STATE OF WASHINGTON

DEPARTMENT OF NATURAL RESOURCES

BERT L. COLE, Commissioner of Public Lands

DON LEE FRASER, Supervisor

DIVISION OF GEOLOGY AND EARTH RESOURCES

VAUGHN E. LIVINGSTON, JR., *State Geologist*

INFORMATION CIRCULAR NO. 50

ENERGY RESOURCES OF WASHINGTON

1974

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Price $1.00

FORWARD

During the last few months of 1973, almost everyone has become aware of the very important role of energy in our lives. World energy consumption during the last 30 years has exceeded the total amount of energy used during all previous historic time; and, at the present rate of increase, that energy consumption could quadruple by the year 2000. The per capita use of energy in this country is greater than in any other country in the world. Because exploration, discovery, and development of fossil fuels in this country have not kept pace with our requirements, we have found ourselves relying more and more on imports from other countries. In fact, many people have advocated the importation of fossil fuels because they felt the environmental impact of domestic exploration and development was too great. However, we are now faced with an embargo of oil products to the United States by oil-producing countries who wish to influence our foreign policy. We must now submit to these economic pressures or else cope with the serious effects of energy shortages on our economy. The shortage of oil has far-reaching effects, ranging from the manufacture of plastics, clothing, and other synthetic materials, to food processing and transportation. We need to accelerate development of energy resources in this country not only because of the present (1973) embargo on oil but also because the oil-producing nations are developing more energy uses for their own citizens. As these countries gradually obtain more material wealth, their need for foreign capital decreases, and they are more apt to cut back on oil production to make their oil exports balance their needs.

We need a three-pronged approach to solve the nation's energy shortage. Firstly, our known energy resources, both economic and subeconomic, should be inventoried. These resources should be reviewed periodically in relation to changing economic and technological conditions. As economic conditions change and technology advances, resources that are not commercial at the present time may become so in the future.

Secondly, we should begin to actively look for new energy-producing resources, and also for undiscovered reserves of presently known resources, such as coal, gas, oil, uranium, and geothermal. The good hydroelectric sites have been utilized, coal resources are fairly well known, less is known about uranium resources, and still less is known about potential fields of oil and gas or geothermal energy. A great deal of research needs to be done on possible future energy sources, such as fusion, hydrogen, solar power, and wind.

Thirdly, conservation measures that are reasonable and well planned should be applied in order to reduce detrimental side effects to a minimum while still retaining the economic feasibility of exploration and production of energy resources.

This report on Washington's energy potential is the first step in developing an inventory of the state's energy resources. The five most commonly used sources of energy are covered—geothermal, coal, oil and gas, uranium, and hydroelectric. The reports on each energy source are preliminary in nature. New research and technologies in the future will undoubtedly provide more information than we are able to present here.

The sections on coal, uranium, and oil and gas are essentially reprinted from existing reports, with some modification and updating of information. The coal section was originally published in the 1973 KEYSTONE COAL MANUAL. The uranium and oil and gas sections were published in the Senate Committee on Interior and Insular Affairs Committee Report on "Mineral and Water Resources of Washington" (U.S. Geological Survey, and others, 1966).

The electrical energy resources section was prepared by Lloyd Buchanan, a utilities engineer with the Washington State Utilities and Transportation Commission, who has made an effort to determine the actual electrical resources of the state. This is a new approach to assessing these resources; previous published reports have dealt with Washington only as part of a large region.

This report presents information on known and potential energy sources in Washington that will prove useful in solving our present energy crisis as well as providing for our long-term future energy needs.

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January 8, 1974

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GEOTHERMAL ENERGY POTENTIAL OF WASHINGTON

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Division of Geology and Earth Resources
Information Circular 50, Energy Resources of Washington

1974

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GEOTHERMAL ENERGY POTENTIAL OF WASHINGTON

By

J. Eric Schuster

INTRODUCTION

Geothermal energy is the heat of the earth's interior, generated largely by radioactive decay of uranium, thorium, and potassium that is present in the rocks of the crust and mantle. Sometimes temperatures in the crust are high enough to melt the rocks; these molten rocks may rise to the surface, forming volcanoes and lava flows, or solidify within the upper crust to form masses of intrusive igneous rock called batholiths.

Molten rocks, in the process of being intruded into the crust or extruded upon it, bring tremendous quantities of heat energy to or near the earth's surface. Ground water often circulates through or near these hot rocks, and the heated water, being less dense than cool water, rises toward the earth's surface. If these waters reach the surface, they form hot springs, geysers, and fumaroles.

Hot springs have been used by man for thousands of years as baths, recreational spas, and for cooking food; but it was not realized until the twentieth century that drill holes could tap live steam for electrical power generation.

Today, electrical energy is generated from geothermal steam at many places, including Italy, Iceland, New Zealand, the Soviet Union, Japan, Mexico, and at The Geysers in California. The total generating capacity from geothermal sources is presently about 1,000 megawatts—about the same capacity as a single coal-fired generating plant, such as the Centralia plant in Lewis County, Washington. Although electrical power from geothermal sources now supplies only a tiny fraction of the world's power needs, the use of geothermal resources has barely begun. Geothermal energy may, in the future, supply several percent of the world's energy needs, and could be particularly important in areas where alternative sources of power are in short supply. The State of Washington is one such area where petroleum and coal are in short supply or economically unattractive, and geothermal energy might supplement hydroelectric power at lower cost than any other alternative.

Geothermal reservoirs that are usable for electrical power generation occur under special geologic conditions. First, there must be a source of heat—this is generally a hot igneous rock, at moderate to shallow depth in the earth's crust. Second, a suitable reservoir rock must exist above the cooling igneous rock. The reservoir rock must have considerable porosity and permeability (the ability to contain and easily transmit large quantities of fluid), and it is often a sandstone or thoroughly fractured igneous rock. Third, fluid must exist in the reservoir rock to provide a medium for heat transfer to the surface. Fourth, a cap rock or barrier must exist on top of the reservoir to prevent the rapid escape of heated reservoir fluids. Fifth, a source of recharge to the reservoir is a desirable feature to replace fluids lost from the geothermal reservoir through natural seepage or production from drilled wells. It is the task of those working in geothermal exploration to find and evaluate information related to these five conditions.

EXPLORATION METHODS

Exploration for geothermal energy can be divided into two phases—discovery and development. The discovery phase is concerned with locating prospective target areas within a large tract of land, most of which will be barren of usable geothermal energy. Development can only take place if the discovery phase has been successful. There is considerable overlap in the geological, geophysical, and geochemical techniques used in these two phases.

During the discovery part of geothermal exploration, geological mapping, sampling of hot springs to determine their temperatures, flows, and chemical compositions, geothermal gradient and heat-flow measurement, and ground-noise surveys have the ability to locate geothermal target areas at low to moderate cost. Geological mapping is a necessary first step (fig. 1) because areas of young volcanic rock, thermal manifestations, suitable reservoir rock, and favorable geologic structures must be located through geologic mapping before it is advisable to apply many of the other techniques.

The purpose of geothermal-gradient and heat-flow measurements is to locate areas where temperature increases with depth more rapidly than usual and the flow of heat through the upper crust is greater than usual. Such areas have a greater probability of containing economically attractive deposits of geothermal energy. However, geothermal-gradient and heat-flow measurements are valuable when applied over a large area even if no strongly anomalous heated areas are found. This value lies in the interpretation of thermal and tectonic events (igneous intrusion and extrusion, folding, and faulting) that can be made when the distribution of heat-flow values is known for a region (see Blackwell, this volume, p. 31). Knowledge of these events can lead to a better understanding of the areas in a region that are the most likely to contain geothermal energy (Blackwell and others, 1973). A program of geothermal-gradient and heat-flow measurements in Washington is being conducted by the Department of Natural Resources, in cooperation with David D. Blackwell, of Southern Methodist University.

An inventory of thermal and mineral springs that includes temperature, flow, and chemical composition can be a relatively inexpensive way to locate promising geothermal areas. For example, the content of silica and the ratio of sodium to potassium are primarily dependent on the temperature reached during the traverse of spring waters from their source. Even though the spring water may be cool when it reaches the earth's surface, these chemical indicators are capable, under the right conditions, of demonstrating that high temperatures exist at depth within some spring systems (table 1). The Department of Natural Resources is engaged in a program of sampling spring water for geothermal exploration purposes; and several other investigators have reported on the chemical composition of spring waters, but not for the purpose of discovering geothermal resources (Campbell and others, 1970; Tabor and Crowder, 1969; Van Denburgh and Santos, 1965).

A relatively new geophysical technique known as ground-noise measurement may prove to be a valuable tool for locating geothermal target areas (Combs, 1972). Moving fluids or perhaps phase changes within geothermal reservoirs are thought to generate low-frequency seismic noise that can be detected using specially designed recording equipment. This technique is not fully developed and the ground-noise phenomenon is not fully understood, but indications are that the method will, in the future, provide an exploration tool that can search large areas at relatively low cost. Robert Crosson and Ian Mayers (1972) conducted a ground-noise survey in Washington during 1971 for the Department of Natural Resources, but the results were inconclusive.

If the above-mentioned regional techniques meet with success, there are many additional tools that can be used in the evaluation of geothermal anomalies or targets. Geological studies, spring water sampling, geothermal-gradient and heat-flow studies, and ground-noise measurements are still applicable; but they are concentrated in smaller areas and are applied more intensely. In addition, gravity measurements, electrical resistivity surveys, isotope studies, and other techniques may be used to help determine the size, shape, temperature, chemical nature, and power-producing potential of a geothermal anomaly. Many of these exploration tools or methods were developed by and borrowed from the oil and minerals exploration industries.

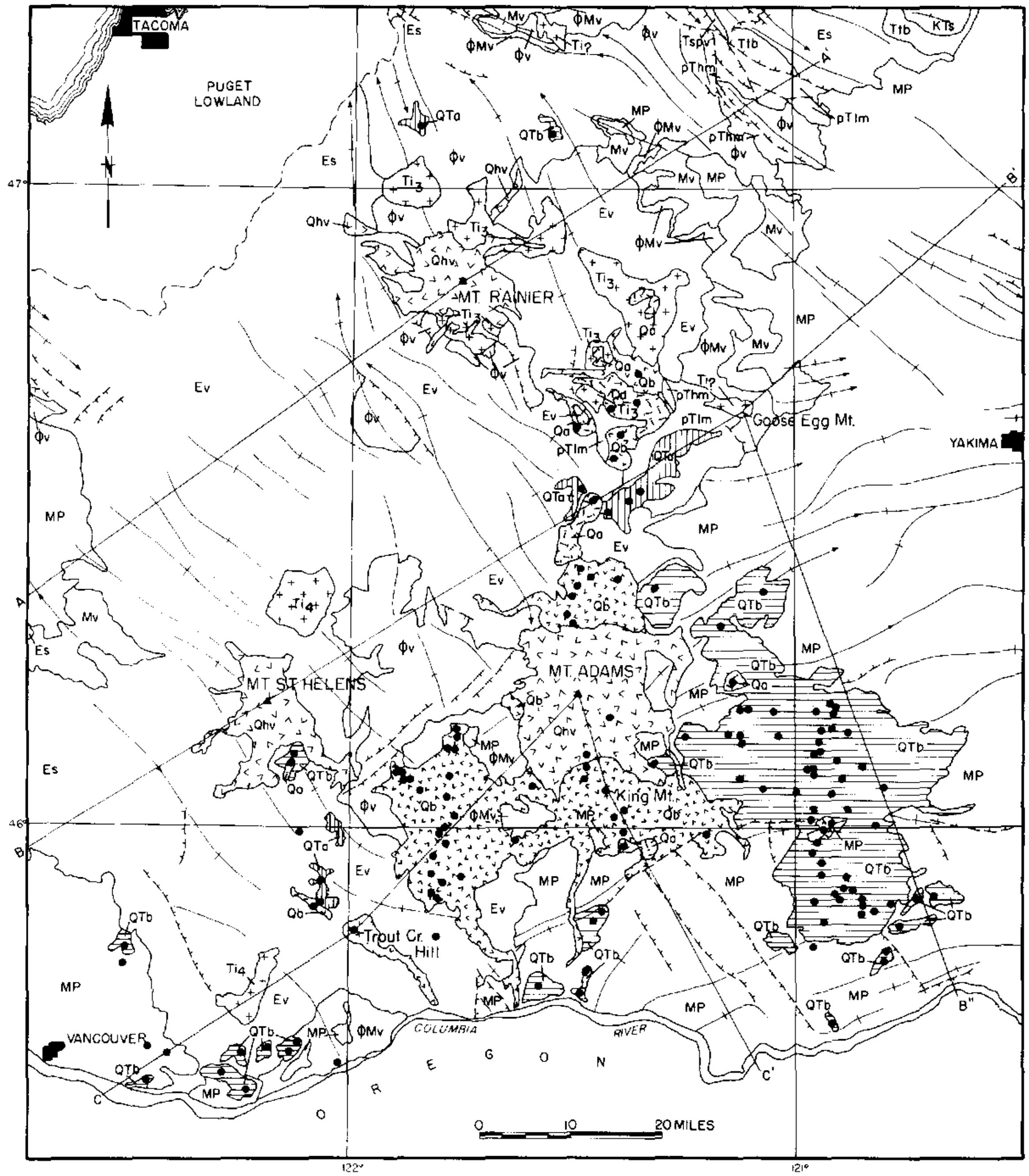
Washington may have two problems that are not generally encountered in other western states where geothermal exploration has taken place. Most of Washington's geothermal potential lies in the Cascade Mountains, much of which is an area of moderate to high rainfall. Because of high rainfall, widespread areas of fractured and porous rock have very deep circulation of cool ground water. The downward percolation of cool water may effectively dilute thermal waters to the point where they are not recognizable, either by temperature or chemical content, as thermal springs when they reach the surface. Heat flow and geothermal gradients are also damped and difficult to interpret (Blackwell, this volume, p. 30). High rainfall and deep circulation of ground water may, in part, explain why the many surface manifestations of geothermal areas in other parts of the western United States are present to a much smaller extent in Washington. High rainfall also leads to a thick, lush canopy of vegetation that makes field investigations more difficult and may hide some thermal and mineral springs that would otherwise have been discovered.

WASHINGTON'S POTENTIAL

GEOLOGIC ASPECTS

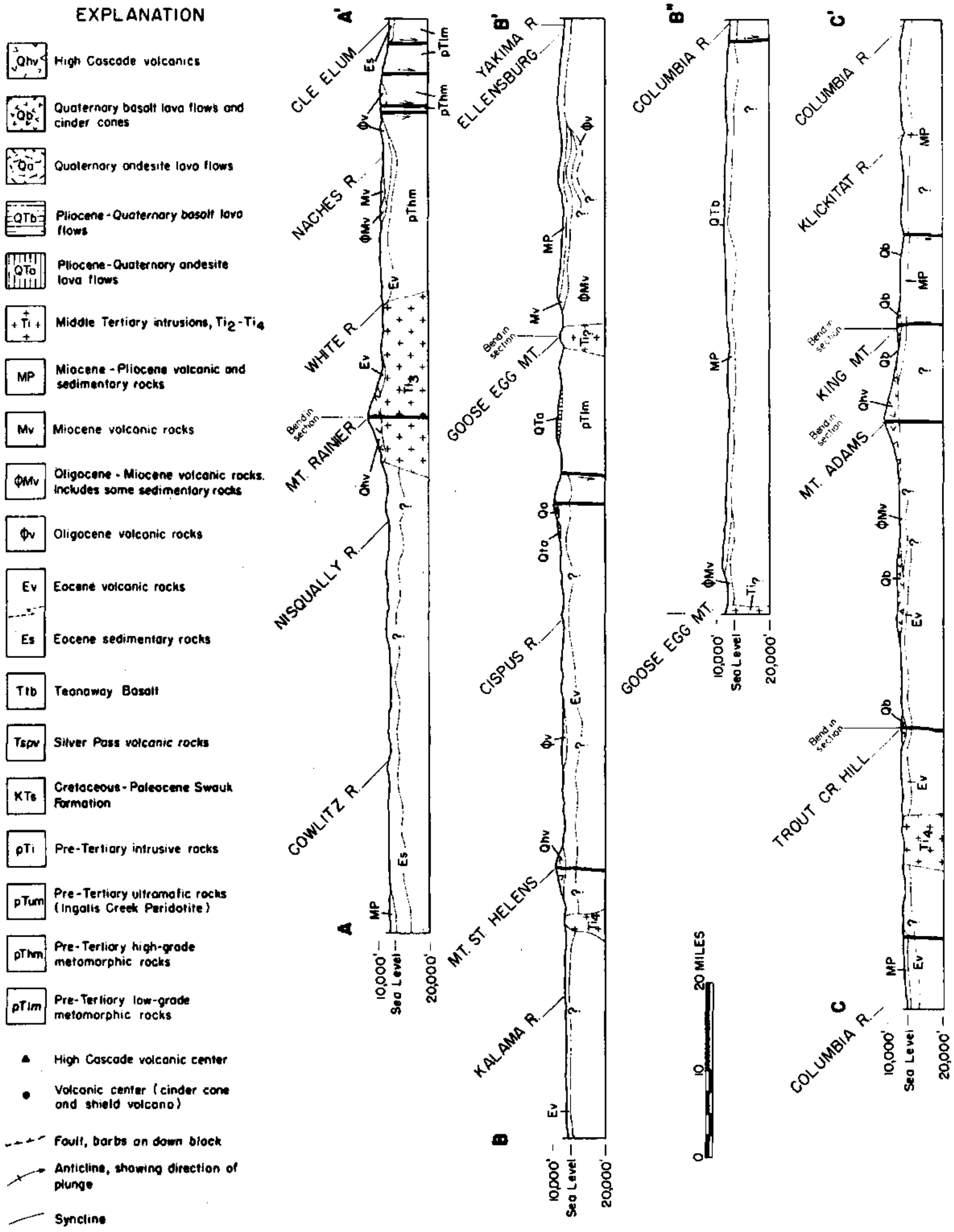
The most obvious indications that Washington has geothermal potential are the five stratovolcanoes that occur in the state. The following excerpt from Livingston (1972) provides a brief description of the geology and eruptive history of these volcanoes:

> Mount Baker is the northernmost of the five volcanoes. It is a 10,778-foot stratocone that has been built on a platform of pre-Tertiary metamorphic and crystalline rocks. The cone probably had its origin back in Pleistocene time. However, there are records of activity in 1843, when quantities of ash were blown out of the summit; in 1854, when the summit was obscured by rolling masses of dense smoke; in 1858,when night clouds over the mountain were illuminated by an eruption; in 1859, when bright jets of flame were seen issuing from two separate fissure openings, and bright flashes of light and dense smoke were reported over the mountain; and, in 1870, when great volumes of smoke issued out of the summit crater. As recently as last year, a steam jet was seen emitting from the mountain.
>
> The next volcanic peak to the south is 10,436-foot Glacier Peak, which is another stratocone, and, like Mount Baker, is built on a platform of pre-Tertiary metamorphic and crystalline rocks. Mapping in the area indicates that there have been no major eruptions of the peak more recent than 12,000 years ago; however, smaller eruptive centers surrounding the peak may have been active as recently as 2,000 years ago. Glacier Peak is very isolated, and it is possible that minor volcanic activity such as steam jets and fumerolic action could have taken place during historic time but gone unnoticed.
>
> Southward about 80 miles from Glacier Peak is Mount Rainier, which is the highest of the five stratocones in Washington. Mount Rainier rises to an elevation of 14,410 feet and is built on a platform of Tertiary volcanic and granitic rocks. Rainier is probably the best known of all the peaks in Washington and has been studied the most extensively. Eruptions were reported in 1843, 1854, 1858, and 1870. If, indeed,



Geology from Hammond, P. E., 1973

FIGURE 1.— Generalized geologic map of



Southern Cascade Range, Washington.

these eruptions did occur, they must have been feeble, because there is no documented evidence to substantiate these reports. In 1878 and again in 1888, early settlers described a series of brown billowy clouds issuing from the crater. Mudflows that have come off the mountain as recently as 1949 have been related to local volcanic hot spots. It is thought by some geologists that heat generated within the mountain melted glaciers on the mountain's slopes, thereby releasing an enormous amount of water that saturated the pyroclastic debris on the slopes of the mountain and caused the debris to flow down the mountainside as mudflow. Several explosions and rock falls have recently occurred on Mount Rainier that might possibly have been caused by heat generation. At the summit of the mountain there is sufficient steam issuing from the easternmost of two small snow- and ice-filled craters to melt out caverns beneath the edges of the ice along the crater wall. Steam emerging from the crater has not been analyzed so its composition is not known.

To the south of Mount Rainier about 50 miles is Mount St. Helens, considered to be the youngest of the stratovolcanoes in Washington. This is a 9,671-foot symmetrical cone built on a platform of Eocene to Oligocene volcanic clastic rocks of the Ohanapecosh Formation. It is reported that this mountain erupted in 1831, 1842, 1844, 1845, 1847, and 1854. The 1842 eruption blew pumice over The Dalles, Oregon, some 30 miles to the southeast. In 1847, a long column of dark smoke was noted above the summit, and, in 1941, five jets of steam were noted about 800 feet below the summit on the west slope of the mountain. The jets, which made no noise nor had any odor, issued from rock crevices up to 3 inches wide. Temperatures of the five vents were 178°F, 180°F, 190°F, 188°F, and 142°F.

The fifth stratocone in Washington is 12,307-foot Mount Adams, which is located about 30 miles to the east of Mount St. Helens. No eruptive activity has been reported from Mount Adams during historic times. There are hot gas jets in the crater of the mountain with reported temperatures of 150°F and a strong hydrogen sulfide odor. Numerous small sulfur deposits in the crater are evidence of past fumarolic action. It was reported by Fowler in 1935 that when the sulfur deposits were penetrated by drilling, fumarolic action would start, using the drill hole as the vent.

Mount Adams has some constructional features that are different from the other four stratocones in Washington. It appears that the mountain originally started as a shield volcano and then in its later phases became a stratocone. The stratocone is perched on top of a large low apron of flow rocks. Associated with Mount Adams are the flat Pleistocene to Recent lava fields of Yakima, Klickitat, and Skamania Counties. Some of the flows that make up the fields appear to be very young and, judging from the trees that are growing on and next to them, are probably not more than 1,000 years old.

The young lava flows in Yakima, Klickitat, and Skamania Counties cover more than 1,000 square miles and constitute, with Mount Adams and Mount St. Helens, a large target area for further geothermal exploration. Within this broad upland area there are many small cinder cones and shield volcanoes (fig. 1) with associated lava flows. Hammond (1973) reports that many of these are less than 50,000 years old. If the magma chambers or conduits that fed these young flows are of sufficient size, they may still contain considerable heat that, under favorable conditions, could support geothermal reservoirs.

Except for the young volcanic rocks of Mount Baker and Glacier Peak, there are no volcanic rocks less than one million years old outside of the area shown on figure 1. There are occurrences of volcanic rocks, probably of Pliocene age, in northwestern Okanogan County (Huntting and others, 1961); west and south of Glacier Peak (Yeats, 1958, Plate 1 and p. 185-186; Vance, 1957, Plate 1 and p. 288-291; Rosenberg, 1961, plate XI and p. 93-95; Spurr, 1901, Plate LXXX and p. 799-801); in Chelan County (Willis, 1950, Plate 46 and p. 117, 119); in Franklin County (Trimble, 1954); and in Asotin County (Huntting and others, 1961), but these rocks are probably too old for the existence of a hot magma chamber or feeder beneath them.

There are no intrusive rocks in Washington that are younger than Pliocene (one million years). Intrusive rocks must be less than about one million years old to support a geothermal reservoir. Model calculations show that the heat from intrusive rocks is lost very quickly, and intrusions of modest size would have little or no heat remaining one million years or so after their emplacement (D. D. Blackwell, written communication, 1973). It is probable that very young intrusives exist in Washington, especially in the southern Cascade Mountains where large volumes of young volcanic rocks attest to widespread activity during Quaternary time and extending into the last few thousand years (Hammond, 1973). These intrusives would, presumably, still be covered by young lavas that have not been removed by erosion.

SPRINGS

In addition to the young volcanic rocks that point to a geothermal potential for Washington, there are some forty-three mineral and thermal springs in Washington (Valentine, 1960, p. 64-67). Hot springs are an obvious clue to the existence of geothermal energy, because they represent an escape of heat from some buried source. If the springs are near boiling, it can be assumed that the heat source is fairly intense, but most of Washington's springs are cold—the warmest are about 50°C. In such cases the measurement of temperature and volume of flow does not provide much information about possible source temperatures. However, the chemical composition of these spring waters can supply considerable information.

The solubility of some chemical constituents of rocks, such as silica, is greater in hot water than in cooler water (White, in press; Fournier and Truesdell, 1970). Even if spring water has cooled considerably when it finally reaches the earth's surface, the dissolved chemical constituents that were taken into solution when the water was hot often remain in the water. Therefore, if the chemical composition of spring waters is compared with published data, source temperatures can often be estimated. Table 1 presents estimated source temperatures for all spring waters in Washington for which chemical data are available. The curve for prediction of source temperature through silica content was taken from Fournier and Truesdell (1970) and is their curve A, to be applied to waters cooled entirely by heat conduction. The curve for prediction of source temperature using Na/K is curve G of A. J. Ellis, published by White (in press).

As figure 1 and table 1 indicate, there are five springs—Mount Baker, Kennedy, Gamma, Longmire, and Summit Creek—that yield silica temperatures in excess of 150°C. A source temperature in excess of 150°C is of possible interest as a geothermal area capable of producing electrical power (Combs, 1972, p. 50).

It must be pointed out that there are several possible sources of error in the prediction of source temperature using silica and Na/K. Some of the following sources of error are discussed by White (in press): (1) Silica temperatures are usually minimum temperatures because heated spring waters are often diluted by low-silica ground water on their way to the surface, and silica may precipitate to some extent on its way to the surface; (2) silica temperatures may be too high for acid waters low in chloride because rock silicates other than quartz (Fournier and Truesdell's curve A is based on the assumption of equilibrium between quartz and water) are dissolved by such waters; (3) Na/K temperatures have no significance for most acid waters; and (4) the Na/K ratio for hot spring waters is dependent not only on source temperature, but also on the mineral assemblage that has reacted with the water, so a knowledge of the type of rock through which the waters have percolated is necessary for an accurate analysis of Na/K values.

In addition, the data of table 1 were collected from several authors, who probably used different sampling and analytical techniques, and whose purposes were other than geothermal exploration. Therefore, some of the data may not be accurate (see the three silica values for Kennedy Hot Spring, table 1);

TABLE 1.--Estimated source temperatures for spring waters

THERMAL SPRINGS

Map number	Spring name	Location	County	Temperature (°C)	Flow (gpm)	pH
8	Kennedy	NE¼ 1, (30-12E)	Snohomish	34	30	7
	Do ---	--------- do ---------	--- do ---	est. 30	est. 3-5	7.7
	Do ---	--------- do ---------	--- do ---	----------	--------	6.5
25	Longmire	Near SE cor. 29, (15-8E)	Pierce	21	--------	6
7	Gamma	est. SE cor. 24, (31-13E)	Snohomish	est. 60	est. 3-4	7.9
4	Mount Baker	SW¼ 20, (38-9E)	Whatcom	42	7	8
12	Garland	NW¼ 25, (28-11E)	Snohomish	21	--------	6
	Do ---	--------- do ---------	--- do ---	7	25	6
11	Olympic	SW¼ 27, (29-8W)	Clallam	46	135	7.5
	Do ---	--------- do ---------	--- do ---	38	--------	7.5
	Do ---	--------- do ---------	--- do ---	47	--------	7.5
	Do ---	--------- do ---------	--- do ---	46	--------	7.5
	Do ---	--------- do ---------	--- do ---	43	--------	7.5
	Do ---	--------- do ---------	--- do ---	47	--------	7.5
	Do ---	--------- do ---------	--- do ---	30.5	--------	7
	Do ---	--------- do ---------	--- do ---	26	--------	6-7
	Do ---	--------- do ---------	--- do ---	48	--------	7.5
10	Sol Duc	NW¼ 32, (29-9W)	Clallam	50	50	7.5
	Do ---	--------- do ---------	--- do ---	42	--------	7.5
	Do ---	--------- do ---------	--- do ---	56	--------	9.2
	Do ---	--------- do ---------	--- do ---	8.5	--------	4.5
6	Sulphur	NW¼ 19, (32-13E)	Snohomish	37	4	8
	Do ---	--------- do ---------	--- do ---	est. 30	est. 1-2	7.8
	Do ---	--------- do ---------	--- do ---	----------	--------	8.6
26	Ohanapecosh	NW¼ 4, (14-10E)	Lewis	40	60	7
40	Bonneville	SW¼ 16, (2-7E)	Skamania	32	20	9.5
41	St. Martin's	SE cor. 21, (3-8E)	--- do ---	49	--------	7
NONTHERMAL SPRINGS						
27	Summit Creek	Near cen. 18, (14-11E)	Lewis	13	--------	6
17	Flaming Geyser	SE¼ 27, (21-6E)	King	12.5	--------	8.5
23	H. E. Mulford	SW¼ 3, (14-18E)	Yakima	15	--------	7.6
24	Malotte	SE½ 32, (16-17E)	--- do ---	17	--------	7.7
36	Bubbling Mike	31, (5-7E)	Skamania	8.5	--------	6.5
39	City of Vancouver	SW¼ 33, (2-2E)	Clark	10	--------	----
42	M. A. Leonardo	NW¼ 21, (2-13E)	Klickitat	14	--------	----
21	Unknown	NW¼ 32, (19-23E)	Grant	----------	--------	----
35	Iron Mike	31, (5-7E)	Skamania	10	--------	7
22	Rattlesnake	NE¼ 29, (12-25E)	Benton	----------	--------	7.8
9	Edwards	SW¼ 24, (31-4E)	Snohomish	10	--------	7.5
20	Maplewood	SE¼ 32, (20-4E)	Pierce	8	--------	----
15	King County Water Dist. 19	SE¼ 29, (23-3E)	King	8	--------	7.3
34	Bear Creek	SE¼ 20, (6-10E)	Klickitat	13	--------	7.1
30	Lonesome Sale Road	NW½ 30, (7-8E)	Skamania	4.5	--------	7.2
1	City of Blaine	SW¼ 3, (40-1E)	Whatcom	----------	--------	7.3
5	U.S. Forest Service	NW½ 25, (37-8E)	--- do ---	12	--------	7.3
29	Spring 72	SE¼ 13, (7-7E)	Skamania	4	--------	6.9
18	State of Washington	NE¼ 33, (20-2E)	Pierce	12	--------	----
2	Larabee	NW¼ 36, (39-2E)	Whatcom	----------	--------	7.3
3	S. R. Burbery	NW¼ 20, (38-26E)	Okanogan	12	--------	7.7
33	Bacon Creek	SE¼ 1, (7-12E)	Yakima	55	--------	6.9
32	Gotchen Creek	SW¼ 18, (7-11E)	--- do ---	3	--------	6.9
16	Diamond	SW¼ 21, (21-6E)	King	11	--------	8
28	Landslide	SW¼ 34, (8-7E)	Skamania	5.5	--------	6.9
37	Little Iron Mike	31, (5-7E)	--- do ---	10	--------	6.5
38	Little Soda	SE¼ 5, (4-7E)	--- do ---	8	--------	6
13	Scenic	28, (26-13E)	King	10	30	5
19	Sequalitchew	SE¼ 19, (19-2E)	Pierce	13	--------	6.9
31	Spring 710	NE¼ 36, (7-7E)	Skamania	4	--------	7.1
8	Upper Kennedy	NE¼ 1, (30-12E)	Snohomish	----------	--------	6.6
14	U.S. Air Force	4, (24-45E)	Spokane	2	--------	6.0

1/ Listed in Selected References.

2/ BDL: Below detection limit.

in Washington. (For spring locations see figure 2.)

(OVER 20° C)

Cl	SiO_2	Na	K	Na/K, Atomic ratio	Predicted Source Temperature (° C)		Source of data[1/]
(parts per million)					SiO_2	Na/K	
612	380	808	67.8	20	227	170	Campbell and others, 1970
643	136	655	64	17	154	188	Tabor and Crowder, 1969
676	0	660	75	15	---	200	Div. Mines and Geology files, 1971
615	170	402	37.2	19	168	175	Campbell and others, 1970
728	150	491	77	11	160	238	Tabor and Crowder, 1969
108	140	165	10	27	157	142	Campbell and others, 1970
2671	120	1592	130	20	148	170	Do
461	BDL	358	28	22	<50?	160	Do
0.5	120	74	1.3	97	148	<80	Do
0.5	90	65	1.1	100	132	<80	Do
0.7	80	78	1.3	102	125	<80	Do.
0.7	70	77	1.3	100	118	<80	Do.
0.6	70	73	1.3	95	118	<80	Do.
0.7	60	77	1.4	94	110	<80	Do
0.4	30	51	0.9	97	75	<80	Do
BDL[2/]	BDL	39	0.7	95	<50?	<80	Do.
BDL	BDL	79	1.5	90	<50?	<80	Do.
1.7	120	84	1.6	88	148	<80	Do.
1.7	70	81	1.2	116	118	<80	Do.
17	58	80	2.6	52	105	95	Van Denburg and Santos, 1965
BDL	BDL	BDL	BDL	---	<50?	---	Campbell and others, 1970
52	120	108	2.4	77	148	<80	Do.
54	75	103	1.7	103	122	<80	Tabor and Crowder, 1969
100	0	96	2	82	---	<80	Div. Mines and Geology files, 1971
869	80	981	51	32	125	128	Campbell and others, 1970
151	BDL	126	1.5	143	<50?	<80	Do.
636	BDL	291	6.2	80	<50?	<80	Do.
(UNDER 20° C)							
1552	170	1790	87	36	168	120	Campbell and others, 1970
5600	90	4640	35	226	132	<80	Do.
9.1	66	13	5.8	4	114	>300	Van Denburgh and Santos, 1965
1.8	53	17	4.3	7	103	>300	Do.
276	50	176	5.1	58	100	88	Campbell and others, 1970
2.9	50	4.2	5.6	1	100	>300	Van Denburgh and Santos, 1965
5.0	48	7.8	2.1	6	98	>300	Do.
6.0	47	------	----	-----	97	---	Do.
318	40	211	6.2	58	90	88	Campbell and others, 1970
2.8	36	7.2	1.7	7	82	>300	Van Denburgh and Santos, 1965
3.6	31	5.6	1.4	7	77	>300	Do.
2.1	30	4.5	1.6	5	75	>300	Do.
6.0	28	6.0	1.2	8.5	70	275	Do.
1	24	5.4	0.6	15	68	200	Div. Mines and Geology files, 1972
6	24	6.0	0.6	17	68	187	Do.
3.3	24	5.8	2.0	5	65	>300	Van Denburgh and Santos, 1965
4.0	23	6.4	2.4	5	65	>300	Do
1	19	3.4	0.6	10	55	252	Div. Mines and Geology files, 1972
3.0	19	5.0	1.4	6	55	>300	Van Denburgh and Santos, 1965
22	19	18	3.0	10	55	250	Do.
1.5	18	9.1	2.8	5.5	53	>300	Do
1	17	59	1.2	84	50	<80	Div. Mines and Geology files, 1972
1	17	3.4	0.2	29	50	136	Do.
1574	BDL	1280	5.5	396	<50?	<80	Campbell and others, 1970
<1	9	3.4	0.2	29	<50	136	Div. Mines and Geology files, 1972
561	BDL	404	9.6	71	<50?	80	Campbell and others, 1970
36	BDL	28	13.6	3.4	<50	>300	Do.
BDL	BDL	BLD	1.2	-----	<50?	---	Do.
3.4	9.8	4.8	1.1	7.4	<50	>300	Van Denburgh and Santos, 1965
1	15	2.6	0.3	15	<50	200	Div. Mines and Geology files, 1972
681	10	626	79	13.5	<50	213	Div. Mines and Geology files, 1971
1.2	11.5	1.8	0.4	8	<50	290	Van Denburgh and Santos, 1965

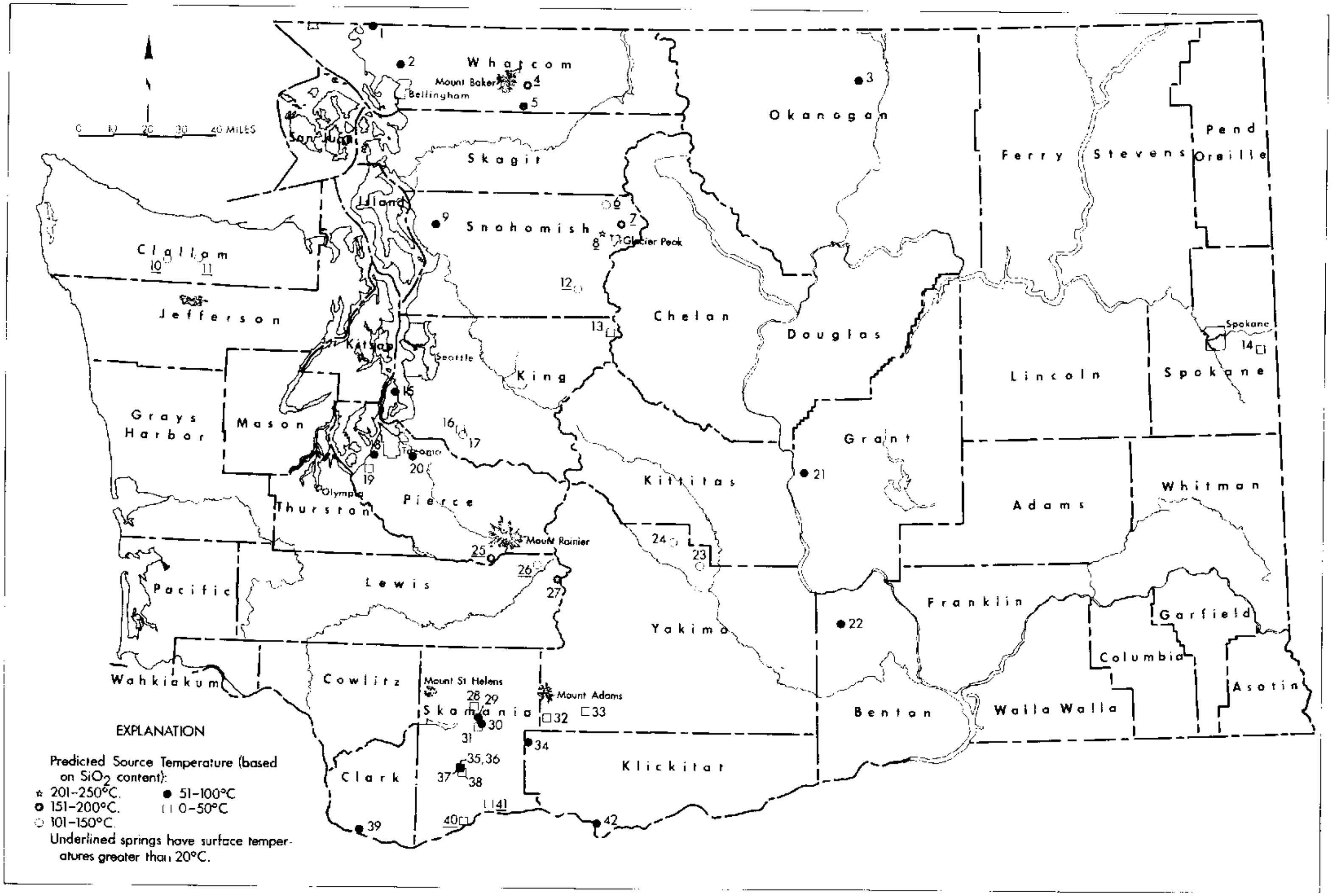


FIGURE 2.—Selected springs in Washington. (See table 1 for analytical data and predicted source temperatures. Spring numbers on this page correspond with map numbers of table 1.)

and it is possible that different investigators sampled different springs that are here reported as the same spring, or that they sampled the same spring at different places along its discharge channel. This might account for some of the variability among what appear to be replicate analyses of the same spring.

The Na/K method was developed to assess data from near-boiling springs, and the method may not be applicable to some of the low temperature waters included in table 1. Low absolute quantities of Na and K in some of these waters might also cause large percentage errors in the analyses (the difference between 1 and 2 parts per million is more difficult to distinguish than the difference between 100 and 200 parts per million) and errors in the resulting Na/K values.

In short, silica temperatures for the springs of table 1 are probably usable, but the possibility of errors must be realized. Na/K temperatures are clearly not as good, and, according to Fournier and Truesdell (1970), "Little reliance should be placed on this ratio (Na/K) as a temperature indicator unless the estimated temperatures also have some support from other data such as silica."

It is interesting to note that the five springs with estimated silica temperatures above 150°C are located near Mount Baker, Glacier Peak, and Mount Rainier (see figure 2), while no equivalent silica temperatures were found associated with Mount St. Helens, Mount Adams, or the large field of young volcanics in the Southern Cascade Mountains. Possibly there has not been enough sampling and analysis of thermal waters in the Southern Cascades to reveal springs with high source temperatures.

RESOURCE ESTIMATES

It may be worthwhile to formulate some ideas about the magnitude of Washington's geothermal resource potential. Such a formulation might lead to a better understanding of the importance of geothermal energy.

If we assume that Washington, on the average, has a normal geothermal gradient of about 30°C/km (degrees Celsius per kilometer) that begins at a surface temperature of 10°C, and we consider all rock down to a depth of 30,000 feet (9.14 km), then the average temperature of this rock is

$$\frac{(9.14 \text{ km})\ (30^\circ\text{C/km})}{2} + 10^\circ\text{C} = 147^\circ\text{C}.$$

Since Washington's area is about 69,127 square miles (179,038 km^2), we have

$$(179{,}038 \text{ km}^2)\ (9.14 \text{ km}) = 1{,}636{,}000 \text{ km}^3$$

of rock above a depth of 30,000 feet at an average temperature of about 147°C. If we assume that this rock has a granitic composition, the heat released in cooling each cubic kilometer is about 6.4×10^{16} calories (White, 1965, p. 14). The total stored heat in rocks of the crust to a depth of 30,000 feet in Washington is

$$(1{,}636{,}000 \text{ km}^3)\ (6.4 \times 10^{16} \text{ cal/km}^3) = 1.05 \times 10^{23} \text{ cal}.$$

Since one calorie equals 1.16×10^{-6} kilowatt hours, the electrical equivalent of this stored heat is

$$(1.05 \times 10^{23} \text{cal})\ (1.16 \times 10^{-6} \text{kwh/cal}) = 1.2 \times 10^{17} \text{ kwh}.$$

Washington used about 6×10^{10} kilowatt hours of power in 1970 (Livingston, 1972), so Washington's total stored heat in the upper crust is, theoretically, sufficient to supply its 1970 power needs for

$$\frac{1.2 \times 10^{17} \text{kwh}}{6 \times 10^{10} \text{kwh/yr}} = 2{,}000{,}000 \text{ years}.$$

Washington's geothermal resource cannot, of course, supply our needs for 2 million years, because we do not possess the technology to extract all of this heat. We do have the ability to extract heat from the earth's crust if a body of hot igneous rock brings the heat near the surface, if a fluid is present to transfer heat to the surface, and if several other geologic conditions are favorable, as outlined earlier in this paper. With these conditions in mind, it is possible to calculate a more realistic estimate of Washington's geothermal-energy potential.

Washington has about 1,300 square miles ($3,400 \text{ km}^2$) of Tertiary intrusive rock exposed at the surface (Huntting and others, 1961). If these rocks are assumed to extend to a depth of 30,000 feet (9.14 km), then their volume is

$$(3,400 \text{ km}^2)\ (9.14 \text{ km}) = 31,000 \text{ km}^3.$$

These rocks range in age from 50 million to 13 million years—a time span of 37 million years (my) (Grant, 1969, p. 23, 26). This means that the rate of intrusion during most of the Tertiary Period was about

$$\frac{(31,000 \text{ km}^3)}{37 \text{ my}} = 840 \text{ km}^3/\text{my}.$$

If this rate of intrusion is assumed to have continued to the present, then 840 cubic kilometers of intrusive rock have been injected into the earth's crust in Washington during the last one million years. If actually present, these intrusive rocks would probably still be buried, and could retain a considerable fraction of their heat. Rocks of granitic composition give up about 7×10^{17} calories per cubic kilometer on cooling from 900°C to mean-earth-surface temperature (White, 1965, p. 14), so, assuming that only 10 percent of these rocks are still molten, they would, theoretically, contain

$$(7 \times 10^{17} \text{cal/km}^3)\ (0.1)\ (840 \text{ km}^3) = 5.9 \times 10^{19} \text{ cal}.$$

The equivalent electrical energy is

$$(5.9 \times 10^{19} \text{cal})\ (1.16 \times 10^{-16} \text{kwh/cal}) = 6.8 \times 10^{13} \text{kwh},$$

enough to supply Washington's 1970 electrical needs for

$$\frac{6.8 \times 10^{13} \text{ kwh}}{6 \times 10^{10} \text{ kwh/yr}} = 1,100 \text{ years}.$$

If conditions are right for the existence of geothermal reservoirs in only 10 percent of this young, hot granitic rock, and only 10 percent of the heat in these reservoirs can be economically converted to electricity, geothermal resources in Washington would, in theory, be able to supply the state's power needs for

$$(1,100 \text{ years})\ (0.1)\ (0.1) = 11 \text{ years}.$$

This estimate is probably quite conservative because only the exposed area of Tertiary intrusive rocks was used in the calculations. It is likely that the area underlain by Tertiary intrusives is larger than 1,300 square miles—many intrusives are probably at least partially covered.

Blackwell (this volume) considers that all parts of Washington east of the western foothills of the Cascade Mountains have equal probability for the presence of geothermal anomalies, because the entire area is characterized by high mantle heat flow. In making the above estimate of geothermal potential, based on an area of exposed Tertiary intrusive rocks, no consideration could be given to blind or covered intrusive rocks, but their existence would certainly increase Washington's geothermal energy potential.

SUMMARY

Washington's five large stratovolcanoes, large fields of young lava flows in the Southern Cascade Mountains, and thermal or mineral springs are evidence of geothermal potential. Five of the springs yield silica temperatures in excess of 150°C (Kennedy, 227°C; Longmire, 168°C; Summit Creek, 168°C; Gamma, 160°C; and Mount Baker, 157°C), and Na/K temperatures are in reasonable agreement for Kennedy, Longmire, and Mount Baker springs. Barring analytical errors, Mount Baker, Glacier Peak, and Mount Rainier, around which these springs are located, must be considered prime geothermal targets. More data must be collected before any assessment of their power potential is made.

Although chemical analyses have, so far, failed to indicate high subsurface temperatures in the young lava fields of the Southern Cascade Mountains, the area has yet to be thoroughly tested. Detailed geologic studies, geochemical sampling of springs, and geophysical investigations need to be continued or begun before an intelligent evaluation of geothermal potential can be made in this area. For example, the young volcanic centers on Hammond's map (figure 1), except for Mount Rainier, Mount St. Helens, Mount Adams, and a few others, have not been studied in detail. Any of these young centers of volcanism might turn out to be the site of a fluid-filled geothermal reservoir, or a hot, buried body of dry magmatic rock.

Although no geothermal reservoirs or hot, buried bodies of magma have been located in Washington, it is possible to calculate the hypothetical magnitude of Washington's geothermal resources. If it is assumed that the state's average geothermal gradient is 30°C/km, then the heat stored above a depth of 30,000 feet is about 1.05×10^{23} calories—equivalent to 1.2×10^{17} kilowatt hours—or enough to supply Washington's 1970 electrical power needs for 2 million years. Since we do not have the technology to extract this heat, a more meaningful estimate of geothermal reserves may be calculated by determining the rate of igneous intrusion during the Tertiary Period and assuming that this rate has continued to the present. Using this method, geothermal resources in Washington are estimated as 5.9×10^{19} calories—equivalent to 6.8×10^{13} kilowatt hours—or enough to supply Washington's 1970 electrical power needs for 1,100 years. If geothermal reservoirs exist in only 10 percent of the young intrusive rock, and only 10 percent of the heat from these reservoirs can be converted to electricity, then a conservative estimate of Washington's geothermal resources is 5.9×10^{17} calories—equivalent to 6.8×10^{11} kilowatt hours—or enough to supply Washington's electrical power needs for 11 years. It is not practical to assume that geothermal energy will ever supply all of Washington's electrical power needs because existing power installations will be in operation well into the future. It is, perhaps, more desirable to state that geothermal energy could supply 10 percent of Washington's electrical power needs, at the 1970 level, for about 110 years.

Discussion of geothermal potential has been confined mostly to the Cascade Mountains and particularly to the Southern Cascades because this is the area where surface manifestations of geothermal energy occur. Because of low heat flow west of the Cascades this part of Washington probably has little geothermal potential; however, it is possible that sources of geothermal energy exist in eastern Washington (Blackwell, this volume, p. 31) without surface expression. Therefore, based on heat-flow studies, all of Washington east of the western foothills of the Cascade Mountains must be considered as having geothermal potential. Because volcanoes, young lava flows, thermal and mineral springs, and prospectively favorable geologic structures exist in the Cascades and particularly the Southern Cascades, this area must be considered the most likely for the discovery of geothermal resources with the least expenditure of time and money.

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TERRESTRIAL HEAT FLOW AND ITS IMPLICATIONS ON THE LOCATION OF GEOTHERMAL RESERVOIRS IN WASHINGTON

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Information Circular 50, Energy Resources of Washington
1974

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INTRODUCTION

The most direct way to study the geothermal potential of an area is to study the variations in the escape of heat from the earth's interior, together with the distribution of recent volcanic rocks and of hot springs. Previous studies of heat flow in the western United States have included a few measurements in the State of Washington (Roy and others, 1968b; Blackwell, 1969; Sass and others, 1971). However, no previous study has focused in any detail upon Washington. The density of heat-flow data in Washington is now as great or greater than for any other state in the western United States; therefore, the thermal pattern is moderately well understood and may serve as a model for understanding the thermal pattern in the rest of the western United States.

HEAT FLOW

GENERAL

Preliminary values of heat flow are presented for 12 different localities in Washington (table 1, figure 1). In addition, gradient data are presented at an additional two localities. Most of the heat-flow determinations in the Cascade Range and in the Okanogan Highlands are from holes drilled for the purpose of mineral exploration, and cuttings or core samples from the holes were made available to the author for thermal conductivity measurements by the exploration companies.

The mechanical details of data acquisition and reduction are summarized by Roy and others, (1968b). The data are listed in table 1. In the table, the gradients are least-squares straight lines fitted to the temperature-depth data, and the conductivity values listed are mean harmonic averages. The geothermal gradients listed are the measured values uncorrected for topography or other effects. Standard errors are shown beneath the appropriate data entry. All of the heat-flow values were calculated either as the product of the least-squares gradient and the average harmonic thermal conductivity, or by fitting a least-squares straight line to the summed thermal resistence and temperatures. Topographic corrections have been applied to all of the heat-flow values listed in table 1. The corrections were calculated in the conventional way (Birch, 1950) and were carried to a distance of 20 kilometers, in most instances. Individual heat-flow measurements will not be discussed here; only the general results will be discussed according to the physiographic provinces outlined in figure 1.

Before discussing the data in detail, however, some general comments about heat-flow information are necessary. In general, the heat flow measured at the surface on a continent is the sum of several components. The two components that usually predominate are the heat flow from the deep interior of the earth (below the crust), and the heat flow generated by the decay of the enclosed uranium, thorium, and potassium in the rocks of the crust. In local areas there may be additional significant components from other causes, such as local heat-source anomalies (for example, high-temperature ground water or shallow crustal magmatic heat sources). In order to evaluate the possibility that a particular measurement reflects a nearby geothermal anomaly, all other components must be subtracted from the measured heat flow.

In the absence of local anomalies, the heat-flow measurements at the surface in plutonic rocks should show a scatter related to the mantle heat flow and

TABLE 1.—Preliminary measurements of gradient, thermal conductivity, and heat flow in Washington

Locality	North latitude	West longitude	Conductivity millical cm sec°C	Geothermal gradient °C/km	Corrected heat flow μcal/cm^2 sec	Geologic unit
Okanogan Highlands						
Curlew	49°00'	118°36'	7.6 [0.3][1]	25.2 [0.6]	1.7	Mesozoic greenstone
Nespelem(3)[2]	48°22'	118°53'	7.8	18.1	1.7	Mesozoic granodiorite
Oroville	49°00'	119°29'	7.6 [0.2]	25.2 [0.1]	1.7	Mesozoic greenstone
Reardan(2)	47°52'	118°07'	7.8	25.6 [0.5]	2.1	Mesozoic quartz monzonite
Republic	48°40'	118°46'	5.7 [0.1]	31.1 [0.2]	1.8	Oliogocene volcanics
Tonasket	48°43'	119°31'	8.3 [0.3]	20.0 [0.3]	1.8	Mesozoic quartz monzonite
Columbia Plateau						
Odessa	47°20'	118°55'	4.0 [0.5]	42.0 [2.0]	1.7	Miocene basalt
Cascade Range						
Mazama	48°37'	120°23'	6.2 [0.1]	24.0 [0.1]	1.7	Mesozoic metamorphics
Randle(2)	46°21'	122°06'	9.0	17.0 [2.0]	1.5	Cenozoic intrusives and extrusives
Roslyn	47°13'	121°00'		21.0		Eocene sediments
Trinity	48°06'	120°50'		55.0 [10.0]		Mesozoic granitic rock
Wenatchee	47°22'	120°18'	5.2 [0.5]	26.8 [0.2]	1.5	Eocene sediments
Puget-Willamette Depression						
Anacortes	48°28'	122°38'	7.8 [0.1]	12.1 [0.2]	0.9	Pre-Mesozoic quartz diorite
Coast Ranges						
Westport	46°51'	124°06'	3.5 [0.1]	26.5 [2.2]	0.9	Pleistocene sediments

[1] Bracketed numbers are standard errors.

[2] The numbers in parentheses following some locality names are the number of drill holes used at that locality.

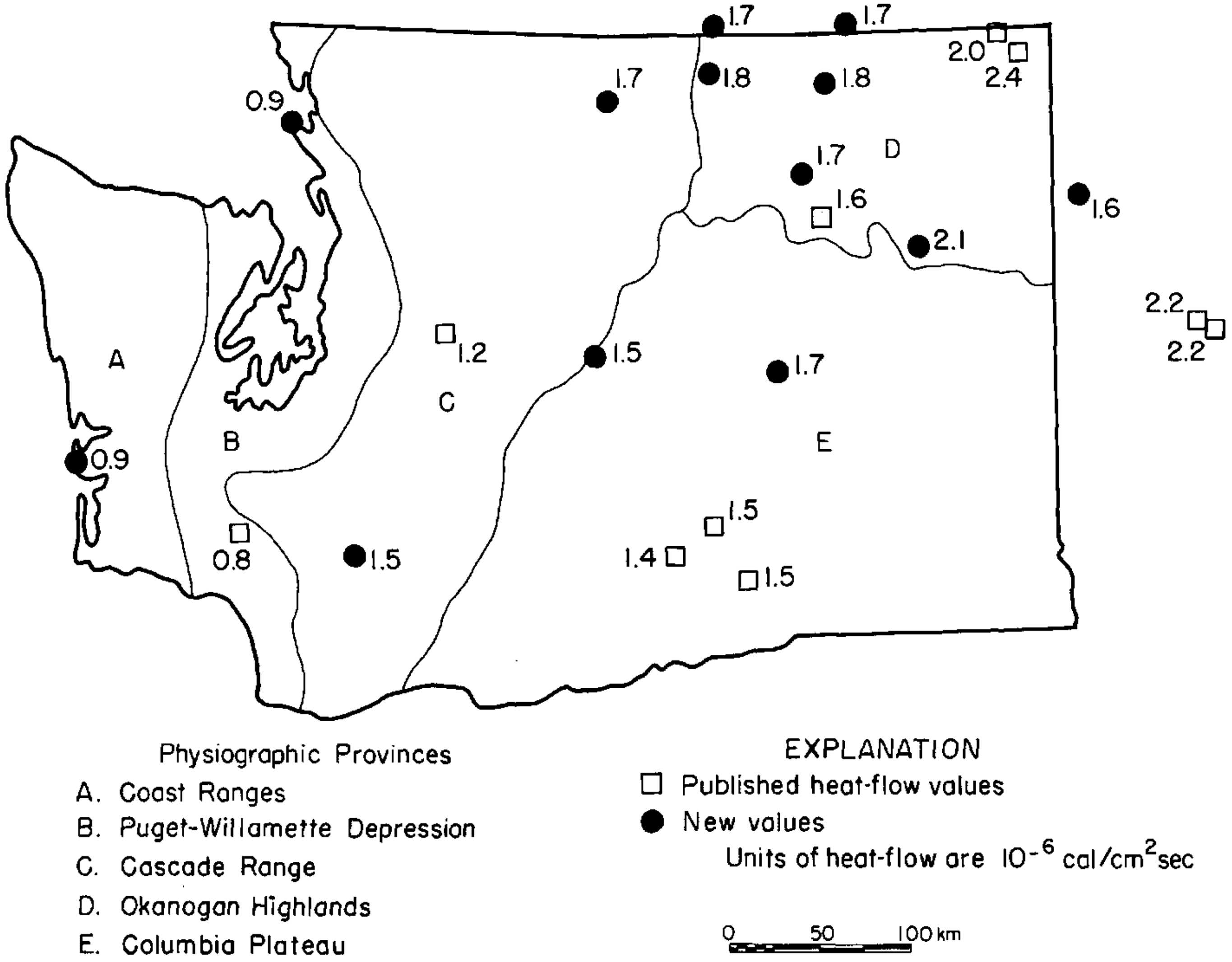

FIGURE 1.—Physiographic provinces and preliminary heat-flow measurements of Washington.

the heat production (from U, Th, and K) of the plutonic rocks (Roy and others, 1968a). In areas where the holes penetrate sedimentary rocks, the appropriate heat-production value to use would be calculated from the basement radioactivity. The vertical average distribution of radioactivity for plutonic rocks is related simply to the surface value (Roy and others, 1968a; Lachenbruch, 1968, 1970).

For plutonic rocks the relationship between surface heat flow and the measured surface heat production is a straight line. The intercept value of this straight line is the heat flow from beneath the radioactive layer (from below 20 to 30 kilometers). The slope of this straight line has the dimensions of length; that is, kilometers. The value of the slope is the scale depth for the distribution of surface heat production. If the slope of the line is known for a particular area, then the contribution of the heat production from radioactive elements in the crust to a particular heat-flow measurement can be calculated by multiplying the value for the slope of the line times the measured heat production. If this value is then subtracted from the measured surface heat flow, the resulting value would be the mantle contribution plus any contribution that might be present from a shallow geothermal source. This value can then be compared with the intercept value (a known constant) for the particular province to determine whether or not there is a near-surface anomaly present in the data. In general, measured surface heat-flow values in excess of 3.0 μcal/cm^{2}sec may be considered immediately to be anomalous. Lower values may also reflect a local anomaly, but the effect of heat production must be considered for those cases. For further discussion see Blackwell (1971) and Roy and others (1972).

Figure 1 shows physiographic provinces and the measured surface heat-flow values. Figure 2 shows values of reduced heat flow, from which have been subtracted the crustal contribution in the manner outlined above. The scale depth used is 10 kilometers. So for an average crustal granitic rock with a heat

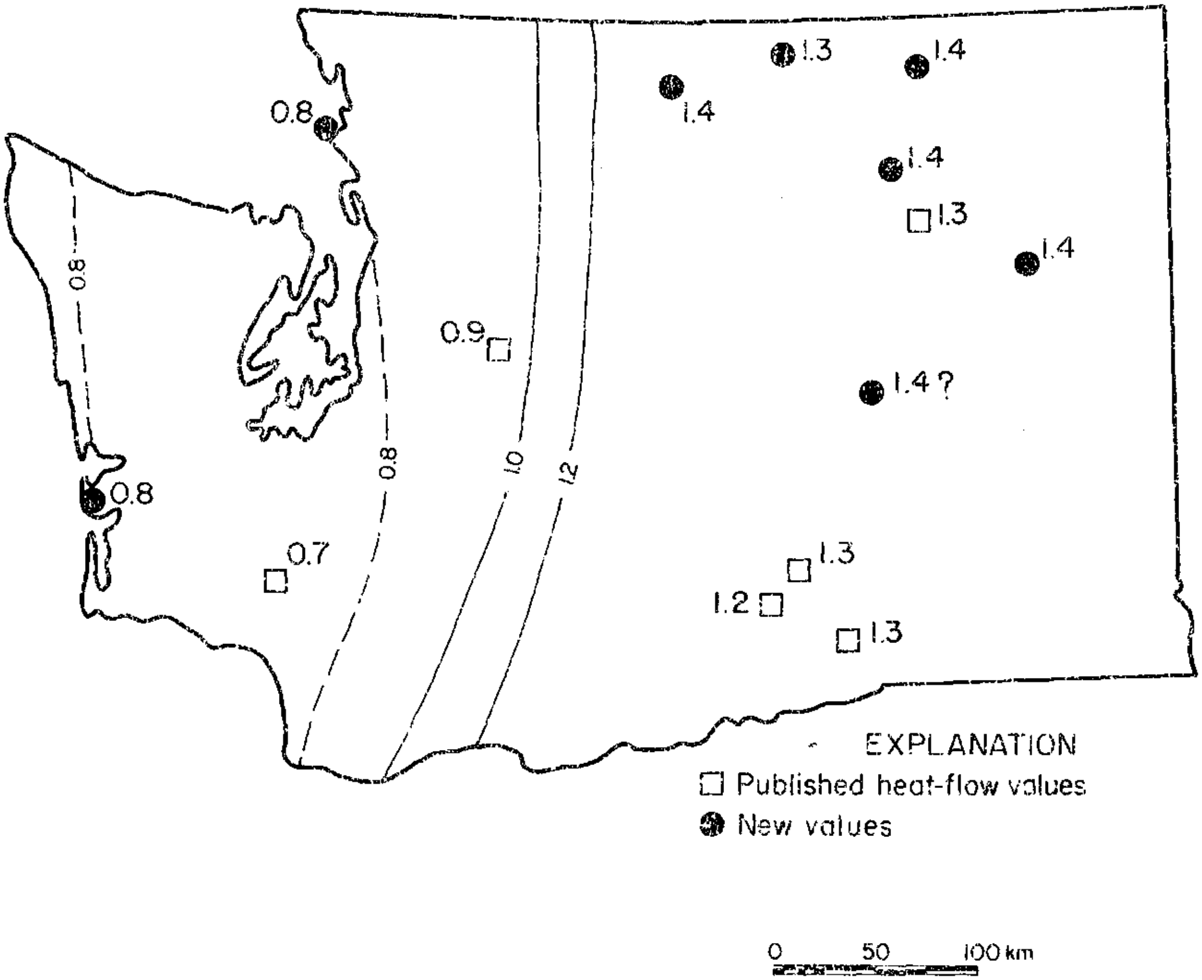

FIGURE 2.—Reduced heat-flow values (heat-flow values minus the crustal component from the decay of U, Th, and K). Calculated by subtracting the heat production times 10 kilometers from the measured surface heat-flow. Values of > 1.3 are characteristic of the areas of Cenozoic volcanism in the wesrern United States.

production of about 5.0 X 10^{-13} cal/cm^3sec, a heat flow of 0.5 μcal/cm^2sec would be attributed to the crust. The areas of high heat flow in the western United States seem to be characterized by a mantle heat flow (reduced heat flow) of approximately 1.4 ± 0.1 μcal/cm^2sec (Roy and others, 1972). Thus if a value shown in figure 2 falls significantly below 1.4, then the area would presumably not be part of the anomalously high mantle heat-flow area. On the other hand, if a single value falls much above 1.4, then that value has an extra component of heat flow, perhaps due to a geothermal reservoir.

OKANOGAN HIGHLANDS

Detailed heat-flow measurements at six new localities are available for the Okanogan Highlands. These heat-flow values range from 1.7 to 2.1 μcal/cm^2sec (table 1 and fig. 1). The average of these values, together with the three previously published values (Blackwell, 1969; Roy and others, 1968b), is 1.87 ± 0.24 μcal/cm^2sec. Use of the heat production measurements to estimate and remove the component of heat flow due to the crustal radioactivity sources results in the values shown in figure 2. The scatter of data is obviously much reduced (corresponding values cannot be calculated for the heat-flow values in the sedimentary rocks of the Kootenay Arc and therefore these points do not appear on the map). The scatter of values is from 1.3 to 1.4 μcal/cm^2sec, well within the range to be expected for the mantle heat flow in what has been called the Cordilleran Thermal Anomaly Zone (the Basin and Range Province, the Columbia Plateau and the northern Rocky Mountains; Blackwell, 1969; Roy and others, 1972). Thus, it appears from this limited data that no areas are indicated where a heat-flow component due to any local geothermal source is present. A much more extensive program of heat-flow measurements would be necessary, however, to prove that no local geothermal sources exist in the Okanogan Highlands.

COLUMBIA PLATEAU

One new heat-flow measurement (table 1) is included for the Columbia Plateau Province. Together with the three published values of heat flow (Sass and others, 1971), these data suggest an average heat flow for the Columbia Plateau between 1.4 and 1.7 μcal/cm^2sec. Gradient values measured in the Columbia Plateau basalts are subject to uncertainty due to the large and presently unpredictable effect of vertical and horizontal ground-water flow in the porous interbeds, both regionally and within a well bore. The gradient presented for the hole near Odessa (Development Associates, Basalt Explorer No. 1) was obtained below a depth of about 3000 feet because above that depth water circulation destroyed the geothermal gradient. On the basis of unpublished data it does appear that there are high gradients (up to 60° C/km) in some wells to the east of approximately 119°W. longitude; however, these estimated gradients in water wells may be seriously in error. The hole near Odessa bottoms in granitic rock. If this granitic rock is similar in heat production to the rocks outcropping to the north, then the reduced heat flow would again be approximately 1.4. However, farther south the actual surface heat flow is only 1.4 to 1.5 μcal/cm^2sec. There, seismic studies (Hill, 1972) suggest that no granite crust is present and that the total crustal section consists of about 20 kilometers of basalt and gabbro. Thus the crustal heat production contribution to the heat flow will be very small (perhaps on the order of .1 to .2 μcal/cm^2sec), and reduced heat-flow values will be in the range of 1.2 to 1.3 μcal/cm^2sec, very similar to values to the north. Therefore, although the surface heat-flow values are somewhat lower in the Columbia Plateau than in the Okanogan Highlands, it would appear that the actual mantle heat flow is nearly the same, and both provinces are part of a region of anomalously high mantle heat flow.

CASCADE RANGE

Only scattered heat-flow data are available from the important Cascade Range Province. Heat-flow data that are available suggest that the province contains a transition in mantle heat flow. Heat-flow measurements are particularly difficult to make in the Cascades because of the extremely rugged topography, and because the rocks seem to be pervasively fractured and subject to large flows of ground water through these fractures. Due to the many uncertainties none of the heat-flow measurements in the Cascades are considered to be as reliable as those made to the east or the west. However, as mentioned previously, the heat-flow values available do tend to suggest a transition in mantle heat flow somewhere near or west of the center of the Cascade Range. Because of this transition it is more difficult to evaluate the heat-flow measurements for the possibility of local geothermal anomalies. Furthermore, because of the variable heat production of plutons in the Cascades, it is more difficult to estimate what the basement heat production might be. None of the presently measured heat-flow data are interpreted to reflect geothermal anomalies; however, it is possible that at the Trinity locality (where only an approximate gradient is available) the heat flow may be "anomalously" high.

COASTAL PROVINCE

The Coastal Province consists of the Puget-Willamette Depression and the Coast Ranges. All the observed heat-flow values in this area are low. Geological reconstructions suggest that the crustal section in this area is a sequence of continental-margin marine sediments with intercalated basalts, probably sitting upon an oceanic type crust (Snavely and Wagner, 1963, for example). Therefore, as in the case of the Columbia Plateau, the crustal contribution to the radioactivity will be small, and the measured surface heat-flow values will be within .1 to .2 μcal/cm^{2}sec of the mantle heat flow. The one value of heat flow in this region measured in basement rocks is on Fidalgo Island (Anacortes) in the Turtleback Complex. Here the reduced heat flow is essentially the same as the surface heat flow because of the extremely low heat production of the rock. However, because of the structural complexities of the area (see Misch, 1966), it is entirely possible that the Turtleback rocks are sitting on top of an oceanic crustal section similar to that beneath the other heat-flow measurements. If so, again, the reduced heat flow would be approximately .8 μcal/cm^{2}sec. Heat-flow measurements are not available for the area of Olympic National Park; however, unless the heat flow there is much higher than it is in the surrounding terrain, it would appear that the hot springs there (Olympic and Sol Duc Hot Springs) must be due to deep circulation rather than to a shallow source of magmatic heat (the relatively low source temperatures given by Schuster, this volume, table 1, tend to support the idea that shallow sources of magmatic heat are absent).

OFFSHORE AREAS

Offshore the heat flow rapidly increases so that along the Juan de Fuca Rise, several hundred kilometers offshore, heat-flow values are extremely high, up to 7 to 10 μcal/cm^{2}sec. These high values of heat flow are interpreted to be due to the formation of new crustal material along the rise. It is possible that with advances in technology the vast amount of heat in the high temperature crustal material offshore might be utilized in the future (Lister, 1973).

GEOTHERMAL POTENTIAL

Based on heat-flow data alone, the State of Washington can be divided into two parts in terms of geothermal potential. From the western foothills of the Cascades to the Pacific, on the basis of the present data, the possibilities for developing economic geothermal reservoirs are small. About the only type of resource that might be present would be moderate-temperature water at fairly great depths (the maximum gradient in the area would appear to be about 30° C/km). On the other hand, all parts of the state from the western foothills of the Cascades to the Idaho border have an equal probability for the presence of geothermal anomalies. The mantle heat flow in these areas, which is the important parameter, is as high as in any other large area in the western United States, such as the Basin and Range Province in Nevada, where many geothermal anomalies have already been identified.

However, the lack of recent volcanics and the relative paucity of hot springs in the Okanogan Highlands and Columbia Plateau Provinces suggest that if geothermal anomalies are present they have little or no surface expression, and thus may be much more difficult to locate than areas that are leaky (associated with hot springs or other thermal features). Nonetheless, in other such areas of the western United States it would appear that as much as 5 to 10 percent of the total surface area might be involved in geothermal anomalies having little or no surface expression. For example, Blackwell and Baag (1973) have described a blind geothermal anomaly in the Precambrian Belt Series rocks of Montana. Observed surface gradients there are as high as 250° C/km, even though there are no surface manifestations of abnormally large gradients. Such blind sources cannot be ruled out in the Okanogan Highlands or the Columbia Plateau Provinces at the present time. In addition, low-grade geothermal resources, in the form of medium- to high-temperature ground water should be present in many areas of these two provinces. The area of young basalt volcanism in Klickitat, Yakima, and Skamania Counties is unfortunately not represented by any heat flow or gradient data. The area appears geologically very attractive and perhaps data can be obtained there in the future.

If geothermal anomalies are actually present in the Columbia Plateau, they may be very difficult to locate because of the pervasive influence of ground water circulation. In the Okanogan Highlands the density of heat-flow measurements is relatively high; but, to fully explore the area for geothermal potential, heat-flow measurements with a spacing of 5 to 10 kilometers would be necessary. So geothermal anomalies may still be discovered there.

The province that looks most attractive from the combined information on heat flow, recent volcanism, and hot spring activity is the Cascade Range. However, some of the problems that might be encountered in prospecting for geothermal reservoirs in the Cascade Range have already been pointed out. These are the same ones that make the measurements of the background heat flow difficult—steep topography, fracturing, and high rainfall.

ORIGIN OF THE HEAT-FLOW PATTERN

As illustrated in figure 2, the heat-flow pattern in Washington is predominated by a transition in heat flow corresponding approximately to the western foothills of the Cascades. East of these foothills, the temperatures in the earth are high and there has been

Cenozoic volcanism and tectonic activity. To the west of this boundary, heat flow is abnormally low and the tectonics have been dominated by continental-margin type interactions. This two-part distribution of heat flow is inferred to be related to the presence of a subduction zone off the Oregon and Washington coasts during most of the Cenozoic (Blackwell, 1971; Blackwell and others, 1973).

It has been suggested that during most of Cenozoic time a lithospheric block, called the Farallon Plate (Atwater, 1970), has been overridden by the North American continent. As this lithospheric plate sank into the mantle, it formed a zone of tectonic activity in western North America, similar to the island arc areas in the western Pacific. The heat-flow pattern associated with these island arc areas consists of abnormally low heat flow between the trench and the first volcanic arc, and a region of high heat flow from the first volcanic arc inward for a distance of several hundred kilometers (Matsuda and Uyeda, 1971). At the present time, the tectonics of the Northwestern United States still reflect this interaction. Only a small remnant of the Farallon Plate, between the Juan de Fuca Rise and the North American continent, remains. This plate is spreading away from the Juan de Fuca Rise and is sinking beneath the Northwestern United States.

The magmatic front, or the first volcanic island arc, is represented in the Northwestern United States by the chain of Cascade volcanoes (see Dickinson, 1970); therefore, the outer arc or low heat-flow region consists of the Puget-Willamette Depression and the Coast Ranges, whereas the high heat-flow inner region is composed of the Okanogan Highlands, Columbia Plateau, and Cascade Range Provinces.

Although this pattern is still being actively reinforced in the Northwestern United States, the pattern in the Southwestern United States is more complicated as the Farallon Plate has completely disappeared and there is strike-slip motion (the San Andreas Fault) between the Pacific Plate and the North American Plate (Atwater, 1970). The pattern in the Northwestern United States also extends northward into Canada (Judge, 1973; Hyndman, 1973). Thus it appears that the Northwestern United States is the type example of the behavior which is thought to have been characteristic of the whole western United States during the Mesozoic and the first half of the Cenozoic.

ACKNOWLEDGMENTS

The cooperation of many mining companies and individuals is greatly appreciated. The research work was supported by National Science Foundation grant GA11351.

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COAL IN WASHINGTON

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Information Circular 50, Energy Resources of Washington

1974

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By

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INTRODUCTION

Because of tremendous coal reserves in the United States, coal should play an important part in helping to relieve the nation's energy crisis. The maximum projected production for the next 15 years indicates that a little over 1 percent of the nation's 780 billion tons of recoverable coal will be used. In 1971, 500 million tons of coal supplied 19 percent of the energy consumed in the United States. By 1985, over 850 million tons will be required to supply 17 percent of the nation's energy requirements. Considering all uses of coal, the National Coal Association estimates that the demand for coal in 1973 will be around 648 million tons, whereas in 1985 it will rise to approximately 1,150 million tons. The bulk of the production will be consumed by electric utility companies, while the remaining production will be shared by industrial plants, coke manufacturers, community and residential users, and by producers of synthesized gas.

The production of synthesized gas, through coal gasification, appears to be a partial solution to the shortage of natural gas that is expected to occur in the next 20 years. However, the coal-gasification industry is not expected to be fully mobilized until around 1980, at which time an additional 300 million tons of coal per year will be required to supply the industry.

Although the nation's coal reserves appear adequate for several hundred years, environmental, labor, and transportation problems, as well as governmental leasing policies, could seriously hamper coal mining to the point where production may not meet future demands. As an example, 60 percent of the coal mined today will not meet (1973) EPA air quality standards.

Although Washington has over 6 billion tons of recoverable coal, it is not an abundant economic resource. With the exception of the Centralia coalfield, most individual fields are limited in quantity, are of variable composition, and because of steeply-dipping beds and great thicknesses of overburden, many beds are not suitable for low-cost, open-pit mining operations. These factors contribute to the high cost of Washington coal and make it impossible for the state's coal producers to compete in out-of-state markets. The average cost of Washington coal in 1972 was $8.21 per ton, whereas the national average was $4.99. In 1972, the average cost of Montana coal was only $2.18 per ton. Improved underground mining methods, such as using a jet of water under very high pressure to break up the coal, may result in lower mining costs for Washington coal. Hydraulic mining methods are being used with success in foreign countries and are being studied by at least one coal company in Washington. However, in order to be competitive with other coal producers, the cost of mining Washington coal in underground mines should not exceed $5.00 per ton.

In spite of apparent coal production obstacles, the use of coal as fuel for coal-fired electric power plants in Washington will probably increase. However, until the state's coal can be mined at a lower cost, much of the coal will have to be supplied by out-of-state producers.

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[1] Report modified from Livingston, Vaughn E., Jr., 1973, Seam analyses and description of U.S. coalfields [Washington]. In 1973 Keystone Coal Industry Manual: Mining Informational Services, Keystone Coal Industry Manual, McGraw-Hill Mining Publications, p. 545-551.

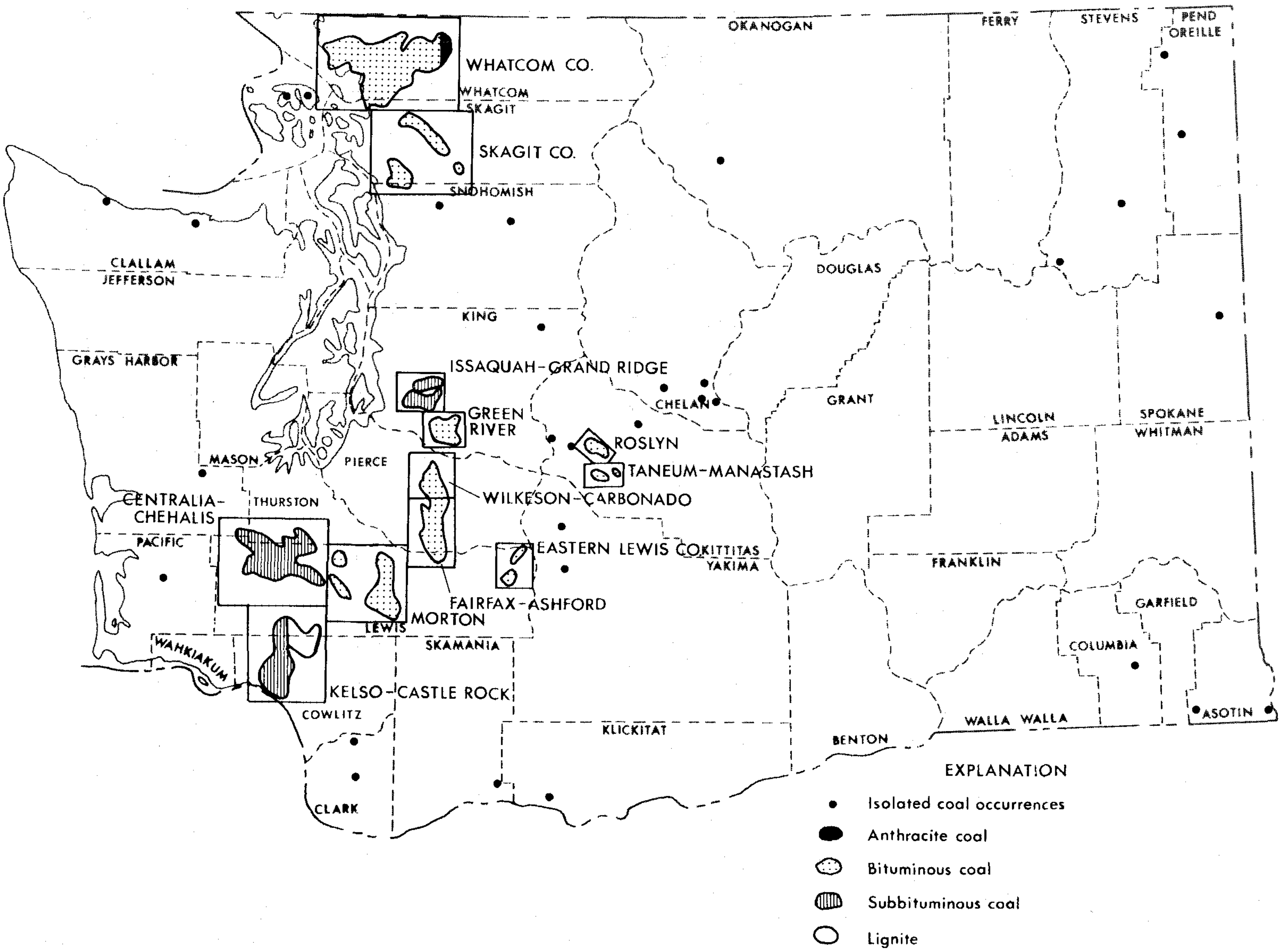

FIGURE 1.—Principal coal areas and isolated occurrences of coal in Washington (modified from Valentine, 1949, plate 9).

COAL MINING IN WASHINGTON

At the end of 1972, only four companies were mining coal in Washington. The most significant of these is the Centralia Steam-Electric Project where coal is mined to supply fuel for a steam-electric generating facility. Annual production of coal in Washington is about 3 million tons, of which 99 percent is mined at the Centralia strip mine.

The active coal mining companies in Washington are Washington Irrigation & Development Co. of Centralia, Black Prince Coal Co. of Centralia, Queen Coal Co. of Wilkeson, and Palmer Coking Coal Co., Inc. of Black Diamond. Washington Irrigation & Development Co. operates the Centralia strip mine and supplies coal exclusively to the steam plant located in the Hannaford Valley, just east of Centralia. Because the facility has only been in operation a short time, a reliable annual average production has not been established. During 1972 the company produced approximately 2,650,000 short tons of coal from the Big and Smith seams.

Black Prince Coal Co. produces about 9,000 to 10,000 short tons of coal annually. The company's production is used totally for domestic heating in the Centralia area. The coal is being mined from the Victory seam.

Queen Coal Co. sells most of their coal to the Wilkeson stone quarry where it is used to produce steam. Almost all of the rock sawing, drilling, and hoisting equipment at the stone quarry are steam operated. Annual production of the Queen Coal Co. is about 400 tons a year, with a small amount being sold for domestic heating. The coal is being produced from the Wingate seam. Because of poor stratigraphic control and complications due to faulting, the Wingate was not correlated with any of the coal seams listed in the analyses or thickness and reserves tables.

Palmer Coking Coal Co. produces about 30,000 short tons of coal a year, most of which is used for industrial heating. The company estimates that no more than 2 or 3 percent of the annual production is purchased for domestic heating. The coal is being produced from the Rogers seam.

RESERVES

Most of Washington's coal reserves occur in areas along the western foothills of the Cascade Mountains. The reserves occur in a discontinuous string of fields from near the Canadian border on the north to the Columbia River in the vicinity of Longview in Cowlitz County to the south. Other significant reserves occur on the eastern flanks of the Cascade Range in the vicinity of Cle Elum in Kittitas County.

Estimated reserves of coal in the state as of January 1, 1973, are as follows:

	Millions of Short Tons
Anthracite	5
Bituminous	1,868
Subbituminous	4,191
Lignite	117

Mining in the bituminous areas of the state has removed about 1.25 million tons of coal during the last 12 years. A new strip mining operation to supply coal for a steam power plant has removed about 3.5 million tons of subbituminous coal in the last 2 years (1971-1972). Estimates above, of coal in place, were extended to a depth of 3,000 feet and include measured, indicated, and inferred reserves.

STRUCTURAL GEOLOGY

In general, the coal measures of Washington occur in rocks that have undergone considerable tectonism. Folding and faulting are common and some beds have dips of 90°. Only in a few areas are dips gentle enough to permit strip mining. The most severely contorted beds are in the Glacier anthracite area of Whatcom County where the beds have been extensively folded, faulted, and sheared. The amount of deformation seems to have had some control in developing the rank of the coal, and, in some cases, may be responsible for certain other properties such as desirability for coking.

COAL-BEARING ROCKS

Coal-bearing rocks of Washington are all Tertiary in age. They range in age from Paleocene in Whatcom and Skagit Counties to Oligocene in Cowlitz County, however, most of the coal-bearing rocks are middle Eocene in age. In western Washington the coal generally occurs in nonmarine rocks that grade westward into marine rocks. In eastern Washington the coal occurs in isolated nonmarine Tertiary sedimentary basins.

COAL-BEARING AREAS

Twelve coal-bearing areas can be identified in Washington. They are shown in figure 1, which indicates the rank of coal produced from these areas, and also shows areas where isolated occurrences of coal have been reported. These twelve areas are listed below:

1. Whatcom County
2. Skagit County
3. Issaquah-Grand Ridge
4. Green River
5. Wilkeson-Carbonado
6. Fairfax-Ashford
7. Centralia-Chehalis
8. Morton
9. Eastern Lewis County
10. Kelso-Castle Rock
11. Roslyn
12. Taneum-Manastash

The fields in Whatcom and Skagit Counties occur in the Bellingham sedimentary basin; the Issaquah-Grand Ridge, Green River, Wilkeson-Carbonado, and Fairfax-Ashford occur in and along the eastern edge of the Puget sedimentary basin; the Centralia-Chehalis and Morton fields are in and on the eastern edge of the Chehalis sedimentary basin; and the Kelso-Castle Rock coalfields are in the Cowlitz basin.

WHATCOM COUNTY AREA

The coal-bearing rocks of Whatcom County underlie an area of over 500 square miles. Most of the rocks appear to lie in a northwest-plunging basin, bounded by metamorphic and igneous rocks on the south and east and covered by glacial drift to the north. The strata in the southern part of the area have been folded into a series of northwest-trending structures. Limbs of some of these folds dip as high as 60°. Most of the coal in the county is high-volatile C bituminous rank.

Two principal beds have been mined in the area, the Bellingham No. 1 and the Blue Canyon. The Bellingham No. 1 has an average thickness of about 14 feet, with the best coal being the upper 7 to 8 feet. The Blue Canyon seam averages about 7 feet thick. Although there are many other coalbeds in the area, these two seem to be the most significant. The Bellingham No. 1 has about 54 million tons of reserves and the Blue Canyon has about 50 million tons of reserves.

Analysis (as-received basis) of the Bellingham No. 1 coal is as follows (Beikman and others, 1961, p. 13):

Moisture (%)................	7.3
Volatile matter (%)..........	35.8
Fixed carbon (%)............	41.3
Ash (%)....................	15.7
Sulfur (%)..................	0.3
Btu.......................	10,542

Analysis (as-received basis) of the Blue Canyon coal is as follows (Beikman and others, 1961, p. 13):

Moisture (%)	1.6
Volatile matter (%)	41.3
Fixed carbon (%)	55.0
Ash (%)	2.2
Sulfur (%)	1.1
Btu	11,919

Of special interest in Whatcom County, because it contains anthracite coal, is the Glacier field. For years operators have attempted to work this field, but to date all attempts have failed. Geologists have estimated that there may be as much as 50 million tons of reserves in the field; however, Beikman and others (1961) estimated 4.8 million tons of indicated reserves.

Analysis of the anthracite is as follows (Beikman and others, 1961, p. 13):

Moisture (%)	5.0
Volatile matter (%)	7.2
Fixed carbon (%)	76.8
Ash (%)	11.1
Sulfur (%)	1.0
Btu	12,660

Thickness of the beds of the Whatcom County coalfields, along with reserves for each, are shown below:

Coalbed	Thickness (feet)	Reserves (millions of short tons)
Blue Canyon	7	50
Lake Whatcom	3	113
Bellingham No. 1	14	54
Bellingham No. 2	2	21
Unnamed	4±	19
Unnamed	...	22
Unnamed	3	27
Unnamed	3	10
	Total	316

SKAGIT COUNTY AREA

Most of the coal-bearing rocks of Skagit County are separated from the Whatcom County coal-bearing rocks by an east-west trending band of pre-Tertiary metamorphic rocks. The coal-bearing rocks cover an area of about 700 square miles. They have been mildly to severely deformed and dip up to 90°. Rank of the coal from only a few complete analyses is bituminous (Beikman and others, 1961, p. 17).

The most significant beds in the county seem to be in the Cokedale area where coking coal was mined during the early part of the century. Analyses (as-received basis) of the Cokedale coal are as follows:

Proximate analysis
(percent)

Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (percent)	Phosphorus
3.0[1]	35.0	60.0	2.0	2.0	...
0.3[2]	3.80	86.38	8.60	0.62	0.30

[1] From Beikman and others, 1961, p. 17.

[2] From Jenkins, 1924, p. 31.

Detailed data on bed thickness and reserves are not available; however, Beikman and others (1961, p. 17) estimate that there are 507 million tons of coal in the Skagit County field.

ISSAQUAH-GRAND RIDGE AREA

The coalbeds in this area occur in six distinct subareas: Newcastle-Grand Ridge, Cedar Mountain, Renton, Tiger Mountain, Niblock, and Taylor.

Newcastle-Grand Ridge Area

The structure of the Newcastle-Grand Ridge area is fairly simple and relatively uniform throughout the coalfield. The beds strike eastward from Newcastle to Issaquah where they warp around to a north-northeasterly strike. Dips are generally 30° to 40° but increase to 75° in the Grand Ridge area. The coalbeds are in nonmarine rocks of the Puget Group and are probably near the top of the Eocene section.

Most of the coal production has come from the No. 4, No. 3, and Muldoon beds, with lesser amounts being produced from the Bagley, May Creek, Dolly Varden, No. 2, and Jones seams. Below are listed analyses (as-received basis) from the more significant coalbeds of the Newcastle-Grand Ridge area (Beikman and others, 1961, p. 34):

	Proximate analysis (percent)					
Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (percent)	Btu
No. 4	16.1	30.5	42.2	9.0	0.5	9,920
No. 3	16.1	31.9	40.6	11.3	.8	9,665
No. 2	13.8	32.5	36.0	17.7	.5	9,140
Bagley	12.7	35.1	40.2	11.9	.4	10,227
May Creek	15.0	34.3	40.2	10.3	.6	10,047
Muldoon	14.4	33.0	38.1	14.3	.7	9,537
Dolly Varden	14.2	32.2	40.4	13.0	.7	9,986
Jones	13.8	35.2	36.2	14.8	.6	9,890

Thickness of the Newcastle-Grand Ridge coalbeds, along with reserves for each, are show below:

Mine (where measured)	Coalbed	Thickness (feet)		Reserves (millions of short tons)
Newcastle-Coal Creek	No. 4	5		34
Newcastle-Coal Creek	No. 3	8		56
Grand Ridge	No. 2	3		7
Newcastle-Coal Creek	Bagley	17		61
Newcastle-Coal Creek	May Creek	3		36
Newcastle-Coal Creek	Muldoon	5		39
Newcastle-Coal Creek	Dolly Varden	2		38
Newcastle-Coal Creek	Jones	5		35
			Total	306

Cedar Mountain Area

The structure of the Cedar Mountain coal area is a southeast-plunging anticline that has been cut by several northwest-trending faults. One main fault cuts the coalfield almost into equal portions, both east and west. Because of poor data, it has not been possible to correlate the seams with any degree of surety from one side of the fault to the other. Total reserves in the field are estimated at 67 million tons.

Most of the production of coal in the Cedar Mountain area came from the Jones and Cedar Mountain No. 1 beds with lesser amounts coming from the New Lake Youngs No. 2, Ryan No. 1, Discovery, and Cavanaugh No. 2 seams. Coals of the Cedar Mountain area range in rank from subbituminous A to high-volatile C bituminous.

Analyses (as-received basis) from coals of the Discovery, Jones, and Cavanaugh No. 2 beds are shown below (Beikman and others, 1961, p. 38).

Proximate analysis
(percent)

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Discovery	10.1	34.4	37.1	18.3	.5	9,755
Jones	10.7	36.1	42.2	10.9	.4	10,700
Cavanaugh No 2	9.7	40.1	43.7	6.5	.9	11,800

Thickness and reserves in millions of short tons are shown below for the coalbeds in the Cedar Mountain coalfield.

Coalbed	Thickness (in feet)		Reserves (millions of short tons)
Cavanaugh No. 2	3.5		5
Jones	3.5		9
Discovery	4		12
Ryan No. 1	9		17
New Lake Youngs No. 2	5		3
Cedar Mountain No. 2	8		8
Cedar Mountain No. 1	12		13
		Total	67

Renton Area

The coal-bearing rocks in the Renton area occur in the Renton Formation. Folding in the area has been moderate to intense with maximum dips reaching 65°. Several northwest-trending faults, of which at least two appear to be significant in size, cut the coal seams. The coals of the Renton area can be classified as either subbituminous A or high-volatile C bituminous. Most of the coal produced from the Renton field came from the No. 3 seam with lesser amounts being mined from the Springbrook, No. 2, and No. 1 beds.

Analyses (as-received basis) of several of the coal seams are as follows (Beikman and others, 1961, p. 38).

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (percent)	Btu
	Proximate analysis (percent)					
No. 1	16.6	32.2	39.9	11.2	0.5	9,546
No. 2	15.0	32.6	38.6	13.8	.6	9,470
No. 3	15.4	34.6	41.5	8.4	.5	10,277
Springbrook	14.1	33.5	46.9	5.6	.4	11,060
Sunbeam	14.9	36.0	42.3	6.8	1.0	10,823
Newenham	13.2	37.4	43.1	6.3	1.6	11,130

Thickness and reserves for the coalbeds in the Renton area are shown below:

Coalbed	Thickness (feet)	Reserves (millions of short tons)
Renton No. 1	17 (with 8 feet of coal)	10
Renton No. 2	14 (with 8 feet of coal)	10
Renton No. 3	10 (with 8 feet of coal)	9
Newenham	4	0.5
Springbrook	6	5
Sunbeam	5	8
Senior	5	9
	Total	55.5

Tiger Mountain Area

Little is known about the geology of the Tiger Mountain coal area. The coal occurs in rocks of the Puget Group. The rocks have been folded and the beds strike northeast and dip about 45° to the northwest. The coal is subbituminous B rank.

Small amounts of coal were produced from the No. 1 and No. 3 seams in the Tiger Mountain area. An analysis (as-received basis) of the No. 1 bed is as follows (Beikman and others, 1961, p. 38):

Moisture (%)	19.2
Volatile matter (%)	32.5
Fixed carbon (%)	35.9
Ash (%)	12.4
Sulfur (%)	0.2
Btu	8,810

Thickness and coal reserves of the beds in the Tiger Mountain area are shown below:

Coalbed	Thickness (feet)	Reserves (Millions of short tons)
No. 1	3	3
No. 3	6	6
	Total	9

Niblock Area

Like the Tiger Mountain area, little is known about the geology of the Niblock area. The coal seams occur in the Puget Group but their stratigraphic position is not definitely known. The coalbeds occur on the west limb of a southeast-plunging anticline. The beds strike about N. 45° W. and dip up to 75° to the southwest. The coal is high-volatile A bituminous.

Information on individual coalbeds is lacking for the Niblock area but Beikman and others (1961, p. 38) estimate the total reserves to be about 14 million tons.

Small amounts of coal have been produced from the No. 5, No. 4, and No. 3 seams in the Niblock area. Analyses (as-received basis) of coals from the Niblock area are as follows (Beikman and others, 1961, p. 38):

Proximate analysis
(percent)

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
No. 5	4.9	27.3	43.5	24.3	1.5	10,580
No. 4	6.1	22.7	58.8	12.4	.9	10,710
No. 3	8.2	27.2	53.9	10.7	.5	12,440

Taylor Area

The coal-bearing rocks of the Taylor area occur in the Renton Formation. The coalbeds crop out around the nose of a southeast-plunging syncline with dips ranging from 40° to 80°. Coals in the Taylor area range in rank from high-volatile B bituminous to high-volatile A bituminous.

A small amount of coal has been mined from the No. 2, No. 4, No. 5, and No. 6 seams with most of the production coming from the No. 5 bed. Analyses (as-received basis) are as follows (Beikman and others, 1961, p. 38):

Proximate analysis
(percent)

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
No. 2	6.4	36.7	41.4	15.5	1.3	11,140
No. 3	4.9	36.1	34.1	24.9	1.9	10,000
No. 4	4.8	36.5	48.6	10.1	.8	12,410
No. 5	4.3	35.6	45.2	14.9	.7	11,870
No. 6	5.6	36.0	44.0	14.4	.9	11,550
Unnamed	6.0	34.2	42.9	16.9	.4	11,000

There are least 10 coalbeds in the Taylor area but reserves data are available for only the following:

Coalbed	Thickness (feet)		Reserves (millions of short tons)
No. 2	5		4
No. 4	3		3
No. 5	4		5
No. 6	4		6
		Total	18

GREEN RIVER AREA

The coalbeds of the Green River area occur in the Puget Group. Although the area has been quite thoroughly mapped, the stratigraphic data are not adequate to make correlations to coalfields in other parts of the Puget basin. The coal-bearing rocks have been extensively folded into a series of north- to northeast- and northwest-trending anticlines and synclines. The folds are cut by numerous northwest-trending faults of greatly differing magnitudes. Some may have displacements of over 1,000 feet. Rank of the coal in the field ranges from subbituminous B to high-volatile A bituminous, however, most of it is high-volatile B bituminous

By far the most production from the Green River area has been from the McKay seam. Other seams that have had substantial production are the Gem; Rogers; Ravensdale Nos. 3, 4, 5, and 9; the Fulton; Franklin No. 10; Dale No. 4; Harris; Navy No. 6; Big Seam; and Bayne Nos. 2 and 3. Analyses (as-received basis) of the Green River coal are shown below (Beikman and others, 1961, p. 54).

		Proximate analysis (percent)					
Mine or prospect	Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (percent)	Btu
Danville	Frazier	15.6	32.5	43.0	8.8	0.5	10,860
	Eight-Foot	8.9	38.1	40.3	7.6	.9	12,555
	Landsburg No. 1	11.1	47.5	41.3	10.0	.3	12,140
	Six-Foot	9.0	39.9	41.2	9.9	.5	12,610
	Rogers	12.3	40.8	42.3	4.6	.4	11,500
Ravensdale	Ravensdale No. 9	7.3	40.3	46.6	5.8	.6	12,370
	Ravensdale No. 5	9.1	36.5	41.3	13.0	.6	10,856
	Ravensdale No. 4	7.4	37.4	44.0	11.2	.5	11,500
	Ravensdale No. 3	9.4	36.3	45.0	9.2	.6	11,455
Dale-McKay	Dale No. 4	16.0	32.6	41.8	9.4	.5	9,855
	Dale No. 7	14.9	32.8	42.9	9.3	.6	10,116

Proximate analysis—Continued
(percent)

Mine or prospect	Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (percent)	Btu
Dale-McKay (Continued)	Gem	11.6	34.7	40.8	12.7	.5	11,438
	McKay	9.7	38.8	46.0	5.2	.5	12,134
	Franklin No. 10	6.1	37.0	40.6	16.2	.6	13,567
Kummer	Kummer No. 4	18.7	32.7	32.9	15.7	.6	10,360
	Kummer No. 1	13.7	32.4	41.6	12.0	.4	10,545
Sunset	No. 1	12.7	31.1	43.7	12.5	.9	9,890
	No. 2	5.0	34.2	42.3	18.4	1.6	11,205
	No. 7	4.9	26.4	30.2	38.5	.4	7,990
Navy	No. 6	5.1	33.9	44.6	16.4	.5	11,488
	No. 4	4.8	33.0	45.1	17.1	.6	11,445
Eureka	Unnamed	5.9	31.3	43.9	18.9	.5	10,940
Occidental	No. 1	5.2	34.6	47.4	12.6	.7	12,075
	No. 2	5.4	33.0	47.1	14.5	.7	11,590
	No. 3	4.4	35.8	47.8	11.8	.9	12,268
	No. 6	5.3	33.0	45.9	20.7	.5	10,660
	No. 14	4.1	34.9	51.6	11.9	.5	......
Carbon-Bayne	Carbon	4.6	32.7	49.5	13.1	.8	12,280
	No. 3 and No. 5	7.5	33.8	44.0	14.5	.6	11,050
	No. 2 and No. 3	4.4	33.3	44.0	18.2	.6	11,362
	No. 1	5.5	32.0	48.9	13.1	.4	11,475
	Pocahontas No. 6	4.6	31.0	52.2	12.2	.7	12,730
Durham	No. 2	3.4	31.4	47.8	17.4	.9	14,300
Elk	Dutch	5.8	31.8	32.9	29.5	.6	13,620
	Victory	7.2	34.4	38.4	19.9	.8	13,305
	No. 1	7.6	33.2	43.7	15.3	.4	12,130
	Big Elk	5.7	35.9	42.6	15.6	.6	11,550
	No. 2	5.6	33.7	45.0	15.6	.6	11,285
Kangley-Alta	Big Seam	4.7	38.0	45.2	12.1	.9	12,420
McIntyre	Unnamed	10.5	35.2	42.4	11.9	.4	10,700

Thickness of the various coal seams in the Green River district and their estimated reserves are shown below:

Coalbed	Thickness (feet)	Reserves (millions of short tons)
Kummer No. 4	5	9
Dale No. 4	5	7

Thickness of the various coal seams in the Green River district and their estimated reserves—Continued

Coalbed	Thickness (feet)	Reserves (millions of short tons)
Harris	3	14
Dale No. 7	3	4
Gem	3	18
Kummer No. 1	5.5	9
McKay	9	59
Kummer No. 0	3 to 5	7
Fulton (No. 12)	23	70
Franklin No. 10	20	55
Occidental No. 1	16	½
Carbon	3	1
Eureka - Unnamed	4.5	1
Navy No. 6	6	2
Sunset No. 1	5	6
Occidental No. 2	3	½
Carbon-Bayne No. 3	5	4
Navy No. 4	8	1
Sunset No. 2	2	3
Durham No. 2	11	½
Occidental No. 3	35	1
Carbon-Bayne No. 2	5	2
Sunset No. 7	3	1
Occidental No. 6	3	1
Carbon-Bayne No. 1	13	4
Occidental No. 14	3	2
Pocahontas	3	1
Frazier	8.5	6
Ravensdale No. 9	3	2
Eight-Foot	7.5	6
Ravensdale No. 5	25	4
Landsburg No. 1	20	15
Ravensdale No. 4	6	4
Six-Foot	5.5	4
Ravensdale No. 3	8	4
Dutch	3	2
Big	5.5	2
Victory	9	7
Elk No. 1	3.5±	4

Thickness of the various coal seams in the Green River district and their estimated reserves—Continued

Coalbed	Thickness (feet)		Reserves (millions of short tons)
Big Elk	11		10
Elk No. 2	2		1
Rogers	10		unknown
		Total	354½

WILKESON-CARBONADO AREA

The coal seams of the Wilkeson-Carbonado area occur in the Carbonado Formation, which is the oldest formation of the Puget Group exposed in the area. The rocks have been tightly folded into a series of north- northwest-plunging anticlines and synclines. Dips are moderate to high, ranging from 30° to vertical. The area is cut by what appears to be three fault systems, one striking northeast, a second striking north-northwest, and a third striking northwest. The coals range in rank from medium-volatile bituminous to high-volatile A bituminous. This field contains several beds of coal that have good coking qualities.

Most of the coal produced in the Wilkeson-Carbonado area came from the Wilkeson Nos. 2, 3, 4, and 5; Carbonado No. 5; and Melmont No. 3 seams. Other coalbeds that have produced are the Wingate, Wilkeson Nos. 1 and 7, Winsor, Morgan, Big Ben, and Melmont Nos. 5 and 6. Analyses (as-received basis) of coals from the Wilkeson-Carbonado area are shown below (Beikman and others, 1961, p. 66, 67).

Proximate analyses
(percent)

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur (percent)	Btu
Wilkeson No. 5	3.9	33.3	54.5	8.4	0.8	13,475
Wilkeson No. 4	3.3	34.2	52.1	10.3	1.1	13,468
Carbonado No. 5	3.8	34.9	50.6	10.6	.6	12,910
Wilkeson No. 3	2.8	31.4	51.4	14.2	.4	12,637
Wilkeson No. 2	3.7	28.8	52.4	14.9	.6	12,302
Wilkeson No. 1	2.7	28.7	52.7	15.7	1.1	12,483
Morgan (No. 7)	2.6	29.9	48.7	18.7	.5	12,398
Wilkeson No. 7	2.8	24.3	61.9	10.8	.5	13,410
Big Ben	3.7	29.9	53.3	13.0	.5	12,843
No. 10 or Winsor	4.91	31.46	43.80	19.82	0.41	10,938
No. 8 or Pittsburg	4.69	32.71	42.22	20.38	.55	10,856
Snell	6.70	25.71	50.10	17.50	.78	11,560

Proximate analyses - Continued
(percent)

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Black Carbon	5.08	32.82	39.14	22.96	0.54	10,442
Melmont No. 1	9.2	9.4	63.7	17.7	.7	11,130
Melmont No. 2	5.8	12.1	64.9	17.2	.4	11,770
Melmont No. 3	3.4	22.5	59.9	15.2	.4	12,580

Thickness of beds and bed reserves for the Wilkeson-Carbonado area are shown below:

Bed	Thickness (feet)	Reserves (millions of short tons)
Wilkeson No. 5	2	20
Wilkeson No. 4	2.5	24
Wilkeson No. 3	4	55
Wilkeson No. 2	4	41
Wilkeson No. 1	3	15
Carbonado No. 5	6	6
Carbonado No. 8	4±	8
Morgan No. 7	5	12
Big Ben	4±	2
Wilkeson No. 7	5	13
Spiketon No. 12	3	8
Spiketon No. 11	3	7
Spiketon No. 10	4	13
Spiketon No. 8	5	14
Spiketon No. 7	4.5	13
Spiketon No. 6	7	9
Crocker	2	5
Snell	2	2
Burnt	3	7
Black Carbon	4	9
Melmont No. 1	4	combined 4
Melmont No. 2	14	
Melmont No. 2½	3	combined 1
Melmont No. 3	10	
Melmont No. 4	3	2
Melmont No. 5	3.5	4
Melmont No. 6	4±	4
	Total	298

FAIRFAX-ASHFORD AREA

The coal in the Fairfax-Ashford area occurs in sedimentary rocks of the Puget Group but the stratigraphic relations have not been determined beyond that. The structure of the area is not completely known but appears to be a series of small northwest-trending anticlines and synclines cut by numerous faults. In the Ashford area the beds have been intruded by igneous rocks. Dips in the area are usually steep, 60° and higher being quite common. The coal varies in rank from medium-volatile bituminous to high-volatile A bituminous and is reported to have coking qualities.

Only limited production has been reported from the Fairfax area and none from the Ashford area. Analyses (as-received basis) of coals from the Fairfax-Ashford area are shown below (Beikman and others, 1961, p. 79).

		Proximate analysis (percent)					
Mine or Prospect	Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Fairfax	No. 3 (McNeill)	1.9	23.3	64.5	10.3	0.5	13,720
	Blacksmith	3.3	21.0	63.0	12.7	.7	13,050
	No. 1	2.9	21.3	63.8	12.0	.7	13,240
	No. 2	3.0	20.6	63.4	16.3	.4	13,050
	No. 3	3.3	22.5	65.5	8.2	.5	13,787
	No. 4	2.0	21.9	64.7	11.4	.6	13,490
	No. 5	3.1	20.9	65.0	10.9	.4	13,390
Prospect	No. 1	4.8	26.4	60.7	8.1	1.1	13,630
	No. 2	2.6	24.8	52.8	19.8	.7	11,860
Montezuma	No. 1	5.7	19.2	62.4	12.7	1.0	12,640
	No. 2	3.0	18.1	56.2	22.7	.7	11,250
	No. 3	4.0	18.1	58.5	19.4	.5	11,820
	No. 4	2.6	21.0	65.6	10.8	.6	13,420
Ashford	Nisqually	5.8	15.3	64.7	24.2	.4	10,410

Thickness of the different beds and the reserves for each are shown below. Because of poor correlation between beds in the area it was impossible to match exactly the names between the analyses and thickness and reserves.

Coalbed	Thickness (feet)	Reserves (millions of short tons)
Montezuma No. 1	3.5	1
Montezuma No. 2	3	2
Montezuma No. 3	2.5	3
Montezuma No. 4	3.5	3

Thickness and reserves of the Fairfax-Ashford area—Continued

Coalbed	Thickness (feet)		Reserves (millions of short tons)
Montezuma No. 5	3		3
Montezuma No.6	2		3
Blacksmith	2		1
McNeill	3		2
Unnamed	3		1
Unnamed	3		1
Unnamed	4±		1
Nisqually	14		13
		Total	34

CENTRALIA-CHEHALIS AREA

Coalbeds in the Centralia-Chehalis area occur in the Skookumchuck Formation of late Eocene Age. The rocks in the area have been gently folded and faulted with most dips being below 30°. The structural trends are dominately northwest with minor folds trending to the north. The coals range in rank from lignite to subbituminous B but most is subbituminous C.

Even though the Centralia-Chehalis coalfield is the largest field in the state, not much coal has been mined there in the past. Production has been reported from the Black Bear, Tono No. 1, Upper Thompson, Lower Thompson, Smith, and Mendota coal seams. Analyses (as-received basis) of the coal seams in the area are shown below (Beikman and others, 1961, p. 87):

Coalbed	Proximate analysis (percent)					
	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Golden Glow	29.0	34.8	28.6	7.6	1.4	8,053
D & F	16.8	33.9	32.0	17.3	4.0	8,700
Tono No. 1	26.9	32.6	32.5	7.9	.9	8,218
Tono No. 2	24.4	32.4	33.9	9.3	1.9	8,270
Upper Thompson	26.4	32.1	30.6	10.8	1.1	7,756
Lower Thompson	26.1	31.0	30.9	12.0	1.5	7,810
Big	24.9	31.7	33.2	10.1	.7	8,350
Little Dirty	24.4	33.1	31.6	11.1	1.4	8,235
Smith	22.8	29.7	29.5	10.1	.6	8,763
Penitentiary	25.5	30.6	31.2	12.7	4.4	7,530
Mendota	22.0	32.0	33.1	12.9	1.7	8,343
Black Bear	18.8	31.1	30.4	19.7	2.2	7,877

Thickness of the various seams and the reserves for each are shown below.

Coal bed	Thickness (feet)	Reserves (millions of short tons)
Tono No. 1	17	913
Upper Thompson	8	609
Golden Glow	4	101
Mendota	6	682
Lucas Creek	5	6
Lower Thompson	6	175
Big	20	742
Little Dirty	5	21
Smith	8.5	309
Penitentiary	3.5	28
D & F	5	12
Tono No. 2	4.5	6
Black Bear	5	88
	Total	3,692

The Big and the Smith seams are currently (1973) being strip mined to provide fuel for the Washington Water Power-Pacific Power and Light steam plant at Centralia, Washington. This plant when in full operation will have a generating capacity of 1,400 MW and consume about 4,800,000 tons of coal per year.

MORTON AREA

Little is known about the geology of the coal seams in the Morton area. The coal occurs in what is thought to be the eastward nonmarine extension of the McIntosh Formation, which is middle Eocene in age. The coal seams dip steeply to the west along along the west limb of a north-trending anticlinal structure. The coal is mostly high-volatile bituminous rank.

There are no reports of significant production from the Morton area beyond digging of prospect adits. Analyses (as-received basis) for the Morton coal seams are shown below (Beikman and others, 1961, p. 101):

Mine or Prospect	Coalbed	Proximate analysis (percent) Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Hi-Carbon	. . .	6.1	34.9	40.9	17.9	0.9	10,765

Proximate analysis— Continued
(percent)

Mine or Prospect	Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Unnamed	. . .	13.5	21.7	49.6	15.2	0.4	. . .
Luthkens	. . .	8.5	27.3	44.8	19.4	.3	10,500
Hofstetter	. . .	8.1	4.6	62.3	25.0	.3	9,820
East Creek	No. 2	4.2	26.7	51.6	17.4	1.2	11,630
	No. 3	6.4	34.4	37.6	20.7	.6	10,160
	No. 4	7.5	31.9	37.2	23.4	.9	9,540
Unnamed	. . .	9.1	27.8	33.2	29.9	.6	8,060
Snow	. . .	11.2	31.2	47.2	10.4	.6	11,160
Unnamed	. . .	9.3	14.4	30.6	45.7	.7	5,740
	. . .	7.7	11.7	54.1	26.5	1.1	9,740
Crystal	. . .	6.3	32.5	38.9	22.3	.6	9,990

Definitive data on thickness of the Morton coalbeds are lacking but Beikman and others (1961, p. 103) estimated there are 44 million tons of reserves in the field.

EASTERN LEWIS COUNTY AREA

The coalbeds in eastern Lewis County occur in a narrow belt of steeply west-dipping sedimentary rocks of Eocene age in the vicinity of Summit Creek east of Mount Rainier National Park. The coal has been subjected to such intense deformation that some of it is anthracite in rank, however, it is very bony and has a high ash content.

There has been no production of coal from this area. Average analysis (as-received basis) for the coals is as follows (Beikman and others, 1961, p. 103):

Moisture (%)	5
Volatile Matter (%)	7
Fixed carbon (%)	51
Ash (%)	26
Sulfur (%)	0.6
Btu	9,700

Definitive data on bed thickness are not available but Beikman and others (1961, p. 103) estimate there are less than 4 million tons of reserves in the area.

KELSO-CASTLE ROCK AREA

Coal seams of the Kelso-Castle Rock area occur in rocks of the Cowlitz Formation of Eocene age and the Toutle Formation of Oligocene age. The coal-bearing rocks in this area have been gently folded into broad open northwest-trending anticlines and synclines. Dips of the beds are low, rarely exceeding 25°. Faults are present but of small displacement. The coal in the Cowlitz Formation ranges in rank from lignite to subbituminous B but is mostly subbituminous C. The Toutle Formation contains only lignite-rank coal.

During the late 1890's, a minor amount of coal was produced from this area but there has been no additional activity since that time. Analyses (as-received basis) of coal from the Kelso-Castle Rock area are as follows (Beikman and others, 1961, p.104):

	Proximate analysis (percent)					
Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Leavell	32.2	29.2	32.1	6.5	0.55	7,200
Cherry Creek	14.1	30.8	33.2	11.9	1.0	7,850
Unnamed	22.2	33.3	27.1	17.4	4.0	. . . .
Do	16.3	36.3	30.1	17.4	4.6	. . . .
Walker	31.0	24.9	23.5	20.6	.2	6,810
Silver Lake	32.0	22.7	17.1	28.2	.9	4,520
Unnamed	19.9	19.8	32.5	27.8	.6	7,250
Schuff	22.3	32.0	35.7	10.0	2.5	8,140
Cedar Creek No. 1	32.5	26.6	24.7	16.2	.5	6,200
Do	30.3	28.6	26.2	14.9	.5	6,680
Unnamed	36.3	26.3	21.0	16.4	.6	5,510

Because of coal seam correlation problems in the area, available bed-thickness data are not reliable. Beikman and others (1961, p. 105) estimate the reserves to be 150 million tons.

ROSLYN AREA

The coal seams in the Roslyn area occur in the rocks of the Roslyn Formation of Eocene age. The major structure of the area is a large northwest-trending, southeast-plunging syncline. The coal ranges in rank from high-volatile A bituminous to high-volatile B bituminous with the latter occurring in the southeastern part of the field.

By far the most extensively mined coalbed in the Roslyn field is the Roslyn seam from which 90 percent of the coal mined in the field was taken. The only other bed with mentionable production is the Big Dirty from which 4 percent of the production came. The remainder was mined from the Plant, Green, and Wright seams. Analyses (as-received basis) of the coals from the Roslyn field are as follows (Beikman and others, 1961, p. 23):

Proximate analysis
(percent)

Coalbed	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Btu
Big Dirty No. 1	3.6	35.8	45.9	14.6	0.3	12,097
No. 3	3.7	34.0	48.8	13.4	.5	12,250
Roslyn (No. 5)	4.5	36.5	47.0	12.0	.4	12,078
Plant (No. 6)	4.2	34.1	46.1	15.6	.5	11,960
Green (No. 7)	3.8	32.8	46.6	16.7	.3	12,035
Wright (No. 8)	4.5	31.8	47.0	17.6	.4	11,840

Thickness of the coal seams and the reserves for each are shown below:

Coal bed	Thickness (feet)		Reserves (millions of short tons)
Big Dirty	15±		75
Roslyn No. 5	6±		54
Plant No. 6	3		93
Green No. 7	2		7
Wright No. 8	3		13
Unnamed	2		40
		Total	282

TANEUM-MANASTASH AREA

Little work has been done in this area. The coal-bearing rocks are Eocene in age and are thought to be part of the Naches Formation.

There has been no production of coal from the Taneum-Manastash area. Analyses (as-received basis) of two samples given by Beikman and others (1961, p. 33) are as follows:

Moisture (%)...........	10.42	7.45
Volatile matter (%)	30.33	37.52
Fixed carbon (%)	36.43	47.88
Ash (%)...............	22.82	7.5
Btu	8,978	12,062

The coal is high-volatile A bituminous rank. Bed thicknesses are not available. Reserves are estimated by Beikman and others (1961, p. 33) to be 40 million tons.

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OIL AND GAS IN WASHINGTON

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Department of Natural Resources
Division of Geology and Earth Resources
Information Circular 50, Energy Resources of Washington

1974

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OIL AND GAS IN WASHINGTON

By

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INTRODUCTION

Over 75 percent of the total energy consumed in the United States comes from petroleum products. According to National Petroleum Council studies, our nation's requirements for energy will double by 1985. Obviously, in this period of time, the need for petroleum will be greatly increased. Several options may be followed in order to cope with these demands: (1) import more foreign oil at the risk of endangering our national security; (2) cut back on our consumption by changing our life style; or (3) increase domestic exploration for petroleum. The latter option was highly recommended by the National Petroleum Council (1973). Regardless of which one or combination of the three options is followed, it is indisputable that there is a definite need to fully explore all possible domestic sources of petroleum.

Washington State, a substantial user of petroleum products, has not yet become a contributor to the supply. Although exploration has been conducted in the state in a modest way over the past 70 years, and over 400 holes have been drilled in search for petroleum with little or no commercial success, only about one-fourth of the holes were located by the use of modern technology.

Considering the size of the areas within the state and on the adjacent Continental Shelf that are regarded as favorable for the occurrence of oil and gas, it can be calculated that less than one test well for every 200 square miles has been drilled. Because of the complex structures and poor exposures in Washington, much closer spacing of exploration drilling must be done before the favorable areas have been adequately tested.

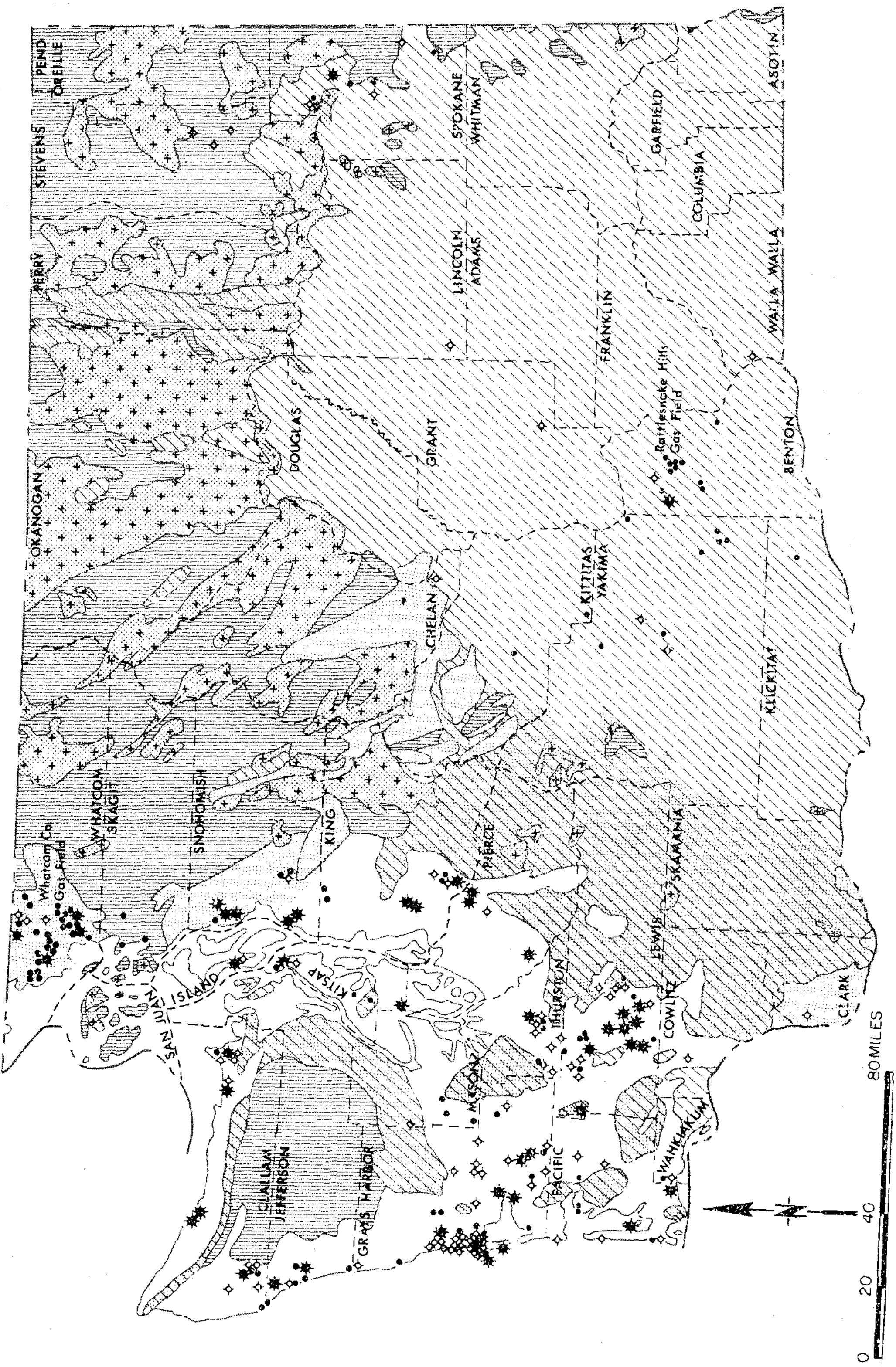
Several sizable areas within Washington State and its Continental Shelf possess all of the major geologic characteristics that are required for the accumulation of commercial quantities of petroleum; for example, source rocks, reservoir rocks, and proper structures and(or) stratigraphy.

One of the most promising areas is the Continental Shelf, which includes both state and federal lands. Continuous seismic profiling surveys indicate that structural and stratigraphic conditions are favorable in many places in this large area where very little drilling has taken place (see Continental Shelf).

The Grays Harbor basin has received moderate exploration, and significant shows of petroleum have been found in the moderately folded and faulted Tertiary sandstone and siltstone sequence of that area. Several major structures have been generally outlined, but they have yet to be adequately tested by drilling.

The Puget Lowland, including much of the area between the Olympic Mountains and the Cascade Range, has for some time been regarded as potentially favorable for oil and gas production. Nonmarine Tertiary sandstones in the eastern part of the basin and marine Tertiary sandstones and siltstones on the west flank of the basin interfinger— this relationship has intrigued geologists and encouraged exploration in this area. Unfortunately, much of the Puget basin is covered with glacial drift, thus making exploration difficult. However, new techniques are being developed that will help to solve this problem. More exploration is required in this potentially favorable area also before it will have been adequately tested.

The north flank of the Olympic Peninsula, including the Strait of Juan de Fuca, is another area


PEND OREILLE
STEVENS
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OKANOGAN
WHATCOM
SKAGIT
Whatcom Co. Gas Field
SNOHOMISH
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CHELAN
DOUGLAS
GRANT
SPOKANE
WHITMAN
LINCOLN
ADAMS
FRANKLIN
GARFIELD
ASOTIN
COLUMBIA
WALLA WALLA
BENTON
Rattlesnake Hills Gas Field
KITTITAS
YAKIMA
KLICKITAT
SKAMANIA
LEWIS
CLARK
COWLITZ
WAHKIAKUM
PACIFIC
THURSTON
MASON
GRAYS HARBOR
CLALLAM
JEFFERSON
KITSAP
ISLAND
SAN JUAN
N
0
20
40
80 MILES

EXPLANATION

EXPLORATORY WELLS: ✸ Greater than 5,000 feet deep ✧ 2,000 feet to 5,000 feet deep • Less than 2,000 feet deep; core holes and most wells less than 500 feet not shown

☐

FAVORABLE

Tertiary sedimentary rocks

Areas in which most commercial oil and gas discoveries will be made; underlain by thick sequences of Tertiary marine and nonmarine strata (stipple = nonmarine); includes Continental Shelf, Juan de Fuca Strait, and Puget Sound

▨

FAVORABLE AND UNFAVORABLE UNDIFFERENTIATED

Tertiary volcanic rocks

Areas in which sedimentary rocks of possible petroleum potential or metamorphic and igneous rocks of no potential are covered by surficial volcanic rocks of variable thickness (stipple = pre-middle Miocene volcanic rocks)

▥

UNFAVORABLE

Metamorphic and intrusive rocks

Areas in which it is extremely unlikely that oil and gas will be found (vertical line pattern = strongly or weakly metamorphosed sedimentary and igneous rocks, mainly of pre-Tertiary age; dense screen pattern with + = large bodies of granitic, dioritic, and basic intrusive rocks)

FIGURE 1.—Generalized geologic map of Washington showing the locations of wells drilled for petroleum between 1900 and 1973, and areas classified according to their petroleum potential.

with promising potential. A thickly folded and faulted sequence of Tertiary marine sandstones and siltstones exists in this area. Some of these rocks are potential source beds or reservoir rocks for petroleum. A few wells have properly tested some of these rocks and have had shows of petroleum, but the area as a whole has by no means been adequately evaluated.

Although the four above-mentioned areas are considered by some workers as having the greatest potential for commercial quantities of oil and gas in this state, other areas in Washington that are thought to be less favorable should not be overlooked.

Most of the discussion on Washington petroleum and natural gas that follows has been extracted from "Mineral and Water Resources of Washington" (United States Geological Survey, and others, 1966, p. 287-297), which was printed for the use of the Committee on Interior and Insular Affairs, United States Senate. The report has been revised in places in order to add more recent information.

PETROLEUM AND NATURAL GAS

Exploratory test wells in the State of Washington have disclosed evidence of petroleum and natural gas in more than 100 wells, but only minor production of these commodities has been obtained and neither is yet economically important. Solid hydrocarbons have been found only in small local occurrences, and no sedimentary rocks classifiable as oil shale are known in the state. Nevertheless, Washington contains within its confines areas that possess the three geologic characters that are required for the accumulation of commercial quantities of petroleum and natural gas. These are as follows:

(1) An adequate source of petroleum-generating material in the form of abundant marine animal or plant life.

(2) The presence of reservoir rocks in which important amounts of oil and gas can accumulate and from which they can be made to flow to wells for production at satisfactory rates.

(3) Suitable structural or stratigraphic conditions that provide a means of localizing and entrapping the oil or gas in the reservoir rocks.

Whether these three factors are to be found in a combination that would provide major commercial production of petroleum has yet to be determined definitely in Washington, although surface and subsurface indications are favorable in many areas. The most obvious indications of the presence of petroleum and natural gas are oil seeps and gas at the surface of the ground. Such seeps have been reported in several places along the west and north coasts of the Olympic Peninsula, at two localities adjacent to Willapa Bay in southwesternmost Washington, in the vicinity of Bellingham in Whatcom County, near Wenatchee in southern Chelan County, and near the Columbia River in southern Skamania County. These areas containing oil seeps were, of course, among the first to be prospected. In searching for other areas to test in Washington, the petroleum geologist must search for less obvious indications and must use basic geologic data gained through geologic and geophysical mapping, and test drilling. Many anticlinal structures suitable for oil accumulation have been mapped in Washington, and many that have been tested by drilling have had promising shows of oil and gas. Many similar structures are probably present but are hidden beneath the thick cover of sand and gravel deposited in Pleistocene time, are obscured by the dense vegetation, are buried under the great basalt flows of the Columbia Basin, or are concealed beneath the Pacific Ocean on the Continental Shelf.

Other traps, such as those that form where a sand lens reservoir rock is entirely encased in impervious shale and is tilted so that the wedge edge points slightly upward, may be common near former shorelines of the Oligocene and Miocene seas. Such shorelines exist at the surface and in the subsurface near the eastern and southern limits of the Puget Lowland, along the north and west coasts of the Olympic Peninsula, and surrounding some of the large outcrop areas of lower to middle Eocene volcanic rocks in the Willapa Hills region.

The oil and gas possibilities of different parts of the State of Washington are dependent principally upon the types of rocks underlying the land surface. Intrusive igneous rocks, such as granite, and extrusive igneous rocks, such as basalt, in themselves afford practically no possibility for commercial petroleum production. Strongly metamorphosed rocks, whether originally sedimentary or not, have generally undergone such radical changes that they have retained little potential as petroleum producers. In general, only those areas that are underlain by marine sediments, and specifically, dark-colored organic-rich shales and porous sandstones, can be considered as good prospects for petroleum generation and accumulation. Consideration must, however, be given to the possibility of petroleum production from marine strata that underlie sediments of continental origin or thick sequences of basalt where adequate stratigraphic traps or structural closures exist.

In figure 1 is depicted a much generalized geologic map of Washington on which the wells drilled to date (January 1973) for petroleum are shown (locations taken mainly from Livingston, 1958), and on which the rocks have been grouped into categories that can be used to discuss the petroleum potential of the six major physiographic regions of Washington. These regions are the Okanogan Highlands, the Columbia Basin, the Cascade Mountains, the Puget

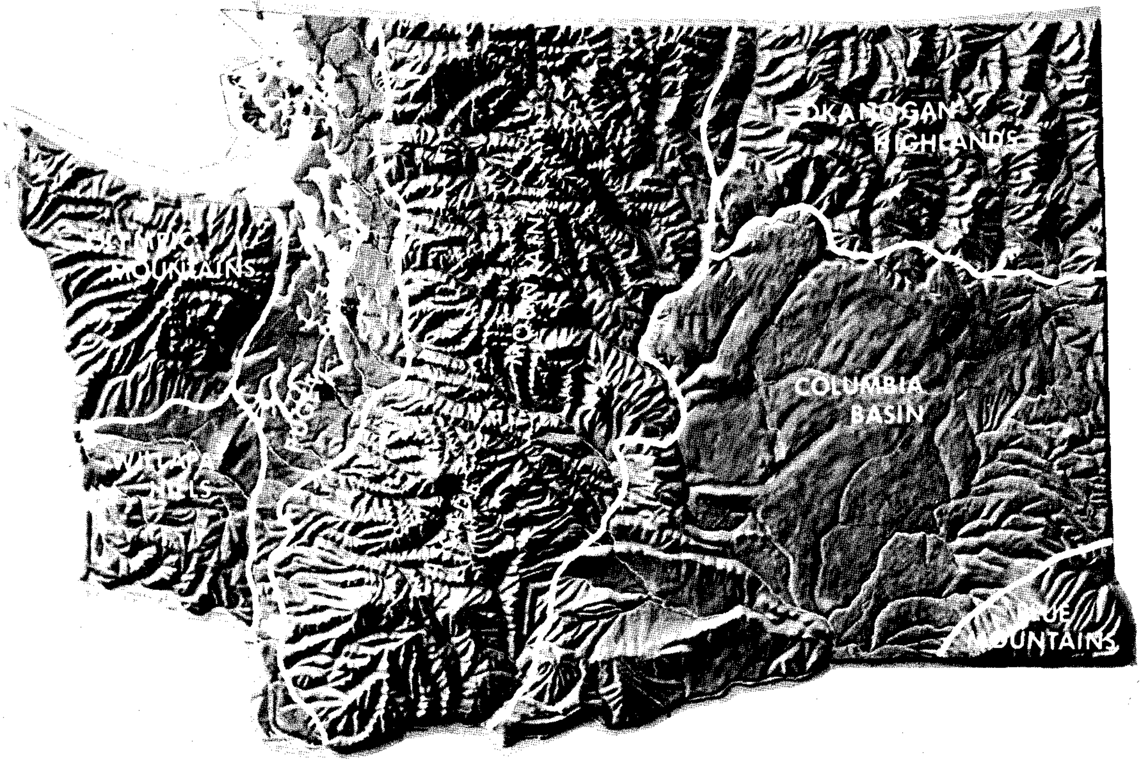


FIGURE 2.—Physiographic divisions of Washington.

Lowland, the Olympic Mountains, and the Willapa Hills (fig. 2). Each region possesses many distinctive geologic characteristics which in turn affect the petroleum potential of the area.

In this discussion of the oil and gas possibilities of Washington, the authors have benefitted greatly from discussions with their associates and have drawn heavily upon published material.

OKANOGAN HIGHLANDS

The Okanogan Highlands in northeast Washington consist principally of igneous and metamorphic rocks in about equal proportions (fig. 3). The igneous rocks are largely granites and associated intrusive rocks of Cretaceous and Tertiary age; the metamorphic rocks are primarily quartzite, crystalline limestone, argillite, and greenstone, ranging in age from Precambrian to Jurassic. In the western part of the Okanogan Highlands the rocks include indurated marine sediments of Permian and Triassic age that have been intruded by large bodies of Cretaceous granite. Thin patches of nearly flat-lying to gently warped volcanic rocks of Eocene and Miocene age overlie the intrusive and metasedimentary rocks in the central and southern parts of the Highlands. The older rocks have been faulted and closely folded into anticlines and synclines.

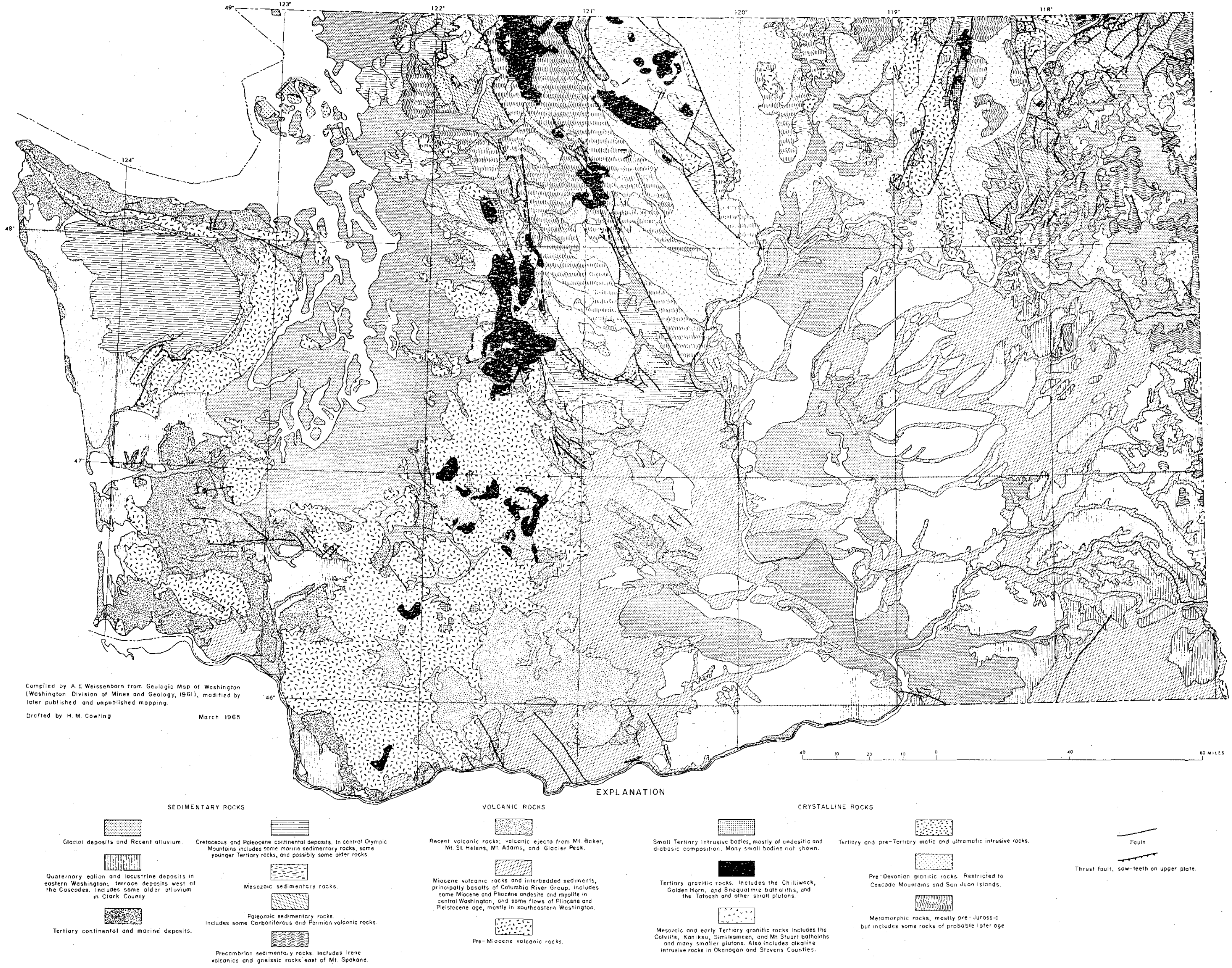
Some of the shale and limestone beds may have served as source beds for oil and gas, but any petroleum originally present would have been destroyed at the time of the Mesozoic and later igneous intrusions and tight folding. The possibilities of finding oil or gas in commercial quantities in this area are very unfavorable. Nine exploratory wells drilled in Stevens and northern Spokane Counties bottomed in Paleozoic sediments and granite. The deepest is reported to have gone 5,280 feet. No shows of oil and gas have been verified in these wells.

COLUMBIA BASIN

The Columbia Basin occupies approximately the southeastern quarter of Washington. It lies south of the Okanogan Highlands and east of the Cascade Mountains, and extends southward far into Oregon and eastward into Idaho to the foothills of the Rocky Mountains. The Basin is underlain mainly by basaltic lava flows, with very minor pyroclastic materials and tuffs all of middle Miocene to early Pliocene age. In many places post-Miocene sedimentary rocks of continental origin overlie the basalt and are in turn overlain by gravels, sands, silts, and clays of Quaternary age. Subordinate local deposits of lignitic fluviatile and lacustrine sediments intercalated within the lava flows probably accumulated in temporary shallow depressions caused by the damming of stream valleys by lava. The lava flows rise gradually toward the southwest onto the broad north-south axial upwarp of the southern part of the Washington Cascades. The Blue Mountains of Oregon extend as an uplifted area in the southeastern corner of the state. In this extension metamorphic rocks of Carboniferous to Triassic age are exposed in river bottoms unconformably under a cover of 2,000 feet or more of basalt.

The basaltic lavas of the Columbia River Group lie in a shallow downwarp into which at least 10,600 feet of lava was extruded. Toward the margin of the basin the number of flows and the total thickness become progressively less. The volcanic rocks in the western part of the basin have been folded into several asymmetric ridges that trend northwest-southeast or east-west generally with low dips on the south and steep to overturned dips to the north.

The lithologic character of the rocks on which the basalt of the Columbia Basin rests is of importance in considering the possibilities of obtaining oil or gas in this region. Along the entire northern boundary



Compiled by A. E. Weissenborn from Geologic Map of Washington (Washington Division of Mines and Geology, 1961), modified by later published and unpublished mapping.

Drafted by H. M. Cowling March 1965

FIGURE 3.—Generalized geologic map of Washington.

of the plateau and southward along the state's eastern boundary to the southeastern corner the basalt flows rest on argillite, schist, crystalline limestone, and quartzite or on granite and similar intrusive rocks. Presumably these metamorphic and igneous rocks extend south and west considerable distances beneath the lavas of the plateau. Along the western margin the lavas lap onto a floor composed generally of folded older lavas and continental sedimentary rocks of Eocene age; sheared argillite, graywacke, and altered lava flows, shown as unfavorable on figure 1, crop out in a small area in western Yakima County. The subsurface extent of these continental sediments is unknown, but it is possible that they may extend southeast to the Rattlesnake Hills area (Weaver, 1938, p. 10). Along the southern boundary of the state, the Columbia River has failed to cut through the basalt cover and nothing is known concerning either the age or lithology of the underlying rocks. About 80 miles to the south in north-central Oregon, however, late Mesozoic marine strata occur in an embayment that may extend to Washington; but no evidence is yet available to indicate how far. In the western part of the Columbia Basin, parts of all of Chelan, Douglas, Grant, Kittitas, Yakima, Klickitat, Adams, Franklin, Walla Walla, and Benton Counties may be underlain in the subsurface by sedimentary rocks possibly productive of petroleum if the structural conditions are favorable.

The Columbia Basin area is not, however, barren of petroleum indications or products. In 1913, a well that was being drilled for water on the northeast slope of the Rattlesnake Hills in northern Benton County encountered a flow of gas estimated at between 70,000 and 500,000 cubic feet per day under about $5\frac{1}{2}$ pounds per square inch pressure. The Rattlesnake Hills gasfield, located on a faulted anticline (Hammer, 1934, p. 852), was not immediately developed, but by 1936 fifteen wells were in production and nearly a billion cubic feet of gas had been distributed to seven towns in the Yakima Valley (Glover, 1936, p. 11, 12). The gas came from porous vesicular zones in the basalt at depths of 700 to 1,260 feet. Analyses of the gas showed an average nitrogen content of nearly 10 percent, a small amount of oxygen, no ethane or heavier hydrocarbons, and an average methane content greater than 80 percent (Kirkham, 1935, p. 229; Glover, 1936, p. 12). The source of the gas is unknown, but the very high methane content and presence of substantial nitrogen suggest a vegetal origin. The Rattlesnake Hills gasfield was abandoned in 1941. In 1958 an attempt was made in that area to drill through the basalt to determine the presence or absence of marine Cretaceous or Eocene strata. At the total depth of 10,655 feet the bit was still drilling in volcanic rock (Popenoe, 1959, p. 1389); but chemical, lithologic, and electric log data suggest that the Miocene basalt flows were drilled through at about 4,000 feet and that the hole bottomed in volcanics of Eocene or Oligocene age.

Exclusive of the drilling in the Rattlesnake Hills gasfield area of Benton County about 25 wells have been drilled in the Columbia Basin area in Spokane, Asotin, Lincoln, Grant, Chelan, Kittitas, Yakima, Klickitat, and Walla Walla Counties. A deep test in southwestern Lincoln County drilled completely through the basalt at 4,465 feet and passed through more than 200 feet of consolidated sand and clay before bottoming in 15 feet of Oligocene? quartz latite at 4,682 feet. Two of the Spokane County wells bottomed in granite and gneiss; all others bottomed in basalt. A deep test in Grant County has a total depth of 4,575 feet, and recorded a gas and tar-like oil show. Two Yakima County wells also recorded gas and tar-like oil shows; and a total of 14 other wells in Kittitas, Yakima, and Klickitat Counties recorded shows of gas. The tar-like oil shows, in addition to the more widely distributed gas, may owe their origin to the heat from a thick basalt flow as it overrode a peat swamp or thin, wet lignitic sediment (Felts, 1954, p. 1669).

CASCADE MOUNTAINS

The Cascade Mountains of Washington consist primarily of a deeply dissected high plateau surface upon which volcanic cones of andesitic lava formed in Quaternary time. The northern part of the range differs markedly from the southern part both topographically and geologically (Weaver, 1945, p. 1390). The northern part is composed largely of Cretaceous and Tertiary granitic intrusive rocks and of pre-Tertiary metamorphic rocks (figs. 1 and 3) that have been folded into a series of anticlines and synclines trending about N. 40° W. The oldest rocks consist largely of pre-Devonian gneissic amphibolite and quartz diorite overlain by lower to upper Paleozoic sandstones, quartzites, crystalline limestones, argillites, phyllites, and greenstones that have been intruded by granite and associated plutonic rocks. Marine shales, sandstones, and conglomerates of Cretaceous age unconformably overlie the older rocks in a large southeast-trending synclinal graben east of the Cascade crest. In western Whatcom County and southeastward to Chelan, Kittitas, and western Yakima Counties the older rocks are overlain unconformably by continental lake and stream deposits of Cretaceous to Eocene age in which coalbeds and basalt flows occur locally. The Eocene beds were folded, eroded, and covered unconformably by andesitic rocks of Eocene to Miocene age.

In the southern part of the Cascade Mountains of Washington the pre-Tertiary rocks are overlain by a thick cover of Tertiary volcanic flows and debris, and subordinate amounts of intercalated continental sedimentary rocks, all of which are gently warped upward along a north-south axis (Weaver, 1945, p. 1391). The volcanic rocks consist of Eocene and Oligocene sequences of tuffs, breccias, and lava flows of basaltic to rhyolitic composition. These volcanic rocks are as much as 5,000 feet thick and contain interbedded sedimentary rocks of lacustrine and fluviatile origin. They are overlain by basaltic and andesitic flows of Miocene, Pliocene, and Quaternary ages.

No marine Tertiary sedimentary rocks are known to occur in either the northern or southern parts of the Cascade Mountains and although small quantities of methane gas may have been formed from vegetal material in the lacustrine clays, the limited areal extent of these nonmarine rocks makes accumulations of commercial importance doubtful. Although shown in the unfavorable category, relatively unmetamorphosed Mesozoic marine sedimentary rocks in a large elongate synclinal graben, trending S. 40° E. from the 121° longitude line at the Canadian border, may have petroleum possibilities. No indications of oil and gas have been reported from them, however.

The only exploratory well in the northern part of the Cascade Mountains was drilled 4,903 feet into the Paleocene strata south of Wenatchee in Chelan County. As stated above, these fresh-water strata contain a few beds of subbituminous coal and much carbonaceous shale which could be a source of gas and, possibly, oil (Glover, 1936, p. 10). This well had reported shows of oil, and in several zones a considerable volume of gas. Oil seeps are reported but unconfirmed in and near the town of Wenatchee. In the southern part of the Washington Cascades the only well drilled was near an oil seep in southern Skamania County. An oil show was reported at 250 feet, and the well was abandoned at 750 feet after having drilled 160 feet in basalt.

PUGET LOWLAND

The nearly level plain that lies between the Cascade Mountains on the east and the Olympic Mountains and Willapa Hills on the west composes the Puget Lowland. The lowland is underlain primarily by Tertiary sedimentary rocks with a locally thick cover of Pleistocene glacial debris. On the south the lowland is limited by a westward extension of the Cascade Mountains held up by Eocene and Miocene volcanic rocks. North of the San Juan Islands, the southernmost part of the Georgia Straits embayment extends into the Bellingham area; an extension of the Willamette Lowland of Oregon barely enters western Clark County.

Resting upon the older granites and schists in the eastern portion of the Puget Lowland, and extending disconnectedly under the central part of the Cascade Mountains, are Cretaceous and Eocene shales and sandstones as much as 14,000 feet thick. They are largely of continental and brackish-water origin, and contain interbedded volcanic rocks and a large number of commercially important coalbeds. Somewhat farther west, these Eocene rocks are interbedded with fine-grained sedimentary rocks containing marine fossils and are overlain by strata of Oligocene age that are largely of brackish water or near-shore marine origin. In the westernmost parts of the lowland, thick sequences of marine siltstone of late Eocene age could be source beds of petroleum, and their interbedded sandstones could form reservoir rocks. These siltstones are overlain by Oligocene and Miocene sedimentary rocks in which are sandstone beds that could serve as reservoir rocks for oil or natural gas that migrated upward along shear zones or fault planes.

Surface geologic mapping has delineated several anticlinal structures and faults in the area of the Puget Lowland (Snavely, and others, 1958, p. 84-93; Vine, 1962; Gower and Wanek, 1963), and geophysical investigations have outlined a few deep structures in the axial part of the basin. Considerable drilling on the surface structures has been done in central Lewis and western King Counties with oil traces or shows reported in 14 tests and gas shows reported in 16.

About 45 other test wells have been drilled in the Puget Lowland in parts of Snohomish, Island, Kitsap, Pierce, Thurston, and Cowlitz Counties. Of these, about 18 reported traces or shows of oil and 25 had shows of gas. A few surface structures and most of the deep structures await test drilling, and stratigraphic traps that formed where wedges of sandstone were overlapped by shale units along the eastern margin of the lowland provide additional exploration targets.

In western Whatcom County, about 5 miles northwest of Bellingham in the southern part of the Georgia Strait embayment, gas in sufficient quantity for domestic use is obtained from glacial sand lenses in Pleistocene sediments at depths less than 500 feet, and commonly at about 170 feet (Livingston, 1958). The gas has a high methane-nitrogen content and possibly originated from the decay of vegetal matter in Upper Cretaceous? to lower Eocene continental sandstones and shales that unconformably underlie the glacial debris, or possibly from marine organic remains and vegetal matter within the Pleistocene clays, sands and gravels (Glover, 1935, p. 42). More than 90 wells have been drilled in western Whatcom County, many of which are not shown on figure 1. Most were shallow wells, only 3 having been drilled deeper than 5,000 feet, 5 deeper than 2,000 feet, and 20 deeper than 1,000 feet. Only 6 wells recorded oil shows, but most of the wells had good gas shows or domestic production.

OLYMPIC MOUNTAINS

Oil was first reported in Washington as early as 1881 along the beach on the western side of the Olympic Peninsula (Lupton, 1915, p. 23) where there are outcrops of sandy shale having a kerosene odor (the "smell muds" of the Indians). At some places a small amount of 40- to 47-gravity paraffin-base oil seeps from the outcrop. In this same general area gas mounds have been formed where mud-laden water saturated with petroleum gas has bubbled to the surface and built up mud cones.

The Olympic Mountains occupy an area of about 4,000 square miles, in the northwestern corner of the state. The core of the range consists of more than 20,000 feet of indurated, complexly folded and faulted argillites and graywackes that presumably have little petroleum potential and are classed as unfavorable on figure 1. Uplifted and eroded lower to middle Eocene basaltic pillow lavas as much as 15,000 feet thick overlie these beds and form a horseshoe-shaped rim around the north, east, and south sides of the mountains. On the north side of the Olympics upper Eocene and Oligocene siltstones and sandstones, more than 15,000 feet thick, overlie the lavas and are in turn overlain by as much as 2,500 feet of Oligocene and Miocene sandstone. Some of the siltstones have a decided petroliferous odor on freshly broken surfaces and are considered to be possible source beds for petroleum.

A few anticlinal structures north and west of the Olympic Mountains have been tested but have not as yet yielded commercial quantities of gas or oil. About 40 wells have been drilled in Clallam and Jefferson Counties of which 18 were drilled deeper than 2,000 feet and 8 deeper than 5,000 feet. More than half had oil shows, and 15 recorded gas shows. In two wells drilled in 1931 and 1936 in northwestern Jefferson County, oil was encountered at shallow depths and might have proved commercial under modern completion techniques. The 1931 test encountered 5 sands saturated with 39.5° paraffin-based oil between 200 and 2,200 feet. The 1936 test struck oil at 287 feet, was completed and, on the pump, partially filled a 50-barrel tank at the rate of approximately $3\frac{1}{2}$ barrels of 40-gravity oil per hour (Glover, 1936, p. 22) before mechanical difficulties led to its abandonment.

WILLAPA HILLS

The Willapa Hills and adjacent areas of southwestern Washington include all the territory south of the Olympic Mountains and west of the Puget Lowland, an area of approximately 3,500 square miles. The stratigraphic sequence consists entirely of Tertiary rocks. The basal unit is early to middle Eocene in age and consists of 2,000 to 10,000 feet of basaltic pillow lavas and breccia. These lavas are overlain locally by a sequence of impure sandstones, but in most places are covered by middle to upper Eocene foraminifera-bearing dark siltstones and silty sandstones as much as 6,000 feet thick. Such fine-grained organic-rich rocks could be source beds for petroleum.

In the eastern part of the Willapa Hills area, the upper Eocene strata consist largely of coal-bearing sandstones as much as 3,000 feet thick. Thin to thick units of basaltic lava and lapilli tuff commonly occur interbedded in this sandstone and siltstone sequence, which is overlain in most places by a basaltic sandstone or conglomerate of early Oligocene age. Tuffaceous marine siltstones, also of Oligocene age, overlie the basaltic sandstone and are as much as 7,000 feet thick in the central western part of the area. They pinch out eastward near the southwestern border of the Cascade Mountains where thick deposits of basaltic fragmental debris and andesitic lavas were being extruded onto the land surface throughout much of early Oligocene time.

A thick sequence of sandstone and pebble conglomerate accumulated in the marine and continental environments of Miocene and Pliocene time, particularly in the western and northern parts of the Willapa Hills area. These younger beds locally are sufficiently porous and permeable to serve as producible reservoir rocks. Thus, in southwestern Washington there are strata that are potential source beds for petroleum generation and potential reservoir rocks for petroleum accumulation. These rocks have been tested locally, excellent indications of petroleum have been found in many tests, and subcommercial production has been obtained in four wells.

The most notable success was based on seismic testing along the Pacific Ocean beach near Ocean City, just northwest of Grays Harbor, in a faulted anticline in strata that may represent the eastern limit of an offshore basin. In reporting on this test, the West Coast Subcommittee on Statistics of Exploratory Drilling classed Washington as the 31st oil-producing state in the nation when the Tanner-Sunshine et al. Medina No. 1 well was completed August 20, 1957, with a rated flow of 178 barrels per day of 39° gravity oil from 3,952-3,958 feet in the Hoh Formation of Weaver (1916), of early Miocene age (Popenoe, 1958, p. 1394). The well was produced intermittently, and flowed approximately 4,500 barrels in 1957, 4,000 in 1958, and 2,000 in 1959. By the end of December 1959, the Medina No. 1 was reported to have become uneconomic and was shut in. Pumping in 1960 and 1961, however, produced about 2,000 additional barrels, bringing the approximate cumulative total to 12,500 barrels of oil. Three other near-commercial wells—the Union Oil Co. State No. 1 and State No. 3; and the Oil and Gas Development Co. Hawksworth-State No. 4—had been drilled in the same area in 1947, 1950, and 1951. Each produced 100 or more barrels of oil. Problems in completion played a large part in the abandonment of the latter of these wells. In 1962, two wells were attempted offshore on an extension of the Ocean City oilfield, but were abandoned because of mechanical problems; in 1964 a well was drilled $2\frac{1}{2}$ miles offshore to a depth of more than 5,000 feet before being abandoned. In 1970, 12 additional wells were drilled onshore in the area. Although good shows were found, no commercial production resulted. In all, some 30 wells were drilled in and near the Ocean City area. Other structures in the Willapa Hills have been tested but with less success.

The only other well of note in the Willapa Hills area was the Continental Oil Co. Sims Royalty No. 1, drilled in 1954 in the Wishkah area of Grays Harbor County. The well was completed flowing 50,000 to 60,000 cubic feet of dry gas per day, but was not considered to be commercial.

CONTINENTAL SHELF

The Tertiary basins of the continental margins of the Pacific Northwest are considered by some to hold great potential for oil and gas production (Braislin, and others, 1971). In 1964, six major companies (Atlantic Refining Company, Pan American Petroleum Corporation, Shell Oil Company, Standard Oil Company of California, Superior Oil Company, and Union Oil Company of California) spent more than 7.7 million dollars in acquiring offshore leases from the Federal Government, west of the Washington coast. Structures to be tested were outlined by aeromagnetic, marine gravity, and seismic surveys that were conducted during 1963-64. As a result of this exploration, six wells were drilled on the Continental Shelf off Washington. None of these proved to be commercial. However, this relatively minor amount of drilling exploration in such a vast area of favorable production potential leaves many structures yet untouched by drilling.

Much of this area is blanketed by a sequence of moderately folded and faulted siltstones and sandstones of late Tertiary age. The underlying older Tertiary siltstones and sandstones are complexly folded and faulted. In places there are indications that diapiric folds or piercement structures have been formed where masses of these highly deformed older rocks have penetrated the overlying Mio-Pliocene sequence (Braislin, and others, 1971). Onshore outcrops of these complexly disarranged older rocks are known to be petroliferous, and therefore they are generally considered favorable for source rock. Seismic records strongly suggest that other potential traps, both stratigraphic and structural, are present, particularly in the Mio-Pliocene sequence off the Washington coast.

GAS STORAGE

The most successful petroleum-related operation in Washington State has been the exploration and development of a much needed underground gas-storage reservoir developed by the Washington Natural Gas Company, the Washington Water Power Company, and the El Paso Natural Gas Company. The operation is located in Lewis County, a few miles south of Chehalis on a 3,000-acre site. The first test wells were drilled in 1962 and, to date, some 60 wells have been drilled.

Reservoir rocks are sandstones of the late Eocene Skookumchuck Formation and the structure has been described as a complexly faulted dome. Presently, this unit has 17.6 billion cubic feet of gas in storage, and the estimated growth is about 2.2 billion cubic feet per year. Its future potential is hoped to be about 30 billion cubic feet of gas. Gas for this unit comes largely from Canada and is stored during off-peak times to be distributed throughout the Pacific Northwest during periods of peak demand.

Aside from the direct benefits the Pacific Northwest receives from this successful operation, it also brings definite encouragement to exploration efforts for natural reserves of gas and oil in Washington. It unquestionably proves the presence of reservoir rocks and structures to contain petroleum.

Other areas with potential for underground gas storage are those generally considered favorable for oil and gas production. Perhaps outstanding among these areas is the eastern part of the Puget basin where thick beds of nonmarine sandstone are known to exist and structures have been mapped. A few test wells for oil and gas production have been drilled in some of these structures and, although reservoir rocks were encountered, no commercial production resulted. This general area is not only geologically favorable but logistically ideal because of its proximity to the large market of the Puget Sound area.

Additional structures in southwest Washington, both near the Centralia-Chehalis area and to the west in the Grays Harbor basin, should also hold definite promise for gas storage potential. Generally, sandstone beds become thinner and finer grained to the west, but nevertheless, beds have been encountered in drilling operations for gas and oil production in the Grays Harbor basin that could definitely serve as reservoirs for gas storage.

CONCLUSIONS

Nearly 400 wells have been drilled in the State of Washington; this exploratory effort does not in any way provide a measure of knowledge of the petroleum possibilities of the state, because very few tests, proportionately, were located on the basis of sound geologic or geophysical data, and few of these provided detailed subsurface information. This was pointed out by Glover (1947, p. 4, 5) who stated:

> . . . of the 244 or so wells drilled, only some 27 were at sites whose selection was determined by carefully, properly conducted geological investigations, and possibly 6 to 10 additional ones were based upon less detailed but fairly adequate geological study . . . .

Since 1947, another 75 or so wells have been drilled at carefully selected sites. Thus, the 100 or so wells drilled to date on scientifically located sites provide an average coverage of only 1 well per

100 square miles in the nearly 10,000 square miles of favorable area in the western part of the state (not counting the Continental Shelf), or 1 well per 200 square miles if potentially favorable areas in the western part of the Columbia Basin are included.

It is certain that exploratory tests spaced closer than an average of one well per each 100 or 200 square miles must be drilled before the petroleum resources of this region of poor exposures and complex structure and stratigraphy can be adequately appraised. The gasfields in Benton and Whatcom Counties and oil production in Grays Harbor and Jefferson Counties have proven that sources of petroleum are present. Furthermore, the successful underground storage of gas in the Lewis County area has proven reservoir conditions are present. Future test drilling alone can establish whether or not oil and gas in commercial quantity occur in Washington State.

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URANIUM IN WASHINGTON

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1974

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INTRODUCTION

Nuclear power growth establishes the basic demand for uranium in the United States. As of September 30, 1972, 28 nuclear power plants were in operation, and 122 plants were under construction. In 1972, nuclear energy supplied 0.8 percent of the energy consumed in the United States. Forecasts indicate that by 1985, around 16 percent of the nation's energy will come from nuclear power plants. It is estimated that by 1974, the industry will require about 18,000 tons of uranium oxide; by 1985, the demand will be around 75,000 tons. Domestic reserves of 273,000 tons of uranium oxide appear to be sufficient for about 10 years. However, to assure an adequate domestic supply after 1983, all known uranium deposits in the United States will have to be explored and developed. The free world's uranium resources of about 1.6 million tons of U_3O_8 in conventional deposits are less than half the minimum projected requirements to the year 2000.

In 1972, a total of 37.6 million pounds of uranium oxide was produced in the United States. Washington's share of the total production amounted to around 750,000 pounds, all of which came from the Midnite mine on the Spokane Indian Reservation, in Stevens County. Dawn Mining Company operates the mine, which produces up to 100,000 tons of ore annually and converts the ore into uranium oxide at the company's mill at Ford.

Since 1970, all uranium produced in Washington has been sold to Jersey Central Power & Light Company and Metropolitan Edison Company, for use as fuel in their nuclear electric power plants on the east coast. Prior to 1970, the uranium produced by Dawn and several other mining companies had been sold to the U.S. Atomic Energy Commission.

The largest known reserves of uranium in Washington are on the Spokane Indian Reservation. Deposits held by Western Nuclear, Inc. are reported to contain 10 million pounds of uranium oxide, while reserves at Dawn Mining Company's Midnite mine probably exceed 2 million pounds. Uranium ore is also present in the Mount Spokane area of Spokane County, as well as in the Lost Creek area of Pend Oreille County; however, the total reserves for these areas are probably less than 100,000 pounds. Uranium reserves at the Midnite mine appear to be sufficient for at least 3 years of continuous operation, while the reserves at Western Nuclear's Sherwood property are sufficient for at least 6 years of production, once their mill is built. Undoubtedly, additional reserves will be developed at both properties; however, it is doubtful that production from new reserves will exceed past production. The production of uranium from areas outside the Spokane Indian Reservation depends to a large part on an increase in the price of uranium oxide. However, the combined known reserves of several past producers appear to be sufficient for only 2 or 3 years of mining. Thus, if Washington is to maintain its uranium production beyond the next 8 years, additional deposits will have to be discovered and developed.

The discussion on Washington uranium, by A. E. Weissenborn, that follows has been extracted from "Mineral and Water Resources of Washington," which was printed for the use of the Committee on Interior and Insular Affairs, United States Senate (United States Geological Survey, 1966, p. 157-166). In order to bring this report up to date, the paragraphs in brackets have been added.

MINERALOGY OF URANIUM

Uranium, the heaviest common element, is a mixture of three semistable radioactive isotopes,

U^{234}, U^{237}, and U^{238}. U^{238} can be converted to plutonium (Pu^{239}). When U^{234} or Pu^{239} are bombarded with neutrons, they fission, energy is released, and a chain reaction can be started. Uncontrolled chain reactions provide the terrible power of the atom bomb; controlled chain reactions in nuclear reactors produce heat which can be converted to power, and also provide radioactive isotopes for research and for industrial and military uses.

Uranium occurs in nearly all geologic environments except those typified by ultramafic rocks, the plateau basalts, and some marine sediments (Stocking and Page, 1956, p. 5). The principal source of uranium in the United States is from deposits in sandstone beds of continental origin, where uranium minerals occur as impregnations between grains. The most important of these deposits are on the Colorado Plateau. Uranium is also found in lacustrine limestones and in some coal beds. It is also found in small concentrations in black shales of marine origin and in deposits of phosphorite. Important deposits occur in veins. Uranium is found in small amounts in many igneous rocks, and uranium minerals are common but minor constituents of many pegmatites.

Uranium is moderately soluble in water and may be carried long distances by the underground circulation. It is chemically reactive and thus may be a constituent of a large number of minerals. It can be removed from solution by adsorption on many different substances, including carbon, and commonly is found concentrated in carbonaceous sediments. These same characteristics account for its presence in many small deposits of little or no economic value.

There are more than 90 minerals that contain uranium (Frondel and Fleischer, 1955). Of these the only ones that occur in significant quantities in Washington deposits are uraninite, an oxide (and pitchblende, a variety of uraninite); coffinite and uranophane, silicates; and autunite, meta-autunite, phosphuranylite, and torbernite, all of which are phosphates.

WASHINGTON URANIUM DEPOSITS

Until 1954, despite persistent search, no uranium occurrences of significance had been found in Washington. In the summer of 1954, uranium minerals were discovered by the LeBret brothers on the Spokane Indian Reservation in Stevens County. The discovery was made while prospecting for tungsten at night, with an ultraviolet lamp. This find became the Midnite mine (fig. 1, No. 1) and touched off a uranium boom in the state. Shortly thereafter uranium was discovered on the Dahl farm on the west slope of Mount Spokane (No. 2), some 40 miles east of the Midnite mine and about 30 miles northeast of Spokane. This became the Daybreak mine and marked the discovery of a second uranium area in the State. Other discoveries were made, but none so far have proved to be of the importance of the original two. As a result of these discoveries, a mill was built in 1957 at Ford in Stevens County to treat the ores and Washington became an important producer of uranium. Total uranium produced from the state to February 28, 1965, is 4.7 million pounds of U_3O_8 from 1.2 million tons of ore.

Midnite Mine Area

The Midnite mine has exposed a number of ore bodies along the western contact of a tongue of schist, phyllite, and quartzite of the Precambrian Togo Formation, which projects southward into porphyritic quartz monzonite of the Cretaceous Loon Lake batholith (Becraft and Weis, 1963, p. 59). Five of these bodies have been mined. Individual ore bodies are as much as 700 feet long, 200 feet wide, and more than 150 feet deep (Sheldon, 1959).

Near the surface, the uranium ore is thoroughly oxidized and consists of a mixture of secondary uranium minerals intimately associated with iron oxide films and coatings. Individual crystals are generally less than 0.5 mm in diameter. Meta-autunite is by far the most abundant mineral, occurring as thin films on fractures or as discrete crystals on iron oxide. Uranophane and phosphuranylite are common, and a few other oxidized uranium minerals have been identified (Becraft and Weis, 1963, p. 58-62).

In 1957, Becraft and Weis identified sooty uraninite and coffinite together with pyrite and marcasite in a few specimens of unoxidized ore. In 1965, specimens of sooty uraninite were relatively plentiful in the Midnite open pit and veins of dense, shiny pitchblende were quite abundant in some of the faces of the open pit. According to Shoichiro Hayashi (written communication, 1964), the pitchblende is an intergrowth of uraninite and a niobium-bearing mineral or minerals.

Almost all the uranium minerals are in the metamorphosed sedimentary rock; only locally are secondary minerals abundant enough in the underlying quartz monzonite to constitute ore. There is some evidence to suggest that the uranium is associated with small, steep faults which cut the Togo Formation near its contact. Some of these fractures may be older than the quartz monzonite. Redistribution of uranium occurred as a result of oxidation of the primary uranium minerals by ground water.

Production from the Midnite mine began in 1955 and ceased in 1962. The Ford mill continued operating on stockpiled ore until July 1, 1965, when the company's contract to deliver uranium concentrate to the Atomic Energy Commission was fulfilled. During the 6½ years of the operation, the mine produced 1,125,637 tons of ore, all of which was treated at the Ford mill. In addition, some ore was shipped to Salt Lake City previous to August 1957, when the Ford mill went on stream. [In 1969, after obtaining markets for 4 million pounds of uranium oxide from private utility companies, production resumed at the mine, and in January 1970, the Ford mill was back in operation. Since 1969, the mine has produced up to 100,000 tons of ore annually.]

Following the discovery of the Midnite mine, several other discoveries were made in the same general area. At the Lowley lease on the Spokane River about 7½ miles south of the Midnite mine, uranium minerals were found in an intensely shattered zone at the contact of impure quartzite and granodiorite. About 285 tons of ore was shipped in 1956 (Becraft and Weis, 1963, p. 66); there has been no production since. In 1958 some diamond drilling was done with the aid of a Defense Minerals Exploration Administration contract. Results were inconclusive.

Small, sparse flakes of secondary uranium minerals were found on the west side of Deer Mountain in sheared rock. The occurrence is at the contact of the Togo Formation and quartz monzonite of the Loon Lake batholith and is about 5 miles northeast of the Midnite mine. No ore-grade material is exposed (Becraft and Weis, 1963, p. 67).

At the Big Smoke lease about a mile north of the Lowley lease, uranium minerals occur along a faulted contact between granodiorite and pyroclastic and sedimentary rocks of the Gerome Andesite. Metatorbernite is found as sparse, small crystals in carbonaceous shale and sandstone. The occurrence has been explored by several shallow percussion holes and by extensive bulldozing. Only minor amounts of uranium have been discovered (Becraft and Weis, 1963, pp. 66-67).

Uranium ore in an entirely different geologic setting was discovered in 1955 at the Peters lease as the result of an airborne scintillation survey. The Peters lease—also known as the Northwest Uranium mine—is about 4½ miles southeast of the Midnite mine. At this locality, uranium is found in the basal member of the Gerome Andesite of Oligocene age. In the mine area the Gerome Andesite consists of interbedded tuffaceous sandstone, arkose, and carbonaceous shale

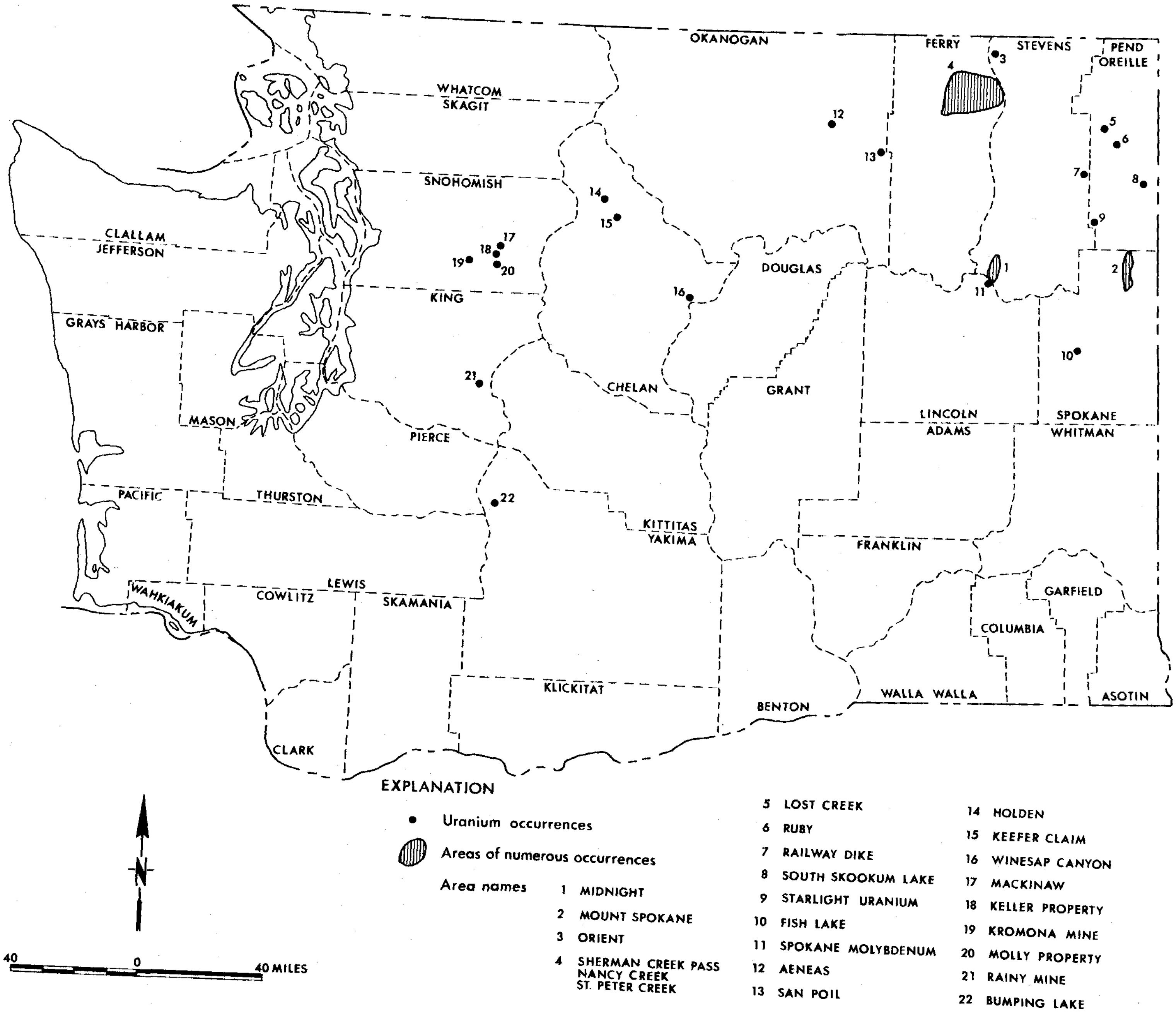

FIGURE 1.—Uranium in Washington.

overlying a poorly sorted conglomerate about 100 feet thick. The formation rests on quartz monzonite of the Loon Lake batholith. The conglomerate, which is poorly cemented, contains many cobbles and boulders as much as a foot in diameter and some that are much larger. The ore zone, which is about 30 feet thick, is near the base of the conglomerate. It contains much carbonaceous materials in thin arkosic lenses and in irregular, sporadically distributed masses. No recognizable uranium minerals are visible at the deposit except for some green stainings at a few places near the surface. The conglomerate above the ore zone contains practically no carbonaceous matter, but carbonaceous material is abundant in some of the beds above the conglomerate. In the mine area the ore zone lies from a few feet to as much as 80 feet below the surface. It is bounded on the west by a north-trending fault and on the south by an east-trending fault. Drill holes show that the ore zone continues west of the north-trending fault but has been down-dropped 285 to 345 feet. The uranium almost certainly was brought in by circulating water and was deposited in the carbonaceous parts of the basal conglomerate. The source of the uranium, however, is uncertain (Becraft and Weis, 1963, pp. 62-66). An interesting feature of the deposit is the very meager surface showings to indicate its existence. The original discovery was made in carbonaceous layers above the conglomerate and was not especially promising. Not until the full thickness of the basal conglomerate had been tested by drill holes did the potential of the deposit become evident.

The deposit was explored with the assistance of a Defense Minerals Exploration Administration contract from 1956 through 1958. It was operated first by the Silver Buckle Mining Co. and later by Dawn Mining Co. [In 1967, Western Nuclear, Inc. extensively explored the property and established reserves of 10 million pounds of uranium oxide. In 1969, the company announced plans for a 2,000-ton-per-day mill; however, construction of the mill has been delayed until the uranium market improves.] Although the ore is low grade, the relatively shallow depth of cover over most of the deposit and the unconsolidated nature of the overburden made possible low cost mining by open-pit methods. Little or no blasting was required in either the ore zone or the overburden. Total production to the time the mine was closed in March 1962 was 87,300 tons of ore containing 305,700 pounds of uranium.

Mount Spokane Area

The first discovery in the Mount Spokane area (fig. 1, No. 2) was made when green crystals of autunite were found in a hole dug for a fence post on the Dahl farm. The discovery was reported in 1955 but is said to actually have been made some years earlier, although the uranium was not identified at the time. Mr. Dahl is said to have seen a specimen of autunite and recognized it as similar to the green crystals he had found on his farm some years previously. This discovery became the Daybreak mine. Since 1955, at least 28 other occurrences have been found in a belt 1 to 1½ miles wide on the west and south slopes of Mount Spokane, extending from the south fork of Deadman Creek (about sec. 7, T. 27 N., R. 45 E.) northwesterly for about 14 miles to the boundary of Spokane and Pend Oreille Counties in Sec. 1, T. 29 N., R. 44 E.

The east side of Mount Spokane is underlain by highly metamorphosed rocks of probable Precambrian age. The Precambrian gneisses and schists have been intruded by biotite quartz monzonite of Cretaceous age—part of a large intrusive mass known as the Loon Lake batholith. The quartz monzonite is similar to other granitic rocks of the Loon Lake batholith except that the only dark mineral present is biotite. Hornblende, which is common elsewhere in the Loon

TABLE 1—Uranium occurrences in Washington

Index No. on fig. 1	Area or property, location	Type of occurrence	Remarks	Reference
	CHELAN COUNTY			
14	Holden mine: Secs. 18-19, T. 31 N., R. 17 E.	Abnormal radioactivity associated with ore on 2,500-ft level in western part of mine.	No uranium mineral identified.	Weis and others, 1958, p. 30.
15	Keefer claims: On west slope of Red Mountain.	Uraninite reported associated with tourmaline chalcopyrite, and other sulfides in intrusive breccia.	....	Do.
16	Winesap Canyon: Sec. 5, T. 26 N., R. 21 E.; near head of Winesap Canyon.	Quartz-feldspar-muscovite pegmatite with minor uraninite.	....	Hunting, 1956.
	FERRY COUNTY			
4	Sherman Creek Pass-Nancy Creek-St. Peter Creek area between Kettle Falls and Republic.	Numerous radioactive anomalies in pegmatite lenses in gneiss.	Numerous claims staked. No production.	Do.
	LINCOLN COUNTY			
11	Spokane Molybdenum mine: Sec. 32, T. 28 N., R. 37 E.	Pitchblende in stringer which cuts quartz vein with molybdenite and other sulfides.	Country rock is quartz monzonite of Loon Lake batholith.	Becraft and Weis, 1963, p. 67-68
	OKANOGAN COUNTY			
12	Aeneas: Sec. 15, T. 36 N., R. 29 E.	Slight radioactivity along pegmatite veins in gneiss.	....	Huntting, 1956.
13	Sanpoil: Sec. 25, T. 35 N., R. 31 E.; on Sanpoil River.	Pegmatite with samarskite and radioactive fluorite.	....	Do.
	PEND OREILLE COUNTY			
5	Lost Creek area: T. 36 N., R. 43 E.; west of Blueslide.	Autunite veins in granite. Somewhat similar to deposits in Mount Spokane area.	Small production from two properties.	Huntting, 1956.
6	Ruby: Sec. 6, T. 34 N., R. 44 E.; near Ruby.	Pegmatite with few scattered grains of autunite and uraninite.	....	Do.
8	South Skookum Lake: Sec. 6, T. 33 N., R. 45 E.; half a mile east of South Skookum Lake.	Autunite in shear zone in granite.	Prospected by Silver Dollar Mining Co.	Do.
9	Starlight Uranium: Sec. 10, T. 32 N., R. 42 E.; near Calispell Creek.	Autunite in weathered granite.	....	Do.
	SNOHOMISH COUNTY			
17	Mackinaw: Sec. 19, T. 29 N., R. 11 E.	Copper-nickel property on contact of serpentine and arkose.	Some samples slightly radioactive.	Broughton, 1942.
18	Keller property: Sec. 6, T. 28 N., R. 11 E., near Mineral City.	Uraninite in quartz veinlets.	....	Huntting, 1956.
19	Kromona mine: Sec. 13, T. 28 N., R. 9 E.	Shear zone with copper minerals. Ore slightly radioactive.	....	Do.

20	Molly: Sec. 30, T. 28 N., R. 11 E.	Uraninite reported with molybdenum and copper.	....	Do.
21	Rainy mine (Western States Copper) Sec. 16, T. 24 N., R. 10 E.	Minor brannerite with quartz, pyrite, and chalcopyrite in breccia pipe in granodiorite.	....	Weis and others, 1958, p. 31.
	SPOKANE COUNTY			
2	Mount Spokane area: Forms belt 1 to 1½ miles wide and 14 miles long on west side of Mount Spokane.	Autunite filling fractures and open spaces in pegmatitic alaskite.	Autunite found in at least 29 localities. Production from 8 properties.	Weis and others, 1958, p. 23, 31; Leo, 1960; Ross, 1963; Huntting, 1956.
10	Fish Lake: Secs. 32-33, T. 24 N., R. 42 E.; just north of Fish Lake.	Slight radioactivity in irregular masses of pegmatite in metamorphic rocks.	....	Huntting, 1956.
	STEVENS COUNTY			
1	Midnite mine area: West of Wellpinit. Secs. 1 and 12, T. 28 N., R. 37 E.	At Midnite mine, series of ore bodies along contact of porphyritic quartz monzonite and schist and phyllite of Togo Formation. At Peters lease, ore body is in conglomerate at base of Gerome Andesite.	Principal uranium-producing area of Washington. Large reserves remain.	Becraft and Weis, 1963, p. 58-67.
3	Orient: Sec. 26, T. 40 N., R. 36 E.	Autunite in pegmatitic gneiss.	....	Huntting, 1956.
7	Railway Dike (Merikay): Sec. 33, T. 34 N., R. 42 E.; on Chewelah Creek.	Large pegmatite which locally shows intense radioactivity. One specimen contained uranium-bearing columbite.	Has produced a few tons of beryl.	Weis and others; 1958, p. 33; Huntting, 1956.
	YAKIMA COUNTY			
22	Bumping Lake: T. 15 N., R. 12 E.; 5 miles south of Bumping Lake Dam.	Strong radioactivity in soil and gravel around radioactive spring.	Over 80 claims staked in rush following discovery.	Huntting, 1956; Weis and others, 1958, p. 81.

Lake batholith, is completely absent. The intrusive contact trends northeasterly nearly through the summit of Mount Spokane. Within a belt a few miles wide bordering the contact, there are irregular patches and masses of rock in which the dark biotite gives way almost completely to white muscovite. This rock, which appears to be largely a metasomatic replacement of the biotite quartz monzonite, has a characteristic dazzling white appearance. Its texture varies from aplitic (a fine-grained sugary texture) to graphic (a texture in which the component minerals form a pattern resembling cuneiform characters). In field mapping, this rock has been termed an alaskite —a name for a type of light-colored granite rock. Quartz-feldspar-mica pegmatites cut the biotite quartz monzonite, as well as some of the gneisses, but become more abundant as the alaskite masses are approached. In the alaskite, the pegmatites are very abundant and in places may make up as much as 25 percent of the rock.

The uranium deposits are closely similar. In all of them, coarsely crystalline autunite [1] (hydrous calcium uranyl phosphate) is the only uranium mineral except for exceedingly finely dispersed uraninite, which is found in some of the autunite crystals (Leo, 1960, p. 110; Ross, 1963, p. 1392). In all the deposits the autunite occurs as fracture fillings and in open spaces in the host rock. Autunite alone fills the voids; there are no gangue minerals. The fracture fillings range in thickness from mere coatings on fracture walls to solid masses of crystals 15 inches or more across. The Daybreak mine in particular has been the source of spectacular specimens of autunite which now grace museums (Weis and others, 1958, p. 26). At all the deposits the country rock has been bleached and altered, but hydrothermal alteration is not intense (Leo, 1960, p. 103). The fractures trend at all angles, but at several of the occurrences—most notably at the Daybreak mine—autunite is particularly abundant in flat-dipping open fractures. The autunite appears to be restricted to the near surface; none has been found at depths greater than about 150 feet. Mapping of the Mount Spokane quadrangle by the author of this chapter has shown that without exception all of the 29 uranium occurrences known to date are in or immediately adjacent to masses of alaskite. This is significant, as it can serve as a guide to future prospecting.

The origin of the deposits is something of an enigma. The deposition of the autunite in open fractures, the absence of any gangue minerals, the restriction to the near surface, and the abundance of radioactive springs in the uranium areas strongly point to deposition from circulating ground water. Pegmatites are abundant in the uranium areas but are equally abundant elsewhere. Leo (1960) has shown that the phosphate in the autunite could have been obtained from the leaching of the apatite in the quartz monzonite (or alaskite). Some of the pegmatites also contain apatite. The source of the uranium is more obscure. An analysis cited by Leo (1960, p. 124) does not indicate that the quartz monzonite contains unusual amounts of uranium. No analyses are available of the alaskite, but numerous scintillator traverses fail to indicate that this rock is notably more radioactive than the quartz monzonite.

Mapping of the Mount Spokane quadrangle has shown that the rocks have been subjected to deep weathering. The weathered zone has been partly stripped off by subsequent erosion but still remains in many places. Scheid (Hosterman and others, 1960), in his work on the clays of northern Idaho and northeastern Washington, recognized a period of deep weathering in Tertiary time, which he termed the "Excelsior period of weathering." He attributed the formation of the clay deposits to this period of weathering. The deep weathering on Mount Spokane probably corresponds to this same period of Tertiary

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[1] Includes meta-autunite I and II, which are less hydrated varieties of autunite.

weathering. It is possible that the Mount Spokane uranium deposits were formed during the same period of Tertiary weathering when the clays were formed. Uranium may have been leached from the weathering alaskite and deposited at favorable places above the then existent water table. To at least a minor extent, solution and deposition of uranium may be still going on.

Most of the uranium mined from the Mount Spokane area has come from the Daybreak mine, but eight different properties have contributed to the total. The total amount shipped to the Ford mill from the Mount Spokane area is 12,361 tons of ore containing 53,809 pounds of U_3O_8. In addition to this, about 6,300 tons of ore was shipped to Salt Lake City before the Ford mill was in operation. [In 1965 and 1966, the only operating mine was the Daybreak, which produced a total of 1,100 tons of ore that contained 6,400 pounds of uranium oxide.] The area is essentially one for the small producer, but given the proper incentive more ore could be mined from known deposits and it is probable that other similar deposits could be discovered.

Other Deposits

Deposits somewhat similar to those of the Mount Spokane area are known in the Lost Creek area (fig. 1, No. 5) in Pend Oreille County. Like the Mount Spokane deposits, they occupy open fractures in a light-colored granitic rock. Small shipments have come from the Lost Creek claim (Triple H and J Mining Co., Inc.) and Quartz Ridge claims (Hi Noon Uranium, Inc.). In addition, one small shipment was made by the Green Nugget Mining Co. from the H.P.S. group of claims, in the Priest Lake area of Pend Oreille County (not shown on figure 1 because its location is uncertain).

There is no record of any other production of uranium in the state, but there are numerous localities where uranium minerals have been noted or anomalous radioactivity has been reported. Many of these are associated with small pegmatite lenses in gneiss, as in the Sherman Creek Pass-Nancy Creek-St. Peter Creek area (fig. 1, No. 4). Many claims have been staked on occurrences of this type, but they are unlikely to have much potential value. Numerous other occurrences have been reported, but little information is available on most of them. The better authenticated ones, together with all localities from which there has been production of uranium ore, are listed in table 1.

FUTURE OF URANIUM MINING IN WASHINGTON

Discoveries made to date are more than sufficient to prove that the geological environment in eastern Washington is favorable for uranium deposits, and the chances for additional discoveries in eastern Washington must be considered good. Given the incentive to prospect, discoveries similar to the Midnite might be made along the margin of the Loon Lake batholith. Other deposits similar to the Peters lease ore body could occur in the conglomerates interbedded in the Gerome Andesite. In both of these environments sizable ore bodies are known to occur, but poor exposures make them hard to find. Additional discoveries of ore bodies of the Mount Spokane type are almost certain to be made in the Mount Spokane area if further search is made, and discoveries are possible elsewhere in Washington where rocks similar to Mount Spokane alaskite are known to occur. These ore bodies are likely to be small, but some may be large enough for a successful small operation.

Uranium occurrences found to date in the Cascade Mountains appear to have little or no potential value. This area, however, has been prospected very inadequately for uranium. Enough anomalies have been found to suggest that the area has possibilities (fig. 1). It is pertinent to remember that the two original discoveries in northeastern Washington—the Midnite and the Daybreak mines—were quite fortuitous. Further search seems definitely warranted at the appropriate time.

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ELECTRICAL ENERGY RESOURCES OF WASHINGTON

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Department of Natural Resources
Division of Geology and Earth Resources
Information Circular 50, Energy Resources of Washington
1974

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By

Lloyd C. Buchanan

INTRODUCTION

The State of Washington is situated in a very enviable position. The Columbia and Snake Rivers provide a vast amount of hydroelectric energy for the state, with the Skagit, Cowlitz, Nisqually, Skokomish, Lewis, Yakima, Spokane, Pend Oreille, and numerous smaller rivers furnishing other large blocks of electric power. The Columbia River and its northern tributaries extend some 498 miles into Canada and drain vast areas of British Columbia, while the Snake River extends over 400 miles south across Idaho into northern Nevada and western Wyoming. Waters from both these watersheds drain into the Columbia, making Washington one of the largest hydroelectric energy-producing states in the nation, and the Bonneville Power Administration the marketing agent for the world's largest hydroelectric power system.

Published reports of electric generation of the Pacific Northwest are supplied on a regional rather than a state basis; such a regional report is the West Group Forecast of Power Loads and Resources, prepared by the Pacific Northwest Utilities Conference Committee. 1/ In contrast to the regional report, the purpose of this report is to inventory the electric energy resources of the State of Washington; and although all generating plants located within the state are listed, the energy output from these plants cannot be identified as being the electric energy resources of the state. The large blocks of power generated within Washington that are committed by long-term contract to out-of-state customers must be taken into account. This is vividly illustrated in table 2. About one-half of the approximately 150 Bonneville customers are out-of-state customers (see table 2, for Washington customers). Pacific Power & Light also exports power it purchases from the PUD's in Grant, Chelan, and Douglas Counties to serve their Oregon and California customers. Equally important are out-of-state generating plants serving firm loads to Washington customers, such as the Noxon plant in Montana and the Cabinet Gorge and Post Falls plants in Idaho that serve Washington Water Power Co. customers in Washington. The Colstrip steam plant located in Montana, now under construction, also will serve Puget Sound Power & Light Co., Pacific Power & Light Co., and Washington Water Power Co. customers in Washington.

TABLE 1.—Utilities participating in the Pacific Northwest Utilites Conference Committee (PNUCC)-West Group of the Northwest Power Pool

- Bonneville Power Administration
- City of Bonners Ferry, Idaho
- City of Centralia
- Chelan County PUD
- Cowlitz County PUD
- Douglas County PUD
- Eugene Water & Electric Board, Oregon
- Grant County PUD
- Grays Harbor PUD
- Pacific Power & Light Company
- Pend Oreille County PUD
- Portland General Electric Co.
- Puget Sound Power & Light Co.
- Seattle City Light
- Tacoma City Light
- The Washington Water Power Company

1/ Pacific Northwest Utilities Conference Committee (PNUCC), 1973, West Group Forecast of Power Loads and Resources, July 1973-June 1984, February 1, 1973.

TABLE 2.— Sales of electrical energy by Bonneville Power Administration, in fiscal year 1972

Customer	Energy Delivered for Year (000) KWH	Revenue from Sales of Energy
NORTHWEST AREA		
Publicly Owned Utilities		
Municipalities		
Albion, Idaho	2,887	$ 9,375
Bandon, Oregon	43,374	147,651
☼Blaine, Washington	25,873	85,703
Bonners Ferry, Idaho	18,200	86,697
Burley, Idaho	69,606	219,465
Canby, Oregon	49,262	173,872
Cascade Locks, Oregon	21,798	58,837
☼Centralia, Washington	49,115	254,637
☼Cheney, Washington	88,069	290,825
☼Consolidated Irrigation District, Wash.	1,158	4,580
☼Coulee Dam, Washington	26,383	92,289
Declo, Idaho	1,779	5,791
Drain, Oregon	25,203	86,186
☼Ellensburg, Washington	142,529	459,815
Eugene, Oregon	1,328,540	3,351,646
Forest Grove, Oregon	118,368	400,615
Heyburn, Idaho	55,453	170,102
Idaho Falls, Idaho	216,508	703,749[1]
☼McCleary, Washington	31,114	102,947
McMinnville, Oregon	193,760	700,789
Milton-Freewater, Oregon	87,277	283,256
Minidoka, Idaho	678	2,331
Monmouth, Oregon	55,489	191,025
☼Port Angeles, Washington	373,320	1,072,838
☼Richland, Washington	329,054	1,062,783
Rupert, Idaho	43,160	135,771
☼Seattle, Washington	1,273,680	2,703,600
Springfield, Oregon	206,779	642,494
☼Sumas, Washington	5,211	18,211
☼Tacoma, Washington	1,010,932	2,533,104
☼Vera Irrigation District, Wash.	85,580	274,381
☼Wash. Public Power Supply System	8,063	20,160
Total Municipalities (32)	5,988,202	$16,345,525
Public Utility Districts		
☼Benton County PUD No. 1	651,281	$ 1,884,529
Central Lincoln PUD	858,768	2,626,002
☼Chelan County PUD No. 1	336,185	751,341
☼Clallam County PUD No. 1	238,561	769,795
☼Clark County PUD No. 1	1,712,850	5,544,093
Clatskanie PUD	674,626	1,629,443
☼Cowlitz County PUD No. 1	1,910,066	4,649,527[1]
☼Douglas County PUD No. 1	295,623	838,552
☼Ferry County PUD No. 1	35,225	109,065
☼Franklin County PUD No. 1	333,645	1,032,920
☼Grant County PUD No. 2	502,527	1,575,912[1]
☼Grays Harbor County PUD No. 1	933,131	2,808,606
☼Kittitas County PUD No. 1	31,833	104,884
☼Klickitat County PUD No. 1	154,337	480,342
☼Lewis County PUD No. 1	379,600	1,181,705
☼Mason County PUD No. 1	32,716	105,693
☼Mason County PUD No. 3	284,422	896,167
Northern Wasco County PUD	59,418	194,284
☼Okanogan County PUD No. 1	314,603	957,924
☼Pacific County PUD No. 2	201,388	667,743
☼Pend Oreille County PUD No. 1	1,547	3,866
☼Skamania County PUD No. 1	72,889	249,162
☼Snohomish County PUD No. 1	3,226,939	10,037,810
Tillamook PUD	279,699	948,895
☼Wahkiakum County PUD No. 1	37,536	126,268
☼Whatcom County PUD No. 1	85,919	231,038
Total Public Utility Districts (26)	13,645,334	$40,405,566
Cooperatives		
☼Benton Rural Elec. Assn.	117,068	$ 352,706
☼Big Bend Elec. Coop.	214,371	570,214
Blachly-Lane County Coop.	91,277	303,217
Central Elec. Coop.	100,101	296,179
Clearwater Power Co.	112,293	369,150
☼Columbia Basin Elec. Coop.	90,853	264,166
Columbia Power Coop. Assn.	31,024	107,269
Columbia Rural Elec. Assn.	95,883	265,180
Consumers Power	203,738	659,822
Coos-Curry Elec. Coop.	221,598	757,540
Douglas Elec. Coop.	92,603	310,645
East End Mutual Elec. Co. Ltd.	5,415	17,625
Fall River Elec. Coop.	54,982	172,407
Farmers Elec. Co.	4,234	14,056
Flathead Elec. Coop.	58,672	179,290
Harney Elec. Coop.	71,787	191,476
Hood River Elec. Coop.	63,864	206,301
Idaho Co. L&P Coop. Assn.	25,816	81,469
☼Inland Power & Light Co.	248,707	787,474
Kootenai Elec. Coop.	73,419	232,328
Lane Co. Elec. Coop.	221,453	724,822
Lincoln Elec. Coop.—Montana	44,123	149,474
☼Lincoln Elec. Coop.—Washington	85,400	235,815
Lost River Elec. Coop.	21,439	61,104
Lower Valley Power & Light, Inc.	111,054	351,701
Midstate Elec. Coop.	81,152	241,198
Missoula Elec. Coop.	49,693	149,666
Nespelem Valley Elec. Coop.	26,182	82,211
Northern Lights	86,037	271,192
☼Okanogan Co. Elec. Coop.	17,024	54,035
☼Orcas Power & Light Co.	67,836	219,687
Prairie Power Coop.	2,636	8,747
Raft River Elec. Coop.	109,159	280,958
Ravalli Co. Elec. Coop.	46,262	148,937
Riverside Elec. Co.	3,900	12,861
Rural Elec. Co.	37,088	117,726
Salem Electric	167,054	545,596
Salmon River Elec. Coop.	18,985	53,554
South Side Elec. Lines	11,931	37,106
Surprise Valley Elec. Corp.	43,447	136,481
☼Tanner Electric	9,930	33,220
Umatilla Elec. Coop. Assn.	145,970	426,015
Unity Light & Power Co.	25,680	83,008
Vigilante Elec. Coop.	39,488	116,601
Wasco Elec. Coop.	58,188	193,290
West Oregon Elec. Coop.	47,367	154,756
Total Cooperatives (46)	3,556,183	$ 11,028,275
Total Publicly Owned Utilities (104)	23,189,719	$ 67,779,366
Federal & State Agencies (19)	607,127	1,743,914
Privately Owned Utilities		
California-Pacific Utilities Co.	34,481	$ 86,445
Idaho Power Co.	29,550	59,100
Montana Power Co.	1,139,784	2,545,082[1]
☼Pacific Power & Light Co.	5,468,060	12,088,494[1]
Portland General Elec. Co.	4,925,951	11,200,324[1]
☼Puget Sound Power & Light Co.	1,483,253	3,202,597
Utah Power Co.	0	0
☼Washington Water Power Co.	474,493	1,072,761
Total Privately Owned Utilities (8)	13,555,572	$ 30,254,803
Aluminum Industries		
☼Aluminum Co. of America		
☼Vancouver Plant	1,924,209	$ 4,028,755
☼Wenatchee Plant	984,623	2,105,209
Anaconda Aluminum Co.	3,137,314	5,900,970
☼Intalco Aluminum Co.	3,516,243	7,204,051
☼Kaiser Aluminum & Chemical Corp.		
☼Spokane Reduction Plant	2,923,998	6,000,187
☼Spokane Rolling Mill	400,757	984,740
☼Tacoma Reduction Plant	1,261,862	2,590,718
☼Martin-Marietta Aluminum Inc.		
The Dalles Plant	1,558,657	2,666,716
☼Goldendale Plant	1,178,649	2,051,494
☼Reynolds Metals Co.		
☼Longview Plant	2,887,960	5,960,596
Troutdale Plant	372,911	934,674
Other Industries		
☼Carborundum Co.	202,789	425,409
Cominco American Inc.	0	0
☼Crown Zellerbach Corp.		
☼Port Angeles Plant	6,689	16,511
☼Port Townsend Plant	92,089	200,257
☼Foote Mineral Co.	98,719	215,470
Georgia-Pacific Corp.	205,013	441,526
Hanna Nickel Smelting Co.	742,544	1,657,399
☼ITT Rayonier, Inc.	38,124	89,159
Oregon Metallurgical Corp.	6,978	17,904
Pacific Carbide & Alloys	56,416	127,798
Pennwalt Corporation	353,648	747,927
Stauffer Chemical Works	487,733	1,071,817
Stewart Elsner	40	273
Union Carbide Corp.	160,987	345,772
Total Industries (19)	22,598,952	$ 45,785,332
OUTSIDE NORTHWEST AREA		
British Columbia Hydro & Power Authority	12,423	$ 27,284
Burbank, Calif.	31,451	68,596
Glendale, Calif.	48,031	96,062
Los Angeles, Calif.	138,960	438,463
Pasadena, Calif.	28,725	75,527
Sacramento, Calif.	40,992	81,984
U.S.B.R.—Central Valley Proj.	1,044,070	3,259,404[1]
U.S.B.R.—Region 3	0	3,315
State of California—Dept. of Natural Resources	50,956	101,912
Pacific Gas & Electric Co.	309,069	618,138
San Diego Gas & Electric Co.	201,770	403,540
Southern California Edison Co.	1,849,612	4,346,223
Total Outside Northwest Area (12)	3,756,059	$ 9,520,448
Total Sales of Electric Energy (149)	63,707,429	155,083,863[2]

[1] Includes capacity sales.

[2] Includes statistical adjustments.

☼ Customers located in Washington State.

Table modified from U.S. Department of the Interior, Bonneville Power Administration, 1972 Annual Report, p. 44.

It is evident then that some method must be employed to identify Washington electrical energy resources, other than the total generation capabilities of all electric generating plants located within the state boundaries.

ASSUMPTIONS

Electrical energy resources of the State of Washington, are determined separately in this report upon the following assumptions:

1. New load requirements for the State of Washington, determined from the Subcommittee on Loads and Resources of the Pacific Northwest Utilities Conference Committee (PNUCC) report for the area, will be adequately served by additions to existing hydro and thermal units and the construction of new hydro and thermal units identified in this report and included in table 11.

2. The Bonneville Power Administration is committed by contractual agreement to provide electric power and energy requirements of the publicly owned electric utilities in the state in excess of generation dedicated to their load, and to provide firm and modified firm power to certain industries. Industrial grade power will be supplied to new electroprocess loads of 35 megawatts or more only if other firm commitments are met and the power is available. If a deficit in power supply with the inability to meet full requirements of all publicly owned electric utilities is forecast, an 8-year prior written notice of insufficiency will be given these public agencies.

3. Power generating facilities along with bulk high-voltage transmission lines will be constructed to transmit energy when and where required.

4. The construction schedule for new generation plants as identified in this report will be maintained.

Washington Electric Energy Resources

Upon these assumptions a determination of the state's electric resources is made. Washington's electric energy resources then become the estimated firm load requirements of all publicly owned utilities and certain major industries served by the Bonneville Power Administration (see table 10), to which has been added all in-state generation of both private and publicly owned electric utilities, plus imports committed to serve Washington customers, less exports committed to serve out-of-state customers.[1]

Because these are firm commitments based upon critical water conditions, they have been considered electric energy resources and are summarized in table 11.

CONCLUSIONS

Requirements

The electrical generation requirements of the region, specifically the West Group of the Pacific Northwest Power Pool, of which the State of Wash-

TABLE 3.—Members of Subcommittee on Loads and Resources of the Pacific Northwest Utilities Conference Committee

Bonneville Power Administration
Chelan County Public Utility District
Coordinating Group of Northwest Power Pool
Douglas County Public Utility District
Eugene Water & Electric Board
Grant County Public Utility District
Pacific Power & Light Company
Portland General Electric
Puget Sound Power & Light Company
Seattle City Light
Tacoma City Light
U.S. Army Corps of Engineers
Washington Water Power Company

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[1] Imports and exports are not computed.

ington constitutes a very important element, have been determined by the Subcommittee on Loads and Resources of the Pacific Northwest Utilities Conference Committee.[1/]

It has been forecast that the present peak energy requirements of almost 23 thousand megawatts will within the next 10 years (1974-1984) be increased to an estimated peak of almost 38 thousand megawatts, and that the present annual energy requirements of 14 thousand average megawatts will be increased to an estimated requirement of almost 22 thousand average megawatts. Corresponding resources required to provide for the present peak demands (1973-1974) of the State of Washington are about 11.5 thousand megawatts. In 10 years it is estimated that the state's peak demands will increase to about 20 thousand megawatts, while the present average annual energy requirements of 7.5 thousand megawatts will increase to approximately 12.7 thousand megawatts. The year by year increase is shown in table 11.

New Construction

There is currently over 8 million kilowatts of hydro and 4 million kilowatts of thermal generation under construction. Within the next 10 years, in addition to the units now under construction, it will be necessary to provide another 4 million kilowatts of hydro and another 4 million kilowatts of thermal generation. It will be noted from table 4 that most of the hydro will be developed from existing plants, either under construction or authorized. The Third Powerplant at Grand Coulee, the proposed units at Chief Joseph, and Second Powerplant at Bonneville are examples.

Future Sources

In the future, still more peaking capacity can be developed at existing plants. However, future energy requirements must also come from new sources, and for the near future from either nuclear or fossil fuel thermal plants. There are several hydroelectric sites still available in the Northwest, within the range of economic development, that have been preserved in their natural state for ecological reasons. Notably, among this group are Ben Franklin on the lower Columbia, Asotin, High Mountain Sheep, and several others on the Snake and Salmon Rivers in Oregon and Idaho, and still other sites on the Flathead in Montana.

Possibility of Delays

As we consider the controversy over raising the height of Ross Dam, when we speculate on the possible delays which may be experienced in getting site approval and construction started on the Sedro Woolley nuclear plant and that it now takes up to 10 years lead time for such a plant, as we learn that Montana and federal new clean air laws may have an adverse effect on the schedule of Colstrip units Nos. 3 and 4, we cannot be certain that these very serious problems will be readily resolved and that somehow everything will fit together on time. In reviewing the electric utility industries' experiences of the past few years, we should be alerted to the possibility of being confronted with these and other problems and be cautiously concerned.

Stopgap Measures

In the past, when new generating units have failed to meet schedule dates, utilities have often resorted to combustion turbines as a stopgap measure.

[1/] Pacific Northwest Utilities Conference Committee, 1973, Long range projection of power loads and resources for thermal planning; West Group Area, 1973-74 through 1992-93: Prepared by Subcommittee on Loads and Resources, April 1973, unpublished report.

Combustion turbines have been the solution to many utility problems. They are inexpensive and readily available. The aircraft turbine that is most often used is normally considered for peaking use rather than for base load application. Recently, an efficient, long life industrial-type turbine, with extremely low pollution characteristics, has been developed. It is suitable for low-grade fuels and may be located in metropolitan load centers.

Probability of Maintaining Schedules

Supplying the state's future energy needs depends on the solution to a series of complex problems related to the environment, energy-resource availability, and the maintaining of schedules for the electrical projects.

The problems related to the gasification and de-ashing of coal, if solved quickly, will strengthen our electrical generating capacity. If the nuclear industry's ability to enrich uranium fuels can be tripled by the early 1980's, and if geothermal steam lives up to its projected potential, the electrical generating problems will be greatly diminished.

Collectively, these problems pose a formidable challenge but they can be solved.

Delays in New Generating Projects
(1973-74 through 1982-83)

Pacific Northwest Utilities Conference Committee (PNUCC) represents all privately owned, publicly owned, and federal electric generating utility agencies in the Pacific Northwest. This committee collates an electric load and resource program, which represents the coordinated efforts of all such agencies, and is intended to determine electric resources sufficient to meet the requirements of the region. While this joint planning for power resource development has been relied upon by electric utilities of the Pacific Northwest for many years in the past, it has never been as closely oriented, as critical, or as complex

TABLE 4.—Federal generator installation schedule, Columbia River Power System

Project		Advance program February 11, 1965	Hydrothermal program January 1969	Congressional Presentation February 1, 1971	September 7, 1973	Delays from advance program to current schedule (months)
LIBBY						
Unit	1	July 1973	July 1973	July 1974	July 1975	24
	2	July 1973	July 1973	July 1974	October 1975	27
	3	September 1973	October 1973	October 1974	January 1976	28
	4	Not Scheduled	January 1974	January 1975	April 1976	...
	5	...	...	...	October 1982	...
	6	...	...	...	January 1983	...
	7	...	...	...	April 1983	...
	8	...	...		July 1983	...
DWORSHAK						
Unit	1	June 1972	June 1972	November 1972	November 1973	17
	2	June 1972	June 1972	February 1973	October 1973	16
	3	June 1972	June 1972	May 1973	September 1973	15

TABLE 4.—Federal generator installation schedule, Columbia River Power System - Continued

Project		Advance program February 11, 1965		Hydrothermal program January 1969		Congressional Presentation February 1, 1971		September 7, 1973		Delays from advance program to current schedule (months)
THE DALLES (Additions)										
Unit	15	June	1970	August	1971	August	1972	January	1973 1/	31
	16	June	1970	August	1971	November	1972	January	1973	31
	17	October	1971	November	1971	February	1973	February	1973	16
	18	December	1971	February	1972	May	1973	March	1973	15
	19	June	1972	May	1972	August	1973	April	1973	10
	20	August	1972	August	1972	November	1973	May	1973	9
	21	October	1972	November	1972	February	1974	September	1973	11
	22	December	1972	February	1973	May	1974	October	1973	10
GRAND COULEE (Third Powerplant)										
Unit	19	April	1973	September	1973	February	1974	August	1975	28
	20	June	1973	March	1974	August	1974	February	1976	32
	21	August	1973	September	1974	February	1975	August	1976	36
	22	Not Scheduled		...		...		April	1977	...
	23	...		...		...		October	1977	...
	24	...		...		...		April	1978	...
CHIEF JOSEPH (Additions)										
Unit	17	June	1972	November	1974	November	1975	March	1977	57
	18	June	1972	February	1975	February	1976	June	1977	60
	19	June	1972	May	1975	May	1976	September	1977	63
	20	August	1972	August	1975	August	1976	December	1977	64
	21	October	1972	November	1975	November	1976	March	1978	65
	22	December	1972	January	1976	January	1977	May	1978	65
	23	April	1973	March	1976	March	1977	July	1978	63
	24	June	1973	May	1976	May	1977	September	1978	63
	25	August	1973	July	1976	July	1977	November	1978	63
	26	October	1973	September	1976	September	1977	January	1979	63
	27	December	1973	November	1976	November	1977	March	1979	63
LOWER GRANITE										
Unit	1	June	1971	June	1974	April	1975	April	1975	46
	2	June	1971	June	1974	April	1975	April	1975	46
	3	June	1971	June	1974	April	1975	April	1975	46
	4	Not Scheduled		...		...		February	1978	...
	5	Not Scheduled		...		...		March	1978	...
	6	Not Scheduled		...		...		April	1978	...
LOST CREEK										
Unit	1	April	1972	April	1974	April	1976	October	1975	42
	2	June	1972	June	1974	June	1976	December	1975	42

TABLE 4.—Federal generator installation schedule, Columbia River Power System - Continued

Project	Advance program February 11, 1965	Hydrothermal program January 1969	Congressional Presentation February 1, 1971	September 7, 1973	Delays from advance program to current schedule (months)
BONNEVILLE (Second Powerplant) [2]					
Unit 11	July 1975	March 1975	February 1978	May 1981	70
12	July 1975	May 1975	April 1978	July 1981	72
13	July 1975 [4]	July 1975	June 1978	September 1981	74
14	September 1975	September 1975	August 1978	November 1981	74
15	November 1975	November 1975	October 1978	January 1982	74
16	January 1976	January 1976	December 1978	March 1982	74
17	...	...	...	May 1982	...
18	...	...	...	July 1982	...
		...	...		
ASOTIN [3]					
Unit 1, 2	June 1974	June 1977	November 1981	Not Scheduled	...
3, 4	Not Scheduled	Not Scheduled	February 1982	Not Scheduled	...
ICE HARBOR (Additions)					
Unit 4	July 1974	July 1973	May 1975	February 1975	7
5	September 1974 [4]	October 1973	August 1975	March 1975	6
6	November 1974	January 1974	November 1975	April 1975	5
TETON					
Unit 1	April 1971	April 1974	April 1975	June 1976	62
2	April 1971	April 1974	July 1975	September 1976	65
3	Not Scheduled	Not Scheduled	April 1978	July 1979	..
LOWER MONUMENTAL					
Unit 4	Not Scheduled	...	...	February 1979	...
5	Not Scheduled	...	...	March 1979	...
6	Not Scheduled	...	...	April 1979	...
LITTLE GOOSE					
Unit 4	Not Scheduled	...	...	February 1978	...
5	Not Scheduled	...	...	March 1978	...
6	Not Scheduled	...	...	April 1978	...

[1] Actual installation date.

[2] Since August 1971, when this schedule was made, the initial operation date for Bonneville Second Powerplant units have been delayed to May 1981. Eight units rated at 68 megawatts each, 544 megawatt total, are now planned.

[3] Subsequent to preparation of the August 1971 Installation Schedule, the Asotin project has been indefinitely delayed because of environmental considerations.

[4] From March 21, 1966 schedule.

Modified from BPA - Branch of Power Resources,
August 30, 1971. Revised September 19, 1973

as it is now. The completion of nearly all the economically desirable and(or) available hydro plants, the siting and development of thermal plants, planning of transmission lines, environmental considerations, and the development of all other multipurpose uses of the Columbia River System have greatly complicated the committee's program.

The PNUCC's program has been based on federal and nonfederal power resource developments that are planned annually to meet the estimated firm load requirements during the following 20-year period. Each annual plan reflects the previous project delays caused by budgetary, physical limitations, or restrictions relating to other river uses. However, because of the lead time now necessary to develop alternative thermal resources, the committee has been hard pressed to find alternative resources that can be developed in time to replace delayed projects.

The federal generator installation schedule (see table 4) indicates the delays in federal projects and unit installations that affect available resources in the Pacific Northwest. For example, projects scheduled in February 1965 for installation in 1972 have now been delayed until 1977. Ten federal projects or project additions have been delayed. Major project delays include a 2-year delay of Libby generators, about a 16-month delay for Dworshak units, over 2½ years for The Dalles additions, from 2 to 3 years on the first three units at Grand Coulee Third Powerplant, roughly 5 years for Chief Joseph additions, nearly 4 years on Lower Granite units, some 6 years for Bonneville Second Powerplant generation, and an average of 6 months for added units at Ice Harbor. Referring to the 1968 schedule, there have been delays of approximately 2,200,000 kw production in federal hydro projects that were originally scheduled for the 1973-74 year. For the 1974-75 year the delay in federal hydro projects amounts to over 4,000,000 kw.

Nonfederal project delays have also occurred. The most important of these is the 4-year delay of the Eugene nuclear powerplant. Another is the January 1973 announcement of a 10-month delay in the schedule for the Trojan nuclear plant, with a loss of an additional 1,100,000 kw.

Some of the reasons for delays are deferred appropriations for federal projects, multilicensing problems for nuclear projects, late equipment deliveries, labor problems, lack of skilled workmen, and environmental and ecological restrictions.

The PNUCC adjusted their schedules to partly accomodate these delays by accelerating the WPPSS Nuclear Project No. 2 (Hanford) and WPPSS Nuclear Project No. 3 (Satsop). WPPSS No. 2 is now scheduled for initial generation September 1, 1978, and WPPSS Nuclear Project No. 3 is scheduled for September 1, 1981. Recently, the shutdown of WPPSS No. 1 was delayed until 1977. In addition to this, Pacific Power & Light Company's Jim Bridger Unit 2 and 3 have been accelerated, with No. 2 scheduled in 1975, and No. 3 accelerated from 1979 to 1976. Portland General Electric Company is now (1973) installing 390 megawatts of combustion turbines (Harborton and Bethel) to supply power that was originally to have been supplied by new federal projects that were delayed. An additional 460 megawatts (Beaver units) is scheduled for mid-1974 to offset delays in their Trojan plant. The PNUCC was also able to accelerate the Centralia Steam-Electric Project. The first 700-megawatt unit was advanced 2 years, September 1973 to September 1971. The second 700-megawatt unit was also accelerated 2 years, September 1974 to September 1972. These units will help meet firm power obligations in 1973-74. Currently, the 1973-74 operation will likely be limited to 1200 megawatts by pollution control regulations.

Although the schedules arranged through the PNUCC have provided enough new generation to meet the anticipated load growth of the area, any cancellations of generating units or delays in meeting construction schedule dates will have an impact on the state and Washington customers and Washington industries will not receive the electric energy they actually need.

Because of continuing project delays, the Pacific Northwest region can expect to be short of power under critical water conditions in 1974-75, 1975-76, 1977-78, and 1978-79.

A light snowpack, a poor spring runoff, and a low streamflow during the 1972-73 operating year resulted in the curtailment of secondary energy normally supplied to northwest utilities and industries. As a result, the utilities were unable to fill many of the major storage reservoirs and entered into the 1973-74 operating year with a deficit in available resources to meet estimated load requirements.

As of October 1, 1973, the regional reservoirs were short of water equivalent to 14 billion kilowatt hours on the basis of a 20½-month critical storage drawdown period. When this is related to a full reservoir condition, representing 46 billion kwh, we can appreciate how critical this shortage has already become.

A continuation of critical water conditions into late fall will adversely affect industry. A continuation of critical water conditions for an extended period, such as the 1928 to 1932 and 1943 to 1945 periods, coupled with delays in providing new generation, is almost certain to be disastrous to the state's economy.

CRITICAL WATER YEAR

In the determination of firm power capabilities of the state's electric power plants, the ability to supply a source of firm dependable energy is limited to that which can be generated under adverse water conditions, referred to as the "critical water year."

During the early years of electrical generation in this region, when water storage was less developed but increasing gradually, the critical water year was a period of 7 to 9½ months, using the historical streamflows of September 16, 1936 to April 15, 1937. As more and more storage was added to the system, both in Canada and the United States, the critical water period was extended to a 20½-month period, using historical streamflows from August 15, 1943 through April, 1945; and then it was extended to a 42½-month period, using historical streamflows from August 15, 1928 through February, 1932. (The scheduling of new thermal plants into the system may affect the length of the critical period, also.) The daily hydrograph of the Columbia River at Grand Coulee (figure 1) shows these three critical water periods, while figure 2 shows the current-year hydrograph at Grand Coulee, with the 1936-37 and the 1943-45 critical streamflows and the median-month streamflow projected on the same coordinates for comparison.

Firm energy resources of Washington are determined by this critical water period as it relates to the West Group of the Northwest Power Pool (table 6). All electric utilities of the state are each an integrated part of this group. In establishing the firm power resource capabilities of the generating utilities in Washington the power resources of the entire region are embraced, including not only Washington and Oregon, but also parts of Idaho, California, and Montana. Through the Pacific Northwest coordination agreement, they are contractually committed to supply to, receive from, and exchange power with other members of this agreement; also with, although less formally (and less binding), other members of the Northwest Power Pool; namely, Utah Power & Light Co., Idaho Power Co., British Columbia Hydro & Power Authority, and West Kootenay Power & Light Co. Critical-period energy capabilities of all hydroelectric plants serving loads within the State of Washington are shown in table 7.

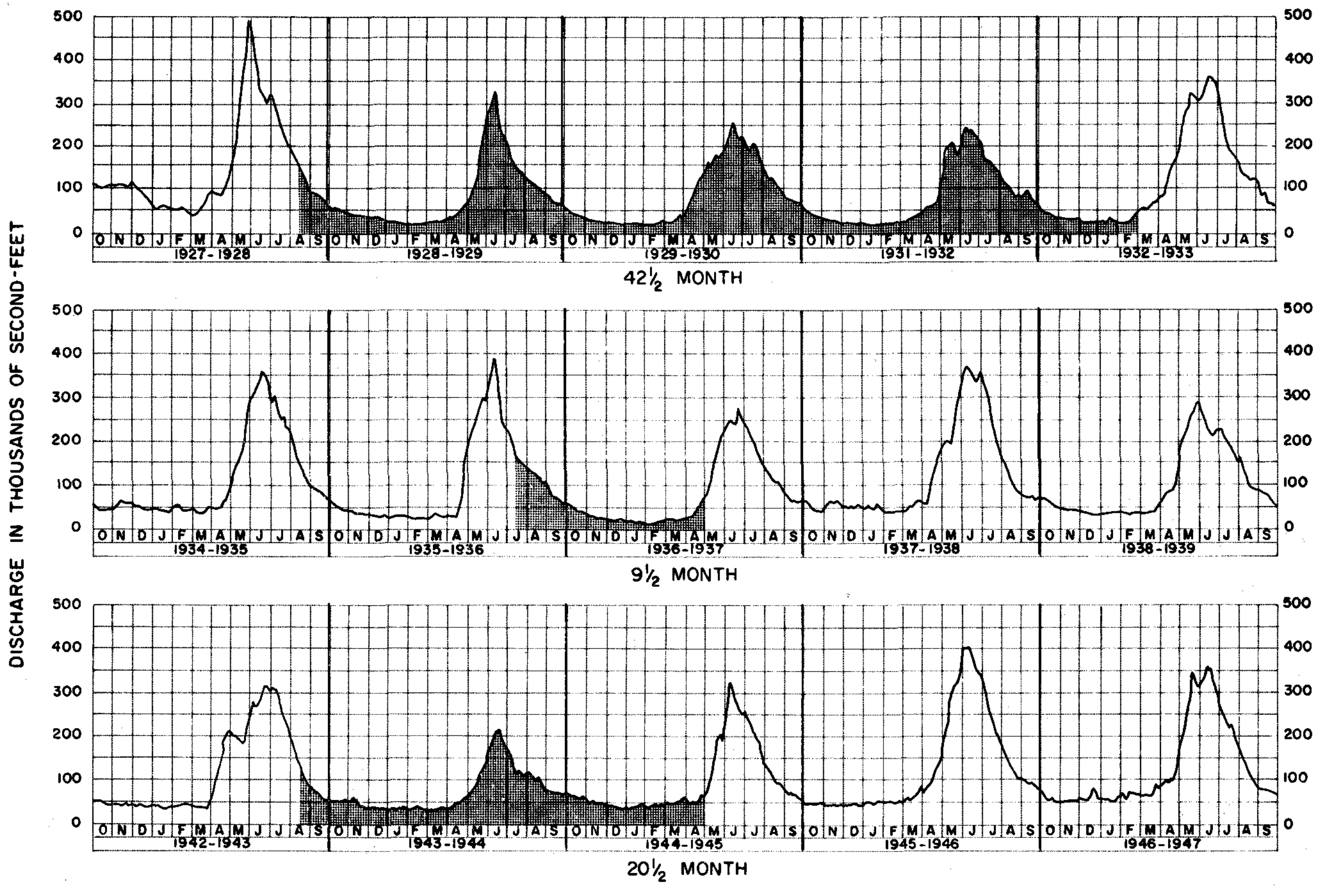

FIGURE 1.—Daily hydrograph of natural streamflow at Grand Coulee, showing critical water periods.

The month of January has been established as the most critical month of the year for electrical power requirements. The most critical water month would then be the last January of the critical water period. Under such adverse water conditions, January 31 would theoretically find the reservoirs at their maximum drawdown condition at a time when peak loads are highest. January 1932 is the critical month for the $42\frac{1}{2}$-month critical water period being used in this report. January peak capabilities are shown in table 8.

The average energy capability developed over the 30 years of recorded experience is called the 30-year-average energy capability (table 9).

At any particular period, secondary energy will be available when the storage content of the coordinated system is at or above pre-established energy-content curves. These operating curves are designed for maximum assurance of water to generate firm power, and to supply secondary loads consistent with the refilling of all reservoir storage.

Thermal plants will, in the future, provide the additional base energy sources for the state's expected growth. During critical water conditions, standby thermal plants are pressed into service in an effort to provide power for the hydrogeneration deficiency. Thermal plant capabilities are included here as a necessary part of the critical water study (see table 5).

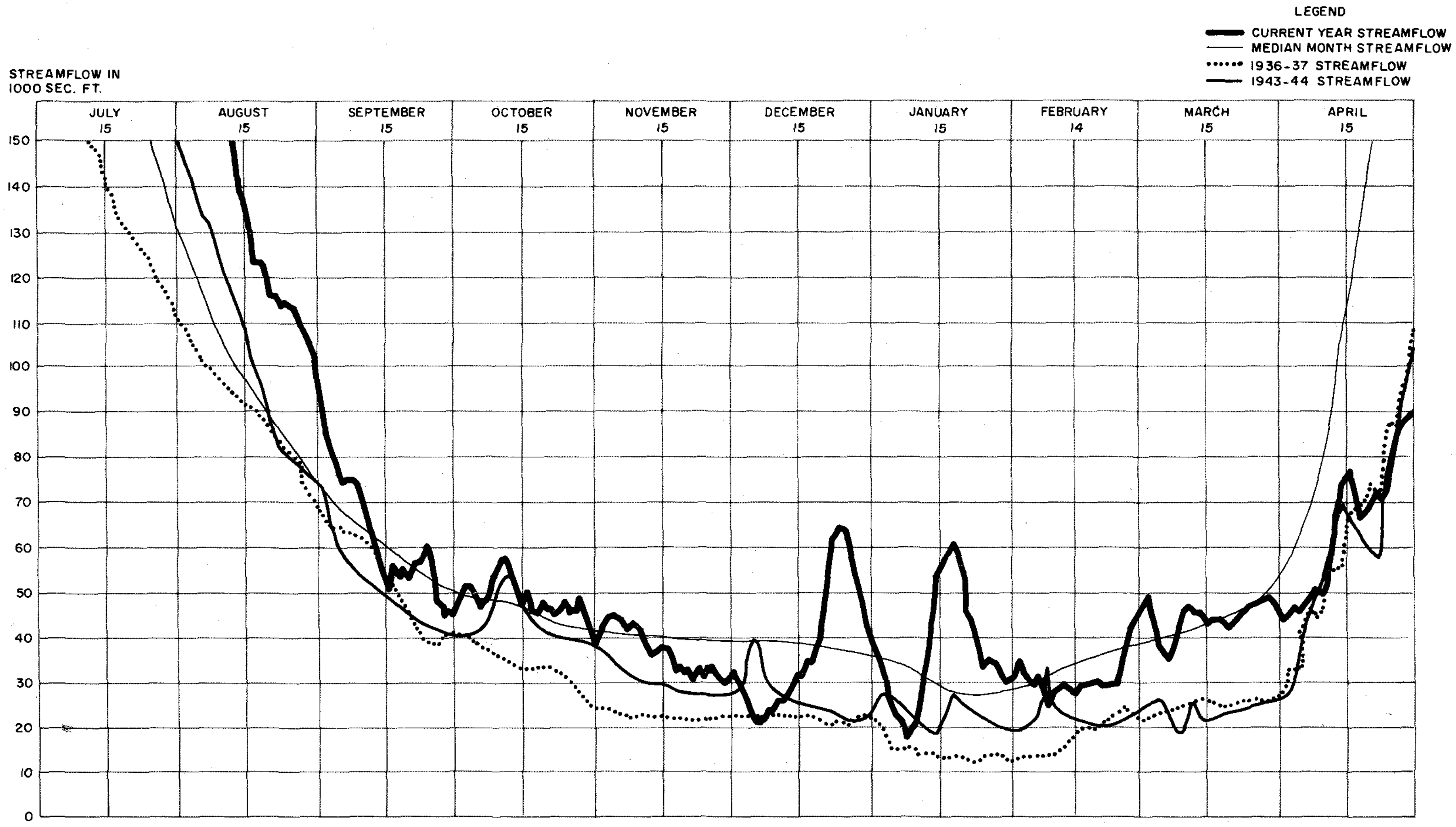

FIGURE 2.—Hydrograph of natural streamflow at Grand Coulee, 1972-73.

TABLE 5.—Capacities of thermal

Figures are megawatts

Utility	Plant	Type	Nameplate	Peak Capacity	Energy capability	1973-74
Cowlitz County PUD	Longview	Steam	26.6	30.0	27.0	27.0
Tacoma City Light	Plant No. 1	Steam	9.0	9.1	0.0	0.0
	Plant No. 2	Steam	50.0	55.4	14.0	21.0
Seattle City Light	Lake Union	Steam	30.0	40.0	36.0	36.0
	Georgetown	Steam	21.0	22.0	19.0	19.0
	Boundary	Combustion turbine	.8	.8	.8	.8
Puget Sound Power & Light Co.	Shuffleton	Steam	90.0	86.0	80.0	80.0
	Crystal Mountain	Diesel	2.8	2.8	2.5	2.5
	Whidbey Island	Combustion turbine	26.5		28.7	28.7
	Colstrip No. 1[1]	Steam	350.0	350.0		
	Colstrip No. 2	Steam	350.0	350.0		
	Colstrip No. 3	Steam		700.0		
	Colstrip No. 4	Steam		700.0		
	Sedro Woolley (Skagit)	Nuclear	1100.0	1100.0		
Pacific Power & Light Co.	Boardman [2]	Nuclear	1260.0			
	Trojan [3]	Nuclear	1216.0			
	Centralia [4] Nos. 1 and 2	Steam	1329.8	1400.0	1365.0	1365.0
	Jim Bridger No. 2	Steam	500.0	500.0		
	Jim Bridger No. 3	Steam	500.0	500.0		
	Dave Johnson No. 1	Steam	104.0	104.0		104.0
	Dave Johnson No. 2	Steam	104.0	104.0		104.0
	Dave Johnson No. 3	Steam	220.0	220.0		220.0
	Dave Johnson No. 4	Steam	330.0	330.0		133.0
Washington Public Power Supply System	WPPSS No. 1 (Hanford)	Nuclear	860.0	860.0	860.0	860.0
	WPPSS No. 1 (Hanford) (new addition)	Nuclear			1220.0	
	WPPSS No. 2 (Hanford)	Nuclear			1100.0	
	WPPSS No. 3 (Satsop) [5]	Nuclear			1100.0	
The Washington Water Power Co.	Othello	Combustion turbine	33.0	33.0		1.0

[1] Colstrip ownership

Unit 1 and 2: Puget Sound Power & Light Co., 50 percent; and Montana Power Co., 50 percent.

Unit 3 and 4: Montana Power Co., 30 percent, Puget Sound Power & Light Co., 25 percent; Washington Water Power Co., 15 percent; Pacific Power & Light Co., 10 percent; and Portland General Electric Co., 20 percent.

[2] Boardman nuclear ownership: Portland General Electric Co., 65 percent; Pacific Power & Light Co., 25 percent; and Eugene City Light, 10 percent.

[3] Trojan nuclear ownership: Portland General Electric Co., 67.5 percent; Pacific Power & Light Co., 2.5 percent; and Eugene City Light, 30 percent.

plants serving Washington State

1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
.8	.8	.8	.8	.8	.8	.8	.8	.8	.8
80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.7
	175.0	175.0	175.0	175.0	175.0	175.0	175.0	175.0	175.0
		175.0	175.0	175.0	175.0	175.0	175.0	175.0	175.0
				350.0	350.0	350.0	350.0	350.0	350.0
					350.0	350.0	350.0	350.0	350.0
							1100.0	1100.0	1100.0
						1260.0	1260.0	1260.0	1260.0
	1130.0	1130.0	1130.0	1130.0	1130.0	1130.0	1130.0	1130.0	1130.0
1365.0	1365.0	1365.0	1365.0	1365.0	1365.0	1365.0	1365.0	1365.0	1365.0
	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
		500.0	500.0	500.0	500.0	500.0	500.0	500.0	500.0
428.0	428.0	428.0	428.0	428.0	428.0	428.0	428.0	428.0	428.0
300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
860.0	(Discontinued 1975)								
							1220.0	1220.0	1220.0
				1100.0	1100.0	1100.0	1100.0	1100.0	1100.0
							1100.0	1100.0	1100.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

4/ Centralia ownership: Pacific Power & Light Co., 47.5 percent; Puget Sound Power & Light Co., 7 percent; Washington Water Power Co., 15 percent; Portland General Electric Co., 2.5 percent; Tacoma City Light, 8.0 percent; Seattle City Light, 8.0 percent; Snohomish PUD, 8.0 percent; and Grays Harbor PUD 4.0 percent.

5/ Washington Public Power Supply System No. 3 (Satsop) nuclear ownership: Pacific Power & Light Co., 10 percent; Washington Water Power, 5 percent; Portland General Electric Co., 10 percent; Puget Sound Power & Light Co., 5 percent; and Washington Public Power Supply System, 70 percent.

TABLE 6.—Members of Northwest Power Pool (NWPP)

West Group

Bonneville Power Administration
Chelan County Public Utility District
Cowlitz County Public Utility District
Douglas County Public Utility District
Eugene Water & Electric Board
Grant County Public Utility District
Pacific Power & Light Company
Portland General Electric Company
Puget Sound Power & Light Company
Seattle City Light
Tacoma City Light
Washington Water Power Company
U.S. Corps of Engineers
(North Pacific Division)
U.S. Bureau of Reclamation Pacific
Northwest Region (South Idaho System)

East Group

Idaho Power Company
Utah Power & Light Company
Montana Power Company

Canadian Group

British Columbia Hydro & Power Authority
West Kootenay Power & Light Company

TABLE 7.—Critical-period energy capability of hydroelectric plants serving Washington loads

Figures are megawatts		1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
Months in Critical Period		42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2
Columbia Mainstem												
Box Canyon	Pend Or. PUD	46	46	46	46	46	46	46	46	46	46	46
Boundary	Seattle	361	361	361	361	361	360	360	360	360	359	359
Spokane River	WWP	81	81	81	81	81	81	81	81	81	81	81
Grand Coulee	BPA	1,831	1,811	1,925	1,942	1,937	1,887	1,886	1,878	1,875	1,865	1,858
Chief Joseph	BPA	1,027	1,021	1,028	1,025	1,026	1,091	1,089	1,087	1,085	1,083	1,081
Wells	Douglas PUD	442	440	441	439	439	438	437	436	436	435	434
Chelan	Chelan PUD	38	38	38	38	38	38	38	38	38	38	38
Rocky Reach	Chelan PUD	649	648	648	647	646	645	644	642	641	640	639
Rock Island	Chelan PUD	155	153	155	155	155	155	154	154	154	153	153
Wanapum	Grant PUD	563	563	562	561	560	559	559	558	557	556	555
Priest Rapids	Grant PUD	530	530	530	528	528	528	527	526	525	525	524
Lower Granite	BPA	- -	82	217	217	217	220	220	219	219	219	218
Little Goose	BPA	212	213	213	213	213	215	215	215	215	214	214
Lower Monumental	BPA	216	218	218	217	217	217	219	218	218	218	218
Ica Harbor	BPA	200	220	220	220	219	219	218	218	218	217	216
McNary*	BPA	650	650	650	648	648	647	646	645	644	643	643
John Day*	BPA	927	929	925	923	921	920	919	917	916	914	912
The Dalles	BPA	773	773	821	819	818	817	816	814	813	812	810
Bonneville*	BPA	551	546	559	556	554	554	554	552	559	592	592
*Located on state boundary (interstate)												
Increase from Additional Units (Included Above)												
Chief Joseph	BPA	- -	- -	- -	1	3	9	12	11	10	20	24
Lower Granite	BPA	- -	- -	- -	- -	0	3	3	3	3	3	3
Little Goose	BPA	- -	- -	- -	- -	0	3	3	3	3	3	3
Lower Monumental	BPA	- -	- -	- -	- -	- -	0	2	2	2	2	2
Ice Harbor	BPA	- -	18	19	19	18	18	18	18	17	17	17
Bonneville	BPA	- -	- -	- -	- -	- -	- -	- -	0	6	47	49
Hydro, Other Than Columbia River System												
Swift #1	PP&L	54	54	54	54	54	54	54	54	54	54	54
Swift #2*	PP&L	20	20	20	20	20	20	20	20	20	20	20
Yale	PP&L	52	52	52	52	52	52	52	52	52	52	52
Merwin	PP&L	51	51	51	51	51	51	51	51	51	51	51
Klamath River	PP&L	55	55	55	55	55	55	55	55	55	55	55
Alder	Tacoma	19	19	19	19	19	19	19	19	19	19	19
LaGrande	Tacoma	33	33	33	33	33	33	33	33	33	33	33
Cushman #1	Tacoma	11	11	11	11	11	11	11	11	11	11	11
Cushman #2	Tacoma	23	23	23	23	23	23	23	23	23	23	23
Mayfield	Tacoma	66	66	66	66	66	66	66	66	66	66	66
Mossyrock	Tacoma	94	94	94	94	94	94	94	94	94	94	94
Ross	Seattle	66	66	66	66	102	102	102	102	102	102	102
Diablo	Seattle	83	83	83	83	83	83	83	83	83	83	83
Gorge	Seattle	93	93	93	93	93	93	93	93	93	93	93
White	Puget	28	28	28	28	28	28	28	28	28	28	28
Upper Baker	Puget	34	34	34	34	34	34	34	34	34	34	34
Lower Baker	Puget	38	38	38	38	38	38	38	38	38	38	38

*Owned by Cowlitz PUD

TABLE 7.—Critical-period energy capability of hydroelectric plants serving Washington loads - Continued

Figures are megawatts		1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
Minor Hydro		42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2	42-1/2
Roza (Net)	BPA	5	5	5	5	5	5	5	5	5	5	5
Yelm	Centralia	9	9	9	9	9	9	9	9	9	9	9
Cedar Falls & Newhalem	Seattle	8	8	8	8	8	8	8	8	8	8	8
Snoqualmie & Minors	Puget	48	48	48	48	48	48	48	48	48	48	48
Meyers Falls	WWP	1	1	1	1	1	1	1	1	1	1	1
Packwood	WPPSS	7	7	7	7	7	7	7	7	7	7	7
Condit, Naches, Naches Drop	PP&L	11	11	11	11	11	11	11	11	11	11	11

TABLE 8.—January peak capability of hydroelectric plants serving Washington loads

Figures are megawatts		1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
Water Year		Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932
Columbia Mainstem												
Box Canyon	Pend Or. PUD	71	71	71	71	71	71	71	71	71	71	71
Boundary	Seattle	650	650	650	650	650	650	650	650	650	650	650
Spokane River	WWP	134	134	134	134	134	134	134	134	134	134	134
Grand Coulee	BPA	2,050	2,205	2,224	4,141	4,148	4,097	5,290	5,859	5,834	5,870	5,870
Chief Joseph	BPA	1,280	1,280	1,280	1,280	1,717	2,373	2,482	2,482	2,482	2,482	2,482
Wells	Douglas PUD	842	842	842	842	842	842	842	842	842	842	842
Chelan	Chelan PUD	50	50	50	50	50	50	50	50	50	50	50
Rocky Reach	Chelan PUD	1,291	1,291	1,291	1,291	1,291	1,291	1,291	1,291	1,291	1,291	1,291
Rock Island	Chelan PUD	157	155	156	155	155	155	154	155	155	153	152
Wanapum	Grant PUD	986	986	986	986	986	986	986	986	986	986	986
Priest Rapids	Grant PUD	912	912	912	912	912	912	912	912	912	912	912
Lower Granite	BPA	- -	0	466	466	466	466	932	932	932	932	932
Little Goose	BPA	466	466	466	466	466	466	932	932	932	932	932
Lower Monumental	BPA	466	466	466	466	466	466	466	932	932	932	932
Ice Harbor	BPA	310	310	693	693	693	693	693	693	693	693	693
McNary*	BPA	1,127	1,127	1,127	1,127	1,127	1,127	1,127	1,127	1,127	1,127	1,127
John Day*	BPA	2,484	2,484	2,484	2,484	2,484	2,484	2,484	2,484	2,484	2,484	2,484
The Dalles	BPA	2,015	2,015	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018	2,018
Bonneville*	BPA	574	574	574	574	574	574	574	574	574	963	1,124

*Located on state boundary (interstate)

Increase from Additional Units (Included Above)												
Chief Joseph	BPA	- -	- -	- -	- -	437	1,093	1,101	1,202	1,202	1,202	1,202
Lower Granite	BPA	- -	- -	- -	- -	- -	0	466	466	466	466	466
Little Goose	BPA	- -	- -	- -	- -	- -	0	466	466	466	466	466
Lower Monumental	BPA	- -	- -	- -	- -	- -	- -	0	466	466	466	466
Ice Harbor	BPA	- -	0	383	383	383	383	383	383	383	383	383
Bonneville	BPA	- -	- -	- -	- -	- -	- -	- -	- -	0	389	550

Hydro, Other Than Columbia River System												
Swift #1	PP&L	161	161	161	161	161	161	161	161	161	161	161
Swift #2*	PP&L	76	76	76	76	76	76	76	76	76	76	76
Yale	PP&L	113	113	113	113	113	113	113	113	113	113	113
Merwin	PP&L	133	133	133	133	133	133	133	133	133	133	133
Alder	Tacoma	28	28	28	28	28	28	28	28	28	28	28
LaGrande	Tacoma	65	65	65	65	65	65	65	65	65	65	65
Cushman #1	Tacoma	17	17	17	17	17	17	17	17	17	17	17
Cushman #2	Tacoma	88	88	88	88	88	88	88	88	88	88	88
Mayfield	Tacoma	133	133	133	133	133	133	133	133	133	133	133
Mossyrock	Tacoma	197	197	197	197	197	197	197	197	197	197	197
Ross	Seattle	251	251	251	251	251	251	251	251	251	251	251
Diablo	Seattle	159	159	159	159	159	159	159	159	159	159	159
Gorge	Seattle	175	175	175	175	175	175	175	175	175	175	175
White	Puget	62	62	62	62	62	62	62	62	62	62	62
Upper Baker	Puget	83	83	83	83	83	83	83	83	83	83	83
Lower Baker	Puget	47	47	47	47	47	47	47	47	47	47	47

*Owned by Cowlitz PUD

TABLE 8.—January peak capability of hydroelectric plants serving Washington loads - Continued

Figures are megawatts		1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
Water Year		Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932	Jan 1932
Minor Hydro												
Roza (Net)	BPA	7	7	7	7	7	7	7	7	7	7	7
Yelm	Centralia	10	10	10	10	10	10	10	10	10	10	10
Cedar Falls & Newhalem	Seattle	32	32	32	32	32	32	32	32	32	32	32
Snoqualmie & Minors	Puget	72	72	72	72	72	72	72	72	72	72	72
Meyers Falls	WWP	1	1	1	1	1	1	1	1	1	1	1
Packwood	WPPSS	30	30	30	30	30	30	30	30	30	30	30
Condit, Naches Naches Drop	PP&L	18	18	18	18	18	18	18	18	18	18	18

TABLE 9. — Thirty-year-average energy capability of hydroelectric plants serving Washington loads

Figures are megawatts		Load Year Studied										
		1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84
Columbia Mainstem												
Box Canyon	Pend Or. PUD	49	49	49	49	49	49	49	49	49	49	49
Boundary	Seattle	443	443	443	443	443	442	442	441	442	440	440
Spokane River	WWP	102	102	102	102	102	102	102	102	102	102	100
Grand Coulee	BPA	1,709	1,993	2,245	2,260	2,266	2,214	2,208	2,196	2,192	2,184	2,177
Chief Joseph	BPA	1,111	1,114	1,103	1,111	1,192	1,318	1,321	1,317	1,316	1,313	1,313
Wells	Douglas PUD	522	523	522	519	515	513	512	510	510	509	509
Chelan	Chelan PUD	46	46	46	46	46	45	46	46	46	45	45
Rocky Reach	Chelan PUD	779	780	780	777	772	768	767	764	764	762	762
Rock Island	Chelan PUD	150	149	150	150	149	149	149	148	148	148	148
Wanapum	Grant PUD	670	672	673	668	658	656	655	653	653	651	652
Priest Rapids	Grant PUD	629	631	632	627	618	616	615	614	613	612	613
Lower Granite	BPA	- -	109	281	281	323	323	323	323	322	322	321
Little Goose	BPA	278	278	278	278	278	318	318	318	317	317	316
Lower Monumental	BPA	285	285	285	285	285	327	327	326	326	326	325
Ice Harbor	BPA	241	308	312	312	311	311	310	310	310	310	309
McNary*	BPA	815	812	812	808	801	799	798	797	796	795	795
John Day*	BPA	1,236	1,234	1,231	1,228	1,226	1,224	1,222	1,221	1,219	1,217	1,215
The Dalles	BPA	1,039	1,037	1,055	1,053	1,052	1,050	1,049	1,047	1,046	1,045	1,044
Bonneville*	BPA	550	548	563	562	560	560	559	571	719	738	738

*Located on state boundary (interstate)

Hydro, Other Than Columbia River												
Swift #1	PP&L	73	73	73	73	73	73	73	73	73	73	73
Swift #2*	PP&L	25	25	25	25	25	25	25	25	25	25	25
Yale	PP&L	64	64	64	64	64	64	64	64	64	64	64
Merwin	PP&L	62	62	62	62	62	62	62	62	62	62	62
Alder	Tacoma	25	25	25	25	25	25	25	25	25	25	25
LaGrande	Tacoma	39	39	39	39	39	39	39	39	39	39	39
Cushman #1	Tacoma	12	12	12	12	12	12	12	12	12	12	12
Cushman #2	Tacoma	24	24	24	24	24	24	24	24	24	24	24
Mayfield	Tacoma	70	70	70	70	70	70	70	70	70	70	70
Mossyrock	Tacoma	108	108	108	108	108	108	108	108	108	108	108
Ross	Seattle	77	77	77	77	77	77	77	77	77	77	77
Diablo	Seattle	82	82	82	82	82	82	82	82	82	82	81
Gorge	Seattle	94	94	94	94	95	95	94	95	95	94	94
White	Puget	36	36	36	36	36	36	36	36	36	36	36
Upper Baker	Puget	39	39	39	39	39	39	39	39	39	39	39
Lower Baker	Puget	44	44	44	44	44	44	44	44	44	44	44

*Owned by Cowlitz PUD

Minor Hydro												
Roza	BPA	7	7	7	7	7	7	7	7	7	7	7
Yelm	Centralia	9	9	9	9	9	9	9	9	9	9	9
Cedar Falls & Newhalem	Seattle	13	13	13	13	13	13	13	13	13	13	13
Snoqualmie & Minors	Puget	54	54	54	54	54	54	54	54	54	54	54
Minor Hydro (Meyers Falls)	WWP	1	1	1	1	1	1	1	1	1	1	1
Packwood	WPPSS	11	11	11	11	11	11	11	11	11	11	11
Condit, Naches, Naches Drop	PP&L	16	16	16	16	16	16	16	16	16	16	16

FIRM POWER COMMITMENTS

The key to determining the electrical resources of the state is the electrical energy generated by federal plants committed to supplying Washington loads. This has been tabulated by Bonneville in table 10. By analyzing this tabulation, a determination can be made of all components taken into account in arriving at the final BPA values included in table 11. To these figures have been added corresponding values for each of the generating utilities within the state, taking into account certain adjustments for those items that have already been included in the Bonneville figures (all duplications were deleted in preparing table 11).

The final tabulation credited to each utility represents a net firm resource not duplicated by Bonneville or any other utility, with losses, reserves, imports, exports, and all other such factors accounted for.

BONNEVILLE CONTRACTUAL COMMITMENTS

In the Bonneville contracts with publicly owned utilities as stated under Assumptions (page 107), Bonneville agrees to provide all electric power required by these customers for 8 years after they (Bonneville) have notified the utility that they will no longer serve their anticipated load growth. Inasmuch as there have been no such notices given and no indication that any such notices will be given in the foreseeable future, it has therefore been established in this report that the electric energy represented by these Bonneville commitments, including also firm commitments to its industrial customers, can be considered firm and therefore determined an energy resource.

WASHINGTON STATE LOADS AND RESOURCES

In this report all such firm commitments by Bonneville to their statutory preferenced customers, publicly owned utilities, and Bonneville firm contracts with industrial customers have been summarized in table 10. To these have been added the generating resources of Washington municipalities and the Public Utility Districts committed to Washington customers. Included also are the resources of investor-owned electric utilities of the state and their out-of-state energy imports committed to serving their Washington customers. In essence, all firm electrical energy resources committed to serve the estimated loads of Washington customers are considered to be the electrical energy resources of the State of Washington. Electric energy resources, as determined in this manner, have been developed in table 11.

The total values of 11,504 megawatt peak and 7,426 megawatt average for the years 1973-74 increasing year by year to 19,914 megawatt peak and 12,720 megawatt average for the years 1983-84 represent the estimated Washington net firm electrical resources for the present and for each year for the next ten-year period.

As previously indicated in this report, only firm electrical energy resources committed to serve the estimated loads of the State of Washington are considered to be electrical energy resources of the state. This takes into account energy generated within the state committed to serve loads out of the state (export) and energy generated outside of the state committed to serve loads within the state (import), and also that Bonneville is committed to providing the firm energy requirements of publicly owned utilities and certain industries.

Table 11 is based upon a report entitled "Long-Range Projection of Power Loads and Resources for Thermal Planning, West Group Area, 1973-74 through 1992-93," dated April 9, 1973, and prepared by the Subcommittee on Loads and Resources of the Pacific Northwest Utilities Conference Committee (see table 3). In the development of table 11, surpluses and deficiencies are made zero by exporting surpluses and importing deficiencies.

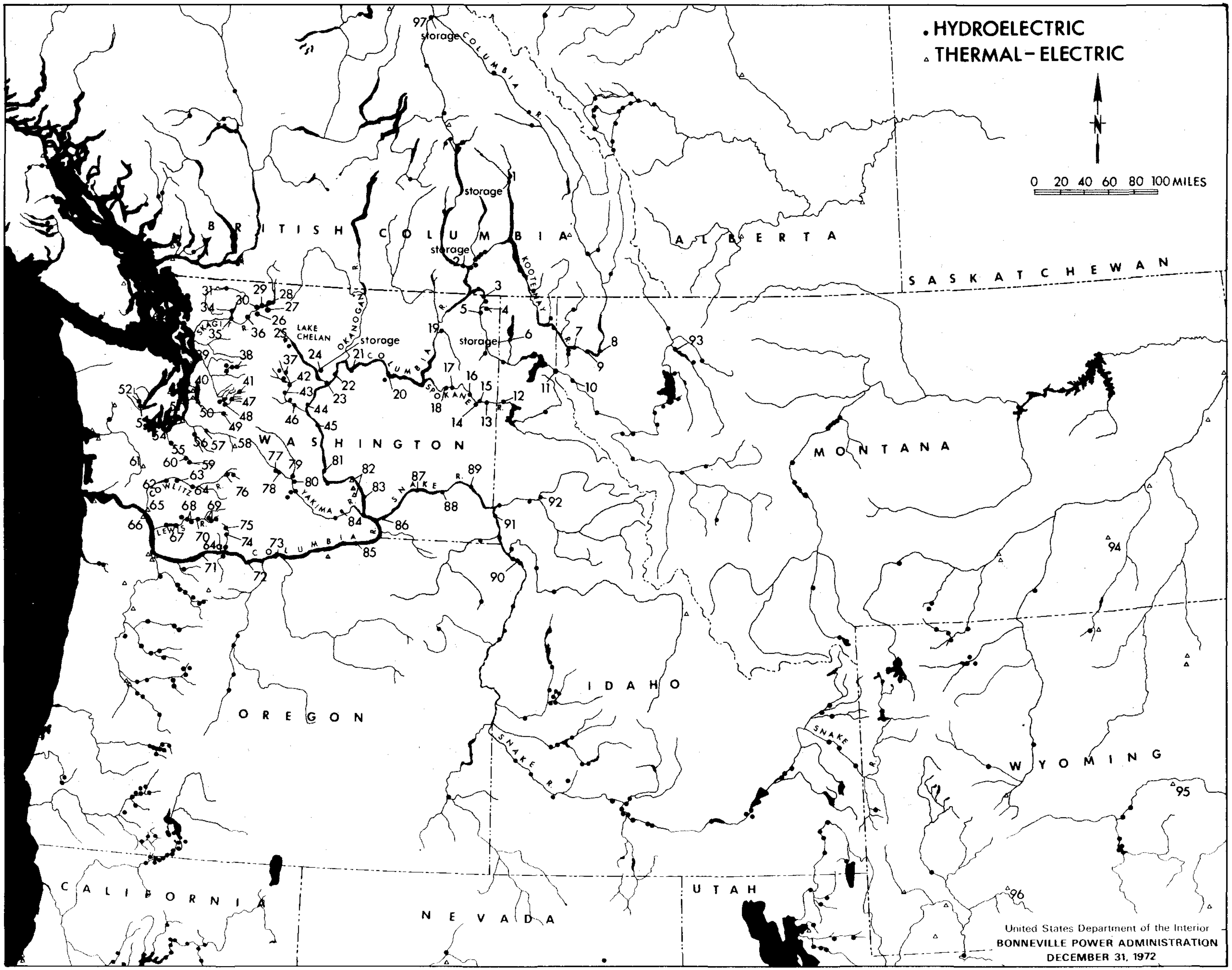

FIGURE 3.—Electric power plants in the Pacific Northwest and adjacent areas. Appendix B—Nameplate ratings lists these plants and indicates whether they are existing, under construction, authorized, or potential.

ELECTRIC POWER PLANTS AS SHOWN ON FIGURE 3

1. Duncan (storage)
2. Arrow (storage)
3. Boundary
4. Sullivan Creek
5. Box Canyon
6. Priest Lake (storage)
7. Kootenai Falls
8. Libby
9. Libby, ML&P, PP&L
10. Noxon Rapids
11. Cabinet Gorge
12. Post Falls
13. Spokane
14. Monroe Street
15. Upper Falls
16. Nine Mile
17. Long Lake
18. Little Falls
19. Meyers Falls
20. Grand Coulee
21. Chief Joseph
22. Wells
23. Chelan
24. Antilon Lake (storage)
25. Stehekin
26. Newhalem
27. Thunder Creek
28. Ross
29. Diablo
30. Gorge
31. Nooksack
32. East Sound
33. Friday Harbor
34. Upper Baker
35. Lower Baker
36. Copper Creek
37. Dirtyface Mountain
38. Sultan 1, 2, 3
39. Whidbey Island
40. Lake Union
41. N. Fk. Snoqualmie
42. Beaver
43. Leavenworth
44. Rocky Reach
45. Rock Island
46. Dryden
47. Mile 5.9
48. Snoqualmie Falls
49. Cedar Falls
50. Shuffleton
51. Georgetown
52. Cushman No. 1
53. Cushman No. 2
54. Tacoma 1, 2
55. Yelm
56. Electron
57. White River
58. Crystal Mountain
59. Alder
60. La Grande
61. Centralia
62. Mayfield
63. Mossyrock
64. Cowlitz Falls
64a. Condit
65. Longview
66. Trojan
67. Yale and Merwin
68. Swift 1, 2
69. Meadows, Lower, Upper
70. Muddy
71. Bonneville
72. The Dalles
73. John Day
74. Trout Creek
75. Ninefoot Creek
76. Packwood Lake
77. Naches Drop
78. Naches
79. Roza
80. Priest Rapids
81. Wanapum
82. WPPSS 1, 2
83. Ben Franklin
84. Chandler
85. McNary
86. Ice Harbor
87. Lower Monumental
88. Little Goose
89. Lower Granite
90. High Mountain Sheep
91. Asotin
92. Dworshak
93. Hungry Horse
94. Colstrip
95. Dave Johnston
96. Jim Bridger
97. Mica (storage)

TABLE 10.—Federal system estimated firm load requirements

Figures are January Peak and Critical

	1973-74		1974-75		1975-76		1976-77	
	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.
Industrial, Committed & Renewal	1,736	1,692	1,686	1,686	1,686	1,660	1,686	1,660
Potential Industry	-	-	-	-	-	-	-	-
Federal Agency Loads	123	131	116	126	126	125	117	125
Public Agency Commitments	38	-	38	-	38	-	45	-
Private Utility Commitments	133	116	150	11	150	11	274	11
Columbia Storage Power Exchange to West Group	-	-	-	45	384	216	524	257
WPPSS No. 1 to West Group	202	225	135	429	107	123	113	92
Exports	-	-	-	-	-	-	-	-
Public Agency Allocations	3,382	2,093	3,687	2,131	4,062	2,529	4,026	2,616
Private Utility Allocations	-	-	-	-	-	-	-	-
Cold Weather Factor	124	-	134	-	147	-	157	-
Load Growth Reserves	-	-	368	172	406	180	358	190
Losses	318	181	326	177	345	178	352	179
Total Firm Load	6,056	4,438	6,640	4,777	7,441	5,022	7,652	5,130

1/ Critical period is 42½ months in all years.

Source: PNUCC, 1973, Long range projection of power loads and resources for thermal for Table 2): Prepared by Subcommittee on Loads and Resources, April 1973.

TABLE 11.—Washington's

Critical Period 42½ Months	1973-74		1974-75		1975-76		1976-77	
Energy in Megawatts	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.
Bonneville Power Admin.	6,056	4,438	6,640	4,777	7,441	5,022	7,652	5,130
Washington Water Power Co.	479	270	504	287	582	353	573	353
Pacific Power & Light Co.	472	267	503	285	535	303	570	323
Puget Sound Power & Light Co.	1,964	1,155	1,989	1,223	2,153	1,367	2,267	1,497
Tacoma City Light	665	301	665	294	665	287	710	287
Seattle City Light	1,445	720	1,503	742	1,501	741	1,775	776
Chelan County PUD No. 1	277	202	282	213	283	213	307	225
Grant County PUD No. 1	65	36	65	36	65	36	105	54
Douglas County PUD No. 1	...	...	3	1	3	2	10	4
Pend Oreille County PUD No. 1	24	13	26	14	28	15	29	15
Cowlitz County PUD No. 1	21	9	21	11	21	11	45	22
Grays Harbor County PUD No. 1	17	3	17	3	17	3	17	3
Snohomish County PUD No. 1	...	...	...	...	...	...	...	...
Minor Hydro	19	12	19	12	19	12	19	12
Additional Skagit Nuclear (Puget Power)	...	...	...	...	...	...	...	...
Total	11,504	7,426	12,237	7,898	13,313	8,365	14,079	8,701

1/ Based on Long-Range Projection of Loads and in Washington, West Group area of Northwest Power Pool

Period Average Energy in Megawatts 1/

1977-78		1978-79		1979-80		1980-81		1981-82		1982-83		1983-84	
Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.
1,822	1,755	1,822	1,784	1,822	1,784	1,822	1,784	1,822	1,784	1,822	1,784	1,822	1,784
-	-	-	-	-	-	38	39	203	196	383	362	484	461
117	125	117	125	117	125	117	125	117	129	117	131	117	131
45	-	51	-	55	-	51	-	51	-	51	-	51	-
294	11	293	11	286	11	277	11	273	11	262	11	246	11
515	263	662	308	648	290	630	273	619	255	591	241	726	291
115	93	117	95	120	87	137	117	137	117	137	117	137	117
-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,362	2,820	4,580	2,968	4,905	3,177	5,233	3,417	5,321	3,500	5,525	3,540	5,850	3,717
-	-	-	-	-	-	-	-	-	-	-	-	-	-
169	-	183	-	196	-	210	-	224	-	238	-	240	-
400	199	269	220	263	221	273	237	355	246	342	256	447	266
384	189	403	195	431	199	454	211	476	218	523	230	538	235
8,223	5,455	8,497	5,706	8,843	5,894	9,242	6,214	9,583	6,456	9,991	6,672	10,658	7,013

planning; West Group Area, 1973-74 through 1992-93 (supporting data

BPA-BPR 7/5/73

electrical resources 1/

1977-78		1978-79		1979-80		1980-81		1981-82		1982-83		1983-84	
Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.	Peak	Avg.
8,223	5,455	8,497	5,706	8,843	5,894	9,242	6,214	9,583	6,456	9,991	6,672	10,658	7,013
639	399	619	387	613	387	610	382	801	509	903	626	900	634
607	344	646	366	688	390	733	416	781	443	832	473	886	503
2,498	1,582	2,711	1,735	2,829	1,868	2,826	1,881	3,338	2,389	3,331	2,393	3,323	2,383
710	287	710	287	710	286	710	286	921	331	921	384	921	381
1,773	775	1,771	773	1,770	771	1,768	770	1,878	814	1,876	866	1,873	864
336	240	340	241	364	252	369	256	374	256	380	259	391	268
105	57	227	124	244	134	261	143	279	153	300	163	320	175
10	5	10	5	10	5	10	5	10	5	10	4	10	4
31	16	33	17	34	18	36	19	38	20	40	20	42	22
45	25	74	41	106	58	106	58	106	58	106	58	106	58
17	3	17	3	17	3	17	3	73	26	73	51	73	51
...	...	...	...	...	...	...	...	112	44	112	98	112	95
19	12	19	12	65	38	65	38	65	35	65	35	65	35
...	...	...	...	...	...	...	...	234	234	234	234	234	234
15,013	9,200	15,674	9,697	16,293	10,104	16,753	10,471	18,593	11,773	19,174	12,336	19,914	12,720

Resources for Thermal Planning, 1973-74 to 1992-93.

This report summarizes resources required for January peaks and to serve critical-period-average energy requirements for each operating fiscal year, 1973-74 through 1983-84. New generation resources include those scheduled on an assured[1] basis, plus several hydro and combustion turbine additions. New hydro additions include one unit each at Mossyrock, Mayfield, and Noxon, 8 units at Rock Island, and the effect of raising the height of Ross Dam. (Combustion turbine additions include Seattle City Light's proposed unit in 1974-75). Included also are Puget Power's Sedro Woolley (Skagit) nuclear unit and Washington Public Power Supply System's nuclear unit No. 3 (Satsop) both scheduled for 1981-82, and new coal-fired units Nos. 3 and 4 at Colstrip.

In addition to generation indicated in the table, utilities are providing sufficient generation for forced outage reserve on a probability of a loss of load one day in 20 years.

Values indicated are net, with maintenance and other such factors having been taken into consideration.

Although table 11 is projected to provide firm energy upon critical water conditions, the assumption is made that the normal industrial interruptible loads will also be carried by Bonneville over and above values shown in table 11 for water conditions above critical levels.

Estimated firm loads to be provided for include Bonneville firm industrial contracts for Washington industries.

Washington Public Power Supply System No. 1 (Hanford) capabilities are now based on production of 4 billion kilowatt-hours per year through 1977. By September 1981, Washington Public Power Supply System No. 1 will have been converted to a 1220 megawatt plant.

CANADIAN ENTITLEMENT

The Columbia River originates some 498 miles upstream from the United States-Canada border. Tributaries of the upper Columbia account for about 30 percent of the total annual water discharge of the Columbia River. These northern tributaries are subject to violent seasonal floods. Not only were these floodwaters wasted over the spillways of the dams downstream at a loss of some $30 million in power each year, but they were also the major cause of the annual runoff floods in the Portland-Vancouver area. One such flood in 1948 destroyed the city of Vanport, Ore., (population 20,000), resulting in 23 persons dead or missing.

To prevent the continued recurrence of these disastrous floods, studies were made that resulted in an agreement between the United States and Canada to construct storage dams and reservoirs on the upper Columbia, one each near Mica Creek, Arrow Lakes, and Duncan Lake. It was agreed that Canada would construct and operate these three dams and reservoirs, with an aggregate storage of 15.5 million acre-feet, and thus regulate the river flow to produce hydroelectric power from these impounded waters, and to provide flood control. Without these upstream storage reservoirs, the 1972 high-water season would have created the greatest flood in the history of the lower Columbia. All increased power resulting from this storage is generated by plants located downstream in the United States and is being shared equally between the United States and British Columbia.

Waters are impounded during flood periods and released to control flooding, or released as needed to provide maximum benefits in power production, as well as flood control. In addition, this same agreement permitted the United States to build the dam and large storage reservoir on the Kootenai River near Libby, Montana. The Libby reservoir extends some 42 miles into Canada. The Kootenai was also subject to flooding.

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[1] Authorized, licensed, and funded.

DOWNSTREAM GENERATION

The downstream benefits of the Canadian Entitlement are many. It included some additional 2.8 million kilowatts of dependable power, which was to be shared equally with British Columbia. Canadian Entitlement to the United States for 1978-79 is 1.5 million kw of capacity and 0.68 million kw of energy.

In May, 1964, a nonprofit corporation called the "Columbia Storage Power Exchange" (CSPE), was organized. CSPE acting as a single purchaser bought the Canadian power entitlement right for 30 years, until April 1, 2003, from British Columbia. CSPE transferred these rights to the group of participants shown on table 12. The participants decided that for the next few years they would not need this power and

TABLE 12.—Columbia Storage Power Exchange

Participants	Percentage
Public Utility District No. 1 of Benton County	0.80
Village of Bonners Ferry, Idaho	0.05
Central Lincoln Peoples' Utility District	1.00
Public Utility District No. 1 of Chelan County	1.00
Public Utility District No. 1 of Clark County	3.00
Clatskanie Peoples' Utility District	0.20
*Coos-Curry Electric Cooperative, Inc.	0.50
City of Coulee Dam, Washington	0.10
Public Utility District No. 1 of Cowlitz County	2.50
*Public Utility District No. 1 of Douglas County	0.20
City of Eugene, Oregon	5.50
*Flathead Electric Cooperative, Inc.	0.10
City of Forest Grove, Oregon	0.30
Public Utility District No. 1 of Franklin County	0.80
Public Utility District No. 2 of Grant County	0.45
Public Utility District No. 1 of Grays Harbor County	1.50
*Idaho County Light and Power Cooperative Association, Inc.	0.10
*Inland Power & Light Company	0.50
*Lane County Electric Cooperative, Inc.	0.40
*Lincoln Electric Cooperative, Inc. (Mont.)	0.10
*Lincoln Electric Cooperative, Inc. (Wash.)	0.10
City of McMinnville, Oregon	0.40
*Missoula Electric Cooperative, Inc.	0.10
*Nespelem Valley Electric Cooperative, Inc.	0.05
*Northern Lights, Inc.	0.35
Pacific Power & Light Company	10.00
Public Utility District No. 1 of Pend Oreille County	0.20
City of Port Angeles, Washington	0.50
Portland General Electric Company	17.50
Puget Sound Power & Light Company	17.50
*Ravalli County Electric Cooperative, Inc.	0.10
City of Richland, Washington	0.80
Salem Electric	0.40
City of Seattle, Washington	12.50
Public Utility District No. 1 of Skamania County	0.20
Public Utility District No. 1 of Snohomish County	1.50
City of Springfield, Oregon	0.50
City of Tacoma, Washington	12.50
*Tillamook Peoples' Utility District	0.50
Vera Irrigation District No. 15	0.20
The Washington Water Power Company	5.00

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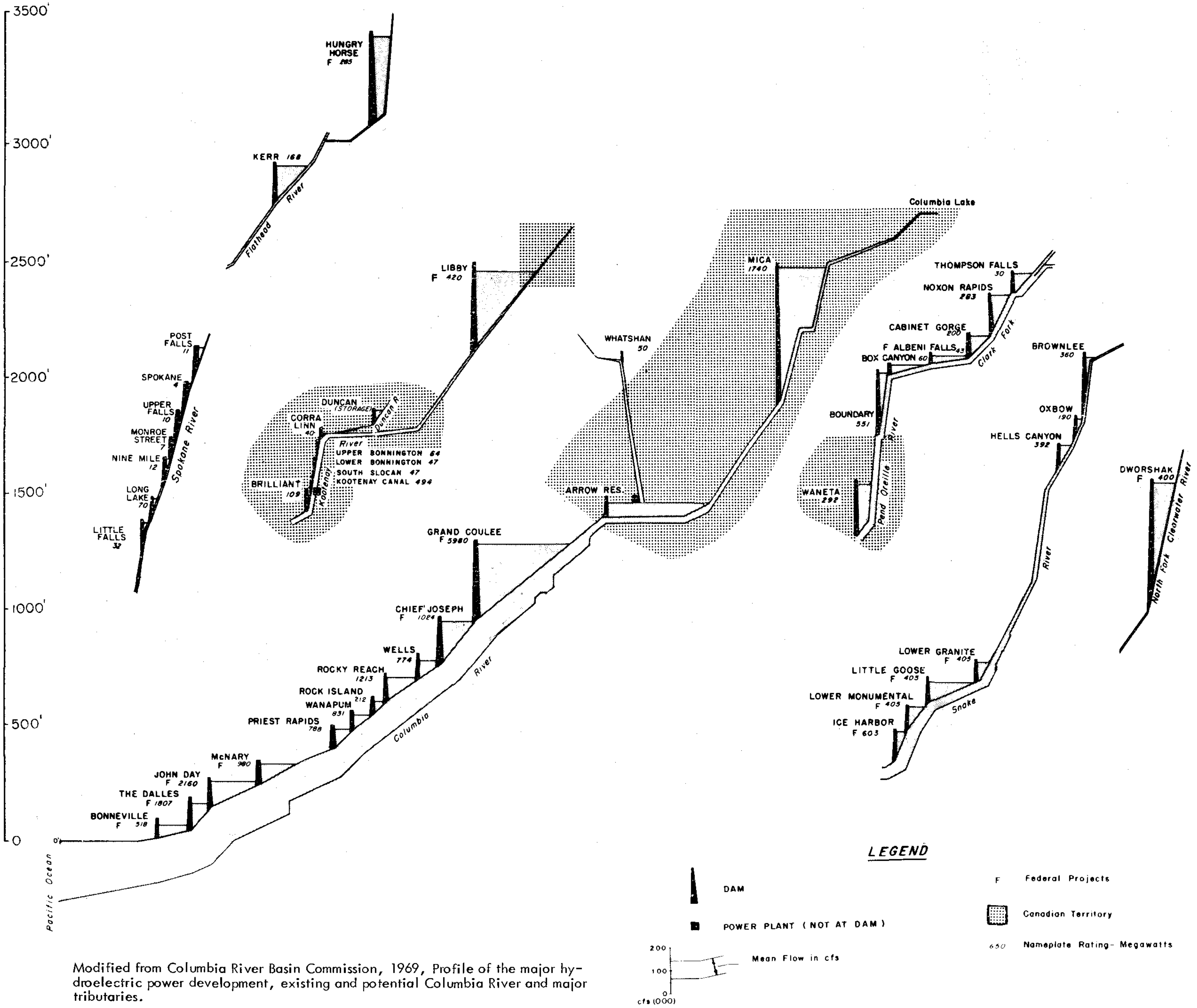
* Approval of this agreement by Rural Electrification Administration required.



Modified from Columbia River Basin Commission, 1969, Profile of the major hydroelectric power development, existing and potential Columbia River and major tributaries.

FIGURE 4.—Power development-Main Columbia River System.

agreed to sell it to purchasers in California. This power has been sold to California utilities for varying periods from 5 to 10 years, after which time it will be available to the 41 participating utilities, starting April 1, 1975.

Downstream benefits are expected to reach a maximum about 1975, then they will sharply decrease. As more plants are installed, the benefits resulting from regulation upstream will decrease until it will become minimal.

The above-mentioned storage dams are shown on the Columbia system profile titled "Power Development-Main Columbia River System" (figure 4). This sketch illustrates the dams located along the Columbia River and its major tributaries, and their relative elevation and distance from the Pacific Ocean. The shaded areas represent Canadian areas. It can be seen how large storage reservoirs at Arrow, Mica, and Duncan in Canada, with Libby, Hungry Horse, and Dworshak in the United States, regulate flooding and power generation of the Columbia River system.

The large reservoirs in Canada, Libby in Montana, and Dworshak in Idaho, now being filled, have increased the storage capacity of the Columbia River Power System by approximately 56 percent. This large increase in water storage increases firm power at the expense of the availability of secondary power used extensively by the electroprocessing industry.

The ability of Bonneville to sell its secondary power to these industries, as interruptible power, has been very advantageous to Bonneville in the past, by adding income from otherwise wasted energy of spilled water.

ELECTRIC GENERATING UTILITIES

FEDERAL COLUMBIA RIVER POWER SYSTEM

Under recent operation there are 25 generating plants, 17 installed and operated by the Corps of Engineers and 8 installed and operated by the Bureau of Reclamation. In addition, two new reservoirs, Libby and Dworshak, are in operation with generating units now being installed and 6 additional plants are under construction or authorized. Bonneville Power Administration (BPA) provides the transmission system and is the market agent for all electrical power generated by these federal agencies.

BPA High-Voltage Transmission System includes approximately 12,000 circuit miles of high-voltage lines, a large number of high-voltage substations, thousands of miles of right-of-way corridors, and the control and dispatch system.

The W. A. Dittmer BPA Control and Dispatch Center located at Vancouver, Washington, includes an elaborate $5 million computer system, referred to as a "Real Time Operations Dispatch and Scheduling System," an 800-kilowatt Gas Turbine Emergency Generator System, a solid-state Uninterruptible Power Supply System, 5 microwave system terminals, and a system of supervisory control and data acquisition terminals for some 50 channels.

Taken together this constitutes the largest, most advanced electric power generation control and dispatch system in the world.

There are 12 federal plants located in Washington. Four of these are located on the lower Columbia where the river forms the boundary between the states of Washington and Oregon. These border plants are Bonneville, The Dalles, John Day, and McNary. No effort was made to determine which state, Washington or Oregon, should claim the generation from these four plants. Rather than make some arbitrary division of the generation produced by these plants, they are being identified as border plants. Bonneville credits the state having the powerhouse with the total generation; thus Washington has credit for The Dalles plant and Oregon is credited with the other three.

Bonneville Energy Exchanges

Columbia Storage Power Exchange (Canadian Entitlement)

Bonneville Power Administration has made an agreement with the CSPE participants for British Columbia's share (one-half) of the additional power from downstream generating plants on the Columbia, resulting from the three storage dams in Canada (Mica, Arrow, and Duncan). In return BPA has agreed to supply utilities with guaranteed amounts of power and energy. This power is currently being sold to California utilities.

Washington Public Power Supply System

WPPSS No. 1 (Hanford).—BPA has an agreement with Washington Public Power Supply System and its 76 participating utilities for Bonneville to acquire all power generated by the plant, and in return BPA is required to reimburse the annual cost with firm power at Bonneville rates.

WPPSS Nos. 2 and 3 (Hanford).—BPA has entered an agreement with WPPSS to take the entire output of WPPSS Nos. 2 and 3. Bonneville is obligated to reimburse the annual costs with firm power at Bonneville rates.

PUBLIC POWER SYSTEMS

City of Centralia

The Centralia Municipal Light Utility was established in 1895. A hydroelectric generating plant was completed by the city on the Nisqually River in 1930. This plant, consisting of two units totaling 4,500 kw, located near Yelm, supplied the city until 1941, at which time it began to purchase power from Bonneville to supplement its own power resources. In 1955, the city added another 4,500 kw unit at its Yelm plant, increasing its generating capabilities of the three plants to 9,000 kilowatts.

Chelan County Public Utility District

Rocky Reach Hydroelectric Project

Capability: 1,213,600 kilowatts

Power output goes to Chelan County PUD, Aluminum Co. of American, Pacific Power & Light Co., Portland General Electric Co., Puget Sound Power & Light Co., and Washington Water Power Co.

History.—Construction started in October 1956 on the $273,100,000 project, located 7 miles upstream from the City of Wenatchee. The dam is 4,800 feet long, including a 750-foot spillway section and a 1,088-foot powerhouse. The structure formed a 42-mile-long reservoir named Lake Entiat. The seventh and final unit of the initial project went on line in 1961, with the dam and powerhouse being completed in 1962. On December 1, 1971, the fourth and final unit of the $40,000,000 Rocky Reach expansion was released for power production, increasing the plant capability to 1,213,600 kilowatts.

Rock Island Hydroelectric Project

Capability: 212,100 kilowatts

Power output goes to Chelan County PUD and Puget Sound Power & Light Co.

History.—Located 12 miles downriver from Wenatchee (at Mile 453.4), Rock Island Dam was the first hydroelectric project built across the Columbia River. The 3,800-foot dam was completed in 1933 with four initial generators. Six generators were added in 1953 by the PUD in a lease arrangement with Puget Sound Power & Light Co. The entire facility was purchased in 1956. In March of 1973, application was made to Federal Power Commission for License Amendment to construct a second powerhouse with a planned installation of 410,000 kw.

Lake Chelan Hydroelectric Project

Capability: 48,000 kilowatts

Power output goes to Chelan County PUD and Washington Water Power Co.

History.—Lake Chelan Dam was built in 1927 by Washington Water Power Co. on the Chelan River, at the foot of 55-mile-long Lake Chelan. The complex was purchased by the district in 1955. The 490-foot-long dam diverts the lake's drainage to the Columbia through an 11,828-foot rock tunnel and steel penstock to drive two generators. A second powerhouse is under investigation to add 239,000 kw.

Future Plans for Additional Generation

Lake Chelan Hydroelectric Project.—To comply with Federal Power Commission requirements for relicensing, the Chelan County PUD has in progress a comprehensive study to determine whether the present hydroelectric facility represents optimum use of the Lake Chelan project power site. The present license expires in 1976.

The existing plant is an efficient firm energy producer with a capability of 48,000 kilowatts. Additional generating capacity under investigation would make the project essentially a producer of peaking power.

The most feasible alternative development appears to be construction of a new control dam and a second powerhouse, with a generating capacity of 239,000 kilowatts, which would bring the total capacity of the project to 290,000.

Rock Island Hydroelectric Project.—In March 1973, the Chelan County PUD filed for a License Amendment to construct a second powerhouse at Rock Island Dam. The expansion plan calls for the construction of a second powerhouse, on the right abutment of the existing dam, to contain eight generating units, with a total installed capacity of 410,000 kilowatts.

The project schedule anticipates the granting of license for construction in early 1974. If all elements of the schedule are met, the first three generating units will be on line before the 1977-78 winter peak load and the remaining five units will be placed in service during 1978.

Antilon Lake Pumped Storage Project.—In December 1972, the Chelan County PUD received a preliminary permit from the Federal Power Commission to investigate the proposed Antilon Lake Pumped Storage Project, located near Manson, Washington.

The proposed plan calls for the conversion of the Antilon irrigation reservoir (soon to be abandoned) to the upper reservoir of a hydroelectric pumped storage project capable of producing 2 million kilowatts of capacity. The project would involve pumping water from Lake Chelan, 1,300 feet up to Antilon Lake during low-power demand periods, then releasing the water back through the turbines to generate electricity during peak demand periods.

The permit gives Chelan County PUD priority for a license over nonfederal entities, but does not authorize construction. The Interim Feasibility Report, received in 1972 from consulting engineers, states that the project has both engineering and economic feasibility. The estimated cost is between $96.8 million and $162 million, depending on plant capacity. The construction period is estimated to be 4 years. Presently scheduled federal peaking capacity would make the plant unnecessary for peaking until after 1990. If schedules are delayed, the plant will be feasible at an earlier date. Until the construction of thermal peaking begins, pumped storage will have the penalty of a reduction of system firm energy capability.

Douglas County PUD No. 1

Public Utility District No. 1 of Douglas County serves the electrical needs of approximately 7,400 consumers, located in Douglas County, Washington. The county is basically agricultural with grain, cattle, and fruit as its principal products. Douglas County is located in the east-central part of the state, with the Columbia River as a major part of its boundary. Along this water boundary is the federally operated Chief Joseph Hydroelectric Project; the Wells Hydroelectric Project, which is owned and operated by Douglas County PUD; and the Rocky Reach and Rock Island Projects, owned and operated by the Chelan County PUD.

The electrical energy generated by the Wells Hydroelectric Project is sold to four major northwest utilities. They are, in the order of power purchased, Puget Sound Power & Light Co., Portland General Electric Co., Pacific Power & Light Co., and Washington Water Power Co. The district retains the right to recall up to 38 percent of the generation from the Wells project to serve the needs of its consumers; thus, assuring a plentiful supply of electrical energy for the future. In addition, the Douglas County PUD has filed with the Federal Power Commission for a preliminary permit to investigate the feasibility of constructing a pump storage generating facility with 1,000,000 kw of peaking power at the Browns Canyon site, which is located in Douglas County, about 40 miles upstream from Wenatchee.

Grant County PUD

Power Generation Operations

On October 19, 1959, the first generator at Priest Rapids was placed on line, and Grant County PUD became an important producer of hydroelectric power in the Pacific Northwest. Full commercial operation was achieved by July 31, 1961. This development now has a capability of 788,500 kilowatts and produced 5,211,598 megawatt hours in 1972.

Wanapum Dam, the second half of this project, began operation July 1, 1963, and was in full commercial operation January 18, 1964. It has a capability of 831,250 kilowatts and produced 5,193,897 megawatt hours in 1972.

With the start of Wanapum generation, the district established a plan of operation whereby the two plants were operated on a coordinated basis, both hydraulically and electrically. This was a complex arrangement, which allowed any or all of their 13 purchasers of power to schedule their share of generation from these plants on an hourly schedule or moment-by-moment basis.

This was a new concept in the industry but laid the groundwork for the development of a moment-by-moment control of the mid-Columbia plants, including Grand Coulee through Priest Rapids. This is called "Hourly Coordination" and has been in operation since January 30, 1973.

Grant County PUD was a prime leader in the development of this concept. The fact that they had developed experienced personnel and suitable equipment was the deciding factor in the selection of Grant's Dispatch Office in Ephrata, Washington, as the Control Center for the complex operation.

This effort is dedicated to the need to increase the usability, both in energy and peak, of the capability of the plants involved regardless of ownership. It is also intended to reduce the impact on environment of river operation as the Northwest moves from all hydro to hydro-thermal power supply. To achieve this, it will be necessary to bring the mid-Columbia plant's hydraulic capacility more nearly in balance. Grand Coulee, Chief Joseph, and Rock Island are, at present, the deficient plants, in terms of hydraulic capacity.

As a record of coordination develops, plans for future additions at Wanapum and Priest Rapids will be refined. The present estimate is that by 1978 the addition of up to 6 additional units at Wanapum, and by 1982 a similar amount of capacity at Priest Rapids will be warranted.

The two plants have been operated efficiently and have served well the power purchasers who were willing to underwrite the venture. These plants were started at a time when the federal government had drastically reduced its own construction program, and they now are major contributors in meeting the very tight northwest power requirements.

As Grant County PUD became a major power generating entity, it assumed a responsible role in northwest and western power problems. Its people played an important part in Canadian treaty negotiations and the related Coordination Contract. The operating personnel are active in the Northwest Power Pool. Both in financing and manpower, the district actively supports the activities of the Western Systems Coordinating Council, the utility forum for major utilities in the fourteen Western States.

Seattle City Light

When the citizens of Seattle incorporated as a city in 1869, they adopted a charter that, among its many other provisions, authorized the newly formed municipality to purchase or construct the necessary facilities for lighting the city. This provision was first implemented in 1902 when Seattle's citizens voted a bond issue for the construction of a dam and power plant at Cedar Falls on Cedar River. Construction began in April of that year, and on October 14, 1904, two 1200-kilowatt units were officially started. Operation had scarcely begun before various citizens were asking for City Light service to their homes. The first residential customer was connected in September 1905, and from that time on the growth of business was so great that the chief concern of City Light engineers was to provide capacity at a sufficient rate to keep up with the demand. The next two units of 4,000 kilowatts were placed in service at the Cedar Falls plant in 1909.

The first phase in the development of Cedar Falls culminated with the construction of the masonry dam, completed in 1914. Two hydroelectric units were installed at Cedar Falls in 1921 and 1929, which ultimately replaced the first four generators that were retired from service in 1932.

The development at the site of the Lake Union steam plant began with the installation in 1911 of a 1500-kilowatt auxiliary hydro unit, which utilized the overflow from the Volunteer Park Reservoir. The first 7500-kilowatt steam unit at this site was placed in service in 1914. The rapid growth of load during and after the First World War necessitated the expansion of this steam plant to a nominal capacity of 30,000 kilowatts with an overload capacity of 40,000 kilowatts, the second unit being added in 1918 and the third in 1921.

In 1918 City Light obtained a permit from the federal government to develop the upper Skagit River, which was favorably located for economical transmission to Seattle, thus beginning the era of Skagit construction. The first two units at the Gorge plant were placed in service in September 1924, and a third was added in 1929. The completion of Diablo Dam in 1930 provided some storage for the operation of the Gorge plant until 1936 when the first unit at Diablo began generating. In 1937, construction commenced on Ross Dam which, from the completion of the first step in 1940, provided storage for Diablo until the first 90,000-kilowatt Ross unit was installed in 1952. The fourth 90,000-kilowatt generator was installed and began operation at Ross powerhouse in 1956. Ross Dam was designed with 5-foot square depressions on its face to permit raising its height at a future date an additional 122.5 feet to its ultimate elevation.

The Gorge Reservoir was raised 88 feet to a pool elevation of 875 feet by completion of the new Gorge 285-foot dam during 1960. The high dam, together with improvements to the powerhouse, has increased the capacity at Gorge powerhouse to 175,000 kilowatts. The Newhalem unit, which was damaged by fire July 16, 1966, was rebuilt and modernized, and placed back in service in February 1970.

In 1961, Seattle City Light was granted a license to construct a hydroelectric plant at the Boundary site on the Pend Oreille River in eastern Washington. Construction began June 24, 1963, and the first of the four units started generation August 24, 1967. The specified capacity of the plant with four units is 650,000 kw. There are provisions for the addition of two more units. Transmission from Boundary is accomplished by a wheeling contract with the Bonneville Power Administration. Energy is transmitted by displacement to the Seattle service area.

Coincident with the growth of the generating plants has been the construction of the transmission and distribution systems. The first Cedar Falls power was transmitted at 45,000 volts. Later the voltage was raised to 60,000 volts. In 1961, the transmission voltage was again raised to 110,000 volts over a single transmission line and the Cedar Falls plant was placed on semiautomatic operation with supervisory control. Transmission from the Skagit project was at 165,000 volts for many years, but was increased to 230,000 volts in 1941. There are now four 230,000-volt lines from the Skagit. Three of them terminate at Bothell Substation north of Seattle, and the fourth at the BPA Snohomish Substation. Two 230,000-volt circuits continue on from Bothell around the east side of Lake Washington to serve the south end of Seattle, while the voltage at Bothell is stepped down to 115,000 volts for serving the north end.

Seattle City Light has an 8 percent ownership interest in the Centralia Steam-Electric Project, amounting to a rated capacity of 112,000 kw.

Generation Development in the Future

Skagit developments being studied are (a) an 83,000-kilowatt plant 6 miles below Newhalem at Copper Creek, (b) increasing the height of Ross Dam another 122.5 feet, and (c) diverting Thunder Creek into Ross Lake.

Other possibilities being studied are thermal plant developments. One such possibility is a 1000-megawatt nuclear plant on Kiket Island near Deception Pass.

Purchased Power

Bonneville Power Administration.—Seattle City Light has a requirements contract, under which BPA agrees to supply power requirements in excess of Seattle's own resources under 1936-37 water conditions. Seattle City Light's resources under this agreement are augmented by the benefits of coordination with Tacoma City Light and reduced by an allowance for reserve generating capacity. The computed demand under this contract was 370,500 kilowatts, as of December 1966, based on energy deficiency. When the Boundary plant came into production in 1967, BPA purchases were reduced to zero. Since 1967, the firm purchases from BPA have increased to 145 megawatts, as of October 1970.

Pend Oreille County PUD No. 1.—(1) A 50-year contract, running to the year 2005, provides Seattle City Light a purchased supply of a minimum of 36,000 kilowatts at 75 percent load factor, plus any additional power available from the Box Canyon plant after the PUD has met its own load requirements. Scheduled callback reduces the amount eventually to 12,000 kilowatts by the year 2000.

(2) A 20-year contract with BPA, running to the year 1975, wheels power purchased from Pend Oreille County PUD over BPA lines to Seattle. This contract provides two 15-year renewal periods.

Grant County PUD No. 2.—(1) A contract running to the year 2005, provides Seattle with a purchased 8 percent (approximately 72,960 kilowatts at 54 percent load factor out of the 788,500 kilowatt capacity) of the output of the Priest Rapids plant.

(2) A contract with BPA, for the wheeling of the purchased Priest Rapids power over BPA facilities to Seattle runs to the year 2005.

Tacoma City Light

The City of Tacoma, Department of Public Utilities, Light Division, owns and operates six hydro projects.

On the Nisqually River heading on Mount Rainier, Alder Reservoir impounds water for release through Alder and LaGrande powerhouses. On the Cowlitz River, also originating on Mount Rainier, Mossyrock Dam has created Lake Davisson. Waters are released from the lake through Mossyrock powerhouse. These waters, after being joined by those of the Tilton River and Winston Creek, pass through the Mayfield Development.

At the southern end of the Olympic Peninsula, the waters of the North Fork of the Skokomish River flow in a southeasterly direction into Lake Cushman, formed by Cushman No. 1 Dam. After passing through Cushman No. 1 powerhouse, the waters flow into Lake Kokanee where they enter Hood Canal by way of Cushman No. 2 powerhouse.

In addition to their six hydro projects, Tacoma City Light owns and operates, as required, two steam plants. Steam Plant No. 1 is located on the City Waterway and Steam Plant No. 2 on Hylebos Waterway. Both plants are oil fired. Steam Plant No. 1 has storage space for 650 barrels and No. 2 can store 30,000 barrels.

The City of Tacoma also owns 8 percent of the Centralia Steam-Electric Project. At present and until 1981, the output from this resource has been assigned to the Bonneville Power Administration and the U.S. Bureau of Reclamation. This plant is fired from coal mined at the nearby coalfield. Water supply for condenser cooling is assured by means of a dam upstream on the Skookumchuck River. A portion of the water impounded behind this dam is available to the City of Centralia upon demand.

While no ownership is involved, Tacoma has a contract with Grant County Public Utility District entitling them to 8 percent of the output of the Priest Rapids Development on the Columbia River.

Tacoma has been and still is a participant in the soon-to-be-converted Hanford Steam Plant owned by the Washington Public Power Supply System. This plant was constructed to utilize the waste heat from the New Production Reactor, which was designed to produce plutonium. The federal government has declared the reactor as surplus. As a result, the reactor will continue in operation as required by special agreement with the Atomic Energy Commission. Plans are in progress to build a new reactor designed specifically for power production rather than plutonium. The entire output of this plant is delivered to BPA as needed and as steam is available from the reactor.

As to future plans, Tacoma expects to have shares in both Washington Public Power Supply System No. 1 (successor to Hanford No. 1) and WPPSS No. 3 (Satsop). Studies are now in progress relating to the expansion of the Mayfield development on the Cowlitz. At this time, it appears installation of another 40.5-megawatt unit could be timed for late 1976 or early 1977. Still available for future consideration is the third 150-megawatt unit for Mossyrock. While no target date has been set, 1980 is presently under consideration.

Below are listed pertinent data for the facilities owned by Tacoma, plus that portion of other projects in which the City has an interest and from which power is currently being received.

Project	Capacity (kw)	Average Annual Output (kwh)
Nisqually (Alder and LaGrande)	114,000	570,000,000
Cushman No. 1 and No. 2	124,200	370,000,000
Cowlitz (Mossyrock and Mayfield)	421,500	1,750,000,000
Priest Rapids (Tacoma's share)	71,000	395,000,000
Steam Plant No. 1	9,000	*
Steam Plant No. 2	50,000	*
Centralia	112,000	835,000,000

* Not operated under "average" conditions.

Washington Public Power Supply System

Washington Public Power Supply System is a municipal corporation organized in 1957 for the purpose of acquiring, constructing, operating, and owning plants and systems for the generation and transmission of electric energy and power. In addition the Supply System is authorized to contract for the sale, exchange, transmission, or use of electric energy with any firm, corporation, or local, state, or federal agency.

Members of the Supply System include the PUD's of Benton, Chelan, Clallam, Clark, Cowlitz, Douglas, Ferry, Franklin, Grant, Grays Harbor, Kittitas, Klickitat, Lewis, Mason, Pacific, Skamania, Snohomish, and Wahkiakum Counties, and the cities of Seattle, Tacoma, and Richland.

The Supply System presently owns and operates one thermal project, the existing WPPSS No. 1 (Hanford); one hydroelectric project (Packwood); has under construction one nuclear project WPPSS No. 2 (Hanford); and is, at present, requesting approval for adding a new nuclear steam supply system to replace the existing Hanford No. 1 reactor after its scheduled shutdown June 30, 1977. Application for WPPSS No. 3 (Satsop) has been filed with the Atomic Energy Commission (AEC), and the Washington Powerplant Site Evaluating Council is considering the proposed Satsop Plant Site.

Packwood Lake Hydroelectric Project

The Packwood Project has a rating of 26.1 megawatts and commenced operation in 1964. Power is sold to BPA for Mason County PUD No. 3.

WPPSS Nuclear Project No. 1 (Hanford)

The Washington Public Power Supply System's 860-megawatt generating plant uses byproduct steam from the existing dual purpose reactor, owned and operated by the AEC at Hanford. The new WPPSS Nuclear Project No. 1 will have an output of 1220 megawatts. The plant will consist of a new pressurized water reactor, a new high-pressure turbine generator, and the existing generators and waste-heat dissipation system already in operation.

WPPSS Nuclear Project No. 2 (Hanford)

The WPPSS Nuclear Project No. 2 is presently under construction. It is located in the Hanford complex, 3 miles from the Columbia River, and 12 miles north of the city of Richland. It will have a capacity of approximately 1,100 megawatts and is scheduled for commercial operation in September 1977.

WPPSS Nuclear Project No. 3 (Satsop)

The site has been selected for WPPSS No. 3—a $707 million nuclear plant to be located at Satsop.

Seventy percent ownership is being retained by the public utilities and 30 percent is being purchased by the private utilities, with 10 percent each going to Pacific Power & Light Co. and Portland General Electric Co., and 5 percent each going to Washington Water Power Co. and Puget Sound Power & Light Co. WPPSS will operate the plant. The pressurized water reactor nuclear steam supply system was recently ordered from Combustion Engineering Inc. and the turbine-generator equipment was ordered from Westinghouse Electric Corp.

INVESTOR-OWNED SYSTEMS

Washington Water Power Company

The Washington Water Power Co. has six hydroelectric generating stations in Washington. Five of these plants are under Federal Power Commission licenses. Monroe Street was the first plant built and was put into operation in 1890. It has a nameplate rating of 7,200 kilowatts and is located on the Spokane River at Spokane. In 1972, the FPC granted permission to remove the damaged timber crib rock-filled dam and replace it with a concrete structure. This year (1973) the intake structure and penstocks will be rebuilt, and the area will be landscaped to coincide with the river beautification plan and Expo '74.

The second power station built in Washington was Little Falls, completed in 1911. Little Falls is located on the Spokane River, 14 miles north of Reardan, and has a nameplate rating of 32,000 kilowatts. It is the only WWP plant in Washington not under an FPC license. Nine Mile Falls plant was built in 1908, by the Inland Empire Railway and Power Co. and is on the Spokane River, at Nine Mile Falls. The plant has a combined nameplate rating of 12,000 kilowatts.

When Long Lake plant was conceived, its turbines had the highest capacity in the world. The plant is on the Spokane River, 25 miles northwest of Spokane, and has a total nameplate rating of 70,000 kilowatts. The first two units were installed in 1915, the third in 1919, and the fourth in 1924.

Upper Falls is in Spokane, on the Spokane River. It was completed in 1922 and has a 10,000 kilowatt nameplate rating. The sixth plant is Meyers Falls. It was completed in 1915 and is on the Colville River. Meyers Falls has a nameplate rating of 1,200 kilowatts.

As to future plans for hydro installations in the State of Washington, there is a possible unit addition at Long Lake station in the distant future. Currently the company, in conjunction with Chelan County PUD, is looking at the feasibility of installing a large hydro unit at the outlet of Chelan Lake for peaking purposes.

Power is imported from company-owned plants in Idaho (Post Falls and Cabinet Gorge) and from Montana (Noxon Rapids) to supply Washington customers.

Puget Sound Power & Light Company

The Puget Sound Power & Light Company, with headquarters in Bellevue, Washington, is the largest electric utility in the state—in terms of number of customers served and in the size of its service area.

Today (1973), Puget Power provides electric service to over 380,000 customers residing in nine counties in Washington, an area of more than 3,200 square miles. Counties in which the company serves include Thurston, Pierce, Kitsap, Jefferson, Island, Whatcom, Skagit, King, and Kittitas.

Puget Power is one of three investor-owned electric utilities serving in Washington. The company has over 25,000 share owners representing every state in the union, as well as 14 foreign countries. The largest number of share owners (over 4,500) live in Washington State.

On July 8, 1912, the present corporate entity of the Puget Sound Power & Light Company came into being. The company, which had been known as the Puget Sound Traction, Light and Power Company, was incorporated in the State of Massachusetts under the executive management of the Stone & Webster Corporation.

The corporate name was changed to Puget Sound Power & Light Company in 1920, dropping the word "Traction" after the sale of the Seattle street railway system to the municipality. However, Puget Power remained in the transportation business into the 1940's and was the major supplier of both electrical and transportation service in the Puget Sound region during that period.

In 1972, Puget Power sold over 8.8-billion kilowatt hours of electricity, an increase of 10.7 percent over 1971. Almost all of this energy was produced by water power, with about 15 percent coming from six company-owned plants and 83 percent being purchased from five projects on the Columbia River.

The six company-owned generating plants and their nameplate ratings are Upper Baker River, 94,400 kilowatts; Lower Baker River, 64,000 kilowatts; White River, 70,000 kilowatts; Snoqualmie Falls, 41,690 kilowatts; Electron, 25,300 kilowatts; and Nooksack Falls, 1,500 kilowatts. In addition, the company owns an oil-fired, thermal plant at Shuffleton in Renton that has a rating of 87,500 kilowatts. However, the plant is used only for standby purposes.

The company purchases power on long-term contracts from these Columbia River projects: Rocky Reach , 768,000 kilowatts; Wells, 414,000 kilowatts; Rock Island, 219,000 kilowatts; Wanapum, 152,000 kilowatts; and Priest Rapids, 130,000 kilowatts.

Puget Power shares 7 percent of the cost and ownership of the Centralia Steam-Electric Project and receives 7 percent of the power produced. The plant has two 700,000-kilowatt generating units—the first went into service in 1971 and the second a year later.

In 1972, Puget Power installed a 28,500 kilowatt combustion-turbine generator on Whidbey Island as an aid in emergencies and during hours of peak use. The company is studying the possibility of locating similar units at other sites in the service area.

Also in 1972, Puget Power and The Montana Power Company signed an agreement to construct two 350,000 kilowatt (330,000 kw, net) coal-fired generating units at Colstrip, Montana. The first unit is scheduled to begin operation in 1975 and the second in 1976.

In January 1973, Puget Power announced that it was studying the possibility of constructing a major nuclear power project on a site northeast of Sedro Woolley in Skagit County. The company has 1,500 acres of property on option and plans to have a 1,000,000-kilowatt plant in operation in 1981. Cost of the project is estimated to be $400 million. The company anticipates ownership arrangements with other utilities. Preliminary engineering and more advance studies are underway to obtain required information to apply for necessary approvals from county, state, and federal agencies.

Pacific Power & Light Company

Pacific Power & Light Company owns and operates an extensive system of electric power and light properties in a wide territory in the Columbia River valley in southern Washington; in northern Oregon; in the Willamette Valley; in western, southern, and central Oregon; northern California; northern Idaho; northwestern Montana; and northwestern, southern, and central Wyoming. They supply electric power and light service to over 240 communities, including Yakima, Walla Walla, Dayton, and Sunnyside, in Washington.

The Company owns 33 hydroelectric generating plants with a rated capacity of 863,393 kilowatts, and seven steam-electric generating plants with a rated capacity of 1,461,093 kilowatts and minor internal combustion generating capacity. The company's generating facilities are interconnected through its own lines or the lines of others; and, along with substantially all other generating facilities and reservoirs located within the region in which the company operrates, they are operated on a coordinated basis to obtain maximum load-carrying capability and efficiency.

The principal generating plants in Washington are as follows:

Yale (hydroelectric) was completed in 1953. The installed capacity is 108,000 kilowatts.

Merwin (hydroelectric) was constructed in 1931 and the last unit installed in 1958. The total installed capacity is 136,000 kilowatts.

Swift (hydroelectric) was placed in commercial operation December 31, 1958, with an installed capacity of 204,000 kilowatts.

Pacific Power & Light Company also has a 47½ percent interest in and is the operator of the 1,400,000 kilowatt Centralia Steam-Electric Project, which is the first in a program involving general ownership and operation of large thermal plants in the Northwest.

Condit (hydroelectric) was constructed in 1913, with an installed capacity of 9,600 kilowatts.

Naches (hydroelectric) was constructed in 1909, with an installed capacity of 6,370 kilowatts.

Naches Drop (hydroelectric) was constructed in 1914, with an installed capacity of 1,400 kilowatts.

Centralia Steam-Electric Project

The Centralia Steam Electric Project is the first of 8 jointly owned large-capacity installations to be planned by the PNUCC. It is unique in that a huge deposit (over 500 million tons) of low sulfur (.75 percent) subbituminous coal lies adjacent to the plant. Pacific Power & Light Co. owns 47.5 percent of the project and operates the generating facilities. Other owners of the project are Washington Water Power Co., 15 percent; Puget Sound Power & Light Co., 7 percent; Portland General Electric Co., 2.5 percent; Seattle City Light, Tacoma City Light, and Snohomish County PUD, 8 percent each; and Grays Harbor County PUD, 4 percent. The mine is operated by the Washington Irrigation and Development Co., a wholly owned subsidiary of Washington Water Power Co. Pacific Power & Light Co. and Washington Irrigation and Development Co. jointly own the mine.

ACKNOWLEDGMENTS

I wish to thank all of the power companies, both public and private, who have been so helpful in supplying information for this hydroelectric report. In particular, I would like to express my appreciation to the following companies and individuals listed here:

Bonneville Power Administration

Neil Freeman
John F. Fallon
Martin J. Lavelle
Clifford Watkins

The Washington Water Power Co.

Harold W. Harding
Glenn Nogle
H. Douglass Young

Pacific Power & Light Co.

Robert B. Lisbakken
Fred M. Gardner
Dallas B. Forest
Tom Lockhart

Puget Sound Power & Light Co.

D. H. Knight

Chelan County PUD

Howard M. Schoffen

Douglas County PUD

John A. Gregg
Eldon E. Landon

Grant County PUD

R. R. Ries

Pend Oreille County PUD

David A. Garrett

Seattle City Light

Lewis K. Ambrose

Tacoma City Light

D. J. Caha
J. D. Cockrell

Washington Public Power Supply System

Jack J. Stein

APPENDIX A
NAMEPLATE RATINGS FOR ELECTRIC GENERATING PLANTS SERVING THE STATE OF WASHINGTON
(March 15, 1973)

Hydroelectric Projects in Washington

Project	Operating Agent [1]	Stream	CAPACITY IN KILOWATTS										Peaking	Estimated date in service*
			Unit	Existing	Unit	Under construction	Unit	Authorized	Unit	Other potential	Unit	Ultimate total		
Grand Coulee [2]	USBR	Columbia	18-3	2,161,000	6	3,719,000			6	3,600,000	30-3	9,780,000	10,780,200	Aug. 1975 May 1978
Grand Coulee [3] (pump generator)	USBR	Columbia			2	100,000	4	200,000			6			
Roza	USBR	Yakima	1	11,250							1	11,250	12,900	
Chandler	USBR	Yakima	2	12,000							2	12,000	13,000	
Chief Joseph	USCE	Columbia	16	1,024,000	11	1,045,000			13	1,573,000	40	3,642,000	4,221,070	Mar. 1977 Mar. 1979
McNary	USCE	Columbia	14	980,000					6	420,000	20	1,400,000	1,610,000	
John Day	USCE	Columbia	16	2,160,000			4	540,000			20	2,700,000	3,105,000	
The Dalles [4]	USCE	Columbia	20-2	1,635,000	2	172,000					22-2	1,807,000	2,015,000	
Bonneville	USCE	Columbia	10	518,400			8	544,000			18	1,062,400	1,124,000	1982 1983
Little Goose	USCE	Snake	3	405,000			3	405,000			6	810,000	931,500	Feb. 1982 Apr. 1979
Lower Monumental	USCE	Snake	3	405,000			3	405,000			6	810,000	931,500	Feb. 1980 Apr. 1980
Ice Harbor	USCE	Snake	3	270,000	3	332,880					6	602,880	693,300	Feb. 1975 Apr. 1975
Lower Granite	USCE	Snake			3	405,000	3	405,000			6	810,000	931,500	Feb. Apr. 1975 Feb. Apr. 1979
Asotin [5]	USCE	Snake		0						540,000		540,000	540,000	
Yelm	Centralia	Nisqually		9,000								9,000	9,000	
Rock Island [6]	Chelan Co. PUD	Columbia		212,100						410,000		622,100	541,000	Mar. 1977 May 1978
Rocky Reach	Chelan Co. PUD	Columbia		1,213,600								1,213,600	1,287,000	
Chelan [7]	Chelan Co. PUD	Lake Chelan		48,000						239,000		287,000	295,000	
Beaver Creek	Chelan Co. PUD	Lake Wenatchee		0						12,700		12,700	14,000	

(See footnotes at end of table.)

* Applies to new capacity, under construction, and authorized, but not other potential.

APPENDIX A
NAMEPLATE RATINGS FOR ELECTRIC GENERATING PLANTS SERVING THE STATE OF WASHINGTON
(March 15, 1973)

Hydroelectric Projects in Washington—Continued

Project	Operating agent[1]	Stream	CAPACITY IN KILOWATTS										Peaking	Estimated date in service
			Unit	Existing	Unit	Under construction	Unit	Authorized	Unit	Other potential	Unit	Ultimate total		
Dirtyface Mountain (pump generator)	Chelan Co. PUD	Lake Wenatchee		0						145,000		145,000	145,000	
Dryden	Chelan Co. PUD	Wenatchee River		0						17,000		17,000	17,000	
Leavenworth	Chelan Co. PUD	Wenatchee River		0						120,000		120,000	120,000	
Antilon Lake (pump generator)	Chelan Co. PUD	Lake Chelan		0						2,000,000		2,000,000	2,000,000	
Wells	Douglas Co. PUD	Columbia		774,300								774,300	842,000	
Browns Canyon (pump generator)	Douglas Co. PUD	Columbia		0						1,000,000		1,000,000	1,000,000	
Priest Rapids	Grant Co. PUD	Columbia	10	788,500						473,100		1,261,600	1,456,000	
Wanapum	Grant Co. PUD	Columbia	10	831,250						498,750		1,330,000	1,576,000	
Swift No. 2 [8]	PP&L	Lewis		70,000								68,000	77,000	
Swift No. 1	PP&L	Lewis		204,000								204,000	268,000	
Yale [9]	PP&L	Lewis		108,000						108,000		216,000	270,000	
Merwin [9]	PP&L	Lewis		136,000						45,000		181,000	200,000	
Naches	PP&L	Naches R.—Wapatox Canal		6,370								6,370	5,000	
Naches Drop	PP&L	Naches R.—Wapatox Canal		1,400								1,400	1,400	
Condit	PP&L	White Salmon		9,600								9,600	15,000	
Muddy	PP&L	Lewis		0						110,000		110,000	126,500	
Meadows, Upper [10]	PP&L	Meadows Creek		0						30,000		30,000	34,500	
Meadows, Lower [10]	PP&L	Rush Creek		0						35,000		55,000	62,350	
Box Canyon	Pend Oreille Co. PUD	Pend Oreille		60,000								60,000	72,200	

Sullivan Creek[11]	Pend Oreille	Sullivan Creek		0				20,400	20,400	23,400
Nooksack	PSP&L	Nooksack		1,500					1,500	1,700
Electron	PSP&L	Puyallup		25,300					25,300	25,000
Snoqualmie Falls	PSP&L	Snoqualmie		41,690					41,690	43,000
White River	PSP&L	White		70,000					70,000	49,000
Lower Baker	PSP&L	Baker		64,000		64,000			128,000	140,000
Upper Baker	PSP&L	Baker		94,400					94,400	102,000
Cedar Falls	Seattle	Cedar		22,856					22,856	30,000
Newhalem	Seattle	Newhalem		2,000					2,000	2,000
Ross[12]	Seattle	Skagit		360,000					360,000	
Diablo	Seattle	Skagit		120,000				120,000	240,000	315,000
Gorge	Seattle	Skagit		134,400					134,400	175,000
Boundary	Seattle	Pend Oreille	4	551,000			2	275,000	826,000	975,000
Copper Creek	Seattle	Skagit		0				83,000	83,000	83,000
Thunder Creek Diversion[13]	Seattle	Thunder Creek		0				135,000	135,000	135,000
Cushman Nos. 1 and 2	Tacoma	Skokomish		124,200					124,200	135,000
Alder	Tacoma	Nisqually		50,000					50,000	51,000
La Grande	Tacoma	Nisqually		64,000					64,000	65,000
Mayfield[9]	Tacoma	Cowlitz		121,500				45,000	166,500	185,000
Mossyrock	Tacoma	Cowlitz		300,000		150,000			450,000	576,000
Upper Falls	WWP	Spokane		10,000					10,000	10,200
Monroe Street	WWP	Spokane		7,200					7,200	7,200
Nine Mile	WWP	Spokane		12,000					12,000	18,000
Long Lake	WWP	Spokane		70,000					70,000	72,500
Little Falls	WWP	Spokane		32,000					32,000	36,000
Meyers Falls	WWP	Colville		1,200					1,200	1,400
Packwood	WPPSS	Lake Creek		26,125					26,125	31,500

(See footnotes at end of table.)

APPENDIX A

NAMEPLATE RATINGS FOR ELECTRIC GENERATING PLANTS SERVING THE STATE OF WASHINGTON

(March 15, 1973)

Thermal Projects in Washington

Project	Operating agent[1]	Type	CAPACITY IN KILOWATTS										Peaking	Estimated date in service
			Unit	Existing	Unit	Under construction	Unit	Authorized	Unit	Other potential	Unit	Ultimate total		
Longview	Cowlitz Co. PUD	Steam		26,600								26,600		
Tacoma No. 1	Tacoma	Steam		9,000								9,000	9,100	
Tacoma No. 2	Tacoma	Steam		50,000								50,000	55,400	
Lake Union	Seattle	Steam		30,000								30,000	40,000	
Georgetown	Seattle	Steam		21,000								21,000	22,000	
Boundary	Seattle	Combustion turbine		800								800		
Crystal Mountain	PSP&L	Diesel		2,750								2,750	2,750	
Shuffleton	PSP&L	Steam		87,500								87,500	87,500	
Whidbey Island	PSP&L	Combustion turbine		28,500								28,500	28,500	
Sedro Woolley [14]	PSP&L	Nuclear		0						1,100,000		1,100,000	1,100,000	1981-82
Centralia Nos. 1 and 2 [15]	PP&L	Steam		1,329,800								1,329,800	1,400,000	
WPPSS No. 1 [16] (Hanford)	WPPSS	Nuclear		860,000		0		360,000				1,220,000	1,220,000	Sept. 1981
WPPSS No. 2 [17] (Hanford)	WPPSS	Nuclear		0		1,100,000						1,100,000	1,100,000	Sept. 1978
WPPSS No. 3 [18] (Satsop)	WPPSS	Nuclear		0				1,300,000				1,300,000	1,238,000	Sept. 1981
Othello	WWP	Combustion turbine		33,000								33,000	33,000	
Friday Harbor	Orcus P&L	Diesel		1,060								1,060	1,060	
East Sound	Orcus P&L	Diesel		1,250								1,250	1,250	

Hydroelectric Projects in Other States That Supply Washington Customers

Cabinet Gorge (Idaho)	WWP	Clark Fork		200,000								200,000	230,000	
Post Falls (Idaho)	WWP	Spokane		11,250								11,250	15,000	
Noxon Rapids (Montana)	WWP	Clark Fork		282,880				70,720				353,600	530,000	

High Mountain Sheep [19] (Oregon-Idaho)	PNP & WPPSS	Snake	0			3,430,000	3,430,000		
China Gardens (Idaho)	PNP & WPPSS	Snake	0			625,000	625,000		

Thermal Projects in Other States That Supply Washington Customers

Colstrip No. 1 [20] (Montana)	PSP&L	Steam	0	350,000			300,000	300,000	1975
Colstrip No. 2 (Montana)	PSP&L	Steam	0	350,000			300,000	300,000	1976
Colstrip No. 3 [21] (Montana)	PSP&L	Steam	0			700,000	700,000	700,000	1978
Colstrip No. 4 (Montana)	PSP&L	Steam	0			700,000	700,000	700,000	1979
Jim Bridger [22] Nos. 2 and 3 (Wyoming)	PP&L	Steam	0	1,016,000			1,016,000	1,000,000	
Dave Johnston (Wyoming)	PP&L	Stream	750,000				750,000	758,000	
Trojan [24] (Oregon)	PP&L	Nuclear	0	762,750					1975
Boardman [25] (Oregon)	PGE	Nuclear	0			1,150,000	1,150,000	1,150,000	1980

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[1] Abbreviations used for operating agents: USBR, U.S. Bureau of Reclamation; USCE, U.S. Corps of Engineers; PP&L, Pacific Power & Light Co.; PSP&L, Puget Sound Power & Light Co.; WWP, Washington Water Power Co.; WPPSS, Washington Public Power Supply System; PGE, Portland General Electric Co.

[2] The Existing Capacity is 18 main units and three service units and includes an increase of 17,000 kw each for 11 rewound main units; Under Construction Capacity includes an increase of 17,000 kw each for seven main units to be rewound and six 600,000 kw units being installed at the Third Powerplant; and Other Potential Capacity is for six more 600,000 kw units for the Third Powerplant.

[3] Pumped from Lake Roosevelt into Banks Lake; tail race returns to Roosevelt Lake.

[4] The Existing Capacity includes two fishway units of 13,500 kw each, 14 units of 78,000 kw each, and six units of 86,000 kw each at The Dalles plant.

[5] Inactive.

[6] Second Powerplant application applied for March 1973, not returned as of August 1973; 620,100 kw nameplate rating encroached by Wanapum Project (lake elevation, 570.0 feet).

[7] Joint venture with Washington Water Power Co. (for peaking).

[8] Owned by Cowlitz County PUD.

[9] Other Potential Capacity licensed.

APPENDIX A

NAMEPLATE RATINGS FOR ELECTRIC GENERATING PLANTS SERVING THE STATE OF WASHINGTON

(March 15, 1973)

10/ License applied for.

11/ Sullivan Creek is outlet for Sullivan Lake.

12/ The original design of Ross Dam provided that the dam would be increased in height so that Ross lake could be operated to a maximum elevation of 122.5 feet higher than its present maximum height of 1602.5 feet above sea level. Turbine modifications are planned to increase the peaking capability with full lake conditions from 450,000 kilowatts to 529,000 kilowatts. Since full lake conditions occur at a time when Northwest utility system peak and Seattle system peak loads are not at their maximum, therefore, the actual firm peaking capacity increase between the high and low projects has to be based on the comparison of the fourth year of 42-1/2 months critical period by averaging the January through April capacity capabilities of the high and low projects and also assuming there is a repetition of water conditions that occurred in the historical flows of 1928 to 1932. This firm capacity gain is calculated to be 274,000 kilowatts after correction for losses. There is also an average firm energy gain of 35,000 kilowatts which is the difference corrected for losses between the 42-1/2 months critical period energy capability of the high and low projects. There is also available, with the high project, a secondary energy gain of 9,500 kilowatts.

13/ The diversion of Thunder Creek into Ross Lake. Thunder Creek now flows into Diablo Lake.

14/ Sedro Woolley site now being considered northeast of Sedro Woolley; to be joint ownership with other utilities.

15/ Joint ownership: Pacific Power & Light, 47½ percent; Puget Sound Power & Light, 7 percent; Seattle City Light, 8 percent; Tacoma City Light, 8 percent; Grays Harbor County PUD, 4 percent; Snohomish County PUD, 8 percent; Portland General Electric, 2.5 percent; Washington Water Power Co., 15 percent. Strip mining is done by Washington Irrigation and Development Co.

16/ An addition to reconstructed plant has been authorized. 1,314,000 kw total nameplate rating; 1,220,000 kw net after deducting station service.

17/ 1,154,000 kw total nameplate rating; 1,100,000 kw net.

18/ 1,316,000 kw total nameplate rating; 1,154,000 kw net.

19/ Joint ownership: Pacific Northwest Power, Portland General Electric, Pacific Power & Light, Washington Public Power Supply System, and Montana Power Co.

20/ Colstrip plants Nos. 1 and 2 are jointly owned by Puget Sound Power & Light (50 percent) and Montana Power Co. (50 percent).

21/ Colstrip plants Nos. 3 and 4 are owned by Puget Sound Power & Light, 25 percent; Montana Power Co., 30 percent; Washington Water Power, 15 percent; Portland General Electric Co., 20 percent; and Pacific Power & Light, 10 percent.

22/ Jointly owned by Pacific Power & Light and Idaho Power Co.; Unit No. 1 serves Idaho Power.

23/ Jointly owned by Pacific Power & Light and Idaho Power Co.

24/ Jointly owned by Portland General Electric Co., 67.5 percent; Pacific Power & Light, 2.5 percent; Eugene City Light, 30 percent.

25/ Jointly owned by Portland General Electric Co., 65 percent; Pacific Power & Light, 25 percent, and Eugene City Light, 10 percent.

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

			LOCATION			NAMEPLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/		STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
FEDERAL																
U.S. ARMY, CORPS OF ENGINEERS																
ALBENI FALLS 4/	H		PEND OREILLE	90.1	IDAHO	42600	0		0	42600	49000	2062.5	1155000	28.3	MAR 25, 1955	P ,R , ,N ,FC,PS, , ,
ASOTIN 4/	H		SNAKE	146.8	WASH IDAHO	0	0	AUTH.	540000	540000	621000	842.5	12500	104.5		P , , ,N , , , , ,
BEN FRANKLIN	H		COLUMBIA	348.0	WASHINGTON	0	0	POT.	848000	848000	938000	400.0	220000	59.0		P , , ,N , , , , ,
BIG CLIFF 4/	H		N SANTIAM	58.1	OREGON	18000	0		0	18000	20700	1206.0	2430	97.0	JUN 12, 1954	P , , , , , ,RR, ,
BONNEVILLE 4/	H		COLUMBIA	145.5	ORE WASH	518400	0	AUTH.	544000	1062400	1124000	74.0	80550	59.0	JUN 6, 1938	P ,R , ,N , , , , ,
CASCADIA	H		SOUTH SANTIAM	41.3	OREGON	0	0	POT.	48000	48000	55200	644.0	145000	203.0		P , ,I ,N ,FC, , , ,
CHIEF JOSEPH 4/	H		COLUMBIA	545.1	WASHINGTON	1024000	1045000	REC.	1573000	3642000	4221070	946.0	46000	167.0	AUG 20, 1955	P ,R ,I , , , , , ,
CHINA GARDENS	H		SNAKE	172.5	WASH IDAHO	0	0	REC.	550000	550000	625000	945.0	45000	102.5		P , , , , , ,RR, ,
COUGAR 4/	H		S FK MCKENZIE	4.5	OREGON	25000	0	AUTH.	35000	60000	69000	1690.0	154000	434.5	FEB 4, 1964	P ,R , ,N ,FC,PS, , ,
CREVICE	H		SALMON	99.7	IDAHO	0	0	POT.	1015000	1015000	1167250	2570.0	2300000	725.0		P , , , ,FC,PS, , ,
DETROIT 4/	H		N SANTIAM	60.9	OREGON	100000	0		0	100000	115000	1563.5	323000	357.5	JUL 1, 1953	P ,R ,I ,N ,FC,PS, ,M ,
DEXTER 4/	H		M FK WILLAMETTE	203.8	OREGON	15000	0		0	15000	17250	695.0	4800	57.0	MAY 19, 1955	P , , , , , ,RR, ,
DWORSHAK 4/	H		N FK CLEARWATER	1.9	IDAHO	0	400000	AUTH.	660000	1060000	1219000	1600.0	2000000	626.0	SCHED. 1973	P ,R , ,N ,FC,PS, , ,
ENAVILLE	H		COEUR D'ALENE	38.8	IDAHO	0	0	POT.	70000	70000	80000	2430.0	700000	272.0		P ,R , , ,FC, , , ,
FORT PECK	H		MISSOURI	1771.5	MONTANA	165000	0		0	165000	181000	2246.0	13900000	213.0	JUL , 1943	P , , ,N ,FC, , , ,
FOSTER 4/	H		S SANTIAM	37.7	OREGON	20000	0		0	20000	23000	637.0	28400	110.0	AUG 22, 1968	P , ,I , ,FC, ,RR, ,
GREEN PETER 4/	H		M SANTIAM	5.7	OREGON	80000	0		0	80000	92000	1010.0	313000	310.0	JUNE 9, 1967	P ,R ,I ,N ,FC,PS, , ,
HILLS CREEK 4/	H		M FK WILLAMETTE	232.5	OREGON	30000	0		0	30000	34500	1541.0	243600	318.0	MAY 2, 1962	P ,R ,I ,N ,FC,PS, , ,
ICE HARBOR 4/	H		SNAKE	9.7	WASHINGTON	270000	332880		0	602880	693300	440.0	24840	98.0	DEC 18, 1961	P ,R ,I ,N , , , , ,
JOHN DAY 4/	H		COLUMBIA	215.6	ORE WASH	2160000	0	AUTH.	540000	2700000	3105000	265.0	154000	100.0	JULY 17, 1968	P ,R ,I ,N ,FC,PS, , ,
KATKA	H		KOOTENAI	161.8	IDAHO	0	0	POT.	100000	100000	115000	1875.0	PONDAGE	102.0		P , , , , , , , ,
KOOTENAI FALLS	H		KOOTENAI	192.3	MONTANA	0	0	POT.	360000	360000	414000	2060.0	PONDAGE	160.0		P , , , , , , , ,
LENORE	H		CLEARWATER	31.1	IDAHO	0	0	POT.	300000	300000	345000	975.0	11000	75.0		P , , , , , ,RR, ,
LIBBY 4/	H		KOOTENAI	219.9	MONTANA	0	420000	AUTH.	420000	840000	966000	2459.0	4965000	344.0	SCHED. 1975	P ,R , ,N ,FC,PS, , ,
LIBBY REREG	H		KOOTENAI	208.9	MONTANA	0	0	POT.	43800	43800	50370	2130.0	30000	54.0		P , , , , , , , ,
LITTLE GOOSE 4/	H		SNAKE	70.3	WASHINGTON	405000	0	AUTH.	405000	810000	931500	638.0	49000	98.0	MAY 19, 1970	P ,R , ,N , , , , ,
LONG MEADOWS	H		YAAK	30.8	MONTANA	0	0	POT.	9000	9000	10350	3100.0	400000	192.0		P ,R , , ,FC,PS, , ,
LOOKOUT POINT 4/	H		M FK WILLAMETTE	206.9	OREGON	120000	0		0	120000	138000	926.0	336500	231.0	DEC 16, 1954	P ,R ,I ,N ,FC,PS, ,M ,
LOST CREEK 4/	H		ROGUE	158.4	OREGON	0	49000		0	49000	56350	1872.0	315000	321.0	SCHED. 1975	P ,R ,I , ,FC,PS, ,M ,
LOWER CANYON	H	A	SALMON	3.7	IDAHO	0	0	POT.	1280000	1280000	1475000	1575.0	2500000	665.0		P , , , ,FC,PS, , ,
LOWER GRANITE 4/	H		SNAKE	107.5	WASHINGTON	0	405000	AUTH.	405000	810000	931500	738.0	43600	100.0	SCHED. 1975	P ,R ,I ,N , , , , ,
LOWER MONUMENTAL 4/	H		SNAKE	41.6	WASHINGTON	405000	0	AUTH.	405000	810000	931500	540.0	20100	100.0	MAY 28, 1969	P ,R ,I ,N , , , , ,
LUCKY PEAK	H		BOISE	63.8	IDAHO	(DAM)0	0	REC.	92400	92400	106300	3060.0	278000	240.0		P ,R ,I , ,FC, , , ,
MCNARY 4/	H		COLUMBIA	292.0	ORE WASH	980000	0	POT.	420,000	1400000	1610000	340.0	185000	74.0	NOV 6, 1953	P ,R , ,N , , , , ,
MILE 5.9	H		N. FK. SNOQUALMIE	5.9	WASHINGTON	0	0	REC.	30,000	30000	32300	1052.0	PONDAGE	572.0		P , , , , , ,RR, ,
N. FK. SNOQUALMIE	H		N. FK. SNOQUALMIE	11.7	WASHINGTON	0	0	REC.	20,000	20000	23000	1549.0	85000	249.0		P ,R , , ,FC, , ,M ,WQ
QUARTZ CREEK	H		CLARK FORK	301.0	MONTANA	0	0	POT.	104000	104000	119600	2895.0	PONDAGE	130.0		P , , , , , , , ,
QUINN SPRINGS	H		CLARK FORK	251.0	MONTANA	0	0	POT.	108000	108000	124200	2630.0	PONDAGE	120.0		P , , , , , , , ,
STRUBE 4/	H		S FK MCKENZIE	2.5	OREGON	0	0	AUTH.	4500	4500	5175	1236.0	3000	63.0		P , , , , , ,RR, ,
THE DALLES 4/	H		COLUMBIA	191.7	ORE WASH	1119000	688000		0	1807000	2015000	160.0	53000	86.0	MAY 13, 1957	P ,R , ,N , , , , ,
TWIN SPRINGS	H		M FK BOISE	163.0	IDAHO	0	0	REC.	90000	90000	103500	3850.0	490000	459.0		P , ,I , ,FC,PS, , ,
WENAHA	H		GRANDE RONDE	26.7	WASHINGTON	0	0	POT.	201000	201000	231150	1770.0	900000	520.0		P , , , ,FC,PS, , ,
WYNOOCHEE	H		WYNOOCHEE	51.8	WASHINGTON	0	STORAGE	POT.	66000	66000	37950	800.0	70000	160.0		P , ,I ,N ,FC, , ,M ,
U.S. BUREAU OF RECLAMATION																
ALCOVA	H		NORTH PLATTE		WYOMING	36000	0		0	36000	36000	5500.0	30330	156.0	JUL , 1955	P , ,I , , , , , ,
ALLENSPUR	H		YELLOWSTONE		MONTANA	0	0	AUTH.	250000	250000	250000		1230000	380.0		P , , , , , , , ,
AMERICAN FALLS	H		SNAKE	714.0	IDAHO	STORAGE	0	POT.	60000	60000	60000	4354.5	45000	82.0	1927	P , ,I , ,FC,PS, ,M ,
ANDERSON RANCH 4/	H		S FK BOISE	43.5	IDAHO	27000	0	POT.	13500	40500	51750	4196.0	423000	330.0	DEC 15, 1950	P , ,I , ,FC,PS, , ,
APPALOOSA	H	A	SNAKE	197.6	ORE IDA	0	0	POT.	1950000	1950000	2242500	1510.0	1500000	520.0		P ,R , , ,FC,PS, , ,
BALD RIDGE	H		CLARK FORK		WYOMING	0	0	AUTH.	23000	23000	23000			500.0		P , , , , , , , ,
BLACK CANYON 4/	H		PAYETTE	38.7	IDAHO	8000	0		0	8000	10200	2497.5	1100	93.5	DEC , 1925	P , ,I , ,FC, , , ,
BOISE RIVER DIV 4/	H		BOISE	61.2	IDAHO (OPERATES APR-SEPT)	1500	0		0	1500	2250	2812.8	0	30.8	MAY , 1912	P , ,I , , , , , ,
BOYSEN	H		BIG HORN	295.0	WYOMING	15000	0		0	15000	15000	4725.0	820000	110.0	1952	P , ,I , ,FC,PS, , ,
BUFFALO RAPIDS #4	H	A	FLATHEAD	36.5	MONTANA	0	0	POT.	516000	516000	593400	2700.0	668000	164.0		P ,R , , ,FC,PS, , ,
CANYON CREEK	H		RATTLESNAKE	35.5	IDAHO	0	0	POT.	25000	25000	25000		PONDAGE	327.0		P , ,I , , , , , ,
CANYON FERRY	H		MISSOURI R	2309.0	MONTANA	50000	0		0	50000	60000	3797.0	1512000	147.0	DEC 18, 1953	P , ,I , , ,PS, , ,
CASCADE	H		N FK PAYETTE	39.9	IDAHO	STORAGE	0		0	0	0	4828.0	653190	69.0	1948	, ,I , ,FC,PS, , ,
CASTILLA	H		DIAMOND CR	1.0	UTAH	0	0	AUTH.	6000	6000	6000			415.0		P , ,I , , , , , ,
CHANDLER 4/	H		YAKIMA	47.1	WASHINGTON	12000	0		0	12000	13000	618.5	0	120.7	FEB 13, 1956	P , ,I , , , , , ,
CLARK RANCH	H		SNAKE	867.3	IDAHO	0	0	POT	30000	30000	30000	5094.0	27000	40.0		P , ,I , ,FC, ,RR, ,
DEER CREEK	H		PROVO	20.0	UTAH	4950	0		0	4950	5680	5417.0	149700	142.0	APR , 1958	P , ,I , , , , ,M ,
DUNCAN FERRY	H		OWYHEE	133.5	OREGON	0	0	REC.	14000	14000	14000	3532.0	743000	212.0		P , ,I , ,FC, , , ,
DYNE	H		DIAMOND CR		UTAH	0	0	AUTH.	33000	33000	33000			848.0		P , ,I , , , , , ,
FLAMING GORGE	H		GREEN		UTAH	108000	0		0	108000	121000	6040.0	3515700	435.0	OCT. 1963	P ,R ,I , , ,PS, , ,
FONTENELLE	H		GREEN		WYOMING	10000	0		0	10000	10000	6506.0	149872	110.0	SEP 1968	P , , , , , , , ,
FREEDOM	H		SALMON	69.3	IDAHO	0	0	POT.	450000	450000	517500	1780.0	24000	205.0		P , , , ,FC, ,RR, ,
FREMONT CANYON	H		NORTH PLATTE		WYOMING	48000	0		0	48000	48000	5850.1	1011000	294.0	DEC 21, 1960	P , , , , , , , ,

(See footnotes at end of table.)

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

		LOCATION			NAMEPLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/	STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
FEDERAL															
U.S. BUREAU OF RECLAMATION															
GARDEN VALLEY	H	S FK PAYETTE	75.9	IDAHO	0	0	REC.	175000	175000	175000	3335.0	1940000	415.0		P, ,I, ,FC,PS, , ,
GARDEN VALLEY RERG	H	S FK PAYETTE	73.0	IDAHO	0	0	REC.	36000	36000	36000	2920.0	5900	120.0		P, , , , , ,RR, ,
GATEWAY	H	WEBER		UTAH	4275	0		0	4275	4275	4950.0	PONDAGE	148.0	DEC , 1958	P, , , , , , , ,
GLENDO	H	NORTH PLATTE		WYOMING	24000	0		0	24000	24000	4653.0	786300	130.0	1958	P, ,I, ,FC, , , ,
GRAND COULEE 4/	H	COLUMBIA	596.6	WASHINGTON	2114000	3736000	REC.	3600000	9780000	10780200	1290.0	5232000	343.0	SEP 28, 1941	P, ,I,N,FC,PS, , ,
GRAND COULEE 4/	PG	COLUMBIA	596.7	WASHINGTON	0	100000	AUTH.	200000			1570.0	700000	362.0	SCHED. 1973	P, ,I, , , , , ,
GREEN SPRINGS	H	EMIGRANT CR	8.0	OREGON	16000	0		0	16000	18400	4403.0	76500	1984.0	MAY 2, 1960	P, ,I, , , , , ,
GUERNSEY	H	NORTH PLATTE		WYOMING	4800	0		0	4800	4800	4420.0	39800	94.0	1927	P, ,I, , , , , ,
GUFFEY	H	SNAKE	445.5	IDAHO	0	0	REC.	85000	85000	85000	2354.0	27000	104.0		P, ,I, , , , , ,
HEART MOUNTAIN	H	SHOSHONE		WYOMING	5000	0		0	5000	6400	5360.0	190000	277.0	1948	P, ,I, , , , , ,
HUNGRY HORSE 4/	H	S FK FLATHEAD	5.2	MONTANA	285000	0		0	285000	328000	3560.0	3161000	477.4	OCT 29, 1952	P, ,I,N,FC,PS, , ,
HUNTER MOUNTAIN	H	CLARK FORK		WYOMING	0	0	AUTH.	14400	14400	14400		150000	638.0		P, ,I, , , , , ,
JUDGE FRANCIS CARR	H	TRINITY DVSN		CALIFORNIA	141444	0		0	141444	152000	1902.0	4180	692.0	MAY 25, 1963	P, ,I, , , , , ,
KESWICK	H	SACRAMENTO		CALIFORNIA	75000	0		0	75000	88800	587.0	23630	87.0	1949	P, , , , , ,RR, ,
KNOWLES	H A	FLATHEAD	2.7	MONTANA	0	0	POT.	512000	512000	568800	2700.0	3084000	230.0		P, , , ,FC,PS, , ,
KORTES	H	NORTH PLATTE		WYOMING	36000	0		0	36000	39000	6142.0	4500	207.0	1950	P, ,I, , , , , ,
LEWISTON DIVERSION	H	TRINITY		CALIFORNIA	350	0		0	350	350	1902.0	2900	60.0	APR. , 1964	P, ,I, , , ,RR, ,
LOWER SCRIVER CR	H	SCRIVER CR	3.9	IDAHO	0	0	REC.	120000	120000	120000	4075.0	4950	740.0		P, , , , , , , ,
LYNN CRANDALL	H	SNAKE	872.5	IDAHO	0	0	REC.	240000	240000	240000	5315.0	1280000	270.0		P, ,I, ,FC, ,RR, ,
MINIDOKA 4/	H	SNAKE	675.0	IDAHO	13400	0		0	13400	16000	4194.5	95180	48.3	MAY 7, 1909	P, ,I, , ,PS, , ,
MOUNTAIN SHEEP (LOW)	H A	SNAKE	192.5	OREGON IDAHO	0	0	POT.	400000	400000	400000	1100.0	30000	152.0		P, , , , , ,RR, ,
NINEMILE PRAIRIE	H	BLACKFOOT	22.0	MONTANA	0	0	POT.	92000	92000	92000	3819.0	885000	284.0		P, , , ,FC,PS, , ,
PALISADES 4/	H	SNAKE	901.6	IDAHO	118750	0	POT.	135000	253750	290250	5620.0	1200000	244.0	FEB 25, 1957	P, ,I, ,FC,PS, , ,
PILOT BUTTE	H	WIND		WYOMING	1600	0		0	1600	1600	5460.0	31600	105.0	1925	P, ,I, , , , , ,
ROZA 4/	H	YAKIMA	127.9	WASHINGTON	11250	0		0	11250	12900	1186.5	0	160.0	AUG 31, 1958	P, ,I, , , , , ,
SEMINOE	H	NORTH PLATTE		WYOMING	32400	0		12600	45000	45000	6357.0	1012000	214.0	1939	P, ,I, , , , , ,
SHASTA	H	SACRAMENTO		CALIFORNIA	422310	0		0	422310	464000	1067.0	4050100	480.0	1944	P,R,I,N,FC, , , ,
SHERIDAN	H	TONGUE		WYOMING	0	0	AUTH.	25000	25000	25000			1200.0		P, ,I, , , , , ,
SHOSHONE	H	SHOSHONE		WYOMING	6012	0		0	6012	6012	5360.0	190000	225.0	1922	P, ,I, , , , , ,
SIXTH WATER	H	SIXTH WATER		UTAH	0	0	AUTH.	90000	90000	90000			823.0		P, ,I, , , , , ,
SMOKY RANGE	H	FLATHEAD	166.0	MONTANA	0	0	POT.	330000	330000	390000	3550.0	1510000	350.0		P, , , ,FC,PS, , ,
SPRING CREEK	H	TRINITY DVSN		CALIFORNIA	150000	0		0	150000	190000	1210.0	228300	623.0	JAN 1964	P, ,I, ,FC,PS, , ,
SPRUCE PARK	H	M FK FLATHEAD	50.0	MONTANA	0	0	POT.	380000	380000	380000	4480.0	600000	920.0		P, , , ,FC,PS, , ,
SUNLIGHT	H	SUNLIGHT CR		WYOMING	0	0	AUTH.	14900	14900	14900		40000	1945.0		P, ,I, , , , , ,
SYAR	H	SIXTH WATER		UTAH	0	0	AUTH.	8000	8000	8000			431.0		P, ,I, , , , , ,
TETON 4/	H	TETON	28.4	IDAHO	0	20000		10000	30000	30000	5320.0	200000	295.0	SCHED. 1976	P, ,I, ,FC,PS, , ,
THIEF CREEK	H	CLARK FORK		WYOMING	0	0	AUTH.	125200	125200	125200		130000	1380.0		P, ,I, , , , , ,
TRINITY	H	TRINITY		CALIFORNIA	105556	0		0	105556	128000	2370.0	2285000	468.0	FEB. 1964	P, ,I, , ,PS, , ,
UPPER SCRIVER CR	H	N FK PAYETTE	15.4	IDAHO	0	0	REC.	37500	37500	37500	4528.0	2600	453.0		P, , , , , , , ,
WANSHIP	H	WEBER		UTAH	1425	0		0	1425	1465	6037.0	PONDAGE	152.0	AUG 5, 1958	P, ,I, , , , , ,
YELLOWTAIL	H	BIG HORN		MONTANA	250000	0		0	250000	250000	3640.0	867000	461.0	JULY 1966	P, ,I, ,FC, , , ,
U.S. NAVY															
CENTRAL	S	BREMERTON		WASHINGTON	12000	0		0	12000	12000				1911	P, , , , , , , ,
U.S. DEPARTMENT OF THE INTERIOR, WAPATO IRRIG DIST															
WAPATO DROP TWO	H	WAPATO CANAL	8.0	WASHINGTON	2000	0		0	2000	2400		PONDAGE	30.0	1942	P, ,I, , , , , ,
WAPATO DROP THREE	H	WAPATO CANAL	9.0	WASHINGTON	1360	0		0	1360	1200		PONDAGE	34.0	1932	P, ,I, , , , , ,
U.S. DEPARTMENT OF THE INTERIOR, FLATHEAD IRRIG DIST															
BIG CREEK	H	BIG CR	6.0	MONTANA	360	0		0	360	450		40	585.0	1916	P, ,I, , , , , ,
U.S. DEPARTMENT OF THE INTERIOR, NATIONAL PARK SERVICE															
BEARTOOTH	IC	BEARTOOTH		WYOMING	8	0		0	8	8				SEP 30, 1966	P, , , , , , , ,
BECHLER	IC	BECHLER		WYOMING	8	0		0	8	8				1964	P, , , , , , , ,
CARBON RIVER	IC	CARBON RIVER		WASHINGTON	8	0		0	8	8					P, , , , , , , ,
CRATER LAKE	IC	CRATER LAKE		OREGON	80	0		0	80	75				1947	P, , , , , , , ,
LAMAR	IC	LAMAR		WYOMING	25	0		0	25	25				FEB 15, 1961	P, , , , , , , ,
LONGMIRE	IC	LONGMIRE		WASHINGTON	120	0		0	120	120				1958	P, , , , , , , ,
MT. WASHBURN	IC	MT. WASHBURN		WYOMING	16	0		0	16	16				1964	P, , , , , , , ,
OHANAPECOSH	IC	OHANAPECOSH		WASHINGTON	29	0		0	29	29					P, , , , , , , ,
PARADISE	H	PARADISE		WASHINGTON	800	0		0	800	800			486.0	1923	P, , , , , , , ,
TOWER FALLS	IC	TOWER FALLS		WYOMING	58	0		0	58	58				SEP 14, 1961	P, , , , , , , ,
WHITE RIVER	IC	WHITE RIVER		WASHINGTON	28	0		0	28	28					P, , , , , , , ,
YAKIMA PARK	IC	YAKIMA PARK		WASHINGTON	297	0		0	297	297					P, , , , , , , ,
YOSEMITE	H	MERCED		CALIFORNIA	2000	0		0	2000	2000			356.0	1918	P, , , , , , , ,

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

		LOCATION			NAMEPLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/	STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
PUBLIC AGENCIES															
BAKER, CITY OF															
BAKER	H	GODDRICH LAKE	2.0	OREGON	115	0		0	115	175		PONDAGE	175.0	1934	P , , , , , , , , ,M ,
BEAVER MUNICIPAL ELECTRIC LIGHT SYSTEM															
BEAVER-LOWER	H	BEAVER		UTAH	275	0		0	275	150				1913	P , , , , , , , , ,
BEAVER-UPPER	H	BEAVER		UTAH	625	0		0	625	510				1942	P , , , , , , , , ,
BONNERS FERRY, CITY OF															
BONNERS FERRY	IC	BONNERS FERRY		IDAHO	240	0		0	240	240				1930	P , , , , , , , , ,
MOYIE LOWER	H	MOYIE	1.8	IDAHO	2000	0		0	2000	2220	2035.3		200.0	1941	P , , , , , , , , ,
MOYIE UPPER	H	MOYIE	1.9	IDAHO	380	0		0	380	380	1923.3	PONDAGE	168.3	1921	P , , , , , , , , ,
BOUNTIFUL, CITY OF															
BOUNTIFUL	IC	BOUNTIFUL		UTAH	8274	0		0	8274	9100				1936	P , , , , , , , , ,
BRIDGER VALLEY ELECTRIC ASSOCIATION															
LYMAN	IC	LYMAN		WYOMING	1704	0		0	1704	1704				1940	P , , , , , , , , ,
BRIGHAM CITY CORP.															
BRIGHAM	H	BOX ELDER CR		UTAH	1200	0		0	1200	1200		6000	575.0	1921	P , , , , , , , , ,
MANTUS VALLEY	H	BOX ELDER CR		UTAH	450	0		0	450	450		2800	500.0	1961	P , , , , , , , , ,
CARLIN, CITY OF															
CARLIN	IC	CARLIN		NEVADA	3092	0		0	3092	3092				1963	P , , , , , , , , ,
CENTRALIA, CITY OF															
YELM	H	NISQUALLY	26.2	WASHINGTON	9000	0		0	9000	10130	318.0	0	208.0	1930	P , , , , , , , , ,
CHELAN COUNTY PUD															
ANTILON LAKE	PG	CHELAN L-ANTILON L.		WASHINGTON	0	0	PER.	1000000	1000000	1000000					P , , , , , , , , ,
BEAVER CREEK	H	WENATCHEE	46.7	WASHINGTON	0	0	LIC.R.	12170	12170	14000	1873.0	32000	60.0		P , , , , , , , , ,
CHELAN	H	CHELAN	4.3	WASHINGTON	48000	0	POT.	48000	96000	104000	1100.0	676100	392.0	1927	P ,R , ,N , ,PS, , ,
CHIWAWA DIVERSION	H	CHIWAWA	11.0	WASHINGTON	0	0	LIC.R.	0	0	0	2545.0	400000	672.0		, , , , , ,PS, , ,
DIRTYFACE MOUNTAIN	H PG	LK WENATCHEE	58.0	WASHINGTON	0	0	LIC.R.	126000	126000	145000	2545.0		672.0		P ,R , , , , , , , ,
DRYDEN (NEW)	H	WENATCHEE	17.5	WASHINGTON	0	0	LIC.R.	17400	17400	20000	968.5	PONDAGE	81.5		P , ,I , , , , , , ,
LEAVENWORTH	H	WENATCHEE	36.4	WASHINGTON	0	0	LIC.R.	104050	104050	120000	1750.0	6000	620.0		P , , , , , , , , ,
ROCK ISLAND	H	COLUMBIA	453.4	WASHINGTON	212100	0	POT.	364000	576100	542000	614.1		37.6	1933	P , , , , , , , , ,
ROCKY REACH	H	COLUMBIA	474.5	WASHINGTON	1213150	0		0	1213150	1287000	707.0	35500	86.5	JUN 13, 1961	P ,R , , , , , , , ,
STEHEKIN	H	COMPANY CR.		WASHINGTON	200	0		0	200	220			1200.0	MAR 20, 1968	P , , , , , , , , ,
STEHEKIN	IC	STEHEKIN		WASHINGTON	150	0		0	150	170				1966	P , , , , , , , , ,
CONFEDERATED SALISH AND KOOTENAI TRIBES & MONTANA POWER CO.															
BUFFALO NO 2	J H A	FLATHEAD	60.7	MONTANA	0	0	LIC.R.	120000	120000	138000	2702.0	PONDAGE	81.0		P , , , , , , , , ,
BUFFALO NO 4	J H A	FLATHEAD	36.5	MONTANA	0	0	LIC.R.	120000	120000	138000	2619.0	PONDAGE	80.0		P , , , , , , , , ,
COWLITZ COUNTY PUD															
LONGVIEW	S	LONGVIEW		WASHINGTON	26640	0		0	26640	31400				1924	P , , , , , , , , ,
MERRILL LAKE	PG	LEWIS	42.0	WASHINGTON	0	0	POT.	1000000	1000000	1000000	1590.0	29000	1100.0	SCHED. 1979	P , , , , , , , , ,
SWIFT NO 2	H	LEWIS	44.2	WASHINGTON	70000	0		0	70000	77000	604.0	0	130.0	DEC 31, 1958	P , , , , , , , , ,
SWIFT NO 2 DIVERSION	H	LEWIS	47.6	WASHINGTON	0	0		0	0	0	604.0	0	130.0	DEC 31, 1958	, , , , ,PS, , ,
DOUGLAS COUNTY PUD															
BROWN'S CANYON	PG	COLUMBIA-BROWN'S		WASHINGTON	0	0	PER R	1000000	1000000	1600000	3095.0	15000	2388.0		P , , , , , , , , ,
WELLS	H	COLUMBIA	516.6	WASHINGTON	774300	0		0	774300	842000	779.0	70000	66.9	JUNE 2, 1967	P , , , , , , , , ,
EUGENE, CITY OF															
CARMEN	H	MCKENZIE	87.6	OREGON	79990	0		0	79990	101600	2605.0	12000	513.0	AUG 17, 1963	P , , , , , , , , ,
EUGENE	S	EUGENE		OREGON	25000	0		0	25000	33800				1931	P , , , , , , , , ,
LEABURG	H	MCKENZIE	38.8	OREGON	13500	0		0	13500	14820	734.0	0	90.0	JAN 6, 1930	P , , , , , , , , ,
TRAIL BRIDGE	H	MCKENZIE	81.9	OREGON	9975	0		0	9975	11470	2092.0	2113	78.0	JUN 20, 1963	P , , , , , , , ,RR, ,
TROJAN	J N	PRESCOTT	72.1	OREGON	0	339000		0	339000	339000				SCHED. 1975	P , , , , , , , , ,
WALTERVILLE	H	MCKENZIE	28.5	OREGON	8000	0		0	8000	9500	598.0	339	55.0	1911	P , , , , , , , , ,
GARKANE POWER ASSOCIATION, INC.															
BOULDER CREEK	H	BOULDER CR		UTAH	4200	0		0	4200	4200		86	1400.0	SEP 12, 1958	P , , , , , , , , ,

APPENDIX B

NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS

(December 31, 1972)

GROUP OWNERSHIP PROJECT	TYPE 1/	LOCATION			NAMEPLATE RATING - KILOWATTS					PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
		STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL						
PUBLIC AGENCIES															
GRANT COUNTY PUD															
PRIEST RAPIDS	H	COLUMBIA	397.1	WASHINGTON	788500	0	LIC	473100	1261600	1456000	488.0	44600	76.5	OCT 19, 1959	P,R, , , , , , ,
WANAPUM	H	COLUMBIA	415.0	WASHINGTON	831250	0		498750	1330000	1576000	571.5	160800	77.8	SEP 1, 1963	P, , ,N, , , , ,
GRAYS HARBOR COUNTY PUD															
CENTRALIA	J S	CENTRALIA		WASHINGTON	56000	0		0	56000	34000				JAN 11, 1972	P, , , , , , , ,
COSMOPOLIS	S	COSMOPOLIS		WASHINGTON	2500	0		0	2500	2500	(CONTRACTED FROM WEYERHAUSER TIMBER CO.)			1966	P, , , , , , , ,
ELECTRIC PARK	S	ABERDEEN		WASHINGTON	12500	0		0	12500	13900				1910	P, , , , , , , ,
GRISDALE	IC	GRISDALE		WASHINGTON	306	0		0	306	340				1951	P, , , , , , , ,
HEBER, CITY OF															
HEBER	H	PROVO		UTAH	600	0		0	600	600				1909	P, , , , , , , ,
SNAKE CREEK	H	PROVO		UTAH	800	0		0	800	850			1895.0	1949	P, , , , , , , ,
HYRUM, CITY OF															
HYRUM	H	BLACKSMITH		UTAH	400	0		0	400	400				1929	P, , , , , , , ,
IDAHO FALLS, CITY OF															
IDAHO FALLS	H	SNAKE	799.9	IDAHO	2000	0		0	2000	2000	4672.0	0	18.0	1913	P, , , , , , , ,
IDAHO FALLS	IC	IDAHO FALLS		IDAHO	2500	0		0	2500	2000				1926	P, , , , , , , ,
IDAHO FALLS, LOWER	H	SNAKE	798.1	IDAHO	3000	0		0	3000	3100	4694.0	0	20.0	1904	P, , , , , , , ,
IDAHO FALLS, UPPER	H	SNAKE	804.7	IDAHO	2400	0		0	2400	2400	4735.0	0	21.0	1930	P, , , , , , , ,
KLICKITAT COUNTY PUD															
NINEFOOT CREEK DIV	H	WHITE SALMON	34.7	WASHINGTON	0	0	LIC.R.	0	0	0	3011.0	DIVERSION			, , , , ,PS, , ,
TROUT CREEK	H	TROUT CR	9.0	WASHINGTON	0	0	LIC.R.	40000	40000	40000	3000.0	7000	904.0		P, , , , , , , ,
LEWIS COUNTY PUD															
COWLITZ FALLS	H	COWLITZ	89.2	WASHINGTON	0	0	POT	45000	45000	45000	860.0	3000	90.0		P, , , , , , , ,
LOGAN, CITY OF															
LOGAN	IC	LOGAN		UTAH	7060	0		0	7060	7060				1927	P, , , , , , , ,
LOGAN	H	LOGAN		UTAH	1400	0		0	1400	1400		17000		1923	P, , , , , , , ,
LOWER VALLEY POWER AND LIGHT, INC.															
STRAWBERRY CREEK	H	STRAWBERRY CR.	5.0	WYOMING	1500	0		0	1500	1500		6	450.0	1951	P, , , , , , , ,
MANTI CITY CORP.															
MANTI CREEK	H	MANTI CR		UTAH	120	0		0	120	120				1920	P, , , , , , , ,
MOUNTAIN SPRINGS	H	MANTI CR		UTAH	400	0		0	400	400			2614.0	1939	P, , , , , , , ,
MCMINNVILLE, CITY OF															
MCMINNVILLE	IC	MCMINNVILLE		OREGON	2740	0		0	2740	2740				1926	P, , , , , , , ,
MONROE CITY CORP.															
MONROE CITY	H	MONROE CR		UTAH	125	0		0	125	160				1937	P, , , , , , , ,
SHINGLE CREEK	H	SHINGLE CR		UTAH	100	0		0	100	100				1924	P, , , , , , , ,
MOON LAKE ELECTRIC ASSOCIATION, INC.															
ALTAMONT	IC	ALTAMONT		UTAH	600	0		0	600	600				1950	P, , , , , , , ,
DUCHESNE	IC	DUCHESNE		UTAH	425	0		0	425	425				1947	P, , , , , , , ,
RANGLEY	IC	RANGLEY		COLORADO	14934	0		0	14934	15437				1954	P, , , , , , , ,
ROOSEVELT	IC	ROOSEVELT		UTAH	1980	0		0	1980	1980				1947	P, , , , , , , ,
UINTAH	H	UINTAH		UTAH	1200	0		0	1200	1200		PONDAGE	450.0	1920	P, , , , , , , ,
WHITE RIVER	S	WHITE RIVER		COLORADO	0	0	POT.	100000	100000	100000					P, , , , , , , ,
YELLOWSTONE	H	YELLOWSTONE CR		UTAH	900	0		0	900	900		18	250.0	1941	P, , , , , , , ,
MOUNT PLEASANT CITY CORP.															
MOUNT PLEASANT	H	PLEASANT CR		UTAH	325	0		0	325	325				1913	P, , , , , , , ,
MURRAY, CITY OF															
GRANITE	H	L COTNWD CR		UTAH	1000	0		0	1000	1000		PONDAGE	565.0	1931	P, , , , , , , ,
MURRAY	IC	MURRAY		UTAH	8378	0		0	8378	8378				1939	P, , , , , , , ,
ORCAS POWER AND LIGHT COOPERATIVE															
EAST SOUND	IC	EAST SOUND		WASHINGTON	1250	0		0	1250	1250				1938	P, , , , , , , ,
FRIDAY HARBOR	IC	FRIDAY HARBR		WASHINGTON	1060	0		0	1060	1250				1941	P, , , , , , , ,

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

GROUP OWNERSHIP PROJECT	TYPE 1/	LOCATION STREAM(IF H) CITY(IF FUEL)	LOCATION MILE ABOVE MOUTH	LOCATION STATE	NAMEPLATE RATING - KILOWATTS EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/	UNDER CONSIDERATION	TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
PUBLIC AGENCIES															
PAROWAN CITY CORP.															
CENTER CREEK	H	CENTER CR		UTAH	600	0		0	600	600				1951	P , , , , , , , ,
PARAGONAH	H	RED CR		UTAH	500	0		0	500	500				1955	P , , , , , , , ,
PEND OREILLE COUNTY PUD															
BOX CANYON	H	PEND OREILLE	34.5	WASHINGTON	60000	0		0	60000	77200	2030.0	10000	40.0	JUN 1, 1955	P , , , , , , , ,
CALISPELL CREEK	H	CALISPELL CR	5.0	WASHINGTON	560	0		0	560	600		1000	309.0	1920	P , , , , , , , ,
SULLIVAN CREEK	H	SULLIVAN CR	4.7	WASHINGTON	(DAM)0	0	LIC. R	20400	20400	23460	2538.0	61600	548.0		, , , , ,PS, , ,
PROVO, CITY OF															
PROVO	S	PROVO		UTAH	14000	0		0	14000	15500				1940	P , , , , , , , ,
ST. GEORGE MUNICIPAL POWER SYSTEM															
ST. GEORGE	H	SPRINGS		UTAH	420	0		0	420	350			1060.0	1942	P , , , , , , , ,
ST GEORGE	IC	ST. GEORGE		UTAH	6868	0		0	6868	5800				1942	P , , , , , , , ,
SEATTLE, CITY OF															
BOUNDARY	H	PEND OREILLE	17.0	WASHINGTON	551000	0	L C.	275500	826500	943900	1990.0	43000	261.0	SEPT 1, 1967	P ,R , , , , , , ,
CEDAR FALLS	H	CEDAR	29.0	WASHINGTON	22856	0		0	22856	30000	1560.0	60000	630.0	OCT 14, 1904	P , , , , , , , ,
CENTRALIA	J S	CENTRALIA		WASHINGTON	112000	0		0	112000	68000				JAN 11, 1972	P , , , , , , , ,
COPPER CREEK	H	SKAGIT	83.9	WASHINGTON	0	0	POT.	83000	83000	83000	495.0	13000	125.0		P , , , , , , , ,
DIABLO	H	SKAGIT	101.0	WASHINGTON	120000	0	LIC.	120000	240000	315000	1205.0	61000	330.0	1936	P , , , , , , , ,
GEORGETOWN	S	SEATTLE		WASHINGTON	21000	0		0	21000	22000				1907	P , , , , , , , ,
GORGE	H	SKAGIT	96.6	WASHINGTON	134400	0		0	134400	175000	875.0	6545	380.0	1924	P , , , , , , , ,
LAKE UNION	S	SEATTLE		WASHINGTON	30000	0		0	30000	40000				SEP , 1914	P , , , , , , , ,
NEWHALEM	H	NEWHALEM	0.5	WASHINGTON	2000	0		0	2000	2000	1017.0	1	507.0	1921	P , , , , , , , ,
ROSS	H	SKAGIT	105.2	WASHINGTON	360000	0		0	360000	450000	1602.5	1052323	397.5	DEC 30, 1952	P , , , ,FC,PS, , ,
THUNDER CREEK DIVERSION	H	THUNDER CR	6.0	WASHINGTON	0	0	PER.	DIVERSION0	0	0	1780.0				, , , , ,PS, , ,
SNOHOMISH COUNTY PUD															
CENTRALIA	J S	CENTRALIA		WASHINGTON	112000	0		0	112000	68000				JAN 11, 1972	P , , , , , , , ,
SNOHOMISH COUNTY PUD & EVERETT, CITY OF															
SULTAN NO 1	H	SULTAN	16.9	WASHINGTON	0	0	LIC.	84000	84000	84000	1450.0	120000	390.0		P , , , , ,PS, ,M ,
SULTAN NO 2	H	SULTAN	13.4	WASHINGTON	0	0	LIC.	32000	32000	32000	1060.0	3150	398.0		P , , , , , , ,M ,
SULTAN NO 3	H	SULTAN	6.3	WASHINGTON	0	0	LIC.	24000	24000	24000	605.0	5000	300.0		P , , , , , , ,M ,
SODA SPRINGS, CITY OF															
SODA CREEK RESERVOIR	H	SODA CR		IDAHO	STORAGE	0		0	0	0	5950.0	2000			, ,I , , ,PS, , ,
SODA SPRINGS NO 1	IC	SODA SPRINGS		IDAHO RETIRED 1970	(205)	0		0	(205)	(165)				(1943)	P , , , , , , , ,
SODA SPRINGS NO 1	H	SODA CR		IDAHO	120	0		0	120	165	5788.0	0	50.0	1916	P , , , , , , , ,
SODA SPRINGS NO 2	H	SODA CR		IDAHO	50	0		0	50	50	5738.0	0	20.0	1932	P , , , , , , , ,
SODA SPRINGS NO 3	H	SODA CR		IDAHO	150	0		0	150	160	5942.0	0	70.0	1936	P , , , , , , , ,
SODA SPRINGS NO 4	H	SODA CR		IDAHO	400	0		0	400	380	5872.0	0	83.5	JUN 23, 1956	P , , , , , , , ,
SPOKANE, CITY OF															
SPOKANE	H	SPOKANE	80.2	WASHINGTON	3900	0		0	3900	5000	1906.0	PONDAGE	35.0	1937	P , , , , , , , ,
SPRINGVILLE MUNICIPAL CORP.															
BARTHOLOMEW	H	HOBBLE CR		UTAH	500	0		0	500	540				1930	P , , , , , , , ,
HOBBLE CREEK	H	HOBBLE CR		UTAH	300	0		0	300	230				1950	P , , , , , , , ,
SPRING CREEK	H	SPRING CR		UTAH	120	0		0	120	135				1930	P , , , , , , , ,
STRAWBERRY WATER USER ASSOCIATION															
PAYSON	H	PETEETNEET CR.	12.0	UTAH	400	0		0	400	275			636.0	1941	P , , , , , , , ,
SPANISH FK LOWER	H	SPANISH FORK	3.2	UTAH	250	0		0	250	250			48.0	1937	P , , , , , , , ,
SPANISH FK UPPER	H	SPANISH FORK	3.8	UTAH	900	0		0	900	745			123.0	1908	P , , , , , , , ,
TACOMA, CITY OF															
ALDER	H	NISQUALLY	35.0	WASHINGTON	50000	0		0	50000	51000	1207.0	179700	273.0	1945	P , , , , ,PS, , ,
CENTRALIA	J S	CENTRALIA		WASHINGTON	112000	0		0	112000	68000				JAN 11, 1972	P , , , , , , , ,
CUSHMAN NO 1	H	N FK SKOKOMISH	11.0	WASHINGTON	43200	0		0	43200	47000	735.0	107000	255.0	1926	P , , , , ,PS, , ,
CUSHMAN NO 2	H	N FK SKOKOMISH	9.0	WASHINGTON	81000	0		0	81000	88000	480.0	2500	480.0	1930	P , , , , , , , ,
LA GRANDE	H	NISQUALLY	33.0	WASHINGTON	64000	0		0	64000	65000	935.0	1000	419.0	1912	P , , , , , , , ,
MAYFIELD	H	COWLITZ	52.0	WASHINGTON	121500	0	LIC.	45000	166500	185000	425.0	21378	181.5	MAY 1, 1963	P , , , , , ,RR, ,
MOSSYROCK	H	COWLITZ	65.5	WASHINGTON	300000	0	LIC.	150000	450000	576000	778.5	1397390	347.5	OCT 19, 1968	P , , , ,FC,PS, , ,
TACOMA NO 1	S	TACOMA		WASHINGTON	9000	0		0	9000	9100				1922	P , , , , , , , ,
TACOMA NO 2	S	TACOMA		WASHINGTON	50000	0		0	50000	55400				1931	P , , , , , , , ,

APPENDIX B

NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS

(December 31, 1972)

GROUP OWNERSHIP PROJECT	TYPE 1/	LOCATION			NAMEPLATE RATING - KILOWATTS					PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
		STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL						
PUBLIC AGENCIES															
TILLAMOOK COUNTY PUD															
-GINGER PEAK	H	TRASK	12.3	OREGON	0	0	POT.	9500	9500	11400	175.0	2900	100.0		P, , , , , ,RR, ,
-TRASK	H	TRASK	14.4	OREGON	0	0	POT.	76000	76000	80000	375.0	54600	200.0		P, , , , ,PS, , ,
UNIVERSITY OF OREGON															
OREGON UNIVERSITY	S	EUGENE		OREGON	5500	0		0	5500	6500					P, , , , , , , ,
U OF O MED SCHOOL	IC S	PORTLAND		OREGON	440	0		0	440	440					P, , , , , , , ,
UNIVERSITY OF WASHINGTON															
WASHINGTON UNIV	S	SEATTLE		WASHINGTON	650	0		0	650	650					P, , , , , , , ,
UTAH STATE AGRICULTURAL COLLEGE															
LOGAN	H	LOGAN		UTAH	450	0		0	450	450			30.0		P, , , , , , , ,
WASHINGTON PUBLIC POWER SUPPLY SYSTEM															
PACKWOOD LAKE	H	LAKE CR	5.3	WASHINGTON	26125	0		0	26125	31500	2858.5	3500	1803.5	MAY 1, 1964	P, , , , , , , ,
WPPSS NO.1 (HANFORD)	N	HANFORD		WASHINGTON	860000	0	POT.	372000	1232000	1232000	(NOT DEPENDABLE)			NOV. 29, 1966	P, , , , , , , ,
WPPSS NO.2 (HANFORD)	N	HANFORD		WASHINGTON	0	1100000		0	1100000	1100000				SCHED. 1977	P, , , , , , , ,
WPPSS NO.3	N			WASHINGTON	0		POT.	1100000	1100000	1100000				SCHED. 1981	P, , , , , , , ,
WASHINGTON STATE UNIVERSITY															
WASHINGTON STATE U.	S	PULLMAN		WASHINGTON	450	0		0	450	450					P, , , , , , , ,
WELLS RURAL ELECTRIC COOPERATIVE, INC.															
WELLS NO.1	H	TROUT CR		NEVADA	120	0		0	120	135			400.0	1927	P, , , , , , , ,
WYOMING, UNIVERSITY OF															
LARAMIE	S	LARAMIE		WYOMING	1150	0		0	1150	1150					P, , , , , , , ,
PRIVATE UTILITIES															
ATLANTA POWER CO.															
ATLANTA	H	M FK BOISE	135.8	IDAHO	150	0		0	150	150			98.0	1941	P, , , , , , , ,
BLACK HILLS POWER AND LIGHT CO.															
BEN FRENCH	S			SOUTH DAKOTA	22000	0		0	22000	25000					P, , , , , , , ,
BEN FRENCH	IC			SOUTH DAKOTA	10000	0		0	10000	10000					P, , , , , , , ,
FALL RIVER FALLS	H	FALL		SOUTH DAKOTA	200	0		0	200	200			105.0		P, , , , , , , ,
GILLETTE	J-S	GILLETTE		WYOMING	0	0	POT.	330000	330000	330000				SCHED. 1977	P
HOT SRINGS	IC			SOUTH DAKOTA	1100	0		0	1100	1100					P, , , , , , , ,
KIRK	S			SOUTH DAKOTA	31500	0		0	31500	31500					P, , , , , , , ,
OSAGE	S	OSAGE		WYOMING	34500	0		0	34500	34500				1948	P, , , , , , , ,
OSAGE	IC	OSAGE		WYOMING	1000	0		0	1000	1000				1948	P, , , , , , , ,
RAPID CITY	IC	RAPID CITY		SOUTH DAKOTA	10000	0		0	10000	10000					P, , , , , , , ,
REDWATER NO 1	H	REDWATER		SOUTH DAKOTA	1000	0		0	1000	1000			100.0		P, , , , , , , ,
REDWATER NO 2	H	REDWATER		SOUTH DAKOTA	346	0		0	346	346			50.0		P, , , , , , , ,
WYODAK	S	GILLETTE		WYOMING	27680	0		0	27680	27680				1945	P, , , , , , , ,
CALIFORNIA-PACIFIC UTILITIES CO.															
CEDAR NO 1	H	VIRGIN		UTAH	750	0		0	750	750				1917	P, , , , , , , ,
CEDAR NO 2	H	VIRGIN		UTAH	500	0		0	500	500			467.0	1920	P, , , , , , , ,
CEDAR NO 3	H	VIRGIN		UTAH	640	0		0	640	640				1926	P, , , , , , , ,
CEDAR NO 4	H	VIRGIN		UTAH	1000	0		0	1000	1000			216.0	1929	P, , , , , , , ,
CEDAR	IC	CEDAR CITY		UTAH	5178	0		0	5178	5178				1930	P, , , , , , , ,
CEDAR CITY	S	CEDAR CITY		UTAH	7500	0		0	7500	7950				1943	P, , , , , , , ,
NEEDLES	IC	NEEDLES		CALIFORNIA	1075	0		0	1075	1075					P, , , , , , , ,
ROCK CREEK	H	ROCK CR	9.0	OREGON	800	0		0	800	900		0	936.0	1905	P, , , , , , , ,
WINNEMUCCA	H	WATER CANYON		NEVADA	120	0		0	120	120					P, , , , , , , ,
WINNEMUCCA	IC	WINNEMUCCA		NEVADA	1515	0		0	1515	1515					P, , , , , , , ,
CHEYENNE LIGHT, FUEL AND POWER CO.															
SNYDER	IC	CHEYENNE		WYOMING	10000	0		0	10000	10000					P, , , , , , , ,

APPENDIX B

NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS

(December 31, 1972)

GROUP OWNERSHIP PROJECT	TYPE 1/	LOCATION			NAMEPLATE RATING - KILOWATTS										
		STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
PRIVATE UTILITIES															
IDAHO POWER CO.															
AMERICAN FALLS	H	SNAKE	713.9	IDAHO	27500	0		0	27500	27300	4296.6	0	48.5	1902	P, , , , , , , ,
BLISS	H	SNAKE	560.0	IDAHO	75000	0	LIC.	25000	100000	105000	2654.0	1200	70.0	NOV 30, 1949	P, , , , , , , ,
BROWNLEE	H	SNAKE	285.0	OREGON IDAHO	360400	0	LIC.	180200	540600	675000	2077.0	980250	272.0	AUG 27, 1958	P, , , ,FC,PS, , ,
C.J.STRIKE	H	SNAKE	492.0	IDAHO	82800	0		0	82800	89000	2455.0	35000	88.0	MAR 3, 1952	P, , , , , , , ,
CASCADE	H	N FK PAYETTE	39.8	IDAHO	300	0		0	300	400	4780.0	0	37.0	1926	P, , , , , , , ,
CLEAR LAKE	H	CLEAR L. SPR.	594.0	IDAHO	2500	0		0	2500	2300	3000.0	0	79.0	NOV 1, 1937	P, , , , , , , ,
HELLS CANYON	H	SNAKE	247.0	OREGON IDAHO	391500	0	LIC.	130500	522000	566670	1688.0	11800	210.0	OCT 23, 1967	P, , , , , , , ,
JIM BRIDGER	J S	ROCK SPRINGS		WYOMING	0	508500		0	508500	508500				SCHED 1974	P
LOWER MALAD	H	MALAD	0.3	IDAHO	13500	0		0	13500	14000	2881.4	0	161.4	1911	P, , , , , , , ,
LOWER SALMON	H	SNAKE	572.9	IDAHO	60000	0	LIC.	15000	75000	85000	2798.6	3600	59.0	1910	P, , , , , , , ,
OXBOW	H	SNAKE	273.0	OREGON IDAHO	190000	0	LIC.	47500	237500	275000	1805.0	5000	117.0	JUL 5, 1961	P, , , , , , , ,
SALMON	IC	SALMON		IDAHO	6825	0		0	6825	6700				1926	P, , , , , , , ,
SHOSHONE FALLS	H	SNAKE	615.0	IDAHO	12380	0		0	12380	12500	3362.0	750	214.0	1907	P, , , , , , , ,
SWAN FALLS	H	SNAKE	456.0	IDAHO	10265	0		0	10265	12000	2314.2	2275	24.5	1910	P, , , , , , , ,
THOUSAND SPRINGS	H	SPR TO SNAKE	584.4	IDAHO	8000	0		0	8000	7600	3061.9	0	182.0	1912	P, , , , , , , ,
TWIN FALLS	H	SNAKE	618.0	IDAHO	13500	0		0	13500	9800	3519.4	750	147.0	1935	P, , , , , , , ,
UPPER MALAD	H	MALAD	1.4	IDAHO	7200	0		0	7200	7600	3011.9	0	129.4	JUN , 1948	P, , , , , , , ,
UPPER SALMON A	H	SNAKE	581.0	IDAHO	18000	0		0	18000	19500	2841.2	0	42.6	SEP 11, 1937	P, , , , , , , ,
UPPER SALMON B	H	SNAKE	582.0	IDAHO	16500	0		0	16500	17500	2878.1	1200	36.9	SEP , 1947	P, , , , , , , ,
MONTANA-DAKOTA UTILITIES															
ACME	S	SHERIDAN		WYOMING	12000	0		0	12000	12000					P, , , , , , , ,
BAKER	IC	BAKER		MONTANA	1000	0		0	1000	1000					P, , , , , , , ,
BEULAH	S	BEULAH		NORTH DAKOTA	13500	0		0	13500	13500					P, , , , , , , ,
BIG STONE	J S	GRANT CO		SOUTH DAKOTA	0	440000		0	440000	440000				SCHED 1975	P, , , , , , , ,
ELLENDALE	IC	ELLENDALE		NORTH DAKOTA	3400	0		0	3400	3400					P, , , , , , , ,
GLENDIVE	S	GLENDIVE		MONTANA	7000	0		0	7000	7000					P, , , , , , , ,
HESKETT	S	HESKETT		NORTH DAKOTA	100100	0		0	100100	100100					P, , , , , , , ,
LEWIS-CLARK	S	SIDNEY		MONTANA	50000	0		0	50000	50000					P, , , , , , , ,
MILES CITY	GT	MILES CITY		MONTANA	20000	0		0	20000	20000					P, , , , , , , ,
WILLISTON	S	WILLISTON		NORTH DAKOTA	2000	0		0	2000	2000					P, , , , , , , ,
WILLISTON	GT	WILLISTON		NORTH DAKOTA	8000	0		0	8000	8000					P, , , , , , , ,
MONTANA LIGHT AND POWER CO.															
LAKE CREEK NO 1	H	LAKE CR	0.6	MONTANA	1000	0		0	1000	1250	2061.0 }	30	161.0	1916	P, , , , , , , ,
LAKE CREEK NO 2	H	LAKE CR	0.6	MONTANA	3500	0		0	3500	4210	2061.0 }		161.0	1949	P, , , , , , , ,
LIBBY	S	LIBBY		MONTANA	12550	0		0	12550	14065				1927	P, , , , , , , ,
TROY	S	TROY		MONTANA	3000	0		0	3000	3200				1956	P, , , , , , , ,
MONTANA POWER CO.															
BLACK EAGLE	H	MISSOURI		MONTANA	16800	0		0	16800	18000	3290.0	1700	51.8	1927	P, , , , , , , ,
BUFFALO NO 2	H A	FLATHEAD	60.7	MONTANA	0	0	LIC.R.	120000	120000	138000	2706.0	PONDAGE	81.0		P, , , , , , , ,
BUFFALO NO 4	H A	FLATHEAD	36.5	MONTANA	0	0	LIC.R.	120000	120000	138000	2625.0	PONDAGE	80.0		P, , , , , , , ,
COCHRANE	H	MISSOURI		MONTANA	48000	0		0	48000	60000	3115.0	4500	76.0	APR 22, 1958	P, , , , , , , ,
COLSTRIP	J S	COLSTRIP		MONTANA	0	350000	POT.	350000	700000	700000				SCHED 1975	P, , , , , , , ,
FLINT CREEK	H	FLINT CR	38.8	MONTANA	1100	0		0	1100	1100	6429.0	23300	717.2	1901	P, , , , , , , ,
FRANK BIRD	S	BILLINGS		MONTANA	69000	0		0	69000	69000				NOV 10, 1951	P, , , , , , , ,
HAUSER LAKE	H	MISSOURI		MONTANA	17000	0		0	17000	16500	3635.4	66500	67.2	1907	P, , , , , , , ,
HEBGEN	H	MADISON		MONTANA	STORAGE	0		0	0	0	6534.9	379800		1915	, , , , ,PS, , ,
HOLTER	H	MISSOURI		MONTANA	38400	0		0	38400	49000	3564.0	82000	109.0	APR , 1918	P, , , , , , , ,
J.E. CORETTE	S	BILLINGS		MONTANA	172800	0		0	172800	180000				SEP 1, 1968	P, , , , , , , ,
KERR	H	FLATHEAD	72.0	MONTANA	168000	0		0	168000	185000	2893.0	1219000	187.0	MAY , 1939	P, , , , ,PS, , ,
MADISON	H	MADISON		MONTANA	9000	0		0	9000	8500	4841.0	39000	119.0	1906	P, , , , , , , ,
MILLTOWN	H	CLARK FORK	364.4	MONTANA	3040	0		0	3040	3400	3260.0	300	29.0	1906	P, , , , , , , ,
MORONY	H	MISSOURI		MONTANA	45000	0		0	45000	47000	2888.0	7900	83.4	JAN , 1930	P, , , , , , , ,
MYSTIC LAKE	H	W ROSEBUD CR		MONTANA	10000	0		0 }	82000	83500	7673.0	20700	1128.0	1925	P, , , , , , , ,
MYSTIC LAKE	PG	W ROSEBUD CR		MONTANA	0	0	POT.	72000 }							P, , , , , , , ,
RAINBOW	H	MISSOURI		MONTANA	35600	0		0	35600	35000	3224.0	1000	109.0	1910	P, , , , , , , ,
RYAN	H	MISSOURI		MONTANA	48000	0		0	48000	60000	3039.0	2800	151.0	1915	P, , , , , , , ,
THOMPSON FALLS	H	CLARK FORK	208.0	MONTANA	30000	0		0	30000	40000	2396.0	15000	59.7	JUL 1, 1915	P, , , , , , , ,
TRIDENT	S	TRIDENT		MONTANA	0	0	POT.	330000	330000	330000				SCHED. 1975	P, , , , , , , ,
YELLOWSTONE LAKE	IC	YELLOWSTONE		MONTANA	2750	0		0	2750	2750				JUL 10, 1967	P, , , , , , , ,
NEVADA POWER CO.															
CLARK	S	EAST LAS VEGAS		NEVADA	190280	0		0	190280	193000				1955	P, , , , , , , ,
ELKO	IC	ELKO		NEVADA	5250	0	POT.	2000	7250	7250					P, , , , , , , ,
LAMOILLE	H	LAMOILLE CR.		NEVADA	200	0		0	200	200				1913	P, , , , , , , ,
MOHAVE	J S	SEARCHLIGHT		NEVADA	221200	0		0	221200	221200				APR , 1971	P, , , , , , , ,
REID GARDNER	S	GLENDALE JCT		NEVADA	227272	0	POT.	113636	340908	357000				1965	P, , , , , , , ,
SUNRISE	S	LAS VEGAS		NEVADA	81600	0	POT.	100000	181600	185000				JUL , 1964	P, , , , , , , ,
WEST SIDE	IC			NEVADA	29315	0		0	29315	30000				1963	P, , , , , , , ,
PACIFIC NORTHWEST POWER CO. - WASHINGTON PUBLIC POWER SUPPLY SYSTEM (JOINT)															
MOUNTAIN SHEEP	J H A	SNAKE	188.9	OREGON-IDAHO	0		LIC. R.	1290000	1290000	1470000	1510.0	2250000	595.3		P, , , ,FC,PS, , ,

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APPENDIX B

NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS

(December 31, 1972)

		LOCATION			NAMEPLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/	STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
PACIFIC GAS AND ELECTRIC CO.															
ALTA	H	BEAR		CALIFORNIA	2000	0		0	2000	1100		0	660.0	1902	P, , , , , , , ,
ANGELS	H	ANGELS CR		CALIFORNIA	1400	0		0	1400	1000		0	448.0	1940	P, , , , , , , ,
AVON	S	AVON		CALIFORNIA	40000	0		0	40000	50000				1940	P, , , , , , , ,
BALCH NO 1	H	N FK KINGS	6.0	CALIFORNIA	31000	0		0	31000	34000	4097.0	967	2378.7	1927	P, , , , , , , ,
BALCH NO 2	H	N FK KINGS	6.0	CALIFORNIA	97200	0		0	97200	106700	4097.0		2389.0	DEC 23, 1958	P, , , , , , , ,
BELDEN	H	N FK FEATHER		CALIFORNIA	117900	0		0	117900	125000	2985.0	900	770.0	SEP 14, 1969	P, , , , , , , ,
BUCKS CREEK	H	N FK FEATHER		CALIFORNIA	66000	0		0	56000	53800	4319.5	1033	2557.6	1928	P, , , , , , , ,
BUTT VALLEY	H	N FK FEATHER		CALIFORNIA	36000	0		0	36000	44000	4484.0	1024172	342.0	DEC 31, 1958	P, , , , , , , ,
CARIBOU NO 1	H	N FK FEATHER		CALIFORNIA	75000	0		0	75000	75000	4142.0		1149.0	1921	P, , , , , , , ,
CARIBOU NO 2	H	N FK FEATHER		CALIFORNIA	109800	0		0	109800	120000	4142.0	32557	1150.0	1958	P, , , , , , , ,
CENTERVILLE	H	BUTTE CR		CALIFORNIA	6400	0		0	6400	6200	1059.5	0	577.0	1904	P, , , , , , , ,
CHILI BAR	H	S FK AMERICAN		CALIFORNIA	7020	0		0	7020	7000	1000.0	1550	57.0	MAR 22, 1965	P, , , , , , , ,
COAL CANYON	H	N FK FEATHER		CALIFORNIA	800	0		0	800	1000		0	350.0	1907	P, , , , , , , ,
COLEMAN	H	BATTLE CR		CALIFORNIA	13800	0		0	13800	13000	8648.0	50	482.0	1911	P, , , , , , , ,
CONTRA COSTA	S	ANTIOCH		CALIFORNIA	1253580	0	POT.	660000	1913580	1930000				1951	P, , , , , , , ,
COURTRIGHT RES	H	HELMS CR	3.0	CALIFORNIA	STORAGE	0		0	0	0	8184.0	123285		1958	, , , , ,PS, , ,
COW CREEK	H	COW CR		CALIFORNIA	1440	0		0	1440	1800		5	715.0	1907	P, , , , , , , ,
CRANE VALLEY	H	N FK WILLOW CR		CALIFORNIA	880	0		0	880	900		45110	120.0	1919	P, , , , , , , ,
CRESTA	H	N FK FEATHER		CALIFORNIA	67500	0		0	67500	70000	1680.0	2208	290.0	1949	P, , , , , , , ,
DEER CREEK	H	DEER CR		CALIFORNIA	5500	0		0	5500	5800	4637.6	20	837.0	1908	P, , , , , , , ,
DE SABLA	H	BUTTE CR		CALIFORNIA	18450	0		0	18450	20000	2732.0	188	1530.0	FEB , 1963	P, , , , , , , ,
DIABLO CANYON	N			CALIFORNIA	0	2268000		0	2268000	2130000				SCHED. 1974	P, , , , , , , ,
DOWNIEVILLE	IC	DOWNIEVILLE		CALIFORNIA	750	0		0	750	750				1966	P, , , , , , , ,
DRUM NO 1	H	BEAR		CALIFORNIA	49200	0		0	49200	54000	4759.7	97	1372.4	1913	P, , , , , , , ,
DRUM NO 2	H	BEAR		CALIFORNIA	44100	0		0	44100	49500	4759.7		1318.0	DEC 18, 1965	P, , , , , , , ,
DUTCH FLAT	H	BEAR		CALIFORNIA	22000	0		0	22000	23000	3382.6	165	643.0	1943	P, , , , , , , ,
ELDORADO	H	PLACERVILLE		CALIFORNIA	20000	0		0	20000	21000	3788.3	400	1910.0	1924	P, , , , , , , ,
ELECTRA	H	MOKELUMN		CALIFORNIA	89100	0		0	89100	92000	1962.6	909	1268.3	1948	P, , , , , , , ,
HAAS	H	N FK KINGS	12.0	CALIFORNIA	135000	0		0	135000	144000	6550.0	128566	2444.5	DEC 23, 1958	P, , , , , , , ,
HALSEY	H	DRY CR		CALIFORNIA	12000	0		0	12000	11000	1813.6	68	331.0	1916	P, , , , , , , ,
HAMILTON BRANCH	H	N FK FEATHER		CALIFORNIA	5390	0		0	5390	5000	4917.5	0	409.7	1921	P, , , , , , , ,
HAT CREEK NO 1	H	HAT CR		CALIFORNIA	10000	0		0	10000	8500	3189.0	0	216.8	1921	P, , , , , , , ,
HAT CREEK NO 2	H	HAT CR		CALIFORNIA	10000	0		0	10000	8500	2968.8	290	197.9	1921	P, , , , , , , ,
HUMBOLDT BAY	S	EUREKA		CALIFORNIA	102400	0		0	162400	172000				DEC 26, 1956	P, , , , , , , ,
HUMBOLDT BAY	N	EUREKA		CALIFORNIA	60000	0		0						FEB 1963	P, , , , , , , ,
HUNTERS POINT	S	SAN FRNCSCO		CALIFORNIA	391350	0		0	391350	419000				1929	P, , , , , , , ,
INSKIP	H	S FK BATTLE CR		CALIFORNIA	6000	0		0	6000	6000	1322.0	0	378.0	1910	P, , , , , , , ,
JAMES B BLACK	H	MONTGOMERY CR		CALIFORNIA	154800	0		0	154800	172000	2664.0	22748	1226.0	DEC. 17, 1965	P, , , , ,PS, , ,
KERCKHOFF	H	SAN JOAQUIN		CALIFORNIA	34080	0		0	34080	37500	985.7	0	350.0	1920	P, , , , , , , ,
KERN	S	BAKERSFIELD		CALIFORNIA	152000	0		0	152000	195000				1948	P, , , , , , , ,
KERN CANYON	H	KERN		CALIFORNIA	8480	0		0	8480	10500	944.0	0	260.0	1921	P, , , , , , , ,
KILARC	H	N FK COW CR		CALIFORNIA	3000	0		0	3000	3200		30	1192.0	1903	P, , , , , , , ,
KINGS RIVER	H	KINGS		CALIFORNIA	44100	0		0	44100	52000	1703.0	135	788.0	MAR 7, 1962	P, , , , , , , ,
LIME SADDLE	H	N FK FEATHER		CALIFORNIA	1600	0		0	1600	2000		254	442.0	1906	P, , , , , , , ,
MARTINEZ	S	MARTINEZ		CALIFORNIA	40000	0		0	40000	50000				1941	P, , , , , , , ,
MELONES	H	STANISLAUS		CALIFORNIA	24300	TO BE RETIRED 0 NOV 1974		0	24300	26000	735.0	101820	230.0	1927	P, , , , , , , ,
MENDOCINO	N	MENDOCINO		CALIFORNIA	0	0	POT.	2435400	2435400	2260000				SCHED 1978	P, , , , , , , ,
MERCED FALLS	H	MERCED		CALIFORNIA	3440	0		0	3440	3500		900	27.0	1930	P, , , , , , , ,
MORRO BAY	S	MORRO BAY		CALIFORNIA	1056816	0		0	1056316	1030000				1955	P, , , , , , , ,
MOSS LANDING	S	SALINAS		CALIFORNIA	2152150	0		0	2152150	2113000				1950	P, , , , , , , ,
MURPHYS	H	ANGELS CR		CALIFORNIA	3600	0		0	3600	4300		41	685.0	1953	P, , , , , , , ,
NARROWS	H	YUBA		CALIFORNIA	9350	0		0	9350	12000	527.0	45000	240.0	1942	P, , , , , , , ,
OLEUM	S	OLEUM		CALIFORNIA	80000	0		0	80000	100000				1942	P, , , , , , , ,
PHOENIX	H	SULLIVAN CR		CALIFORNIA	1600	0		0	1600	1900		0	1087.0	1940	P, , , , , , , ,
PIT NO 1	H	PIT		CALIFORNIA	56000	0		0	56000	61000	3303.8	600	454.0	1922	P, , , , , , , ,
PIT NO 3	H	PIT		CALIFORNIA	80190	0		0	80190	71600	2737.5	14440	315.0	1925	P, , , , , , , ,
PIT NO 4	H	PIT		CALIFORNIA	90000	0		0	90000	95000	2422.5	1198	382.0	OCT 1, 1955	P, , , , , , , ,
PIT NO.5	H	PIT		CALIFORNIA	140560	0		0	140560	156000	2040.5	0	615.0	APR , 1944	P, , , , , , , ,
PIT NO.6	H	PIT		CALIFORNIA	79200	0		0	79200	86200	1425.0	8605	155.0	AUG 14, 1965	P, , , , , , , ,
PIT NO.7	H	PIT		CALIFORNIA	164490	0		0	104400	108000	1270.0	15361	205.0	SEP 10, 1965	P, , , , , , , ,
PITTSBURG	S	PITTSBURG		CALIFORNIA	2028400	0		0	2028400	2014600				1954	P, , , , , , , ,
POE	H	N FK FEATHER		CALIFORNIA	124200	0		0	124200	120000	1390.0	478	475.6	OCT 26, 1958	P, , , , , , , ,
POTRERO	S	SAN FRNCSCO		CALIFORNIA	317855	0	POT.	990000	1307855	1322000				1931	, , , , , , , ,
POTTER VALLEY	H	POTTER VALLEY		CALIFORNIA	9040	0		0	9040	9600	1488.5	1140	476.5	1910	P, , , , , , , ,
ROCK CREEK	H	N FK FEATHER		CALIFORNIA	113400	0		0	113400	110000	2215.0	2525	535.0	1950	P, , , , , , , ,
SALT SPRINGS	H	N FK MOKELUMNE		CALIFORNIA	39050	0		0	39050	45800	5818.2	46930	2108.8	1931	P, , , , , , , ,
SAN JOAQUIN 1A	H	WILLOW CR		CALIFORNIA	340	0		0	340	400		0	43.0	1919	P, , , , , , , ,
SAN JOAQUIN 2	H	WILLOW CR		CALIFORNIA	2880	0		0	2880	3300		11	307.0	1917	P, , , , , , , ,
SAN JOAQUIN 3	H	WILLOW CR		CALIFORNIA	4000	0		0	4000	4000		20	405.0	1923	P, , , , , , , ,
SOUTH	H	S FK BATTLE CR		CALIFORNIA	4000	0		0	4000	4900		0	500.0	1910	P, , , , , , , ,
SPAULDING 1	H	S FK YUBA		CALIFORNIA	7040	0		0	7040	9600	5014.6	74444	197.0	1928	P, ,I, , , , , ,
SPAULDING 2	H	S FK YUBA		CALIFORNIA	3713	0		0	3713	3900	5014.6		344.0	1928	P, , , , , , , ,
SPAULDING 3	H	S FK YUBA		CALIFORNIA	6300	0		0	6300	5900	5332.9	0	318.3	1929	P, , , , , , , ,
SPRING GAP	H	M FK STANISLAS		CALIFORNIA	6000	0		0	6000	7000	4876.0	0	1865.0	1921	P, , , , , , , ,
STANISLAUS	H	STANISLAUS		CALIFORNIA	81900	0		0	81900	92000	2602.3	307	1525.0	APR , 1963	P, , , , , , , ,
THE GEYSERS	GO	CLOVERDALE		CALIFORNIA	321763	237600		907400	1466763	1451400				SEP 25, 1960	P, , , , , , , ,
TIGER CREEK	H	N FK MOKELUMNE		CALIFORNIA	51000	0		0	51000	58000	3558.7	42	1218.6	1931	P, , , , , , , ,
TRINITY CENTER		TRINITY CNTR		CALIFORNIA	300	0		0	303	300				OCT 1948	P ,(LEASED FROM PP&L CO.)
TULE	H	TULE		CALIFORNIA	4800	0		0	4800	5400			1443.0	1914	P, , , , , , , ,
VOLTA	H	MILLSEAT CR		CALIFORNIA	6400	0		0	6400	7200	3454.0	46	1254.0	1906	P, , , , , , , ,
WEST POINT	H	N MOKELUMNE		CALIFORNIA	13600	0		0	13600	14800	2334.6	1007	312.2	1948	P, , , , , , , ,
WISE	H	AUBURN RAVINE		CALIFORNIA	12000	0		0	12000	14400	1414.6	25	519.0	1917	P, , , , , , , ,
WISHON	H	SAN JOAQUIN		CALIFORNIA	12800	0		0	12800	20000	2399.5	25	1412.0	1910	P, , , , , , , ,

APPENDIX B

NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS

(December 31, 1972)

		LOCATION			NAMEPLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/	STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
PRIVATE UTILITIES															
PACIFIC POWER AND LIGHT CO.															
ALBANY	H	S SANTIAM	18.0	OREGON	800	0		0	800	500		0	36.0	1923	P, , , , , , , ,
ASPEN LAKE	PG	ASPEN CR	3.0	OREGON	0	0	POT.	36000	36000	36000	4380.0		240.0		P, , , , , , , ,
ASTORIA	S	ASTORIA,		OREGON	8000	0		0	8000	8800				1921	P, , , , , , , ,
BEAR SPRINGS	H	KLAMATH	229.7	OREGON	0	0	POT.	25000	25000	25000	3327.0	0	127.0		P, , , , , , , ,
BEND	H	DESCHUTES	166.3	OREGON	1110	0		0	1110	1000	3591.5	0	15.0	1913	P, , , , , , , ,
BIG FORK	H	SWAN	1.5	MONTANA	4150	0		0	4150	4560	3000.0	109	105.0	1901	P, , , , , , , ,
BIG MEADOW	H	BIG CR	5.0	WASHINGTON	0	0	POT.	STORAGE	0	0	3360.0	70000			, , , , ,PS, , ,
CENTRALIA	J S	CENTRALIA		WASHINGTON	665000	0		0	665000	403750				JAN 11, 1972	P, , , , , , , ,
CLEARWATER NO 1	H	CLEARWATER	9.0	OREGON	15000	0		0	15000	18700	3863.3	154	551.3	JUN 16, 1953	P, , , , , , , ,
CLEARWATER NO 2	H	CLEARWATER	5.7	OREGON	26000	0		0	26000	32000	3180.0	96	750.0	NOV 30, 1953	P, , , , , , , ,
CLINE FALLS	H	DESCHUTES	144.7	OREGON	1000	0		0	1000	1000	2820.0	0	50.0	1913	P, , , , , , , ,
CONDIT	H	WHITE SALMON	3.3	WASHINGTON	9500	0		0	9600	15000	299.2	1081	178.0	1913	P, , , , , , , ,
COPCO NO 1	H	KLAMATH	208.6	CALIFORNIA	20000	0		0	20000	26500	2607.5	12500	124.5	1918	P, , , , , , , ,
COPCO NO 2	H	KLAMATH	208.5	CALIFORNIA	27000	0		0	27000	30000	2483.0	0	152.0	1925	P, , , , , , , ,
CURLY CREEK DIV	H	CURLY CR	3.8	WASHINGTON	0	0	POT.	DIVERSION	0	0	2533.0	0			, , , , ,PS, , ,
DAVE JOHNSTON	S	GLENROCK		WYOMING	750000	0		0	750000	786700				JAN , 1959	P, , , , , , , ,
EAGLE POINT	H	S BUTTE CR	11.4	OREGON	2813	0		0	2813	3200		0	409.0	NOV 1, 1957	P, , , , , , , ,
EAST SIDE	H	LINK	261.3	OREGON	3200	0		0	3200	3300	4142.0	465400	47.5	1924	P, ,I, , , , , ,
EDEN RIDGE	H	S FK COQUILLE	20.5	OREGON	0	0	LIC. R.	77000	77000	89000	2155.0	110000	1515.0		P, , , , , , , ,
EDEN RIDGE	S	POWERS		OREGON	0	0	POT.	100000	100000	100000					P, , , , , , , ,
FALL CREEK	H	FALL CR	8.0	CALIFORNIA	2200	0		0	2200	2300		0	680.0	1903	P, , , , , , , ,
FISH CREEK	H	FISH CR	7.3	OREGON	11000	0		0	11000	12400	3024.4	78	1042.4	JUN 30, 1952	P, , , , , , , ,
IRON GATE	H	KLAMATH	200.0	CALIFORNIA	18000	0		0	18000	20000	2328.0	19131	158.0	FEB 1, 1962	P, , , , , ,RR, ,
JIM BRIDGER	J S	ROCK SPRINGS		WYOMING	0	1017000		0	1017000	1017000				SCHED. 1975	P, , , , , , , ,
JOHN C BOYLE	H	KLAMATH	234.4	OREGON	79990	0		0	79990	88000	3793.0	1507	466.0	OCT 1, 1958	P, , , , , , , ,
KENO	H	KLAMATH	242.4	OREGON	DAM	0	LIC.	100000	100000	100000	4086.5	PONDAGE	293.5	SCHED 1973	P, , , , , , , ,
LANDER	IC	LANDER		WYOMING	1000	0		0	1000	1000				1948	P, , , , , , , ,
LEMOLO NO 1	H	NORTH UMPQUA	93.0	OREGON	29000	0		0	29000	30000	4077.0	12553	752.0	JUL , 1955	P, , , , , , , ,
LEMOLO NO 2	H	NORTH UMPQUA	88.4	OREGON	33000	0		0	33000	35100	3184.5	235	728.5	NOV 1, 1956	P, , , , , , , ,
LIBBY	GT	LIBBY		MONTANA	26000	0		0	26000	26000				DEC. 6, 1972	P, , , , , , , ,
LINCOLN	S	PORTLAND		OREGON	35500	0		0	35500	48200				1919	P, , , , , , , ,
MEADOWS LOWER DROP	H	RUSH CR	1.6	WASHINGTON	0	0	LIC. R.	55000	55000	63250	2361.0	180	1061.0		P, , , , , , , ,
MEADOWS UPPER DROP	H	MEADOWS CR	1.0	WASHINGTON	0	0	LIC R.	30000	30000	30000	3211.0	200	850.0		P, , , , , , , ,
MERWIN	H	LEWIS	19.5	WASHINGTON	135000	0	LIC.	45000	180000	191000	239.6	261366	185.0	SEP 8, 1931	P, , , , ,PS, , ,
MUDDY	H	LEWIS	59.8	WASHINGTON	0	0	LIC. R.	110000	110000	126500	1300.0	277000	300.0		P, , , , , , , ,
NACHES	H	NACHES-WAPATOX CANAL	9.7	WASHINGTON	6370	0		0	6370	5000	1496.4	0	148.6	1906	P, , , , , , , ,
NACHES DROP	H	NACHES-WAPATOX CANAL	11.7	WASHINGTON	1400	0		0	1400	1400	1561.3	0	54.0	1914	P, , , , , , , ,
NORTH BEND	S	NORTH BEND		OREGON	15000	0		0	15000	14800				1924	P, , , , , , , ,
POWERDALE	H	HOOD	3.0	OREGON	6000	0		0	6000	6500	291.6	0	209.6	1923	P, , , , , , , ,
PROSPECT NO 1	H	N FK ROGUE	169.4	OREGON	3760	0		0	3750	4600	2477.0	20	495.0	JAN 1912	P, , , , , , , ,
PROSPECT NO 2	H	N FK ROGUE	169.5	OREGON	32000	0	LIC. R.	16000	48000	55200	2590.0	100	607.0	JAN , 1928	P, , , , , , , ,
PROSPECT NO 3	H	S FK ROGUE	9.0	OREGON	7200	0		0	7200	7800	2640.0	0	720.0	1932	P, , , , , , , ,
PROSPECT NO 4	H	N FK ROGUE	169.8	OREGON	1000	0		0	1000	1300	2590.0	20	112.0	1944	P, , , , , , , ,
RUSH CREEK DIV	H	RUSH CR	2.5	WASHINGTON	0	0	POT.	DIVERSION	0	0	2382.0	0			, , , , ,PS, , ,
SALT CAVES	H	KLAMATH	224.4	OREGON	0	0	POT.	80000	80000	80000	3200.0	0	420.0		P, , , , , , , ,
SLIDE CREEK	H	NORTH UMPQUA	73.0	OREGON	18000	0		0	18000	19000	1974.0	0	169.0	JUL 18, 1951	P, , , , , , , ,
SODA SPRINGS	H	NORTH UMPQUA	69.8	OREGON	11000	0		0	11000	12000	1805.0	710	114.0	MAR 21, 1952	P, , , , , , , ,
SPRINGFIELD	S	SPRINGFIELD		OREGON	5000	0		0	5000	4600				1906	P, , , , , , , ,
STAYTON	H	N SANTIAM	28.6	OREGON	600	0		0	600	700	465.0	0	15.0	1924	P, , , , , , , ,
SWIFT NO 1	H	LEWIS	47.9	WASHINGTON	204000	0		0	204000	258000	1000.0	446995	396.0	DEC 31, 1958	P, , , , ,PS, , ,
TOKETEE	H	NORTH UMPQUA	75.3	OREGON	42500	0		0	42500	44500	2430.0	1420	448.0	JAN 3, 1950	P, , , , , , , ,
TROJAN	J N	PRESCOTT	72.1	OREGON	0	28250		0	28250	28250				SCHED 1975	P, , , , , , , ,
TRONA	S	GREEN RIVER		WYOMING	15625	0		0	15625	15625				OCT. 1, 1968	P, , , , , , , ,
WALLOWA FALLS	H	E FK WALLOWA	2.0	OREGON	1100	0		0	1100	1100	5687.0	2	1187.0	1921	P, , , , , , , ,
WARM SPRINGS	H	KLAMATH	219.6	CALIFORNIA	0	0	POT.	38000	38000	38000	2780.0	0	155.0		P, , , , , , , ,
WEST SIDE	H	LINK	260.9	OREGON	600	0		0	600	800	4142.0	465400	49.0	1908	P, ,I, , , , , ,
YALE	H	LEWIS	34.2	WASHINGTON	108000	0	LIC.	108000	216000	268000	490.0	189535	250.0	SEP 7, 1953	P, , , , ,PS, , ,
PORTLAND GENERAL ELECTRIC CO.															
BETHEL	GT	SALEM		OREGON	0	110000		0	110000	127700				SCHED. 1973	P, , , , , , , ,
BOARDMAN	N	BOARDMAN		OREGON	0	0	POT.	1150000	1150000	1150000				SCHED. 1980	P, , , , , , , ,
BULL RUN	H	BULL RUN	1.5	OREGON	21000	0		0	21000	22000	655.0	970	326.0	1912	P, , , , , , , ,
CENTRALIA	J S	CENTRALIA		WASHINGTON	35000	0		0	35000	21250				JAN. 11, 1972	P, , , , , , , ,
FARADAY	H	CLACKAMAS	28.0	OREGON	34450	0		0	34450	44000	520.0	550	132.6	1907	P, , , , , , , ,
HARBORTON	GT	PORTLAND		OREGON	0	220000		0	220000	257500				SCHED 1973	P, , , , , , , ,
LITTLE SANDY R DIV	H	LITTLE SANDY	1.7	OREGON	DIVERSION	0		0	0	0		0		1912	, , , , ,PS, , ,
NORTH FORK	H	CLACKAMAS	30.1	OREGON	38400	0		0	38400	54000	665.0	5994	134.8	NOV 24, 1958	P, , , , , , , ,
OAK GROVE	H	OAK GROVE FK	5.1	OREGON	51000	0		0	51000	49000	1988.0	546	879.0	1924	P, , , , , , , ,
PELTON	H	DESCHUTES	102.8	OREGON	108000	0		0	108000	124000	1580.0	3800	151.3	DEC 20, 1957	P, , , , , , , ,
PORTLAND L	S	PORTLAND		OREGON	75500	0		0	75500	72300				1911	P, , , , , , , ,
RIVER MILL	H	CLACKAMAS	23.3	OREGON	19050	0		0	19050	23000	388.8	770	82.0	1911	P, , , , , , , ,
ROUND BUTTE	H	DESCHUTES	110.6	OREGON	247050	0		0	247050	330000	1945.0	274225	365.0	AUG 7, 1964	P, , , , ,PS, , ,
SANDY R DIVERSION	H	SANDY	30.0	OREGON	DIVERSION	0		0	0	0		0		1912	, , , , ,PS, , ,
SULLIVAN	H	WILLAMETTE	26.6	OREGON	15400	0		0	15400	15000	54.0	0	40.0	NOV , 1888	P, , , , , , , ,
SUMMIT	IC	GOVERNMENT CAMP		OREGON	5500	0		0	5500	6000				1970	P, , , , , , , ,
TIMOTHY MEADOWS	H	OAK GROVE FK	15.9	OREGON	STORAGE	0		0	0	0	3190.0	61740		SEP 25, 1956	, , , , ,PS, , ,
TROJAN	J N	PRESCOTT	72.1	OREGON	0	762750		0	762750	762750				SCHED 1975	P, , , , , , , ,

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

		LOCATION			NAMEPLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/	STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	STATE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE IN SERVICE	PURPOSE 3/
PUGET SOUND POWER AND LIGHT CO.															
CENTRALIA	J S	CENTRALIA		WASHINGTON	98000	0		0	98000	59500				JAN 11, 1972	P, , , , , , , ,
COLSTRIP	J S	COLSTRIP		MONTANA	0	350000	POT.	350000	700000	700000				SCHED 1975	P, , , , , , , ,
CRYSTAL MOUNTAIN	IC	CRYSTAL MOUNTAIN		WASHINGTON	2850	0		0	2850	2850				DEC 13, 1969	P, , , , , , , ,
ELECTRON	H	PUYALLUP	42.0	WASHINGTON	25500	0		0	25500	26400	1537.9	54	871.0	1904	P, , , , , , , ,
LOWER BAKER	H	BAKER	1.0	WASHINGTON	64000	0	LIC.	64000	128000	142800	438.6	142365	261.4	1925	P, , , , , , , ,
NOOKSACK	H	NOOKSACK	65.3	WASHINGTON	1500	0		0	1500	1700	1596.0	PONDAGE	195.0	1906	P, , , , , , , ,
SHUFFLETON	S	RENTON		WASHINGTON	87500	0		0	87500	86000				1929	P, , , , , , , ,
SNOQUALMIE FALLS 1	H	SNOQUALMIE	36.0	WASHINGTON	11600	0		0	11600	13000	401.0	390	257.0	1898	P, , , , , , , ,
SNOQUALMIE FALLS 2	H	SNOQUALMIE	36.0	WASHINGTON	30090	0		0	30090	31000	401.0		287.0	1910	P, , , , , , , ,
UPPER BAKER	H	BAKER	9.3	WASHINGTON	94400	0		0	94400	103000	724.0	220634	285.0	NOV 1, 1959	P, , , ,FC,PS, , ,
WHIDBEY ISLAND	GT	WHIDBEY ISLAND		WASHINGTON	0	26500		0	26500	26500				SCHED. 1978	P, , , , , , , ,
WHITE RIVER	H	WHITE	40.0	WASHINGTON	70000	0	LIC.	49000	119000	113000	543.0	44137	489.0	1912	P, , , , , , , ,
SIERRA PACIFIC POWER CO.															
BATTLE MOUNTAIN	IC	BATTLE MOUNTAIN		NEVADA	8000	0		0	8000	8000				JULY 9, 1963	P, , , , , , , ,
BRUNSWICK	IC	CARSON CITY		NEVADA	6000	0		0	6000	6000				1960	P, , , , , , , ,
FALLON	IC	FALLON		NEVADA	2000	0		0	2000	2000				1966	P, , , , , , , ,
FARAD	H	TRUCKEE R.		NEVADA	2800	0		0	2800	2750		0	80.5	1933	P, , , , , , , ,
FLEISH	H	TRUCKEE R.		NEVADA	2000	0		0	2000	2600		0	115.0	1914	P, , , , , , , ,
FORT CHURCHILL #1	S	YERINGTON		NEVADA	220000	0		0	220000	220000				1968	P, , , , , , , ,
GABBS	IC	GABBS		NEVADA	0	0	POT.	5000	5000	5000				SCHED. 1974	P, , , , , , , ,
KINGS BEACH	IC	KINGS BEACH		CALIFORNIA	16500	0		0	16500	16500				1969	P, , , , , , , ,
LAHONTAN (LEASED FROM TRUCKEE-CARSON IRRIG. DIST.	H	TRUCKEE-CARSON R.		NEVADA	2400	0		0	2400	2400				1911	P, , , , , , , ,
LAHONTAN	IC	FALLON		NEVADA	2000	0		0	2000	2000				1949	P, , , , , , , ,
PORTOLA	IC	PORTOLA		CALIFORNIA	6000	0		0	6000	6000				1965	P, , , , , , , ,
TRACY	S	SPARKS		NEVADA	133000	0	POT.	110000	243000	255000				1963	P, , , , , , , ,
TRACY	GT	SPARKS		NEVADA	25000	0		0	25000	22600				1961	P, , , , , , , ,
TWENTY-SIX FOOT DROP	H	V CANAL		NEVADA	800	0		0	800	800				1955	P, , , , , , , ,
VALLEY ROAD	IC	RENO		NEVADA	6000	0		0	6000	6000				1960	P, , , , , , , ,
VERDI	H	TRUCKEE R.		NEVADA	2400	0		0	2400	2200				1911	P, , , , , , , ,
WASHOE	H	MOGUL R.		NEVADA	1500	0		0	1500	1900				1904	P, , , , , , , ,
WINNEMUCCA	GT	WINNEMUCCA		NEVADA	15000	0		0	15000	13900				1970	P, , , , , , , ,
UTAH POWER AND LIGHT CO.															
AMERICAN FK UPPER	H	AM FK CR		UTAH	950	0		0	950	950		0	574.0	1907	P, , , , , , , ,
ASHTON	H	HENRYS FORK	44.0	IDAHO	5800	0		0	5800	5040	5156.6	1800	47.2	1917	P, , , , , , , ,
BEAR LAKE	H	BEAR LAKE CR		IDAHO UTAH	STORAGE	0		0	0	0	5923.6	1450000		1915	, ,I, , ,PS, , ,
BEAVER, LOWER	H	BEAVER		UTAH	600	0		0	600	600		0	460.0	1917	P, , , , , , , ,
BEAVER, UPPER	H	BEAVER		UTAH	2400	0		0	2400	2400		0	1000.0	1907	P, , , , , , , ,
CARBON	S	CASTLE GATE		UTAH	188636	0		0	188636	188636				NOV 26, 1954	P, , , , , , , ,
COVE	H	BEAR	130.0	IDAHO	7500	0		0	7500	7430	5031.8	0	93.0	1917	P, , , , , , , ,
CUTLER	H	BEAR	40.0	UTAH	30000	0		0	30000	29100	4407.0	15300	127.0	1927	P, , , , , , , ,
FOUNTAIN GREEN	H	BIG SPRING		UTAH	320	0		0	320	320		0	400.0	1922	P, , , , , , , ,
GADSBY	S	SALT LAKE		UTAH	251636	0		0	251636	251636				SEP 18, 1951	P, , , , , , , ,
GRACE	H	BEAR	120.0	IDAHO	44000	0	LIC.	11000	55000	51000	5554.8	250	524.0	1908	P, , , , , , , ,
GRANITE	H	BIG COTNWD CR		UTAH	1500	0		0	1500	1240		0	430.0	1896	P, , , , , , , ,
HALE	S	OREM		UTAH	59000	0		0	59000	64500				AUG 6, 1936	P, , , , , , , ,
HUNTINGTON CANYON	S	HUNTINGTON		UTAH	0	400000	POT.	400000	800000	860000				SCHED. 1974	P, , , , , , , ,
JORDAN	S	SALT LAKE		UTAH	25000	0		0	25000	24750				1911	P, , , , , , , ,
LITTLE MOUNTAIN	GT	OGDEN		UTAH	16000	0		0	16000	16000				APR 1, 1971	P, , , , , , , ,
NAUGHTON	S	KEMMERER		WYOMING	707200	0		0	707200	715000				MAY 15, 1963	P, , , , , , , ,
OLMSTED	H	PROVO	7.0	UTAH	12700	0		0	12700	9300	4940.0	0	340.0	1904	P, , , , , , , ,
ONEIDA	H	BEAR	105.0	IDAHO	30000	0	LIC.	10000	40000	39920	4882.9	11500	145.0	1915	P, , , , , , , ,
PARIS	H	PARIS CR		IDAHO	550	0		0	650	600		0	350.0	1910	P, , , , , , , ,
PIONEER	H	OGDEN		UTAH	5000	0		0	5000	4750	4771.4	0	423.0	1897	P, , , , , , , ,
RIVERDALE	H	WEBER		UTAH	3750	0		0	3750	2675		0	201.0	1912	P, , , , , , , ,
ST ANTHONY	H	HENRYS FORK	32.0	IDAHO	500	0		0	500	570	4970.0	0	14.0	1915	P, , , , , , , ,
SNAKE CREEK	H	SNAKE CR	6.0	UTAH	1180	0		0	1180	1180		0	720.0	1910	P, , , , , , , ,
SODA	H	BEAR	147.0	IDAHO	14000	0		0	14000	13900	5717.5	11800	79.0	1924	P, , , , , , , ,
STAIRS	H	BIG CTNWD CR		UTAH	1000	0		0	1000	1000		0	340.0	1899	P, , , , , , , ,
WEBER	H	WEBER		UTAH	2500	0		0	2500	3465	4863.5	100	185.0	1911	P, , , , , , , ,
WASHINGTON WATER POWER CO.															
CABINET GORGE	H	CLARK FORK	149.9	IDAHO	200000	0		0	200000	230000	2175.0	42780	97.2	SEP 30, 1952	P, , , , , , , ,
CENTRALIA	J S	CENTRALIA		WASHINGTON	210000	0		0	210000	127500				JAN 11, 1972	P, , , , , , , ,
LITTLE FALLS	H	SPOKANE	29.3	WASHINGTON	32000	0		0	32000	34700	1362.0	2220	72.0	1910	P, , , , , , , ,
LONG LAKE	H	SPOKANE	33.9	WASHINGTON	70000	0		0	70000	72500	1536.0	105080	171.0	1915	P, , , , ,PS, , ,
MEYERS FALLS	H	COLVILLE	5.5	WASHINGTON	1200	0		0	1200	1400	196.0	PONDAGE	125.0	1915	P, , , , , , , ,
MONROE STREET	H	SPOKANE	74.2	WASHINGTON	7200	0		0	7200	7200	1806.0	0	68.1	1890	P, , , , , , , ,
NINE MILE	H	SPOKANE	58.1	WASHINGTON	12000	0		0	12000	18000	1606.6	4600	65.0	1908	P, , , , , , , ,
NOXON RAPIDS	H	CLARK FORK	169.7	MONTANA	282880	0	LIC.	70720	353600	530000	2331.0	230680	152.0	SEP 1, 1959	P, , , , ,PS, , ,
OTHELLO	GT	OTHELLO		WASHINGTON	0	30000		0	30000	30000				SCHED 1973	P, , , , , , , ,
POST FALLS	H	SPOKANE	102.1	IDAHO	11250	0		0	11250	13200	2128.0	223100	56.1	1906	P, , , , ,PS, , ,
PRIEST LAKE	H	PRIEST	43.9	IDAHO	STORAGE	0		0	0	0	2437.6	70400		1950	, , , , ,PS, , ,
UPPER FALLS	H	SPOKANE	76.2	WASHINGTON	10000	0		0	10000	10200	1870.5	800	64.5	1922	P, , , , , , , ,

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

GROUP OWNERSHIP PROJECT	TYPE 1/	LOCATION STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	PROVINCE	NAMEPLATE RATING - KILOWATTS EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE INSERVICE,	PURPOSE 3/
PUBLIC AGENCIES															
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY															
ABERFELDIE 5/	H	BULL	8.4	BC	5000	0		0	5000	5000	2880.0	PONDAGE	275.0	1922	P , , , , , , , ,
ALERT BAY	IC	ALERT BAY		BC	1550	0		0	1550	1560					P , , , , , , , ,
ALOUETTE 5/	H	ALOUETTE		BC	8000	0		0	8000	9000	482.0	171174	141.0	1928	P , , , , ,PS, , ,
ARROW RESERVOIR 5/	H	COLUMBIA	780.6	BC	STORAGE	0		0	0	0	1444.0	7145000	42.0	OCT 10, 1968	, , , ,FC,PS, , ,
ASH RIVER 5/	H	ASH		BC	25200	0		0	25200	28000	1085	64463	820.0	JUN 20, 1959	P , , , , , , , ,
BELLA COOLA	IC	BELLA COOLA		BC	3607	0		0	3907	3007				DEC , 1955	P , , , , , , , ,
BLUE RIVER 5/	IC	BLUE RIVER		BC	1750	0		0	1750	1750				1961	P . . . .
BRIDGE RIVER NO 1 5/	H	BRIDGE		BC	180000	0		0	180000	204000	2136.0	} 816000	1346.0	1934	P , , , , ,PS, , ,
BRIDGE RIVER NO 2 5/	H	BRIDGE		BC	248000	0		0	248000	290000	2136.0	}	1351.0	SEP 27, 1959	P , , , , ,PS, , ,
BULL RIVER	H	KOOTENAY R	313.6	BC	0	0	POT.	134000	134000	154100	2660.0	3981000	147.0		P , , , ,FC,PS, , ,
BURNS LAKE 5/	IC	BURNS LAKE		BC	2936	0		0	2936	2936				1947	P , , , , , , , ,
BURRARD 5/	S	IOCO		BC	750000	150000		0	900000	972000				DEC 18, 1961	P , , , , , , , ,
CALAMITY CURVE	H	COLUMBIA	1105.0	BC	0	0	POT. .	120000	120000	128000	2591.0	PONDAGE	116.0		P , , , , , , , ,
CHEAKAMUS 5/	H	CHEAKAMAS		BC	140000	0		0	140000	144000	1240.0	39670	1120.0	OCT 20, 1957	P , , , , , , , ,
CLAYTON FALLS	H	CLAYTON CR		BC	700	0		0	700	700	260.0	PONDAGE	215.0	DEC , 1961	P , , , , , , , ,
CLOWHOM 5/	H	CLOWHOM	0.0	BC	30000	0		0	30000	31600	175.0	66645	175.0	JAN , 1958	P , , , , , , , ,
DAWSON CREEK 5/	IC	DAWSON CREEK		BC	13000	0		0	13000	13000				1953	P , , , , , , , ,
DOWNIE CREEK	H	COLUMBIA	969.0	BC	0	0	POT. .	1000000	1000000	1150000	1905.0	480000	255.0		P , , , , ,PS, , ,
DRY DOCK	IC	PRINCE RUPRT		BC	6401	0		0	6401	6401	0			1950	P , , , , , , , ,
DUNCAN 5/	H	DUNCAN	8.3	BC	STORAGE	0		0	0	0	1892.0	1411000	110.0	JULY 31, 1967	, , , , ,PS, , ,
ELKO 5/	H	ELK	14.5	BC	9600	0		0	9600	12000	2893.0	PONDAGE	193.0	1924	P , , , , , , , ,
FALLS RIVER	H	BIG FALLS CR	-	BC	9600	0		0	9600	9600		PONDAGE	248.0	1930	P , , , , , , , ,
FORT NELSON	IC	FORT NELSON		BC	4161	0		0	4161	4161				1960	P , , , , , , , ,
GEORGIA 5/	GT	CHEMAINUS		BC	75500	0		0	75500	72000				SEP , 1957	P , , , , , , , ,
GOLDEN 5/	IC-GT	GOLDEN		BC	8000	0		0	8000	8000				1968	P , , , , , , , ,
GORDON M. SHRUM 5/	H	PEACE	814.0	BC	1816000	227000	POT.	227000	2270000	2610000	2200.0	34300000	550.0	SEPT 1968	P , , , , ,PS, , ,
HAZELTON 5/	IC	HAZELTON		BC	3150	0		0	3150	3150				1965	P , , , , , , , ,
JOHN HART 5/	H	CAMPBELL	3.0	BC	120000	0		0	120000	124500	458.0	2300	405.0	DEC 15, 1947	P , , , , , , , ,
JORDAN RIVER 5/	H	JORDAN	2.2	BC	150000	0		0	150000	150000			870.0	DEC 13, 1971	P , , , , , , , ,
KOKISH RIVER	H	KOKISH		BC	0	0	LIC.R.	37000	37000	37000		PONDAGE			P , , , , , , , ,
KOOTENAY CANAL	H	KOOTENAY CANAL	13.3	BC		500000		0	500000	500000	1745.3	817000SHARED	272.0	SCHED 1975	P , , , , , , , ,
LADORE FALLS 5/	H	CAMPBELL	8.0	BC	54000	0		0	54000	51800	585.0	250512	127.0	DEC , 1956	P , , , , ,PS, , ,
LA JOIE 5/	H	BRIDGE		BC	22000	0		0	22000	24500	2460.0	587702	176.0	DEC 20, 1957	P , , , , ,PS, , ,
LAKE BUNTZEN NO 1 5/	H	BURRARD INLET		BC	50000	0		0	50000	55000	397.0	} 183471	397.0	1903	P , , , , , , , ,
LAKE BUNTZEN NO 2 5/	H	BURRARD INLET		BC	26700	0		0	26700	27000	397.0	}	397.0	1913	P , , , , , , , ,
MASSET	IC	MASSET		BC	4950	0		0	4950	4950				1969	P , , , , , , , ,
MCBRIDE	IC	MCBRIDE		BC	3400	0		0	3400	3400				1951	P , , , , , , , ,
MICA	H	COLUMBIA	1018.1	BC	0	1740000	LIC.	870000	2610000	2610000	2475.0	11685000	570.0	1976	P , , , ,FC,PS, , ,
MICA CREEK	IC	MICA	1018.0	BC	11175	0		0	11175	11175				1965	P , , , , , , , ,
MOBILE	IC			BC	3000	0		0	3000	3000					P , , , , , , , ,
MORAN	H	FRASER	228.0	BC	0	0	PER.R.	682000	682000	682000	1533.0	9500000	730.0		P , , ,N ,FC, , , ,
MURPHY CREEK	H	COLUMBIA	760.0	BC	0	0	LIC.R.	300000	300000	300000	1402.0	PONDAGE	62.0		P , , , ,FC,PS, , ,
PORT HARDY	IC	PORT HARDY		BC	5200	0		0	} 91200	91200				1960	P , , , , , , , ,
PORT HARDY	GT	PORT HARDY		BC	5000	40500	POT.	40500	}					1969	P , , , , , , , ,
PORT MANN 5/	GT	PORT MANN		BC	100000	0		0	100000	100000				SEP 1, 1959	P , , , , , , , ,
PRINCE RUPERT	GT	PRINCE RUPERT		BC	0	57240		0	57240	57240				SCHED 1973	P , , , , , , , ,
PUNTLEDGE 5/	H	PUNTLEDGE		BC	27000	0		0	27000	24500	444.0	68000	356.0	AUG 10, 1913	P , , , , , , , ,
PYRAMID MOUNTAIN	H	MURTLE		BC	0	0	POT.	96000	96000	96000					P , , , , , , , ,
REVELSTOKE 5/	IC	REVELSTOKE		BC	2000	500		0	2600	2500				1909	P , , , , , , , ,
REVELSTOKE CANYON	H	COLUMBIA R	934.0	BC	0	0	POT.	630000	630000	724500	1650.0	220000	196.0		P , , , , ,PS, , ,
RUSKIN 5/	H	STAVE	2.5	BC	105600	0		0	105600	104000	212.0	17000	128.0	OCT 14, 1930	P , , , , , , , ,
SANDSPIT	IC	SANDSPIT		BC	2700	0		0	2700	2700				1962	P , , , , , , , ,
SETON 5/	H	SETON		BC	42000	0		0	42000	42500	774.0	6000	166.0	AUG 20, 1956	P , , , , , , , ,
SHUSWAP FALLS 5/	H	SHUSWAP		BC	5200	0		0	5200	5700		125000	80.0	1929	P , , , , , , , ,
SMITHERS 5/	IC	SMITHERS		BC	6880	0		0	6880	6880				1951	P , , , , , , , ,
SPILLIMACHEEN 5/	H	SPILLIMACHEN	4.5	BC	4000	0		0	4000	4000	2837.0	PONDAGE	230.0	APR [illegible], 1955	P , , , , , , , ,
STAMP RIVER	H	STAMP		BC	0	0	LIC.R.	26000	26000	26000	329.0	423000	165.0		P , , , , , , , ,
STAVE FALLS 5/	H	STAVE	6.0	BC	52500	0		0	52500	57000	341.3	489912	129.3	1911	P , , , , , , , ,
STEWART	IC	STEWART		BC	2611	0		0	2611	2611				1965	P , , , , , , , ,
STRATHCONA 5/	H	CAMPBELL	23.0	BC	67500	0		0	67500	67500	727.0	809256	142.0	JUL 9, 1958	P , , , , ,PS, , ,
VALEMOUNT	IC	VALEMOUNT		BC	3550	0		0	3550	3550				1962	P , , , , , , , ,
WAHLEACH LAKE 5/	H	WAHLEACH CR		BC	60000	0		0	60000	63000	2105.0	51570	2035.0	DEC 6, 1952	P , , , , , , , ,
WALTER HARDMAN 5/	H	CRANBERRY CR	14.0	BC	8000	0		0	8000	8000	2245.0	11000	850.0	1960	P , , , , , , , ,
WHATSHAN 5/	H	WHATSHAN	5.0	BC	50000	0		0	50000	50000	2104.0	93000	660.0	1951	P , , , , ,PS, , ,
EDMONTON, CITY OF (ALBERTA)															
ROSEDALE	S GT	EDMONTON		ALBERTA	405000	0		0	405000	405000				1939	P , , , , , , , ,
CLOVER BAR	S	EDMONTON		ALBERTA	165000	165000			330000	330000				1970	P , , , , , , , ,
LETHBRIDGE, CITY OF (ALBERTA)															
LETHBRIDGE	S GT	LETHBRIDGE		ALBERTA	33375	0		0	33375	33375				1931	P , , , , , , , ,
MEDICINE HAT, CITY OF (ALBERTA)															
MEDICINE HAT	S	MEDICINE HAT		ALBERTA	38000	0		0	38000	39200				NOV , 1913	P , , , , , , , ,
NELSON, CITY OF (BRITISH COLUMBIA)															
BONNINGTON FALLS	H	KOOTENAY	14.8	BC	8670	0		0	8670	8670	1682.7	PONDAGE	72.0	DEC 28, 1906	P , , , , , , , ,

APPENDIX B
NAMEPLATE RATINGS FOR ELECTRIC POWER PLANTS IN THE PACIFIC NORTHWEST AND ADJACENT AREAS
(December 31, 1972)

		LOCATION			NAM PLATE RATING - KILOWATTS										
GROUP OWNERSHIP PROJECT	TYPE 1/	STREAM(IF H) CITY(IF FUEL)	MILE ABOVE MOUTH	PROVINCE	EXISTING	UNDER CONST	UNDER CONSIDERATION STATUS 2/		TOTAL	PEAKING CAPABILITY (KILOWATTS)	NORMAL POOL ELEV (FT)	USABLE STORAGE (ACRE FT)	GROSS HEAD (FT)	INITIAL DATE INSERVICE,	PURPOSE 3/
PRIVATE UTILITIES															
ALUMINUM LIMITED OF CANADA															
KEMANO	H	KEMANO		BC	812800	0		0	812800	934400	2800.0	4000000	2500.0	JUL 17, 1954	P
KENNY DIVERSION	H	NECHAKO		BC	STORAGE	0		0	0	0	2800.0			1954	PS
KITIMAT	IC	KITIMAT		BC	5000	0		0	5000	5000				1962	P
BAMFIELD POWER AND LIGHT CO.															
BAMFIELD	IC	BAMFIELD		BC	250	0		0	250	250				1962	P
CALGARY POWER, LTD.															
BARRIER	H	KANANASKIS	6.0	ALBERTA	9560	0		0	9560	13000	4515.0	20000	151.0	1947	P
BEARSPAW	H	BOW	237.0	ALBERTA	15300	0		0	15300	17000		200002	48.0	NOV , 1954	P
BIG BEND	H	BRAZEAU	3.0	ALBERTA	305500	0		0	324940	324940		900000	386.0	1965	P
BIG BEND	PG	BRAZEAU	14.9	ALBERTA	19440	0		0						1965	P
BIG HORN (ALTA. GOVT.)	JH	N. SASKATCHEWAN		ALBERTA	108000	0		0	108000	108000			245.0	1972	P
CANYON DIVERSION	H	SPRAY	23.0	ALBERTA	STORAGE	0		0	0	0	5583.0	160000	165.0	1951	PS
CASCADE	H	CASCADE	8.0	ALBERTA	34000	0		0	34000	36000		100000	320.0	1942	P
GHOST	H	BOW	262.0	ALBERTA	46650	0		0	46650	51000	3910.0	73000	105.0	1929	P
GHOST RIVER DIV	H	GHOST	30.0	ALBERTA	DIVERSION	0		0	0	0		0		1954	PS
HORSESHOE	H	BOW	280.0	ALBERTA	18000	0		0	18000	18000	4126.0	PONDAGE	75.0	MAY , 1911	P
INTERLAKES	H	KANANASKIS		ALBERTA	5040	0		0	5040	5000		100000	100.0	1955	P PS
KANANASKIS	H	BOW	282.0	ALBERTA	16360	0		0	16360	19000	4200.0	PONDAGE	74.0	1913	P
POCATERRA	H	KANANASKIS		ALBERTA	13500	0		0	13500	15000		20000	226.0	1955	P
RUNDLE	H	RUNDLE CANAL	0.3	ALBERTA	46750	0		0	46750	47000	4615.0	PONDAGE	318.0	1951	P
RUSSELL	H	BOW	272.0	ALBERTA	0	0	POT.	75000	75000	75000	4050.0	78000	140.0		P
SPRAY	H	GOAT V CANAL		ALBERTA	80800	0		0	80860	80800	5520.0	PONDAGE	905.0	1951	P
SUNDANCE	S	WABAMUM		ALBERTA	286000	286000	LIC.R.	750000	1322000	1350000				1970	P
THREE SISTERS	H	SPRAY	8.0	ALBERTA	3400	0		0	3400	3400	5583.0	160000	63.0	1951	P
WABAMUM	S	WABAMUM		ALBERTA	582000	0		0	582000	594000				1956	P
ALBERTA POWER, LTD. (FORMERLY CANADIAN UTILITIES, LTD.)															
BATTLE RIVER	S	STETTLER		ALBERTA	216800	0	POT.	1500000	366000	366000				NOV. 1956	P
DRUMHELLER	S	DRUMHELLER		ALBERTA	17500	0		0	17500	17500				1948	P
FORT MCMURRAY	IC	FORT MCMURRAY		ALBERTA	10050	0		0	10050	10050				1951	P
H.R. MILNER	S	GRANDE CACHE		ALBERTA	140000	0		0	140000	140000				1972	P
RAINBOW LAKE	GT	RAINBOW LAKE		ALBERTA	58000	0		0	58000	58000				1968	P
SIMONETTE	GT	CLEAR HILLS		ALBERTA	20000	0		0	20000	20000				OCT 1966	P
STURGEON	GT	VALLEY VIEW		ALBERTA	18500	0		0	18500	18500				1958	P
VERMILION	S	VERMILION		ALBERTA	5000	0		0	9000	9000				1948	P
ELK FALLS CO., LTD.															
ELK FALLS	S	CAMPBELL RIVER		BC	4025	0		0	4025	4025				1964	P
NORTH WESTERN PULP & POWER, LTD.															
HINTON	S	HINTON		ALBERTA	21760	0		0	23860	23860				1956	P
HINTON	IC	HINTON		ALBERTA	2100	0		0						1957	P
NORTHLAND UTILITIES, LTD.															
FAIRVIEW	IC	FAIRVIEW		ALBERTA	6000	0		0	6000	6000				1954	P
JASPER	IC	JASPER		ALBERTA	4525	0		0	4525	4525				1941	P
WEST KOOTENAY POWER AND LIGHT CO.															
CRESTON	IC	CRESTON		BC	300	0		0	300	300				1954	P
ERICKSON	H	GOAT	7.7	BC	1280	0		0	1280	1280		PONDAGE	65.0	1933	P
LOWER BONNINGTON	H	KOOTENAY	14.3	BC	47250	0		0	47250	42300	1610.7	PONDAGE	66.8	1899	P
CONSOLIDATED MINING AND SMELTING CO.															
BRILLIANT	H	KOOTENAY	1.9	BC	108800	0		0	108800	125000	1467.7	PONDAGE	90.0	1944	P
CORRA LINN	H	KOOTENAY	16.1	BC	40500	0		0	40500	48000	1745.3	817000 SHARED	62.6	1932	P FC,PS
KIMBERLEY	S	KIMBERLEY		BC	4500	0		0	4500	4500				1927	P
SEVEN MILE CREEK	H	PEND OREILLE	6.0	BC	0	0	POT.	372000	372000	428000	1714.0	PONDAGE	198.0	SCHED 1977	P
SOUTH SLOCAN	H	KOOTENAY	13.4	BC	47250	0		0	47250	54000	1540.7	PONDAGE	73.0	1928	P
UPPER BONNINGTON	H	KOOTENAY	14.8	BC	55124	0		0	55124	60000	1682.7	PONDAGE	72.0	1907	P
WANETA	H	PEND OREILLE	0.5	BC	292500	0		0	292500	375000	1516.0	3370	210.0	MAR 15, 1954	P
WESTERN CHEMICALS, LTD.															
TWO HILLS	S	DUVERNAY		ALBERTA	2100	0		0	13537	13537				1953	P
TWO HILLS	IC	DUVERNAY		ALBERTA	3000	0		0						1958	P
TWO HILLS	GT	DUVERNAY		ALBERTA	8437	0		0						1958	P

1/ H = HYDRO, PG = PUMP-GENERATOR, S = STEAM, IC = INTERNAL COMBUSTION, GT = GAS TURBINE, GO = GEOTHERMAL, N = NUCLEAR, J = JOINTLY OWNED, A = ALTERNATIVE PROJECT AND CONFLICTS WITH ANOTHER PROJECT SHOWN.

2/ AUTH. = AUTHORIZED FOR FEDERAL CONSTRUCTION, REC. = RECOMMENDED FOR CONSTRUCTION BY THE FEDERAL CONSTRUCTION AGENCY, POT. = POTENTIAL, LIC. = LICENSE GRANTED BY FPC, LIC.R. = LICENSE REQUESTED OF FPC, PER. = PRELIMINARY PERMIT GRANTED BY FPC, PER.R. = PRELIMINARY PERMIT REQUESTED OF FPC.

3/ P = POWER, R = RECREATION, I = IRRIGATION, N = NAVIGATION, FC = FLOOD CONTROL, PS = POWER STORAGE, RR = REREGULATING RESERVOIR, M = MUNICIPAL WATER SUPPLY, WQ = WATER QUALITY.

4/ FEDERAL COLUMBIA RIVER POWER SYSTEM PROJECT EXISTING, UNDER CONSTRUCTION OR AUTHORIZED.

5/ BRITISH COLUMBIA HYDRO AND POWER AUTHORITY INTERCONNECTED SYSTEM PROJECT.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BPA - BRANCH OF POWER RESOURCES
DECEMBER 31, 1972