows that the current at the locality of its greatest velocity will be approximately 6 miles per hour with a flow of 410,000 second-feet. Flows of this amount or greater have an average duration as shown on plate 36² of little more than 1 month during the year. Plate 40² shows the maximum discharge for each year during the 17-year period from 1913 to 1929, inclusive. There were 2 years during the period when the maximum flow was less than 410,000, and 4 more years when it did not greatly exceed that amount. For the remaining 11 years the maximum flows were greater than 410,000 second-feet for a short period in each year.

(L) ESTIMATE OF POSSIBLE SAVINGS IN TRANSPORTATION COSTS BASED ON POTENTIAL RIVER TONNAGE

531. Navigation costs are estimated under the following conditions:

Condition (a): Open river with no further improvements.

Condition (b): Open river with improvements to give a 7-foot channel.

Condition (c): Lateral canals to Celilo, above Celilo, condition (b).

Condition (d): Slack water secured by dams for power, as proposed under power section of this report.

532. *Condition (a)—Open river with no further improvements.*—The river in its present condition has controlling currents between Port-

² Not printed.

land and the mouth of Snake River of 10 miles per hour at low water, and as high as 15 miles per hour at high water, at several critical points. Under this condition no costs of former improvements have been considered in estimating the navigation costs. The cost of the river improvements above Vancouver to the mouth of Snake River are as follows:

	New work	Operation and maintenance
Cascades Canal.....	\$3,908,780.30	\$473,000.00
The Dalles-Celilo Canal.....	4,670,600.53	288,000.00
Columbia River-Celilo to Snake.....	399,610.00	96,826.92
Total.....	8,973,991.78	\$87,826.92

533. *Condition (b)—Open river with improvements to give a 7-foot channel.*—Under this condition the channels would be straightened by the removal of rock pinnacles and projecting ledges, and gravel shoals dredged to give 7-foot depth at low water, as outlined in paragraph 516. The controlling currents, even with these improvements, would be the same as for the open river in its present condition. However, due to the removal of many existing hazards and the straightening and widening of the existing channel, the time consumed in navigating the river above The Dalles-Celilo Canal would be reduced, and in computing navigation costs under this condition, it is estimated that, due to this saving of time, the ton-mile costs would be approximately 10 percent less than under open river with no further improvement. The estimated costs of the additional improvements under this condition (b) are \$556,200; the annual charges, consisting of interest and maintenance on this amount, would be about \$55,000, not including any charges for improvements completed before 1931.

534. *Condition (c)—Lateral canals.*—Under this condition there would be a lateral canal from Warrendale to head of Cascades Gorge; an extension of The Dalles-Celilo Canal downstream to foot of Three Mile Rapids; and open river improvement (as in par. 533) from The Dalles-Celilo Canal to Snake River. With these improvements the controlling currents below The Dalles-Celilo Canal would be the same as for slack-water conditions under condition (d). For the section of the river above Celilo, the controlling currents would be the same as those for open river above Celilo Canal under condition (b).

535. It has been assumed in estimating the cost of navigation under this condition of improvement that barge navigation would be practicable to The Dalles, and would have the same operating costs as under slack-water conditions, and that above The Dalles the costs of navigation would be about the same as under condition (b) above. It has been estimated in paragraph 518, of this report, that the improvements for this condition (c) would amount to \$23,515,000. The annual charges, consisting of interest, operation, and maintenance, would amount to about \$1,025,600; of this sum \$35,000 consists of operation of the present Cascade Canal and of The Dalles-Celilo Canal.

536. *Condition (d)—Slack water secured by dams for power, as proposed under power section of the report.*—Under this condition the controlling currents, on an average, would vary from 3 miles per hour

for 8 months of the year to between 3 and 6 miles per hour for 3 months, and over 6 miles per hour for the remaining 1 month of the year. During the flood period averaging about 1 month per year barge navigation would be very difficult, if not entirely suspended. Ice conditions would occasionally render navigation impossible for not to exceed an additional month per year. The cost of the navigation features only, of the power dams, that is, the locks necessary to carry boats through the dams, has been estimated at \$14,600,000. The annual charges comprising interest, operation and maintenance for the navigation features would amount to \$884,000.

537. Plates 41² and 42² show for the years 1928-29 the actual freight movements by rail in and out of the counties selected as the probable origin of river traffic. A total of 392,707 tons moved east, or upstream, by rail, and a total of 1,563,585 tons moved west, or downstream, by rail. The average length of rail haul was about 200 miles. The total rail freight charges on the above tonnage was \$9,239,414.46 with an average rate per ton-mile of \$0.025, which includes all terminal and similar charges that the shipper had to pay.

538. A detailed study of wheat movement was made by this office. A summary of this study showing the tonnage of grain marketed in zones of the Columbia and Snake Rivers, Oreg. and Wash., 1926-30, is shown on plate 43.²

539. Appendix B, page 1751, presents traffic data compiled by this office covering the fiscal year 1928-29 taken from a tonnage study conducted by the Columbia Valley Association, the University of Oregon, and Martin's Shipyard, Inc., Portland, Oreg. The area embraced assumes a water haul as far as Lewiston, Idaho, and therefore is not identical with that considered in this study, which assumed no water haul above the mouth of Snake River. Plates 44² to 47² covering detailed cost analysis for tonnage, assume a water haul only below the mouth of the Snake River.

540. In estimating the probable costs of river transportation, two features are considered, the cost of operating the boats themselves, and the cost due to terminals and overhead. These costs apply only to points on the river bank. They do not include the charges due to river improvement or the cost of hauling freight from inland points to the river. It is assumed that the boats would be fully loaded downstream and carry a 25 percent load upstream. This corresponds to the proportion of total rail traffic moving in each direction. Wheat moves westward downstream and is the largest single commodity moved. It constitutes about 60 percent of the total west-bound rail tonnage.

541. Freight rates per ton-mile by rail and water for moving wheat were used as a basis for determining transportation costs for other commodities. It was assumed that the cost of moving other commodities by river would bear the same ratio to the charges of moving these commodities by rail that the cost of moving wheat by river bears to the charge of moving wheat by rail. The cost of moving all of the tonnage shown on plates 41 and 42 by water was then worked out using these rates.

542. The boat costs per ton-mile were estimated for each of the four conditions of river improvement stated in paragraph 531 above. The method of estimating costs is described in the paragraphs following.

² Not printed.