DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 253

WATER POWERS OF THE CASCADE RANGE

PART I.—SOUTHERN WASHINGTON

BY

JOHN C. STEVENS

PREPARED IN COOPERATION WITH THE STATE OF WASHINGTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
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WATER POWERS OF THE CASCADE RANGE.

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By J. C. Stevens.

INTRODUCTION.

Perhaps no area in the United States presents more favorable opportunities for water-power development than that traversed by the Cascade Range. The general elevation of the summit of the range is from 6,000 to 8,000 feet, and many of its peaks extend into the region of eternal snow. Among these peaks are Mount Baker (10,827 feet), Mount Rainier (14,363 feet), Mount St. Helens (9,750 feet), Mount Adams (12,307 feet), Mount Hood (11,225 feet), Mount Jefferson (10,300 feet), Mount McLaughlin or Pitt (9,760 feet), and Mount Shasta (14,380 feet). The streams draining this range have steep slopes and are fed during the low-water period by the many snow banks and glaciers that mantle the high peaks or by the liberal supplies of ground water. The precipitation on the area is abundant, although its distribution is by no means uniform. The streams possess the requisite properties of water-power development—rapid fall, abundant water, and comparative uniformity of flow; and the almost unlimited resources of timber, mines, and soil, as yet hardly touched, afford a promising market for these water powers and fixes for them a high potential value.

The primary source of rainfall in the Pacific States is evaporation from the Pacific Ocean, the water vapor being carried over the land by prevailing westerly winds. Whenever the moisture-laden air is cooled below the point of saturation, rain falls, and no precipitation can occur unless the air is thus cooled. The temperatures over the ocean are not nearly so variable as those over the land. In summer the land is relatively much warmer than the ocean, while in winter the reverse is true. Hence the general tendency is for the water vapor to be carried eastward over the mountains in summer and to

[a] This paper is the first of a proposed series dealing with the water powers of the streams flowing from the Cascade Range in Washington and Oregon. It is the intention to gather sufficient data each season to constitute the material for one unit of the report.

be precipitated on them in winter. Thus we have the wet and dry seasons.

When the air in its eastward course encounters the western slope of the mountain ranges it is deflected upward into regions of diminished pressure. The resulting adiabatic expansion cools the air and the water vapor is precipitated. Thus the rainfall on the windward side of the range is much greater than on the leeward side, while the maximum rainfall probably occurs just over the divide. The summit of the Coast Range receives about 150 inches of rainfall in a year and the Cascade Range about 100 inches. Only about 5 per cent of this falls during the summer months, so that during this period the streams draw upon water stored in the ground and in snow banks and glaciers during the previous winter. The low-water period therefore occurs just before the fall rains begin.

The area treated in this paper comprises the drainage basins of Klickitat, White Salmon, Little White Salmon, Lewis, and Toutle rivers and is located in the southern extremity of the Cascade Range in Washington. The broad crest of this portion of the divide lies wholly within the Columbia and Rainier national forests, within which all streams of the region have their sources.

Special investigations made on these streams during the season of 1909 form the basis for this report. Each of the streams investigated is considered in detail. Descriptions of the several drainage areas are given, together with profiles of the streams and principal tributaries,[a] discharge data, and a detailed compilation of the water powers capable of being developed at the average minimum stage. The report must be considered rather as an inventory of the latent power resources of this section than as an engineering report on feasible power projects. It is, however, based on engineering principles, and the present practices of water-power development have been given due consideration.

The field investigations were made by two parties of four men each, which were in the field from July 1 to October 1. One party, in charge of H. D. McGlashan, junior engineer, United States Geological Survey, made the surveys of Klickitat, White Salmon, and Little White Salmon rivers. The other, in charge of C. W. Harris, instructor in hydraulics, University of Washington, made the surveys of Lewis and Toutle rivers. Warren O. Harmon, Charles Leidl, F. W. Whalley, and C. F. Holmes, students at Washington State College, were employed as rodmen. A map and a profile of each stream were made and data were gathered as to the discharges at critical points in each drainage area. From these data the undeveloped water powers have been computed. Except for a

[a] Plans and profiles of each river surveyed are bound on stubs at the end of this volume.

200-horsepower plant at Husum, on White Salmon River, there are no developed powers on any of the above-named streams.

In presenting the power statistics the average minimum flow of the streams has been used. The average minimum may be defined as the mean discharge for the lowest week in each year, averaged for a succession of years, say ten. The absolute minimum in a ten-year cycle might be as low as a third or a fourth of the average minimum, but it would continue only for one or two days, possibly only for a few hours.

METHOD OF INVESTIGATION.

A brief outline of the plan followed in field work will convey some idea of the degree of accuracy obtained in the results.

Each party consisted of one chief, two rodmen, and one man as cook and packer, and was provided with four pack horses, two small tents, and the necessary camp equipment. The chief of party was also instrumentman.

All distances were determined by stadia and all elevations by vertical angles. Initial elevations were taken from railroad bench marks and reduced to United States Geological Survey datum by known equations. The upper portion of Klickitat River is included in the Mount Adams quadrangle, and elevations were adjusted to agree with a line of United States Geological Survey bench marks following the upper course of the stream. The datum of the survey was taken from the Spokane, Portland and Seattle Railway crossing of Klickitat River near Lyle.

Klickitat and Lewis river surveys were made by azimuth control, meridian being obtained by direct solar observations. On the other streams magnetic control was used, permitting much more rapid but not so accurate work. In portions of the area where land surveys have been made frequent ties to section corners were possible; hence the necessity for refined control is not so great. If it were not for local variation in the vicinity of lava beds and basaltic areas magnetic control would have been used altogether.

The plan was to follow the river as closely as possible and take sufficient "shots" on the water surface to define the course of the streams with reference to land lines and determine the general grade of the water surface, small undulations of the water grade being disregarded. In many places it was impossible to follow the river closely on account of nearly vertical canyon walls, or dense underbrush, or both. In such places the survey followed the lines of least resistance, making side lines to the river at frequent intervals. In some portions an apparently impassable stretch was surveyed by wading up the stream, if not too deep, or by following the water's edge closely with a rodman on each side and wading across on riffles where necessary. The average run per day for all working days in the season was 1.5 miles for each party, but runs of 6 or 7 miles in a day were occasionally made.

At selected points gages were installed and discharge measurements made. Wherever a local resident was available he was employed to keep a daily record of gage heights. In this manner it was possible to determine the minimum flow for the season. Then by comparing the determined minimum flow for 1909 with that of other years on streams where longer records of discharge were available, some idea of the relative value of 1909 records in a cycle of years was obtained.

No systematic records of stream flow had previously been kept by the United States Geological Survey on any of the streams of this region, but through courtesy of certain power and irrigation companies and private individuals a few gage records, somewhat scattered and interrupted, and a few discharge measurements were made available. These data have been used for comparison, and those that appear in the report are published with the consent of the persons supplying the information.

The total cost of the report ready for publication is analyzed in the following table:

Cost of water-power investigations in Washington, 1909.

River.	River profiles and topography.	Gaging discharge.	Drafting and compiling.	Total cost.	Miles surveyed.	Cost per mile.
Klickitat	$1,060.65	$86.50	$228.43	$1,375.58	81.2	$16.94
White Salmon	543.13	15.35	96.22	654.70	34.2	19.14
Little White Salmon	141.73	7.67	22.79	172.19	8.1	21.26
Lewis	1,097.23	50.00	182.86	1,330.09	65.0	20.46
Toutle	557.11	16.35	167.67	741.13	59.6	12.43
	3,399.85	175.87	697.97	4,273.69	248.1	17.11
Per cent of total	80	4	16	100		

SUMMARY OF RESULTS.

Klickitat River leads all others in this region in opportunities for water-power development. Seventy-three miles of the main river were surveyed with a range of 3,255 feet elevation. The river next in importance is the White Salmon, with a fall of 2,660 feet in 32 miles. Lewis River was surveyed for 51 miles, in which distance a fall of 1,495 feet was found. Toutle River is 54 miles long, the entire length being mapped. It has a fall of 3,153 feet. Little White Salmon River is of secondary importance. The discharge is low, but the stream has a steep grade, a fall of 1,285 feet being found in the 8 miles surveyed.

The following table gives a summary of the data obtained during the season of 1909 in this region. The total horsepower for the average minimum discharge of the streams as surveyed is 386,500.

Summary of water-power surveys.

Stream system.	Miles surveyed.	Total horsepower for average minimum discharge.
Klickitat	81.2	154,000
White Salmon	34.2	105,000
Little White Salmon	8.1	5,500
Lewis	65.0	78,000
Toutle	59.6	44,000
	248.1	386,500

It would probably be safe to add about 8,000 horsepower for small tributaries and portions of the main streams not surveyed, giving in round numbers 395,000 horsepower for the streams named above. The principal streams not surveyed in this region are Wind River, Washugal River, Salmon River, South Fork of Lewis River, Kalama River, South Fork of Toutle River, and Green River. The aggregate power on these streams at low stage is probably not over 30,000 horsepower, making a grand total for this entire area of 425,000 horsepower.

It has been estimated from very meager data that the total water power in the Columbia River basin will aggregate 10,500,000 horsepower at the average minimum stage of the rivers.[a] The possible water-power development of the region under discussion, therefore, is only 4 per cent of this total. At present the water-power plants in operation in the State of Washington have an aggregated rated capacity of about 81,000 horsepower, so that the possible development in this region is five times that already developed in the State.

COOPERATION AND ACKNOWLEDGMENTS.

In 1909 the legislature of Washington passed an act providing for state cooperation with the United States Geological Survey which reads in part as follows:

> In order to complete the topographic map of the State of Washington, and for the purpose of making more extensive stream measurements and otherwise investigating and determining the water supply of the State, there is hereby appropriated the sum of thirty thousand dollars, for cooperation with those branches of the United States Geological Survey engaged in this work. This appropriation, however, shall be contingent upon, and not become available unless the United States Government apportion an equal amount to be expended for similar purposes within the State. The Board of Geological Survey is hereby authorized and directed to enter into such agreements with the Director of the United States Geological Survey, as will insure that the said surveys and investigations be carried on in the most economical manner and that the maps and data be available for the use of the public as quickly as possible.

[a] Rept. Nat. Conservation Comm., Senate Doc. 676, 60th Cong. 2d sess., p. 169.

The money thus appropriated was met by an equal allotment from funds of the United States Geological Survey and divided, for the first year's work, as follows:

For topographic mapping:	
State	$10,000
Government	10,000
For water resources:	
State	5,000
Government	5,000

Expenditures for this report were made from the water-resources fund.

The State Board of Geological Survey, consisting of the governor, treasurer, secretary of state, and the presidents of the State University and State Agricultural College, represents the State in this cooperative work. The board elected Henry Landes, professor of geology at the State University, as state geologist and intrusted him with supervisory authority to represent the State in the details of these cooperative surveys. The field work was done and the report has been prepared by the United States Geological Survey.

The writer is indebted to Prof. Henry Landes, state geologist, for his hearty cooperation in all matters pertaining to the joint work in the State, of which the material gathered for this report is a part.

Acknowledgments are due to the following companies and individuals for heretofore unpublished stream-flow data and gage records and for cooperation in the maintenance of certain gaging stations: Portland Railway, Light, and Power Company, of Portland, Oreg.; William R. King, of Portland, Oreg., civil and hydraulic engineer; Klickitat Irrigation and Power Company, of Seattle, Wash.; H. L. Gilbert, of Portland, Oreg., civil and hydraulic engineer; Ham, Yearsley & Ryrie, of Spokane, Wash.

Acknowledgments are also due to Mr. Ralph Williamson, attorney for the United States Reclamation Service at North Yakima, for an abstract of the Washington laws relating to water filings.

CONDITIONS GOVERNING HYDRAULIC DEVELOPMENT.

From the standpoint of the public an answer to the question, "How much water power is there on a certain stream or in a certain territory?" is of great importance. In areas where great water powers are known to exist and public-service corporations are appropriating them as fast as or faster than a market for them grows, the interest of the public in their development becomes a paramount issue.

The long-distance transmission of electric energy has changed our perspective of this resource amazingly during the last ten years. A few years ago the use of water power was limited to the immediate locality where it was developed. Now a hydro-electric plant can serve the industrial and community needs of an area 200 miles or more from it. This fact makes water power a public utility. The natural laws that govern the development of hydro-electric powers and the social and industrial conditions that supply the market for them make consolidation and community of interest among those engaged in their operation inevitable. In the operation of power plants for public service it is of prime importance that continuity of service be assured. The natural conditions of stream flow make it almost impossible for a single plant depending on water power alone to insure continuous service. Hence the necessity that one company should operate several plants.

The requirements of power consumers are by no means uniform. They vary from hour to hour, from day to day, and with the seasons. This nonuniform consumption requires that a certain reserve be maintained at all times to meet "peak loads" during the day and for regular and extraordinary demands that arise from time to time. Hence even where one company operates several plants it is virtually required to maintain auxiliary steam plants to be used in connection with the water-power plants.

From the standpoint of the consumer also, whether an individual, a company, or a municipality, there is every advantage in having the sources of power under one administration. Efficiency in operation and economy in consumption therefore demand consolidation of interests. Such a consolidation, which makes for conservative and efficient use of the natural-power resources, should not be prevented. The public concern, therefore, must be aimed, not toward prevention of consolidation, but toward prevention of the harm to the public interest that might result from an unscrupulous administration of such a consolidation. The solution appears to lie in a wise legislative regulation of the manner in which power privileges shall be acquired and power plants maintained in order that the consumer shall be assured the necessary energy at a reasonable cost, consistent with a just and reasonable income on the investments by the power companies.

The factors that govern power development are three—(1) the volume of water available, (2) the fall through which this water can be utilized, (3) the market for the power when developed.

A project is feasible or not according as these factors are favorable. The market feature is, of course, independent of the other two and is subject to evolutionary laws. Therefore in a public inquiry such as that covered by this report it is necessary to consider only the physical features of discharge and fall, and to include all portions of a stream where such features make power development possible.

Yet a consistent regard must be had for practicability of development, and some standard of comparison must be adopted.

In developing power plants it is profitable to install power units for a much larger amount of power than that represented by the minimum flow of the stream, for it is always necessary to have auxiliary steam plants which can be used to tide over a period of shortage of water and are called on for the peak loads. The interest, depreciation, and maintenance charges of a steam plant must be carried in conjunction with the fixed charges on the water-power plant. Hence the excess of power capacity which it is profitable to install over that afforded by the stream in extreme low water will depend on the relative cost of steam and water power and on the peculiarities of the particular market served. This excess may vary from 50 to 300 per cent.

In presenting general power statistics it is impossible to estimate this excess, and all that can be done is to state the power for the average minimum discharge of the stream and the known fall. The theoretical power thus obtained is arbitrarily reduced 30 per cent to represent "brake" horsepower, or the power that could probably be delivered to the turbine shafts. Where special studies are made the figure so derived can be increased or reduced according to the exigencies of the case.

WATER LAWS OF WASHINGTON.

The water laws of Washington relate chiefly to the use of water for irrigation, mining, logging, and municipal supplies. As water power may be applied to the generation and transmission of electric energy for pumping water for irrigation it is likely that the general provisions in the irrigation statutes would be applicable. There is no rigid line of demarcation between the uses of water for any beneficial purposes. Many of the provisions, by inference, apply to its use for water power, but no specific laws relating to hydro-electric developments have been enacted, except that of granting the right of eminent domain to "all corporations that are now or that may hereafter be incorporated under the laws of this State, or of any State or Territory of the United States and doing business in this State, for the purpose of conveying water by ditches, flumes, pipe lines, tunnels, or any other means for the utilization of water power." [a]

> Any corporation authorized to do business in this State, which under the present laws of the State is authorized to condemn property for the purpose of generating and transmitting electrical power, * * * shall be deemed to be in respect of such purposes a public-service corporation. * * * Any such corporation shall have the right to sell electric light outside the limits of a municipality, and electric power both

[a] Pierce's Washington Code, 5155.

inside and outside such limits to private consumers. * * * In exercising the power of eminent domain for public purposes it shall not be an objection thereto that a portion of the electric current generated will be applied to private purposes, provided the principal uses intended are public.[a]

The use of the waters of this State for irrigation, mining, and manufacturing purposes shall be deemed a public use.[b]

The following is a summary of present Washington statute law relating to water rights, abridged from a summary of irrigation law prepared by Ralph B. Williamson, attorney, United States Reclamation Service. In the footnote references in this summary the first number given refers to Ballinger's "Code and statutes," the second number to Pierce's "Code and statutes."

APPROPRIATION AND ACQUIRING OF THE RIGHT.

The right to use the waters of the State may be acquired by appropriation, the first in time being the first in right.[c] Written notice must be posted near the point of intended storage or diversion, stating the amount, purpose, places of use and means of diversion or storage, and such notice must be filed with the county auditor of the county where the notice is posted for record within ten days.[d] All amounts must be multiples or fractions of a cubic foot per second of time.[e]

Construction of works.—An appropriator must begin construction of works within three months after posting of notice if use is by storage; if by diversion within six months, and must diligently prosecute them to completion,[f] compliance with which gives priority as of time notice was posted.[g] It would seem that actual construction of a ditch gives right to unappropriated waters at the time construction is begun for irrigation[h] and pumps may be used when the land can not be reached by gravity flow.[i] Head-gates of existing canals may be changed or extended on streams where naturally made necessary, subject to existing rights.[j]

Filing of maps.—Within ninety days after construction or enlargement of a canal, there must be filed with the county clerk of the county in which the head-gate is located, a map showing location of head-gate, route of ditch, legal subdivisions crossed and names of owners, with statement showing location of works, depth, width, and grade of ditch, its carrying capacity and time of commencement of the work. Such filing will give priority from date of commencement of the work; if after ninety days, only from date of filing of the map.[k]

Seepage and springs.—Water from seepage and springs is governed by the general laws, provided that a man on whose land such waters first appear has prior right thereto;[l] and a man whose lands have been thus irrigated by seepage, has priority as of time of use of seepage, if by natural cause he must construct ditch to source of seepage to irrigate the lands.[m] Same rule applies to artesian wells.[n]

Change of use.—The purpose of appropriation may be changed to any beneficial use without losing the priority of the original appropriation.[o]

Transfer.—The right to the use of water is not made appurtenant to land but is allowed to be transferred, like property, by deed.[p]

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[a] Chapter 159, Session Laws, 1907.
[b] Constitution, Art. XXI.
[c] Sec. 4091; sec. 5131.
[d] Sec. 4092; sec. 5132.
[e] Sec. 4090; sec. 8942.
[f] Sec. 4093; sec. 5133.
[g] Sec. 4094; sec. 5134.
[h] Sec. 4110; sec. 5825.
[i] Sec. 4113; sec. 5828.
[j] Sec. 4140; sec. 5855.
[k] Sec. 4141; sec. 5856.
[l] Sec. 4114; sec. 5829.
[m] Sec. 4115; sec. 5830.
[n] Sec. 4117; sec. 5832.
[o] Sec. 4099; sec. 5139.
[p] Sec. 4096; sec. 5136.

Surplus waters.—Riparian owners of lands on any stream are given the right to use any surplus or unappropriated waters.[a] Same privilege granted to nonriparian owner.[b]

Loss of rights.—It is provided that failure to comply with the requirements of the statutes deprives the appropriator of his priority against a subsequent appropriator.[c] Lack of diligence in construction forfeits rights.[d]

RIGHT OF WAY.

State lands.—Right of way across state lands is given to irrigation districts for all irrigation work.[e]

Private lands.—A right of way for ditches sufficient for the purpose required[f] is given to all persons, corporations, etc., who may have a right to use water[g] and same may be acquired by condemnation.[h] Such right of way must be the shortest possible route across such land[i] and no landowner will be burdened with more than one ditch, if one will serve the purpose.[j]

Natural streams.—Any person may take water which he has acquired the right to use along any of the streams or lakes of the State, not raising the water above high-water mark.[k]

EMINENT DOMAIN.

Public use.—The use of the waters of the State is deemed a public use[l] and the right of condemnation is given to all persons having a right to use it, for purposes of acquiring rights of way.[m] Procedure is provided in Laws of 1899, page 262.

Riparian rights.—Riparian rights in any natural stream or lake may be condemned[n] but this applies to riparian rights and can not be applied to take water from the person himself using it for irrigation.[o] Procedure is prescribed.[p]

DUTIES OF DITCH OWNERS.

Head-gates, embankments, repairs.—Every ditch owner, owner being the person having charge and control and liable as owner,[q] must erect and keep in good repair a sufficient head-gate at the head of his ditch to control the ordinary flow therein. He must keep embankments[r] and all flumes or other conduits in good repair so as not to injure the premise of others.[s] He is made liable for damages resulting through refusal or neglect to comply with these provisions.[t]

Waste.—Drain ditch shall be provided to return water to stream with as little waste as possible.[u]

Unnecessary diversion.—It is unlawful for any person to run a greater quantity of water through his ditch than is absolutely necessary for irrigation of lands watered and for domestic and stock purposes. A violation of this provision is a misdemeanor punishable by a fine not exceeding $1,000.[v]

DETERMINATION OF RIGHTS.

Basis of determination.—Whenever called into question in any court or before any commissioners (infra) the determination shall be based upon the used volume of water annually flowing in the stream or lake, and in the event of unusually low water, all rights shall be proportionately reduced.[w]

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[a] Sec. 4101; sec. 5816.
[b] Sec. 4106; sec. 5821.
[c] Sec. 4094; sec. 5134.
[d] Sec. 4142; sec. 5857.
[e] Sec. 4203; sec. 5773.
[f] Sec. 4103; sec. 5818.
[g] Sec. 4133; sec. 5848.
[h] Sec. 4109; sec. 5824.
[i] Sec. 4139 and Laws, 1899, p. 261; sec. 5854.
[j] Sec. 4138; sec. 5853.
[k] Sec. 4112; sec. 5827.
[l] Constitution, Article XXI.
[m] Laws, 1899, p. 261.
[n] Sec. 4193; sec. 5763.
[o] Sec. 4156; sec. 5871.
[p] Sec. 4153; sec. 5868.
[q] Sec. 4124; sec. 5839.
[r] Sec. 4119; sec. 5834.
[s] Sec. 4137; sec. 5852.
[t] Sec. 4123; sec. 5838.
[u] Sec. 4119; sec. 5834.
[v] Sec. 4121; sec. 5836.
[w] Sec. 4109; sec. 5824.

Hearing and adjudication of priorities.—When the owner of any canal in any water district (infra) shall present a written petition to the superior court praying the court to adjudicate priorities between the several canals in the district, the court shall, if deemed practical to proceed, appoint a day to commence to hear and take evidence in such adjudication. All interested parties may offer evidence. The court shall ascertain the date of commencement of the ditch, its original size and capacity, or the time of enlargement and increased capacity, the diligence of construction, and all facts tending to show compliance with the law. He shall determine on the evidence, the priority of appropriation with amounts which each has perfected thereunder, expressed, if possible, in second-feet; if not, by width, depth, and grade of canal.[a]

Certificate.—The clerk shall issue, upon reasonable fee, to each party interested, a certificate, showing dates and amounts of appropriation adjudicated and specifying number of the ditch and of the priority.[a]

Procedure.—Notice of time for adjudication shall be published once a week for four successive weeks; notice containing a copy of said order shall be posted in ten public places[b] in water districts, and proof of such publication and posting shall be made.[c] Service of notice is also provided for.[d]

Decree.—The court in its decree shall number the ditches in the district in the order of priority, and also number appropriations consecutively, beginning with the oldest. Both shall be incorporated in said certificate of the clerk, issued to claimant.[e]

DISTRIBUTION OF WATER.

Water districts.—Each county in the State shall be constituted an irrigation district.[f]

Water commissioners.—A commissioner for each district may be appointed by the county commissioners in each county, at a salary fixed by them, provided that if 12 freeholders, irrigating lands, shall petition therefor the county commissioners must appoint such commissioner.[f]

Such commissioner shall take oath of office and give a bond as may be required by the county commissioners, for the faithful performance of duties,[g] and shall be entitled to compensation at $4 per day, actual employment.[h]

The commissioner may, in emergency cases, employ one or more assistants, who take the same oath and shall receive $3 per day.[i]

Duties of commissioner.—Commissioners must divide the water in natural streams among the ditches taking water therefrom, and in times of scarcity must shut down and fasten head-gates of ditches not entitled to water.[j]

Register of priorities.—A register of priorities must be kept by commissioner when such priorities shall have been determined by commissioner from decrees or other legal source.[k] He must keep record of certificates of courts (supra), with contracts of same.[l]

COURT COMMISSIONERS.

Where insufficient water.—When volume of water in any stream is insufficient, upon application of any party interested, the superior court shall appoint three commissioners to go upon such stream and apportion water, as they may deem equitable. Such apportionment shall be for domestic purposes before any is given for irrigation.[m]

To determine proper diversion.—In the same way the court shall appoint three commissioners to inquire and determine whether or not more water is being diverted than

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[a] Sec. 4159; sec. 5874.
[b] Sec. 4161; sec. 5876.
[c] Sec. 4162; sec. 5877.
[d] Sec. 4163; sec. 5878.
[e] Sec. 4164; sec. 5879.
[f] Laws, 1903, p. 65.
[g] Sec. 4126; sec. 5841.
[h] Sec. 4129; sec. 5844.
[i] Sec. 4130; sec. 5845.
[j] Sec. 4127; sec. 5824.
[k] Sec. 4132; sec. 5847.
[l] Sec. 4160; sec. 5875.
[m] Sec. 4108; sec. 5823.

is properly used. Their decision is final. They may order the ditch owner to turn back unnecessary water. Failure to comply with the order is punishable as contempt of court.[a]

Rotation of water.—In case of insufficient water in a stream to supply the wants of the entire country through which it passes, the superior court shall appoint three commissioners to apportion in equitable manner a certain amount of water upon alternate days in certain localities with due regard to legal rights of all.[b]

Individual ditches.—When any ditch shall not be entitled to a full supply of water, the amount actually diverted shall be prorated among shareholders and users of water in such ditch.[c]

MISCELLANEOUS PROVISIONS.

Meaning of words "person" and "ditch."—The word "person" wherever used in the statutes means natural person or persons, corporation, or association, and the word "ditch" means dike, flumeway, or irrigation canal.[d]

Interference with appliances.—Every person interfering in any way with head-gates or measuring boxes without authority shall be guilty of a misdemeanor and subject to a fine of not less than $25 or more than $100, or maximum imprisonment of six months, or both.[e]

Injury to ditches.—Any person breaking or injuring the embankment or head-gates of any ditch with malicious intent, or for private gain to injury of persons lawfully using said ditch, shall be guilty of a misdemeanor, punishable by the maximum fine of $500 or maximum imprisonment of six month, or both.[f]

Corporations—deemed common carriers.—Any corporation organized in the State therefor may construct ditches for irrigation, and may condemn rights of way therefor, whether or not said corporation owns lands upon the line of such ditch.[g] Such corporation is deemed a public carrier, and is subject to legislative rules and regulations relating thereto.[h]

Federal Government.—Authority is given to the United States to avail itself of the provisions of the law.[i] Upon authoritative notice to the land commissioner that the Government contemplates the construction of irrigation works, all waters specified will be withdrawn from appropriation under foregoing laws for a period of one year, which withdrawal may be extended three years by certificate from duly authorized agent within the said year that work undertaken appears feasible and further investigation is intended to be made;[j] and upon the letting of contract for construction work the United States may appropriate all unappropriated waters in the manner provided for private persons, the title to beds and shores of state lakes thus utilized passing to the United States upon such appropriation.[k]

CONDITIONS AFFECTING STREAM FLOW.

All water supply is dependent on rainfall. It follows, therefore, that variations in rainfall from year to year are reflected in a general way by variations in stream flow, but local conditions govern the exact relation between rainfall and stream flow to such an extent that only the more prominent modulations are apparent. It is a

[a] Sec. 4111; sec. 5826.
[b] Sec. 4105; sec. 5820.
[c] Sec. 4116; sec. 5831.
[d] Sec. 4118; sec. 5833.
[e] Laws, 1909, p. 271.
[f] Sec. 4157; sec. 5757. See also sec. 7154; sec. 1627; and State *v.* Tiffany et al., December 19, 1906, sheets.
[g] Sec. 4154; sec. 5869.
[h] Sec. 4155; sec. 5870.
[i] Sec. 4165; sec. 5880.
[j] Laws, 1905, p. 180, sec. 3.
[k] Laws, 1905, p. 180, sec. 4.

common practice among engineers, when stream-flow data are not available—and sometimes even when they are—to make estimates of stream discharge from precipitation data. Such attempts are usually futile in this State. First, because such scattered rainfall stations as are being maintained are located in the valleys or in river canyons in situations which do not afford records representative of large areas; second, because practically no records of precipitation have been kept on the higher portions of the drainage basins, the portions that supply most of the water; third, because local peculiarities of soil, topography, vegetation, etc., render the close determination of the relation between rainfall and stream flow well-nigh impossible, almost every acre of drainage area being a law unto itself, and formulas apparently applicable to one drainage basin being inapplicable to an adjacent one, or even to smaller subdivisions of the same area.

The complexity of the factors that determine the relation between rainfall and river discharge is very evident. The amount of stored water held by the drainage area, either as ground water, in snow banks and glaciers, or in natural lakes and swamps, varies greatly on different areas, and even on different portions of the same area, and it also varies widely with the variations in the amount of precipitation from year to year. Even if the variation in the yearly amount of precipitation were eliminated there would still result great variations in the amount of stored water, depending on the manner and the conditions under which precipitation occurred. Thus snow falling on frozen ground will nearly all appear in the stream when it melts; if the ground is not frozen when the snow falls a large portion of the water may filter into the soil; if gentle rains last for several days less water reaches the stream than if the same amount falls in one day. Hence it is evident that even if the amount of precipitation on a catchment basin were actually determined it would afford a very indifferent indication of the stream discharge.

But, assuming for the moment that precipitation is uniform from year to year, both as to its amount and its distribution as regards time, and that it falls under the same temperature conditions each year, there still remain a number of factors that exert unknown influences on stream discharge. The first and most important of these is the porosity of the soil of which the area is composed. If the soil is practically pure sand, as in the drainage areas of Niobrara and Loup rivers in Nebraska, a very uniform rate of flow will prevail, independent of the monthly variations in rainfall, while the proportionate amount of run-off will be relatively small. If the soil is pumiceous and is underlain with porous lava rocks, as on Deschutes River in Oregon, the same or even greater uniformity of flow will result, with even a less proportion of total rainfall appearing as run-off. If the soil is of compact clay or other impervious material, like that of the Crooked or John Day river basins of Oregon, a relatively larger proportion of the total rainfall will appear as stream discharge, but its distribution as regards time will follow more closely the distribution of rainfall, and the stream will be "flashy." These examples illustrate extreme conditions, and of course all intermediate conditions are encountered.

Another important factor is topography. A relatively flat area will discharge a smaller proportion of rainfall, and the flow will tend to uniformity, while the opposite conditions prevail on areas with steep slopes. Soil conditions may be so favorable for ground storage, however, that the effect of topography is entirely obscured.

A third factor is vegetation, both cultivated and natural. Cultivation and cropping tend to render soil porous and thus to increase its power of absorption. This, in turn, tends to increase the uniformity of stream flow. But this factor is comparatively unimportant for the region under discussion, because rarely, if ever, in this country, are the water-producing portions of the drainage area cultivated. It will, however, apply to the plains country of the Middle West and the minor streams that head in the wheat belts of the Northwest. In the scale of importance the vegetation factor is far down the list.

Forests, including brush and undergrowth, constitute the really important class of vegetation that influences stream flow, but the effect of a forest as an equalizer of rainfall is not nearly so great as is popularly believed. The great value of a forest on a drainage area is to prevent soil wash. Still there is no doubt that forests in general have some conserving influence on rainfall, as they aid to some extent infiltration into the soil. Yet this ground water is itself depleted by the forest, for tree growth requires large quantities of water. Thus its beneficial effect is somewhat neutralized by its own requirements. Other things being equal, an open area covered with small bushes, ferns, vines, and tangled underbrush is just as good or even a better conserver of rainfall than a primeval forest, for it offers more resistance to the flow of water along the surface of the ground than is offered by large trees, and permits the formation of snowdrifts, really the great source of surface-water storage.

It is doubtful if the influence of forests as a factor in the run-off will ever be determined with exactness. Their effect is so completely lost in that of a multitude of other factors that it can not be segregated. The citation of a few examples will show that forestation is by no means a guaranty of uniformly flowing streams or of a condition anywhere approaching uniformity, although by no number of such examples can it be proved or disproved that the flow of the streams would be less uniform if it were not for the forest.

Deschutes River, in Oregon, is a stream of remarkably uniform flow and about 30 per cent of its drainage area is forested; but its largest tributary, Crooked River, which has about the same proportion of forested area, is perhaps the most "flashy" stream in the State. John Day River, draining the area adjacent to that of Crooked River, is similar in character; it has an enormous flood flow and falls exceedingly low in summer; about 35 per cent of its area, the heaviest water-producing portion, is rather heavily forested. Donner und Blitzen River, in central Oregon, is a very uniform stream with a well-maintained summer flow, but its area does not produce a tree, except here and there a juniper. On the other hand, Silvies River, which exists under the same climatic conditions as Donner und Blitzen River and discharges its waters into the same lake, is anything but uniform in its flow, although its drainage area is heavily forested. Niobrara and Loup rivers, in Nebraska, are very uniform in flow, but there is hardly enough timber on both areas to build a cabin. Nearly all the streams of western Oregon and Washington are subject to enormous floods, and all run comparatively low in summer, yet no streams in the world have more densely forested drainage areas. These examples are not cited to prove that forests have no conserving effect, but rather to show that vegetation is a relatively unimportant factor. The cause of uniform or nonuniform flow can almost invariably be traced to the influence of soil and topography.

Thus it is seen that the determination of the relation between rainfall and stream discharge involves the study of a multitude of very complex conditions. The more data that are gathered and analyzed on this subject the farther away appears to be the solution of the problem. It is far better, therefore, to forego the attempt, except to outline the very broadest tendencies, and instead to place dependence on actual gagings. Even a single year's record of flow is of infinitely more value in determining the behavior of a stream than all the precipitation data that can be compiled. By comparing a single year's record with records for longer time on adjacent or similar areas and using rainfall data for relative yearly variations in a broad way the probable behavior of a stream can be approximately determined.

VARIATION IN STREAM FLOW.

WET AND DRY YEARS.

In determining discharges for the streams under discussion the plan outlined in the preceding section has been followed, except that the record of only the summer flow for one year was available instead of a complete year's record. For water-power development alone the summer flow is the more important portion of the yearly discharge. A record of this flow, with an approximate idea of the maximum flood discharge, will usually furnish sufficient data for preliminary analysis of available power and design of structures.

The relative value of 1909 as a water year, in the cycle of wet and dry years, will first be determined. It is an unimportant fact that no rainfall records of value are available for any one of the five drainage areas under consideration. All rain in this region comes from the Pacific Ocean, and any good record of precipitation in the path of the prevailing winds will show relative variations. It is not safe to place too much dependence on the records of a single station; nor can the results at widely separated stations be averaged without showing the more prominent influences of those stations receiving the heavier rainfall. Strictly speaking, the rainfall at any station should be weighted by the area it serves. But this weight is well-nigh impossible to determine, so the more simple expedient has been adopted of expressing the rainfall for each year as a percentage of the mean annual rainfall for that station. The percentages can then be averaged, and the result will show the relative annual variations for the area considered.

In compiling rainfall data for comparison with stream discharge the calendar year for which both rainfall and stream-flow data are published should be discarded and a climatic year substituted. In this paper the climatic year has been used throughout, and has been arbitrarily begun on November 1 and ended on October 31 following. The year in which the ten months appear is used to designate the climatic year. Thus climatic year 1909 began November 1, 1908, and ended October 31, 1909.

By combining the rainfall data at Portland and Fort Vancouver and by supplying a few missing months by estimation from the Astoria records a 57-year record of rainfall has been obtained. A record of thirty years is available at Cascade Locks, one of twenty-five years at Hood River, and one of forty-six years at The Dalles. These are the only stations of value in the vicinity of the region under consideration. They practically indicate the rainfall passing the Columbia River Gap in the Cascade Range, and doubtless afford some indication of precipitation on the Columbia National Forest.

The mean annual rainfall for the climatic year at Portland is 42.3 inches, for Cascade Locks 77.9 inches, for Hood River 35.9 inches, and for The Dalles 16.8 inches. The rainfall for each year for each station has been represented in percentages of the respective means and these percentages have been averaged. The result is called the per cent rainfall for Columbia River Gap. In figure 1 this per cent rainfall is shown in order of magnitude. To illustrate the error of

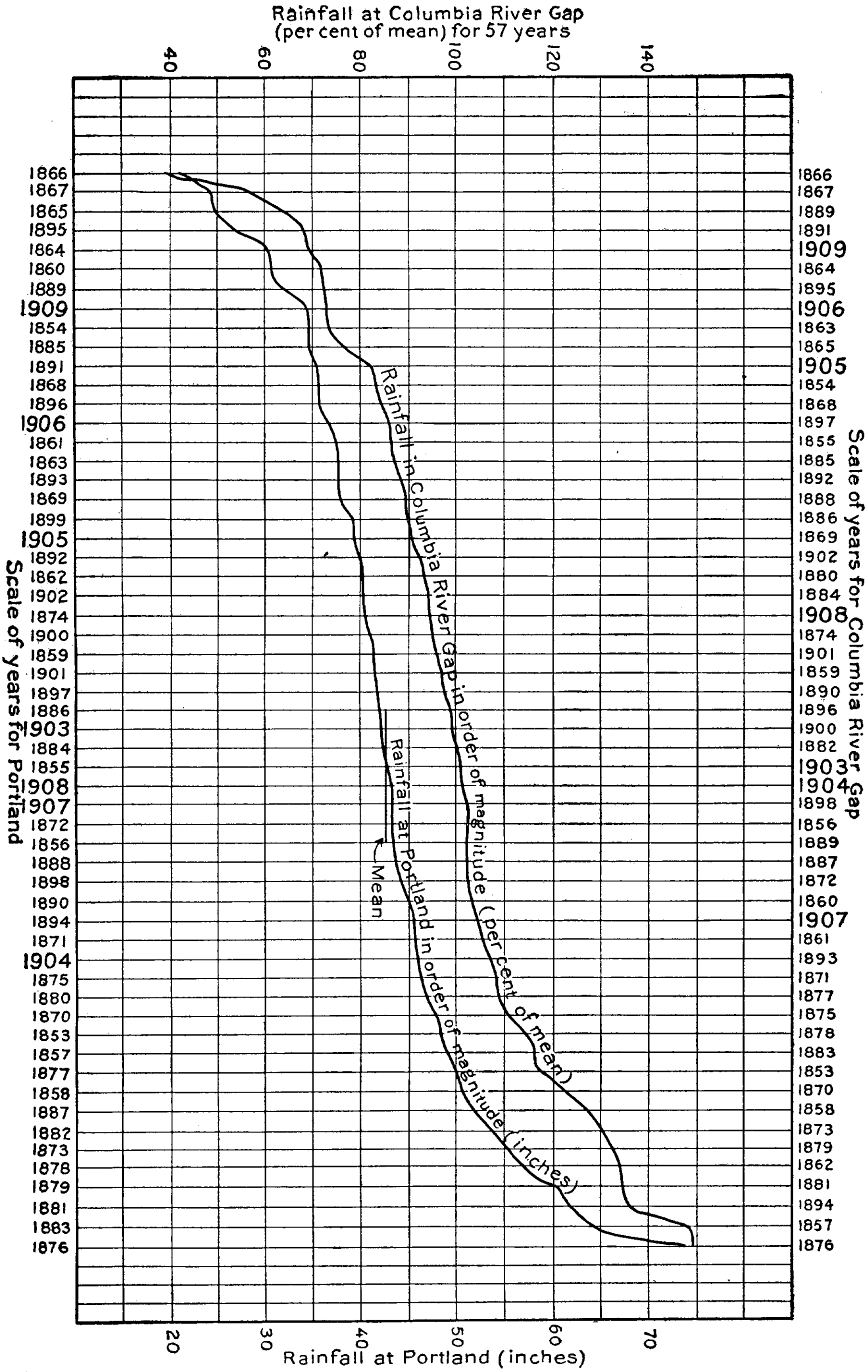


FIGURE 1.—Rainfall curves for Portland and Columbia River Gap, in order of magnitude.

using the records from a single station in place of the mean for several stations, the same arrangement is shown for the Portland records. In this case, however, the actual rainfall in inches for the climatic years is given.

Rainfall and other climatic phenomena undoubtedly recur in cycles, but all attempts to determine the laws that govern their recurrence have been more or less of a failure. About all that can be said is that wet and dry years usually occur in groups, although a wet year frequently precedes or follows a very dry year. This general tendency can be shown by "smoothing" the rainfall curves. This may be done graphically or algebraically. In the present case the per cent rainfall curve for Columbia River Gap has been "smoothed" by the formula $R' = \frac{1}{10}(a + 2b + 4c + 2d + e)$, where c is the rainfall for any one year, b that for the preceding year, and a for the next preceding; d is for the following, and e the next. R′ is the smoothed or cycle value for the year c. This curve is shown in figure 2 for both the per cent rainfall for Columbia River Gap and the Portland record in inches. The actual record, by years, for Portland is also shown by dotted line.

The next question is to determine how closely river discharge may be expected to follow variations in rainfall. Two features will be considered—(1) the annual yield of a drainage area and (2) the minimum flow. Wherever the natural flow of a stream is to be utilized for power development the minimum flow determines the design of the plant; wherever storage is to be employed the annual yield of the drainage area is desired. In this report the water-power tabulations are based on the average minimum flow. In order to properly analyze the variations in this quantity from year to year and the causes therefor, recourse is had to such records of stream flow as are available for streams other than those considered in this report but existing under the same general climatic conditions.

In this general region only one long-time record of stream flow is available, that of Columbia River at The Dalles. By combining the records of gage heights at The Dalles with those at Cascade Locks a continuous record since 1879 has been compiled. A rating curve for the cross section of the river at The Dalles has been developed from gagings made both by the U. S. Engineer Corps and by the United States Geological Survey. The older records of gage heights have been applied to this rating curve and daily discharges determined for the 31 years from 1879 to 1909.

In the same manner the discharge of Willamette River at Albany has been computed from records kept by the United States Weather Bureau for the 17 years from 1893 to 1909.

The annual discharge for both Columbia and Willamette rivers has been reduced to equivalent inches of rainfall over their respec-

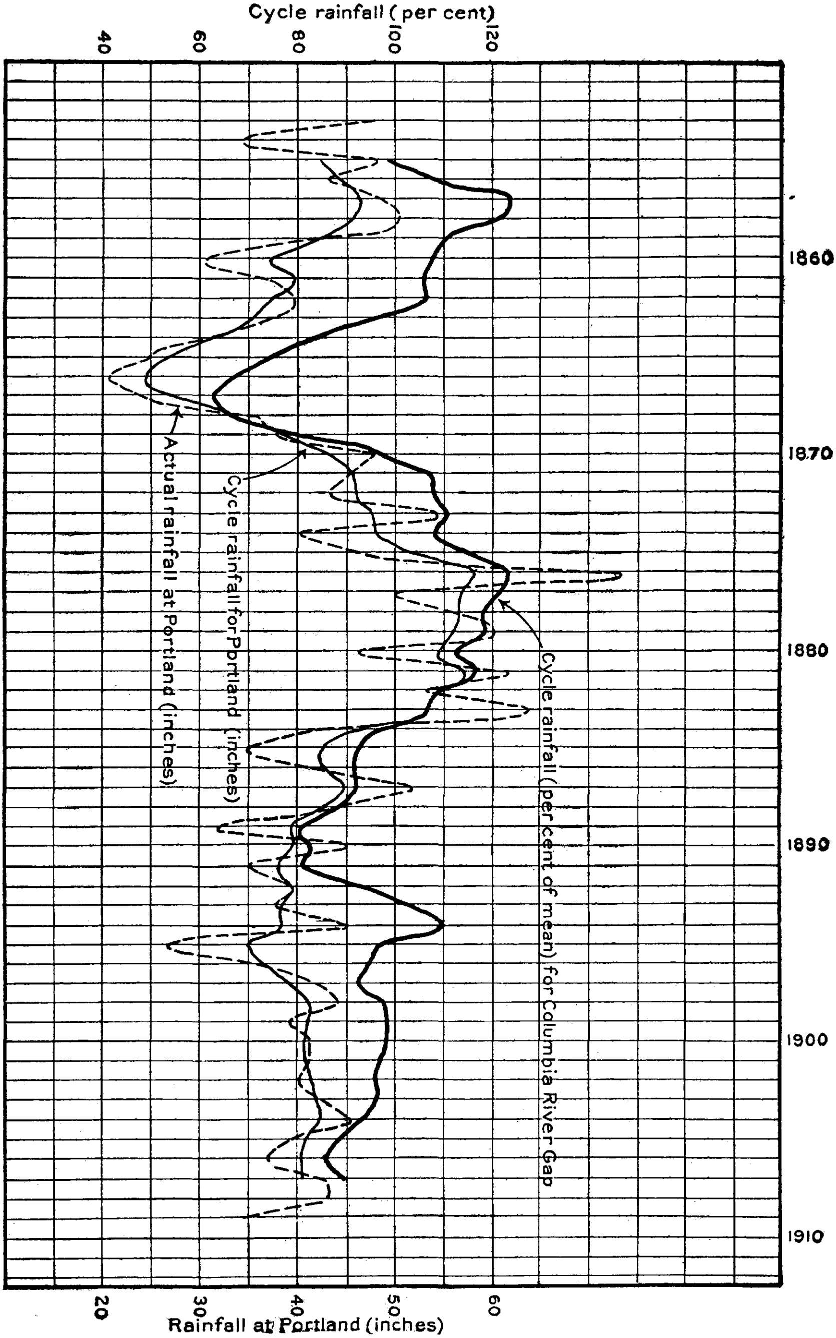


FIGURE 2.—Rainfall cycles, Columbia River Gap and Portland.

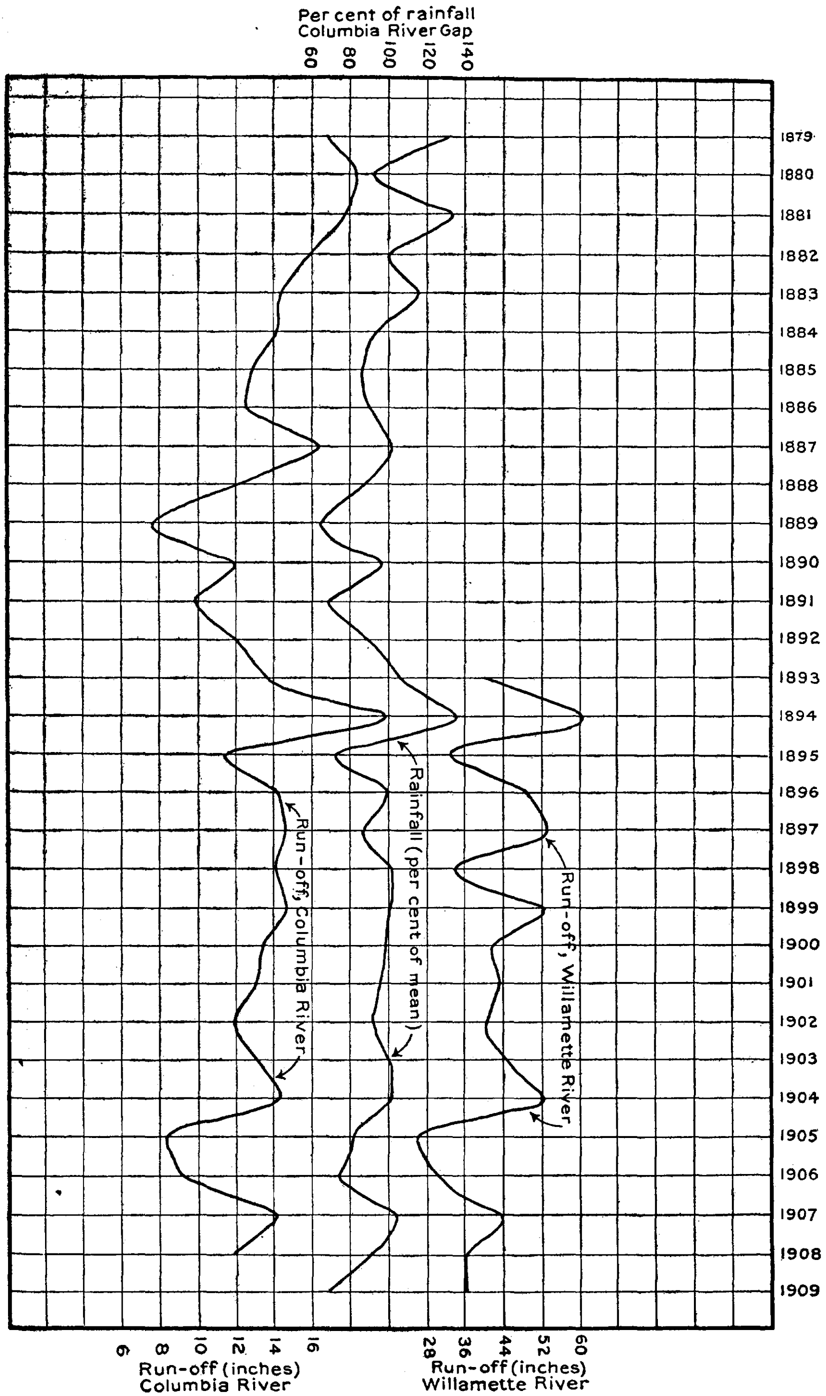


FIGURE 3.—Relation of rainfall to discharge, Columbia and Willamette rivers.

tive drainage areas. The results are plotted in figure 3. On the same diagram is shown the per cent rainfall for Columbia River Gap, as explained on page 18. The climatic year has been used.

The general parallelism of the rainfall and run-off curves is very striking, particularly in those of Columbia River. Smaller streams would not show this conformity to rainfall variations. No records on small streams of the Northwest are of sufficient length to permit comparison.

ANNUAL YIELD AND MINIMUM FLOW.

Heretofore nearly all stream-flow data in this region have been gathered chiefly for use in connection with irrigation enterprises. The summer flow on these streams is more or less influenced by diversion or artificial storage above the points where the measurements were taken, and the existing stream-flow data are not applicable in such analysis as is presented in this report. However, the data that are available for the Pacific Northwest are given below. The tables give the mean annual discharge for each year and the average discharge for the lowest week, with dates. The average for the lowest week is used instead of the absolute minimum, as this is a more stable quantity for comparison and represents more nearly the quantity that would be used in power-plant design. For Columbia River and Clark Fork, however, the minimum for one day has been used, as sufficient data were not at hand for determining a seven-day average. In addition to these quantities, their value per square mile of drainage area is added, also the variation, in percentage of the yearly value, from the average of all the years given. The climatic year is used throughout—that is, a year beginning November 1 and ending October 31. Where the lowest water occurred in November, this has been credited to that calendar year. Thus, on Umatilla River in 1902 the lowest week ended November 4 and is given in the climatic year 1902, although strictly it falls in the climatic year 1903. If this were not done, we might have two successive minimums from the same low-water period. In general, the minimums selected from low-water periods should be separated by a high-water period. In the analysis of stream-flow data this distinction is not generally made, but it is important when analyzing the minimums for successive years.

The climatic year has distinct advantages in this respect. By adopting it we can deal with a period beginning at a time when conditions of rainfall, stream flow, and temperatures vary little from year to year, and when ground storage and snow and ice storage in mountainous regions are also nearly uniform. The period selected begins just at the end of the low-water period. In other localities different limits would probably have to be selected.

For a description of the streams selected for this comparison and additional stream-flow data, reference is made to Water-Supply Paper 252 and previous annual publications of the United States Geological Survey on surface-water supplies.

Annual and average minimum discharge of representative streams in the Pacific northwest.

COLUMBIA RIVER AT THE DALLES.

[Drainage area, 237,000 square miles.]

Climatic year.	Mean discharge for the year.			Minimum discharge.			
	Second-feet.	Second-feet per square mile.	Variation from average (per cent).	Month.	Second-feet.	Second-feet per square mile.	Variation from average (per cent).
1879	295,000	1.27	+26	Feb.	66,500	0.278	0
1880	320,000	1.37	+37	Dec.	65,600	.275	− 2
1881	308,000	1.32	+32	..do.	78,700	.329	+18
1882	279,000	1.20	+19	Feb.	67,400	.282	+ 1
1883	252,000	1.08	+ 8	Jan.	65,600	.274	− 2
1884	244,000	1.05	+ 5	Feb.	50,300	.211	−25
1885	223,000	.96	− 4	Jan.	73,400	.307	+10
1886	219,000	.94	− 6	..do.	63,000	.264	− 6
1887	284,000	1.22	+22	Feb.	60,800	.254	− 9
1888	212,000	.91	− 9	Jan.	48,500	.203	−27
1889	133,000	.57	−43	Feb.	58,700	.246	−12
1890	208,000	.89	−11	Jan.	50,300	.211	−25
1891	172,000	.74	−26	Mar.	56,600	.237	−15
1892	211,000	.91	−10	Feb.	64,800	.271	− 4
1893	238,000	1.02	+ 2	..do.	62,000	.260	− 7
1894	338,000	1.45	+45	..do.	86,900	.363	+30
1895	199,000	.86	−15	..do.	78,700	.329	+18
1896	246,000	1.06	+ 5	Jan.	68,400	.286	+ 3
1897	258,000	1.11	+11	Mar.	[a] 83,100	.348	+24
1898	244,000	1.05	+ 5	Nov.	80,600	.337	+21
1899	256,000	1.10	+10	Dec.	57,200	.239	−14
1900	234,000	1.00	0	Oct.	97,000	.406	+45
1901	227,000	.97	− 3	..do.	75,400	.315	+13
1902	208,000	.89	−11	Feb.	57,200	.339	−14
1903	221,000	.95	− 5	Dec.	70,600	.296	+ 6
1904	262,000	1.12	+12	Oct.	73,800	.309	+11
1905	144,000	.62	−38	Feb.	51,800	.217	−22
1906	161,000	.69	−32	Jan.	58,400	.244	−12
1907	240,000	1.03	+ 3	..do.	76,200	.319	+14
1908	206,000	.88	−12	Feb.	59,000	.267	−12
1909	194,000	.83	−17	Jan.	62,000	.259	− 7
Average	233,000	1.00			66,700	.282	

WILLAMETTE RIVER AT ALBANY, OREG.

Climatic year.	Mean discharge for the year.			Mean discharge for the lowest week.			
	Second-feet.	Second-feet per square mile.	Variation from average (per cent).	Week ending—	Second-feet.	Second-feet per square mile.	Variation from average (per cent).
1879	16,400	3.37	+ 9	Sept. 27	1,870	0.385	−36
1892				Nov. 7	2,950	.607	+ 1
1893	14,300	2.94	− 5	Aug. 31	3,000	.623	+ 3
1894	21,700	4.46	+45	Sept. 27	4,000	.823	+37
1895	11,600	2.38	−23	Nov. 6	2,200	.453	−25
1896	17,200	3.54	+15	Oct. 23	2,950	.607	+ 1
1897	18,400	3.78	+23	Sept. 30	3,330	.685	+14
1898	10,300	2.12	−31	Aug. 26	2,760	.568	− 6
1899	18,800	3.87	+25	Oct. 16	3,880	.798	+32
1900	14,800	3.04	− 1	Oct. 1	2,760	.568	− 6
1901	15,600	3.21	+ 4	Aug. 16	2,950	.607	+ 1
1902	14,500	2.98	− 3	Sept. 7	2,950	.607	+ 1
1903	15,900	3.27	+ 6	Oct. 3	3,330	.685	+14
1904	18,900	3.89	+26	Oct. 7	3,140	.646	+ 7
1905	9,250	1.90	−39	Sept. 1	2,400	.494	−18
1906	11,000	2.26	−27	Oct. 5	2,740	.564	− 6
1907	15,600	3.21	+ 4	Oct. 29	2,580	.531	−12
1908	12,900	2.66	−14	Oct. 3	2,810	.578	− 4
1909	12,900	2.66	−14	Oct. 10	2,950	.607	+ 1
Average	15,000	3.09			2,930	.602	

[a] Probably lower in February, but record incomplete.

Annual and average minimum discharge of representative streams in the Pacific northwest—Continued.

DESCHUTES RIVER NEAR BIGGS (MORO), OREG.

[Drainage area, 9,180 square miles.]

Climatic year.	Mean discharge for the year.			Mean discharge for the lowest week.			
	Second-feet.	Second-feet per square mile.	Variation from average (per cent).	Week ending—	Second-feet.	Second-feet per square mile.	Variation from average (per cent).
1898	6,560	0.715	− 8	Oct. 28	5,200	0.566	−3
1899	7,740	.842	+ 8	Oct. 11	5,680	.607	+6
1906				Sept. 7	5,140	.560	−4
1907	7,970	.868	+12	...do	5,700	.621	+6
1908	6,830	.743	− 4	Sept. 30	5,320	.579	−1
1909	6,560	.715	− 8	Aug. 31	5,150	.561	−4
Average	7,130	.776			5,360	.582	

JOHN DAY RIVER AT McDONALD, OREG.

[Drainage area, 7,800 square miles.]

1905	1,470	0.188	−20	Sept. 11	93	0.012	−33
1906	1,990	.255	+ 9	...do	163	.021	+18
1907	2,950	.378	+60	Sept. 19	210	.027	+51
1908	1,400	.180	−24	Sept. 15	137	.018	− 1
1909	1,360	.174	−25	Sept. 4	90	.012	−35
Average	1,830	.235			139	.018	

UMATILLA RIVER AT GIBBON, OREG.

[Drainage area, 353 square miles.]

1896				Sept. 27	80	0.277	+ 8
1897	653	1.84	+25	Sept. 24	75	.212	+ 1
1898	496	1.40	− 5	Aug. 18	74	.210	0
1899	746	2.11	+42	Aug. 11	(*a*)		
1900				July 31	83	.235	+12
1901	722	2.05	+38	Aug. 31	83	.235	+12
1902	509	1.44	− 2	Nov. 4	110	.311	+48
1903	519	1.47	− 1	Aug. 7	78	.221	+ 5
1905	243	.69	−54	...do	56	.159	−25
1908	428	1.21	−18	Aug. 22	58	.164	−22
1909	389	1.10	−25	Sept. 2	45	.128	−39
Average	523	1.48			74.2	.209	

NACHES RIVER NEAR NILE, WASH.

[Drainage area, 636 square miles.]

1904				Sept. 21	143	0.225	−33
1905	1,020	1.62	− 9	Sept. 12	287	.452	+33
1906	1,060	1.67	− 5	Sept. 4	235	.369	+ 9
1907	1,520	2.39	+36	Oct. 29	203	.319	− 6
1908	1,290	2.03	+15	Oct. 13	228	.359	+ 6
1909	721	1.13	−37	Sept. 20	195	.307	− 9
Average	1,120	1.77			215	.338	

a The lowest week for 1899 gives 233 second-feet, but no gagings were made during the year and the record is so doubtful that it is omitted.

Annual and average minimum discharge of representative streams in the Pacific northwest—Continued.

TIETON RIVER NEAR NACHES, WASH.[a]

[Drainage area, 289 square miles.]

Climatic year.	Mean discharge for the year.			Mean discharge for the lowest week.			
	Second-feet.	Second-feet per square mile.	Variation from average (per cent).	Week ending—	Second-feet.	Second-feet per square mile.	Variation from average (per cent).
1902				Oct. 27	231	0.80	−1
1903	866	3.00	+26	...do...	360	1.25	+55
1904	743	2.57	+8	Nov. 7	232	.803	0
1905	570	1.97	−17	Nov. 17	216	.748	−7
1906	480	1.66	−31	Sept. 17	190	.657	−19
1907	896	3.10	+30	Oct. 10	233	.807	0
1908	702	2.43	+2	Oct. 28	238	.825	+2
1909	568	1.96	−18	Oct. 31	163	.565	−30
Average	689	2.38			233	.807	

METHOW RIVER AT PATEROS, WASH.

[Drainage area, 1,710 square miles.]

1903				Sept. 10	703	0.411	+48
1904	2,210	1.29	+25	Oct. 9	420	.246	−12
1905	1,890	1.10	+7	Sept. 24	528	.308	+11
1906	1,500	.88	−15	Oct. 14	435	.254	−9
1907	1,860	1.09	+5	Nov. 20	453	.265	−5
1908	1,620	.95	−8	Oct. 16	388	.227	−18
1909	1,530	.90	−14	Sept. 22	403	.236	−15
Average	1,770	1.04			476	.278	

NOTE.—Lower values for some years are shown in winter, but this is doubtless due to ice conditions.

SPOKANE RIVER AT SPOKANE, WASH.

[Drainage area, 4,000 square miles.]

1896				Nov. 1	1,910	0.478	−4
1897	9,690	2.42	+23	...do...	1,970	.493	−1
1898	10,300	2.57	+32	Oct. 7	2,440	.610	+23
1899	9,400	2.35	+21	Oct. 16	2,360	.589	+19
1900	7,820	1.95	−1	Sept. 23	2,150	.538	+9
1901	8,940	2.23	+14	Oct. 31	2,310	.578	+17
1902	7,640	1.91	−3	Oct. 28	2,110	.527	+6
1903	8,810	2.20	+12	Oct. 5	2,370	.594	+20
1904	8,050	2.02	+2	Nov. 16	1,300	.325	−34
1905	3,850	.96	−50	Oct. 1	1,370	.342	−31
1906	5,350	1.34	−33	Oct. 15	1,560	.375	−24
1907	8,370	2.09	+6		(b)		
1908	6,070	1.52	−23		(b)		
Average	7,860	1.96			1,980	.495	

[a] On March 7, 1906, the station was moved above Oak Creek; 5 per cent has been added to the annual yield, but no correction has been made to minimum, as Oak Creek is practically dry in summer. Since July, 1907, records are from headworks station and 10 per cent is added to annual yield, but corrections have not been made to minimum on account of small ditches in the canyon.

[b] Low-water period artificially controlled by storage in Cœur d'Alene Lake.

Annual and average minimum discharge of representative streams in the Pacific northwest—Continued.

CLARK FORK AT NEWPORT, WASH.

[Drainage area, 24,000 square miles.]

Climatic year.	Mean discharge for the year.			Minimum discharge.			
	Second-feet.	Second-feet per square mile.	Variation from average (per cent).	Month.	Second-feet.	Second-feet per square mile.	Variation from average (per cent).
1904	29,500	....	+13	Feb.	10,400	0.433	+22
1905	15,300	....	−41	Jan.	5,700	.237	−33
1906	16,800	....	−35	Mar.	a 6,700	.279	−22
1907	34,800	....	+34	Oct.	a 8,420	.351	− 1
1908	30,900	....	+19	Mar.	a 9,150	.381	+ 7
1909	28,600	....	+10	...do.	a 10,800	.450	+27
Average	26,000	....	....	....	8,530	.355	....

CEDAR RIVER NEAR RAVENSDALE, WASH.

[Drainage area, 170 square miles.]

Climatic year.	Mean discharge for the year.			Mean discharge for lowest week.			
	Second-feet.	Second-feet per square mile.	Variation from average (per cent).	Week ending—	Second-feet.	Second-feet per square mile.	Variation from average (per cent).
1895	....	....	....	Nov. 9	120	0.706	−37
1896	755	4.44	+ 3	Oct. 21	158	.930	−17
1897	1,160	6.82	+58	Sept. 28	313	1.84	+65
1898	750	4.41	+ 2	Sept. 19	80	.470	−58
1902	....	....	....	Sept. 26	125	.735	−34
1903	780	4.59	+ 6	Aug. 23	140	.823	−26
1904	698	4.10	− 5	Oct. 31	135	.794	−29
1905	557	3.28	−24	(b)	....	....	....
1906	581	3.44	−21	(b)	....	....	....
1907	749	4.40	+ 2	(b)	....	....	....
1908	698	4.10	− 5	(b)	....	....	....
1909	621	3.66	−16	(b)	....	....	....
Average	735	4.32	....	....	190	1.12	....

a Probably lower in January or February, but there is no record of daily flow for these months.
b Low-water period artificially controlled by storage in Cedar Lake.

It is often said that as the small stream varies so will the large one, but the truth is tersely stated in the homely expression "A river is a river and a creek is a creek." A large river is the final integration of an infinite number of small contributions. Any one of the small tributaries may vary within wide limits with no noticeable effect on the river into which it flows. The Heppner flood of 1903, on Willow Creek, Oregon, destroyed a hundred lives and changed the appearance of the entire valley through which it flowed; but the waters were swallowed by Columbia River with hardly a ripple on its surface.

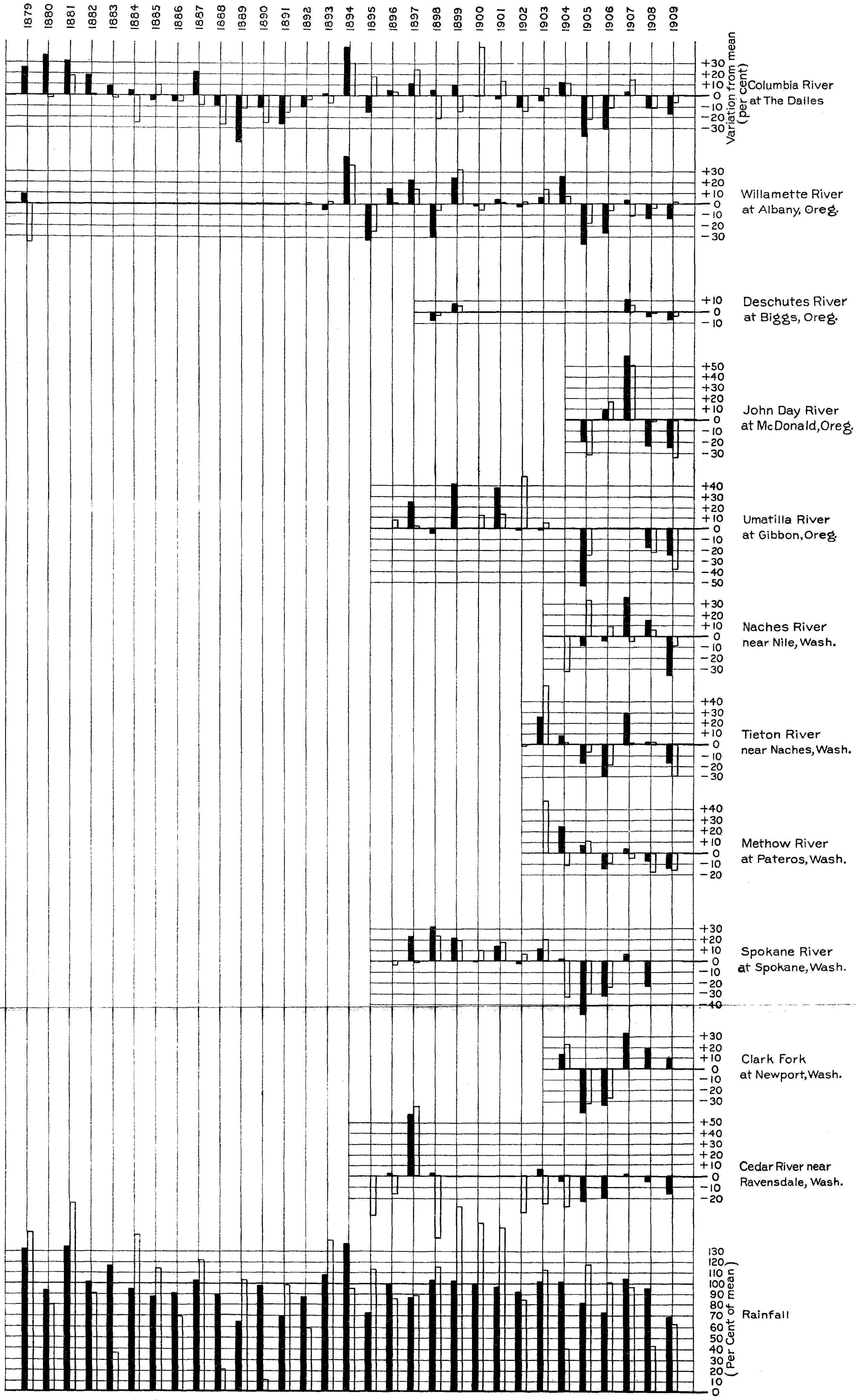
The variation in the flow of large rivers can be caused only by climatic conditions that affect the entire drainage area. This statement is true also for small creeks, but climatic influences on small areas are called local influences. Hence we expect large rivers to respond to general climatic changes and small streams to local influences. We must not necessarily expect small streams to show the lowest water in dry years nor the highest annual yield in wet years. A wet year on the Columbia River basin as a whole may be a dry one on the Spokane basin within it. In Oregon and Washington, and particularly west of the Cascade Range, these exceptions are not so pronounced, however, because the areas are nearer the source of rainfall supply. In other words, the effect of local climate is restricted to much smaller areas here than in States farther east. A corollary of the foregoing proposition is that the minimum flow in a small drainage area may be high in a dry year, owing to local summer showers that do not add anything to the flow of a larger stream.

Unfortunately we do not have discharges data on small drainage areas of sufficient length to test the validity of this statement. Such small streams as have been measured are those used for irrigation, and the summer flow of nearly every one of them is practically all diverted above the point of measurement.

It will be noticed from the foregoing tables that the average minimum varies greatly in the same stream from year to year. On streams where the absolute summer flow is low the variations from year to year will be much greater than on streams where it is relatively high. Thus the minimum for a five-year record on John Day River varies between 90 and 210 second-feet, the range being 133 per cent of the lower figure; on Deschutes River a five-year record shows minimums from 5,150 to 5,700 second-feet, or a variation of only 11 per cent. The same thing is seen to be true of the annual yield. It follows therefore that in a stream characterized by uniformity of flow a record of two or three years' duration will indicate its probable behavior within safe limits, while on nonuniform streams records for ten years or more may be necessary to define its range within the same percentage of error.

It will be seen from the foregoing tables that the minimum does not always vary in the same direction as the annual discharge. In other words, a year of low run-off may have a high summer flow and vice versa. This, however, is more apparent on the smaller streams. The general tendency of the minimums for streams in this list is to follow in the direction of the annual yield.

In order to bring out the relative variations between the annual yield and the minimum rate of flow, Plate I has been prepared. In this plate the solid black bars represent the percentage variation for each year of the mean annual flow, from the average of all the years comprising the record. The climatic year has been used. The open bars represent in the same manner the percentage variation of the mean discharge for the lowest week from the average of all years comprising the record. Those above the zero line, therefore, show



RELATION OF RAINFALL TO DISCHARGE FOR REPRESENTATIVE STREAMS OF THE NORTHWEST.

that the discharge for that year was above the average or that the percentage variation was in a positive direction. The preceding tables must be consulted for actual values, for only the relative yearly variations are depicted in the diagram.

At the bottom of the diagram are shown the annual variations in rainfall for the stations at Portland, Cascade Locks, Hood River, and The Dalles. The rainfall for each year at each station is first expressed in percentage of the mean annual rainfall for that station. These percentages are then averaged for the several stations. These are shown as solid black bars.

In the same manner the percentage variation of rainfall during the months of August and September for each year at Portland, Cascade Locks, Hood River, The Dalles, Olympia, Ellensburg, and Spokane stations is shown by the open bars. The amount the bars exceed or fall short of 100 per cent indicates the variation from the normal.

The first striking thing about the diagram is the meagerness of available stream-flow data in the Northwest that can be used for a study of this kind. For streams comparable with those of the region under consideration about five years' records constitute the available data. Fortunately these five years include three dry years, one wet year, and one normal year. The year 1905 was a very dry year and was followed by another one in which the precipitation was even less, but the stream discharge did not fall quite so low. The year 1909 also was a very dry year, almost on a parallel with 1905. Segregating the results for these three dry years, we find the following variations:

Variation in percentage of annual discharge and rainfall from the average.

	Length of record (years).	1905.	1906.	1909.
Discharge:				
Columbia River	31	−38	−32	−17
Willamette River	18	−39	−27	−14
Deschutes River	5	....	....	−8
John Day River	5	−20	+9	−25
Umatilla River	9	−54	....	−25
Naches River	5	−9	−5	−37
Tieton River	7	−17	−31	−18
Methow River	6	+7	−15	−14
Spokane River	12	−50	−33	....
Clark Fork	6	−41	−35	+10
Cedar River	10	−25	−21	−16
Precipitation	57	−18	−27	−31

With the exception of John Day River in 1906, Methow River in 1905, and Clark Fork in 1909, all these streams show a run-off decidedly below the average, and the precipitation for the Northwest was also very low for these three years. The precipitation in 1909 was 31 per cent below the average for fifty-seven years. The lowest year for the period was 1866, when the precipitation was 60 per cent below the normal, followed by 1867 with a precipitation 53 per cent below the normal. (See fig. 1.) The accuracy of these earlier records, however, is in considerable doubt. Discarding them we find two years in which the precipitation during the climatic year was lower than in 1909. These are 1889, in which it was 36 per cent below the normal, and 1891, in which it was 32 per cent below the normal. In 1899 the run-off from the basin of Columbia River was 43 per cent below the 31-year average, and in 1891 it was 26 per cent below. As regards precipitation and run-off from the large rivers of the Northwest, the conditions in 1909 resulted in severe water shortage.

We will now segregate the weekly minimum discharges and the summer rainfall for these years.

Variation in percentage of weekly minimum discharge and summer rainfall from the average.

	Length of record (years).	1905.	1906.	1909.
Discharge:				
Columbia River	31	−22	−12	− 7
Willamette River	19	−18	− 6	+ 1
Deschutes River	6	....	− 4	− 4
John Day River	5	−33	+18	−35
Umatilla River	10	−25	....	−39
Naches River	6	+33	+ 9	− 9
Tieton River	8	− 7	−19	−30
Methow River	7	+11	− 9	−15
Spokane River	11	−31	−24	....
Clark Fork	4	−33	−22	....
Summer rainfall	31	+17	....	−37

The general conformity of these data with those in the foregoing table is very satisfactory, but it must be remembered that the drainage areas of these streams are not small and the tendencies indicated for them might not hold good for areas of, say less than 100 square miles. The figures for 1909 are particularly significant. The rainfall during August and September is seen to be 37 per cent below the average for thirty-one years. The average minimum discharge for John Day and Umatilla rivers, draining the Blue Mountains in Oregon, was 35 and 39 per cent, respectively, below the average. For Naches and Tieton rivers, draining the eastern slope of the Cascade Range in Washington, it was respectively 9 and 30 per cent below the average. It should be remembered also that during the five to ten years comprising these records three exceedingly low years are included. It follows therefore that the average for the period of record is low, and as this average is used to determine the relative yearly variations, it must be conceded that the low-water conditions in 1909 are more severe than would at first appear from the above table.

In applying these deductions to the region under consideration an arbitrary allowance will have to be made for the data obtained during the low-water season of 1909. In the opinion of the writer it would be conservative to increase the average minimum discharges obtained during the summer season of 1909 on the streams surveyed and treated in this report by 20 per cent to obtain a quantity that would represent the average for the past ten years, say, if records had been kept during that period. On this basis, therefore, the tables of water powers have been compiled. That is, the mean discharge for the lowest week in 1909, obtained by current-meter measurement and records of gage height, has been increased 20 per cent, and this quantity is considered as the average minimum discharge for that particular point on the stream.

FLOODS.

It is impossible to determine flood discharge with any degree of accuracy without actual gagings. It is not necessary to measure the discharge at the peak of the flood, but it is necessary to develop a discharge curve for the greater part of the range of the river's stage. This can then be safely extended to cover the highest known stage if the station is at a point where channel conditions are stable.

Many formulas have been advanced for determining the maximum discharge in terms of the drainage area. These formulas, however, are applicable only for the streams used in determining them. When the complex factors that enter into the problem are considered, the futility of devising a general formula, or even formulas for classified conditions, is at once apparent. The maximum rate of flow depends on the maximum rate of rainfall, the temperatures, the quantity of water stored as ice or snow at the time, the condition of the ground at the time of snowfall, the physical nature of the soil, the topography, the vegetation, the times of maximum rainfall and snow melting on tributary portions of the drainage area and the resultant combinations these will produce, and a multitude of other factors, all of which are practically unknown and almost indeterminable.

In the absence of actual data, however, it is frequently necessary to make a tentative estimate of the probable maximum discharge for preliminary study and design. In order that such estimates can be made within reasonable limits, such data as are available on streams draining the Cascade Range are presented in the following table. These have all been determined from actual measurements, as above outlined, and constitute practically all the reliable data known for this region.

It is seen that the discharge per square mile varies between wide limits on different streams. In general, this quantity varies inversely with the drainage area. This results from two causes: First, in mountainous regions most of the water is supplied from the higher altitudes—that is to say, below the mountain slopes and higher foothills comparatively little is added to the discharge; second, the rate of discharge always decreases downstream. The flood wave therefore has a sharp crest where it originates, which gradually broadens as it advances downstream. Thus the rate of flow is less in the lower portions of the river than in the higher, while the same total quantity of water may pass both places during the entire flood period.

The maximum flood discharge is a very intangible quantity, and it is doubtful if the absolute maximum has yet been recorded on more than a few of the streams in the following list. Wherever these data are used, therefore, liberal allowances should be made in the capacities of spillways.

Flood discharge of streams draining the Cascade Range.

Stream and location.	Drainage area (square miles).	Date of flood.	Maximum discharge.	
			Second-feet.	Second-feet per square mile.
Streams draining the eastern slope.				
Methow River at Pateros, Wash	1,710	June 17,1903	13,100	7.66
Wenatchee River at Cashmere, Wash	1,190	Nov 30,1909	20,700	17.4
Yakima River near Martin, Wash	56	Nov. 14,1906	7,200	129
Yakima River at Clealum, Wash	500	.....do.......	25,600	51.2
Yakima River at Umtanum, Wash	1,540	Nov. 15,1906	41,000	26.6
Yakima River at Yakima, Wash	3,300	.....do.......	67,000	20.3
Clealum River at Roslyn, Wash	205	.....do.......	18,700	91.2
Naches River near Easton, Wash	63	Nov. 14,1906	7,000	111
Naches River near Nile, Wash	263	.....do.......	27,700	74.4
Tieton River near Naches, Wash	289	Nov. 15,1906	21,000	72.7
Deschutes River at Lava, Oreg	720	Feb. 10,1907	2,300	3.2
Deschutes River at West's ranch, Oreg	1,240	.....do.......	4,000	3.23
Deschutes River at Biggs, Oreg	9,180	Feb. 6,1907	30,600	3.33
Columbia River at The Dalles, Oreg	237,000	June 6,1894	1,390,000	5.87
Hood River at Winans, Oreg	282	Nov. 14,1906	6,580	23.3
Streams draining the western slope.				
Skagit River near Marblemount, Wash	2,340	Nov. 29,1909	86,000	36.7
Cascade River near Marblemount, Wash	222	.....do.......	40,000	160
Cedar River near Ravensdale, Wash	170	Nov. 15,1906	10,800	63.5
Willamette River at Albany, Oreg	4,860	Dec. 8,1861	220,000	45.3
Clackamas River at Cazadero, Oreg	685	Nov. 22,1909	46,800	68.3
South Fork of Santiam River at Waterloo, Oreg	640	Nov. 15,1906	36,900	57.6
North Fork of Santiam River at Mehama, Oreg	740	Feb. 4,1907	48,900	67.3
McKenzie River near Springfield, Oreg	960	Nov. 22,1909	43,500	45.3
Middle Fork of Willamette River at Jasper, Oreg	1,450	Nov. 23,1909	123,000	84.8
Molalla River at Molalla, Oreg	220	Feb. 5,1907	15,000	68.2
Santiam River at Jefferson, Oreg	1,890	Nov. 22,1909	98,000	51.8
South Fork of Umpqua River near Brockway, Oreg	1,800	Jan. 4,1907	75,400	41.9
North Fork of Umpqua River at Winchester, Oreg	1,000	Feb. 4,1907	58,600	58.6
Umpqua River near Elkton, Oreg	3,680	Jan. 7,1907	140,000	38
Rogue River near Tolo, Oreg	2,020	Nov. 23,1909	60,000	29.7

KLICKITAT RIVER DRAINAGE BASIN.

DESCRIPTION.

Klickitat River drains the eastern slope of the southern portion of the Cascade Range in Washington. Its position is similar to that of Deschutes River in Oregon, except that the two streams flow in opposite directions. Both empty into Columbia River a short distance east of the divide. A map of this drainage basin appears in Plate II.

Klickitat River rises in Goat Mountain, at an elevation of 8,500 feet above the sea, flows generally southward, paralleling the main range of the Cascades, and empties into Columbia River near the town of Lyle. The total length of the main stream is 105 miles. The principal tributaries, named in their order downstream, are, from the west, McCreedy Creek, West Fork, Cunningham Creek, Big Muddy River, Bacon Creek, and Outlet Creek; from the east, Diamond Fork,[a] Piscoe Creek, Surveyors Creek, White Creek, Little Klickitat River, and Swale Creek. The total drainage area is 1,160 square miles, distributed as follows:

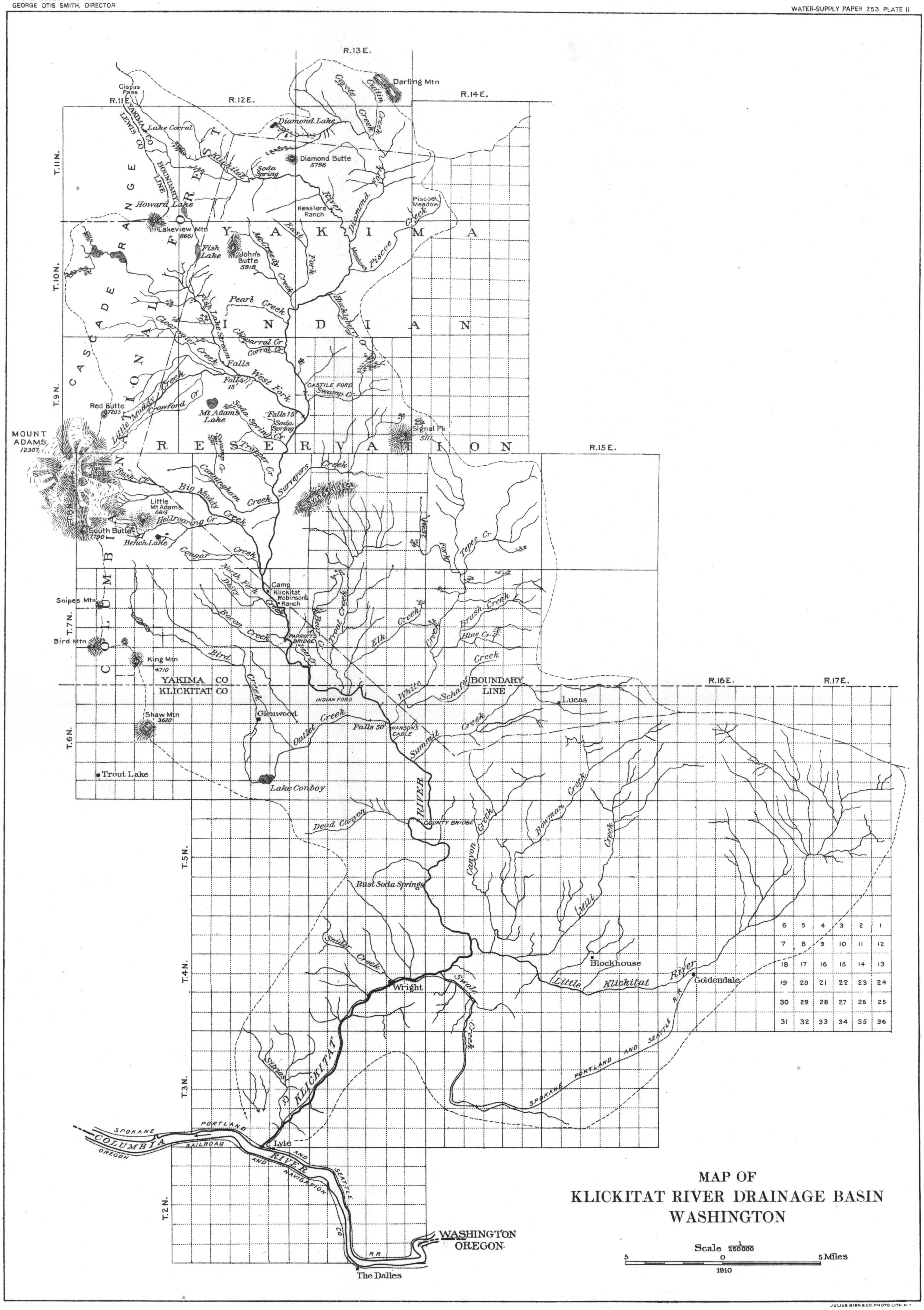
	Square miles.
Below the mouth of Diamond Fork	85
Below the mouth of West Fork	254
Below the mouth of Big Muddy River	347
Below the mouth of Little Klickitat River	995
Diamond Fork	43
West Fork	92
Big Muddy River	33
Outlet Creek	87
Little Klickitat River	285

The most prominent feature of the area is Mount Adams, which crowns the summit of the divide at an elevation of 12,307 feet. (See Pl. XII, *A*.) The glaciers on this peak cover 2,300 acres. Those to the east supply the water in Big Muddy River and Little Muddy Creek during the summer months.

The region has been the scene of pronounced volcanic activity and its general topography is in consequence abrupt and rugged. The streams as a rule flow in deep canyons cut into the basalt and lavas. Near the summit of the divide and the spurs that extend from it are a number of grassy meadows bordered by low benches of level or gently rolling land. Many of the meadows are swampy during wet seasons, and lakes occupy the deeper depressions. From the summit of the range eastward the steep slopes of the mountains give way to high, rolling table-lands, into which the streams have cut deeply. The canyon walls are very steep and angular and in places 2,000 feet high. For the most part the rivers occupy the entire floors of the canyons, although on the inside of bends there is usually a flood plain 100 to 500 feet in width.

The soil of the area has resulted from the disintegration of the lavas and basalts. Some of the lavas are very porous, having the

[a] Diamond Fork is locally known as Little Klickitat. It should not be confused with Little Klickitat River, the largest eastern tributary.



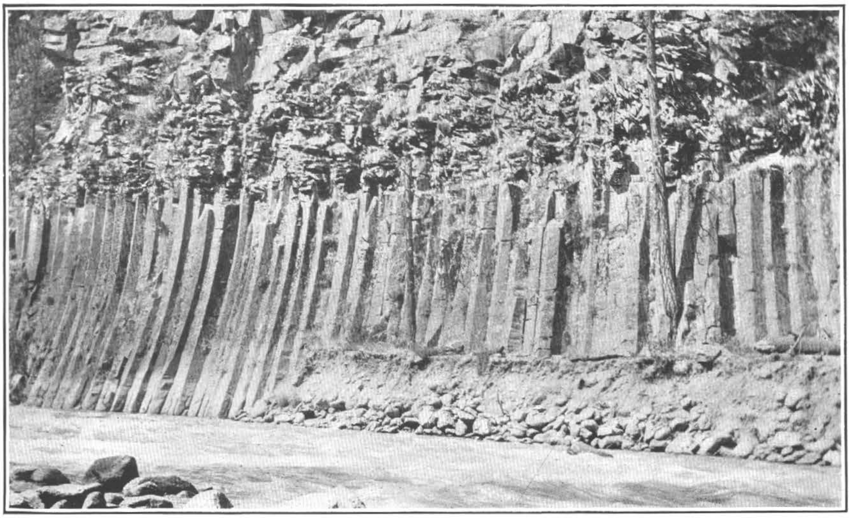
JULIUS BIEN & CO. PHOTO. LITH. N.Y.

appearance of sponge, and in places considerable scoria and pumice are found. The rocks produce a coarse porous soil that absorbs large quantities of water and readily delivers it to the ground rocks. Thus the ground-storage capacity of the area is relatively high. The result is that the streams have a fairly uniform flow and maintain a good discharge during the summer months. This natural tendency is further augmented by additional waters supplied by the glaciers on Mount Adams and the snowbanks that stand in favored spots well into the summer.

The entire area except the extreme eastern portion is more or less covered with timber. On the west side of the river the growth is heavy, but it gradually thins out toward the eastern boundary of the basin. Only 4 per cent of the total area lies within the Columbia National Forest. In this portion about 80 per cent is heavily timbered and 18 per cent has been burned over. Of the entire area about 75 per cent is timbered, but the stand on over half of this is less than 2,000 feet board measure per acre. In the national forest about 55 per cent of the timber is yellow pine. Red or yellow fir constitutes 20 per cent of the stand, tamarack 10 per cent, white pine 5 per cent, mountain hemlock 5 per cent, and all other species 5 per cent. Over the entire area yellow pine is the predominating species. The sides and bottoms of the canyons are studded with patches of scrub oak in the lower portions, and cottonwoods and alders grow profusely near the water's edge.

Only a small part of the land suitable for agriculture is cultivated. In the vicinity of Glenwood an important amount of hay is cut from the moist table-lands. Irrigation is practiced to some extent on these lands. Hay and the hardier vegetables constitute the principal crops. Wheat is raised in considerable quantities on the high lands in the eastern portion of the drainage area. Irrigation is practiced also on the lower stretches of the river, but the irrigated tracts are small and lie in narrow strips along the river bank in the bottom of the canyon. About 3 miles below Little Klickitat there is a garden and strawberry patch of about 3 acres, which produces abundantly under irrigation.

The only railroad in the area is the Goldendale branch of the Spokane, Portland and Seattle Railway (the "north bank" route). This branch runs from Lyle, on the main line, to Goldendale, near the southeastern border of the area. It follows the river canyon for 17 miles, crossing the river twice in that distance. It leaves the river a short distance above Wright and follows Swale Creek canyon to the uplands. A county road from Goldendale to Glenwood crosses the river near the mouth of Dead Canyon. Between Wright and Parrott's Bridge the canyon is without trails and is well-nigh impassable. From Parrott's Bridge to the source a trail follows the river or the bench lands bordering it. There are also trails along the ridges, but



A. COLUMNAR BASALT, KLICKITAT CANYON, NEAR GLENWOOD.

B. MAZAMA GLACIER AND HEADWATERS OF HELLROARING CREEK.

they are almost impassable during the winter months except on snowshoes.

There are a number of mineral springs in the area. Rest Soda Springs is a famous camping resort to which a road has been built down the canyon from the Goldendale-Glenwood road. A ferry was also installed by popular subscription. The soda springs below West Fork furnish an abundance of mineral water fully equal to the water of the famous Shasta Springs in California. Below McCormick Meadows is another soda spring of excellent quality. The water issues from seams in the bed rock.

So far as known the area contains no very large reservoir sites. Many small ones, however, could be developed in the swamps and lakes of the upland benches. The best sites are found on Fish Lake Stream, a tributary of West Fork. Fish Lake, Howard Lake, and Two Lakes could probably be developed to a moderate extent. The grade of Fish Lake Stream is comparatively flat and detailed investigation would probably discover good storage sites. Near the headwaters of Hellroaring Creek there is a favorable site for storage. The waters of this stream are largely supplied from Mazama Glacier (Pl. III, *B*). About a mile below the glacier the stream spreads in two branches through a comparatively flat meadow. The south branch has a good dam site at the east end of the meadow, where a dam 100 feet high could be constructed. The north branch falls over the escarpment, dropping over 200 feet in one-fourth mile. It is likely that considerable storage could be developed at McCormick Meadows on the main stream, 5 miles by trail above the mouth of Diamond Fork. There is little doubt that all these reservoirs would be filled every season.

Discharge data for this river system are very meager. In August, 1900, Sidney Arnold[a] made a brief reconnaissance of Diamond Fork (called Gold Fork in his report, while the main stream above this tributary was called Diamond Fork) in order to determine the feasibility of diverting water from this stream into Atanum Creek basin. The results of Mr. Arnold's investigation show the utter futility of any attempt to divert from the Klickitat basin into the Atanum basin.

The following discharge measurements were made by Mr. Arnold:

August 18, 1900, Diamond Fork near mouth, 48 second-feet.

August 18, 1900, Klickitat River above mouth of Diamond Fork, 113 second-feet.

In conjunction with the determination of river profiles, discharge measurements of all important tributaries and of the main river at various points were made by the United States Geological Survey during the summer of 1909. Lack of observers made it impossible

[a] Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 4, 1902, pp. 454-455.

to obtain daily gage heights at the desired points, although gages were installed and favorable sites selected for gaging stations to be established at some future date. One permanent gaging station was established at Wright, where daily gage heights are being recorded. The discharge data at other points in the drainage basin must be estimated from the individual measurements made during the progress of the survey. These are listed as miscellaneous measurements and are arranged in order downstream.

KLICKITAT RIVER ABOVE AND BELOW BIG MUDDY RIVER.

From October, 1904, to June 26, 1908, the Klickitat Irrigation and Power Company made a series of measurements on Big Muddy River and Klickitat River above and below the mouth of the Big Muddy. Through the courtesy of the company the results are presented here as furnished, except that, following the rule of the Geological Survey, discharge data are given only to three significant figures. They were computed to hundredths of a second-foot by the company. No gage heights were recorded.

Discharge measurements on Klickitat River 1,000 feet above the mouth of Big Muddy River, 1905.

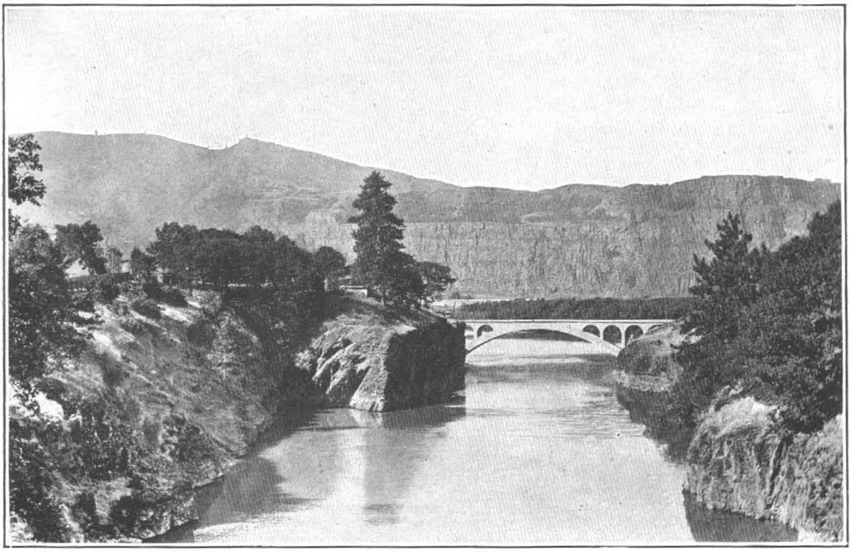
[By Klickitat Irrigation and Power Company.]

	Sec. ft.		Sec. ft.
June 19	717	August 11	377
June 29	655	August 18	360
July 8	574	September 2	312
July 15	465	September 15	342
July 22	426		

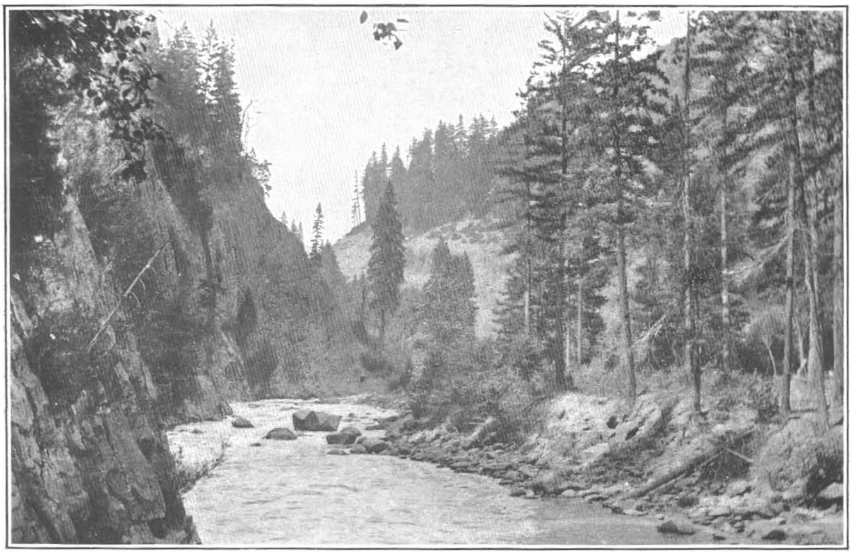
Discharge measurements of Klickitat River below mouth of Big Muddy River.

[By Klickitat Irrigation and Power Company.]

Date.	Locality.	Discharge.	Date.	Locality.	Discharge.
1905.		*Second-feet.*	1908.		*Second-feet.*
June 5	At Parrot's bridge	1,490	April 3	At Camp Klickitat	1,000
June 12	do	1,590	April 7	do	912
June 19	do	1,210	April 10	do	1,180
June 28	At Robertson's ranch	989	April 14	do	1,770
July 8	do	879	April 18	do	3,050
July 15	do	764	April 21	do	3,270
July 22	do	955	April 24	do	2,700
Aug. 12	do	668	April 28	do	1,940
Aug. 19	do	662	May 1	do	2,270
Sept. 1	do	538	May 5	do	2,190
Sept. 15	do	545	May 8	do	2,510
			May 12	do	1,980
1907.			May 16	do	1,850
July 9	At Camp Klickitat	1,190	May 19	do	1,830
July 16	do	1,080	May 23	do	1,960
July 22	do	950	May 26	do	2,070
July 29	do	884	May 29	do	2,200
Aug. 5	do	824	June 2	do	1,940
Aug. 12	do	695	June 5	do	1,950
Aug. 19	do	753	June 9	do	2,850
			June 12	do	3,010
1908.			June 16	do	2,570
Mar. 23	do	1,250	June 19	do	2,050
Mar. 27	do	1,150	June 23	do	1,600
Mar. 30	do	1,060	June 26	do	1,950



A. KLICKITAT RIVER AT MOUTH.



B. KLICKITAT RIVER AT CAMP KLICKITAT.

In 1908 and 1909 William R. King, chief engineer of the Klickitat Valley Development Company, made some discharge measurements and had gage readings taken to determine the discharge at the lowest stage during the winter of 1908–9. The results are published here through the courtesy of Mr. King.

The discharge measurements were made with a Lallie meter, the rating table furnished by the manufacturers being used. Later this meter was rated at the United States Geological Survey rating station at Chevy Chase, Md., and it was found that the manufacturer's table gave velocities nearly 17 per cent too low. The original notes of Mr. King have therefore been recomputed, and a revision of his first estimates is given below.

The first gage established by Mr. King was near the Camp Klickitat gaging bridge (Pl. IV, *A*) of the Klickitat Irrigation and Power Company, and the measurements were made from the bridge. The results are therefore comparable with those obtained by that company.

Two measurements were made at this point and gage heights were observed during September and October, 1908. From these the table of discharges has been computed.

Discharge measurements of Klickitat River at Camp Klickitat, 1908.

[By W. R. King.]

Date.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
	Feet.	*Square feet.*	*Ft. per sec.*	*Feet.*	*Second-feet.*
September 13	82	200	3.90	1.30	780
October 23	79	177	3.49	1.08	619

Gage height and estimated discharge on Klickitat River at Camp Klickitat, 1908.

Date.	Gage height.	Estimated discharge.	Date.	Gage height.	Estimated discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
September 13	1.3	790	October 4	1.0	560
September 18	1.0	560	October 7	1.0	560
September 19	1.0	560	October 11	1.0	560
September 21	1.1	635	October 13	1.4	870
September 23	1.0	560	October 17	1.2	710
September 25	1.0	560	October 19	1.3	790
September 28	1.0	560	October 23	1.2	710
October 1	1.1	635	October 25	1.1	635

KLICKITAT RIVER AT HANSON'S CABLE.

The second gage installed by Mr. King was at Hanson's cable, a short distance below the mouth of Outlet Creek. This gage was read during the fall and winter of 1908–9, and probably represents as severe low-water conditions during the winter as will be encountered.

Discharge measurements of Klickitat River at Hanson's cable.

[By W. R. King.]

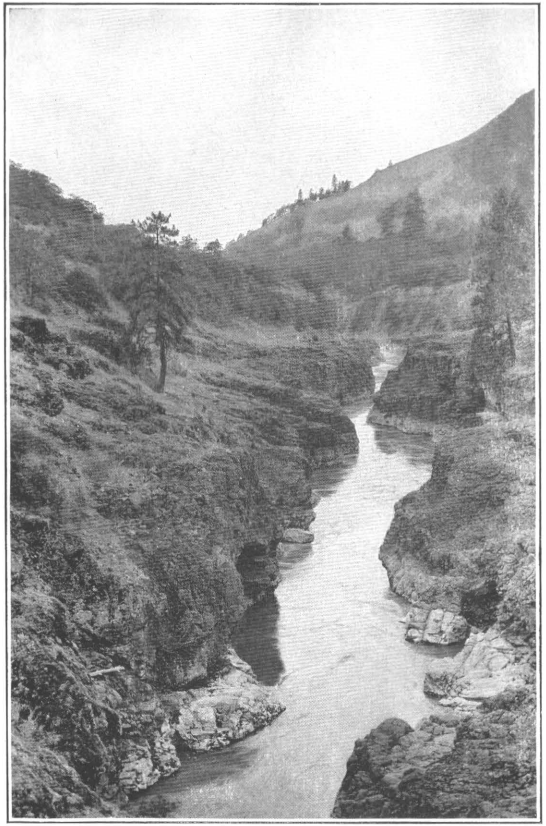
Date.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
1908.	*Feet.*	*Square feet.*	*Ft. per sec.*	*Feet.*	*Second-feet.*
October 24	102	237	3.51	2.00	808
October 30	103	273	3.86	2.28	1,050

Gage height and estimated discharge of Klickitat River at Hanson's cable, 1908-9.

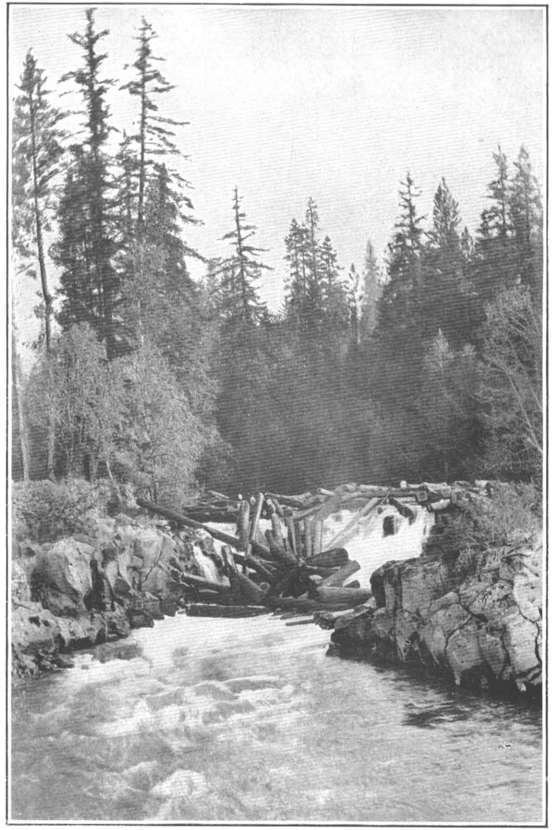
Day.	1908.						1909.			
	October.		November.		December.		January.		February.	
	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
	Feet.	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*	*Feet.*	*Sec.-ft.*
1			2.2	970	2.1	890			2.5	1,250
2							1.9	670		
3			2.1	890	2.1	890			2.5	1,250
4							2.1	890		
5			2.1	890	2.0	810			2.4	1,150
6							1.9	740		
7			2.1	890	2.1	890				
8							1.9	740		
9			2.1	890	2.1	890				
10							1.8	670		
11			2.0	810	2.2	970			2.3	1,060
12							1.9	740		
13			2.0	810	2.0	810				
14							1.9	740		
15			2.0	810	1.9	740			2.3	1,060
16							2.0	810		
17			2.1	890	1.9	740			3.2	2,000
18							2.3	1,060		
19			2.4	1,150	1.9	740			3.2	2,000
20							3.1	1,890		
21			2.5	1,250	1.9	740			3.0	1,780
22							2.5	1,250		
23			2.4	1,150	2.0	810			2.8	1,560
24	2.0	810					3.0	1,780		
25			2.3	1,060	2.0	810				
26							2.8	1,560		
27			2.2	970	2.2	970				
28							2.3	1,060		
29			2.2	970	2.1	890				
30	2.3	1,060					3.1	1,890		
31					2.0	810				

KLICKITAT RIVER AT WELS FERRY.

In 1908 and 1909 daily gage heights were recorded at Wels Ferry, about 8 miles below Wright, by Ham, Yearsley & Ryrie, of Spokane. These heights are published through the courtesy of that firm.



A. BOX CANYON ON KLICKITAT RIVER NEAR MOUTH.



B. LOG DRIVING ON WHITE SALMON RIVER NEAR HUSUM GAGING STATION.

Daily gage height, in feet, of Klickitat River at Wels Ferry, near Lyle, Wash., 1908-9.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
1908.											
1	0.7	−0.2	0.4	0.75	......	1.1	0.85	......	......	......	......
2	.55	− .15	.45	.7	......	1.0	.85	......	......	......	......
3	.45	− .1	.4	.7	1.2	.95	.9	......	......	......	......
4	.4	......	.35	.75	1.25	.95	.8	......	......	......	......
5	.35	.1	.35	.75	1.25	.95	.7	......	......	......	......
6	.3	.4	.3	.7	1.3	1.0	.65	......	......	......	......
7	.3	.2	.3	.65	1.3	1.15	.7	......	......	......	......
8	.35	.1	.25	.6	1.25	1.35	.7	......	......	......	−0.4
9	.7	.3	.25	.65	1.25	1.45	.7	......	......	......	......
10	.65	.5	.20	.7	1.2	1.6	.75	......	......	......	......
11	.55	.45	.20	.75	1.15	1.65	.7	......	......	−0.35	......
12	.5	.4	.35	.9	1.1	1.6	.7	......	......	......	......
13	.5	.3	.45	1.05	1.05	1.5	.75	......	......	......	......
14	.45	.2	.35	1.15	1.0	1.35	.7	......	......	......	......
15	.35	.15	1.9	1.1	1.1	1.3	.65	......	......	......	......
16	.3	.1	2.7	1.15	1.25	1.25	.6	......	......	......	......
17	.5	.15	2.75	1.4	1.25	1.15	.55	......	......	......	......
18	.45	.2	2.45	1.85	1.2	1.05	.45	......	......	......	......
19	.55	.25	1.9	2.15	1.2	1.0	.45	......	......	......	......
20	.65	.3	1.55	2.1	1.15	.9	.45	......	......	......	......
21	.6	.25	1.35	1.9	1.1	.85	.45	......	......	......	......
22	.4	.2	1.35	1.65	1.05	.75	.4	......	......	......	......
23	.3	.2	1.3	1.6	1.0	.6	.4	......	......	......	......
24	.25	.3	1.25	1.55	1.15	.65	.4	......	......	......	......
25	.25	.3	1.25	1.45	1.2	.75	.35	......	......	− .4	......
26	.2	.35	1.2	......	1.25	.85	......	......	......	......	......
27	.15	.4	1.15	......	1.25	.85	......	......	......	......	......
28	.1	.45	1.1	......	1.25	.8	......	......	......	......	−0.4
29	.05	.35	1.0	......	1.25	.85	......	......	......	......	......
30	− .1	......	.9	......	1.25	.85	......	......	......	......	......
31	− .15	......	.85	......	1.2	......	......	......	......	......	......
1909.											
1	......	.4	1.25	1.05	.95	1.6	.4	0.05	−0.15	− .25	− .15
2	......	.65	1.3	1.0	1.0	1.85	.4	.05	− .15	− .25	.15
3	......	.8	1.2	.95	1.15	1.8	.4	.1	− .15	......	.75
4	......	.65	1.05	.9	1.35	1.7	.4	.1	−1.1	......	1.15
5	......	.75	.95	.85	1.45	1.65	.4	.1	− .1	......	.65
6	......	.65	.85	.75	1.35	1.4	.5	.15	− .1	......	.5
7	......	.55	.75	.7	1.25	1.3	.45	.15	− .15	......	.45
8	......	.45	.7	.7	1.15	1.2	.4	.1	− .15	......	.35
9	......	.4	.65	.75	1.10	1.15	.4	.1	− .15	......	.25
10	......	.35	.65	.85	1.05	1.1	.35	.05	− .2	− .3	.1
11	......	.25	.6	.9	1.0	1.1	.35	.05	− .2	− .3	.05
12	......	.3	.65	1.0	.9	1.05	.35	0	− .2	− .3	0
13	......	.4	.7	1.05	.9	1.1	.3	− .05	− .2	− .3	0
14	......	.45	.75	1.1	.95	1.05	.3	− .05	− .2	− .3	− .15
15	......	.55	.85	1.05	.95	1.0	.25	− .1	− .2	− .3	− .3
16	......	.95	.9	1.0	.95	1.0	.25	− .1	− .2	− .3	− .3
17	......	1.85	.95	1.05	1.0	1.05	.2	− .15	− .2	− .3	− .25
18	......	2.25	1.05	1.05	1.0	1.1	.2	− .15	− .2	− .3	− .1
19	......	1.95	.95	1.0	1.05	1.05	.2	− .2	− .25	− .3	1.45
20	......	1.65	.9	1.05	1.1	.95	.15	− .1	− .25	− .3	1.75
21	......	1.35	.85	.95	1.15	.9	.2	− .05	− .25	− .3	......
22	......	1.15	.8	.85	1.1	.8	.25	......	− .25	− .3	......
23	......	1.05	.7	.85	1.05	.75	.2	......	− .3	− .3	......
24	.95	1.35	.75	.9	1.1	.7	.2	......	− .3	− .3	......
25	.85	1.45	.8	1.0	1.15	.65	.2	......	− .3	− .3	......
26	.7	1.45	.8	1.05	1.35	.6	.2	......	− .25	− .3	......
27	.65	1.1	.85	1.15	1.95	.55	.15	......	− .25	− .3	......
28	.5	1.05	.95	1.05	1.55	.5	.15	......	− .25	− .3	......
29	.35	......	1.05	1.0	1.4	.45	.1	− .2	− .2	− .3	......
30	.3	......	1.15	.9	1.45	.45	.1	− .2	− .2	− .3	......
31	.3	......	1.15	......	1.55	......	.05	− .2	......	− .25	......

KLICKITAT RIVER AT WRIGHT.

This station was established July 3, 1909. The gage is on the right bank just back of the post-office, 14 miles above the mouth of the river. At present discharge measurements are made from the railroad bridge, three-fourths of a mile upstream from the gage. The reference point at the bridge is the top of a railroad spike in the downstream end of the right abutment. The water surface at the time of gaging is referred to this reference point as well as to the gage three-fourths of a mile downstream.

The bench mark at the gage is a 20-penny spike in the stream face of a 12-inch alder on the right bank 8 feet back and 3 feet downstream from the gage. Its elevation is 8.15 feet above the zero of the gage. The banks of the river at this point will not overflow and the channel conditions are favorable for good results.

Only two measurements have thus far been made. The one in 1907 has been referred to the gage by comparative readings on it and the reference point at the bridge.

Discharge measurements of Klickitat River at Wright, Wash.

[By H. D. McGlashan.]

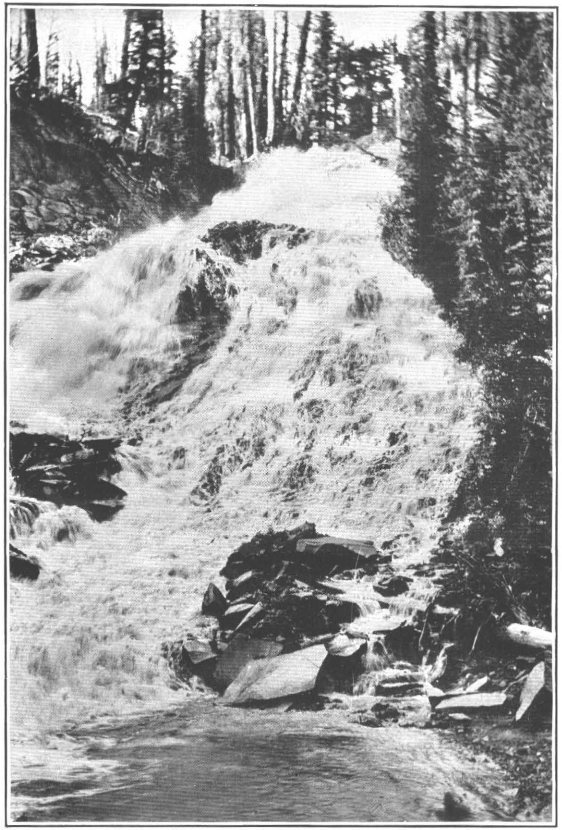
Date.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
	Feet.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*
Sept. 6, 1907	86	204	5.19	2.15	1,050
July 14, 1909	93	266	5.83	2.58	1,550

Daily gage height, in feet, of Klickitat River at Wright, Wash., for 1909.

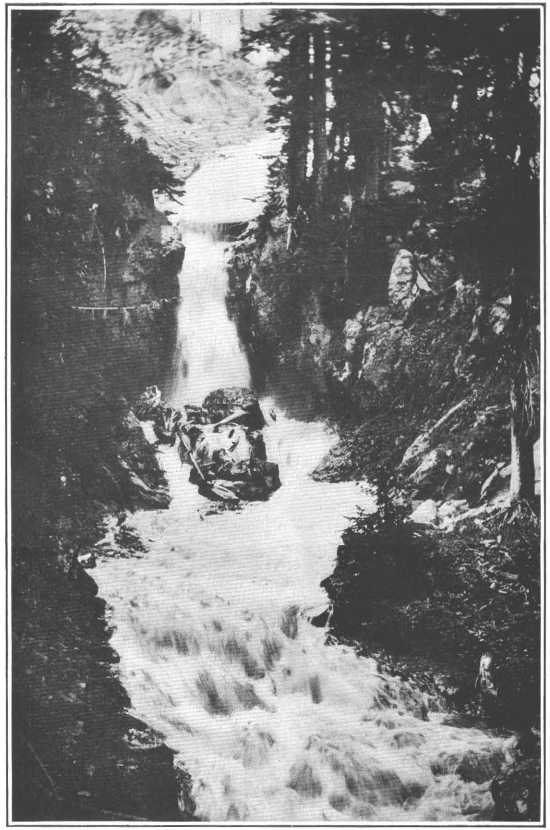
[Mrs. M. A. Young, observer.]

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	2.34	2.05	1.92	2.40	4.9	16	2.6	2.15	2.00	1.90	1.95	3.45
2	......	2.29	2.05	1.90	3.00	4.5	17	2.5	2.18	1.98	1.90	2.10	3.32
3	2.9	2.30	2.02	1.90	3.82	4.1	18	2.48	2.18	1.92	1.88	2.88	3.20
4	2.85	2.28	2.08	1.90	3.45	3.8	19	2.45	2.22	1.92	1.92	4.11	3.14
5	2.85	2.28	2.05	1.98	2.95	3.67	20	2.45	2.22	1.92	1.95	4.12	3.08
6	2.82	2.22	2.05	1.92	2.45	3.55	21	2.45	2.18	2.02	1.95	3.42	2.75
7	2.8	2.21	2.02	1.90	1.98	3.4	22	2.5	2.08	1.98	1.92	(a)	2.75
8	2.8	2.21	2.05	1.90	1.98	3.4	23	2.5	2.10	1.92	1.90	(a)	2.70
9	2.8	2.21	2.08	1.95	2.48	3.3	24	2.5	2.08	1.92	1.90	(a)	2.72
10	2.75	2.22	2.00	1.98	2.40	3.2	25	2.42	2.08	2.00	1.90	5.40	2.80
11	2.7	2.18	1.95	1.98	2.32	3.18	26	2.38	2.20	1.95	1.90	4.70	2.75
12	2.68	2.18	1.98	1.95	2.22	3.60	27	2.36	2.12	2.00	1.88	4.25	2.72
13	2.61	2.18	2.00	1.92	2.20	4.08	28	2.38	2.05	2.00	1.90	4.40	2.65
14	2.6	2.18	2.00	1.95	2.12	3.72	29	2.38	2.05	2.00	1.90	4.85	2.58
15	2.6	2.12	2.00	1.95	1.92	3.52	30	2.39	2.05	1.95	1.88	5.50	2.62
							31	2.32	2.05	......	1.92	......	2.69

[a] Water over the gage.



A.



B.

FALLS ON HELLROARING CREEK NEAR HEAD.

Daily discharge, in second-feet, of Klickitat River at Wright, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	1,250	950	828	11	1,080	855	882	21	1,080	920	855
2	1,200	950	810	12	1,080	882	855	22	980	882	828
3	1,210	920	810	13	1,080	900	828	23	1,000	828	810
4	1,190	980	810	14	1,080	900	855	24	980	828	810
5	1,190	950	882	15	1,020	900	855	25	980	900	810
6	1,120	950	828	16	1,050	900	810	26	1,100	855	810
7	1,110	920	810	17	1,080	882	810	27	1,020	900	794
8	1,110	950	810	18	1,080	828	794	28	950	900	810
9	1,110	980	855	19	1,120	828	828	29	950	900	810
10	1,120	900	882	20	1,120	828	855	30	950	855	794
								31	950	....	828

Monthly discharge of Klickitat River at Wright, Wash., for 1909.

[Drainage area, 1,090 square miles.]

Month.	Discharge in second-feet.				Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	
August	1,250	950	1,080	0.99	B.
September	980	828	897	.82	B.
October	882	794	828	.76	B.
The period	1,250	794	935	.86	

BIG MUDDY RIVER.

The following estimates of the discharge of Big Muddy River are made by taking the differences of discharges measured during 1905 above and below its mouth on the same or succeeding days. Some spring water is contributed above Robertson's ranch and Camp Klickitat. For estimates made at Parrot's bridge Dairy Creek should be included. The discharge of Dairy Creek August 6, 1909, was 4 second-feet.

Discharge measurements of Big Muddy River above mouth of Cougar Creek, 1908.

[By Klickitat Irrigation and Power Company.]

Date	Sec.-ft.	Date	Sec.-ft.
May 5	168	June 2	193
May 8	172	June 5	194
May 13	159	June 9	311
May 16	152	June 12	304
May 19	158	June 16	327
May 23	165	June 19	258
May 26	180	June 23	207
May 29	191	June 26	251

Estimates of discharge of Big Muddy River, 1905.

	Sec.-ft.		Sec.-ft.
June 19	490	August 11, 12	290
June 28, 29	343	August 18, 19	302
July 8	305	September 1, 2	226
July 15	300	September 15	202
July 22	528		

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements were made in the Klickitat basin in 1909:

Miscellaneous measurements in Klickitat River basin, 1909.

[By H. D. McGlashan.]

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*
August 25	Diamond Fork [a]	Mouth	22	18	1.61	29
Do	Klickitat River [b]	Below Diamond Fork	37	45	2.00	90
Do	Piscoe Creek	Mouth (estimated)				6
August 21	McCreedy Creek	do				20
August 19	Pearl Creek	do				2
August 20	Klickitat River [c]	Above Pearl Creek	61	61	1.92	117
August 19	Chaparral Creek	Mouth (estimated)				1
Do	Corral Creek	do				1
August 18	Klickitat River [d]	Above West Fork	60	106	1.45	154
August 31	do. [e]	do	54	91	1.57	143
August 18	Swamp Creek	Mouth (estimated)				6
Do	West Fork [f]	1½ miles above mouth	57	91	3.36	306
August 31	do. [g]	1 mile above mouth	65	96	2.75	264
August 28	Fish Lake Stream [h]	Mouth	40	66	1.61	106
Do	Little Muddy Creek	½ mile above mouth	31	29	4.03	117
Do	Clearwater Creek [i]	Mouth	22	41	1.15	47
August 16	Soda Springs Creek	Soda Springs (estimated).				1
August 31	Klickitat River [j]	Soda Ford	104	148	2.24	331
August 16	Surveyors Creek	1 mile above mouth	12	8.9	.94	8.4
August 13	Cunningham Creek	Mouth (estimated)				12
September 3	Klickitat River [k]	Above Big Muddy River	68	112	3.5	397
September 4	Hellroaring Creek [l]	2 miles above mouth	21	32	2.87	92
August 9	Cougar Creek [m]	Mouth (estimated)				3
Do	Klickitat River [n]	¾ mile below Big Muddy River.	84	198	3.7	732
September 3	do. [o]	do	83	191	3.86	738
August 6	Dairy Creek	Mouth (estimated)				4
August 4	Bacon Creek	do				8
July 31	Outlet Creek	Bodie ranch	10	6.5	.92	5.7
July 14	Klickitat River [p]	Wright	93	2.66	5.83	1,550

[a] Water surface 2.97 feet below 10-penny nail in 24-inch cottonwood on left bank, 150 feet upstream from United States Geological Survey bench mark.

[b] Water surface 3.60 feet below 10-penny nail in 5-inch alder on right bank, 8 feet below two 18-inch cotton woods, 300 feet below mouth of Diamond Fork.

[c] Made 900 feet above mouth of Pearl Creek, opposite water-right notice of Klickitat Irrigation and Power Company.

[d] Water surface 2.76 feet below 10-penny nail in upstream side of foot log near right bank, 600 feet above mouth of West Fork.

[e] Water surface 2.86 feet below reference point described for gaging of August 18.

[f] Water surface 3.10 feet below 10-penny nail in upstream face of 18-inch cedar on right bank, near trail crossing.

[g] Gaged one-half mile below point of measurement of August 18; water surface 3.14 feet below reference point described for that gaging.

[h] Fish Lake Stream and Little Muddy Creek unite to form West Fork. Gaging made below mouth of Clearwater Creek.

[i] Tributary of Little Muddy River; water clear; high-water marks 1.5 feet above this stage.

[j] Gage height 2.20 feet on gage established on right bank, 25 feet above trail crossing 1 mile below Soda Ford, 4 miles below West Fork; excellent site for gaging station.

[k] Water surface 4.33 feet below crosscut on stream face of 12-inch alder on right bank near perpendicular basalt cliff; results excellent.

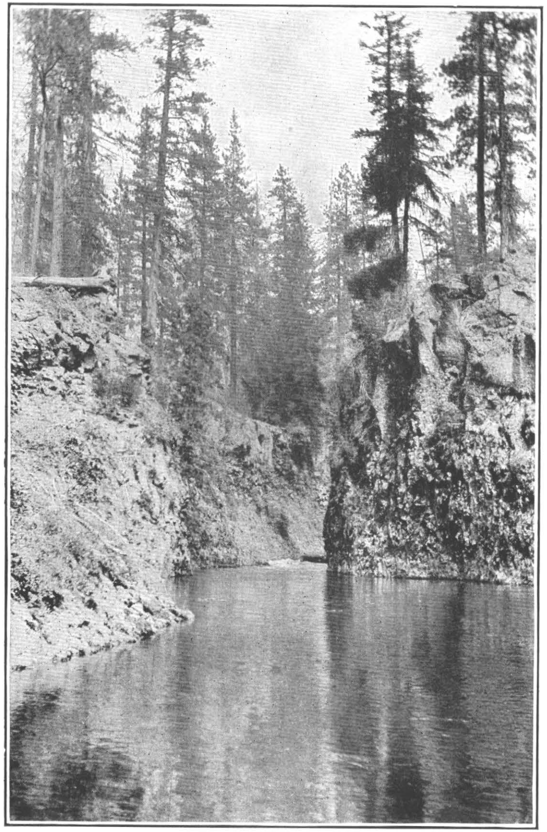
[l] Tributary of Big Muddy river, gaged at sheep bridge 2 miles above mouth; extreme high water is about 1.0 foot above present stage; water is color of dark chocolate.

[m] Tributary of Big Muddy River.

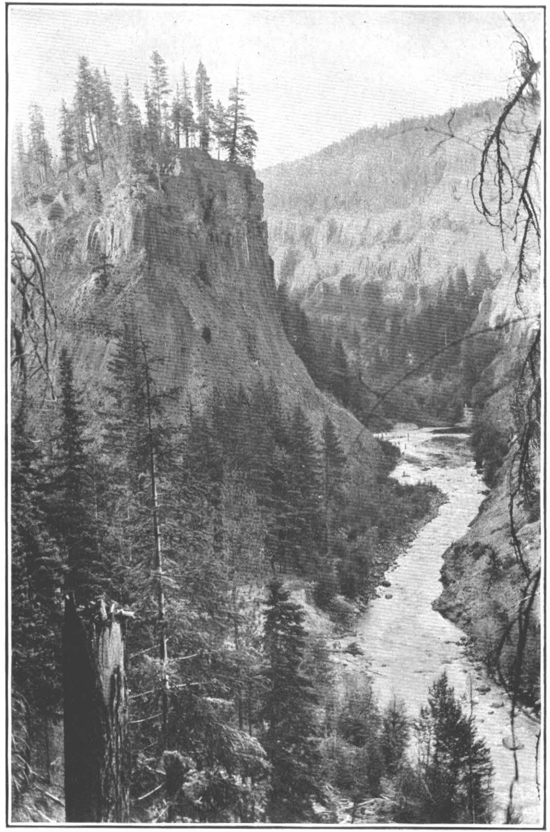
[n] Gaged from bridge at Camp Klickitat; an old gage 50 feet upstream from bridge on right bank read 0.55; channel conditions not favorable for good results.

[o] Gaged from bridge at Camp Klickitat; gage read 0.47.

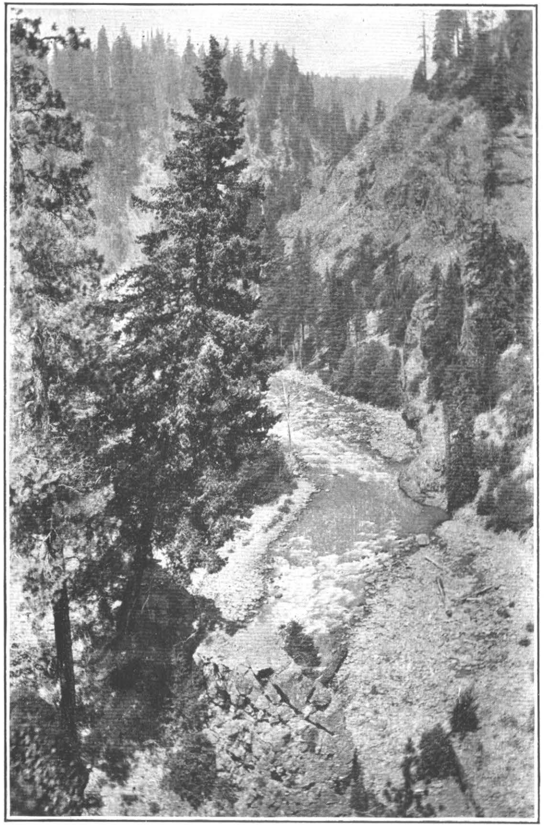
[p] Gaged from railroad bridge; gage height 2.58 at Wright.



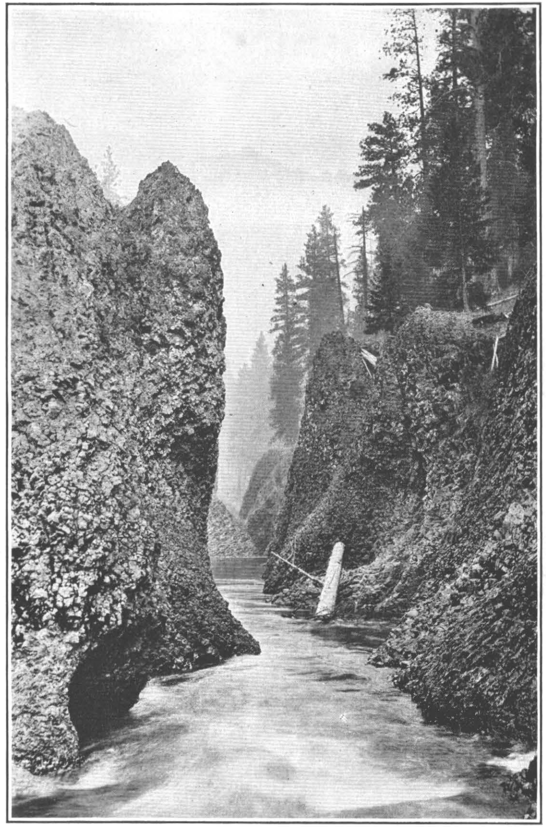
A. DAM SITE ON KLICKITAT RIVER ABOVE WEST FORK.



B. MUDDY POINT, AT MOUTH OF BIG MUDDY RIVER.



A. KLICKITAT RIVER NEAR GLENWOOD.



B. KLICKITAT RIVER NEAR CASTILE FORD.

AVERAGE MINIMUM DISCHARGE.

From the foregoing data the following table has been compiled. The average minimum is taken as the mean discharge for the lowest week and is arbitrarily increased 20 per cent, as explained on page 31. Where only miscellaneous measurements are available the average minimum has been estimated by considering the relation of the time at which these measurements were made to that of the lowest week. Allowance has also been made for intervening accretions to the flow as indicated by springs or tributaries measured or estimated.

Average minimum discharge for Klickitat River drainage basin.

Locality.	Drainage area.		Date.	Measured discharge.	Adjusted to average minimum.
	Square miles.	Per cent of total.			
Klickitat River:				Sec.-ft.	Sec.-ft.
Below Diamond Fork	85	7	August 25, 1909 [a]	90	80
Below McCreedy Creek	129	11			105
At Castile Ford	150	13			120
Below West Fork	254	22			370
Below Big Muddy River	347	30	October 11, 1908 [b]	560	590
Below Outlet Creek	528	46	January 12, 1909 [b]	720	790
At Alvord's bridge, sec. 12, T. 5, R. 13	663	57			800
Below Little Klickitat River	995	86			900
At Wright gaging station	1,090	94	October 30, 1909 [b]	807	970
At head of box canyon	1,140	99			1,000
Fish Lake Stream and West Fork:					
At head of survey	38		August 28, 1909 [a]	106	120
Below Little Muddy Creek	83		Winter	264	190
Big Muddy River below Hellroaring Creek	23		do		100

[a] Date of miscellaneous measurement used as a guide.
[b] Date of ending of week for which the mean discharge was the lowest.

These discharges are compiled for the purpose of estimating water power; therefore the use of the water for that purpose must be considered. On the glacial streams (Big Muddy River and its tributaries and Little Muddy Creek) the lowest period occurs during the cold weather in the winter. Their availability for power development is therefore governed by the winter minimums. On the main stream the summer minimums govern. During the summer low-water period the glacial streams are comparatively high; during the winter low-water period the nonglacial streams are comparatively high. Hence for a power plant on Big Muddy River the estimated winter minimum of 100 second-feet is used; but for a plant on the main Klickitat below Big Muddy River an estimate of 200 second-feet is used for that part contributed by the Big Muddy during this minimum period on the main stream. Similarly, for Fish Lake Stream (nonglacial) the estimate is 120 second-feet, while for West Fork below the mouth of the Little Muddy 190 second-feet is used for the winter flow on account of portions contributed by Little Muddy Creek. But for the main stream below West Fork 250 second-feet is used as the probable contribution of West Fork, because during the summer season Little Muddy Creek is comparatively high.

WATER POWERS.

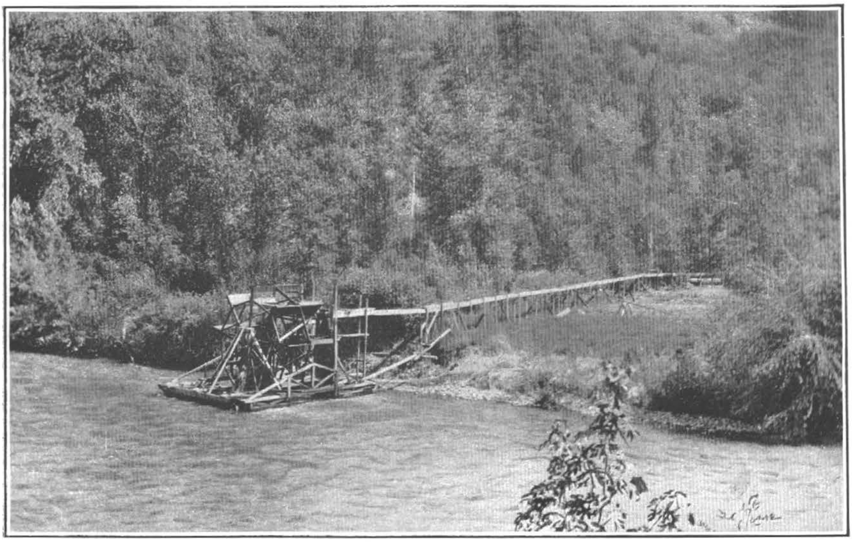
On account of the fairly steep grade, well-maintained flow, and rocky canyons through which Klickitat River and its tributaries flow, the system offers some exceptionally favorable opportunities for power development. At present, however, there are no such developments in the drainage area, although several water filings have been made for power and irrigation.

The filings of the Klickitat Irrigation and Power Company contemplate the diversion of the waters of Klickitat River for the irrigation of lands in the Horseheaven district. The lands to be irrigated lie on the high table-land between Columbia and Yakima rivers south of the city of Prosser. The project involves the construction of a canal about 150 miles long and the development of such storage facilities as the area to be traversed affords. The water is to be diverted from Fish Lake Stream and the main Klickitat above the mouth of West Fork.

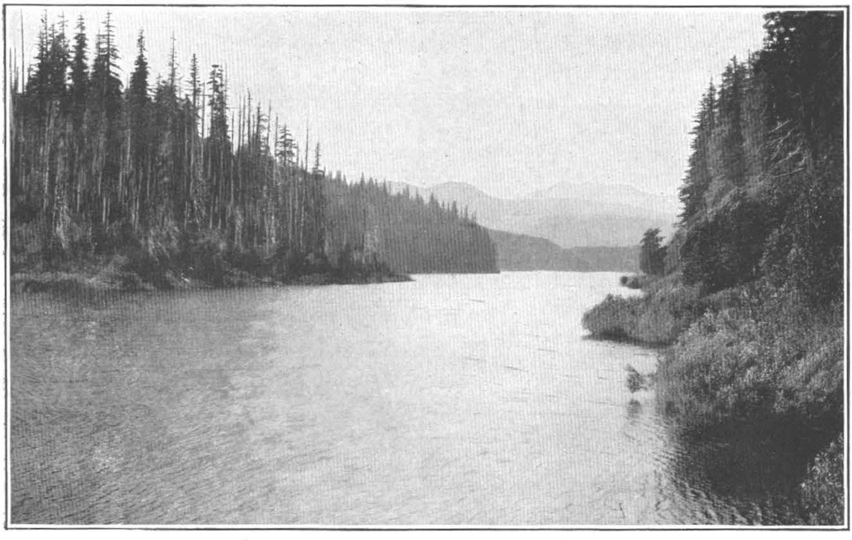
The Klickitat Valley Development Company is engaged in the construction of a project for the irrigation of the table-lands in the vicinity of Glenwood. Water diverted below the mouth of Big Muddy River can be carried upon the lands by gravity flow, affording some good incidental opportunities for power development.

Ham, Yearsley & Ryrie, of Spokane, Wash., have made filings on the lower Klickitat for power development. This project contemplates the laying of large pipe lines along the sides of the canyon and the erection of a power house near the mouth of the river.

West Fork and Big Muddy River offer some favorable opportunities for high-head developments. The streams flowing directly from Mount Adams, are almost literally "on end," and there are numerous falls which could readily be utilized for power development. Below the mouth of Hellroaring Creek Big Muddy River enters a box canyon, in places not over 6 feet wide, cut into the basalt. The total fall in the last 3½ miles is 968 feet. Above the mouth of Hellroaring Creek this stream falls 1,300 feet in 4 miles over large bowlders that fill the river bed. The bed of Hellroaring Creek is similarly strewn with bowlders, and the waters fall nearly 2,000 feet in 5¼ miles. (See Pl. VI, *A* and *B*.) One-half mile above the mouth of West Fork there are falls 15 feet in height. Another drop of about the same height occurs three-fourths mile below the mouth of Little Muddy Creek and there are several falls on Fish Lake Stream, a short distance above its mouth. The grade of the main Klickitat is fairly uniform, averaging 44.5 feet to the mile for the 73 miles surveyed. The fall gradually decreases from 63 feet to the mile below Diamond Fork

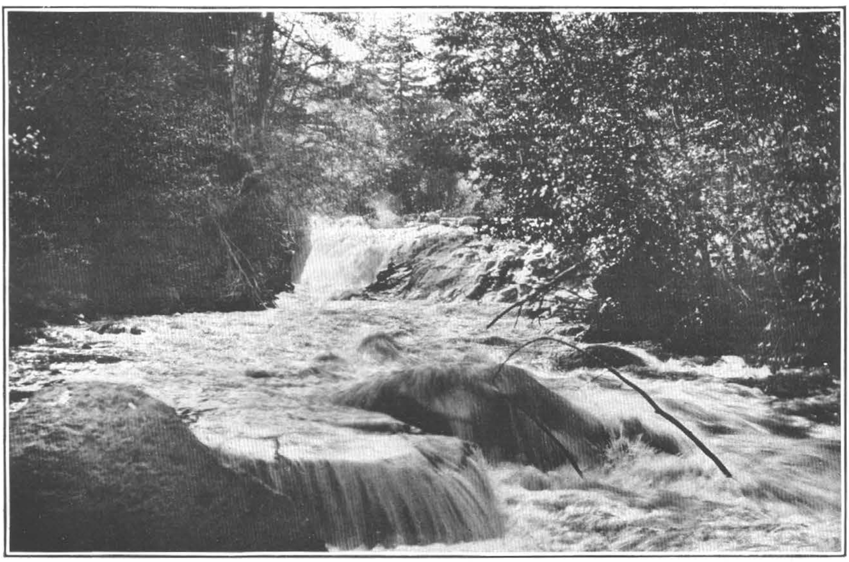


A. IRRIGATION WHEEL ON KLICKITAT RIVER NEAR WRIGHT.



B. LAKE MERRILL, ON LEWIS-KALAMA RIVER DIVIDE.

A. FALLS ON WEST FORK OF KLICKITAT RIVER.



B. FALLS ON BIG MUDDY RIVER.

to 20 feet to the mile at the head of the box canyon (Pl. V, *A*). This box canyon continues from a point about half a mile above the lower railroad bridge to the mouth of the river, but the lower 1½ miles are subject to backwater from Columbia River. The canyon has been cut in the solid basalt (Pl. III, *A*), and in places is not over 10 feet in width, with perpendicular sides of jagged rock. The total fall here is 75 feet in three-fourths of a mile. Favorable sites for dams are numerous on the main stream (Pls. VII, *A;* VIII, *A*), and the benches along the river in some places render construction of open canals entirely feasible. On the steep canyon sides, however, water would be more safely carried in large pressure pipes. During warm weather the waters, particularly those from Mount Adams, carry considerable glacial silt which would cut machinery badly.

In computing the water powers in this drainage basin the streams have been considered in sections. The sections are limited by some tributary or otherwise divided in order to keep their length within possible limits of diverting canals or pipe lines. The elevations of the water surface at the extremities of these sections, the total fall, the fall per mile, and the drainage area of each section considered are given below. The discharge at the upper end of the section has been estimated from the data already presented. In determining this discharge an attempt has been made to give an average minimum in the manner previously described. This figure is the most uncertain part of the data, but it is believed to be conservative.

The horsepower given is 70 per cent of the theoretical power that is computed from the known fall in the section and the estimated discharge at its upper extremity. Seventy per cent is, of course, an arbitrary proportion, but it represents very nearly the power on turbine shafts that is actually realized in many plants in operation at the present time.

Water powers in Klickitat River drainage basin.

Point on stream.	Distance above mouth.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Drainage area.	Average minimum discharge.		Available horsepower (70 per cent of theoretical).
							Second-feet.	Second-feet per square mile.	
Klickitat River.									
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Sq. miles.*			
Below mouth of Diamond Fork	72.70	3,330	....	....	......	85	80	0.94	....
Above mouth of McCreedy Creek	67.35	2,995	5.35	335	62.6	110	....	....	2,270
Below mouth of McCreedy Creek	67.35	2,995	....	....	......	129	105	.81	....
Castile Ford	62.15	2,715	5.20	280	53.8	150	120	.80	2,340
Above mouth of West Fork	60.50	2,545	1.65	170	10.3	162	....	....	1,600
Below mouth of West Fork	60.50	2,545	....	....	......	254	370	1.46	....

Water powers in Klickitat River drainage basin—Continued.

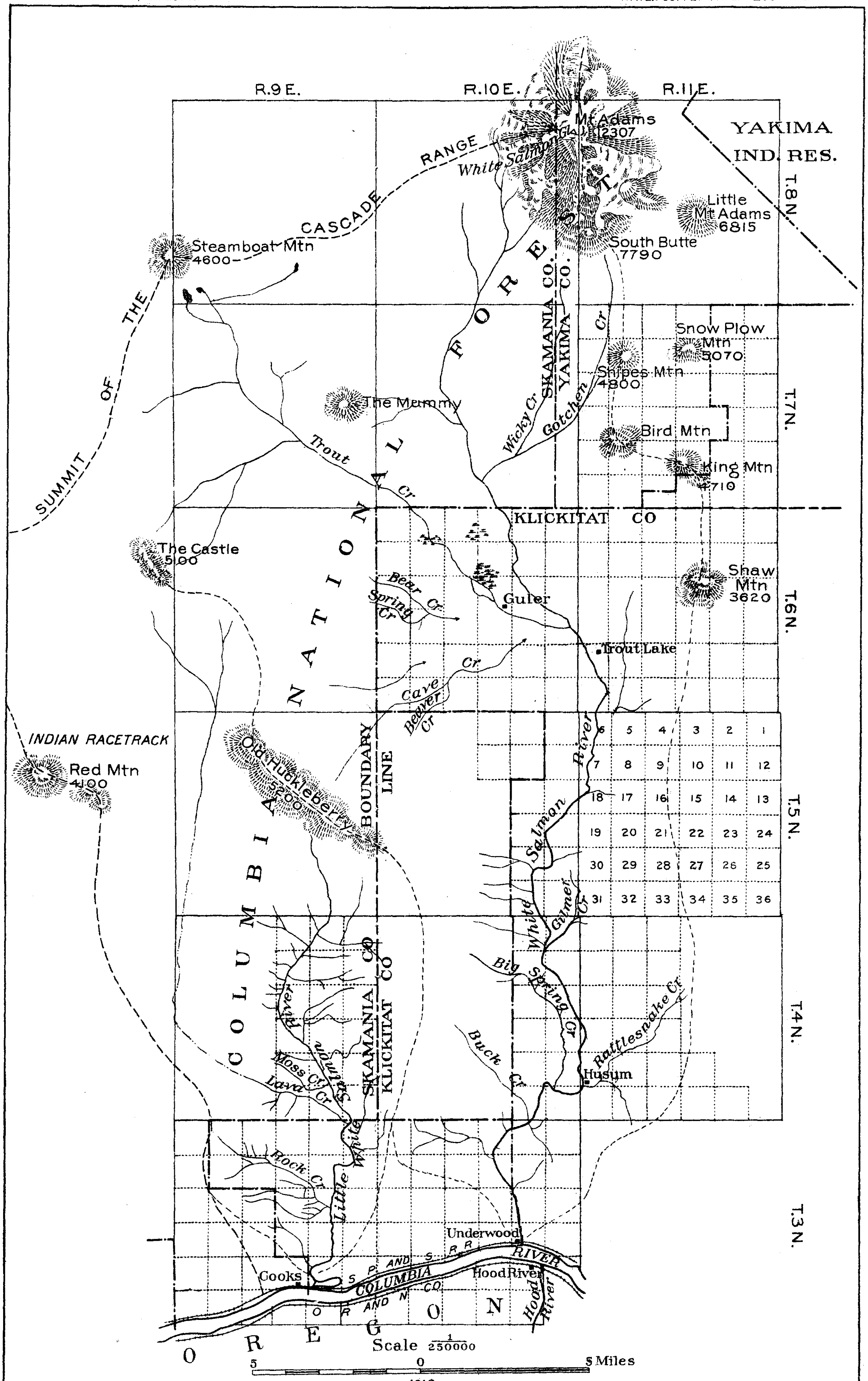
Point on stream.	Distance above mouth.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Drainage area.	Average minimum discharge.		Available horsepower (70 per cent of theoretical).
							Second-feet.	Second-feet per square mile.	
Klickitat River—Continued.									
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Sq. m.*			
Above mouth of Big Muddy River	51.85	1,982	8.65	563	65.1	314			16,500
Below mouth of Big Muddy River	51.85	1,982				347	590	1.71	
Above mouth of Outlet Creek	37.85	1,155	14.0	827	59.0	441			38,900
Below mouth of Outlet Creek	37.85	1,155				528	790	1.50	
Alvord's Bridge, sec. 12, T. 5, R. 13	30.30	855	7.55	300	39.8	663	800	1.21	18,900
Above mouth of Little Klickitat River	19.55	565	10.75	290	27.0	710			18,400
Below mouth of Little Klickitat River	19.55	565				995	900	.90	
Wright	13.65	445	5.90	120	20.3	1,090	970	.89	8,600
Head of box canyon	2.20	150	11.45	295	25.7	1,140	1,000	.88	22,800
Foot of rapids	1.45	75	.75	75	10.0	1,160			6,000
West Fork and Fish Lake Stream.									
Head of survey	6.75	3,370				38	120		
Above mouth of Little Muddy Creek	4.42	3,012	2.33	358	15.4	42			3,400
Below mouth of Little Muddy Creek	4.42	3,012				83	190		7,100
Mouth		2,545	4.42	467	10.6	92			
Big Muddy River.									
Below mouth of Hellroaring Creek	3.45	2,950				23	100		
Mouth		1,982	3.45	968	28.1	33			7,700
									154,000

WHITE SALMON RIVER DRAINAGE BASIN.

DESCRIPTION.

White Salmon River has its source in three glaciers on the west side of Mount Adams. The largest of these is White Salmon River Glacier. To the north of this lies Pinnacle Glacier and to the south Avalanche Glacier. The river flows southward and empties its waters into Columbia River at the town of Underwood. The source and mouth of the river lie on the same meridian. The river has a total length of 38.5 miles and a total drainage area of 352 square miles. Plate XI is a map of this drainage area.

Trout Creek is the principal tributary. It drains the high spurs and secondary peaks to the southwest of Mount Adams, flows in a southeasterly direction, and empties into White Salmon River near Trout Lake post-office. Three small creeks—Big Spring Creek from the west and Gilmer and Rattlesnake creeks from the east—empty into the river below Trout Creek in the vicinity of Husum. Gotchen



JULIUS BIEN & CO. PHOTO. LITH. N.Y.

MAP OF DRAINAGE BASINS OF WHITE SALMON, AND LITTLE WHITE SALMON RIVERS, WASHINGTON

Creek, the principal tributary above Trout Creek, drains the high spurs to the southeast of Mount Adams.

The drainage area of White Salmon River is distributed as follows:

	Square miles.
Above the mouth of Trout Creek	84
Below the mouth of Gilmer Creek	290
At Husum	300
At Underwood	352
Trout Creek	85

The prominent topographic feature of the area is Mount Adams (Pl. XII, *A*) and the spurs and secondary peaks that surround it. These peaks crown the bounding lines of the drainage area, which is roughly V-shaped with Mount Adams at the apex. On the west Steamboat Mountain (at an elevation of 4,600 feet), the Castle (5,100 feet), and Old Huckleberry (5,200 feet) stand like sentinels on the summit of the divide. South Butte (7,790 feet), Snow Plow (5,070 feet), Snipes Mountain (4,800 feet), King Mountain (4,710 feet), and Snow Mountain (3,620 feet) prominently mark the eastern boundary. The basin is therefore roughly trough-shaped with several smaller peaks within it. The topography is bold and picturesque. The streams flow in deep canyons on beds of bowlders, with here and there ledges of basalt or stretches of box canyons that have vertical jagged sides and solid beds.

The whole drainage basin is covered with lava and basalt, in which the canyons have been carved. Near Mount Adams many cinder cones and bombs give evidence of recent volcanic activity. Red Butte, 3 miles northeast of Mount Adams, has an elevation of 7,203 feet. The cone is 500 feet high, with a crater 175 feet in diameter and 75 feet deep. Much of the pumice, scoria, and lava from these cones is highly colored, and volcanic glass is found in various shades from black masses to transparent globules. The bombs on the lower slopes of Mount Adams are rough spherical masses of lava, of homogeneous texture, ranging up to 30 feet in diameter. Near the headwaters are large areas of partly exposed lava beds. A line of caves may be traced along this formation for 20 miles or more. In some places the caves have been formed by the liquid mass flowing from under a solidified crest; in others they may have resulted from the action of gases and are in effect huge bubbles. One of these in sec. 25, T. 6 N., R. 9 E is widely known as the Ice Cave. The temperature is so low that water accumulating and freezing during the winter does not thaw out during the following summer. The ice is found in masses on the floor and in stalactites and stalagmites formed by surface water dripping through crevices in the roof. These form during the winter and are partly melted during the summer. The area in which these caves lie is drained by Trout Creek. The basin contains several small intermittent watercourses in which the water sinks at many points. It is likely that much of the surface water finds its way deep into these lava beds, emerging into lower portions of White Salmon River or even into the adjacent drainage basin of Little White Salmon River.

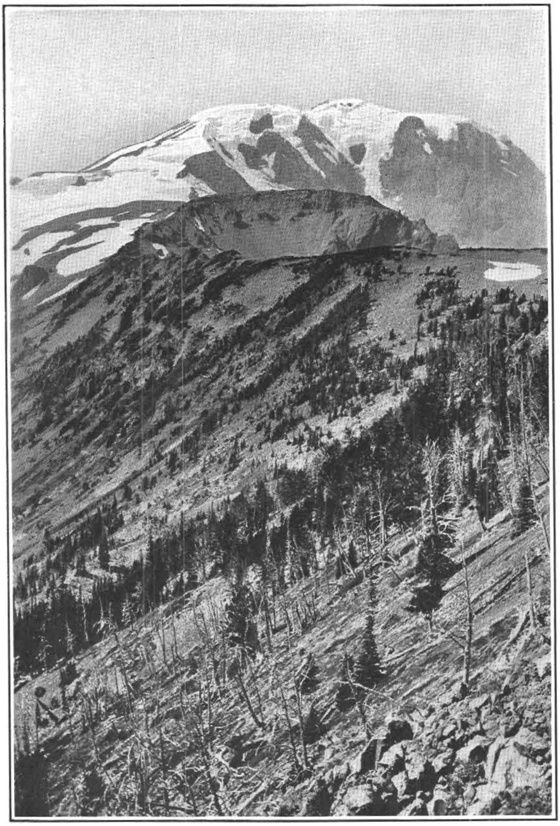
The main river flows in a deep canyon whose sides are bordered by heavily rolling table-lands or mountains. From a point 3 miles below Trout Creek to a point 2½ miles above Husum the river flows in a narrow box canyon. This has been cut squarely into the basalts and the recent lava flows that have overspread them. The canyon is about 11 miles long and nearly every part of it would afford a favorable site for a dam. Trout Creek, on the other hand, is essentially a surface stream below Trout Lake. The banks are bordered by fairly level stretches of open meadows and agricultural land.

The north line of T. 6 N. forms the southern boundary of the Columbia National Forest. Logging operations have been carried on for years in this drainage area, for the most part on lands adjacent to the river (Pl. V, *B*, p. 44). The entire drainage area is heavily forested except where cleared for agriculture. Within the national forest the timbered area constitutes 73 per cent of the total, 26 per cent is burned, and 1 per cent is above timber line. The species are distributed in about the same proportion as those in the adjacent Klickitat basin, except that there is more red or yellow fir and less yellow pine. The stand of timber within the national forest is about as follows:

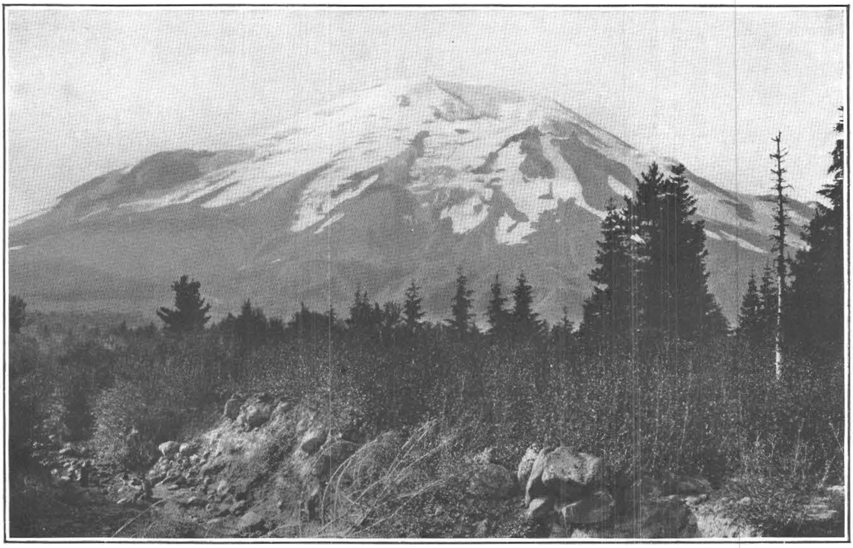
	Per cent.
0 to 2,000 feet b. m. per acre	18
2,000 to 5,000 feet b. m. per acre	30
5,000 to 10,000 feet b. m. per acre	40
10,000 to 25,000 feet b. m. per acre	8
25,000 to 50,000 feet b. m. per acre	4

There are no railroads in the drainage area except the Spokane, Portland and Seattle Railway which crosses the river at its mouth in its course along the right bank of Columbia River. The principal towns are Underwood and White Salmon, the latter being on the high table-land east of the river near its mouth. Husum post-office is at the mouth of Rattlesnake Creek. Trout Lake post-office is near the mouth of Trout Creek, on the east side of the river, and Guler is on Trout Creek near the outlet of Trout Lake. Good wagon roads and stage lines connect all the towns. The upper portion of this area is a favorite summer resort, and many campers will be found around Trout Lake and Guler in the summer.

The rolling benches along the lower part of the river have been cleared for agriculture. Most of these lands are in orchards and the



A. MOUNT ADAMS FROM THE SOUTHEAST.



B. MOUNT ST. HELENS FROM THE NORTHEAST.

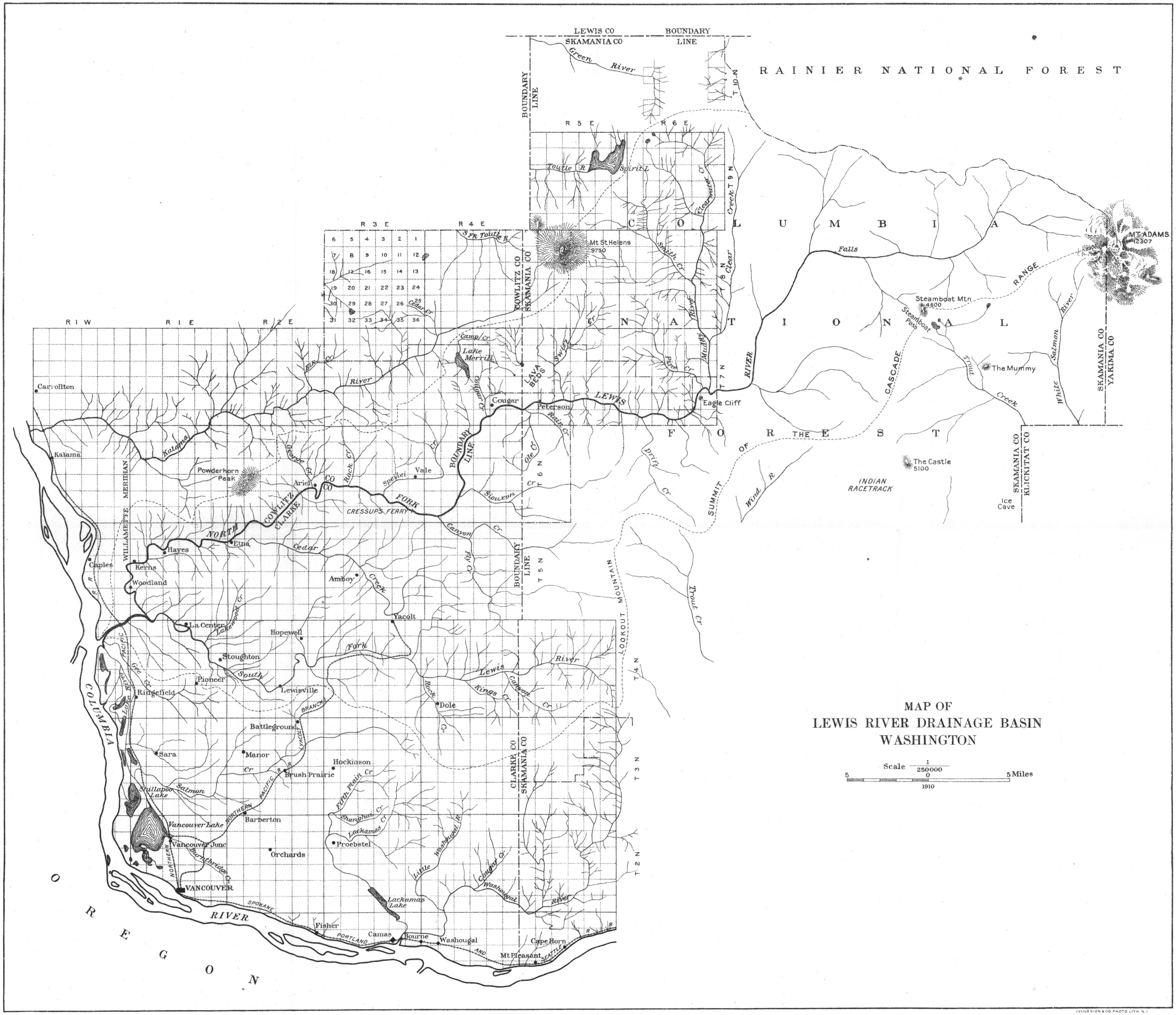
territory has become justly famous for the excellent quality of its apples and other fruit. In T. 6 N. the lands along the river are comparatively flat and some of them were natural meadows. These open lands have been enlarged by clearing the timber around them and the whole valley presents a delightful picture of prosperity. In this portion of the valley irrigation is practiced extensively. The water for the ditches is diverted from Trout Creek and White Salmon River. These ditches are small but numerous and they have an abundant supply of water.

At present lumbering is the principal industry of this territory. The Wind River Lumber Company has constructed several splash dams on White Salmon River by means of which logs are floated from the upper portion of the drainage area to the mouth of the river, when they are gathered and transported in rafts to the mills on the lower Columbia.

At Husum is a small power plant owned and operated by the Husum Power Company. The present capacity of the plant is 200 horsepower. It is developed by a Sampson twin turbine with 26-inch wheels, belt connected to a 75-kilowatt General Electric alternator, generating at 2,300 volts. Current is transmitted to White Salmon, 6½ miles, and up the valley 2 miles, for lighting and power. The water is supplied to the wheels by a canal 200 feet in length. The canal normally carries 120 second-feet and develops a head of 17 feet around falls in the river at this point.

So far as known, the basin affords no large reservoir sites. Trout Lake is the only flat area that would be suitable, but the outlet is a broad valley and no favorable dam sites are found. Most of the water runs off during the spring, exposing the lake bed as a marshy flat. A small amount of storage might be developed at Steamboat Lake near the headwaters of Trout Creek.

Owing to the porous lava rocks of which the area is composed and the soil resulting from its disintegration, a large amount of water is held in ground storage. Springs are numerous along the river and seepage into it is large. Most of the summer flow, however, is supplied by the glaciers on Mount Adams. Above Trout Creek, White Salmon River has its lowest discharge during cold weather, while on hot summer days the discharge is high and the water is heavily loaded with glacial silt. Trout Creek, on the other hand, has its lowest period at the end of the summer season. During the winter months the discharge is relatively high from surface drainage from the large area through which it flows. The two streams, therefore, maintain a well-balanced flow during the year. Floods occur during heavy rains when accompanied by chinook winds, which suddenly melt the snow on the hills. The heaviest floods are likely to occur in the



JULIUS BIEN & CO. PHOTO LITH. N.Y.

autumn after an early snowfall. A flood from this cause of greater or less magnitude may be expected about the middle of each November and at other times during the winter months. Spring floods occur periodically, but are rarely so severe as the fall floods and are not so sudden. These result from the more gradual melting of snow in the mountains as warm weather approaches. This melting is arrested at night, with the result that the stream shows daily variations of considerable magnitude.

No discharge data are available except those gathered during the course of the survey in the summer of 1909. Measurements were made at several points on the main stream and its tributaries. Two permanent gaging stations were established, on Trout Creek at Guler and on White Salmon River at Husum.

WHITE SALMON RIVER AT HUSUM.

This station was established September 23, 1909. The gage is a vertical staff on the right bank 1,200 feet above the bridge at Husum and above the power-canal intake. No permanent equipment was installed for making measurements at high stages.

On account of the extensive and continual use of the stream for floating logs, the gage heights are more or less affected by backwater when they lodge in the channel. (See Pl. V, *B*.)

A discharge measurement was made September 23, 1909, by H. D. McGlashan:

Gage height, 3.12 feet; area, 249 square feet; mean velocity, 2.61 feet per second; discharge, 650 second-feet.

Daily gage height, in feet, of White Salmon River at Husum, Wash., for 1909.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		2.85	3.12	5.85	16		3.03	3.15	4.12
2		3.00	4.15	5.10	17		3.00	3.14	4.10
3		3.00	5.90	4.80	18		3.00	3.95	4.06
4		3.10	6.20	4.65	19		3.00	6.35	4.03
5		3.10	4.25	4.45	20		3.05	6.80	4.02
6		2.90	3.80	4.33	21		3.10	4.90	4.00
7		2.90	3.50	4.20	22		3.00	5.25	3.90
8		3.00	3.52	4.12	23		3.05	7.30	3.90
9		2.95	3.70	4.01	24	3.10	3.08	7.65	3.90
10		3.05	3.60	3.98	25	3.10	3.06	5.90	3.88
11		3.08	3.45	3.96	26	3.03	3.00	5.20	3.85
12		3.00	3.30	4.16	27	3.00	2.92	4.80	3.83
13		2.90	3.21	4.60	28	3.10	2.96	4.75	3.80
14		2.90	3.20	4.45	29	3.05	3.12	5.25	3.75
15		2.95	3.18	4.20	30	3.25	3.10	7.30	3.85
					31		3.18		3.85

Daily discharge, in second-feet, of White Salmon River at Husum, Wash., for 1909.

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1		510	11		629	21		640
2		585	12		585	22		585
3		585	13		535	23		612
4		640	14		535	24	640	629
5		640	15		560	25	640	618
6		535	16		602	26	618	585
7		535	17		585	27	585	545
8		585	18		585	28	640	565
9		560	19		585	29	612	651
10		612	20		612	30	722	640
						31		684

TROUT CREEK AT GULER.

This station was established September 16, 1909.

The gage is a vertical staff located 500 feet below the highway bridge on the left bank. The station is above all diversions for irrigation. Measurements are made by wading or from the bridge at high stages. The conditions are favorable for good results, and the data will be valuable for irrigation and general statistical purposes.

A measurement was made September 16, 1909, by H. D. McGlashan:

Gage height, 1.32 feet; area, 34 square feet; mean velocity, 1.38 feet per second; discharge, 47 second-feet.

Daily gage height, in feet, of Trout Creek at Guler, Wash., for 1909.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1		1.58	2.61	7.00	16	1.32	1.32	2.90	4.00
2		1.41	4.10	6.41	17	1.32	1.32	3.10	4.00
3		1.41	6.71	6.05	18	1.32	1.32	3.60	4.00
4		1.41	6.25	5.25	19	1.34	1.39	6.00	3.76
5		1.72	4.66	5.00	20	1.55	1.74	5.55	3.76
6		1.74	4.32	4.75	21	1.64	1.96	5.00	3.75
7		1.73	4.32	4.53	22	1.52	1.87	4.62	3.75
8		1.64	4.34	4.31	23	1.45	1.75	5.30	3.73
9		1.54	5.00	4.30	24	1.36	1.72	6.00	3.70
10		1.46	4.72	4.30	25	1.38	1.65	7.16	3.70
11		1.38	3.40	4.30	26	1.35	1.55	6.42	3.65
12		1.38	2.80	4.41	27	1.32	1.55	5.15	3.63
13		1.37	2.80	4.40	28	1.32	1.54	4.86	3.50
14		1.36	2.75	4.34	29	1.50	1.64	5.52	3.50
15		1.33	2.82	4.30	30	1.61	2.15	6.25	3.20
					31		2.20		3.00

Daily discharge, in second-feet, of Trout Creek at Guler, Wash., for 1909.

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1		70	11		52	21	76	114
2		55	12		52	22	65	101
3		55	13		52	23	58	88
4		55	14		51	24	51	84
5		84	15		48	25	52	77
6		86	16	48	48	26	50	68
7		85	17	48	48	27	48	68
8		76	18	48	48	28	48	67
9		67	19	49	53	29	63	76
10		59	20	68	86	30	73	147
						31		157

MISCELLANEOUS MEASUREMENTS.

Miscellaneous discharge measurements were made in this basin as shown in the following table. The normal capacities of irrigation ditches diverting water from White Salmon River and Trout Creek were also determined from the quantity carried at the time of making the survey.

Miscellaneous measurements in White Salmon River basin, 1909.

[By H. D. McGlashan.]

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Sq. feet.*	*Ft. per sec.*	*Sec.-feet.*
September 11	Unnamed [a]	Mouth (estimated)				1.5
Do	Unnamed [b]	do				10
September 13	Gotchen Creek	do				25
Do	Unnamed [c]	do				1
Do	White Salmon River [d]	Sheep bridge	28	56	3.68	206
September 23	Gilmer Creek	Mouth (dry)				0
September 24	Rattlesnake Creek	Mouth (estimated)				2
Do	Big Spring Creek	do				10
September 25	Little Buck Creek	do				4
Do	Unnamed [e]	do				1

[a] Tributary from left 4.8 miles above boundary line of national forest.
[b] Tributary from left 3.8 miles above boundary line of national forest.
[c] Tributary from right 1 mile above boundary line of national forest.
[d] Water surface 2.05 feet below 10-penny nail in stream face of small alder on left bank 100 feet below bridge at trail crossing 1 mile above boundary line of national forest.
[e] Tributary from left 3.5 miles above mouth of White Salmon River.

Irrigation ditches in White Salmon River drainage basin.

DIVERTING WATER FROM WHITE SALMON RIVER.

Name of ditch.	Location of head-gate.	Bank of stream.	Approximate capacity.
			Sec.-feet.
Wagnitz	NE. ¼ sec. 3, T. 6, R. 10	Right	3
Thomas	NW. ¼ sec. 14, T. 6, R. 10	do	2
Coats and Duncan	do	Left	10
Coats Bros	SE. ¼ sec. 14, T. 6, R. 10	do	5
Dutch	do	do	5
Pearson	do	do	5
Huber	SE. ¼ sec. 24, T. 6, R. 10	Right	3
Trout Lake	NE. ¼ sec. 31, T. 6, R. 11	Left	25
DIVERTING WATER FROM TROUT CREEK.			
McDonald	NE. ¼ sec. 22, T. 6, R. 10	Right	8
Pearson-Thompson	do	do	7

AVERAGE MINIMUM DISCHARGE.

From the foregoing data the following table has been compiled. The average minimum for the Husum and Guler stations is taken as the mean discharge for the lowest week and is arbitrarily increased 20 per cent, as explained on page 31. The miscellaneous measurements have been used in combination with the data obtained at the gaging stations in estimating the average minimum discharge at other points on the stream. Allowance has also been made for intervening accretions to the flow, as indicated by springs or tributaries. No allowance has been made for ditches diverting water, as the aggregate diversion is but a small portion of the total discharge of the main streams.

For the portion above Trout Creek the winter minimums would govern power development; below Trout Creek the summer minimums would govern, as Trout Creek would be enough higher during the winter low-water period to more than balance the reduced flow in the main stream due to cold weather.

Average minimum discharge for White Salmon River drainage basin.

Locality.	Drainage area.		Date.	Measured discharge.	Adjusted average minimum.
	Square miles.	Per cent of total.			
White Salmon River:				*Sec.-feet.*	*Sec.-feet.*
Head of survey	37	10	Winter		100
Boundary Columbia National Forest.	69	20	do		150
Below Trout Creek	169	48	October		470
Splash dam, sec. 6, T. 5, R. 11	256	73	do		660
Falls, sec. 25, T. 5, R. 10	266	75	do		670
Below Gilmer Creek	290	82	do		700
Husum gaging station	300	85	October 18, 1909	590	710
North line sec. 10, T. 3, R. 10	337	96	October		770
Trout Creek, Guler gaging station	82		October 18, 1909	50	60

WATER POWERS.

Owing to the steep grade, well-maintained summer flow, and rocky canyons through which White Salmon River flows, opportunities for water-power developments are abundant. The average fall of the main river for that portion surveyed—32.1 miles—is 83 feet to the mile. Nine miles of the river's course above the mouth of Gilmer Creek has an average fall of 117 feet to the mile; in the last 3 miles the fall averages 53 feet to the mile. Trout Creek falls 115 feet from Trout Lake to its mouth, somewhat more than 2 miles. Where the north line of sec. 25, T. 5, R. 10, crosses White Salmon River there are two falls with a total drop of 35 feet. At Husum there is a drop of 15 feet, and at a point 4 miles above the boundary of the national forest there is a drop of 5 feet.

The Wind River Lumber Company has splash dams for floating logs in sec. 14, T. 6, R. 10; sec. 6, T. 5, R. 11; and sec. 14, T. 3, R. 10. The waters of the river are used extensively for this purpose, and doubtless certain water rights have attached.

Power developments could best take the form of pipe or open-canal diversion for high heads. In computing the water powers in this area, therefore, the streams are divided into sections of a length that would probably represent feasible lengths for open canals or pressure pipes.

The elevations of the water surface at the extremities of these sections, the total fall, the fall per mile, and the drainage area are given below for each section considered. The discharge at the upper end of the section has been estimated from the data presented above. In determining this discharge an attempt has been made to give an average minimum in the manner already described. This figure is the most uncertain part of the data, but it is believed to be conservative.

The horsepower given is 70 per cent of the theoretical power that is computed from the known fall in the section and the estimated discharge at its upper extremity. Seventy per cent is of course an arbitrary proportion, but it represents very nearly the power on turbine shafts that is actually realized in many plants in operation at the present time.

Water powers in White Salmon River drainage basin.

Point on stream.	Distance above mouth.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Drainage area.	Average minimum discharge.		Available horsepower (70 per cent of theoretical).
							Second-feet.	Second-feet per square mile.	
Main stream.	*Miles.*	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Square miles.*			
Head of survey	32.10	2,705				37	100	2.7	4,020
Boundary Columbia National Forest	28.60	2,200	3.50	505	143	69	150	2.2	3,700
Above mouth of Trout Creek	24.55	1,890	4.05	310	76.5	84			
Below mouth of Trout Creek	24.55	1,890				169	470	2.8	10,100
Splash dam in sec. 6, T. 5, R. 11	20.32	1,620	4.23	270	63.9	256	660	2.6	28,900
Foot of falls, sec. 25, T. 5, R. 10	15.60	1,070	4.72	550	117	266	670	2.5	22,400
Below mouth of Gilmer Creek	12.00	650	3.60	420	117	290	700	2.4	16,200
Husum bridge	7.40	360	4.60	290	63	300	710	2.4	8,500
North line sec. 10, T. 3, R. 10.	3.12	210	4.28	150	35	337	770	2.3	10,100
Underwood (mouth)		45	3.12	165	52.9	352			
Trout Creek.									
Guler	2.15	2,005				82	60	.70	
Mouth		1,890	2.15	115	53.5	85			550
									105,000

LITTLE WHITE SALMON RIVER DRAINAGE BASIN.

DESCRIPTION.

Little White Salmon River drains the extreme south end of the Cascade Range in Washington. It lies between the main summit of this range and the White Salmon River drainage basin. The river rises on Old Huckleberry Mountain, at an elevation of 5,200 feet, flows almost directly south, and empties into Columbia River near the town of Cooks, 6½ miles downstream from the mouth of White Salmon River. The principal tributaries enter from the west, and in order downstream are Moss Creek, Lava Creek, and Rock Creek. The main river has a total length of 17 miles and a total drainage area of

132 square miles. The drainage area above Moss Creek is 37 square miles, and at a point below the mouth of Lava Creek 110 square miles. Lava Creek drains 72 square miles. Plate XI shows this drainage area.

The general topographic features of the country are similar to those of the territory drained by White Salmon River. Old Huckleberry, the highest mountain, has no well-defined summit, but is rather an elongated ridge with projecting spurs to the north and south. The area is rough and mountainous. The stream flows in a very deep canyon with steep and rugged sides. There are benches paralleling the river several hundred feet above the water surface for a portion of its length. The immediate valley is occupied almost entirely by the stream, the flood plain being very narrow.

The forests on this area are similar to those in the Klickitat and White Salmon drainage basins, previously described, except that the stand is heavier and the species show the change from a semiarid to a humid climate.

The southern boundary of the Columbia National Forest crosses the river about 7 miles above its mouth. Within this area 93 per cent of the land is covered with forest and 7 per cent has been burned. Nearly all of the burned areas are being restocked, and the forest cover has been established. About 55 per cent of the stand of timber is red and yellow fir, 10 per cent hemlock, 10 per cent red cedar, 5 per cent white pine, 5 per cent yellow pine, and 15 per cent other species. The average stand of timber for this drainage area is over 4,000 board measure per acre; 24 per cent of the area has a stand of less than 2,000 feet board measure per acre, 60 per cent from 2,000 to 5,000 feet, 7 per cent from 5,000 to 10,000 feet, and 9 per cent from 10,000 to 25,000 feet.

There are no railroads in the drainage area except one which crosses the river at its mouth. A wagon road follows the main river from Crooks to the head of the stream. Agriculture is not extensively practiced, although a few small tracts, mainly on bench lands along the river, have been cleared and planted to crops. On the right bank, 3 miles above the mouth, there is a bench containing over 600 acres. The timber on this bench has been logged and the land is now on the market at $150 an acre. The conditions are favorable for raising fruit. On the opposite side of the river is another narrow bench extending for several miles upstream. These lands would doubtless raise fruit of good quality if cleared. It is estimated that there are 30,000 acres of land in the Little White Salmon River drainage area suitable for agriculture after the timber has been removed.

The principal industry at present is lumbering. Large quantities of timber have already been cut from the area outside of the national forest. The logs removed are generally hauled by wagon down the canyon road. One mill is in operation at present 3 miles above the mouth. The sawed lumber is floated in a flume to Columbia River.

No discharge data has been gathered on this stream by the Geological Survey other than those procured at the time of making the river survey. The river is subject to heavy floods during the fall and winter, and the summer discharge is comparatively low. During the summer months the principal source of supply is Moss Creek. Though this stream is not long, it is probably well supplied with water from underground sources. Lava Creek is an intermittent stream flowing through lava beds, and although its drainage area is comparatively large, a large proportion of the water falling upon its sinks into the ground, probably to reappear at points farther down. It is very likely that Moss Creek receives considerable water from the territory through which Lava Creek flows.

LITTLE WHITE SALMON RIVER BELOW LAVA CREEK.

From 1903 to 1906 the Portland Railway, Light and Power Company made determinations of discharge of Little White Salmon River below Lava Creek. A rectangular weir, 16.2 feet in length, was installed and daily records kept. Through the courtesy of the company these records are given in the following table:

Daily discharge, in second-feet, of Little White Salmon River below the mouth of Lava Creek for 1903–1906.

Day.	Nov.	Dec.	Day.	Nov.	Dec.	Day.	Nov.	Dec.
1903.			1903.			1903.		
1	....	(a)	11	275	278	21	278	(a)
2	....	(a)	12	270	268	22	278	(a)
3	89	(a)	13	278	277	23	278	(a)
4	135	(a)	14	266	277	24	278	(a)
5	185	(a)	15	266	277	25	278	(a)
6	225	(a)	16	257	290	26	278	(a)
7	275	303	17	257	302	27	303	(a)
8	220	303	18	257	315	28	325	300
9	235	278	19	265	325	29	315	280
10	220	268	20	245	(a)	30	370	353
						31	....	353

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
1	328	(a)	(a)	(a)	(a)	(a)	(a)	264	187	92	54	315
2	328	340	(a)	(a)	(a)	(a)	(a)	256	180	87	54	315
3	317	340	(a)	(a)	(a)	(a)	(a)	254	180	87	52	315
4	317	328	(a)	(a)	(a)	(a)	(a)	246	170	86	50	295
5	317	327	(a)	(a)	(a)	(a)	(a)	243	170	80	48	278
6	317	328	(a)	(a)	(a)	(a)	(a)	235	160	80	44	256
7	300	328	(a)	(a)	(a)	(a)	(a)	234	160	77	44	254
8	315	339	(a)	(a)	(a)	(a)	(a)	224	160	76	44	254
9	326	340	(a)	(a)	(a)	(a)	(a)	220	150	75	44	254
10	230	351	(a)	(a)	(a)	(a)	(a)	210	150	74	44	254
11	275	328	(a)	(a)	(a)	(a)	(a)	210	138	94	44	270
12	300	328	(a)	(a)	(a)	(a)	(a)	210	138	83	44	300
13	(a)	315	(a)	(a)	(a)	(a)	(a)	199	138	75	47	330
14	(a)	300	(a)	(a)	(a)	(a)	(a)	199	138	72	48	(a)
15	(a)	280	(a)	(a)	(a)	(a)	(a)	198	128	69	50	(a)

[a] Discharge more than 350 second-feet; water flowing around weir.

Daily discharge, in second-feet, of Little White Salmon River below the mouth of Lava Creek for 1903–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.												
16	(a)	280	(a)	(a)	(a)	(a)	(a)	190	128	68	53	(a)
17	(a)	302	(a)	(a)	(a)	(a)	(a)	190	117	68	54	203
18	(a)	316	(a)	(a)	(a)	(a)	(a)	190	110	64	57	(a)
19	(a)	327	(a)	(a)	(a)	(a)	350	179	110	64	60	(a)
20	(a)	350	(a)	(a)	(a)	(a)	328	179	110	64	350	(a)
21	(a)	338	(a)	(a)	(a)	(a)	328	168	110	60	280	(a)
22	(a)	328	340	(a)	(a)	(a)	316	168	110	60	280	(a)
23	(a)	340	(a)	(a)	(a)	(a)	316	168	104	60	178	(a)
24	(a)	350	(a)	(a)	(a)	(a)	314	160	104	58	178	(a)
25	(a)	340	(a)	(a)	(a)	(a)	303	160	104	63	178	(a)
26	(a)	315	(a)	(a)	(a)	(a)	303	150	104	58	178	(a)
27	(a)	327	(a)	(a)	(a)	(a)	290	150	93	57	250	(a)
28	(a)	350	(a)	(a)	(a)	(a)	290	168	93	57	244	(a)
29	(a)	......	(a)	350	(a)	(a)	276	168	93	56	248	(a)
30	(a)	......	(a)	340	(a)	(a)	276	185	92	54	300	(a)
31	(a)	......	(a)	329	(a)	......	267	180	......	54	......	(a)
1905.												
1	(a)	340	(a)	......	......	......	......	......	40	26	44	63
2	(a)	325	(a)	......	......	......	......	......	40	26	43	67
3	(a)	327	(a)	......	......	......	......	......	40	30	41	73
4	(a)	330	(a)	......	......	......	......	......	37	40	40	77
5	(a)	316	(a)	......	......	......	......	......	36	40	40	78
6	(a)	316	(a)	......	......	......	......	......	36	38	39	92
7	(a)	325	(a)	......	......	......	......	......	34	60	38	127
8	(a)	330	340	......	......	......	......	......	34	60	37	146
9	(a)	330	336	......	......	......	......	......	30	50	36	130
10	(a)	336	336	......	......	......	......	......	30	46	36	120
11	(a)	340	336	......	......	......	......	......	30	41	36	113
12	(a)	318	336	......	......	......	......	......	37	37	36	105
13	350	304	337	......	......	......	......	......	34	38	36	103
14	338	304	228	......	......	......	......	......	34	39	36	100
15	338	290	226	......	......	......	......	......	34	45	35	98
16	338	270	226	......	......	......	......	......	33	45	34	126
17	329	158	226	......	......	......	......	......	33	47	34	220
18	328	158	(b)	......	......	......	......	......	28	50	33	245
19	328	240	......	......	......	......	......	......	27	50	93	265
20	328	240	......	......	......	......	......	54	27	50	87	267
21	317	250	......	......	......	......	......	54	27	48	75	250
22	323	335	......	......	......	......	......	54	28	47	64	235
23	353	158	......	......	......	......	......	50	28	48	60	195
24	353	350	......	......	......	......	......	46	28	49	57	135
25	340	(a)	......	......	......	......	......	46	28	50	53	215
26	340	(a)	......	......	......	......	......	46	34	48	60	312
27	(a)	(a)	......	......	......	......	......	46	30	50	60	308
28	(a)	(a)	......	......	......	......	......	46	28	47	60	310
29	(a)	......	......	......	......	......	......	46	27	46	62	309
30	(a)	......	......	......	......	......	......	43	26	44	63	270
31	(a)	......	......	......	......	......	......	40	......	44	......	230
1906.												
1	210	(a)	(a)	......	290	280	242	129	......	......	......	......
2	190	(a)	(a)	350	290	280	239	140	......	......	......	......
3	182	(a)	(a)	320	289	279	233	138	......	......	......	......
4	190	338	(a)	323	288	279	230	135	......	......	......	......
5	195	328	(a)	320	287	276	227	132	......	......	......	......
6	220	313	(a)	342	287	275	222	......	......	......	......	......
7	245	300	(a)	336	285	274	218	......	......	......	......	......
8	246	288	(a)	338	284	272	214	......	......	......	......	......
9	250	280	(a)	350	283	271	210	......	......	......	......	......
10	238	268	(a)	340	283	271	209	......	......	......	......	......
11	240	264	(a)	332	282	270	207	......	......	......	......	......
12	230	255	(a)	328	281	268	200	......	......	......	......	......
13	237	245	(a)	320	281	270	197	......	......	......	......	......
14	225	242	(a)	320	285	275	193	......	......	......	......	......
15	212	240	345	320	294	283	190	......	......	......	......	......

[a] Discharge greater than 350 second-feet; water flowing around weir.
[b] No record March 18 to August 19, 1905.

Daily discharge, in second-feet, of Little White Salmon River below the mouth of Lava Creek for 1903–1906—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
16	214	237	330	320	290	280	186	......	......	......	......	......
17	220	240	315	316	284	274	180	......	......	......	......	......
18	218	(a)	305	314	284	269	177	......	......	......	......	......
19	210	(a)	270	311	282	267	172	......	......	......	......	......
20	195	(a)	255	310	281	267	169	......	......	......	......	......
21	193	(a)	260	310	280	266	166	......	......	......	......	......
22	198	(a)	267	309	280	262	164	......	......	......	......	......
23	350	(a)	273	309	280	260	163	......	......	......	......	......
24	(a)	(a)	278	307	280	256	157	......	......	......	......	......
25	(a)	(a)	289	303	280	254	152	......	......	......	......	......
26	(a)	(a)	305	297	280	252	148	......	......	......	......	......
27	(a)	(a)	310	294	280	248	145	......	......	......	......	......
28	(a)	(a)	304	293	280	245	142	......	......	......	......	......
29	(a)	......	303	291	280	244	140	......	......	......	......	......
30	(a)	......	350	291	280	243	135	......	......	......	......	......
31	(a)	......	......	......	280	......	130	......	......	......	......	......

[a] Discharge greater than 350 second-feet; water flowing around weir.

LITTLE WHITE SALMON RIVER NEAR COOKS.

This temporary station was established October 4, 1909. It is located at the fish hatchery one-half mile above the mouth of the river. The gage is a vertical staff spiked to the right abutment of a bridge supporting an old lumber flume 200 feet below the fish hatchery. Measurements are made by wading a short distance below the gage. No permanent equipment has been installed for making measurements at high stages, as at such times the station is not beyond influences of backwater from Columbia River. A discharge measurement was made October 4, 1909:

Gage height, 2.09 feet; area, 136 square feet; mean velocity, 1.25 feet per second; discharge, 170 second-feet.

Daily gage height, in feet, of Little White Salmon River near Cooks, Wash., for 1909.

Day.	Oct.	Nov.	Day.	Oct.	Nov.	Day.	Oct.	Nov.
1	......	3.16	11	2.05	......	21	2.05	......
2	......	2.90	12	2.04	......	22	2.07	......
3	......	2.82	13	2.04	......	23	2.04	......
4	2.10	2.72	14	2.02	......	24	2.02	......
5	2.09	2.68	15	2.02	......	25	2.00	......
6	2.08	2.58	16	2.01	......	26	2.00	......
7	2.08	2.49	17	2.00	......	27	1.98	......
8	2.08	2.42	18	2.00	......	28	1.98	......
9	2.07	2.38	19	2.00	......	29	1.98	......
10	2.06	2.54	20	2.02	......	30	2.04	......
						31	2.08	......

Daily discharge, in second-feet, of Little White Salmon River near Cooks, Wash., for 1909.

Day.	Oct.	Nov.	Day.	Oct.	Nov.	Day.	Oct.	Nov.
1		249	11	164		21	164	
2			12	163		22	167	
3			13	163		23	163	
4	171		14	161		24	161	
5	170		15	161		25	158	
6	168		16	159		26	158	
7	168		17	158		27	155	
8	168		18	158		28	155	
7	167		19	158		29	155	
10	166		20	161		30	163	
						31	168	

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements were made in the basin of Little White Salmon River in 1909:

Miscellaneous discharge measurements, Little White Salmon River Basin, 1909.

[By H. D. McGlashan.]

Date.	Stream.	Locality.	Width.	Area of section.	Mean veloc.	Discharge.
			Feet.	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*
October 3	Little White Salmon	Above Moss Creek	23	33	0.39	13
Do	do.[a]	Below Moss Creek	36	61	.72	44
Do	do.[b]	Below Lava Creek	29	67	.69	46
Do	Lava Creek	Mouth	10	8.5	.42	3.6

[a] Water surface 2.66 feet below 10-penny nail in stream face of upstream pile in left abutment of bridge.
[b] Made near weir installed by Portland Railway, Light, and Power Company. Length of weir 16.2 feet head on weir, 0.91 foot; computed discharge, 47.2 second-feet.

AVERAGE MINIMUM DISCHARGE.

From the foregoing data the mean discharge for the lowest week of each year is found to be as follows: Week ending November 12, 1904, 44 second-feet; week ending September 25, 1905, 28 second-feet. Increasing the discharge for 1905 by 20 per cent gives 34 second-feet as a probable value for the average minimum discharge at this point. The measurement made October 3, 1909, gave 46 second-feet, but the river fell considerably lower at the end of October. The mean discharge at the Cooks gaging station was 159 second-feet for the lowest week, ending October 29. This is 6 per cent lower than the gaging of October 3 at that point. The discharge below Lava Creek was doubtless lower on October 29 than on October 3 by a much greater percentage. The increase in discharge from Lava Creek to the mouth is due to numerous springs in the lava beds through which the river flows. As the stream has a small drainage area its flow can not be expected to follow the general tendencies observed for larger areas. The effect of lava beds is an unknown and undeterminable factor in controlling stream flow.

The discharge of Lava Creek was found to be less than 4 second-feet on October 3, yet the stream has a topographic drainage area of 72 square miles. Moss Creek, on the other hand, is not 3 miles long, yet the discharge at the same time was found to be 31 second-feet by measurements of the main stream above and below its mouth. The porous texture of the lavas that cover these areas tends to vitiate any and all laws of stream discharge when expressed in terms of drainage area.

WATER POWERS.

This stream affords an opportunity for a comparatively small plant under a high head. It is likely that during nine months of the year considerable power could be developed, but in the summer season the water supply is too small for a plant of large capacity. If developed, water would be diverted below the mouth of Lava Creek and carried about 6 miles along the side of the canyon in a pressure pipe. In this manner over 1,100 feet of head could be utilized.

The discharge of the main river increases rapidly downstream owing to numerous springs. A second pipe line diverting water below the mouth of Rock Creek could be used to carry water to the same power house at the mouth of the stream. On this basis the following power table has been compiled, an estimated average minimum discharge of 120 second-feet being used for the main stream below Rock Creek, all of which is inflow below Lava Creek:

Water powers in Little White Salmon River drainage basin.

Point on stream.	Distance above mouth.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Drainage area.	Average minimum discharge.		Available horsepower (70 per cent of theoretical).
							Second-feet.	Second-feet per square mile.	
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Sq. mi.*			
Below mouth of Moss Creek	8.1	1,330	....	....	....	37	30	0.81	....
Above mouth of Lava Creek	6.1	1,235	2.0	105	52.5	38	....	....	250
Below mouth of Lava Creek	6.1	1,235	....	....	....	110	34	.31	....
Fish hatchery	.5	45	5.6	1,190	213	132	....	....	3,100
Below mouth of Rock Creek	3.5	590	....	....	....	120	120	1.00	....
Fish hatchery	.5	45	3.0	545	182	132	....	....	5,200
									8,550

LEWIS RIVER DRAINAGE BASIN.

DESCRIPTION.

Lewis River has its source in Adams Glacier, on the northwest slope of Mount Adams, flows in a general southwesterly direction, and empties into Columbia River 19 miles below Vancouver, Wash.

Its lower half forms the boundary line between Cowlitz and Clarke counties, Wash.; its upper half is entirely within Skamania County. Plate XIII is a map of this drainage area. The total length of the main river is 110 miles, and the stream drops 7,900 feet in that distance.

The principal tributaries in order downstream are, from the north, Muddy River, Pine Creek, Swift Creek, Cougar Creek, and Speilei Creek; from the south, Drift Creek, Siouxon Creek, Canyon Creek, Cedar Creek, and South Fork. Of these South Fork has the largest drainage area, but contributes a relatively small portion of the flow. Muddy River and Pine and Swift creeks supply a large part of the tributary discharge.

The total area drained by Lewis River is 1,070 square miles, distributed as follows:

	Square miles.
Above mouth of Muddy River	250
Above mouth of Swift Creek	474
Below mouth of Cougar Creek	552
At Ariel	728
Above the mouth of South Fork	860
At mouth	1,070
Muddy River	121
Pine Creek	21
Swift Creek	26
Cougar Creek	6
South Fork	195

Mount Adams, 12,307 feet high, and Mount St. Helens (Pl. XII, *A* and *B*), 9,750 feet (height not accurately determined), are the prominent topographic features of this territory. Mount Adams is just to the east of the summit of the Cascade Range and Mount St. Helens is 35 miles almost due west from Mount Adams and 14 miles southwest from the nearest point on the divide. Other peaks are Steamboat Mountain (4,600 feet) and The Castle (5,100 feet), standing southwest of the headwaters. Powderhorn Peak is near the mouth and north of the river.

The area is characterized by rough mountains and by ridges and spurs from the higher peaks. Toward the summit of the range the country becomes more abrupt and rugged. The streams all flow in canyons. In the upper portions the canyon sides are steep and rugged; in the lower stretches there are high benches of fairly level land and valleys of small extent bordering the river.

The rocks are almost entirely of igneous origin and comprise basalts, lavas, and pumice. Some recent lava flows lie around the bases of Mount St. Helens and Mount Adams. The rivers have cut deeply into these formations and in some places ten or more distinct lava flows can be counted. The soil resulting from the disintegration of these rocks is mixed with volcanic ash and is very fertile.

Trees and brush grow in profusion, and where valley lands have been cleared good crops can be raised.

About one-fourth of the Lewis River drainage basin lies within the Columbia National Forest. Within this area the average stand of timber is over 13,000 feet b. m. per acre. The entire area is essentially densely forested, and although logging operations have been carried on for years the cut-over area forms a relatively small part of the total. The lands contiguous to the lower portion of the river are the only ones that show the effect of these logging operations, and they are rapidly being restocked except where they have been cleared for agriculture. Red and yellow fir are the predominating species and constitute about 50 per cent of the total stand. There are also large quantities of hemlock, Noble fir, and cedar. All through the forests the underbrush is very dense. Wherever the continuous shade of the large trees has been broken by logging or on burned areas the undergrowth is most pronounced. Salal, vine maple, huckleberry, dogwood, syringa, snowberry, wild rose, blackberry, and salmonberry are prevalent species. These, mingled with young seedlings of the conifers and with ferns, vines, and brambles and the decaying and moss-covered trunks of fallen trees, make an almost impenetrable mass.

The Seattle and Portland line of the Northern Pacific Railway crosses Lewis River near its mouth, and a logging branch line runs from Vancouver to Yacolt, near the headwaters of Cedar Creek. The main stream is navigable for small boats as far as Ariel except during the low-water season. A river steamer runs regularly between Portland and Woodland, and a small steamboat runs from Woodland to Ariel, or Runyons Landing, as this place was known before the post-office was established.

A wagon road follows the north bank of the river from Woodland to Petersons and there is a good trail from Petersons to Pine Creek. There is also a wagon road on the south side of the river from Woodland to Cressup's ferry. The drainage area of South Fork is not so mountainous and is much better improved, there being a goodly number of settlers and roads in all directions.

The percentage of farming land in this area is comparatively small. Where timbered lands have been cleared, however, as along the rolling table-lands and broader valley of South Fork and the lower portions of the main river, good crops can be grown. Farther upstream the valley becomes narrower and the suitable farm land is in small benches or narrow strips in the floor of the canyon. All crops common to a mild and moist climate are grown. Fruits of all kinds are found in abundance. Apples, pears, cherries, and small fruits and berries are grown with excellent results. At present, however, the principal industry is lumbering. There are a number of lumber and shingle mills near the mouth of the river, although most of the logs cut are transported by water to the mills on Columbia River. At many points along the main stream flumes lead from the high mountains to the river bank. These are used for floating shingle bolts from the hills into the river.

So far as known there are no favorable sites where a large amount of storage could be developed. In the canyon of the main stream there are numerous dam sites where a moderate amount of storage could be developed for the use of a power plant with daily load variations.

Lake Merrill (Pl. IX, *B*) lies on the divide between the headwaters of Cougar Creek and Kalama River. It has no surface outlet, but its waters probably find their way through the lavas that surround it into both these streams. It could doubtless be raised and water could be diverted in either direction, although diversion into Kalama River would be the easier. The formations indicate that the larger portion of the water now flows into Kalama River. The water surface of the lake is less than 1 square mile and the drainage area comprise 6.9 square miles.

So far as could be learned no records of discharge or of gage heights have been kept on any of the streams in this basin. There is a gage at Woodland which is used as a guide for determining the time of running boats, and another one was found at Ariel, but no systematic records of river heights have been kept from either of them.

During the course of the survey, gages were established and discharges during the summer of 1909 were determined at the following points:

Lewis River above Muddy River.
Lewis River above Swift Creek.
Lewis River at Ariel.
Muddy River at the mouth.
Pine Creek at the mouth.
Swift Creek at the mouth.

The last habitation is that of Ole Peterson, who lives 5 miles above Cougar post-office, 2 miles below the mouth of Swift Creek. Mr. Peterson kept daily gage records of the station on Lewis River above Swift Creek and on Swift Creek and made occasional trips to the upper stations. Daily records were also procured at Ariel. In this manner the summer flow for the season is fairly well determined. All stations were discontinued as soon as high water came in the fall except the one on Lewis River above Swift Creek, which is being maintained in cooperation with H. L. Gilbert, civil and hydraulic engineer, of Portland, Oreg.

In addition to the data obtained at these stations, miscellaneous discharge measurements were made of other tributaries and at other points on the main stream, as given in the table following those for the regular station. A few gagings were made by H. L. Gilbert in 1907. These are published in Water-Supply Paper 252, page 80, but are repeated here for comparison with the results obtained in 1909:

LEWIS RIVER ABOVE MUDDY RIVER, NEAR COUGAR.

This station was established August 8, 1909, for the purpose of determining discharge during the low-water season only. The gage is a vertical staff on the right bank one-half mile above the mouth of Muddy River. It is fixed near the downstream end of a rocky bluff on the right bank, at the first riffle below this bluff. Measurements were made by wading opposite the gage. No facilities were installed for making measurements at high stages.

Discharge measurements of Lewis River above Muddy River, near Cougar, Wash., in 1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*
August 8	C. W. Harris	147	247	1.72	1.06	[a] 427
August 13	do	88	164	2.62	1.04	[b] 430

[a] Made by wading opposite gage. [b] Made by wading 2 miles above gage.

Daily gage height, in feet, of Lewis River above Muddy River, near Cougar, Wash., for 1909.

[Ole Peterson, observer.]

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1				11				21			
2				12				22	1.0		
3				13	1.04			23			
4		0.92		14				24			
5				15			0.80	25			
6				16				26			
7				17				27			
8	1.06			18				28	.95		
9				19			.90	29			
10				20				30			
								31			

Daily discharge, in second-feet, of Lewis River above Muddy River, near Cougar, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	500	295	240	11	440	200	160	21	350	350	500
2	500	295	200	12	425	200	160	22	350	240	350
3	440	262	160	13	410	200	160	23	295	240	425
4	440	262	200	14	410	200	160	24	295	200	350
5	440	295	240	15	425	200	160	25	295	200	240
6	440	240	295	16	410	160	160	26	295	160	240
7	440	240	295	17	350	160	160	27	295	160	200
8	440	240	240	18	350	160	240	28	295	160	295
9	425	240	240	19	350	295	240	29	295	160	425
10	440	200	200	20	350	350	350	30	295	200	425
								31	295		595

Monthly discharge of Lewis River above Muddy River, near Cougar, Wash., for 1909.

[Drainage area, 250 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Depth in inches on drainage area.	Total in acre-feet.	
August	500	295	380	1.52	1.75	23,400	B.
September	350	160	225	.90	1.00	13,400	B.
October	595	160	265	1.06	1.22	16,300	B.
The period	500	160	290	1.16	3.97	53,100	

LEWIS RIVER AT PETERSON'S, NEAR COUGAR.

This station was established July 27, 1909. It is located 1,000 feet above the mouth of Swift Creek, at the first riffle below a large outcrop of rock on the right bank. The gage is a vertical staff graduated to feet and tenths in two sections, the first 12 feet being attached to a point of the rock above mentioned. Measurements are made by use of a meter running on a small cable and operated from the bank. The river is crossed by means of a raft.

This station is intended as a permanent one, although facilities for making measurements at high stages have not yet been installed. It is maintained in cooperation with H. L. Gilbert, of Portland, Oreg.

Discharge measurements of Lewis River at Peterson's, near Cougar, Wash., for 1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*
July 27	C. W. Harris	125	333	3.75	3.45	1,250
August 19	do	108	254	3.06	2.95	776

Daily gage height, in feet, of Lewis River at Peterson's, near Cougar, Wash., for 1909.

[Ole Peterson, observer.]

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		3.32	2.73	2.75	3.75	9.60	16		2.95	2.62	2.55	4.30	4.90
2		3.28	2.73	2.70	8.20	7.10	17		2.95	2.60	2.52	4.50	4.80
3		3.25	2.80	2.70	9.60	6.20	18		2.95	2.53	2.50	7.50	4.60
4		3.20	2.80	2.65	7.40	6.00	19		2.95	2.60	2.80	11.40	4.40
5		3.15	2.80	2.65	6.30	5.60	20		2.95	2.95	3.30	9.50	4.30
6		3.10	2.75	2.82	6.30	5.10	21		2.95	2.83	3.50	8.40	4.20
7		3.10	2.70	2.80	5.30	4.10	22		2.95	2.72	3.10	14.60	4.00
8		3.05	2.70	2.70	5.90	4.70	23		2.85	2.70	3.15	14.10	3.95
9		3.03	2.63	2.65	5.90	4.50	24		2.80	2.65	3.00	12.00	3.90
10		3.05	2.63	2.62	5.95	4.50	25		2.82	2.62	2.90	8.90	3.85
11		3.02	2.65	2.60	5.70	4.60	26		2.75	2.62	2.90	7.20	3.80
12		3.00	2.62	2.53	5.30	6.10	27	3.50	2.75	2.60	2.85	6.80	3.70
13		2.95	2.62	2.60	5.00	5.80	28	3.45	2.75	2.60	2.90	7.00	3.70
14		2.92	2.60	2.52	4.70	5.60	29	3.42	2.75	2.63	3.10	12.75	3.70
15		3.00	2.60	2.55	4.50	5.20	30	3.40	2.75	2.65	3.05	11.40	3.75
							31	3.45	2.80		3.40		3.80

Daily discharge, in second-feet, of Lewis River at Peterson's, near Cougar, Wash., for 1909.

Day.	July	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1	....	1,110	633	645	16	....	778	571	535
2	....	1,070	633	615	17	....	778	560	520
3	....	1,040	675	615	18	....	778	525	510
4	....	990	675	588	19	....	778	560	575
5	....	945	675	588	20	....	778	778	1,090
6	....	900	645	688	21	....	778	694	1,320
7	....	900	615	675	22	....	778	627	900
8	....	858	615	615	23	....	708	615	945
9	....	840	576	588	24	....	675	588	815
10	....	858	576	571	25	....	688	571	740
11	....	832	588	560	26	....	645	571	740
12	....	815	571	525	27	1,320	645	560	708
13	....	778	571	560	28	1,255	645	560	740
14	....	755	560	520	29	1,220	645	576	900
15	....	815	560	535	30	1,200	645	588	858
					31	1,255	675	....	1,200

Monthly discharge of Lewis River at Peterson's, near Cougar, Wash., for 1909.

[Drainage area, 474 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Depth in inches on drainage area.	Total in acre-feet.	
August	1,110	645	804	1.70	1.96	49,400	A.
September	778	560	604	1.28	1.43	35,900	A.
October	1,320	510	712	1.50	1.73	43,800	A.
The period	1,320	510	707	1.49	5.12	129,100	

LEWIS RIVER AT ARIEL.

This station was established July 7, 1909. It is located opposite Ariel post-office, one-fourth mile above the mouth of George Creek. It was intended as a temporary station only, and no facilities were installed for making measurements at high stages. The gage is a vertical staff fixed to an alder stump on the right bank near the post-office and store. Measurements were made from a boat held in place by a small cable spanning the stream. Conditions at the station are not favorable for good results. The stream is used principally for floating logs. These logs lodging on the riffle in the vicinity of the station cause variable backwater conditions for which it is impossible to make correction.

Discharge measurements of Lewis River at Ariel, Wash., for 1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec.-ft.*
July 8	C. W. Harris	316	1,080	3.15	3.07	3,410
August 23	....do	262	708	1.71	1.75	1,210

Daily gage height, in feet, of Lewis River at Ariel, Wash., for 1909.

[C. R. Keiger, observer.]

Day.	July.	Aug.	Sept.	Oct.	Nov.	Day.	July.	Aug.	Sept.	Oct.	Nov.
1		2.20	1.60	1.98	3.66	16	2.72	1.87	1.56	1.55	4.04
2		2.15	1.60	1.68	9.65	17	2.6	1.83	1.55	1.51	4.55
3		2.15	1.66	1.60	10.30	18	2.54	1.78	1.54	1.50	5.85
4		2.12	1.66	1.66	7.18	19	2.41	1.76	1.53	1.65	9.75
5		2.10	1.69	1.76	5.55	20	2.32	1.74	1.88	2.23	9.30
6		2.05	1.66	1.68	4.70	21	2.45	1.72	2.06	2.88	8.10
7	3.23	2.02	1.64	1.58	5.30	22	2.45	1.74	1.65	2.85	9.26
8	3.02	2.00	1.65	1.56	5.46	23	2.48	1.72	1.62	2.41	10.85
9	2.92	2.00	1.64	1.52	5.34	24	2.50	1.80	1.52	2.22	8.60
10	2.9	1.96	1.60	1.57	5.68	25	2.70	1.80	1.58	2.18	7.57
11	3.32	1.92	1.61	1.60	5.36	26	2.65	1.80	1.55	2.10	7.50
12	3.22	1.90	1.60	1.60	4.72	27	2.6	1.82	1.56	2.00	6.85
13	2.98	1.90	1.60	1.60	4.36	28	2.42	1.58	1.54	2.12	7.25
14	2.82	1.88	1.60	1.60	4.19	29	2.34	1.68	1.70	2.38	9.25
15	2.78	1.90	1.58	1.57	3.71	30	2.3	1.65	2.06	2.46	10.90
						31	2.25	1.64		2.90	

Daily discharge, in second-feet, of Lewis River at Ariel, Wash., for 1909.

Day.	July.	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1		1,870	1,050	1,530	16	2,750	1,380	1,010	1,000
2		1,790	1,050	1,150	17	2,540	1,330	1,000	950
3		1,790	1,120	1,050	18	2,440	1,270	980	940
4		1,740	1,120	1,120	19	2,220	1,240	970	1,110
5		1,710	1,160	1,240	20	2,060	1,220	1,390	1,920
6		1,640	1,120	1,150	21	2,280	1,190	1,650	3,030
7	3,690	1,590	1,100	1,030	22	2,280	1,220	1,110	2,980
8	3,290	1,560	1,110	1,010	23	2,340	1,190	1,070	2,220
9	3,110	1,560	1,100	960	24	2,370	1,290	960	1,900
10	3,070	1,500	1,050	1,120	25	2,710	1,290	1,030	1,840
11	3,870	1,450	1,060	1,050	26	2,620	1,290	1,000	1,710
12	3,670	1,420	1,050	1,050	27	2,540	1,320	1,010	1,560
13	3,210	1,420	1,050	1,050	28	2,230	1,030	980	1,740
14	2,930	1,390	1,050	1,050	29	2,100	1,150	1,170	2,170
15	2,850	1,420	1,030	1,020	30	2,030	1,110	1,650	2,300
					31	1,950	1,100		3,070

Monthly discharge of Lewis River at Ariel, Wash., for 1909.

[Drainage area, 728 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Depth in inches on drainage area.	Total in acre-feet.	
August	1,870	1,030	1,400	1.52	1.75	86,100	B.
September	1,650	960	1,110	1.92	2.21	66,000	B.
October	3,070	960	1,510	2.07	2.39	92,800	B.
The period	3,070	960	1,340	1.84	6.35	245,000	

MUDDY RIVER AT MOUTH, NEAR COUGAR.

This station was established August 6, 1909. The gage is a vertical staff located one-half mile above the mouth of the river on the first riffle below a rocky gorge. The station was established for temporary purposes only, to determine the low-water flow for 1909, and no facilities were installed for making measurements at high stages. Measurements were made with a meter suspended from a small cable spanning the stream and operated from the river bank. The following measurement was made by C. W. Harris, August 6, 1909:

Width, 87 feet; area of section, 149 square feet; mean velocity, 2.13 feet per second; gage height, 0.80 foot; discharge, 317 second-feet.

Gage height, in feet, of Muddy River at mouth, near Cougar, Wash., for 1909.

[Ole Peterson, observer.]

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1				11				21			
2				12				22	0.75		
3		0.60		13				23			
4				14	0.70			24			
5				15			0.35	25			
6	0.80			16				26			
7				17				27			
8	.80			18				28			
9	.78			19			.60	29			
10				20				30			
								31			

Daily discharge, in second-feet, of Muddy River at mouth, near Cougar, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	315	220	185	11	290	185	155	21	290	142	400
2	315	220	185	12	265	185	155	22	290	142	370
3	315	220	170	13	265	185	155	23	290	155	370
4	315	242	170	14	265	170	142	24	242	155	370
5	315	242	185	15	265	170	142	25	220	155	342
6	315	220	202	16	265	170	142	26	220	155	315
7	315	202	185	17	265	170	142	27	220	170	290
8	315	202	170	18	265	155	170	28	220	170	290
9	305	185	170	19	265	155	220	29	220	170	342
10	290	185	170	20	290	155	315	30	220	185	315
								31	242	......	400

Monthly discharge of Muddy River at mouth, near Cougar, Wash., for 1909.

[Drainage area, 121 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Depth in inches on drainage area.	Total in acre-feet.	
August	315	220	274	2.26	2.61	16,800	B.
September	242	142	182	1.50	1.67	10,800	B.
October	400	142	236	1.95	2.25	14,500	B.
The period	400	142	231	1.90	6.53	42,100	

PINE CREEK AT MOUTH, NEAR COUGAR.

This station was established August 4, 1909. The gage is a vertical staff on the left bank of the stream at the old camp grounds, about one-fourth mile above the mouth of the stream, near the quarter corner between secs. 23 and 24, T. 7 N., R. 6 E.

The station was established to determine low-water conditions during the summer season of 1909, and no permanent equipment was installed for making measurements at high stages. Measurements were made with a meter suspended from a light cable spanning the stream and operated from the bank.

A measurement was made by C. W. Harris, August 4, 1909, as follows:

Width, 32 feet; area, 53 square feet; mean velocity, 2.68 feet per second; gage height, 1.00 feet; discharge, 142 second-feet.

Gage height, in feet, of Pine Creek at mouth, near Cougar, Wash., for 1909.

[Ole Peterson, observer.]

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1				11				21			
2				12				22			
3				13			0.95	23			
4	1.00			14				24			
5				15				25			
6				16	0.97			26			
7				17				27			
8				18				28			
9				19			1.00	29			
10				20				30			
								31			

Daily discharge, in second-feet, of Pine Creek at mouth, near Cougar, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	142	142	142	11	142	136	136	21	138	155	155
2	142	142	142	12	142	136	136	22	138	149	149
3	142	142	142	13	142	136	136	23	138	149	142
4	142	142	142	14	142	136	136	24	138	142	142
5	142	142	142	15	142	136	136	25	138	142	142
6	142	136	136	16	138	136	136	26	138	142	142
7	142	136	136	17	138	136	136	27	138	136	149
8	142	136	136	18	138	136	136	28	138	136	149
9	142	136	136	19	138	142	142	29	138	136	149
10	142	136	136	20	138	149	149	30	138	136	149
								31	138		149

Monthly discharge of Pine Creek at mouth, near Cougar, Wash., for 1909.

[Drainage area, 21 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Depth in inches on drainage area.	Total in acre-feet.	
August	142	138	140	6.67	7.69	8,610	B.
September	155	136	140	6.67	7.44	8,330	B.
October	155	136	141	6.71	7.74	8,670	B.
The period	155	136	140	6.68	22.87	25,600	

SWIFT CREEK AT MOUTH, NEAR COUGAR.

This station was established July 27, 1909. It is located 2 miles from Peterson's ranch, one-fourth mile above the mouth of the stream, near the point where the north line of sec. 28, T. 7 N., R. 5 E. crosses Swift Creek. The gage is a vertical staff fixed to the right bank. Measurements are made from a foot log or by wading near the gage. As the station was established only to determine low-water conditions during the summer season of 1909, no equipment was installed for making measurements at high stages.

A measurement was made July 27, 1909, by C. W. Harris, as follows:

Width, 49 feet; area, 78 square feet; mean velocity, 2.30 feet per second; gage height, 2.20 feet; discharge, 179 second-feet.

Gage height, in feet, of Swift Creek at mouth, near Cougar, Wash., for 1909.

[Ole Peterson, observer.]

Day.	July	Aug.	Sept.	Oct.	Day.	July.	Aug.	Sept.	Oct.
1					16		2.1		
1					17				
3			2.1		18				
4			2.1	2.1	19		2.15		2.15
5		2.2	2.1		20				
6			2.1	2.2	21				
7			2.1	2.2	22				
8			2.1	2.15	23				
9					24		2.1		
10				2.1	25				
11					26				2.2
12		2.15		2.05	27	2.2			
13					28	2.2			
14		2.1			29				
15		2.1			30	2.2			
					31				

Daily discharge, in second-feet, of Swift Creek at mouth, near Cougar, Wash., for 1909.

Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.	Day.	Aug.	Sept.	Oct.
1	179	167	167	11	179	167	167	21	173	167	173
2	179	167	167	12	173	167	162	22	173	167	173
3	169	167	167	13	173	167	162	23	167	167	173
4	179	167	167	14	167	167	162	24	167	167	179
5	179	167	173	15	167	167	167	25	167	167	179
6	179	167	179	16	167	167	167	26	167	167	179
7	179	167	179	17	167	167	167	27	167	167	179
8	179	167	173	18	173	167	173	28	167	167	179
9	179	167	167	19	173	167	173	29	167	167	179
10	179	167	167	20	173	167	173	30	167	167	179
								31	167		179

Monthly discharge of Swift Creek at mouth, near Cougar, Wash., for 1909.

[Drainage area, 26 square miles.]

Month.	Discharge in second-feet.				Run-off.		Accuracy.
	Maximum.	Minimum.	Mean.	Mean per square mile.	Depth in inches on drainage area.	Total in acre-feet.	
August	179	167	173	6.65	7.67	10,600	A.
September	167	167	167	6.42	7.16	9,940	A.
October	169	167	172	6.61	7.62	10,600	A.
The period	179	167	171	6.56	22.45	31,140	

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements have been made in the basin of Lewis River:

Miscellaneous discharge measurements in Lewis River basin.

[By C. W. Harris and H. L. Gilbert.]

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Sq. feet.*	*Ft. per sec.*	*Sec.-feet.*
Aug. 12, 1909	Lewis River [a]	Upper falls	143	96	2.53	243
Aug. 13, 1907	do. [b]	Above Muddy River				404
Do	Muddy River	Mouth				220
July 21, 1909	Cougar Creek [c]	Cougar post-office	32	39	2.70	105
Do	Siouxon Creek	Yale post-office	33	49	.93	46
July 10, 1907	Canyon Creek	Mouth, near Yale				71
July 7, 1907	Lewis River	Cressup's ferry				1,510
Sept. 21, 1907	do	do				1,350

[a] Made below first falls, 15 miles above mouth of Muddy River; water surface marked by notch cut in cedar log buried in bed on left bank at foot of falls.
[b] Made 300 feet above mouth of Muddy River. Water surface 11.7 feet below reference point on 24-inch fir on right bank.
[c] Made from foot log back of Schroder's house. Gage installed this date read 0.52.

AVERAGE MINIMUM DISCHARGE.

From the foregoing data the following tables have been compiled. The first one gives the mean discharge for the lowest week during 1909 at all gaging stations. The second table gives the discharges for these stations combined to represent the upper extremities of sections chosen for computing water power. Those obtained by measurement during 1909 have been increased 20 per cent to represent the average minimum discharge, as explained on page 31. From these data and the miscellaneous measurements the average minimum discharges for other points on the stream have been estimated.

It will be noticed that the minimum discharges per square mile at the gaging stations show no degree of consistency whatever. This has been frequently observed on other river systems where continuous and reliable records have been kept. It results from the fact that the topographic drainage area is not always the effective drainage area. For instance, Pine Creek flows through immense lava beds that extend into the Muddy River drainage basin, and it is conceivable that portions of the Muddy drainage area are connected through underground channels with the Pine Creek drainage area. In a country of lava flows the topographic drainage area can never be even an approximate indication of the discharge. The areas of Swift and Pine creeks and Muddy River consist largely of lava flows. Swift Creek and Muddy River receive glacial water from Mount St. Helens, but Pine Creek does not. Under such conditions a consistency in discharges per square mile of topographic drainage area would be most surprising.

Mean discharge for lowest week at gaging stations in Lewis River drainage basin, 1909.

Station.	Drainage area.	Week ending—	Discharge.	
			Second-feet.	Second-feet per square mile.
	Sq. miles.			
Lewis River above Muddy River	250	October 17	160	0.64
Lewis River at Peterson's	474	....do	530	1.12
Lewis River at Ariel	728	October 18	1,090	1.50
Muddy River at mouth	121	October 17	148	.12
Pine Creek at mouth	21	October 18	136	6.50
Swift Creek at mouth	26	October 15	164	6.30

Average minimum discharge for Lewis River drainage basin.

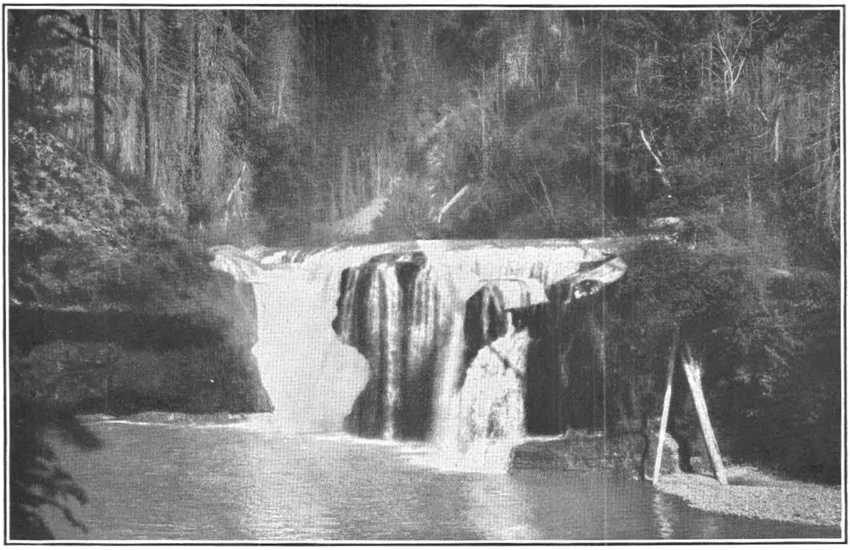
Locality.	Drainage area.	Date.	Measured discharge.	Adjusted for average minimum.
North Fork of Lewis River:	*Sq. miles.*		*Sec.-ft.*	*Sec.-ft.*
Upper Falls	114	Aug. 12, 1909 [a]	243	120
Below Muddy River	371	Oct. 17, 1909 [b]	308	367
Below Pine Creek	392	....do. [b]	444	533
Below Swift Creek	500	....do. [b]	694	832
Below Cougar Creek	552			1,090
Cressup's ferry	665	Sept. 21, 1907 [a]	1,350	1,210
Ariel	728	Oct. 18, 1909 [b]	1,090	1,310
Muddy River:				
Below Clearwater Creek	28			130
Below Clear Creek	114	Oct. 17, 1909 [b]	148	177
Pine Creek, head of survey	20	Oct. 18, 1909 [b]	136	163
Swift Creek, head of survey	24	Oct. 15, 1909 [b]	164	197
Cougar Creek, head of survey	4	July 21, 1909 [a]	105	30

[a] Date of miscellaneous gaging used as a guide.
[b] Date of ending of week for which measured discharge was lowest.

WATER POWERS.

Lewis River has a fairly well maintained flow during the summer season. This flow is largely supplied from the glaciers on Mount Adams and Mount St. Helens (Pl. XII). The grade of the main stream, however, is not exceptionally steep until the ascent of the main range is begun. From Ariel to the falls, 14 miles above the mouth of Muddy River, the stream falls 1,495 feet in 51.4 miles, an average of 29 feet to the mile. In the upper 14 miles of this distance the average fall is 39.5 feet to the mile; in the last 7 miles the average fall is only 11.3 feet to the mile. Muddy River was surveyed for 9 miles above its mouth, and an average fall of 44.4 feet to the mile was found. Pine Creek drops 233 feet in the last 1.6 miles, an average of 146 feet to the mile. Swift Creek has an average fall at its mouth of 172 feet to the mile, and Cougar Creek 125 feet to the mile.

Many favorable sites for dams are found along the main stream and tributaries. (See Pl. XIV, *B*.) These occur where the canyons narrow to chasms with vertical jagged walls of solid rock. In many



A. LOWER FALLS ON LEWIS RIVER 72 MILES ABOVE MOUTH.

B. DAM SITE ON LEWIS RIVER 48 MILES ABOVE MOUTH.

places bed rock is exposed in the bed of the stream or is lightly covered with gravel and bowlders. Along the canyon sides there are many benches upon which open canal construction would be possible. The more feasible sites are along the upper portions of the river, and it is likely that opportunities for high-head developments will be found beyond the limits of the survey. This portion of the river, however, is best reached from the east side of the range—that is, by way of White Salmon River, Trout Creek, and the Indian Race Tracks. There are no trails along Lewis River above Muddy River. The river canyon is almost impassable in this portion, and no further progress could have been made without adding an unwarranted amount to the expense of the investigation.

Being glacier fed, the river is heavily loaded with glacial silt near the headwaters. This silt, however, gradually settles out, and in the lower reaches the water is comparatively clear. Muddy River, the most pronounced glacial tributary, is supplied from the glaciers on Mount St. Helens. Pine Creek is not a glacial stream, the water being largely supplied from ground storage in the lava beds through which it flows. Swift Creek, on the other hand, is glacial, and the waters are white with silt during warm weather.

In computing the water powers in this drainage area the streams have been considered in sections, the length of each section being governed by an important tributary or an abrupt change in grade or the streams being otherwise divided to keep the sections within a reasonable length. The elevations of the water surface at the extremities of these sections, the total fall, the fall per mile, and the drainage area of each section are given. The discharge at the upper end of the section has been estimated from the data presented in the foregoing tables. In determining this discharge an attempt has been made to give an average minimum in the manner already described. Although this figure forms the most uncertain part of the data, it is believed to be conservative.

The horsepower given is 70 per cent of the theoretical power that is computed from the known fall in the section and the estimated discharge at its upper extremity. Seventy per cent is of course an arbitrary proportion, but it represents very nearly the power on turbine shafts that is actually realized in many plants now in operation.

Water powers in Lewis River drainage basin.

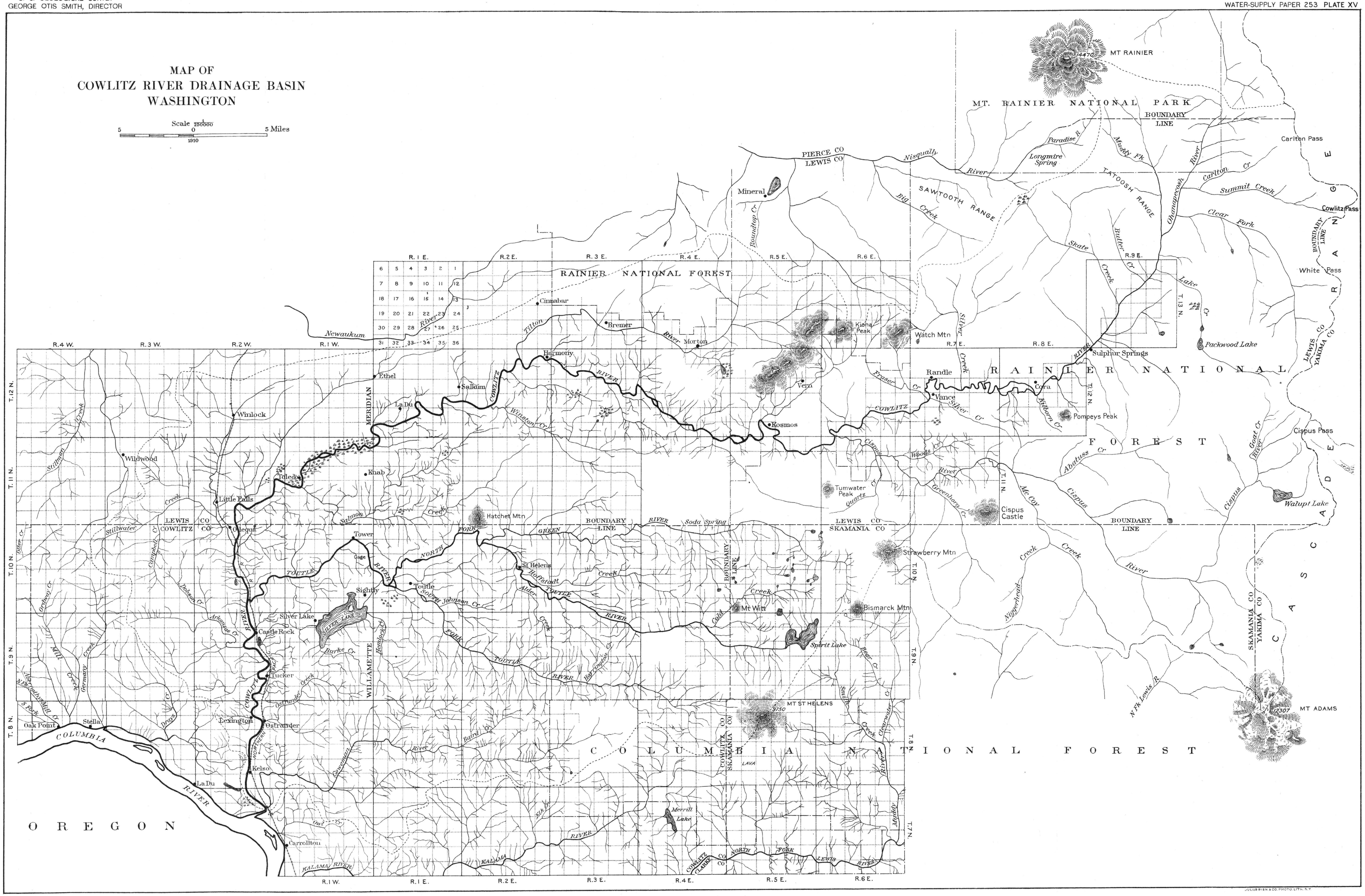
Point on stream.	Distance above mouth.	Elevation.	District between points.	Fall between points.	Fall per mile.	Drainage area.	Average minimum discharge.		Available horsepower (70 per cent of theoretical).
							Second feet.	Second-feet per square mile.	
Main stream.	*Miles.*	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Sq. m.*			
Above upper falls	74.00	1,585				114	120	1.05	
Below lower falls	72.33	1,435	1.67	150	89.8	114	120	1.05	1,430
Above mouth of Muddy River	59.92	1,030	12.41	405	32.6	250			3,860
Below mouth of Muddy River	59.92	1,030				371	367	.99	
Above mouth of Pine Creek	59.35	1,012	.57	18	31.6	371			520
Below mouth of Pine Creek	59.35	1,012				392	533	1.36	
Above mouth of Swift Creek	47.38	625	11.97	387	32.3	474			16,400
Below mouth of Swift Creek	47.38	625				500	832	1.64	
Above mouth of Cougar Creek	41.70	430	5.68	195	34.3	540			12,900
Below mouth of Cougar Creek	41.70	430				552	1,090	1.97	
Cressup's ferry	30.75	175	10.95	255	23.3	665	1,210	1.82	22,100
Ariel	23.20	90	7.55	85	11.3	728	1,310	1.80	8,700
Muddy River.									
Below mouth of Clearwater Creek	9.45	1,450				28	130	4.64	
Below mouth of Clear Creek	4.60	1,205	4.85	245	50.5	114	177	1.55	2,540
Mouth		1,030	4.60	175	38.0	121			2,480
Pine Creek.									
Head of survey	1.60	1,245				20	163	8.15	
Mouth		1,012	1.60	233	146	21			3,020
Swift Creek.									
Head of survey	1.37	860				24	197	8.20	
Mouth		625	1.37	235	172	26			3,680
Cougar Creek.									
Head of survey	1.40	605				4	30	7.5	
Mouth		430	1.40	175	125	6			420
									78,000

TOUTLE RIVER DRAINAGE BASIN.

DESCRIPTION.

Toutle River, the largest tributary of Cowlitz River, has its source in Spirit Lake, on the northwestern slope of Mount St. Helens, flows in a general westerly direction, and empties into Cowlitz River 2 miles above Castle Rock, Wash. The total length of the river from the outlet of Spirit Lake to its junction with Cowlitz River is 54.3 miles, and the total fall in that distance is 3,153 feet. Plate XV is a map of the Cowlitz River drainage basin, of which Toutle River drains a part.

The principal tributaries, in their order downstream, are Cold Creek, Hoffstadt Creek, and Green River from the north and Alder Creek, South Fork, and Outlet Creek from the south.


MAP OF
COWLITZ RIVER DRAINAGE BASIN
WASHINGTON
Scale 1/250000
5 0 5 Miles
1910
MT RAINIER
MT. RAINIER NATIONAL PARK
BOUNDARY LINE
RAINIER NATIONAL FOREST
COLUMBIA NATIONAL FOREST
CASCADE RANGE
OREGON
COLUMBIA RIVER
MT ST HELENS
MT ADAMS
Spirit Lake
Silver Lake
Packwood Lake
Walupt Lake
Merrill Lake
Mineral
Morton
Randle
Kosmos
Toledo
Winlock
Castle Rock
Kelso
Carrollton
Sulphur Springs
Cowlitz Pass
Carlton Pass
White Pass
Cispus Pass
WILLAMETTE MERIDIAN
SAWTOOTH RANGE
TATOOSH RANGE
PIERCE CO
LEWIS CO
COWLITZ CO
SKAMANIA CO
YAKIMA CO
CLARKE CO
JULIUS BIEN & CO. PHOTO. LITH. N.Y.

The total drainage area is 510 square miles, distributed as follows:

	Square miles.
Spirit Lake outlet	12
Above mouth of Green River	143
Above mouth of South Fork	295
At Tower gaging station	474
Mouth	510
Green River	128
South Fork	134
Outlet Creek	42

The prominent topographic feature of the area is Mount St. Helens (Pl. XII, *B*). The elevation of this peak has not been accurately determined, but is given as between 9,750 and 10,000 feet. The general topography of the region is bold and rugged, somewhat similar to that of the adjoining basin of Lewis River. The area is probably the dissected and eroded remainder of a broad plateau that was modified by distorting uplifts and more or less covered with lava flows.

The country to the north and east of Mount St. Helens is included in the St. Helens mining district, and here the volcanic rocks are absent. The general formation in the mining district is syenite cut by porphyry dikes striking almost northwest and dipping 60° or 70° W. Northwest of the syenite belt the country rock is mostly quartzite, broken and traversed by a series of almost perpendicular veins, whose general strike is northeast and southwest. Many of the veins of the district are of great width and carry sulphide ores, mostly of copper, iron, and lead. They are true fissure veins and are found along the contact between the porphyry dikes and the country rock.[a]

The lands contiguous to the lower portion of the river are high and rolling but not rugged. Upstream these rolling lands are gradually replaced by narrower valleys and bench lands topped by bold peaks with scarred and eroded sides. The river canyons, however, are not so abrupt as those of the other streams considered in this report, but the sides are of more uniform slope with here and there a rocky bluff on one bank or the other. The stream flows on a bed of gravel and cobblestones through almost its entire length, with scattered ledges of partly exposed bed rock dipping steeply into the gravel bed of the river. This indicates that the river canyons at one time were deeper but that they have been filled by water-deposited gravel and talus from the canyon sides.

Only a small portion of this area lies within the Columbia National Forest. The west line of T. 5 N. is the western boundary of this forest, but practically all tracts along the river within it are patented lands.

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[a] Ann. Rept. Washington Geol. Survey for 1901, vol. 1, pt. 2.

The average stand of timber on the area is probably 10,000 feet b. m. per acre except where it has been logged off. The timber from the easily accessible tracts has been partly removed, but the greater portion of the timber in the basin is still in its virgin state. Most of the logged-off areas are being restocked and all is covered with young growth and underbrush except where the lands have been cleared for agriculture.

The species found are those common to the western slope of the Cascade Range. Red or yellow fir constitutes about 50 per cent of the stand, cedar about 10 per cent, hemlock 5 per cent, and white fir 5 per cent, with considerable quantities of Noble fir, mountain hemlock, and Englemann spruce. The rivers are lined with dogwood, alders, and maple, and over all there is a dense undergrowth of vines, brambles, ferns, and deciduous shrubs.

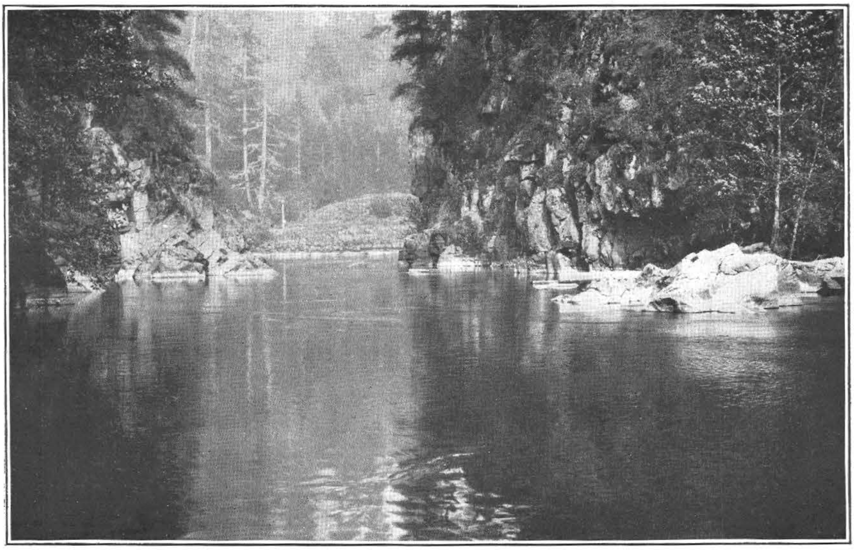
The Seattle and Portland line of the Northern Pacific Railway crosses the river near its mouth, but elsewhere there are no railroads in the area. There is a wagon road from Castle Rock to Spirit Lake and from it roads and trails lead in various directions. A trail follows Green River to the Saint Helens mining district. The lower portion of the drainage area is well provided with wagon roads. Roads lead from Castle Rock to Silver Lake and Sightly and to points on South Fork and the rolling lands between that stream and Cowlitz River.

The first discoveries of metalliferous ores in the mining district were made in 1891 and the district was formed September 22, 1892. At the present time there is considerable activity in this region, and there is every indication that if transportation facilities were provided some valuable mining property would be developed here. The mines and proposed transportation lines to them should afford a good market for water power.

Agriculture plays no small part in this region. All along the river and on the rolling lands nearer the mouth many tracts have been cleared for diversified farming or planted to orchards. The soil is rich and the climate is favorable for fruit raising and other forms of intensive agriculture. Hay and grains are plentiful along the shores of Silver Lake, and garden vegetables, potatoes, and small fruits and berries are raised in abundance wherever the attempt has been made.

Lumbering, however, has been and probably will continue for some years to be the principal industry. Several small shingle and lumber mills are in operation, but the greater portion of the logs are transported to the larger mills on lower Cowlitz and Columbia rivers.

At present there are no developed water powers in the drainage area, but near the outlet of Spirit Lake some power rights have reached



A. DAM SITE ON TOUTLE RIVER NEAR MOUTH.

B. DRIFTWOOD ON TOUTLE RIVER NEAR ST. HELENS.

the point of preliminary construction of crib dams and diverting flumes. (See Pl. XVI, *A*.)

The properties are claimed by adverse interests, so that all work has been stopped by injunction and the respective rights are in litigation.

Spirit Lake, at the head of the main stream, has a total drainage area of 12 square miles and a normal surface area of 2.2 square miles. About 80,000 acre-feet could be developed by raising the water surface 50 feet. This is equivalent to a uniform flow of 200 second-feet for 200 days. There is no doubt that this reservoir would be filled each winter season. Silver Lake (or Toutle Lake, as it is sometimes called), in the lower portion of the area, has a drainage area of 42 square miles and a surface area of 5.1 square miles. Its water surface could not be raised very much, but it is probable that 50,000 acre-feet could be stored. The run-off from the drainage area, however, is relatively small, and Outlet Creek, which joins it to the trunk stream, is usually dry in summer.

Toutle River is a glacial stream. The summer flow is largely supplied by the glaciers on the northern slope of Mount St. Helens. The waters from these glaciers do not flow into Spirit Lake, but reach the main stream through three tributaries from the south. Some water from the glaciers on the west side of the mountain flows into South Fork, but the contribution to that stream from this source is small. Green River, as its name implies, is not glacier fed, but the waters are supplied from surface drainage and ground storage during the summer. Its headwaters reach into the high spurs of the main range and it doubtless draws from snow banks that remain well into the summer.

During the course of the surveys discharge data were obtained at critical points. A temporary station was established on Toutle River at St. Helens and a permanent station near Tower, below all important tributaries. In addition to these data, discharge measurements were made at several points, the results of which are given as miscellaneous measurements.

TOUTLE RIVER AT ST. HELENS.

This station was established September 11, 1909. It is located at the county bridge across Toutle River in the SE. ¼ sec. 15, T. 10 N., R. 2 E., above the mouth of Alder Creek. The gage is a vertical staff 10 feet long, graduated to feet and tenths, and fixed to the downstream end of the left abutment of the bridge. Discharge measurements are made from the highway bridge. The station was established for temporary purposes only, and observations were suspended at the close of the summer season.

Discharge measurements of Toutle River at St. Helens, Wash., for 1909.

Date.	Hydrographer.	Width.	Area of section.	Mean velocity.	Gage height.	Discharge.
		Feet.	*Sq. ft.*	*Ft. per sec.*	*Feet.*	*Sec. ft.*
September 11	C. W. Harris	81	133	1.89	1.07	252
September 21	do	81	140	2.25	1.19	313

Daily gage height, in feet, of Toutle River at St. Helens, Wash., for 1909.

[Iner Fouske, observer.]

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1		1.10	11	1.07		21	1.09	
2		1.06	12	1.05		22	1.05	
3		1.04	13	1.02		23	1.03	
4		1.03	14	1.01		24	1.05	
5			15	1.01		25	1.07	
6			16	1.02		26	1.03	
7			17	1.04		27	1.01	
8			18	1.02		28	1.03	
9			19	1.02		29	1.10	
10			20	1.10		30	1.14	

Daily discharge, in second-feet, of Toutle River at St. Helens, Wash., for 1909.

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1		270	11	257		21	266	
2		253	12	248		22	248	
3		244	13	235		23	240	
4		240	14	231		24	248	
5			15	231		25	257	
6			16	235		26	240	
7			17	244		27	231	
8			18	235		28	240	
9			19	235		29	270	
10			20	270		30	290	

TOUTLE RIVER NEAR TOWER.

This station was established September 4, 1909. The gage is a vertical staff located at the downstream end of a rocky bluff on the right bank one-fourth mile above G. K. Walker's house, near the quarter corner between secs. 12 and 13, T. 10 N., R. 1 E., 2½ miles below the mouth of South Fork of Toutle River and Outlet Creek.

It is intended that this station shall be permanent, but as yet no facilities have been installed for making measurements at high stages. Measurements during the low-water period can be made by wading, and in this manner estimates for the present season have been made.

A measurement was made by C. W. Harris, September 4, as follows:

Width, 124 feet; area, 234 square feet; mean velocity, 1.78 feet per second; gage height, 1.24 feet; discharge, 416 second-feet.

Daily gage height, in feet, of Toutle River near Tower, Wash., for 1909.

[G. K. Walker, observer.]

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	....	1.45	2.49	5.82	16	1.19	1.21	2.75	3.78
2	....	1.35	6.10	4.95	17	1.19	1.20	2.55	3.53
3	....	1.30	7.60	4.42	18	1.18	1.19	3.30	3.32
4	1.24	1.25	5.60	4.00	19	1.15	1.22	5.40	3.18
5	1.25	1.22	4.50	3.72	20	1.15	1.80	6.50	3.04
6	1.21	1.44	4.00	3.45	21	1.85	2.38	5.40	2.95
7	1.21	1.67	3.52	3.30	22	1.42	2.30	7.52	2.80
8	1.20	1.45	3.90	3.25	23	1.30	1.89	8.00	2.70
9	1.18	1.40	4.00	3.20	24	1.25	1.97	8.85	2.64
10	1.20	1.38	4.10	3.17	25	1.26	1.84	6.50	2.60
11	1.35	1.36	3.70	3.16	26	1.30	1.73	5.34	2.55
12	1.24	1.30	3.40	5.34	27	1.21	1.65	4.65	2.50
13	1.21	1.29	3.32	5.30	28	1.20	1.59	5.00	2.45
14	1.21	1.29	3.09	4.56	29	1.34	1.75	6.25	2.40
15	1.20	1.25	2.89	4.12	30	1.67	1.81	7.60	2.33
					31	....	1.90	....	2.90

Daily discharge, in second-feet, of Toutle River near Tower, Wash., for 1909.

Day.	Sept.	Oct.	Day.	Sept.	Oct.	Day.	Sept.	Oct.
1	....	468	11	442	445	21	574	....
2	....	442	12	415	430	22	460	....
3	....	430	13	408	428	23	430	585
4	415	418	14	408	428	24	418	....
5	418	410	15	405	418	25	420	572
6	408	465	16	403	408	26	430	542
7	408	526	17	403	405	27	408	520
8	405	468	18	400	403	28	405	504
9	400	455	19	394	410	29	440	548
10	405	450	20	394	561	30	526	564
						31	....	588

MISCELLANEOUS MEASUREMENTS.

The following miscellaneous discharge measurements were made in the basin of Toutle River:

Miscellaneous discharge measurements in Toutle River basin.

[By C. W. Harris and H. L. Gilbert.]

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Sq. ft.*	*Ft. per sec.*	*Sec.-ft.*
May 27, 1907	Toutle River	Outlet of Spirit Lake				206
Sept. 18, 1909	do[a]	do	39	21	1.45	30
Sept. 10, 1909	Green River[b]	Lithow	67	68	.82	56
May 24, 1907	South Fork of Toutle River	Toutle				336
Sept. 7, 1909	do	do.[c]	68	71	1.25	87

[a] Made at spillway of upper dam. Water surface 7.76 feet below spike in root of 18-inch white fir on right bank 20 feet above dam.
[b] Made by wading 300 feet below highway bridge. Water surface 4.62 feet below 10-penny nail in lower board of left abutment of bridge, upstream end.
[c] Water surface 5.49 feet below lowest rivet of upper longitudinal seam on northwest side of northwest tube of middle pier of county bridge.

AVERAGE MINIMUM DISCHARGE.

From the foregoing data the following table has been prepared, giving the average minimum discharge at the upper extremity of each section used in computing water powers. The mean discharge for the lowest week as measured at tributaries has been increased 20 per cent, as explained on page 31.

The streams are supplied partly by glacial waters, but the greater portion of the summer flow comes from surface drainage and ground storage. The entire drainage area is more or less effective in producing run-off, and in this respect the stream presents a strong contrast to Lewis River, whose drainage area joins that of Toutle River on the south. The average minimum discharges per square mile (given in power table) are seen to be fairly consistent among themselves. The value for Green River is less than those for the main stream and for South Fork, as would be expected, since it does not draw from the glaciers on Mount St. Helens.

Average minimum discharge in Toutle River drainage basin.

Location.	Drainage area.	Date.	Measured discharge.	Discharge adjusted to average minimum.
Main stream.	*Sq. miles.*	1909.	*Sec.-ft.*	*Sec.-ft.*
Outlet Spirit Lake	12	Sept. 18 [a]	30	36
Above Cold Creek	33			92
East line sec. 12, T. N., 9 R 3 E	74			185
St. Helens gaging station	120	Sept. 19 [b]	235	282
Below Green River	271	do. [b]	290	348
Below South Fork	429	do. [b]	390	469
Tower gaging station	474	Sept. 20 [b]	401	481
North line sec. 21, T. 10 N., R. 1 W	487			490
Green River.				
Lithow bridge	127	Sept. 10 [b]	56	64
South Fork.				
Head of survey	122	Sept. 7 [b]	87	100

[a] Date of miscellaneous measurement used as a guide.
[b] Date of ending of week for which mean discharge was the lowest.

WATER POWERS.

Toutle River has an average fall, in the 54.3 miles from Spirit Lake to its mouth, of 58.1 feet to the mile. The fall in the upper 10 miles averages 137 feet and in the lower 10 miles 19 feet to the mile. Green River at the mouth has an average fall of 20.8 feet to the mile, but the fall increases rapidly as the stream is ascended. South Fork at its mouth has an average fall of 19.2 feet to the mile, but the grade does not increase greatly until near the spurs of Mount St. Helens.

Although the stream in general flows on a gravel bed, there are many favorable localities for diversion of the water into open canals or pressure pipes. The sides of the canyon and the benches along the river afford opportunities for canal construction. The main stream therefore has been divided into sections. The elevations of the water surface at the extremities of these sections, the total fall, the fall per mile, and the drainage area of each section considered are given below. The discharge at the upper end of the section has been estimated from the data already presented. In determining this discharge an attempt has been made to give an average minimum in the manner described on page 31. This figure is the most uncertain part of the data, but it is believed to be conservative.

The horsepower given is 70 per cent of the theoretical power that is computed from the known fall in the section and the estimated discharge at its upper extremity. Seventy per cent is, of course, an arbitrary proportion, but it represents very nearly the power on turbine shafts that is actually realized in many plants in operation under full load.

Water powers in Toutle River drainage basin.

Point on stream.	Distance above mouth.	Elevation.	Distance between points.	Fall between points.	Fall per mile.	Drainage area.	Average minimum discharge.		Available horsepower (70 per cent of theoretical).
							Second-feet.	Second-feet per square mile.	
Main stream.	*Miles.*	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Sq. mi.*			
Spirit Lake outlet	54.30	3,204				12	36	3.00	
Above mouth of Cold Creek	47.62	2,140	6.68	1,064	159	33	92	2.80	3,040
East line T. 9 N., R. 3 E	42.75	1,620	4.87	520	107	74	185	2.50	3,800
St. Helens bridge	31.80	885	10.95	735	67.1	120	282	2.35	10,800
Above mouth of Green River	27.55	720	4.25	165	38.8	143			3,700
Below mouth of Green River	27.55	720				271	348	1.28	
Above mouth of South Fork	16.45	420	11.10	300	27.0	295			8,300
Below mouth of South Fork	16.45	420				429	469	1.09	
Castle Rock gaging station	13.10	305	3.35	115	34.4	474	481	1.01	4,300
North line sec. 21, T. 10 N., R. 1 W	7.60	160	5.70	145	25.5	487	490	1.01	5,500
Mouth		51	7.60	109	14.2	510			4,200
Green River.									
Lithow Bridge	1.20	745				127	64	.50	
Mouth		720	1.20	25	20.8	128			120
South Fork.									
Head of survey	1.30	445				122	100	.82	
Mouth		420	1.30	25	19.2	134			200
									44,000

RECORDS OF PRECIPITATION.

In order to present data for more extensive study of the effect of rainfall on stream flow, all available records of precipitation for the territory treated in this report have been compiled from published reports of the United States Weather Bureau and are presented in the following table. So few stations have been maintained within the area itself that the records from outlying stations are also given:

Rainfall stations in and near area considered.

Station.	County and State.	Latitude.	Longitude.	Elevation.	Length of record.
		° ′	° ′	*Feet.*	*Years.*
Portland	Multnomah, Oreg	45 32	122 43	32	41
Vancouver	Clarke, Wash	45 38	122 42	75	32
Cascade Locks	Hood River, Oreg	45 40	121 56	100	31
Hood River	.....do	45 42	121 30	243	26
The Dalles	Wasco, Oreg	45 36	121 12	112	52
Lyle (Pine Hill)	Klickitat, Wash	45 30	121 0	600	18
Goldendale	.....do	45 49	120 49	1,600	3
Fort Simcoe	Yakima, Wash	46 29	120 48	1,427	17
Ellensburg	Kittitas, Wash	47 00	120 32	1,571	21
Yale	Cowlitz, Wash	45 57	122 19	375	4
Olympia	Thurston, Wash	47 03	122 54	25	31

Precipitation at rainfall stations in and near area considered.

PORTLAND, OREG.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1858	......	......	......	1.35	1.51	0.13	......	......	......	......	......	......	....
1859	......	8.95	7.85	1.44	1.51	.13	0.22	0.87	......	......	......	......	....
1870	4.85	4.30	4.30	4.30	1.95	1.95	.20	.20	0.45	0.55	6.05	4.40	33.50
1871	7.60	5.06	9.84	3.64	5.18	.50	.55	.45	1.15	1.19	2.77	7.62	45.55
1872	6.56	12.13	5.28	2.96	.92	1.52	.20	.13	1.26	1.80	4.67	9.47	46.90
1873	8.49	6.58	12.76	2.35	2.18	2.96	1.02	.84	.00	3.86	4.33	5.15	50.52
1874	9.46	4.28	5.15	3.68	2.38	2.68	.19	.83	1.70	.36	10.22	5.24	46.17
1875	4.49	1.99	9.41	2.10	2.87	2.05	.02	.53	.71	6.73	15.77	13.41	60.08
1876	4.80	7.50	9.12	5.34	1.88	2.35	.96	.56	1.09	10.53	10.03	.88	55.04
1877	2.75	7.56	11.31	2.44	2.24	2.05	.54	1.70	3.36	5.03	12.45	6.87	58.30
1878	6.67	12.16	6.23	1.86	2.17	.13	1.10	.50	3.54	3.22	5.61	4.52	47.71
1879	5.28	13.22	11.70	2.19	6.60	2.18	1.75	.97	2.18	4.23	4.56	7.36	62.22
1880	12.27	5.67	4.48	2.92	3.13	1.59	.59	1.31	1.34	1.47	3.17	13.93	51.87
1881	8.57	13.36	2.83	3.51	1.38	2.34	1.16	2.11	2.64	6.60	6.91	6.64	58.05
1882	5.06	10.49	2.53	4.60	1.84	1.91	.95	.07	.91	11.63	7.11	20.14	67.24
1883	13.71	2.34	6.40	7.88	1.67	.08	.10	.19	.67	3.91	8.26	6.34	51.45
1884	3.70	4.88	2.25	3.57	1.34	1.42	1.80	.33	4.25	4.01	3.24	7.52	38.31
1885	4.57	6.72	.63	1.12	4.69	1.77	.24	.00	2.48	1.68	8.52	7.17	39.57
1886	9.33	1.96	5.39	3.16	1.32	.67	.32	.03	1.19	2.87	1.00	11.52	38.76
1887	12.31	2.81	8.00	5.06	4.77	1.44	.03	.58	3.06	1.34	3.43	11.34	54.17
1888	8.50	2.42	2.87	2.06	.68	5.38	1.04	.05	1.13	4.97	4.47	5.19	38.76
1889	4.78	1.07	1.80	2.72	4.02	.51	Tr.	.90	1.61	4.59	3.97	5.79	31.76
1890	11.13	9.85	6.23	1.41	1.08	2.23	.59	.13	.10	2.79	.50	4.34	40.38
1891	3.62	6.26	2.06	4.00	1.83	4.07	.24	.93	2.17	5.04	5.74	11.45	47.41
1892	4.79	2.48	2.82	4.82	1.57	1.41	.70	.17	1.63	2.16	4.34	6.69	33.58
1893	2.12	5.19	3.48	4.89	2.30	.99	.14	Tr.	2.56	5.01	7.74	4.61	39.03
1894	9.65	5.16	7.48	2.57	1.09	2.16	.10	Tr.	1.32	3.56	2.76	3.47	39.32
1895	8.53	1.01	2.84	1.91	3.42	.57	.23	.37	1.16	Tr.	2.93	7.79	30.76
1896	6.52	3.44	2.19	4.09	3.55	1.41	Tr.	1.32	.47	1.76	13.12	6.26	44.13
1897	3.25	5.57	4.00	1.76	.90	1.35	.65	.26	2.79	1.99	11.65	8.84	43.01
1898	3.91	6.51	2.17	2.12	1.78	1.88	.79	.15	2.69	1.58	6.03	4.29	33.90
1899	6.42	4.20	2.30	3.73	3.16	.62	.47	2.50	1.37	3.97	7.56	5.91	42.21
1900	4.58	3.36	4.63	1.30	3.90	1.76	.34	2.04	1.93	3.87	4.50	6.01	38.22
1901	7.80	6.52	4.12	4.05	2.41	1.39	.12	.17	3.57	.75	6.14	4.01	41.05
1902	3.11	8.66	5.79	3.71	2.19	.80	1.76	.44	4.75	1.72	9.94	10.28	50.15
1903	5.43	1.44	4.29	2.25	1.71	2.00	.51	.81	1.13	2.20	10.71	3.14	35.62
1904	5.22	11.08	8.73	2.26	.59	.45	.73	.20	.28	2.29	7.40	7.14	46.37
1905	3.66	1.77	5.03	1.71	2.56	2.12	.12	.19	2.79	4.73	3.01	6.41	34.10
1906	5.72	6.76	2.23	2.02	2.00	3.03	Tr.	.05	2.20	3.43	8.30	7.55	43.29
1907	8.23	3.54	3.86	3.57	1.37	1.84	1.19	1.02	1.73	.93	6.51	9.10	42.89
1908	4.73	2.85	4.39	3.38	4.66	.67	.05	1.34	.23	5.17	3.10	3.80	34.37
1909	9.29	7.03	2.35	.89	1.79	.17	2.26	.65	.95	2.01	12.49	4.47	44.35

Precipitation at rainfall stations in and near area considered—Continued.

VANCOUVER, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1849	......	......	......	......	......	......	......	......	......	......	......	6.00	......
1850	6.66	2.60	6.71	0.60	0.40	3.22	8.35	0.00	0.98	2.69	4.90	1.29	38.40
1851	9.55	2.04	4.08	......	......	......	......	......	......	......	......	7.93	......
1852	9.31	4.77	4.26	6.56	3.49	1.77	......	......	......	1.55	7.37	13.37	55.95
1853	9.30	4.21	2.47	1.72	2.33	.90	.30	.39	2.00	3.66	11.57	3.22	42.07
1854	......	2.83	1.22	2.78	.75	2.41	.00	1.72	.00	2.31	3.19	8.34	32.75
1855	13.29	3.84	3.99	2.04	3.77	2.43	......	.00	.46	1.41	2.05	10.77	45.43
1856	5.00	3.07	1.01	4.01	4.08	3.26	2.89	.08	2.37	4.81	6.62	15.37	52.57
1857	6.74	4.39	7.30	.37	3.04	2.09	......	.14	1.87	.96	7.01	12.28	47.57
1858	5.62	6.90	4.20	1.98	2.30	1.82	.00	.71	4.37	3.55	4.25	4.76	40.46
1859	5.77	5.10	9.60	1.90	2.00	.16	.25	1.02	4.19	2.22	4.15	2.40	38.86
1860	5.57	2.77	2.93	1.95	2.92	1.00	1.25	.35	1.52	3.78	6.31	4.12	34.47
1861	4.60	6.32	3.05	3.05	3.40	2.70	.00	.20	.75	2.88	7.70	7.40	42.05
1862	3.47	1.80	5.31	3.10	3.87	3.05	1.43	1.00	.45	1.30	.85	4.87	30.40
1863	8.70	6.46	2.75	3.50	2.45	.90	1.10	.65	1.70	3.61	4.23	6.36	42.41
1864	5.35	1.73	3.94	1.90	.67	1.79	.34	.30	2.81	1.05	5.93	5.67	31.48
1865	2.38	1.32	2.71	......	.76	.94	.83	.68	......	.68	6.53	1.55	25.91
1866	.80	.89	4.15	2.11	......	......	......	......	.08	1.53	2.63	4.69	......
1867	3.85	3.68	.97	1.98	.90	.79	1.19	.00	1.14	2.45	2.14	16.04	35.13
1868	2.22	1.02	2.89	2.36	1.01	3.78	.55	......	......	......	......	......	......
1891	3.53	4.37	1.84	4.46	1.70	3.42	.38	1.30	2.68	4.52	6.50	9.70	44.40
1892	4.22	2.35	2.49	......	......	......	......	......	......	......	......	......	......
1898	......	......	......	......	2.42	2.01	.85	.18	2.89	1.84	5.48	4.49	......
1899	6.46	4.39	2.46	3.75	4.00	1.20	.10	3.03	1.83	5.05	9.07	5.86	47.20
1900	4.00	3.90	4.55	2.13	4.40	2.66	.82	.32	1.96	4.25	4.34	7.10	40.43
1901	6.66	6.70	4.71	3.36	2.29	1.89	.18	.18	3.07	1.10	6.74	3.68	40.56
1902	3.86	9.14	4.76	3.14	2.28	.75	1.94	.31	1.92	1.74	10.00	11.13	50.97
1903	5.29	1.84	4.07	2.40	1.71	2.06	.37	.56	1.58	2.26	9.34	2.77	34.25
1904	4.49	9.13	7.69	2.44	1.16	.39	.51	.15	.21	2.23	7.21	6.82	42.43
1905	4.46	1.95	4.05	1.54	3.36	2.40	.24	.18	2.53	4.15	2.97	5.47	33.30
1906	4.90	5.90	2.47	1.63	2.41	3.34	Tr.	.05	2.09	3.25	9.42	6.92	42.38
1907	6.55	4.67	2.67	2.81	1.56	1.80	.99	1.38	2.17	.68	5.77	8.81	39.86
1908	4.20	2.80	3.85	3.05	4.31	.80	.08	1.68	.16	4.40	3.26	4.1	32.77
1909	9.33	6.26	2.10	.87	1.91	.14	2.41	.07	1.41	2.43	12.79	4.52	44.24

CASCADE LOCKS, OREG.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1879	......	......	16.48	5.02	7.19	1.18	3.97	1.45	5.02	7.91	11.67	15.43	......
1880	19.64	9.08	7.50	5.17	5.05	3.40	.55	2.38	1.73	4.73	7.93	15.52	82.68
1881	14.23	24.71	7.26	7.05	2.32	5.31	1.61	1.69	3.83	11.23	9.53	10.14	98.91
1882	10.56	12.75	4.40	7.42	1.93	1.82	2.05	.45	1.15	14.75	6.19	19.06	82.53
1883	22.70	2.87	5.39	10.80	1.90	.30	.00	.00	1.00	7.81	15.21	8.89	76.87
1884	9.27	10.89	3.06	6.22	1.75	1.99	1.08	.00	6.38	10.22	4.80	15.42	71.08
1885	5.45	16.72	1.60	.78	4.60	1.55	.23	.00	7.50	2.89	12.19	12.64	66.15
1886	11.01	6.81	10.00	4.27	3.42	.31	.56	.00	2.93	4.72	3.38	20.94	68.41
1887	29.90	3.85	14.09	8.15	6.68	1.32	.00	.40	4.02	3.98	7.65	20.60	100.64
1888	10.90	3.59	5.74	2.23	.36	6.43	1.72	.15	.97	9.56	9.68	8.65	59.98
1889	4.54	2.79	3.39	5.38	4.34	1.89	.00	1.00	4.95	6.52	6.80	8.46	50.06
1890	14.42	22.28	7.10	2.81	.75	6.54	.48	.39	.02	6.86	1.74	7.57	70.96
1891	9.00	9.69	6.52	5.60	1.94	4.45	1.22	1.84	3.02	8.31	13.25	21.50	81.23
1892	9.89	4.98	4.63	8.79	2.18	.80	1.66	.21	2.44	4.81	13.19	9.95	63.22
1893	2.14	11.46	10.03	13.81	4.70	3.02	.15	.16	7.06	8.00	15.10	13.37	89.60
1894	21.80	10.71	16.52	7.76	2.31	3.73	.42	.00	5.89	11.21	6.93	6.94	94.22
1895	12.71	3.46	7.35	5.34	7.91	.43	1.15	.13	3.88	.20	8.87	19.60	71.03
1896	11.45	11.18	7.68	9.44	7.54	3.02	.00	.65	1.66	3.85	23.65	14.85	94.97
1897	6.20	14.37	11.47	4.04	1.33	2.75	.62	1.43	4.01	3.95	19.24	19.26	88.67
1898	10.63	14.48	5.56	3.13	2.67	1.83	1.65	1.28	6.78	3.36	16.75	8.16	76.28
1899	15.34	13.93	6.85	11.65	4.65	2.41	.08	4.82	2.69	7.04	16.66	11.83	97.95
1900	11.06	9.65	7.15	2.15	4.49	3.33	.26	1.32	3.00	12.84	10.52	10.96	76.73
1901	11.87	15.28	9.54	5.61	2.66	1.95	.13	.19	4.60	1.96	11.32	11.94	76.97
1902	7.80	12.73	11.26	7.56	4.11	1.49	1.51	.27	3.09	2.69	21.01	19.83	93.35
1903	17.28	2.47	3.89	3.84	2.52	4.63	.68	.47	4.50	7.39	16.21	8.36	72.24
1904	12.12	14.94	15.09	3.45	.69	2.08	1.04	.31	.09	3.33	8.66	14.46	76.26
1905	5.66	3.68	8.97	1.49	4.75	1.08	.00	.73	5.43	9.41	5.27	12.19	58.66
1906	7.84	11.54	2.71	2.80	2.84	1.62	.00	.09	4.84	7.93	17.84	13.42	77.98
1907	11.95	9.33	5.77	9.53	1.87	2.19	.84	1.80	3.45	1.62	12.53	18.81	79.69
1908	9.08	5.86	12.39	4.08	4.98	2.22	.17	2.22	.45	7.87	5.57	10.26	65.15
1909	1.72	11.26	5.27	3.03	4.30	.89	1.29	.58	2.34	4.59	26.10	4.25	65.62

Precipitation at rainfall stations in and near area considered—Continued.

HOOD RIVER, OREG.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1884	3.70	5.90	1.30	3.35	1.10	1.15	0.25	0.10	3.30	3.60	1.70	12.70	38.15
1885	5.40	8.15	.30	.60	1.30	1.30	.00	.00	2.65	1.15	5.00	6.50	32.35
1886	10.65	1.90	4.35	2.10	.80	.15	.05	.00	1.30	2.20	1.15	10.40	35.05
1887	16.80	3.50	4.90	1.40	2.00	.65	.00	.25	1.75	.65	2.90	10.75	45.55
1888	8.15	1.70	2.95	1.10	.20	4.00	.55	.05	.03	4.10	4.10	5.25	32.18
1889	2.90	.65	1.90	1.95	1.25	.25	.02	.23	2.00	2.10	3.75	5.50	22.50
1890	7.60	9.70	3.70	1.20	.40	.85	.20	.10	.00	3.25	.10	3.85	30.95
1891	2.45	6.70	2.80	1.10	1.00	1.20	.35	.05	1.18	2.45	4.55	12.85	36.68
1892	4.45	1.50	1.80	4.02	.75	.54	.27	.12	.90	2.12	5.83	10.94	32.24
1893	3.25	8.03	4.23	5.76	2.58	.58	.33	.00	3.26	9.81	9.56	6.86	54.17
1894	11.72	5.03	12.67	1.68	1.56	1.79	Tr.	.00	2.00	3.93	3.78	4.13	48.29
1895	10.85	1.16	3.68	1.90	3.33	[.25]	.64	.15	2.91	.01	3.82	12.83	....
1896	7.61	4.53	5.00	3.17	3.78	.54	Tr.	.22	.98	1.81	16.55	7.17	51.36
1897	2.85	7.45	6.78	1.84	.81	.95	.18	.30	1.29	1.24	10.64	12.54	46.87
1898	3.72	5.83	2.10	.95	.86	1.31	.80	.09	2.74	1.15	7.35	4.17	31.07
1899	7.55	5.89	4.04	3.89	2.16	1.66	Tr.	2.01	.68	3.62	7.72	4.96	44.18
1900	[6.40]	[5.80]	1.43	.86	.50	1.00	.00	.29	1.89	4.59	5.46	5.45	....
1901	7.66	7.81	2.93	2.82	.51	.42	Tr.	.27	3.30	.12	6.29	4.75	36.88
1902	3.81	7.09	3.61	3.34	1.06	.30	.38	.01	1.04	1.30	9.49	10.57	42.00
1903	8.94	1.83	2.50	.62	.29	1.29	.07	.31	.89	3.01	7.74	2.73	30.22
1904	3.91	8.96	6.70	1.46	.13	.52	.15	.38	.32	2.02	4.58	6.06	35.23
1905	4.32	1.22	3.74	.41	1.66	1.22	.05	.31	1.67	3.57	2.04	4.81	25.12
1906	2.82	4.87	1.63	.75	1.52	.63	1.97	.00	1.49	2.87	10.54	7.24	35.71
1907	5.97	3.72	3.32	4.86	.37	.49	.10	.42	.66	.37	4.55	8.60	33.43
1908	3.60	2.15	4.47	1.45	.90	.40	.13	.90	.05	4.10	2.20	5.70	26.05
1909	4.19	4.50	1.20	.46	.27	Tr.	.45	Tr.	.45	1.75	11.75	1.86	26.88

THE DALLES, OREG.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1850	......	......	......	......	......	......	0.01	0.00	0.09	0.91	1.14	0.19	....
1851	3.81	1.70	1.79	......	......	......	......	......	......	......	......	......	....
1852	......	......	......	......	......	......				.25	2.75	8.01	....
1853	3.02	1.09	.27	1.29	0.62	0.00	.08	.61	1.41	.24	4.90	.95	14.48
1854	2.79	.73	.36	1.52	.00	.15	.00	.18	.84	1.91	1.41	2.50	12.39
1855	3.03	.63	1.87	.17	1.08	.24	.10	.00	.69	.15	1.44	2.24	12.90
1856	......	.54	.91	.79	......	......	......	......	......	......	3.50	10.79	....
1857	7.08	1.85	2.83	.00	.23	1.02	.58	.00	2.70	.25	5.38	7.42	29.34
1858	5.60	9.41	2.91	1.36	1.70	1.03	.00	.75	5.16	3.32	6.48	5.83	43.65
1859	5.33	6.00	6.07	2.00	1.27	.20	.06	.47	5.77	2.14	4.25	3.66	35.96
1860	5.30	2.00	1.33	.83	1.73	.59	1.83	.40	.35	.48	3.46	3.47	21.32
1861	2.68	3.26	1.59	1.46	1.34	2.08	.00	.14	.33	.75	6.97	8.25	28.85
1862	4.47	2.25	3.54	.20	2.61	1.03	.22	.07	.64	.43	.20	.63	16.29
1863	3.38	2.17	.62	.48	.65	.11	.88	.08	.30	.48	.74	4.11	14.00
1864	5.88	.22	......	......	.09	.36	......	......	.16	.27	1.44	2.95	....
1865	4.00	1.66	1.52	.06	.00	.08	.55	.57	.59	2.06	6.37	2.55	26.18
1866	6.35	2.83	5.56	......	......	......	......	......	......	......	......	......	....
1875	4.17	.31	2.13	.59	.81	1.65	.14	.12	.72	4.80	6.18	4.80	26.42
1876	2.76	1.39	2.20	1.09	.20	.34	.07	.02	.13	2.37	4.31	.46	15.34
1877	.78	1.68	3.66	1.21	1.03	.15	.48	.10	1.24	1.66	4.18	1.58	17.75
1878	2.96	2.32	1.99	.20	.26	.02	.08	.13	1.01	1.53	1.22	1.61	13.33
1879	1.43	6.32	3.15	1.34	2.94	.11	.31	.48	.79	.88	1.24	2.57	21.56
1880	2.04	1.33	.16	1.03	.94	.02	.02	.43	.08	.12	.69	6.75	13.01
1881	6.37	6.23	.38	1.29	.14	1.82	.11	.23	.26	2.62	.75	1.76	21.96
1882	1.49	2.92	.23	.53	.27	.60	.12	.72	.43	2.30	.75	5.14	15.50
1883	4.85	.61	2.32	1.21	.54	.01	.00	.00	.01	.46	2.19	1.77	13.97
1884	1.33	3.10	.74	1.33	.69	.93	.44	.12	.65	1.27	.82	7.04	18.46
1885	1.10	2.88	.14	.31	.81	1.01	.00	.00	.87	.28	1.78	2.64	11.82
1886	5.45	.53	.95	.30	.11	.07	.00	.02	.14	.70	.21	5.06	13.54
1887	4.01	1.13	.79	.46	.32	.67	.00	.18	.36	.15	1.06	3.01	12.14
1888	3.36	.41	.94	.05	.70	.92	.29	.00	.02	.95	1.34	2.71	11.69
1889	.51	.04	1.26	.42	.66	.29	Tr.	Tr.	.26	.90	1.27	2.00	7.61
1890	2.97	4.33	1.79	.24	.04	.27	.06	.04	.11	1.16	.00	1.19	12.20
1891	1.13	2.47	.53	.01	.32	.51	.24	.11	.13	1.14	1.39	4.14	12.12
1892	1.35	.68	.70	1.00	.67	.06	.27	Tr.	.14	.90	1.16	5.04	11.97
1893	.69	1.84	.96	1.69	.69	.06	.30	.00	1.21	4.40	4.36	1.77	17.97
1894	4.84	1.83	3.73	.64	.47	1.15	.10	Tr.	1.02	2.08	.51	1.65	18.02
1895	4.72	.47	.65	.24	.94	.00	.32	.05	1.14	.00	1.20	4.15	13.88
1896	3.45	.72	1.00	.95	.63	.10	Tr.	.28	.42	.60	5.87	2.74	16.76
1897	1.14	2.98	1.94	.23	.27	1.07	.24	.08	.54	.24	3.84	4.03	16.60
1898	.82	.98	.30	.11	.03	.90	.17	.02	.85	.13	2.13	1.14	7.58
1899	2.82	2.19	.94	1.05	.45	.20	.00	.86	.81	1.56	3.57	2.29	16.74
1900	1.90	1.94	1.62	.42	.03	.47	Tr.	.55	1.09	2.02	2.25	1.33	13.62
1901	3.46	4.15	.68	.09	.39	.20	Tr.	.16	1.84	.13	1.69	3.04	15.83
1902	1.61	3.79	.52	1.82	.63	.13	.26	.00	.36	.78	3.53	4.00	17.43
1903	2.87	.47	.56	.23	.05	2.11	.12	.11	.15	.10	4.44	.56	12.77
1904	1.52	4.50	3.10	.98	.09	.46	.40	.04	.61	1.44	1.01	1.79	15.94
1905	3.27	.51	.63	.18	.66	1.27	.19	.10	1.19	1.88	.84	1.07	11.79
1906	1.90	1.67	1.21	.11	.95	1.05	Tr.	.31	.35	.23	3.99	3.07	14.84
1907	3.92	3.08	1.30	1.67	.14	.42	.22	.74	.29	.29	2.22	5.50	20.06
1908	1.06	.77	1.50	.17	.92	.10	.36	.16	.03	1.42	.48	1.21	8.18
1909	4.06	1.41	.33	.08	.13	.13	.39	.00	1.05	.83	4.55	3.09	16.05

Precipitation at rainfall stations in and near area considered—Continued.

PINE HILL, NEAR LYLE, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1892	......	......	......	......	......	......	0.26	Tr.	0.36	1.14	2.43	6.11	....
1893	1.28	4.15	2.27	2.65	1.03	0.16	.25	......	2.57	7.03	6.03	3.84	....
1894	6.66	3.44	8.10	1.13	1.01	2.66	.24	Tr.	1.88	2.79	1.66	3.58	33.15
1895	7.21	.83	1.84	.69	2.25	Tr.	.40	.12	1.15	Tr.	1.66	9.27	25.42
1896	4.42	2.23	2.65	2.09	1.90	.23	Tr.	.62	.64	1.12	9.95	4.59	30.44
1897	2.16	4.97	3.61	.50	.52	.89	.28	.10	.92	.57	6.34	7.82	28.68
1898	1.89	2.69	.78	.33	.26	1.03	.25	.01	1.95	.54	4.34	2.13	16.20
1899	6.60	3.60	1.63	1.98	.64	.35	.00	1.24	.89	2.19	5.97	3.49	28.58
1900	3.07	3.41	2.50	.77	.29	.75	Tr.	.12	1.16	3.07	5.00	3.49	23.63
1901	6.72	7.31	1.90	.97	.35	.47	Tr.	.23	2.01	.18	3.84	4.10	28.08
1902	2.68	6.01	1.49	2.40	.83	.12	.30	Tr.	.69	.92	5.64	7.72	28.80
1903	4.52	1.27	1.36	.35	.11	2.00	.02	.21	.60	2.22	6.05	1.59	20.30
1904	2.63	6.90	4.96	1.40	.19	.71	.29	.38	.60	2.00	2.10	4.03	26.19
1905	3.88	.97	1.82	.23	1.00	1.23	Tr.	.32	1.26	2.68	1.71	3.10	18.20
1906	2.79	3.29	2.07	.33	1.28	1.96	Tr.	.06	1.11	1.14	7.24	5.07	26.34
1907	6.66	4.89	1.51	2.73	.56	.51	.33	.28	.49	.41	4.69	8.50	31.56
1908	1.64	1.46	2.02	.66	1.14	......	1.02	.65	.06	2.57	1.50	3.33	....
1909	6.03	3.08	.64	.23	.18	.62	.45	Tr.	1.07	1.72	11.59	......	25.61

GOLDENDALE, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1905	......	......	......	......	......	......	......	......	......	......	0.98	1.72	....
1906	(2.8)	2.35	1.70	0.18	1.05	1.00	0.10	0.02	0.68	0.40	4.54	3.36	18.2
1907	......	2.30	1.92	1.55	1.98	......	......	......	......	......	......	......	....
1908	......	.41	.68	.41	1.20	Tr.	.02	.40	......	1.90	......	......	....
1909	......	......	......	......	......	......	......	.00	.38	1.43	5.03	3.35	....

FORT SIMCOE, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1857	......	......	......	0.00	0.04	0.04	0.11	0.00	0.03	0.32	0.73	......	....
1858	2.11	4.54	1.06	.49	.54	.48	.03	1.04	.85	.83	.84	0.95	13.76
1859	2.50	1.19	1.38	.50	......	......	......	......	......	......	......	......	....
1891	3.17	2.48	1.05	.00	.44	.62	.19	.14	.06	.58	1.02	3.81	13.56
1892	2.60	.18	.62	.68	1.42	.08	.00	.00	.38	.78	2.25	3.35	12.34
1893	1.00	3.45	1.15	1.30	1.12	.11	.61	.00	.32	1.33	2.59	1.30	14.28
1894	1.45	1.28	2.18	.73	.96	.33	Tr.	.00	Tr.	1.55	.99	3.20	12.67
1895	6.15	.40	.60	.20	.67	Tr.	.12	.00	1.65	.00	.66	2.81	13.26
1896	3.12	1.43	1.24	.80	1.14	.17	.00	.54	.12	.03	6.89	2.30	17.78
1897	.78	1.76	.69	.09	.32	1.15	Tr.	.00	.48	1.39	5.47	4.75	16.88
1898	.40	1.54	Tr.	.02	.18	.35	.00	.26	.48	Tr.	1.49	1.50	6.22
1899	3.71	.92	.22	.25	.64	.13	.00	.62	.34	1.25	4.03	......	....
1905	......	......	......	......	......	1.82	Tr.	.36	.40	1.66	.70	1.15	....
1906	1.61	2.07	1.39	.05	1.56	.69	Tr.	Tr.	.00	.22	5.41	3.26	....
1907	3.86	1.85	2.03	.81	.46	2.05	.20	.20	......	......	......	......	....
1908	......	.03	.52	.35	1.27	.00	.12	.17	.00	.98	......	.43	....
1909	5.45	2.12	.59	.10	.01	.45	.66	.00	.40	.51	5.71	2.12	18.12

PLEASANT GROVE, NEAR ELLENSBURG, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1884	3.40	1.98	0.62	1.26	0.17	0.47	1.16	Tr.	0.33	0.71	0.16	2.97	....
1885	.90	.44	Tr.	.03	1.18	.57	.01	Tr.	.39	.06	1.69	1.55	....
1886	2.62	.30	.24	.98	......	......	......	......	......	......	......	......	....
1892	.05	.27	.52	.62	1.84	.16	.35	0.00	.13	.50	1.32	......	....
1893	.19	1.21	.84	2.17	1.38	......	.47	.00	1.11	.71	1.65	.33	....
1894	1.21	.81	1.03	67	.46	.53	.00	.00	.13	.94	.99	1.04	7.81
1895	2.37	.25	.02	.18	.62	Tr.	Tr.	Tr.	.98	.00	.20	2.25	6.87
1896	1.89	.58	.71	.94	1.26	.17	.00	......	.63	.22	3.45	1.36	....
1897	1.62	1.93	.15	.08	.42	.80	.17	......	.19	.47	3.92	2.93	....
1898	.36	.47	.12	.03	.12	.73	.05	.29	.22	.22	.56	.54	3.71
1899	2.44	1.68	.18	.10	.39	.19	.05	.99	.40	.65	2.27	.58	9.92
1900	.97	.70	.91	.50	.42	.05	.10	.23	1.40	.98	1.27	1.14	8.67
1901	1.97	1.74	.31	.32	.88	.29	.00	.03	.52	.27	2.20	.89	9.42
1902	1.26	3.20	.43	1.79	.66	.05	.51	.00	.17	.74	1.53	3.24	13.58
1903	.67	.28	.27	.51	.10	1.28	.05	.30	.69	.60	3.59	.41	8.75
1904	.56	2.37	2.32	.73	Tr.	.63	.40	.28	.20	.19	1.25	1.44	10.37
1905	1.81	.36	.41	.16	.54	4.54	.15	.34	.38	1.42	.47	.77	11.35
1906	1.08	1.20	1.02	.00	1.23	.87	.09	.33	.27	.20	3.20	2.81	12.30
1907	2.09	1.33	.62	.30	.38	1.37	.27	.40	1.20	.29	.66	2.12	11.03
1908	.82	.79	.61	.18	1.42	.10	1.67	.04	.04	1.31	.70	.42	8.10
1909	2.31	.86	.36	Tr.	.26	.41	.89	.00	.56	.58	2.71	1.08	10.02

Precipitation at rainfall stations in and near area considered—Continued.

YALE, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1906	......	......	......	2.16	......	......	0.00	Tr.	9.55	12.53	22.66	19.37	......
1907	12.14	9.84	7.14	6.44	2.54	2.59	1.16	2.18	3.52	2.63	15.49	20.85	87.12
1908	10.86	8.56	18.50	7.28	7.51	2.77	.36	3.92	.95	10.45	7.15	14.45	92.76
1909	14.69	16.62	6.16	3.82	4.86	1.20	3.34	.23	......	6.55	31.02	6.57	......

OLYMPIA, WASH.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1877	......	......	......	......	......	......	0.24	1.64	6.64	7.00	19.88	11.73	......
1878	9.82	14.20	7.90	1.21	1.36	0.24	.98	.32	4.87	4.32	11.09	7.03	63.34
1879	5.96	15.59	14.44	2.10	4.72	.44	2.62	2.11	2.38	6.17	5.49	11.42	73.44
1880	19.69	5.16	5.57	2.47	4.10	1.44	.52	.22	1.05	2.83	3.06	16.66	62.77
1881	8.90	16.28	4.03	4.93	1.54	1.93	.98	.71	2.47	8.18	6.75	8.86	65.56
1882	6.11	9.60	2.24	4.57	2.30	1.00	.67	.81	1.24	6.96	5.77	10.32	51.59
1883	5.68	3.18	2.99	10.78	2.55	.21	Tr.	.01	2.24	3.73	5.10	5.14	41.61
1884	5.47	4.17	1.57	3.60	1.46	3.20	.60	.96	3.06	4.30	1.37	5.82	35.58
1885	6.23	7.67	.50	.39	2.84	.79	1.10	.00	3.69	2.84	10.18	5.72	41.95
1886	9.47	3.39	4.07	4.04	1.90	1.26	1.15	.42	3.17	4.15	1.73	13.38	48.13
1887	9.83	4.28	10.60	3.94	5.66	1.01	.74	.18	3.34	1.51	4.94	15.75	61.78
1888	11.38	2.71	5.96	1.72	.21	......	......	......	......	......	......	......	......
1891	5.15	4.80	3.04	4.89	1.95	3.56	.23	1.36	3.65	5.66	10.83	13.61	58.73
1892	4.26	1.98	2.53	5.45	2.22	1.17	.88	.68	3.49	3.25	12.74	10.76	49.41
1893	2.21	8.51	5.71	10.18	3.58	2.43	.19	.47	2.21	5.59	12.86	7.68	61.62
1894	10.14	7.37	8.89	3.75	1.56	2.40	.37	.13	3.66	7.17	8.37	4.76	58.57
1895	9.85	2.77	4.47	4.46	5.93	.05	.35	Tr.	1.56	......	......	14.96	......
1896	10.86	6.53	3.59	4.06	3.98	1.31	.00	.83	2.30	3.88	13.98	14.14	65.46
1897	5.81	6.58	6.29	1.28	1.02	1.49	.89	.36	2.62	1.55	13.01	17.60	58.50
1898	3.96	9.47	1.98	2.10	1.96	2.68	.28	.50	4.61	2.51	6.84	5.33	42.22
1899	12.60	5.99	3.37	5.63	3.39	1.23	.02	1.37	1.97	4.69	14.63	7.33	62.22
1900	5.96	5.37	6.89	1.84	5.34	3.75	.28	.68	1.86	8.26	6.11	10.03	56.37
1901	8.57	7.16	4.25	7.24	3.06	1.04	.49	.12	2.69	2.94	11.52	6.01	55.09
1902	7.15	11.68	6.78	5.17	2.43	.74	1.76	.24	2.71	2.98	15.09	14.04	70.77
1903	11.27	2.80	7.77	3.92	2.16	3.10	.46	1.18	3.64	4.06	11.72	4.80	56.88
1904	7.88	12.17	9.30	3.64	.69	1.68	1.79	.43	.21	2.33	13.23	8.32	61.67
1905	6.14	4.17	5.12	.71	2.85	3.18	.66	.30	3.33	7.36	3.73	8.88	46.43
1906	8.57	5.16	1.41	1.41	4.77	3.74	.30	.02	5.24	6.33	16.43	10.48	63.86
1907	7.22	5.43	3.24	3.79	.97	1.50	1.22	1.03	3.79	.99	10.47	12.03	51.68
1908	6.63	8.00	8.38	4.75	2.68	.21	.41	1.28	.19	4.26	6.75	9.84	53.20
1909	10.79	10.79	3.02	.77	2.02	.77	1.22	.21	1.14	4.27	19.44	6.30	60.74

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