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CHAPTER II.—DATA

A. COLUMBIA RIVER BASIN

(A) GENERAL

9. Columbia River rises in British Columbia. It enters the United States in northeastern Washington, flows southerly to the mouth of Snake River, thence westerly between Oregon and Washington, and empties into the Pacific Ocean 610 miles north of San Francisco Bay and 160 miles south of the Strait of Juan de Fuca. The total length of the river is approximately 1,210 miles; drainage area, 259,000 square miles; extreme low-water flow above the mouth of Willamette about 50,000, and maximum discharge of record about 1,160,000 cubic feet per second. The average summer freshet discharge due to melting snows in the upper watershed is about 660,000 second-feet. The mean low-water flow below the mouth of the Willamette is about 70,000 second-feet, exclusive of tide water. The effect of tides is observed on the Columbia to a point about 36 miles above Vancouver and on the Willamette to a point about 11 miles above Portland. (See U.S. Coast and Geodetic Survey charts nos. 5902, 6151, 6152, 6153, 6154, 6155, and 6146; also Geological Survey map of Washington.)

10. The bed and banks of the river from the International Boundary to Vancouver are composed of rock, gravel, and sand. The width varies from a few hundred feet at some of the rapids to about 15,000 at Blalock Island. Below Vancouver the bed is composed mostly of sand, and width varies from about 2,000 to 20,000 feet.

11. Usually for a period averaging about 2 weeks annually the Columbia above Vancouver is closed to navigation on account of ice.

12. The river below the mouth of Snake River is divided by physical characteristics into several sections, as shown in the following tabulation. Five of these sections are under improvement.

Section	Distance	Fall	Currents	Remarks
Snake River to head of Celilo Falls.....	<i>Miles</i> 123.5	<i>Feet</i> 185	Swift and rapids..	Open river improvement.
Head Celilo Falls to The Dalles.....	11.5	82	Rapids.....	Dalles-Celilo Canal and locks.
The Dalles to head of Cascades.....	41.5	4	Moderate.....	Natural 8-foot channel.
Cascades to Warrendale.....	7	37	Rapids.....	Cascades Canal and locks 4½ miles under improvement.
Warrendale to Vancouver.....	35.5	5	Fairly swift.....	Tidal, unimproved, 8-foot channel.
Vancouver to mouth.....	104.5	5.6	Tidal.....	Improved for ocean-going vessels.
Mouth of Columbia.....			do.....	Do.

13. The portion of the drainage basin of Columbia River that comes within the scope of this report (that below the mouth of Snake River) embraces approximately 46,500 square miles in Washington and Oregon. It may be considered in three sections; that east of the Cascade Range of mountains, that through the Cascade Range, and that westward from the mountains to the sea. The length of the river through these sections is 323.5 miles. (See pl. 2.)

14. The section east of the mountains to the mouth of Snake River a distance of about 146 miles, has an area of 27,000 square miles. It is, for the most part, treeless. In its natural state it was covered by bunch grass and sage brush. The rainfall is slight, except on the Blue Mountains and the slopes of the Cascade Range. The immediate valley of the river is from 2 to 5 miles in width. Steep, rocky slopes, or series of cliffs rise to a height of 500 feet or more on both the Oregon and Washington sides. An exception to this is found in Morrow and Umatilla Counties, Oreg., where low-lying country extends back from the river for a number of miles.

15. At the present time large areas on both the north and the south sides of the river in the eastern section are under plow and are devoted to the growing of grain by dry-farming methods. There is some irrigation, notably in Umatilla and Morrow Counties, in which the Umatilla project of the United States Bureau of Reclamation is located. There are also some locally managed irrigation projects along Umatilla, Deschutes, and Hood Rivers. As a rule the productive lands lie back several miles from the Columbia, and for this reason all of the larger towns above The Dalles are away from the river. Below The Dalles, scattering timber prevails. The eastern sections ends in the two fruit-growing valleys, Hood River on the south and White Salmon on the north, which lie sheltered from the cold east winds behind the foothill ridges of the mountain range.

16. The principal tributaries in the eastern section, named in order downstream, together with the area in the drainage basin of each, are as shown in following tabulation:

	<i>Square miles</i>
Walla Walla River, Oreg.-Wash.....	1,500
Umatilla River, Oreg.....	2,160
Willow Creek, Oreg.....	910
John Day River, Oreg.....	7,940
Deschutes River, Oreg.....	9,180
Klickitat River, Wash.....	1,150
Hood River, Oreg.....	366
White Salmon River, Wash.....	384

17. The second section (1,000 square miles), that through the Cascade Range, is taken as including the portion of the river between White Salmon and Hood Rivers on the east and Bridal Veil, Oreg., or Cape Horn, Wash., on the west, a distance of 40 miles. In this distance the river cuts squarely across the axis of the range of mountains. The terrain on both banks is rugged in the extreme. Rainfall is heavy in this section.

18. The principal tributary in this section is Wind River, which enters Columbia River from the north about 12 miles below White Salmon River. The drainage area of this and of the other tributary streams in this section is small.

19. The western and lower section of Columbia River drainage area (18,500 square miles), which reaches from the Cascade Range to the sea, a distance of about 137 miles, cuts the Coast Range of mountains just before entering the Pacific Ocean. It flows through a valley that is for the most part narrow but widens where tributaries debouch. The principal tributaries in this section, named in order downstream, together with the drainage area of each are:

	<i>Square miles</i>
Sandy River, Oreg.	480
Willamette River, Oreg.	11, 200
Lewis River, Wash.	1, 050
Cowlitz River, Wash.	2, 490

Numerous shorter tributaries drain the hilly country adjacent to the river.

20. Except for the main floor of Willamette Valley, which is comparatively level, and the valleys of some of its principal tributaries, the drainage basin of this western section of the Columbia is rolling and hilly. It has a comparatively heavy precipitation and originally was covered in large part with dense forests. Logging operations and clearing for home sites have greatly reduced the forests. However, much of the logged-off land that is not suited to agriculture is producing or can be made to produce successive forest growth.

21. Along the Columbia, below the mouth of Willamette River, are numerous bottom lands which are normally above water level but are subject to inundation during freshets. These areas are very fertile and in large part are under cultivation. To protect them from floods diking districts have been organized and dikes, or levees, have been constructed. These areas are discussed in more detail in this report in connection with flood control.

22. Willamette Basin, 11,200 square miles in area, extends southward over half way to the California boundary. It is an extensive agricultural valley bounded by the Cascade Range on the east and the Coast Range on the west. The annual precipitation varies from 30 inches on the low lands to over 130 inches in the mountains. West of the Coast Range drainage is toward the Pacific Ocean.

23. The flood plain of the western section of the lower Columbia is narrow, generally less than 5 miles in total width, of which 2 miles, more or less, is occupied by the channel proper and the remainder by low bench lands, bottom lands, marshes, and sand bars. Numerous low wooded islands occur in the lower 35 miles. The river is estuarial in character in the lower 28 miles of its course. An extreme width of 7 miles is found near Astoria, Oreg. This port is 11 miles from North Head, which is near Cape Disappointment, a landmark on the Pacific Ocean at the river mouth.

(B) GEOLOGY

24. Columbia River below mouth of Snake River, on its course to the sea, cuts through the Cascade and Coast Ranges of mountains. From the mouth of the Snake to Cascade Range it traverses the Great Columbia Lava Plateau region, and between the Cascade and Coast Ranges it traverses an area of intervening lowland of which Willamette Valley in Oregon and Cowlitz Valley in Washington comprise a part. A view of the general geology of this part of its watershed may be presented, therefore, by referring briefly to a succession of provinces or divisions based on these features of the topography of the region which the river traverses.

25. *Coast Range*.—The Coast Range of mountains, where cut by Columbia River, and both north and south to the limits of its drainage, consists of a series of low folds in strata of Tertiary age. The rocks are marine shales and sandstones, and gradations between these two, and great thicknesses of basaltic lava with a lesser amount of volcanic tuffs and agglomerates. These volcanics occur as intercalated flows of varying extent, dikes, sills, and some intrusive masses. Flat-lying beds of gravels, sands, and clays of probably Quaternary age cling as terraces along the ocean slopes of the range, and sediments of equivalent age and position occur in the interior valleys.

26. *Interior Valley*.—To the eastward of the Coast Range these same Tertiary beds with their associated volcanic rocks drop beneath and form the floor of the broad Willamette-Cowlitz Valley depression, and in general rise again in or pass beneath the uplifted structure of the Cascade Range beyond. This down-warping of the rock strata as a structural feature probably extends northward to connect with the Puget Sound Basin; the cross-cutting of the Columbia having, however, severed it into the two parts which now drain to the Columbia from opposite directions. In places at the easterly side of this valley surface features suggest the probable existence of a north-south line of faulting to account for some of the more abrupt topography along the front of the Cascade Range. Faulting has also occurred to an important extent in these rocks in parts of the Coast Range.

27. The floor of this extensive valley depression is covered quite generally by alluvial and eolian materials, through which rise occasional hills of the more resistant underlying sedimentary and volcanic rocks. The western portion of the city of Portland is built against and upon such an uplifted high ridge of basalt which parallels Willamette River for 20 miles, and up-standing basalt layers are the cause of the falls in this river at Oregon City.

28. *Cascade Range*.—A complete cross section in which is displayed the composition and anticlinal structure of the Cascade Range of mountains is afforded in the walls of the spectacular gorge which the Columbia River has made directly across this range. Two to three thousand feet or more of the Columbia basalt flows are involved in the main uplift. The lava layers of this formation in the canyon walls rise from the westward or down-river side and in a wide-spreading arch lower again beneath the easterly slopes of the range. Two accessory arches in the basalt, of lesser magnitude, appear in the gorge to the eastward of the main uplift.

29. This huge body of lava is made up of dozens of individual flows. Being of wide extent it is termed the Columbia lava formation, and is considered upper Miocene Tertiary in age. Underneath the main arch of the Columbia Lava, several hundred feet of the earlier Eagle Creek formation of Oligocene age are exposed in the center of the range in the vicinity of Cascade Locks. It is composed of bouldery agglomerate, tuffs, gravels, ash and ashy clays or shales, sandstone and some lava.

30. A cross section of this range shows also hundreds of feet of later lavas, tuff and agglomerate above the main basalt formation, much or all of these having been erupted through vents whose locations are indicated today by the array of volcanic peaks along its summit. Its height has been greatly added to by the piling up of these later volcanic out-pourings. The alinement of the present day peaks and craters which mark the range crest suggests the possibility of their positions being determined by a north-south line or zone of shear faulting, though evidence of such a belt of weakness is not positively recognized in the Columbia gorge where the structure of the range is fairly well laid bare from its summit to practically sea level.

31. Many of the smaller streams, which drain the westerly slopes of this range, have cut deep canyons through hundreds of feet of the younger volcanic rocks, and the larger streams have cut entirely through the basalts and into the older underlying formations. In the canyons of some of these streams, notably those of the Clackamas, of the Santiam, and of the McKenzie, in the headwater branches of the Willamette itself, and in Washington, those of the Cowlitz and the Lewis, are occasionally intrusive bodies of more acid and semi-crystalline rocks, where mineral veins and some bodies of ore have been found.

32. *Columbia Plateau.*—On up the Columbia and beyond the Cascade Range the basalt flows of the Columbia lava formation flatten out, but continue in a series of lesser undulations, beneath hundreds of square miles in eastern Oregon and Washington, and on into Idaho. This region may be referred to as the Columbia Plateau province. Columbia River has eroded a canyon of varying depth into this plateau, but at no place, from the center of its gorge in the axis of the Cascade Range to where joined by Snake River well toward the south-eastern corner of Washington, has it opened to view any older or underlying rocks. The bed of its channel and the side walls of its canyon are throughout this 170-mile stretch entirely of layers of hard jointed basalt.

33. Owing to the differential warping which it has undergone, and doubtless also to the former irregularities of the surface on which the lava flows originally came to rest, this series of basalt layers has, however, been severed to its base and subjacent formations exposed in the canyons of some of its larger tributary streams. Deschutes River is closest to and runs parallel with the eastern base of the Cascade Range in Oregon for more than 150 miles. This river flows for most of its length in a precipitous canyon cut in the Columbia Lava and in more recent overlying flows and fragmental volcanic beds. Midway of its length, however, it has exposed several hundred feet of the underlying John Day tuffs and clays, and the scraggy lavas

and tuffs of the still older Eocene Clarno formations. These are in equivalent stratigraphic position to Eagle Creek beds found in the center of the range, but quite different in character from them. Crooked River, a tributary of the Deschutes, which takes its rise far to the eastward in the slopes of the Blue Mountain uplift, flows in all of its lower course through a canyon cut likewise in the basalt and more recent beds; but in its headwater regions has uncovered both earlier Tertiary rocks and considerable areas of Paleozoic sedimentaries, limestone, sandstone, and shales.

34. John Day River also enters the Columbia from the Oregon side, about 17 miles upstream from the mouth of the Deschutes, and like the latter traverses a deep precipitous basalt-walled parallel canyon for 50 to 60 miles before joining the Columbia. Midway of its length it too has uncovered large areas of varicolored Oligocene tuffs and clays, and of Eocene tuffs, agglomerates and more acid lavas which are below the basalt flows. Later deposits of gravels, ash and some rhyolitic lavas overlie the basalt in places.

35. The watershed of John Day River reaches far back to the south-eastward into the westerly slopes of the Blue Mountain region. Its headwater streams have not only cut deeply everywhere through Columbia basalt, but have disclosed within this drainage area, in addition to bodies of intrusive granitoid rocks which have been the provocation of many zones of mineralization, a variety of metamorphic rocks, schists, serpentine, quartzite and marble, and sedimentary sandstones, shales, conglomerate, and limestone, in age from pre-Paleozoic to Tertiary.

36. It should be stated that geologically the elevated Blue Mountain region of northeastern Oregon is an area in which the older rocks, including Blue Mountain granite batholith, have been uncovered and now protrude above the lavas of the surrounding Columbia Plateau. This region has an extensive area and the streams flow westwardly to the Columbia, or north and easterly into the Snake which encircles its base in those directions. In it are located the principal mining districts of eastern Oregon.

37. Still within the Plateau province, in which Columbia basalt dominates the topography as well as the underground structure, the next large river to enter the Columbia beyond the John Day, is Snake River, whose confluence is just above the Oregon line in southeastern Washington. Umatilla and Walla Walla Rivers, and a few others of lesser size heading in the Blue Mountains slope, flow in canyons cut in the basalt, as does the Snake also for the first 150 miles above its mouth. The underlying granitic bedrock shows at but one place, in this distance, Granite Point on Snake River, and extends to the Idaho-Washington State line.

38. Drainage from the portions of the Plateau to the north and northeastward of this part of Snake River is mainly by way of Palouse River, whose canyon is cut in Columbia lava, but whose head-streams originate far up in the granitic and metamorphic belt of Central Idaho. To the southward and within the sweeping curve made by this part of its canyon, the slope of the adjacent plateau country conforms to the inclination of the underlying basalt flows and rises with them into the main heights of the Blue Mountain region of northeastern Oregon.

(C) TOPOGRAPHY

I. GENERAL

39. Most of the portion of the Columbia's basin that is south of the international boundary and east of the Cascade range of mountains, is within what has been called the great Columbia Lava Plateau. This plateau is some 250,000 square miles in extent and embraces most of eastern Oregon, southeastern Washington, Snake River Valley in southern Idaho, and a small portion of northern Nevada. The elevation of most of this plateau ranges from 1,000 to 4,000 feet above sea level, though in southeastern Oregon there are areas with elevations in excess of 5,000 feet. Rising out of this plateau in northeastern Oregon, and extending into the southern edge of Washington, are the Blue Mountains, whose higher peaks rise to elevations in excess of 6,000 feet. This plateau region is semi-arid in character and generally devoid of timber, but contains large areas covered with sage brush and other desert vegetation. The Blue Mountains, however, are in large part heavily forested with coniferous trees. Portions of the basin east of the Cascades that are outside of this extensive lava plateau are generally mountainous. They embrace the Salmon River Mountains in central Idaho, the Bitter Root Range which defines most of the boundary between Idaho and Montana, and the mountainous area along the international boundary between the Rockies in Montana and the Cascade Range in Washington. These mountainous areas rise to heights of over 7,000 feet in Idaho and Montana, and to over 3,000 feet in northern Washington. They are in general heavily timbered, as is also the Cascade Range in Oregon and Washington.

40. The valleys of most of the tributary streams are, as a rule, narrow and canyonlike, exceptions being the valleys of the upper Snake and lower Yakima Rivers. These two rivers pass through broad plains having elevations of from 30 to 300 feet above the adjacent stream beds. There are practically no flood plains along the Columbia or its tributaries in the basin east of the Cascades. The bottom lands usually consist of comparatively narrow strips through which the rivers course their ways. Except in the vicinity of the mouths of its principal tributary streams, and more particularly the Yakima, Snake, and Umatilla, where broad, gentle slopes border these streams, the canyon of the Columbia east of the Cascade Range is generally from 2 to 5 miles in width. Its walls rise from a few hundred feet to as much as 2,500 feet above the river bed.

41. There is a wide variation in the nature of the slopes that define the canyon walls, consisting more or less of gently rising rolling hills covered with sage brush, or a succession of steep basaltic cliffs, which rise in a series of terraces, the so-called "rim-rock" bluffs of Columbia Lava Plateau region.

42. The Columbia flows in a narrow gorge directly across the axis of the heavily timbered Cascade Mountain Range. This gorge has a width varying from 1 to 2 miles from rim to rim. The precipitous slopes and cliffs rise in many places to heights of over 3,000 feet above the channel.

43. The basin west of the Cascades presents a marked contrast with the plateau region to the east. Rainfall is more abundant, and

originally a heavy stand of timber extended to the coast line of the Pacific.

44. Tide-water is reached at Warrendale, about 140 miles from the sea. Here the canyon widens to an average of about 5 miles between basaltic cliffs. The stream itself also widens and is bordered by intermittent extensive lowlands that are overflowed during flood periods. Aside from the valleys of the tributary streams, and more particularly the broad fertile valley of the Willamette, which is the main tributary west of Cascade Range, the drainage basin of the Columbia from here to the ocean is generally mountainous in character.

45. The lava walls of the canyon approach to within 3 miles of each other, at a point about 28 miles above the river's mouth. Below this point where the stream widens into a tidal estuary the valley spreads out to a width of from 5 to 7 miles. In the lower 25 miles of its course the river passes through the Coast Range of mountains. The higher parts of these mountains, adjacent to the river, are from 1,000 to 3,000 feet in elevation. The Columbia enters the Pacific between a sandy peninsula on the Oregon side and a low rocky headland on the north or Washington shore.

2. RIVER PROFILE

46. The profile of Columbia River between mouth of Snake River and Pacific Ocean may be considered as made up of 3 long sections having comparatively even slopes and 2 short sections in which falls or abrupt rapids occur. For convenience of presentation, the 3 long stretches are here designated the upper, middle, and lower sections.

47. The upper section extends from mouth of Snake River to head of Celilo Falls, a distance of 124 miles, in which, at time of low water, there is a fall of 184.5 feet. Of this fall 86.1 feet is concentrated in 16 rapids having an aggregate length of 19 miles. The slope in these rapids is from 3 to 8.3 feet per mile. The average slope at low water over the reaches between rapids is 0.93 feet per mile.

48. Between the upper and middle sections there is a fall of 81 feet at low water. This fall, for the most part, is concentrated in Celilo Falls, at the head of this stretch, and in the following rapids, named in order down stream: Ten Mile Rapids, Five Mile Rapids, and Three Mile Rapids.

49. The middle section extends from foot of Three Mile Rapids, about $1\frac{1}{2}$ miles above The Dalles, Oreg., to head of Cascades Rapids. The fall in this stretch, at low water, is only 4 feet in a distance of 43 miles.

50. Between the middle and lower sections the river has a fall, at low water, of 37 feet in a distance of about 7 miles, terminating at head of tidal reach at Warrendale, Oreg. Of this 37 feet 25 feet is concentrated in a distance of about 3,000 feet through Cascades Rapids proper and the remaining 12 feet occurs in the gorge below. The fall of 12 feet through the gorge does not occur as a uniform slope, but is broken at two places, namely, Summit Rapids, about three fourths of a mile below foot of Cascades Rapids, and Bonneville Rapids, at foot of Bradford Island, $3\frac{1}{4}$ miles below Summit Rapids.

51. The lower section extends from head of tidal reach at Warrendale, Oreg., a distance of 140 miles to the Pacific Ocean. The tides

reverse the current at very low stages of river to a point a few miles above St. Helen, Wash., about 90 miles from the sea.

3. ARABLE LANDS

52. The approximate area of Columbia River Basin below the mouth of the Snake is 29,669,000 acres. The arable portion totals about 5,300,000 acres, of which about 2,500,000 acres are in cultivation. The arable lands may be grouped under the classes:

(1) Irrigable.....	Irrigated and not irrigated.
(2) Humid.....	Cropped and idle.
(3) Dry-farming lands.....	Do.
(4) Overflow lands.....	Do.

53. The main part of the irrigable lands lie in the arid and semi-arid portions of the States east of the Cascade Mountains. Without irrigation, these areas are generally nonproductive, although portions at higher elevations above sea level are capable of producing crops each alternate year under dry-farming methods.

54. Most of the humid areas are found west of the Cascade Range. These areas are generally successfully farmed, although in some districts the most efficient production can be realized only by the use of supplemental irrigation during the late summer.

55. Dry-farming lands lie wholly east of the Cascades. These areas are devoted to grain production and are cropped during alternate years. About half of the idle arable lands of the basin belong to this group. Dry-farming lands usually are too high in elevation for the application of irrigation water, although some of the lower portions of the areas are included in possible irrigation projects.

56. Overflow lands are found adjacent to Columbia and Willamette Rivers in their lower reaches, and on islands in both rivers. About 119 square miles of such lands have been reclaimed by protective dikes. (See pars. 1095 to 1108 of this report.)

57. The tabulation following summarizes the various classes of arable land in the Columbia Basin below the mouth of the Snake.

Summary—Arable lands in Columbia Basin below Pasco

	Oregon	Washing- ton	Total	Grand total
Cropped:	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	
Humid.....	919,664	127,257	1,046,921	
Dry farmed.....	808,257	320,329	1,227,586	
Irrigated.....	240,704	36,584	277,288	
	2,058,625	493,170	2,551,795
Idle:				
Humid.....	384,122	45,344	429,466	
Dry farming.....	924,595	330,971	1,255,566	
Irrigable.....	688,220	369,491	1,057,711	
	1,996,937	745,806	2,742,743
Total arable.....	1,996,937	745,806	5,294,538

¹ Includes 115,000 acres overflow lands along lower Columbia and Willamette Rivers.

58. The figures in the above tabulation are the result of estimates made for the various counties in the basin, based on field examinations of the greater part of the areas, supplemented by available published

statistics. Acreage cropped and capable of being cropped without irrigation were obtained from the 1930 census of the United States Department of Commerce. The figures for irrigable acreage are given in paragraph 1154 of this report. Lands west of the Cascades for which supplementary irrigation may be desirable are not included in the estimate of irrigable lands as they appear in the cropped land estimate. Overflow lands are included in the irrigable area. Estimates for the counties appear in table 1-A and 1-B following:

TABLE 1.—Arable lands of Columbia Basin below the mouth of Snake River (acres)

A.—OREGON

County	Approximate gross area of counties in basin	Arable lands							Grand total	
		Cropped				Idle				
		Hu-mid	Dry farmed	Irrigated	Total cropped	Hu-mid	Dry farmed	Irrigable		Total idle
Umatilla	2,050,000	0	281,561	56,423	337,984	0	273,377	126,000	399,377	737,361
Grant	2,350,000	0	6,335	47,000	53,335	0	22,674	20,000	42,674	96,009
Morrow	1,296,000	0	149,948	10,200	160,148	0	165,288	154,000	319,288	479,436
Gilliam	768,600	0	137,871	3,300	141,171	0	120,113	35,000	155,113	296,284
Wheeler	1,090,600	0	13,254	10,193	23,447	0	33,031	3,000	36,031	59,478
Sherman	535,000	0	140,908	300	141,208	0	145,371	0	145,371	286,579
Wasco	1,499,500	0	99,726	5,803	105,529	0	101,086	11,000	112,086	217,615
Jefferson	1,138,600	0	56,998	5,207	62,205	0	51,777	126,398	178,173	240,378
Crook	1,877,800	0	11,656	30,382	42,038	0	11,878	42,124	54,002	96,040
Deschutes	1,800,000	0	0	44,528	44,528	0	0	74,721	74,721	119,249
Klamath	384,000	0	0	75	75	0	0	13,083	13,083	13,158
Hood River	345,600	1,000	0	22,933	23,933	3,707	0	10,896	14,603	38,536
Multnomah	277,800	27,152	0	75	27,227	11,459	0	27,000	38,459	65,686
Clackamas	1,195,500	100,713	0	1,000	101,713	23,143	0	0	23,143	124,856
Marion	763,500	102,982	0	3,000	165,982	58,616	0	0	58,616	224,598
Linn	1,445,100	147,772	0	0	147,772	107,277	0	0	107,277	255,049
Lane	2,200,000	79,715	0	285	80,000	55,000	0	0	55,000	135,000
Columbia	275,000	14,200	0	0	14,200	5,250	0	121,000	26,250	40,450
Washington	425,000	114,684	0	0	114,684	15,408	0	0	15,408	130,092
Yamhill	432,000	112,208	0	0	112,208	28,441	0	0	28,441	140,649
Polk	400,000	100,688	0	0	100,688	32,961	0	0	32,961	133,649
Benton	360,000	54,000	0	0	54,000	39,800	0	0	39,800	93,800
Clatsop	290,000	4,550	0	0	4,550	3,060	0	124,000	27,060	31,610
Various ²	100,000	0	0	0	0	0	0	0	0	0
Total	23,299,600	919,664	898,257	240,704	2,058,625	384,122	924,595	688,220	1,996,937	4,055,562

¹ Overflow lands.² Douglas, Tillamook, Lincoln, Union, and Wallowa Counties.

B.—WASHINGTON

Columbia	250,000	0	47,000	500	47,500	0	43,700	500	44,200	91,700
Walla Walla	600,000	0	153,500	27,500	181,000	0	182,000	50,000	232,000	413,000
Benton	485,000	0	28,000	2,000	30,000	0	20,000	210,000	230,000	260,000
Yakima	485,000	0	6,000	0	6,000	0	7,200	0	7,200	13,200
Klickitat	1,125,000	0	94,829	6,500	101,329	0	78,071	60,991	139,062	240,391
Skamania	1,078,400	4,112	0	84	4,196	1,299	0	5,000	6,299	10,495
Pierce	46,000	0	0	0	0	0	0	0	0	0
Lewis	925,000	36,000	0	0	36,000	12,660	0	0	12,660	48,660
Cowlitz	737,900	16,566	0	0	16,566	10,364	0	13,000	23,364	39,930
Clarke	405,800	65,379	0	0	65,379	15,055	0	20,000	35,055	100,434
Wahkiakum	170,900	4,500	0	0	4,500	5,310	0	4,000	11,310	15,810
Pacific	60,000	700	0	0	700	650	0	4,000	4,650	5,350
Total	6,369,000	127,257	329,329	36,584	493,170	45,344	330,971	369,491	745,806	1,238,976

¹ Overflow lands.

(D) CLIMATE

1. GENERAL

59. Columbia Basin, below the mouth of the Snake, presents unusual extremes in precipitation, temperature, and growing season. The precipitation ranges from a yearly average of 7 inches at Kennewick, Wash., near the mouth of the Snake, to probably 150 inches on the summit of the Coast Range west of Portland, Oreg. Temperatures range from 40° Fahrenheit below zero to 120° above. The average number of days between the last day of frost in the spring and the first frost in the fall varies from less than 80 days in some sections to over 280 days in others.

2. PRECIPITATION

60. The eastern portion of Columbia Basin below Snake River is semiarid and the precipitation is low, averaging less than 15 inches a year on the agricultural sections. Along the summit of the Blue Mountains, which lie in the southeastern part of this section, the annual precipitation varies from 30 to 45 inches, but the area affected is small.

61. Along the summit of the Cascade range, which dominates the central portion of the basin, the annual precipitation varies from 70 to over 100 inches. This precipitation decreases rapidly on the east slopes to an average of about 20 inches at the foot of the range and gradually on the west slopes to an average of about 40 inches.

62. In the western portion of the area in the Willamette Basin, the precipitation averages approximately 40 inches in the valley proper. To the west it gradually increases until, along the summit of the Coast Range, it varies from 70 to an estimated maximum annual average of 150 inches. To the west of the Cascades, north of the Columbia in Washington, the average precipitation is greater than for the Willamette Valley. This appears due to the character of the topography, the area being much more broken up and rugged and the valleys much smaller and narrower.

63. Plate 3² shows the distribution of precipitation over the lower Columbia Basin. This chart was prepared from published records of the United States Weather Bureau for all stations which have been maintained within and immediately adjacent to the basin, and illustrates the distinctive features previously mentioned.

64. The United States Weather Bureau maintains only a few stations at or near the summit of the mountains. For this reason the actual annual precipitation at higher altitudes is more or less uncertain. On the other hand many stations have been, or are now, maintained on the lower slopes and in the valleys, and these records furnish sufficient data to show the precipitation distribution prevailing in areas where agriculture is or may be followed. Table 1 of appendix B, page 1751, gives a list of all stations within the lower Columbia Basin for which precipitation records have been published by the United States Weather Bureau. These stations have, for ready comparison, been listed under the tributary drainage basins in which they are located or to which they are immediately adjacent and applicable.

65. About 30 to 40 percent of the annual precipitation east of the Cascades occurs during the 5 months from May to September,

² Not printed.

inclusive. The summer rainfall is nearly all in the form of heavy showers of short duration. Over small areas these showers frequently reach the intensity of cloudbursts. West of the Cascades heavy summer showers are also of common occurrence, but the total yearly precipitation is so much greater than in the area to the east that the same 5 months produce only about 20 percent of the yearly total. Plate 4² shows graphically the seasonal distribution of precipitation and the average frost-free periods at 16 Weather Bureau stations within the basin. These stations have been selected to illustrate typical precipitation conditions on the agricultural areas within Columbia Basin below the mouth of the Snake.

66. Table 2 of appendix B, page 1755, gives the seasonal distribution of precipitation for the above 16 stations in tabular form, and table 3, paragraph 72, gives general climatological data for the same stations. Table 2 below gives the seasonal distribution of precipitation for five stations typical of conditions within the lower Columbia Basin.

67. Kennewick, Wash., near the mouth of Snake River, has the least, and Glenora, Oreg., on the west slope of the Coast Range, has the greatest average annual precipitation of which there is any record. The latter station is just outside of the lower Columbia drainage area, but the record is of interest as showing the probable precipitation at the summit of the Coast Range. The record for Pendleton is typical of the distribution east of the Cascades. The record for Albany shows conditions in Willamette Valley, while the record for Castle Rock is representative of the seasonal distribution north of the Columbia and west of the Cascades.

TABLE 2.—Average monthly precipitation in inches

[United States Weather Bureau records]

Station	Kennewick, Wash.	Glenora, Oreg.	Pendleton, Oreg.	Albany, Oreg.	Castle Rock, Wash.
Elevation (feet above sea level).....	370	575	1100	212	59
Period of record.....	1884-1930	1892-1918	1890-1930	1879-1930	1917-30
Month:					
January.....	1.02	19.59	1.70	6.64	8.38
February.....	.80	15.80	1.56	5.34	6.31
March.....	.49	12.56	1.39	4.12	5.68
April.....	.41	8.96	1.06	2.87	3.74
May.....	.46	5.92	1.31	2.24	2.81
June.....	.42	3.60	.98	1.31	1.63
July.....	.13	1.29	.42	.39	.49
August.....	.25	1.34	.51	.54	1.29
September.....	.38	5.71	.89	1.85	2.93
October.....	.53	9.30	1.12	3.06	4.32
November.....	1.03	25.15	1.58	6.32	6.85
December.....	1.05	22.33	1.62	6.85	9.37
Average yearly total.....	6.97	131.54	14.22	41.53	53.70

68. Snow falls over the whole basin, the range in total depth varying from an annual average of only 6 inches near the mouth of the Columbia to more than 325 inches at Government Camp on the Cascade Range. With a recorded depth of nearly 30 feet at Government

² Not printed.

Camp, which is at an elevation of only 3,879 feet above sea level, it is certain that greater depths may be expected at higher elevations. In the Willamette Valley the average annual depth of snow varies from 5 to 20 inches; in the Lewis and Cowlitz Valleys, from 12 to 36 inches, and east of the Cascades, along the river bench lands and plateau regions under 5,000 feet in elevation, from 15 to 70 inches.

3. TEMPERATURE

69. East of the Cascade Range temperatures vary from 40° F. below zero to 120° above, although both extremes are unusual. The periods of low temperature are of longer duration than in the area of milder climate west of the Cascades.

70. The number of days between frosts varies from over 200 days for the lower bench lands lying along the Columbia River between the John Day and Snake Rivers to less than 80 days in the upper bench lands at elevation of from 3,500 to 4,500 feet above sea level. At Bend, in the plateau region of the Deschutes Basin, elevation 3,629, the average number of days between frosts over a period of 23 years is only 75 days. West of the Cascades temperatures range from 24° below zero to 108° above. Temperatures of 15° and more below zero, however, are unusual. For charts showing periods of frost, see plate 4.

71. The growing season in the Willamette Basin varies from 150 to 250 days. On the Washington side the season is somewhat shorter, varying from 150 to 200 days, while along the lowlands of the Columbia, between Vancouver and the coast, the season varies from 200 to 280 days.

72. Table 3 gives a summary of climatological data for the 16 stations which have been selected as fairly representing conditions over the whole lower Columbia Basin.

TABLE 3.—*Climatological data for typical United States Weather Bureau stations within Lower Columbia Basin*

Station	County and State	Period of the record	Years of record	Elevation of station (feet above sea level)	Temperatures F.			Number of days with 0.01 inch or more of rain	Average yearly snow-fall in inches	Frost data						Average number of days between frosts
					Maximum	Mean	Minimum			Frost ends in spring			Frost begins in fall			
										Earliest	Average	Latest	Earliest	Average	Latest	
Kennewick	Benton County, Wash.	1894-1930	34	507	115	53.9	-29	51.0	13.8	Mar. 17	Apr. 19	May 18	Sept. 12	Oct. 15	Nov. 12	179
Walla Walla	Walla Walla County, Wash.	1886-1930	45	1,000	113	53.5	-17	107.0	23.6	Feb. 18	Apr. 1	May 9	Sept. 24	Nov. 4	Dec. 3	218
Umatilla	Umatilla County, Oreg.	1895-1930	30	340	115	54.2	-23	58.0	6.2	Feb. 17	Apr. 12	May 10	Sept. 12	Oct. 23	Dec. 10	194
Pendleton	1890-1930	40	1,100	119	51.9	-28	81.0	23.5	Mar. 31	May 3	June 24	Sept. 3	Oct. 5	Nov. 3	155	
Dayville	Grant County, Oreg.	1895-1930	35	2,200	111	50.2	-33	82.0	14.4	Apr. 13	May 16	July 21	Aug. 24	Sept. 26	Oct. 29	133
Condon	Gilliam County, Oreg.	1894-1930	25	2,884	111	47.1	-25	70.0	32.3	Apr. 22	May 28	July 3	Aug. 26	Sept. 27	Oct. 27	122
Bend ¹	Deschutes County, Oreg.	1901-1930	23	3,629	104	46.6	-25	70.0	39.2	Apr. 10	June 13	July 29	Aug. 14	Sept. 7	Oct. 27	86
The Dalles	Wasco County, Oreg.	1875-1930	55	96	115	52.9	-30	73.0	31.8	Mar. 3	Apr. 11	May 12	Sept. 24	Oct. 23	Nov. 16	195
Goldendale	Klickitat County, Wash.	1908-1930	22	1,000	109	48.5	-29	78.0	26.6	Apr. 21	May 19	June 12	Sept. 7	Oct. 4	Nov. 29	138
Wind River	Skamania County, Wash.	1910-1930	20	1,300	103	48.3	-13	152.0	94.2	May 3	May 15	June 3	Sept. 19	do.	do.	142
Cascade Locks	Hood River County, Oreg.	1891-1930	40	1,100	107	52.1	-9	150.0	36.3	Feb. 19	Apr. 6	May 20	Oct. 4	Nov. 12	Dec. 12	219
Portland	Multnomah County, Oreg.	1872-1930	59	57	104	53.2	-2	154.0	14.5	Jan. 25	Mar. 16	May 2	Oct. 13	Nov. 22	Dec. 25	251
Albany	Linn County, Oreg.	1887-1930	40	212	104	52.5	-15	142.0	9.5	Jan. 18	Apr. 3	May 31	Sept. 24	Nov. 1	Dec. 15	207
Yale	Cowlitz County, Wash.	1906-1918	13	375	104	50.9	+3	163.0	36.9	Mar. 29	Apr. 29	June 19	Sept. 23	Oct. 29	Dec. 8	182
Castle Rock	do.	1917-1930	13	80	105	51.4	-13	154.0	13.6	Apr. 8	May 1	June 7	Sept. 1	Oct. 19	Nov. 12	171
Astoria	Clatsop County, Oreg.	1883-1930	42	175	97	50.9	+10	187.0	5.8	Jan. 6	Mar. 7	May 30	Oct. 19	Dec. 10	No frost	278

¹ During 1903, freezing temperature every month.

(E) STREAM FLOW AND STORAGE

1. STREAM FLOW

73. *a. Main River.*—For a study of the flow of Columbia River below the mouth of the Snake records for two gaging stations on the Columbia are available. The records at Wenatchee, Wash., from May 1913 to October 1916, and at Vernita, Wash., from October 1916 to September 30, 1930, have been considered as a continuous record extending from May 1913 to September 30, 1930. The additional flow entering between Wenatchee and Vernita is so small that its effect on the main stream is negligible and no appreciable error results from combining these separate records. The other record is for The Dalles, Oreg. This is the longest continuous record available, covering the period from June 1878 to date.

74. During the above period of record the average daily discharge for the Columbia at The Dalles has been 202,400 second-feet. During this same period the maximum discharge occurred on June 6, 1894, and was equal to an average for the day of 1,160,000 second-feet. The minimum occurred January 18 and 21, 1930, on which days the average discharge was 40,000 second-feet.

75. Prior to the year 1920 the published low flows of the Columbia at The Dalles are subject to corrections as shown by a revised rating table on page 10 of United States Geological Survey, Water Supply Paper No. 554. These corrections apply only to flows under 100,000 second-feet. In 1929 modern gaging equipment was installed at this station, and observations made since then have necessitated a change in the discharge relation curve (rating curve) used since 1920. During 1930 it was possible to make discharge measurements at lower stages than previously and, therefore, more weight should be given the present curve insofar as low flows are concerned. Since the new rating curve falls between the one used previous to 1920 and the one used from 1920 to 1929 and as the errors involved are small, not exceeding 6 percent, the actual discharges as published in the several water-supply papers have been used without correction in the following discussion on stream flow and storage.

76. In addition to the two records of the main stream described in paragraph 73 there are available discharge records for all the principal tributaries. Several of these records, however, are of only a few years' duration.

TABLE 4.—*List of principal stream gaging stations below Wenatchee, Wash., and period of record*

Columbia River at Wenatchee, Wash., May 1913 to October 1916.
Columbia River at Vernita, Wash., October 1916 to October 1930.
Columbia River at The Dalles, Oreg., June 1878 to October 1930.
Yakima River at Kiona, Wash., August 1896 to March 1915.
Snake River at Riparia, Wash., October 1915 to October 1922; October 1928 to October 1930.
Snake River at Burbank, Wash., September 1909 to March 1917.
Walla Walla River near Milton, Wash., March 1903 to June 1906; April 1918 to October 1930.
Walla Walla River at Wallula, Wash., 1925 only.
Touchet River near Bolles, Wash., February 1924 to October 1930.
Umatilla River at Gibbon, Oreg., August 1896 to November 1911.
Umatilla River near Umatilla, Oreg., November 1903 to October 1930.
John Day River near Dayville, Oreg., December 1908 to October 1914; July 1920 to October 1921; April 1925 to October 1930.

- John Day River at McDonald, Oreg., December 1904 to October 1930.
 Deschutes River below Bend, Oreg., October 1914 to October 1930.
 Deschutes River at Moody, Oreg., October 1906 to October 1930.
 Crooked River near Culver, Oreg., October 1, 1917, to October 1930.
 Metolius River near Grandview, Oreg., October 1921 to October 1930.
 White River below Tygh Valley, Oreg., December 1917 to October 1930.
 Klickitat River near Glenwood, Wash., October 1909 to October 1920; October 1920 to October 1928, broken record; October 1928 to October 1930.
 Klickitat River near Klickitat, Wash., July 1909 to February 1912.
 Hood River at Powerdale, Oreg., April 1913 to October 1930.
 White Salmon near Underwood, Wash., March 1915 to October 1930.
 Sandy River below Bull Run River, near Bull Run, Oreg., October 1910 to February 1912; August 1912 to October 1915.
 Willamette River at Albany, Oreg., December 1878 to May 1880; February 1892 to October 1930.
 Willamette River at Salem, Oreg., October 1909 to October 1916; October 1927 to October 1930.
 Lewis River near Amboy, Wash., February 1911 to October 1930.
 Lewis River near Ariel, Wash., August 1923 to October 1930.
 Kalama River near Kalama, Wash., July 1901 to January 1912; December 1912 to October 1913; September 1916 to October 1930.
 Cowlitz River at Mossyrock, Wash., January to April 1912; January to July 1913; October 1913 to October 1917; April 1926 to October 1930.

77. Table 4 lists the principal stream gaging stations for which discharge records within the Columbia Basin below the mouth of Snake River have been published by the United States Geological Survey and gives the period of the respective records. The list includes the following stations which are not within the lower Columbia Basin: Columbia at Wenatchee-Vernita, the Yakima at Kiona, and the Snake at Burbank-Riparia.

78. The flow at The Dalles is affected by numerous diversions for irrigation above the gaging station. In order to show the effect of past and present irrigation on the probable natural run-off, correction has been made in accordance with table 5, which was prepared from information embodied in the unpublished report by Donald J. F. Calkins, assistant engineer, United States Geological Survey, on "Analysis and Computations to Determine Flow of Columbia River at Umatilla Rapids After Ultimate Irrigation Is in Effect." When this report was written in 1924 the area under irrigation was estimated at 3,711,000 acres. The present figure (1930) is 4,000,000 acres.

79. Table 5 shows that during the 6 months October to March, inclusive, irrigation has tended to increase the natural flow of the Columbia by the plus quantities which represent estimated return flow. The natural flow during the remaining 6 months has been decreased by the minus quantities which are the estimated amounts diverted for irrigation purposes less the return flow during these months.

The records indicate that irrigation has had a regulating effect upon the flow of the Columbia. During the months of average low discharge the flow has been increased and during months of average high discharge it has been decreased.

80. In order to compare the shorter record of the Columbia at Wenatchee-Vernita and the shorter records of tributaries with the longer record of the Columbia at The Dalles station, the yearly flow for The Dalles has been expressed in percentages of normal. (See table 6.) The term normal as used in the text or as shown on charts and in tables represents the average flow or average precipitation for the 33-year period 1894 to 1926, inclusive. This 33-year period in-

cludes the year of maximum discharge, 1894, and the year of minimum discharge, 1926, and may be considered as fairly representing average conditions. Also, the average flow for this period is nearly the same as the average for the 44-year period, 1883 to 1926. The 33-year period was adopted for convenience in making comparisons between flow and precipitation for the reason that although several Weather Bureau records are continuous for the 33-year period, only a few are continuous over the longer period of 44 years.

TABLE 5.—Effect of irrigation on flow of Columbia River at The Dalles, Oreg.

1 Month	2		3		4		5		6	
	Acre-feet	Second-feet	Acre-feet	Second-feet	Acre-feet	Second-feet	Acre-feet	Second-feet	Acre-feet	Second-feet
Period.....	1880-91	1891-1902	1902-13	1913-24	1930					
Acres irrigated.....	928,000	1,856,000	2,783,000	3,711,000	4,000,000					
October.....	+138,000	+2,240	+275,000	+4,470	+412,000	+6,700	+550,000	+8,950	+593,000	+9,650
November.....	+169,000	+2,840	+388,000	+5,680	+507,000	+8,510	+676,000	+11,360	+625,000	+10,500
December.....	+100,000	+1,650	+203,000	+3,260	+301,000	+4,900	+401,000	+6,520	+432,000	+7,000
January.....	+69,000	+1,120	+138,000	+2,240	+208,000	+3,330	+277,000	+4,500	+298,000	+4,850
February.....	+49,000	+880	+98,000	+1,770	+147,000	+2,650	+196,000	+3,530	+211,000	+3,800
March.....	+29,000	+470	+58,000	+940	+87,000	+1,420	+116,000	+1,890	+128,000	+2,040
April.....	+246,000	-4,130	-422,000	-8,260	-739,000	-12,400	-985,000	-16,700	-1,062,000	-17,800
May.....	-690,000	-8,620	-1,060,000	-17,250	-1,594,000	-25,900	-2,120,000	-34,500	-2,285,000	-37,200
June.....	-718,000	-12,100	-1,440,000	-24,200	-2,150,000	-36,200	-2,870,000	-48,300	-3,093,000	-52,000
July.....	-755,000	-12,550	-1,510,000	-24,500	-2,250,000	-36,800	-3,020,000	-49,100	-3,255,000	-52,900
August.....	-620,000	-10,160	-1,240,000	-20,200	-1,860,000	-30,300	-2,480,000	-40,300	-2,673,000	-43,500
September.....	-227,000	-3,820	-454,000	-7,640	-860,000	-11,400	-1,507,000	-22,550	-1,978,000	-30,000
Net yearly effect.....	-2,542,000	-3,511	-5,089,000	-7,029	-7,617,000	-10,521	-10,166,000	-14,041	-11,062,000	-15,280

NOTE.—To obtain estimated natural flow at The Dalles reverse the signs and add or subtract from recorded flow.

TABLE 6.—Observed and estimated natural run-off of Columbia River at The Dalles, Oreg.

[Run-off in acre-feet and in percent of normal]

Year ending Sept. 30—	Observed run-off		Estimated natural run-off		
	Acre-feet in millions	Percent of normal	Correction for irrigation in millions of acre-feet	Acre-feet in millions	Percent of normal
1	2	3	4	5	6
1879	175	121	1.2	176.2	115
1880	192	132	1.4	193.4	126
1881	183	126	1.6	184.6	120
1882	168	116	1.8	169.8	111
1883	154	106	2.0	156.0	102
1884	155	107	2.3	157.3	103
1885	155	107	2.5	157.5	103
1886	153	105	2.7	155.7	101
1887	189	130	3.0	192.0	125
1888	147	101	3.2	150.2	98
1889	96.9	67	3.5	100.4	65
1890	142	98	3.7	145.7	95
1891	120	83	3.9	123.9	81
1892	144	99	4.1	148.1	97
1893	159	109	4.4	163.4	106
1894	225	155	4.6	226	150
1895	140	97	4.9	144.9	95
1896	166	114	5.1	171.1	112
1897	176	121	5.3	181.3	118
1898	167	115	5.6	172.6	113
1899	170	117	5.8	175.8	115
1900	163	112	6.1	169.1	110
1901	158	109	6.3	164.3	107
1902	143	99	6.5	149.5	98
1903	153	105	6.7	159.7	104
1904	176	121	6.9	182.9	119
1905	101	70	7.1	108.1	71
1906	114	78	7.4	121.4	79
1907	166	114	7.6	173.6	113
1908	143	98	7.8	150.8	98
1909	139	96	8.1	147.1	96
1910	154	106	8.3	162.3	106
1911	136	94	8.6	144.6	94
1912	133	92	8.8	141.8	92
1913	154	106	9.0	163.0	106
1914	135	93	9.2	144.2	94
1915	106	73	9.5	115.5	75
1916	173	119	9.7	182.7	119
1917	151	104	10.0	161.0	105
1918	148	102	10.2	158.2	103
1919	124	85	10.3	134.3	88
1920	114	78	10.4	124.4	81
1921	167	115	10.5	177.5	116
1922	133	92	10.5	143.5	94
1923	130	90	10.6	140.6	92
1924	99.3	69	10.7	110.0	72
1925	146	100	10.8	156.8	102
1926	85.5	59	10.8	96.3	63
1927	149	103	10.9	159.9	104
1928	168	116	11.0	179.0	117
1929	93.2	64	11.1	104.3	68
1930	95.2	66	11.1	106.3	69
Average for period 1879-1930	146.7	101	-----	153.5	100
Normal year ¹	145.1	100	-----	153.3	100

¹ Normal run-off is the average run-off for the 33-year period 1894 to 1926, inclusive. Correction for irrigation is the amount by which observed flow should be increased to allow for losses due to irrigation demands, computed from table 5 of text.

81. Table 6 gives the observed yearly run-off of the Columbia at The Dalles in acre-feet and in percent of normal. Column 4 gives the estimated correction to be applied in order to obtain natural run-off; column 5 gives the estimated natural run-off in acre-feet; and column 6 the percent of normal for the natural run-off. Instead of making the correction for irrigation at intervals as shown in table 5, the correction has been prorated through the whole period of the record.

82. It will be noted that, with due allowance for possible errors in assumptions made in determining losses due to irrigation, the effect of the demands for this purpose is such that at the present time the average yearly natural run-off of the Columbia of 153,500,000 acre-feet is reduced by 11,100,000 acre-feet, or a little over 7 percent. This reduction of flow is, however, not a matter of serious concern as the yearly yield from the Columbia Basin is ample to take care of all requirements for navigation and with proper regulation will take care of all possible needs for future irrigation and navigation.

83. The percent of normal figures under columns 3 and 6 are used where it is necessary to extend short records of other streams in order to obtain a figure for the normal discharge for these streams. Column 3 is used for tributaries such as the Umatilla from which a large quantity of water is diverted for irrigation purposes, and column 6 for those streams where the flow is not materially affected by irrigation diversions, as in the case of the Willamette.

84. Plate 5² is a duration relation curve for the Columbia at The Dalles, Oreg. An additional duration relation curve and hydrographs for the Columbia will be found in connection with the subjects of navigation and power.

85. Plate 6² shows the relation between discharge and stage for the Columbia at The Dalles, Oreg.

86. Table 7 gives yearly precipitation in percent of normal for 14 Weather Bureau stations with long records. The stations are well distributed over the whole basin or immediately adjacent thereto and were selected in order to give a fair approximation of the precipitation characteristics for the basin. It will be noted that the year of precipitation has been taken as ending August 31 in order to be comparable with the run-off year ending September 30. The precipitation occurring during September is assumed as affecting the run-off after October 1.

87. Figure 2, plate 7,² shows graphically the average precipitation given in table 7 and the percent of normal run-off of the Columbia at The Dalles as given in table 6.

TABLE 7.—*Precipitation for typical stations within and adjacent to Columbia Basin*
 [In percent of normal for year ending Aug. 31. Compiled from records of the U. S. Weather Bureau]

Season ending Aug. 31	Astoria, Oreg.	Portland, Oreg.	Roseburg, Oreg.	Seattle, Wash.	The Dalles, Oreg.	Walla Walla, Wash.	Spokane, Wash.	Porthill, Idaho	Baker, Oreg.	Boise, Idaho	Winnemucca, Nev.	Salt Lake City, Utah	Yellowstone Park, Wyo.	Missoula, Mont.	Average of all stations
Elevation.....	175	57	510	125	96	1,000	1,943	1,665	3,471	2,739	4,344	4,408	6,200	3,025
1854.....					92										
1855.....	89														
1856.....	79														
1857.....	95														
1858.....	88				268										
1859.....	106														
1860.....	87				204										
1861.....	108				141										
1862.....	106				213										
1863.....	94				71										
1864.....	105														

² Not printed.