Waterpower Resources in Trask River Basin Oregon

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1610-B

Waterpower Resources in Trask River Basin Oregon

By L. L. YOUNG

With sections on GEOLOGY OF SITES

By R. G. WAYLAND *and* D.. L. GASKILL

WATERPOWER RESOURCES OF THE UNITED STATES

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1610-B

A discussion of potential power and of development possibilities including discussions of geology and out-of-basin diversion

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WATERPOWER RESOURCES IN TRASK RIVER BASIN, OREGON

By L. L. Young

ABSTRACT

The Trask River originates in the Oregon Coast Range about 35 miles west of Portland and empties into Tillamook Bay at Tillamook, Oreg. The drainage basin is mountainous and sparsely settled. The runoff is derived principally from rainfall that occurs in a seasonal pattern, which results in 77 percent of the total annual discharge occurring in a 5-month period during the winter and early spring months. The available storage sites are not adequate to regulate completely the high winter flows or store the water for summer use.

The potential power is estimated by considering an illustrative plan including five sites. Powerplants at these sites could have generated 14,000 kilowatts of power continuously during the period 1938–52, or a minimum of 41,000 kilowatts from November 1 to March 31 each year during the period. At average discharge and total head the potential power of these sites would be 34,000 kilowatts. A pumped-storage addition to one of the sites could produced a peaking potential of 68,000 kilowatts.

The Trask River could be diverted to the Tualatin River basin for municipal purposes and irrigation and still permit some power production. About one-third of the water now passing the gage near Tillamook could be diverted through or pumped over a ridge between the Middle Fork North Fork Trask River and the Tualatin River. The potential power of a diversion by gravity at an altitude of 800 feet is about 3,000 kilowatts continuous. By pumping the water 700 feet into a higher level canal and diverting it over the divide at an altitude of 1,500 feet, a considerable block of peaking power could be made available.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to evaluate the waterpower potential of the Trask River basin. The basic data for the report are topographic quadrangles covering the basin, a special map of the river, large-scale damsite maps, geologic reports on the damsites, and streamflow records. The above data were all gathered by the Geological Survey. In addition to these, use was made of the precipitation and evaporation records of the U.S. Weather Bureau and of the isohyetal map prepared by the Corps of Engineers, U.S. Army, for western Oregon.

Up to the present there has been little thought given to the possibilities of developing power on the Trask River. However, many of the more economical projects of the Columbia River basin have now received rather extensive studies and attention will shift to other sites. As the Columbia basin is developed the need for power to firm the system will also become greater. The Trask River could make a modest contribution in this respect. The Tillamook County Public Utilities District has filed an application with the Federal Power Commission (Federal Power Project No. 2274) for a power project on the Trask River and has also considered development of waterpower on the Nehalem River.

Any power development will require adequate provision for fish passage, road relocation, and reimbursement to land owners for damages resulting from inundation. Opposition to power development is lessened by improved methods of getting fish over dams and otherwise protecting them from harm by project works, added recreational benefits afforded by the new lakes, construction of new and better roads in the vicinity of power projects, and more adequate compensation to dislodged property owners.

The potential power of the river is estimated by considering a series of possible developments entirely within the basin, and an alternative plan is discussed in which its water could be diverted to the Tualatin River by gravity or by pumping.

PREVIOUS INVESTIGATIONS

Jones (1924) and Helland (1953), Engineers of the U.S. Geological Survey, have made investigations that included the Trask River.

The engineering firm of Cornell, Howland, Hayes, and Merryfield, of Corvallis, Oreg., recently prepared a report for the Tillamook County Public Utilities District entitled "Report of Reconnaissance Study of Hydroelectric Development of Trask River, June 1959."

MAPS RELATING TO THE AREA

A map of the Trask River was made and published by the U.S. Geological Survey (1955). This map was supplemented by the mapping of four damsites, resulting maps of which are in preparation for publication. Geologic examinations have been made of the following damsites and the results included in this report. The first four were examined by R. G. Wayland and the fifth by D. L. Gaskill.

Site	*Stream*	*Location*
Clear Creek	North Fork	Sec. 24, T. 1 S., R. 7 W.
Keyhole	do	Sec. 27, T. 1 S., R. 7 W.
Bark Shanty	do	Sec. 29, T. 1 S., R. 7 W.
Hollywood	South Fork	Sec. 6, T. 2 S., R. 7 W.
Ginger Peak	Trask River	Sec. 29, T. 1 S., R. 8 W.

The Blaine, Enright, Fairdale, Nehalem, Tillamook, and Timber topographic quadrangles, completed in 1955, scale 1 : 62,500, cover the entire basin.

GENERAL DESCRIPTION OF THE BASIN

PHYSICAL CHARACTERISTICS

The Trask River drains an area of about 170 square miles of mountainous timberland in northwestern Oregon. Most of the basin is within Tillamook County; minor portions are in Washington and Yamhill Counties. It heads in the Oregon Coast Range about 35 air miles west of Portland in mountains more than 2,000 feet high. Its course is almost west to its mouth at Tillamook on Tillamook Bay. It is one of five rivers entering the bay. The name is for an early settler and leader in Tillamook County, Elbridge Trask. The mouth of the bay is about 5 miles northwest of Tillamook and about 65 air miles west of Portland. The basin in outlined by a dashed line on figure 1.

The Trask River basin is bounded on the north by the Wilson River basin, on the east by the Tualatin and Yamhill River basins, on the south by the Nestucca River basin, and on the southwest by the Tillamook River basin.

The Trask and Wilson Rivers flow in the large Tillamook Valley for about 5 miles. The divide between them rises abruptly there to an altitude of 2,000 feet. On its eastern end this divide is above 3,000 feet. Hembre Ridge is 3,409 feet, an unnamed peak is 3,535 feet, and Saddle Mountain is 3,461 feet in altitude. The Tualatin and Yamhill basins are separated from the Trask by a north-south ridge, having peaks of 3,170, 2,941, 2,371, 3,423, and 2,878 feet in altitude. The lowest pass on this ridge is about 1,550 feet in altitude. The ridge dividing Trask and Nestucca River drainage is almost as high. Its peaks are 2,913, 2,700, 2,500, and 3,012 feet in altitude; the last is that of Grindstone Mountain. The highest peak on the divide between the Trask and Tillamook Rivers is Edwards Butte, 3,168 feet in altitude. Elevations on this ridge decrease rapidly from that point to the Tillamook Valley.

ECONOMICS

Tillamook is the only town within the basin. It had an estimated population of 4,261 (Oregon State Board of Census, 1960) July 1,

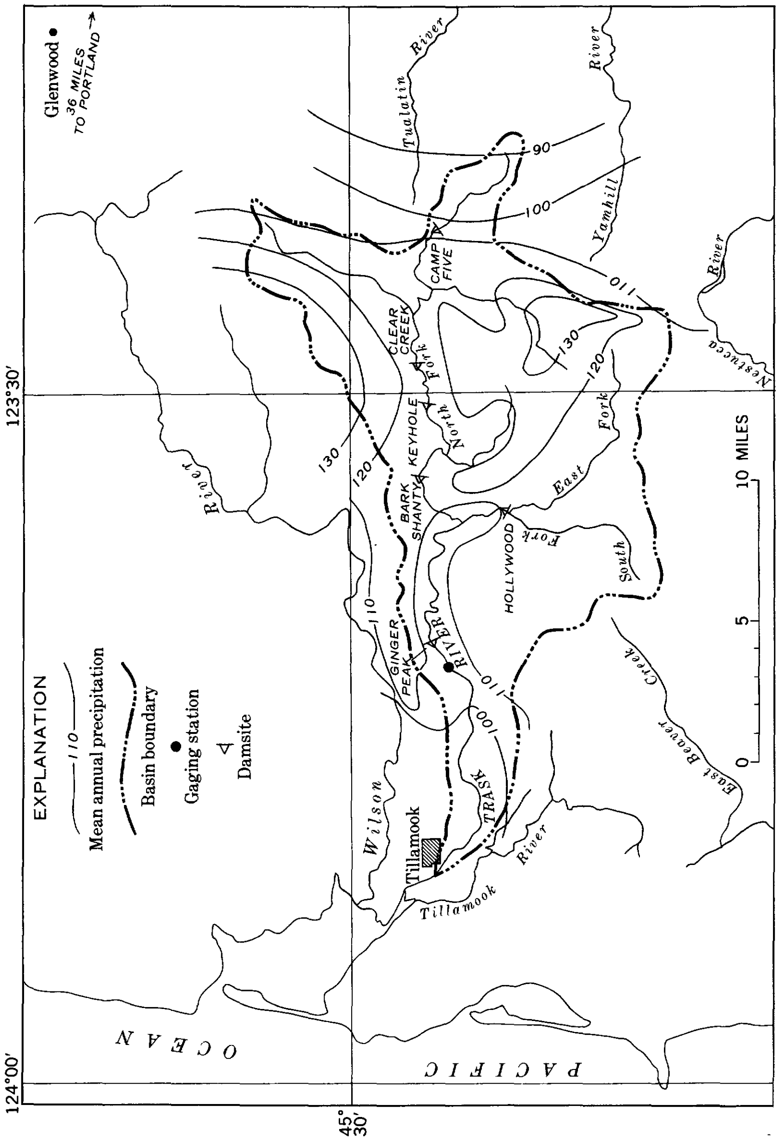

FIGURE 1.—Map of Trask River basin, Oregon, showing provisional isohyets and damsites.

1960, which was an increase of 15.6 percent over the 1950 population. There has been an increase of only 2 percent since 1950 in the population of Tillamook County. The 1960 population was 18,969, whereas in 1950 it was 18,606. Although most of the county is outside the basin, waterpower developed on the Trask River would benefit the whole county.

Captain Robert Gray sailed the *Washington* into Tillamook Bay in 1778 (Orcutt, 1951) 4 years before his discovery of the Columbia. Clark of Lewis and Clark visited the Tillamook coastal areas in 1806 (Orcutt, 1951). The first white settler, Joe Champion, arrived in 1851; and although he stayed only for the one summer season, others came and white settlement has been continuous.

For a great many years the only transportation link with civilization was the sea. The Tillamook Bay bar was exceptionally treacherous, however, and although some ships were built at Tillamook, transportation difficulties retarded economic growth.

The Trask River toll road between Yamhill in the Willamette Valley and Tillamook was established in 1871. This was the first wagon road to cross the Coast Range within Tillamook County. Mail and freight were carried over the road until 1911 when the railroad now owned by Southern Pacific was completed between Portland and Tillamook.

A surfaced highway now follows the river from Tillamook to the Trask guard station at the junction of the North and South Forks. Secondary roads cover the remaining reaches of stream and branch into the mountains to afford access to timber and for fire protection. There is no highway between Portland and the coast within the Trask basin. Oregon Route 6 crosses Tillamook valley and is within the basin for about 4 miles. U.S. Highway 101 along the Oregon coast passes through Tillamook.

The large valley around Tillamook Bay furnishes excellent farm and pasture land, and the early settlers were soon raising cattle and milking cows. The cattle were driven to market, and the dairy products were shipped as best they could be. Cheese became an important product because it is the least perishable of the conventional dairy products. The cheese industry makes a very substantial contribution to the present economy of the area.

The pioneers found the Trask basin covered by a dense forest of cedar, hemlock, fir, and spruce. Active exploitation of these abundant timber resources together with those of other basins brought a great number of people to the area. The period of growth began about 1890 and ended in 1933, the date of the great Tillamook burn. The burn devastated 140 of the 170 square-mile Trask River basin.

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Lumbering has been and probably will continue to be one of the principal industries. However, there is no longer sufficient timber to maintain former rates of exploitation. The burn caused immense tax losses to the county and a large part of the burnt area has been taken over by the State and Federal governments for reseeding. Subsequent burns in 1939 and 1945 which covered virtually the same area, have removed all possibilities of reforestation by natural reseeding. Reseeding by other methods is being done by land owners, State and Federal agencies, and citizen organizations.

Tourists, vacationers, and fishermen come to the area in ever-increasing numbers from year to year, and the basin has good possibilities for additional development of outdoor recreational activities. The river is fished for trout, steelhead, and salmon. If dams are constructed on the river, facilities for fish passage should be included. The new reservoirs would enhance the present recreational values.

WATER SUPPLY

PRECIPITATION

The U.S. Weather Bureau has records of precipitation at Tillamook for 42 years. Stations of the Bureau outside the basin at Seaside, Astoria, and Vernonia maintain precipitation records, which are indices of precipitation for the general area. The Corps of Engineers, U.S. Army, has prepared an isohyetal map of western Oregon that includes the Trask basin. An isohyetal map for the Trask basin was prepared by adapting data from the above sources to conform closely to the topography as shown on 1:62,500 scale quadrangles. The new map was used in estimating runoff by measuring areas between the several isohyets for the various drainage basin units. The approximate isohyets are shown in figure 1. The rainfall averages determined range from a minimum of about 90 inches on the coast and in the extreme eastern part of the basin to more than 130 inches on the higher mountain peaks. Throughout the basin precipitation has the usual coastal distribution, heavy in the fall and winter and lighter in the spring and summer.

RUNOFF

The average discharge of the Trask River from 1931 to 1955 was 982 cfs at a station 6 miles east of Tillamook, where the drainage area is 143 square miles. This is equivalent to 710,900 acre-feet annually.

A detailed analysis was made of the records for water years 1938 through 1952. For that period average discharge was 942 cfs, 40 cfs less than for the entire period of records. The lower yield 15-year period 1938 through 1952 is used in the computations for this report.

The difference between the determined precipitation and runoff depths for the drainage area above the gage was about 26 inches. Runoff amounts were determined for the subareas by subtracting 26 inches from annual precipitation depths determined in the previous section. The loss probably varies throughout the basin, but lack of discharge measurements makes refinement impractical.

Table 1 shows the rainfall and runoff estimates for the river at the damsites studied.

TABLE 1.—*Area and estimated precipitation and runoff at selected sites in Trask River basin*

Damsite, gage or basin	Drainage area (sq mi)	Estimated precipitation (inches)	Estimated average discharge (cfs per sq mi)	Estimated annual runoff [1] (acre-feet)	Percent of runoff at gage
Camp Five [2]	9	98	5. 36	35, 000	5. 1
Clear Creek	53	117	6. 69	257, 000	37. 7
Keyhole	57	117	6. 71	277, 000	40. 6
Bark Shanty	75	118	6. 77	368, 000	54. 0
Hollywood	49	115	6. 56	233, 000	34. 2
Ginger Peak	140	116	6. 63	672, 000	98. 5
Gaging station	143	116	[3] 6. 59	[3] 682, 000	100. 0
Mouth	170	114	6. 48	798, 000	117. 0

[1] Allows a difference of 26 in. between precipitation and runoff.
[2] Possible site for diversion to Tualatin River by gravity.
[3] Average for 1938–52.

A flow duration analysis (fig. 2) for the water years 1938 through 1952 shows Q95,[1] 79 cfs (0.55 cfs per sq mi); Q50, 490 cfs (3.43 cfs per sq mi); and Qmean, 942 cfs (6.59 cfs per sq mi). There is a pronounced seasonal variation in runoff corresponding to the seasonal variation in precipitation. The runoff is greatest during the period November through March and least during the period of July through September. The average monthly discharge, in cubic feet per second and the percentages of the average annual runoff for the Trask River at the gage are shown below.

Month	cubic feet per second	Percent of average annual	Month	cubic feet per second	Percent of average annual
October	489	4. 40	April	865	7. 54
November	1532	13. 36	May	521	4. 69
December	2148	19. 36	June	283	2. 47
January	1640	15. 13	July	160	1. 44
February	2069	16. 98	August	102	. 91
March	1399	12. 60	September	129	1. 12

[1] Discharge in cubic feet per second. Q95 = discharge equaled or exceeded 95% of the time.

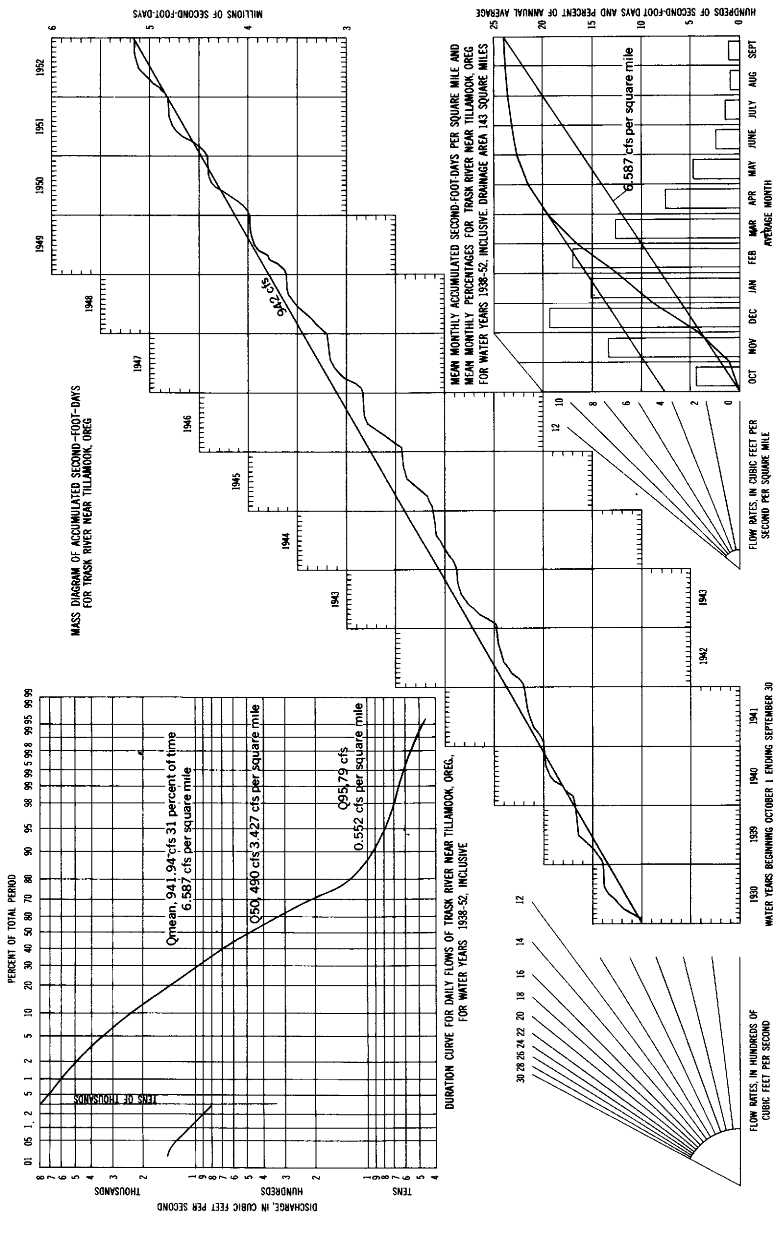

FIGURE 2.—Mass diagram and flow-duration curves, Trask River, Oreg.

The runoff pattern shown by this tabulation and by figure 2, which shows accumulated flows and flow duration, was used throughout the basin.

REGULATION AND STORAGE SITES

The distribution of annual runoff is such that reservoirs are necessary to regulate the flow by reducing the high winter runoff and increasing low summer flows. There are no reservoirs in the basin, but there are several sites topographically suitable for reservoirs. Costs of land acquisition and forest road relocations should be relatively moderate. The necessity for fish protection might tend to limit the development of reservoirs. It should be noted that rather high and massive dams will be required to create reservoirs with only relatively small storage capacities.

To find the storage requirements of the sites, the estimated total water yield at each damsite was distributed over the 15-year period studied by adapting the mass diagram and accumulated second-foot-day table for the gage to the particular site under consideration. In other words, the gaging-station records provide the pattern for distributing the runoff estimates made in the previous section throughout the year.

Estimates of evaporation losses were made from Weather Bureau records of evaporation rates in Oregon. An annual loss of 30 inches, of which 27 inches occurs between April 1 and October 31 and 3 inches between November 1 and March 31, was used.

The estimated monthly evaporation losses for the Trask River basin are as follows:

Month	Evaporation (inches)	Month	Evaporation (inches)
January	0.3	July	5.6
February	.5	August	5.1
March	.8	September	3.8
April	2.5	October	1.5
May	4.0	November	1.0
June	4.5	December	.4

The surface area of the reservoirs when they contained one-half their usable capacities was used to determine the evaporation loss for yearly, winter, and summer periods. An additional allowance equal to 5 cfs plus one-fifth the annual evaporation loss rate was made for leakage and other unmeasurable losses. The total loss was rounded to the nearest 5 cfs. Using this method, all losses are rounded to 10 cfs except those for Ginger Peak, which are 15 cfs for the annual and summer periods and 10 cfs for the winter months. During reservoir-filling periods or during times when diversions from the basin were being made, a conservation release equal to the flow at the sites 95 percent of the time rounded to the nearest 5 cfs or 50 cfs, whichever is smaller, has been allowed.

Five reservoir sites are considered in this report; three on the North Fork Trask River, one on the South Fork Trask River, and one on the Trask River. Their locations on the river are shown in figures 1 and 3.

GEOLOGY

By R. G. Wayland

All damsites described in this report are in a series of volcanic rocks of Eocene age described by Warren, Norbisrath and Grivetti (1945, 1946) as the Tillamook volcanic series. Recent geologic mapping on a regional scale (Wells and Peck, 1961) has resulted in a tentative differentiation within the Tillamook series in the Trask River area. West of the forks at the Trask Guard Station, the dark-greenish-gray aphanitic to porphyritic basalt flows and flow breccias described here in the contribution by Gaskill on the Ginger Peak damsite would be an older series to be correlated with the Siletz River volcanic series of early Eocene age (Snavely and Baldwin, 1948; Baldwin, 1959). East of the forks, the upper part of the Tillamook series consists of some of the same type of basaltic rocks; but it also includes andesitic flows (or sills?) and interbedded dark-gray tuffaceous shale, siltstone, and thin-bedded sandstone. This upper part of the Tillamook series is now tentatively correlated with the Nestucca Formation (Snavely and Vokes, 1949) of late Eocene age, and may also include equivalents of the Yamhill Formation (Baldwin and others, 1955), of Eocene age.

The petrographic description by Snavely and Baldwin (1948) for the Siletz River volcanic series farther south seems to describe the basaltic flows and flow breccias of the upper Trask River so well that it is abstracted here:

> The predominant rock in the flows is a dark-greenish-gray aphanitic to porphyritic basalt. Rectangular phenocrysts of plagioclase and equant to rounded phenocrysts of augite are visible in hand samples. Vesicular and amygdaloidal basalts are common, with the amygdules composed of radiating zeolites and calcite. Unaltered basalt is rare, and locally chloritization is so advanced that a green-stone has resulted. Typical pillow structure is common through the series, individual pillows averaging 3 feet in diameter. Columnar joints which radiate from the center of the essentially ellipsoidal pillows can be seen in most exposures. Flow breccia is not rare, and is probably the result of autobrecciation by steam explosion which accompanies submarine extrusion. Sporadic pillows are found in many of the flow breccias, testifying to their subaqueous origin.

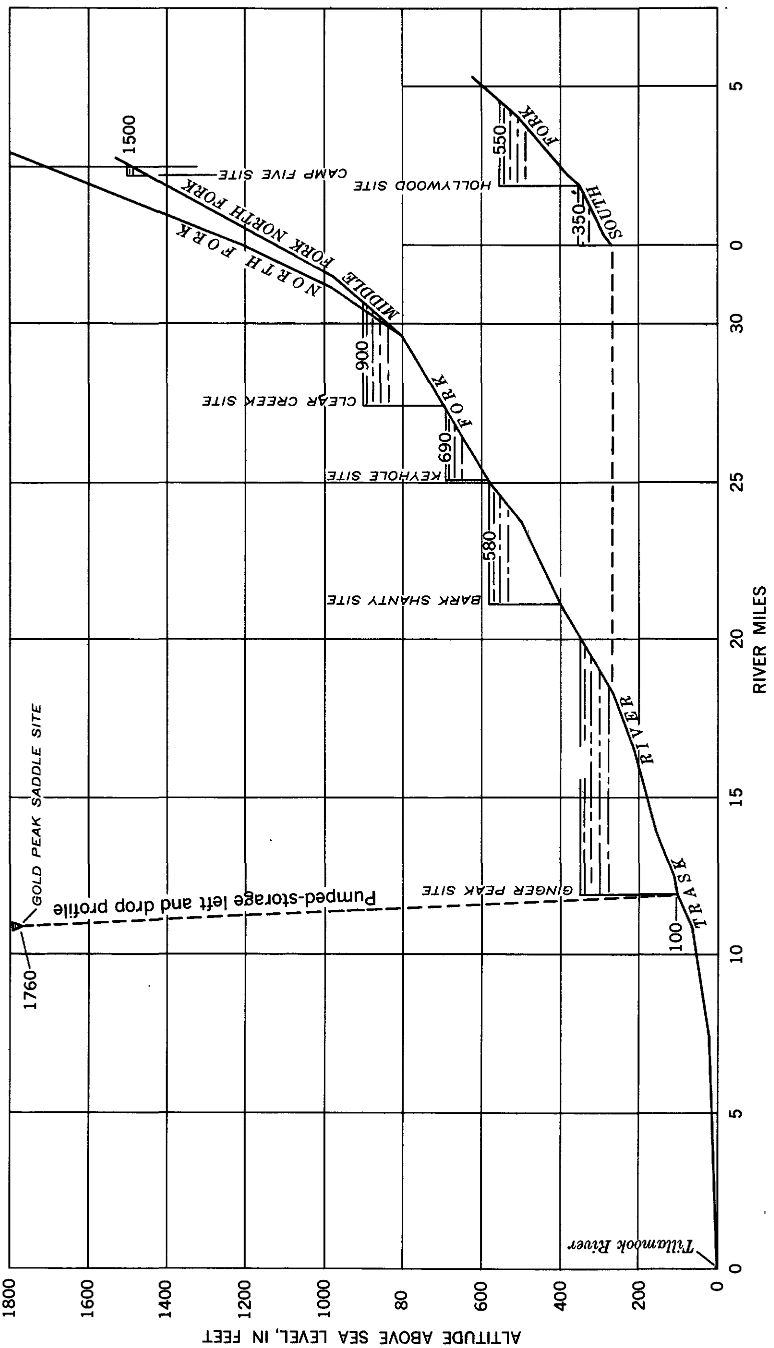

FIGURE 3.—Profile of Trask River, Oreg., showing power and storage sites.

Microscopic study shows that the basalt is holocrystalline to hemicrystalline with porphyritic to glomeroporphyritic and vesicular textures. The groundmass varies from trachytic to intersertal. Phenocrysts of plagioclase (* * * labradorite) and augite are set in a groundmass of plagioclase laths * * *, granules of augite and magnetite, and volcanic glass. The phenocrysts and laths of plagioclase constitute about 50 percent of the total rock. * * * Augite phenocrysts and granules constitute 2–25 percent of the basalt with only 1–5 percent occurring as phenocrysts. Magnetite is an important constituent of the groundmass, forming 5–15 percent of the sections. Glass in the groundmass of the basalt forms 15–65 percent of the sections, averaging 30 percent. In several of the basalts the glass was partly devitrified and altered to palagonite.

A hydrothermal type of alteration * * * has developed abundant secondary minerals. Zeolitic minerals (stilbite, mordenite, and natrolite) are common in most of the basalt and breccia, making up as much as 30 percent of some sections. Calcite is abundant, filling vesicules and irregular fractures, and chloritic minerals are present in most of the sections studied. Other secondary products identified are palagonite, epidote, opal, analcite, limonite, and serpentine.

The writer has also tentatively identified the mineral leonhardite, a variety of laumontite, among zeolites collected at the Clear Creek site. The identification was made in refractive oils, and the laumontite crystal structure was verified by Mary E. Mrose by X-ray (written communication, 1960). The augite phenocrysts appear from optical properties in oils to be the variety called pigeonite.

As pointed out by Baldwin (1947), the basaltic flow breccia when newly exposed is dark green to nearly black. Upon exposure to the atmosphere, the rock crumbles, becomes brownish buff in color, and the palagonite (altered basaltic glass) breaks down to yellow clay.

Snavely and Baldwin (1948) describe the tuffs and interbedded sediments as follows:

The pyroclastic rocks range from fine tuff to agglomerate. * * * In some exposures the fine tuff contains sporadic blocks of dense basalt. Microscopically the tuff contains altered basaltic fragments, calcic feldspar, and augite crystals set in a groundmass of opal, palagonite, calcite, and chloritic minerals. The interbedded sedimentary rocks are predominant water-laid tuff and tuffaceous siltstone and sandstone, with subordinate amounts of basaltic grits, sandstone, and conglomerate. Some of the finer tuff closely resembles a well indurated carbonaceous siltstone. These tuffaceous sediments weather to spheroidal masses, each concentric shell being coated with a film of manganese dioxide.

Observations by this writer were largely confined to the immediate localities of the Hollywood, Bark Shanty, Keyhole, and Clear Creek damsites. However, it was noted that the flows exposed along the North Fork near its mouth appear in general to dip gently southwestward, the dip direction ranging from westerly to southerly. Three miles northeast along the North Fork, in the vicinity of the Bark Shanty damsite, the rocks in the lower half of the valley section consist of interbedded flows, tuffs, dark tuffaceous shales, siltstones, and sandstones, all dipping westward about 10°. The westward dip appears to persist for 2 more miles as one ascends the North Fork.

In the vicinity of the Keyhole damsite, the exposed rocks in the gorge are massive basaltic breccias similar to and perhaps belonging to the older series, equivalent with the Siletz River volcanic series. The younger, interbedded series makes up the higher valley walls above the "Keyhole," and where it is exposed along the road northeast of the Keyhole in NE¼ sec. 27, T. 1 S., R. 7 W., it is considerably folded and disturbed. This disturbed zone may include drag folding related to a fault of northeast trend shown on a new unpublished regional geologic map of Oregon west of the 121st meridian (Wells and Peck, written communication, 1960). This fault zone apparently follows the river valley through the west side of sec. 27 and then climbs the valley wall just north of the "Keyhole," passing out of the section at the northeast corner. The southeast side of this fault would be the upthrown side, bringing the older volcanic series up to where the river is now intrenching.

The principal anticlinal axis of the area appears to cross the valley in about the center of sec. 26. A mile farther east, at the Clear Creek site, the regional dip seems to be eastward at about 10°. The lower part of the valley here is entirely within massive flow breccias, the same flows as exposed at the Keyhole damsite.

The general westward dip observed along the North Fork between the Trask Guard Station and the Keyhole site suggests that the shales and sandstones in or near the valley bottom in this area are stratigraphically below the basaltic breccias and flows west of the guard station, or that there may be either a fault or monoclinal fold near the guard station, as yet unrecognized. However, as Baldwin (1947) and others have pointed out, in places in western Oregon there is a major unconformity which separates the beds of late Eocene age from those of middle Eocene age. The western margin of the upper Eocene overlap (Nestucca Formation) may be in the general vicinity of the guard station.

Lineaments observable on the topographic maps and aerial photographs suggest that the principal near-vertical jointing along the North Fork west of the Keyhole site strikes about N. 20° W. and dips steeply westward. Other less prominent jointing is suggested at N. 40° E. with a steep northwesterly dip and N. 55° W. with a steep southwesterly dip. East of the Keyhole site, the topography suggests that the most prominent jointing is vertical and strikes N. 10°–20° W.; other near-vertical jointing appears to strike approximately N. 60° W., N. 85° E., and N. 50° E. Along the South Fork about 2 miles south of the guard station near the Hollywood damsite, the most

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prominent topographic expression of near-vertical jointing is N. 20° E., probably with a steep westerly dip. Other lineaments in that area are N. 20° W. and N. 80° W.

In the following sections the geology of the Clear Creek, Keyhole, Bark Shanty, and Hollywood reservoir sites is by R. G. Wayland; that of the Ginger Peak site is by D. L. Gaskill.

CLEAR CREEK RESERVOIR SITE

DESCRIPTION OF SITE

The damsite is on the North Fork Trask River in sec. 24, T. 1 S., R. 7 W., about three-fourths of a mile downstream from the confluence of Clear Creek and the North Fork. The topography of this site is shown on plate 1. Drainage area at the site is 53 square miles, and the water surface altitude is 690 feet. A reservoir with a maximum water surface altitude of 900 feet would be 2½ miles long and would have areas and capacities as listed below.

Area and capacity of Clear Creek reservoir site

Altitude (feet)	Area (acres)	Capacity (acre-feet)	Altitude (feet)	Area (acres)	Capacity (acre-feet)
690	0	0	840	260	15, 100
720	20	300	880	420	28, 700
760	80	2, 300	920	520	47, 500
800	150	6, 900	960	740	72, 700

By comparison with the gaging station about 396,000 acre-feet of storage would be needed for controlling the average estimated flow of 355 cfs. It is obviously not feasible to effect a high degree of control at this site. By using 35,000 acre-feet for regulation, a discharge of not less that 130 cfs after losses could have been maintained during the period 1938–1952. The reservoir could have been operated to produce a minimum discharge of 460 cfs from November 1 to March 31 each year during the period if the summer releases were restricted to 30 cfs (Q95) when that was necessary for refilling in dry summers.

A possible use of the Clear Creek reservoir would be in connection with diversion to the Tualatin River basin. A tunnel 5.4 miles long could connect the 800-foot altitudes in both basins. The capacity of the reservoir above the 800-foot level would be 30,000 acre-feet.

In computing the divertible water in the above example a minimum discharge of 30 cfs (Q95) was left in the river for conservation purposes and losses were subtracted as explained.

GEOLOGY

At the Clear Creek damsite, plate 1, the North Fork of the Trask River flows in an inner gorge 400 to 500 feet deep cut in basaltic flows and flow breccias of probable early to middle Eocene age. Flow breccias predominate, and the individual flows are much the same in appearance and composition. Flow contacts are tight and irregular. One distinctive flow of porphyritic basalt (loc. 1) is readily observable along the left abutment about 150 feet above river level; it appears to dip to the east about 10°. Other flow contacts cannot be traced easily because of limited exposures. No interbedded tuffs or sediments were observed in the probable abutment areas. Some amygdaloidal basalt is present in most talus and in many outcrops, as at localities 2 and 3.

The exposed basaltic rocks are only slightly decomposed by weathering. Hydrothermal alteration includes some minor calcite and zeolite veinlets, amygdules, and breccia filling; the original basaltic glass is largely altered to palagonite, and in some areas there is considerable chloritization. Despite this alteration the rocks seem relatively impervious, moderately strong, and competent for well-spread foundation loads.

At locality 4 a slickensided shear zone with right-lateral movement strikes N. 70° E. and dips about 80° N. The zone was traced up the hillside into a chloritized area in the right abutment. No other evidence of faulting was noted. Jointing as observed in outcrops is widespaced, tight, irregular, and inconspicuous. At locality 2, the minor joints observed in the eastward dipping flows were random and inconsistent in strike and dip. Topographic expression within a 2-mile radius at the site suggests, however, some joint control of drainage, the joints striking approximately N. 10°–20° W., N. 60° W., N. 50° E., and N. 85° E.

Among the zeolites, pinkish natrolite is conspicuous at locality 2, and leonhardite was tentatively identified by the writer at locality 3.

Bedrock is exposed in the channel and the abutments, or is lightly covered with thin soil and with talus composed of relatively small gravel-sized fragments. Fresh rock can be exposed by shallow stripping. The slope on the right bank at section *A–A′* is about 35°, and at locality 5 the slope of this bank is about 40°. On the left bank at section *A–A′* the slope is as steep as 50°. The relatively smooth, uniform slopes and the small size of the talus fragments are a natural consequence of the autobrecciation within the flows. In contrast, the porphyritic flow (loc. 1) and some flows or sills observable near the top of ridges to the north and east of the site present oversteepened or clifflike outcrops and coarse talus. On exposure to weathering, the flow breccias disintegrate along breccia fragment contacts more than they do along joints. It does not appear that this mode of physical weathering proceeds any faster than disintegration along joints in nonbrecciated rocks in the Trask River area, but it would be desirable to test the breccias for any possible rapid disintegration due to alternate wetting and drying in a reservoir or to wave action.

No deep-seated active landslides were noted or are discernible on the aerial photographs. Some shallow-seated sliding, creep or wash of the surface mantle into the reservoir may be expected where the adjacent valley sides have been denuded of forest cover by fire or lumbering operations.

Leakage would not seem to be a serious problem. Certain flows may contain vesicular tops that are slightly permeable, but the process of autobrecciation should have helped assure close configuration of each new flow with the irregular surface of the preceding flow. Subsequent cementation with zeolites and calcite would also have sealed most permeable openings. In the left abutment area, the contact between the porphyritic flow and the underlying flow breccia is a possible leakage zone; but due to its altitude, it would be under low hydraulic pressure. Water was observed in side gulches despite dry weather during and before field inspection.

There is no natural spillway site, but a spillway tunnel might be cut through the flow breccias on either abutment if an overflow spillway is not desired. Such a tunnel would require little structural support, but the rock may require lining and should be tested to determine its resistance to disintegration along natural breccia fragments under conditions of alternate wetting and drying, as mentioned above, and under static rock pressure. The known shear zone (loc. 4) should be avoided, as should other minor shear zones that may be found during a more extensive subsurface investigation of this site or during stripping.

As aggregate, the flow breccias should be viewed with suspicion, and tested for the presence of opal or chalcedonic silica. Better aggregate is probably available in river bars upstream, or possibly on some of the high river terraces. One such terrace appears to be above the left abutment at an altitude of about 1,200 feet. It is understood that gabbro or diorite sills or dikes occur in the SE¼ sec. 30, the S½ sec. 18, T. 1 S., R. 6 W., W.M. and in the east wall of the canyon of Elkhorn Creek. These localities were not visited. Dense fresh porphyritic basalt from nonbrecciated nonamygdaloidal flows would also be worthy of consideration. Such rocks, as well as the intrusive rocks, should be suitable for riprap.

Impervious materials might be found in the mantle in broader sections of the valley upstream 1¼ miles on the North Fork, or half a mile up Clear Creek. They may also be available on those highest flat-topped uplands that are remnants of the Miocene erosion surface (Baldwin, 1947, p. 50). This latter might include part of Gobblers Knob. Another possible source might be some of the shaly, tuffaceous beds of the Nestucca(?) Formation higher in the valley walls above the lava flows exposed at the damsite.

In conclusion, the site seems suitable for either an earth dam or a broad-based concrete dam. A concrete arch dam might be considered if testing and subsurface investigations recommended above give satisfactory results.

A diversion of water from a Clear Creek reservoir to the Tualatin basin has been considered. The regional maps suggest that any diversion tunnel would be largely in the Nestucca(?) Formation. Such a tunnel would require support in some sections, and lining might be required in the weaker tuffs and shales. Some Tertiary diorite or gabbro dikes and sills are known from regional mapping in this general area and might be encountered. A fault trending about N. 15° E. from Elkhorn Creek would apparently be intersected by a diversion tunnel in sec. 21, T. 1 S., R. 6 W.

KEYHOLE RESERVOIR SITE

DESCRIPTION OF SITE

The damsite is on the North Fork Trask River in sec. 27, T. 1 S., R. 7 W. The topography of the damsite is shown on plate 1. The drainage area there is 57 square miles. The altitude of the stream at the site is 580 feet. The maximum altitude of the reservoir surface would be limited to 690 feet, the stream altitude at the Clear Creek site. The dam for this reservoir altitude would have a crest length of about 260 feet. The site might be suitable for a gravity or an arch dam. Areas and capacities for this reservoir site are as follows:

Area and capacity of Keyhole reservoir site

Altitude (feet)	Area (acres)	Capacity (acre-feet)	Altitude (feet)	Area (acres)	Capacity (acre-feet)
580	0	0	680	80	4,200
600	20	200	720	160	9,000
640	50	1,600	760	270	17,600

The reservoir described above would provide capacity sufficient to reregulate discharges from Clear Creek reservoir and would create an average head of 95 feet for production of power.

GEOLOGY

The "Keyhole" is a conspicuous section of the inner gorge of the North Fork of the Trask River where the river flows between near-vertical cliffs cut in basaltic flows and flow breccias of probable early to middle Eocene age. Two particularly prominent outcrops are diagonally opposite each other (pl. 1, section *A–A′* and fig. 4) and suggest a natural site for a narrow base dam that could be higher than the 110 feet required by the scheme of river development presented. There are, however, certain problems of a geologic nature that must be thoroughly investigated, and drilling will be required before the site can be fully certified.

Both abutments are composed of the same basaltic rocks. The contacts between flows are irregular and tight. Without close examination it is difficult to distinguish the individual flows with certainty. There is little or no color contrast between the dark-greenish to black flows. Textural variations include pillow lavas and some amygdaloidal tops, but they are not conspicuous enough to allow individual flows to be followed far by eye or with binoculars from below the cliffs or from across the river. However, on the basis of several random observations, it appears that breccia predominates in the middle and upper part of the abutments and dense flows are at the bottom. It also appears that the flows dip gently north, northeast, or northwest. No interbedded tuffs or sediments are in the abutments.

FIGURE 4.—Keyhole damsite. View from downstream, looking east to the "Keyhole." Photograph by J. L. Colbert.

The basaltic rocks exposed in the abutments are virtually free of decomposition by weathering; but the talus fragments are relatively small, indicating physical disintegration along breccia fragment contacts. At locality 1, above the right abutment, the basalt is disintegrated and weathered to brownish buff.

Fresh vitreous augite phenocrysts are common in most flows and flow breccias, and feldspar phenocrysts are common in a few flows. The groundmass of the basalt is largely altered to palagonite, and the augite of the groundmass is partly chloritized. Zeolites may be found in some flows as amygdules and as local breccia filling, along with minor amounts of calcite. Some of the breccia readily absorbs water, indicating considerable local porosity but probably no extensive permeability. In general, the rocks of the abutments, section *A–A′*, are relativeley fresh, strong, and competent. No direct evidence of faulting at the actual site was observed. As stated under the general section on geology, there is some evidence that a northeast-trending fault may pass into the reservoir area just north of the Keyhole site, perhaps within a few hundred feet of locality 1. Northeast of the Keyhole site, the trend of the axial plane of some of the folding observable in the disturbed zone suggests the possibility of an intersecting fault from the south, just east of the Keyhole site. The rocks of the abutments at the actual damsite seem to be unaffected, but inspection of the canyon bottom may disclose a fracture zone or strong jointing that facilitated the rapid downcutting by the river.

Wide-spaced jointing at the damsite is no doubt responsible for the external shapes of the conspicuous outcrops. One joint plane observable in both abutments strikes N. 5°–20° E. and dips steeply west. Another strikes N. 10°–30° W., also with steep westerly to vertical dip. A third plane strikes N. 45°–55° W. and dips about 60° SW.; a fourth strikes east-west and dips moderately southward. At localities 2, 3, and perhaps 4, a near-vertical joint striking approximately N. 60° E. may be responsible for the parallelism of several faces of cliffs on the right abutment and adjacent outcrops. This joint was observed at locality 3, and at locality 5 just west of the left abutment, as well as in the left abutment itself. Topographic expression within a two-mile radius of the damsite confirms the major joint trends as N. 10°–30° W. and N. 5°–20° E., and also the joints striking N. 45°–55° W. The jointing, like the possible fault north of the site, may be of some small concern in the matter of reservoir leakage but would not seem to create a major problem in the founding of a dam at the actual site or be an important cause of reservoir leakage. A slab on the left abutment fronting an open joint will have to be removed or grouted.

At the site, the river is flowing on coarse alluvium consisting largely of gravel, cobbles, and small boulders of porphyritic basalt. The depth to bedrock along section *A–A′* may be 10 feet, and possibly as much as 20 feet. Bedrock is at river level upstream on the left bank and downstream on the right bank but is covered by alluvium or talus at section *A–A′*. The nearest nickpoint in the stream profile appears to be slightly downstream (pl. 1); it is relatively inconspicuous, but supports the observation that the river is not at present cutting into bedrock where it crosses section *A–A′*.

Drilling will be necessary to determine not only the depth to bedrock under the channel but the nature of the bedrock. From observations in the reservoir area it is assumed to be flow breccia.

Shallow-seated landslides into the reservoir may be expected but would apparently be of little consequence. Leakage from the reservoir along the fault projected through the ridge north of the right abutment could be considerable. The ridge should be drilled for subsurface geologic information and for pressure testing. The left abutment may afford a good location for a tunnel spillway.

The flow breccias at the damsite and the intake and outlet of a spillway should be tested for resistance to disintegration from wave action, alternate wetting and drying, and current erosion. The presence of a natural bridge in the prominent outcrop at locality 6 demonstrates this need.

As aggregate, the possible presence of opal in the flow breccias as well as their tendency to disintegrate would suggest selection of other material, such as alluvial gravels just upstream from the site or the sources mentioned in connection with the Clear Creek site.

Impervious materials may include the tuffaceous shales overlying the basaltic flows, or possibly some materials available on the highest flat-topped upland remnants of the Miocene erosion surface.

In conclusion, the site seems suitable for a narrow-base concrete dam, if subsurface exploration of a possible fault zone north of the right abutment indicates that area is sufficiently strong and tight to withstand the relatively low hydraulic head from a dam 110 feet high, if the channel bottom is found tight and competent, and if the flow breccias pass tests for resistance to disintegration.

BARK SHANTY RESERVOIR SITE

DESCRIPTION OF SITE

The damsite is at river mile 2.8 on the North Fork Trask River in sec. 29, T. 1 S., R. 7 W. The drainage area at this location is 75 square miles, and the water surface is at an altitude of about 400 feet. Average discharge at the damsite is estimated to be 508 cfs. A dam that would raise water to the 600-foot level would create a reservoir with a capacity of 27,000 acre-feet. Use of 25,000 acre-feet for regulating the stream could have provided a discharge of at least 145 cfs during the test period. Operated in conjunction with the Clear Creek reservoir, the minimum discharge could have been increased to 215 cfs. Both amounts are after subtracting an appropriate allowance for losses. The reservoir could have been operated to produce minimum discharge of 600 cfs between November 1 and March 31 of each year during the period if summer releases were restricted to 30 cfs (Q95) when that was necessary for refilling in dry summers.

The maximum reservoir altitude at this site would be limited to 580 feet if the Keyhole site were to be developed. Areas and capacities for this site are as follows:

Area and capacity of Bark Shanty reservoir site

Altitude (feet)	Area (acres)	Capacity (acre-feet)	Altitude (feet)	Area (acres)	Capacity (acre-feet)
400	0	0	520	150	7, 500
440	19	380	560	240	15, 300
480	93	2, 600	600	350	27, 000

Operated together, the reservoirs at the Clear Creek and Bark Shanty sites could have assured a minimum discharge of 700 cfs during the 5-month winter period.

GEOLOGY

At the Bark Shanty damsite the North Fork Trask River passes through a local constriction between a spur of the ridge on the right bank and an oversteepened left bank. A prominent terrace occurs about 130 feet above the river on the right bank, and various other inconspicuous terraces are discernible. The terraces slope gently to the west and appear to be due to differential erosion within a series of lavas, tuffs, siltstones and thin-bedded standstones which constitute the bedrock in this area. As discussed in the general section on geology, this series is now tentatively correlated with the Nestucca formation. Geology and topography at the site are shown on plate 1.

The valley constriction below the prominent terrace is due to the thick flows (or sills?) of gray porphyritic andesite. These flows are overlain by tuffs, tuffaceous sediments, and thin flows. Some interbedded tuff is probably also present in the andesite flows, as at locality 1 and as inferred in section *A–A′*. At the damsite the flows strike about N. 10°–30° E. and dip west at approximately 4° to 7°, considerably steeper than the 1° westerly stream gradient. The upper massive flow appears to be 60 to 80 feet thick. Its line of outcrop forms a vertical cliff on the left bank at stream level (loc. 2) and an ascending near-vertical cliff southwestward from there along the left abutment to and beyond locality 3. Although outcrops are discontinuous, it appears that this same flow forms the prominent terrace on the right abutment. A lower massive flow crops out in the road cut and was located tentatively in other areas on the basis of float (pl. 1). The thin flow at about 600 feet altitude, section *A–A′*, was located by float and topographic expression.

Upstream a quarter of a mile in the reservoir area, the left bank is seen to consist of distinctly interbedded flows, with underlying tuffs, dark shaly beds, and sandy beds. Here the andesite flows have an aggregate thickness of perhaps 150 feet.

On examination of the andesite under a petrographic microscope using refractive oils, the feldspar phenocrysts were determined to be andesine and the ferromagnesian phenocrysts to be augite. For this reason the rock is here classed as an augite andesite, although further petrographic examination with thin sections would be desirable. It was observed that the feldspars are somewhat altered to clay minerals and the augite to chlorite, even in specimens that appear on visual examination to be fresh. The fresh rock is very hard and tough. On exposure, it breaks along joints into large angular blocks.

Exposures are largely limited to the road cut and to the over-steepened parts of the left abutment. Joints in the exposed flows are closely spaced. Most appear to be crude columnar jointing, but some horizontal jointing is present, roughly parallel to the flow bedding. The largest joint blocks observed in the talus and the streambed were about 15 feet long. No persistent joint directions could be observed in the limited outcrops along the river, and the rock exposed in the roadcut has slumped out of position. The drainage pattern within a 2-mile radius of the damsite, however, suggests well-defined near-vertical jointing that strikes N. 5°–10° W., another joint of N. 55° W. strike (the course of the river at the damsite), another that strikes N. 20°–40° E., and still another than strikes N. 65°–75° E. The courses of the two minor streams mapped on the left abutment (pl. 1) appear to be governed by two of these joints.

Bedrock is not exposed in the valley bottom along section *A–A′*. The river here is flowing on alluvium ranging from coarse sand to boulders. In the channel most of the alluvium is well rounded, but off to the side of the channel, angular talus blocks predominate. Most of the alluvium and talus consists of augite andesite derived from the flows. The depth to bedrock in the channel section along the axis, and the nature of the bedrock, will have to be determined by stripping or drilling. About 1,000 feet downstream from section *A–A′* the top of the uppermost flow is exposed in the river channel; this outcropping suggest that the depth to bedrock at section *A–A′* is not more than 10 feet. If the aggregate thickness of the massive andesite flows is 150 feet, the bedrock under the channel at section *A–A′* is the underlying tuffaceous sediments.

Because of the different physical characteristics of the flows and the interbedded and underlying shaly tuffs, the site is probably not suitable for a concrete structure but may be suitable for an earth dam as high as 200 feet above present river level. Leakage should be anticipated along the more permeable interbedded tuffs and along near-vertical joints in the flows, probably requiring considerable grouting. The ends of the dam can be well anchored in the competent flow rock of the abutments, but a cutoff wall in the less-competent beds under the channel at the axis will probably be required. Considerable stripping will be necessary to expose sound rock in the channel and the right abutment. There is a possibility that the right abutment may have been involved in a slide. Protection of tuffs and sediments from slaking and from wave action will probably be necessary. Pressure testing as part of subsurface investigation would seem necessary. Differential compaction of flows, tuffs, and sediments under load must be allowed for in design of rigid structures. Other possible flaws include a possible shear zone along one of the directions discussed above under the heading of joints, a deeper buried channel than suspected from the limited surface evidence, and a cavernous zone in the flows.

A spillway could possibly be laid on the dip slope of a competent bed or flow overlying the massive flows, with intake near the left end of the dam.

Rock fill, riprap, and aggregate can probably be obtained from the andesite flows at the site and from the talus and alluvium along the channel. Soils or clays for impervious curtains, screens, cores, grouting, and other uses, will be of limited availability in the damsite area and may be unsatisfactory in quality. Nonplastic borrow materials needed for an earth dam may probably be obtained from the tuffs and sediments of the reservoir area upstream from the damsite.

HOLLYWOOD RESERVOIR SITE

DESCRIPTION OF SITE

The damsite is on the South Fork Trask River below the mouth of East Fork in sec. 6, T. 2 S., R. 7 W., at river mile 1.9. Drainage area at this site is 49 square miles, and the water surface altitude is 350 feet. Average discharge at the damsite is estimated to be 320 cfs. The reservoir site has a storage capacity of 34,000 acre-feet at an altitude of 550 feet. By using 30,000 acre-feet for regulating the stream, a minimum discharge of 110 cfs after losses could have been maintained during the test period. The reservoir could have been operated to insure a minimum discharge of 450 cfs from November 1 through March 31 of each year during the period if the summer releases were restricted to 25 cfs (Q95) when that was necessary to refilling in dry summers.

The topography of the damsite is shown on plate 1. Areas and capacities of the reservoir site are as follows:

Area and capacity of Hollywood reservoir site

Altitude (feet)	Area (acres)	Capacity (acre-feet)	Altitude (feet)	Area (acres)	Capacity (acre-feet)
350	0	0	460	161	6, 160
360	3	15	480	212	9, 880
380	12	165	500	279	14, 800
400	34	625	520	320	20, 780
420	68	1, 640	560	500	37, 180
440	111	3, 440			

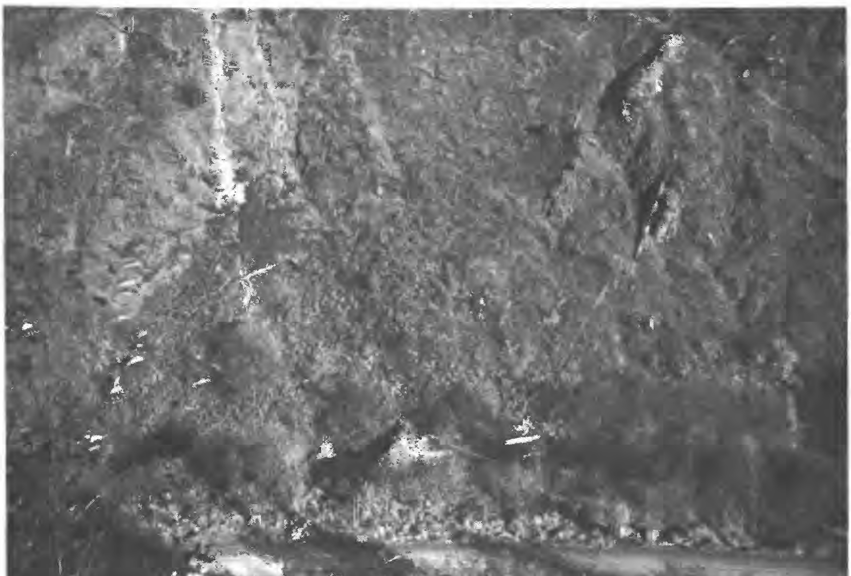
GEOLOGY

At the Hollywood damsite the South Fork Trask River flows northward through a local constriction about half a mile long. The bedrock on both sides of the valley and in the channel consists of nearly horizontal basaltic flow breccia. At the narrowest part of this valley, near section *A–A′*, small igneous dikes across the valley. The greater resistance of these dikes to erosion probably accounts for the constricted cross section of the valley. Geology is shown on plate 1.

The basaltic flow breccias are typical of those described in the section of this report on general geology. They are of probable middle Eocene age, and may correlate with the Siletz River volcanic series. The individual flows are massive but thoroughly brecciated. Observable contacts between flows are tight, irregular, and inconspicuous. The larger breccia fragments consist of porphyritic basalt, some of which are amygdaloidal. The breccias are well compacted, and although they are porous enough to absorb water noticeably when dry, they do not appear to be sufficiently permeable to cause a leakage problem. The homogeneous nature of the flow breccias is illustrated in the damsite area by the smooth nearly continuous exposures in the right bank, as at locality 1; by the abundant potholes developed by the river in its present channel (fig. 5*A*); and by the broadly spaced inconspicuous jointing found in the outcrop areas (loc. 2).

White crystalline zeolites occurring as amygdules as well as breccia filling are common in the exposed flow breccias. Some calcite is also present, but analcite seems to predominate. Relatively little chloritization was observed in the outcrops, but under the microscope in-

A



B

FIGURE 5.—Hollywood damsite. *A*, View from camera station 1 showing pothole in flow breccia in the foreground and dike in the right background. *B*, View from camera station 2 showing dike ascending right abutment from stream level.

cipient chloritization of the ferromagnesian minerals is seen to be widespread. The groundmass of some breccia fragments appears to consist of altered basaltic glass; in others it is finely crystalline basalt or dense porphyry with a few small augite phenocrysts.

In the stream channel the flow breccia is very fresh in appearance. On the steep right abutment the exposed rock disintegrates into breccia fragments before it can be extensively decomposed by chemical weathering. Elsewhere, particularly on the left abutment where exposures are very poor, the depth of disintegration and decomposition may be considerable. The mantle derived from this weathering conceals nearly all bedrock. The outcrop of breccia shown at locality 3 is probably not firmly in place.

The dikes shown in figure 6 are of differing textures but of apparently similar composition. Judging from the color of their aphanitic groundmass and the presence of zoned feldspar phenocrysts, they are mostly porphyritic andesite. The larger dike at locality 4 and in figure 5*B* is a dense gray-green rock with some inconspicuous phenocrysts identified as andesine in refractive oils. The groundmass appears to be a dense mat of partly kaolinized feldspars and chloritized amphiboles or pyroxenes. The small dike 300 feet north is mainly an aphanite, but it contains some very small andesine and ferromagnesian phenocrysts. Upstream in the reservoir area about 800 feet south of section *A–A′* a highly porphyritic andesite dike crosses the road and river; it has numerous light-colored feldspar phenocrysts that are conspicuously zoned; it also has a few euhedral doubly terminated pyroxene phenocrysts that are pseudomorphously altered to chlorite.

In the mapped area the dikes are best exposed in the stream channel and along the right abutment. They all dip northward at about 65° to 70° and strike N. 85° W. Jointing in the dikes is feebly columnar in nature. On the left bank no natural outcrop of the dikes could be found because of the brush and the mantle; but joint blocks of porphyritic andesite were seen in a shallow excavation at locality 5, and rubble derived from such rock was observed up and down the hillside from this locality. It is assumed that the dike zone crosses the left abutment in the general area shown on plate 1 by the inferred contacts.

Jointing in the flow breccias, as seen in outcrops, has been described above and shown on plate 1. Sheeting was also observed, but sheets, once loose, tend to disintegrate into breccia fragments. The drainage pattern within a 2-mile radius of the damsite suggests relatively strong, near-vertical widely-spaced jointing that strikes N. 30°–40° E., N. 20° E., N. 20° W., and N. 75°–80° W. No direct evidence of faulting was observed within the mapped area.

Above the bedrock channel in which the river is now flowing is a terrace about 150 feet wide along section *A–A′* and wider to the north. It represents an earlier stream channel and flood plain. Terrace deposits consist of stream-sorted gravels and sands interbedded with poorly sorted mantle material washed down from the left bank. Bedrock near section *A–A′* is assumed to be higher under the terrace than in the present channel, but a buried channel under the present road is a possibility.

The right abutment appears to be free of danger from landslides. The left abutment may possibly be a remnant of an old deep-seated slide. In the reservoir area some minor sliding of the mantle should be expected.

Leakage would not seem to be a problem once solid flow breccia or andesite bedrock are exposed in the left abutment and under the terrace. The amount of material to be removed in these areas to expose sound bedrock cannot be estimated without a subsurface investigation. The dikes will probably tend to seal off percolation between flows or along joints in the flows. They will also add strength for the founding of masonry structures, probably without introducing a problem of differential compactibility.

A spillway might be cut through the left abutment. The resistance of the flow breccias to erosion and to slaking under alternate wetting and drying should be tested and taken into account in the design of structures.

Terrace gravels upstream or downstream from the site will probably provide suitable aggregate. The flow breccias should be avoided for this purpose or for riprap. If quarrying is necessary, andesite dikes are available in the reservoir area, and a coarse-grained intrusive igneous rock of intermediate composition is understood to be exposed a few miles southwest of the site, on Joyce Creek (H.G. Schlicker, Oregon Department of Geology and Mineral Industries, oral communication, 1960). Soils or clays for impervious cores may possibly be available in parts of the valley bottom a few miles downstream from the damsite, occurring as sediments in former temporary lakes. More likely, impervious materials will have to come from downstream below the mouth of the Trask River canyon. Nonplastic material needed for an earth dam will be available in river terrace deposits at several nearby localities.

GINGER PEAK RESERVOIR SITE

DESCRIPTION OF SITE

The damsite for this reservoir site could be at one of several possible locations between mile 5 and mile 8 on the Trask River in secs. 20, 21, 28, and 29, T. 1 S., R. 8 W. The water surface altitude is 100 feet at the downstream end of this reach and about 180 feet at the upstream end. Raising the water surface from an altitude of 100 feet to an altitude of 350 feet, which backs water to the Hollywood site on the South Fork, would provide about 117,000 acre-feet of storage. Areas and capacities for this site are shown in the following table.

Area and capacity of Ginger Peak reservoir site

Altitude (feet)	Area (acres)	Capacity (acre-feet)	Altitude (feet)	Area (acres)	Capacity (acre-feet)
100	0	0	240	411	20, 750
120	21	210	260	535	30, 210
140	41	830	280	678	42, 340
160	80	2, 040	300	855	57, 670
180	150	4, 340	320	1, 003	76, 250
200	229	8, 130	340	1, 163	97, 910
220	311	13, 530	360	1, 312	122, 660

The geologic report, which follows, considers three possible sites within the reach. (See pl. 2.) The downstream site, *C–C′*, will be used for storage analyses. The average discharge is estimated at 928 cfs.

By using 100,000 acre-feet the reservoir could have regulated the stream to a minimum discharge of 395 cfs after losses during water years 1938 to 1952, inclusive. Operated in conjunction with the usable capacities of upstream reservoirs, a minimum discharge of 570 cfs could have been assured during the test period. If used to produce the greatest possible discharges during the 5 wet months, November through March of each year, the reservoir could have assured a minimum of 1,235 cfs by itself. With all usable storage in the upstream reservoir sites, this could have been increased to 1,510 cfs. These amounts are after losses. Average head at the Ginger Peak dam would have been about 200 feet for either type of operation. Simulated operating schedules for the most critical years are shown for winter months in table 3 in the summary of regulating possibilities.

GEOLOGY

By D. L. Gaskill

Rocks in the Ginger Peak damsite area seem to consist principally of a thick sequence of basaltic breccia flows, although some nonbrecciated flows are present. The breccia generally has a rough blocky appearance, but it may exhibit some vesicular, scoriaceous, or in places ropy structures. The larger components are composed of dark-gray, fine-grained or slightly porphyritic basalt well cemented by a basaltic matrix of finer particles in volcanic glass or palagonite(?).

Talus material locally includes specimens of basalt porphyry, amygdaloidal basalt, and important quantities of hydrothermally altered dioritic breccia. The flows are cut by many small basalt dikes and a number of larger diabasic and felsitic dikes. These rocks have been assigned to the Tillamook volcanic series of Eocene age by Warren, Norbisrath, and Grivetti (1945), who give an estimated thickness of 6,000 to 10,000 feet of lava exposed in the canyon of the Trask River from its mouth to its forks near mile 11.

Little is known of the local structure. Flow contacts generally appear to be very irregular and flow attitudes vary moderately from the horizontal. No faults were definitely recognized, but faulting has undoubtedly modified the local structure. A number of lineaments shown on plate 2 were interpreted from aerial photographs.

Remnants of alluvial terrace deposits are locally preserved along the Trask River. These deposits are probably related to three well-developed terraces at the mouth of the Trask River Canyon.

SECTION A–A′, MILE 7½

Bedrock is exposed in the channel of the Trask River and at weathered outcrops on the southwest abutment. These and other exposures downstream, particularly at localities 1 and 2 and in the vicinity of section *B–B′*, indicate that nearly all the abutment and foundation rocks are composed of thick sheets of basaltic flow breccia. More resistant dikes of dark-gray basalt cut these exposures locally. Upon exposure to weathering, the breccia is reduced to an unconsolidated rubble of its component parts. Deeply weathered breccia is exposed at scattered outcrops on the southwest abutment and on "The Peninsula" at locality 1.

No reliable attitudes were taken on these flow sheets, but the general attitude is near horizontal. At one weathered outcrop on the southwest abutment the flows strike roughly north and dip about 15° west. A few thin tight joint sets trend downstream and north-south in the river channel, but they are rather poorly developed and inconspicuous. Several lineaments appear to cut the southwest abutment on aerial photographs. These lineaments may represent zones of fractured or faulted bedrock. Both abutments are steep and covered with varying amounts of weathered residual mantle and slope wash, however, the northeast abutment is more massive and not so deeply weathered as the southwest abutment. Some 25 feet or more of unconsolidated alluvial terrace deposits overlies foundation rock on the northeast side of the river and lesser quantities of coarse alluvial material and slope detritus lie at the base of the southwest abutment.

Bedrock exposures are limited here, but they indicate a gentle attitude of the flow structures. Bedrock exposures in the river channel downstream from section *A–A′* indicate excellent foundation conditions. The southwest abutment appears to be much more deeply weathered and probably is structurally weaker than the northeast abutment.

Stripping requirements should not be excessive on the northeast abutment but may be extensive south of the river. This site seems to be very favorably located topographically.

SECTION B–B′, MILE 6

A view of this site is shown in figure 6. Foundation rocks are well exposed along the river in the area of section *B–B′*. These rocks exhibit layers of relatively fresh basaltic flow breccia, locally cut by thin, tight, widely spaced joints and large dikes of porphyritic basalt. Flow contacts are very uneven and undulating; but they appear to dip about 20° SE., although the topmost flow on the south bank has an apparent downstream or southwest dip at section *B–B′*. Joint sets trend north and northwest and dip steeply downstream. Less conspicuous fractures are healed with calcite and quartz veinlets. The most notable structures are the large resistant dikes, as much as 6 feet or more in width, which trend east-west and dip 40° to 50° north across the riverbed here. The dike rock has an aphanitic groundmass with small feldspar phenocrysts oriented parallel to the strike of the dike. The position of the largest dike with reference to the observed attitude of the bedrock suggests a possible offset of flow layers along this structure.

Abutment rocks are generally concealed by heavy forest vegetation. The steep bluff at locality 2 exposes massive outcrops of rough-textured vesicular scoriaceous blocky fragmental lava, cut by north-striking subvertical joints, a few irregular dikes and many small calcite veins (fig. 7). Secondary minerals, chlorite and zeolites, are abundantly developed in places along irregular fractures. Individual flows are not well defined, but they have an apparent near-horizontal position or dip moderately eastward. This outcrop, although considerably more altered than those in the river channel, is much less weathered than outcrops on "The Peninsula" at locality 1, and for the most part identical in structure and composition to all the exposures described in the area of sections *A–A′* and *B–B′*.

Flow layers in the river channel dip 20° to 30° southeast across the river, but they may be overlaid on the abutments by flows having a moderate downstream dip. Exposures upstream at locality 2, however, indicate near-horizontal flow attitudes. Joints and flow con-

FIGURE 6.—View downstream of section *B–B'*, Ginger Peak damsite, from locality 2.

FIGURE 7.—Typical exposure of basaltic breccia at locality 2, Ginger Peak damsite.

tacts may be effectively sealed in part by the large north-dipping dikes which apparently cut the southeast abutment.

Stripping requirements at this site are likely to be somewhat less than at sections *A–A′* or *C–C′*; however, considerable excavation of soil, slope debris, and weathered bedrock will be necessary on both abutments. Timber removal would be a more important phase of reservoir preparation than would be the case of a site selection at section *A–A′*.

The topography is very adaptable for a dam up to a maximum height of 500 feet above the river. Appurtenant works might be cut through the bedrock spur forming the southeast abutment.

SECTION C–C′, MILE 4.8

The Trask River flows here in a very narrow gorge cut in basaltic breccia. As many as eight individual flows are clearly exposed to a height of 15 feet or more above the river. Flow contacts are generally irregular and some of the thinner flows wedge out in cross section. On the northwest abutment, above the narrow bedrock channel, foundation rock is overlaid by alluvial terrace remnants and talus material. The terace deposits are probably more than 15 feet thick at section *C–C′* and are, in turn, overlain by a considerable thickness of roughly sorted slope debris including large boulders of hydrothermally altered breccia. The breccia is altered, in part, to greenstone. Basaltic breccia is exposed to a height of 100 feet, or higher, on the steep southeast abutment. The flows dip about 20° north-northwest with a slight upstream component of dip. The breccia is cut by small basalt dikes and one very large andesitic dike, about 50 feet wide, that trends east-west and dips about 70° N.

The basaltic breccias are similar in composition and structure to those described upstream at sections *A–A′* and *B–B′*. The hydrothermally altered talus blocks apparently were derived from a source on the northwest canyon wall and are similar to altered dioritic breccia at the large quarry near the mouth of the Trask River Canyon. Similar metavolcanic rocks crop out in the canyon along roadcuts one-half to three-quarters of a mile below section *C–C′*.

This site is in the deepest and narrowest stretch of the Trask River Canyon. The canyon is 2,000 feet deep at this point with steep slopes that average at least 30°. Abutments above the 200-foot contour were not investigated.

This site might be considered for a high dam. Some 25 feet of terrace and slope detritus overlies bedrock on the northwest abutment, but bedrock is exposed in the narrow river channel and on the southeast abutment. Flow sheets dip gently upstream and into the northwest abutment. Where examined at or near river level, the bedrock appears structurally stable, perhaps more ideally so with regard to a dam structure than either of the upstream sites. A dam height of 260 feet (Helland, 1953), would make the crestline of a dam at section *C–C′* about 1,100 feet long or approximately equal in length to the crestline of sections *A–A′* or *B–B′*. Stream gradients from *A–A′* to tidewater average about 23.8 feet per mile and decrease to about 20 feet per mile at section *C–C′*. A disadvantage to this site might be the extreme height of the canyon walls with consequent exposure to landsliding.

It is highly probable that thin interbeds of pyroclastic or tuffaceous sedimentary material separate some of the flow layers in the area. The presence of such beds in the foundation or abutment rocks could have major engineering significance. An analysis of breccia matrix should be made together with tests of the bearing strength of this rock.

CONCLUSIONS AND RECOMMENDATIONS

Bedrock exposures in the Ginger Peak damsite area exhibit massive flow layers of homogeneous basaltic breccia. The fresh rock is tough and well bonded, but it crumbles into its component particles when exposed to weathering. Joints are not everywhere conspicuous, but where well developed, appear tight and impermeable. No evidence of recent fault movement was observed. Only moderate grouting should be required although more information would be necessary for a critical evaluation. Crosscutting dikes are very resistant and must have important effect on the local topography and groundwater movement. Some of the larger dikes might serve as impermeable subvertical plates in foundation and abutment rocks where favorably alined. Contact zones between flow sheets are very irregular, often wedge-shaped, and in most places appear sufficiently watertight and insoluble to prevent excessive leakage around dam structures. A moderate dip of the flow layers in foundation and abutment rocks probably does not greatly detract from the structural stability of the bedrock, owing in part to the rough irregular contacts between flows. Lineaments discernible on aerial photographs appear to be developed along prominent fractures that may represent important structural anomalies. Lineaments should be carefully explored where they bisect a potential site.

Most of the reservoir site and drainage basin is within the area of the great Tillamook burn, with little reforestation of denuded slopes. This condition increases the possibility of flooding and abnormal siltation, particularly as these brushy-covered areas of the old burn are vulnerable to repeated fires at this stage of regrowth.

Stripping requirements of foundation rock at each of the sites investigated would be minimal. Unconsolidated deposits and much of the weathered bedrock on abutments could be removed by light excavation methods. Overflow spillways would be feasible, but light protection of bedrock from plucking may be necessary. Tunnels in the flow breccia would probably require lining where intersected by faults or badly fractured zones, but may require little or no support during construction in fresh rock.

The reservoir may be subject to some leakage along flow or fracture planes at the damsite, but the probable amount is believed to be negligible. The water table is assumed to be everywhere above the potential reservoir site.

Geologic conditions do not seem to be greatly different between sites within the area, but geologic structures are imperfectly known and should be explored in greater detail at the site selected.

All three of the sites described in this reconnaissance examination seem to be geologically suitable for a rockfill, earthfill, or possibly a concrete-type dam.

Moderate to strong seismic activity in this region (Coast and Geodetic Survey, 1950) should be considered in designing large construction projects in this area.

CONSTRUCTION MATERIALS

Rockfill and riprap material could probably be quarried at or near the damsites. Much of the unconsolidated material in this area, particularly talus, slope detritus, and the regolith mantle, would be unsuitable as construction material because of the susceptibility of basalt to weathering. Unconsolidated terrace deposits include roughly sorted gravel and cobbles, a few thin beds of clay, and a shallow soil cover. Large flood-plain deposits of sand and alluvial soil are available below the mouth of the Trask River canyon. All those basaltic materials are susceptible to rapid decomposition by ground water. According to Mielenz (1948, p. 8), "basaltic sands and gravels commonly become coated with opal * * * leached from the basalt pebbles. These opal coatings are deleteriously reactive with cement alkalies."

A large quarry has been developed in tough hydrothermally altered pyritized dioritic breccia at the mouth of the Trask River canyon in the SE cor. sec. 36, T. 1 S., R. 9 W. The breccia is composed of large angular blocks tightly bonded in a silicic matrix of smaller fragments. Irregular fractures indiscriminately cut the component blocks as well as the matrix. The breccia exhibits flow structures indicating a replacement or rheomorphic origin. Similar rocks are exposed along the highway in sec. 30, T. 1 S., R. 8 W. These breccia, as well as the porphyritic dikes, and possibly the thick basic nonbrecciated nonamygdaloidal flows of this area, should prove suitable for riprap or rockfill material.

SUMMARY OF REGULATING POSSIBILITIES

It would require about 1 million acre-feet of storage for complete regulation of the river at the Ginger Peak site. This is much beyond the capacity of the available reservoir sites. In fact, the reservoir sites are so small in relation to the volume of the dams required that they may not be economically feasible until and unless the need for peaking power is greater than at present. The 5 dams discussed in this report, assuming dams of earth-fill type, would have a combined total volume of about 6 million cubic yards and would form reservoirs with a combined total capacity of only 224,000 acre-feet.

The simulated operations shown in tables 2 and 3 assume that 195,000 acre-feet of the stored water would be available for regulation. The remainder would be used for conservation purposes and creation of head. The principal value of upstream storage would be for supplementing Ginger Peak storage. Use of the three largest of the upstream reservoir sites would make it possible to increase winter flows at Ginger Peak by 225 cfs over the amount that could be regulated by Ginger Peak alone.

The regulating capabilities of the reservoir sites are summarized in table 2. Table 3 shows simulated operations during the driest winters of the 1938 to 1952 test period. As previously mentioned, the locations of the reservoir sites are shown in figure 3.

POTENTIAL POWER

The sections on water supply and regulation show that power developments on the Trask River will not be practicable unless the river is regulated by storage reservoirs. Water yield is high, but the basin is small, and stream gradients are so steep that runoff is rapid. There are no spacious reservoir basins available, and except for the extra high-water yield there probably would be few, if any, powersites where development would be economic.

SUGGESTIONS FOR DEVELOPING POWER

Table 4 gives three optional-use suggestions for developing power, as follows:

1. For the maximum continuous regulation using all upstream usable storage plus the average amount of excess power and energy that would have been available between November 1 and March 31 of each water year between 1938 and 1953.
2. With the same storage, the maximum dependable power that would have been available during the five winter months with no power generation during the summer.
3. The maximum dependable power that would have been available during the 5 winter months with one reservoir on the North Fork (Clear Creek), one on the South Fork (Hollywood), and Ginger Peak on the main Trask.

TABLE 2.—*Regulating capabilities of reservoir sites in the Trask River basin*

Site	Reservoir capacity (acre-feet)		Regulated flow (cfs)[1]				Average head (feet)
			Annual		November 1–March 31		
	Gross	Usable	Individual site	Combined[2]	Individual site	Combined	
Clear Creek	39, 000	35, 000	130	130	460	460	165
Keyhole	7, 000	5, 000	40	140	(3)	485	95
Bark Shanty	27, 000	25, 000	145	215	600	700	150
Hollywood	34, 000	30, 000	110	110	450	450	160
Ginger Peak	117, 000	100, 000	395	570	1, 235	1, 510	200

[1] After losses to evaporation×1.2+5 cfs, rounded to nearest 5 cfs.
[2] Includes upstream usable capacity, if any.
[3] Not computed.

TABLE 3.—*Illustrative schedule of operations to produce greatest November–March discharge for the period Nov. 1, 1940, to Oct. 31, 1945, for a Ginger Peak reservoir with usable capacity of 51,000 second-foot-days (101,000 acre-feet)*

[Explanation of operations: I, without benefit of upstream regulation; II, with usable capacity of 17,000 second-foot-days at Clear Creek and 15,000 second-foot-days at Hollywood reservoir sites; and III, including II, with an additional 12,000 second-foot-days at Bark Shanty reservoir site. All figures in second-foot-days]

Date	Inflow	I Ginger Peak		II Ginger Peak, Clear Creek, Hollywood		III Ginger Peak, Clear Creek, Bark Shanty, Hollywood	
		Release [1]	Contents	Release [2]	Contents	Release [3]	Contents
1940							
Oct. 31			51, 000		83, 000		95, 000
Nov	22, 762	37, 200	36, 562	43, 500	62, 262	45, 900	71, 862
Dec	32, 806	38, 440	30, 928	44, 950	50, 118	47, 430	57, 238
1941							
Jan	49, 007	38, 440	41, 495	44, 950	54, 175	47, 430	58, 815
Feb	17, 587	34, 720	24, 362	40, 600	31, 162	42, 840	33, 562
Mar	14, 170	38, 440	92	44, 950	382	47, 430	302
Apr.–Oct	77, 400	26, 492	51, 000	14, 700	63, 082	15, 700	62, 002
Nov	31, 339	37, 200	45, 139	43, 500	50, 921	45, 900	47, 441
Dec	78, 739	72, 878	51, 000	50, 660	79, 000	47, 430	78, 750
1942							
Jan	25, 387	38, 440	37, 947	44, 950	79, 437	47, 430	56, 707
Feb	42, 490	34, 720	45, 717	40, 600	61, 327	42, 840	56, 357
Mar	22, 300	38, 440	29, 577	44, 950	38, 677	47, 430	31, 227
Apr.–Oct	63, 587	42, 164	51, 000	19, 264	83, 000	15, 700	79, 114
Nov	78, 350	78, 350	51, 000	78, 350	83, 000	62, 464	95, 000
Dec	85, 054	85, 054	51, 000	85, 054	83, 000	85, 054	95, 000
1943							
Jan	47, 590	47, 590	51, 000	47, 590	83, 000	47, 590	95, 000
Feb	67, 537	67, 537	51, 000	67, 537	83, 000	67, 537	95, 000
Mar	36, 057	38, 440	48, 617	44, 950	74, 017	47, 430	83, 627
Apr.–Oct	92, 866	90, 483	51, 000	83, 973	83, 000	81, 493	95, 000
Nov	19, 606	37, 200	33, 406	43, 500	59, 106	45, 900	68, 706
Dec	41, 707	38, 440	36, 673	44, 950	55, 863	47, 430	62, 983
1944							
Jan	34, 669	38, 440	32, 902	44, 950	45, 582	47, 430	50, 222
Feb	33, 101	34, 960	31, 043	42, 050	36, 633	44, 370	38, 953
Mar	27, 119	38, 440	19, 722	44, 950	18, 802	47, 430	18, 642
Apr.Oct	71, 549	40, 271	51, 000	14, 700	75, 651	15, 700	74, 491
Nov	23, 202	37, 200	37, 200	43, 500	55, 353	45, 900	51, 793
Dec	21, 805	38, 440	20, 367	44, 950	32, 208	47, 430	26, 168
1945							
Jan	57, 693	38, 440	39, 620	44, 950	44, 951	47, 430	36, 431
Feb	56, 197	44, 817	51, 000	40, 600	60, 548	42, 840	49, 788
Mar	63, 146	63, 000	51, 000	44, 950	78, 744	47, 430	65, 504
Apr.–Oct	84, 186	84, 186	51, 000	77, 930	83, 000	54, 690	95, 000

[1] Includes losses:
1. In winter minimum of 1,240 cfs less 5 cfs losses, net 1,235 cfs.
2. In summer minimum of 60 cfs less 10 cfs losses, net 50 cfs.

[2] Includes losses:
1. In winter minimum of 1,450 cfs less 15 cfs, net 1,435 cfs.
2. In summer minimum of 70 cfs less 20 cfs, net 50 cfs. The summer minimum was exceeded except in 1941 and 1944.

[3] Includes losses:
1. In winter minimum of 1,530 cfs less 20 cfs, net 1,510 cfs.
2. In summer minimum of 75 cfs less 25 cfs, net 50 cfs.

TABLE 4.—*Potential power and energy of the Trask River, with regulation* [1]

Option	Discharge and potential power of Trask River for indicated powersite and average head (feet)											
	Clear Creek (165)		Keyhole (95)		Bark Shanty (150)		Hollywood (160)		Ginger Peak (200)		Total	
	cfs	kw	cfs	kw	cfs	kw	cfs	kw	cfs	kw	kw	kwhr
1. Continuous November–March	130	1, 460	140	900	215	2, 190	110	1, 200	570	7, 750	13, 500	118, 000, 000
Average excess	530	5, 950	570	3, 680	720	7, 340	490	[2] 5, 330	1, 160	15, 780	[3] 38, 080	138, 000, 000
Total												256, 000, 000
2. November–March only	460	5, 160	485	3, 130	700	7, 140	450	4, 900	1, 510	20, 540	40, 870	148, 000, 000
3. November–March only (three dams)	460	5, 160					450	4, 900	1, 435	19, 520	29, 580	107, 000, 000

[1] Regulation at the site and at upstream sites, if any.
[2] Varied at Ginger Peak between a low 5-month average excess of 340 cfs (winter of 1941) to a high average excess of 1,700 cfs (winter of 1946).
[3] The limits of variation would have been between 40,000,000 and 190,000,000 kwhr.

There would be a considerable amount of dump energy possible in any of the options because of the inadequacy of storage for saving water from wet winters for use in summer and for carryover from wet years for use in dry periods. The November–March excess in option (1) is a rough measure of the amount of such energy.

The average discharge at the gage was 942 cfs for the 1938–52 test period. The November–March average was 1,759, and the April–October average was 364 cfs during that period. Given adequate generating capacity, much of the excess winter flow could be utilized.

Figure 3 shows the dam and reservoir sites discussed in this report. The dams shown would develop 940 feet of the 1,500 feet of fall downstream from the Camp Five diversion site. Total head is used to measure the present potential of the various powersites. In computations of capability for producing power, average head is used. The average head for each site is considered to be the difference between the tailrace altitude and that of the water surface when the reservoir has had one-half its usable contents drawn out.

The illustrative development considers dams only as a means of developing head. The illustration is used for estimating the gross power potential and is not a suggested plan. It will probably not be practical to develop all the sites included. A maximum development might be a reservoir and powerplant on each fork and the Ginger Peak reservoir and plant on the main stem as shown in option II of table 3.

The Trask River could make a modest contribution to the Northwest's power network by its capacity to furnish firming power in winter. It is normal for the Columbia to flow at rates greater than average for 4 months, April, May, June, and July, and at rates less than average the remaining 8 months. The Trask's flow rates are higher than average for 5 months and less than average for the remaining 7 months. However, all these 5 high-rate months, November, through March, occur when the Columbia is low. They are also months when demand for power is highest. Figure 8 compares the monthly percentages of average annual discharge for the Trask and Columbia Rivers.

Potential power estimates based on natural flow and regulated flow are shown in table 5 for the 5 sites that have been discussed in this report. The estimates based on natural flow were made in the same manner as that used for measuring potential power in the United States for presentation in table 3 of Circular 367 (Young, 1954). The estimates based on regulated flow are intended to show the dependable power possible of development considerating the regulating capabilities of the site in question supplemented by upstream regulation, if any. All power is computed at 80 percent efficiency.

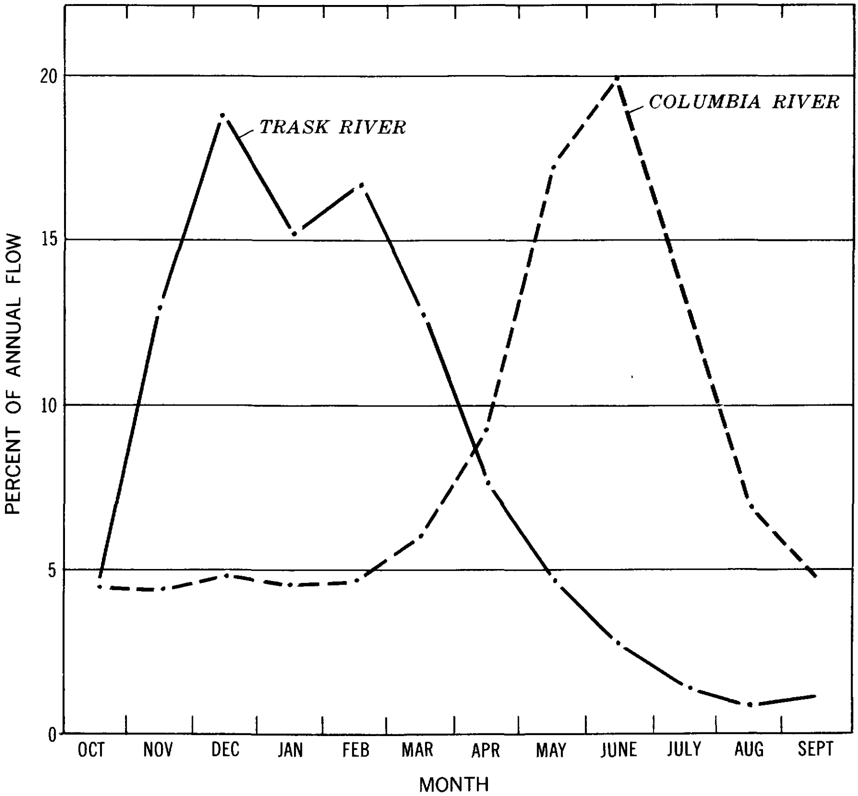


FIGURE 8.—Mean monthly percent of average annual flow for Trask River near Tillamook and Columbia River near The Dalles.

PUMPED STORAGE POSSIBILITIES

Since the coast streams may have their principal value for furnishing peaking power during the high-demand winter months, it is logical to look for pumped-storage sites near the reservoirs to which water could be pumped during the off-peak hours and used to meet morning and evening peaking demands. The Trask River contains such a site. A saddle on Gold Peak ridge at altitude 1,760 feet (in the NE¼ sec. 32, T. 1 S., R. 8 W.) could be turned into a reservoir with a capacity of 400 or 500 acre-feet by constructing 2 dikes, each about 800 feet long by 30 feet high. Water could be pumped from the Ginger Peak reservoir. The lift would vary between 1,410 and 1,690 feet, depending upon the level of the water in the lower and upper reservoirs. The penstock would be about 1 mile long.

Pumps delivering 300 cfs for 16 hours would lift about 400 acre-feet of water, which could be returned through the turbines at a rate of 600 cfs for 8 hours. Assuming an average upper reservoir altitude

TABLE 5.—*Summary of potential power with natural flow and regulated flow*

Site	Natural flow				Regulated flow			
	Percent of time or period	Estimated flow (cfs)	Head (feet)	Power (kw)	Period	Estimated flow (cfs)	Head (feet)	Power (kw)
Clear Creek	95	30	200	410	Continuous	130	165	1,460
	50	180	200	2,450	November-March	460	165	5,160
	Mean	355	200	4,830				
	November-March	530	200	7,210				
Keyhole	95	30	110	220	Continuous	140	95	900
	50	200	110	1,500	November-March	485	95	3,130
	Mean	380	110	2,840				
	November-March	570	110	4,260				
Bark Shanty	95	30	180	370	Continuous	215	150	2,190
	50	250	180	3,060	November-March	700	150	7,140
	Mean	508	180	6,220				
	November-March	720	180	8,810				
Hollywood	95	25	200	340	Continuous	110	160	1,200
	50	170	200	2,310	November-March	450	160	4,900
	Mean	321	200	4,370				
	November-March	600	200	8,160				
Ginger Peak	95	80	250	1,360	Continuous	570	200	7,750
	50	490	250	8,330	November-March	1,510	200	20,540
	Mean	928	250	15,780				
	November-March	1,730	250	29,410				

of 1,775 feet and a tailrace altitude of 100 feet, the average head would be 1,675 feet. The generating capacity at 80 percent efficiency would be 68,000 kilowatts, or 544,000 kilowatthours per day.

The pumped water would require about 1.4 kilowatthours of off-peak energy per kilowatthour of peaking energy (Hammond, 1958, p. 87). For a generating capacity of 68,000 kilowatts operating 8 hours a pumping capacity of 47,600 kilowatts would be required if operated the remaining 16 hours of each day.

An alternative arrangement that would use the same high-level reservoir, power drop and powerhouse could be effected. The water could be pumped from the Hollywood reservoir and carried along the north side of Gold Peak ridge. The lift pipeline would be about 1 mile long and the conduit length to the high-level reservoir, about 3 miles. There would be a saving of about 0.125 kilowatthour pumping energy per kilowatthour of generating energy and 42,000 kilowatts pumping 16 hours would lift the required water. The energy saved is not believed to be sufficient to justify construction of the added lift and conduit works.

DIVERSION TO TUALATIN RIVER BASIN

The Tualatin basin, especially in the areas being developed as Portland suburbs, is approaching a point where it must seek additional water. The Nehalem, Wilson, and Trask Rivers are possible sources for this water, and there are several sites in the headwaters of each where diversions to the Tualatin might be made. It seems possible to divert an average of about 800,000 acre-feet annually from the 3 streams combined. About 235,000 acre-feet could be diverted annually from the Trask River. A small diversion could easily be made by gravity. Diversion of a substantial amount of water will require reservoirs and tunnels or pumping.

CAMP FIVE SITE

Water could be diverted from the Middle Fork North Fork Trask River at a point in sec. 27, T. 1 S., R. 6 W. to the Tualatin River basin. The altitude at the point of diversion is 1,500 feet, and the drainage area is 9 square miles. Average annual runoff at the diversion site during the 15-year period 1938–52 was estimated to be about 35,000 acre-feet with an average discharge rate of 48 cfs. Because of the greater demand for water in the Tualatin basin, such a diversion should be regarded as a possibility. The river could be carried near the 1,500-foot altitude along the right bank of the Tualatin River for about 4½ miles and dropped to an altitude of about 550 feet at Haines Falls in the SE¼ sec. 20, T. 1 S., R. 5 W.

Some degree of regulation of the water could be effected to that a modest power installation might be justified. The winter diversion could average about 90 cfs. This diverted water if dropped through a head of 950 feet would generate nearly 6,000 kilowatts at 80 percent efficiency.

CLEAR CREEK SITE

Planners contemplating diversion of Trask River water to the Tualatin River should investigate the possibilities of diverting it from the Clear Creek reservoir by tunnel or pumping. The reservoir site has a capacity of 30,000 acre-feet above the 800-foot altitude. A tunnel at that altitude would begin at the junction of the North Fork and the Middle Fork North Fork Trask River in sec. 20, T. 1 S., R. 6 W., and would surface on the Tualatin River in sec. 19, T. 1 S., R. 5 W. Its length would be about 5.4 miles, according to the Fairdale 15-minute quadrangle. By carrying the water near the 800-foot altitude along the right bank of the Tualatin River for 5 miles, a head of 500 feet could be created at Cherry Grove in secs. 35 and 36, T. 1 S., R. 5 W. The Clear Creek reservoir could regulate the Trask sufficiently to permit a minimum diversion rate of 90 cfs after losses and provision for passage of 30 cfs down the Trask River during periods of low water.

The potential power of 90 cfs acting through a head of 500 feet is 3,000 kilowatts at 80 percent efficiency.

Because of the higher value of winter peaking power, the water might be diverted in winter by pumping it to the 1,500-foot altitude from the Clear Creek reservoir, then carrying it along the right bank of the Trask River across the divide and down the right bank of the Tualatin River to the 950-foot drop at Haines Falls described for the Camp Five diversion.

The Clear Creek reservoir with 30,000 acre-feet usable could assure a minimum November through March discharge of 450 cfs. Acting through a head of 950 feet, the potential power would be 29,000 kilowatts at 80 percent efficiency.

If brought across the divide in winter, the water would have to be stored until needed for irrigation and municipal use. An adequate reservoir for that purpose could be constructed on Scoggin Creek.

A dam on Scoggin Creek to raise the water 190 feet in sec. 20, T. 1 S., R. 4 W., would have a crest length of 3,200 feet, according to the Gaston 7½-minute quadrangle. The reservoir would store more than 200,000 acre-feet of water. At a site 1½ miles downstream the same storage capacity could be created by raising the water 175 feet by a dam with a 1,500-foot crest length. The upper site might be a necessary choice, however, because of existing uses of the lands in the lower part of the valley. If the water were dropped at Haines Falls, it could be made to run into the Scoggin Creek reservoir by gravity through a 5-mile canal that would include a short tunnel in sec. 19, T. 1 S., R. 4 W. If dropped at Cherry Grove, the powerhouse tailrace might have to be raised somewhat higher than would otherwise be desirable to make gravity conduit to the reservoir possible. The conduit route would be about 3½ miles long including 1 mile of tunnel.

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