Geology of Proposed Powersites at Deer Lake and Kasnyku Lake Baranof Island Southeastern Alaska

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GEOLOGY OF WATERPOWER SITES IN ALASKA

GEOLOGICAL SURVEY BULLETIN 1211-C

*A geologic feasibility study of
two proposed powersites on
Baranof Island, Alaska*

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGY OF PROPOSED POWERSITES AT DEER LAKE AND KASNYKU LAKE, BARANOF ISLAND, SOUTHEASTERN ALASKA

By Alexander A. Wanek and James E. Callahan

ABSTRACT

The proposed powersites are on the east side of Baranof Island, southeastern Alaska. One powersite is at Kasnyku Lake in the northern part of Baranof Island, 20 miles northeast of Sitka; the other is at Deer Lake in the southern part of Baranof Island, 48 miles south of Kasnyku Lake. The region is rugged, mountainous, and extremely glaciated and lies within the Chilkat–Baranof Mountains section of the Pacific Border Ranges province. Few roads or trails exist, and most of the interior of Baranof Island is accessible only by float plane, helicopter, or foot travel. The climate is mild and wet, characteristic of southeastern Alaska. The snow cover is gone from lower altitudes by June and from higher altitudes by August. Hemlock, spruce, and cedar grow in dense stands, and alder, devilsclub, and berry bushes form thick undergrowths on alluvial fans and landslide areas.

The rocks of Chichagof and Baranof Islands lie in broad belts that strike northwest and conform with the structural trend of southeastern Alaska. Southern Baranof Island is underlain by metamorphic rocks of Triassic to Cretaceous age that are intruded by dioritic rocks believed to be satellite to the Coast Range batholith on the mainland. Northern Baranof Island is underlain by metamorphosed sedimentary rocks that range from probably Paleozoic to Cretaceous age. These rocks form two broad structural features, a northwest-trending anticlinorium flanked by a north-northwest-tending synclinorium. The metamorphosed sedimentary rocks are intruded by igneous rock that ranges in composition from diorite to quartz diorite. The northeast and northwest sides of northern Baranof Island are bound by northwest-trending lineaments that are probably traces of major faults. Many of the conspicuous linear features on Baranof Island are believed to be along prominent joint systems. No evidence of faulting was found at the powersites.

Deer Lake is at the altitude of 374 feet and is 876 feet deep. It occupies a narrow basin gouged in bedrock by a large valley glacier. The powersite is underlain by competent metamorphosed graywacke of Jurassic and Cretaceous age which is suitable as a foundation for the construction of a concrete gravity-type dam or earthfill-type dam about 40 feet high and 400 feet long. The tunnel route, which is about 1,500 feet long, is underlain by competent bedrock, and the tunnel would not require lining except where it crosses major joints. Unconsolidated ma-

terials, chiefly talus deposits, can be crushed for use as concrete aggregate. Deposits of sand and gravel are not available. The waterpower development of Deer Lake would be best accomplished by the construction of a dam to raise the lake level and by a drawdown below normal lake level for maximum power capacity.

Kasnyku Lake is at the altitude of 595 feet and is 393 feet deep. It occupies a bifurcate basin gouged out by glacial ice. The drainage basin is small, and proposed waterpower development could be best accomplished by the construction of a dam to raise the lake level 100 feet and by a drawdown below normal lake level. The powersite area is underlain by competent quartz diorite that could support a concrete gravity-type dam. The channel section and abutments in the damsite are covered by coalescing talus deposits as much as 60 feet thick. The fill must be excavated to bedrock to give adequate support for the dam foundation. The talus is too permeable to be grouted. A tunnel route 4,300 feet long from Kasnyku Lake to Ell Cove is underlain by competent biotite diorite over most of its length. Concrete lining will not be necessary except where the conduit crosses a major joint set. If the damsite is not suitable for a dam because of the depth and the permeability of the talus in the channel section, the possibility of regulating the storage capacity of Kasnyku Lake by drawdown alone should not be eliminated.

INTRODUCTION

This report is based on reconnaissance geologic investigations of proposed powersites at Deer Lake and Kasnyku Lake on the east side of Baranof Island. The sites were examined during the summer of 1964 at the request of the Branch of Waterpower Classification, Conservation Division, to furnish geologic information for use in evaluating some of the waterpower resources of southeastern Alaska. Fieldwork included geologic mapping of the proposed damsites at the outlets of Deer Lake and Kasnyku Lake, the reservoir areas, and the possible tunnel routes from the damsites to the powerhouse sites. The damsite locations are accessible by fixed-wing float aircraft and can also be reached on foot.

The field investigations were made in June and July 1964. The authors acknowledge the logistic support provided by J. B. Dugwyler, Jr., hydraulic engineer, U.S. Geological Survey.

GEOGRAPHY

The areas investigated are widely separated on the east coast of Baranof Island, southeastern Alaska. Kasnyku Lake lies 20 miles northeast of Sitka, in the northern part of the island, and is about 48 miles due north of Deer Lake (fig. 1). Baranof Island, one of the larger outer islands in the Alexander Archipelago, lies approximately between lat 56° 00′ and 58° 00′ N. and long 134° 00′ and 136° 00′ W., and is separated from Admiralty Island to the east by Chatham Strait and from Chichagof Island to the north by Peril Strait. Baranof Island is about 100 miles long and has a maximum width of about 25 miles. The island is rugged and mountainous and is within the Chilkat–Baranof
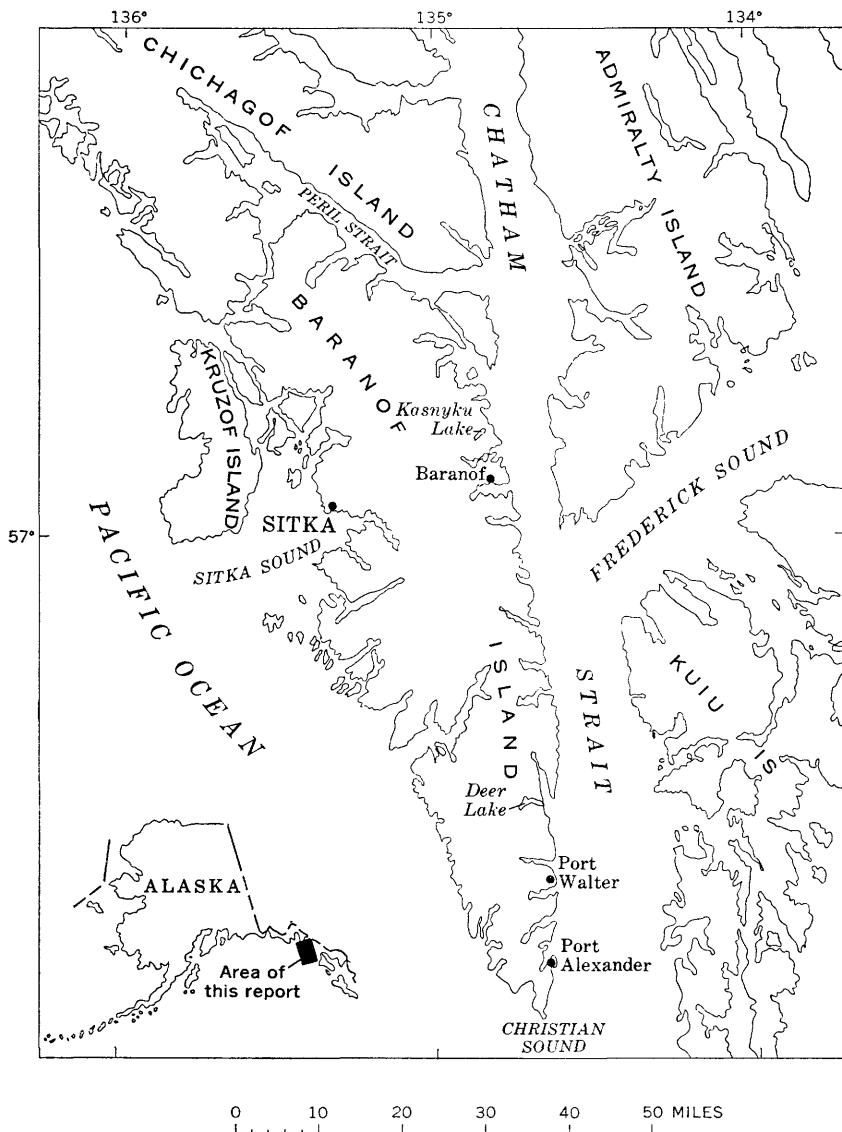
FIGURE 1.—Location of Deer and Kasnyku Lakes, southeastern Alaska.

Mountains section of the Pacific Border Ranges province (Wahrhaftig, 1965). Few roads or trails exist, and the interior of Baranof Island is mainly accessible by float plane.

Transportation to Baranof Island is by airplane or boat. Commercial airlines have scheduled flights to Sitka and charter flights to other points on the island. Air-charter service is also available from air-taxi

operators based at Juneau, Ketchikan, and Petersburg. The State of Alaska ferry system provides weekly transportation between Sitka and other points in southeastern Alaska. Most inlets and bays provide good anchorage for boats; however, strong tidal currents make entry hazardous at times other than slack water.

The population of Baranof Island is small and chiefly concentrated along the coastline. Sitka, which is on the west side of the island, is the largest city; it has a population of about 7,000. Small settlements such as Port Alexander, Port Walter, and Baranof are fishing centers.

TOPOGRAPHY AND DRAINAGE

Baranof Island is rugged and mountainous, and high relief between valley floors and adjacent ridges is characteristic of the area. The altitude of the land surface is generally less than 4,000 feet, but in the interior southwest of the town of Baranof, some peaks rise above 5,000 feet. The slopes are precipitous, and the summit areas are small and jagged—typical of glaciated areas. At higher altitudes snowfields and valley glaciers are fairly common.

The indented coastline and the deep lake-filled valleys of Baranof Island show a strikingly similar and parallel linear orientation that appears to reflect a well-developed northeast-trending system of joints. A less well defined northwest-trending system of joints, foliation, and, locally, faulting has influenced the development of some linear features along the east coast (Brew and others, 1963).

CLIMATE AND VEGETATION

Baranof Island has a mild and wet climate which is characteristic of southeastern Alaska. The summers are cool and have heavy precipitation; the winters are generally mild, and snowfall is heavy. June is one of the drier months, and the amount of precipitation increases progressively to reach a peak in October. According to the weather records kept over a period of 16 years (1936–52) at Little Port Walter in the southern part of Baranof Island, the annual precipitation averaged about 222.47 inches (U.S. Weather Bureau, 1958). This area receives the heaviest precipitation on Baranof Island. According to weather records kept over a period of 30 years (1922–52), the average annual precipitation at Sitka is about 96.30 inches (U.S. Weather Bureau, 1958). At Baranof for the period 1936–52 the annual precipitation averaged about 151.68 inches. The mean annual minimum and maximum temperatures at Little Port Walter from 1936–52 were 38.3° F and 48.0° F, respectively; mean minimum and maximum temperatures for July were 48.9° F and 60.8° F, respectively. Over the same

period the mean annual minimum and maximum temperatures at Baranof were 35.8° F and 47.3° F, respectively.

For the period 1922–52 the mean annual snowfall for Baranof was 211.0 inches; the greatest amount occurs during December, January, and February (U.S. Weather Bureau, 1958). The snow cover is generally gone by June at lower altitudes, and by August most of the ridges are free from snow. Lakes in deep basins are usually covered by ice until mid-July. Some lakes at higher altitudes are not free from ice until mid-August.

A heavy growth of vegetation covers much of the area. Hemlock, spruce, and cedar are the most abundant of the conifers and usually grow in dense stands. Alder, devilsclub, and berry bushes form thick undergrowth on alluvial fans and in landslide areas. Small peat bogs are in undrained depressions on bedrock. Timberline is generally about 2,000 feet, and above this altitude the bedrock is covered by a growth of grass, lichen, and heather. The entire island is part of the Tongass National Forest.

PREVIOUS INVESTIGATIONS

The earliest reconnaissance geologic studies of Baranof Island were made in 1895 and 1896 by Becker (1898, p. 78–80), who examined the geology near Sitka and described the gold mining in Silver Bay. The first general geologic investigation was made by Wright and Wright (1905) from Taku Inlet to Sitka by way of Peril Strait, where they studied the geology of Silver Bay and the west coast of Baranof Island. In 1903, 1904, and 1905 the Wrights studied the geology along the east coast of Baranof Island and around Chichagof Island. The regional geology from Peril Strait to Silver Bay and the mineral deposits of the Sitka mining district were described by Knopf (1912). Waring (1917) described the chemical analysis of water from the hot springs at Baranof. Buddington and Chapin (1929) investigated the power potential and possible waterpower development of the lakes in southeastern Alaska. The waterpower sites are described in a report to the Federal Power Commission and U.S. Forest Service (1947). Loney, Pomeroy, Brew, and Muffler (1964) made a reconnaissance geologic study of Baranof Island and prepared maps based on the results of their investigations and the previous investigations of other geologists. Berg and Hinckley (1963) made detailed examinations of the geology along the shore of northern Baranof Island.

PRESENT INVESTIGATIONS

The present investigations consisted of field examinations of the proposed damsites and reservoir areas at Deer Lake and Kasnyku

Lake. Traverses were made along possible tunnel routes and also at a powerhouse site at Mist Cove. The powerhouse site at Ell Cove near Kasnyku Lake was not examined on the ground. The geologic mapping was done on aerial photographs and on river survey topographic maps. Deer Lake and Kasnyku Lake are shown on the U.S. Geological Survey Port Alexander and Sitka 1 : 250,000-scale reconnaissance topographic maps and the Port Alexander (C–3, B–3 and B–4) and Sitka (A–3) 1 : 63,360-scale topographic quadrangle maps. The damsites are also shown on the Deer Lake and Kasnyku Lake 1 : 24,000- and 1 : 2,400-scale river-survey maps. The areas are included in the U.S. Navy aerial photographs SEA 127–141 through 143, SEA 132–56 through 58, and SEA 132–78 through 80, taken August 1948, scale approximately 1 : 40,000 at sea level. Aerial photographs were also used to determine the general structural features in the map area and the adjacent areas. Many observations were made at the abutments of the damsites, and samples of the bedrock were taken for petrographic and chemical analyses. A two-man rubber boat was used in the geologic mapping along the shores of the lakes.

REGIONAL GEOLOGY

The areas in this investigation are included in the general description of the geology of Baranof Island by Knopf (1912). According to Knopf, the rocks of Chichagof and Baranof Islands lie in broad belts that strike northwest and conform with the prevailing structural trend of southeastern Alaska. The core of Baranof Island consists largely of Jurassic and Cretaceous granitoid rocks, mainly quartz diorites, which are generally intruded parallel to the stratified rocks. Loney, Pomeroy, Brew, and Muffler (1964) in recent investigations found that southern Baranof Island is underlain by metamorphic rocks of Triassic to Cretaceous age that are intruded by igneous masses believed to be satellite to the Coast Range batholith on the mainland. Berg and Hinckley (1963) suggested that the metamorphosed sedimentary rocks of northern Baranof Island and adjacent small islands form two broad structural features, chiefly an anticlinorium that trends north-northwest through Katlian Bay and Fish Bay, and a synclinorium that trends north-northwest through Point Benham and Saook Bay. Metamorphic rocks of probable Paleozoic age form the core of the anticlinorium, which is flanked on the southwest by metamorphosed sedimentary rocks of the Kelp Bay Group of Triassic or Jurassic age that also form the southwestern part of the synclinorium. The intrusive igneous rocks of Jurassic and Cretaceous age in the northern part of Baranof Island are generally gray medium-grained granitoid rocks which range in composition from quartz diorite to granodiorite and diorite.

The northeast and southwest sides of northern Baranof Island are bound by two great northwest-trending lineaments that are probably the traces of major faults (Twenhofel and Sainsbury, 1958; Loney and others, 1963). The lineaments are developed along zones of intense crushing that are as much as 1 mile wide. A major lineament trends along Peril Strait and appears to branch off the Chatham Strait lineament, an inferred fault which extends for 250 miles along Chatham Strait and Lynn Canal (Wright and Wright, 1908; Martin and Williams, 1924). The Chatham Strait lineament is a split, or extension, of the Denali lineament, a great arcuate fault that extends for 1,600 miles from Lynn Canal to Bristol Bay (St. Amand, 1957).

Many northeast-trending lineations were mapped on southern Baranof Island by Loney, Pomeroy, Brew, and Muffler (1964). With the exception of the Big Branch Bay fault along the southwest coast, joints are believed to control the trend of these linear features (Brew and others, 1963). At this locality the existence of a fault is inferred from the offset of geologic contacts across Big Branch Bay.

GLACIATION

Baranof Island was intensely glaciated during Pleistocene time. The ice sheet covered the island to an altitude of about 3,000 feet, as shown by glacial smoothing and rounding of valleys and ridges. Above this altitude many peaks are serrated and precipitous, in contrast to other areas once covered by the ice sheet. Some of the high valleys still contain remnants of valley glaciers.

The basin of Deer Lake was occupied by a large valley glacier that flowed east to Chatham Strait. The ice gouged more deeply into bedrock at the head of the valley than in the lower part and cut two deep basins which extend below sea level. The steep gradient of the ice flowing from the summit area probably resulted in the plucking and scouring of bedrock in the lower and less steep valley floor. A convection, or churning flow, of the ice mass may have occurred at these localities where the joint sets and foliation in bedrock provided surfaces that eroded easily. The configuration of the lake bottom indicates that such ice action could have formed the two deep basins in Deer Lake. The lake is impounded behind a transverse ridge or rock lip which separates it from Chatham Strait.

Some postglacial change in sea level is evident at Mist Cove. The U-shaped valley of Deer Lake becomes V-shaped at its mouth at the approximate altitude of 270 feet. This modification of the former glacial valley suggests some adjustment of the land surface to sea level. More recent evidence of this change in sea level is the low wave-cut rock terrace that is present along the coastline.

The Kasnyku Lake basin also shows some evidence of isostatic uplift. The drainage basin is bifurcate. The precipitous walls show much ice scour and smoothing. However, a short distance east of the lake outlet, the U-shaped character of the valley is modified by postglacial erosion. The canyon becomes V-shaped and drops at steep gradient to sea level. The upper part of the canyon is filled with large talus blocks to an undetermined depth, and the stream from Kasnyku Lake flows underground from the outlet to a small pond nearly 0.3 mile downstream. In the lower part of the canyon, the stream plunges in spectacular falls to sea level.

It appears that the most pronounced glacial erosion was due to the great Cordilleran ice sheet which in Pleistocene time probably flowed from centers north and northeast of Baranof Island and from local centers on Baranof Island (Coulter and others, 1965). Locally, alpine-type glaciation in Wisconsin and Recent time resulted in the present sculpturing of the landscape. Many of the cirques lie below the level of the immense ice sheet which once covered the island. Postglacial changes in the former land level are also evident—U-shaped valleys become V-shaped at their mouths. Streams emptying from these valleys cut deep canyons and often plunge in spectacular falls to sea level. Reed and Coats (1941) noted that many glacial valleys are V-shaped at their mouths on northwest Chichagof Island and postulated a former lower land or higher sea level of at least 300 feet on the west side of the island.

EARTHQUAKE HISTORY

The damsites are in seismically active areas. They are near major faults or lineaments, such as the Peril Strait fault or the Chatham Strait fault, that have been active since the Tertiary Period. Between 1843 and 1956, 18 earthquakes that had an estimated intensity of 5 or more on the modified Mercalli scale (Heck, 1958) were reported in southeastern Alaska. The Chatham Strait fault is believed to be a split off the Denali fault, a great arcuate fault along which the epicenters of many earthquakes have been recorded (St. Amand, 1957). The presence of active faults within areas of recorded seismic activity makes it imperative that the location of dams and appurtenant works be chosen carefully. All structures must be designed for adequate protection against earthquakes and possible tsunamis.

DEER LAKE POWERSITE

WATERPOWER DEVELOPMENT

The general plans for waterpower development in this area were described in the report by the Federal Power Commission and U.S. Forest Service (1947). According to Dort (1924), the drainage area of the Deer Lake basin is estimated at 7.8 square miles. The surface area of Deer Lake is estimated to be 969 acres and that of the upper lake is estimated to be 139 acres. The average discharge at the Deer Lake outlet measured from October 1921 to July 11, 1922, was estimated at 150 cubic feet per second and measured over another period, 1951–60, was 156 cubic feet per second (U.S. Geological Survey, 1962). The complete regulation of Deer Lake would require a storage capacity of 65,000 acre-feet, for which the power capacity is estimated at about 3,800 kilowatts. Dort postulated that the water could be conveyed in a conduit 1,500 feet long that included 1,000 feet of tunnel and a 500-foot penstock from the dam to a powerhouse at Mist Cove near the falls. The gross effective head at normal lake level is estimated to be 374 feet.

Water storage could be accomplished by construction of a dam at the outlet of Deer Lake to raise the lake surface above its natural level, by drawing the lake surface below its natural level, or by a combination of the two methods. The report by the Federal Power Commission and U.S. Forest Service (1947) estimated that a dam 40 feet high at the outlet and having a crest 230 feet long would give the required storage of 65,000 acre-feet. Recent investigations indicated, however, that a dam of this height would require a crest 320 feet long for the required storage.

Development by building a dam to raise the lake level would, therefore, result in a head and a consequent power capacity greater than development based on drawdown alone and would provide a fuller use of a potential resource (Johnson, 1963). Actual development must be based on the most favorable economic factors.

TOPOGRAPHY

Deer Lake, in the southern part of Baranof Island, occupies a narrow northeast-trending basin which has been carved in the rugged coastal mountains by the glacial ice. The valley is U-shaped and has steep slopes that rise to an altitude of more than 3,000 feet at the west end. The drainage area is about 5 miles long and nearly 2 miles wide and includes several lakes in cirques that feed streams flowing into Deer Lake. Runoff also occurs from the short tributary streams that fall precipitously from the divide areas to valley level.

Deer Lake is at the altitude of 374 feet and is 3.2 miles long and 0.7 mile wide. Soundings made in Deer Lake by the U.S. Geological Survey indicate that the lake bottom is formed by two deep basins separated by a transverse submerged ridge. The west basin is 876 feet deep, and the bottom is 502 feet below sea level; the east basin is 598 feet deep, and the bottom is 224 feet below sea level.

Southeast of the outlet at Deer Lake, two saddles, or notches, are cut through the ridge about 50 feet above the present water surface. These notches were probably cut by melt water from the glacier which once occupied the basin or by drainage from a former lake which had filled the basin to this altitude. The saddles were eroded along the major joints that cut the bedrock.

Deer Creek flows from the outlet of Deer Lake southeast through a shallow valley. The valley floor is hummocky where the bedrock has been scoured by ice. Some places are poorly drained and contain thin deposits of peat and soil; depressions contain ponds which are rapidly filling in. The valley terminates at the rim of a northeast-trending canyon that is cut by Deer Creek along a major fracture. The stream plunges in spectacular falls into the canyon that strikes normal to the trend of the upper valley and then flows at high gradient to Mist Cove.

A wave-cut terrace or bench is everywhere present along the coastline in Mist Cove. This former higher shoreline is approximately 10 feet above the present high-water line and indicates a former lower land surface or a higher sea level. No marine deposits of Quaternary age were observed on this terrace in Mist Cove.

GEOLOGY

BEDROCK

The basin of Deer Lake is underlain by competent bedrock which is classified as lineated and schistose graywacke of Jurassic and Cretaceous age (Loney and others, 1964; pl. 1). The sequence of metamorphosed sedimentary rocks consists of thin-bedded to massive fine- to medium-grained dark-gray to dark-brown graywacke intercalated with interbeds of argillite. The rocks are hard and very siliceous and break with a hackly fracture. They are cut by many joint sets and show well-defined foliation. Stringers and lenses of quartz occur in the graywacke generally along foliation or joint sets.

Bedding is usually even, rhythmic, and very persistent and generally ranges in thickness from 1 to 6 feet. Some individual beds in the massive metamorphosed graywacke are as much as 40 feet thick and locally alternate with shaly metamorphosed graywacke or argillite that is thin bedded. At Mist Cove the outcrops in the wave-cut

terrace consist of thin alternating beds of fine-grained metamorphosed graywacke and argillite. The hard siliceous graywacke resists weathering more readily than the argillite; consequently, the eroded bedrock appears fluted or corrugated. The rocks are generally dark gray and brownish gray, but some of the more massive graywacke beds weather light gray.

The graywacke is composed of grains that range in diameter from about 1 to 2 mm in the coarser grained beds. Quartz, feldspar, biotite, chert, chlorite, and rock fragments are most abundant; magnetite, pyrite, and epidote make up less than 1 percent. The groundmass consists chiefly of quartz, clay, chlorite, and fine rock detritus.

At most localities the foliation in the metamorphosed graywacke appears parallel to the bedding. In the shaly graywacke the grains are oriented with the long axis parallel to the foliation, but in the massive coarser grained graywacke the parallelism is less pronounced. The low-grade metamorphic rocks show some lineation or schistosity. Loney, Pomeroy, Brew, and Muffler (1964) believe that the rocks are lineated and are semischistose graywacke derived by dynamothermal metamorphism of the Sitka Graywacke of Jurassic and Cretaceous age. At Deer Lake the lowest grade rocks are epidote-muscovite-albite quartz schistose rocks. The presence of younger biotite in the schistose rocks indicates subsequent slight thermal metamorphism (Loney and others, 1964).

UNCONSOLIDATED DEPOSITS

All streams that are tributary to Deer Lake flow in precipitous courses from the divide areas and carry very little sediment. In many localities along the shore, small alluvial cones of coarse detritus form at the base of rock chutes or at stream entrances into the lake. The deposits are small and consist of boulders and rock fragments as much as 3 inches in diameter. At the west end of Deer Lake, some large landslide areas that are evident on the aerial photographs may furnish coarse aggregate for dam construction. Sand and gravel deposits are not present in the basin or along Mist Cove; such material must be manufactured or transported from other areas.

STRUCTURE

The principal zones of weakness are the Peril Strait lineament and the Chatham Strait fault (St. Amand, 1957). No evidence of faulting within the powersite was found. The low-grade metamorphic rock has been folded in steeply dipping beds. Foliation is well developed along a northwest direction, and the trend of foliation ranges from N. 15° to 35° W. and is vertical or nearly vertical. The major joint sets at the damsite strike northeast and dip steeply; most of the drain-

age appears oriented along this jointing. Brew, Loney, Pomeroy, and Muffler (1963) stated that because of isoclinal folding in the Sitka Graywacke, the foliation and the boundaries of lithographic units are almost everywhere parallel and that it is unlikely that a topographic feature controlled by the original unit would diverge appreciably from the strike of the foliation. The general fabric of the bedrock, however, indicates that the dominant joint set controlled the trend of the northeast-trending linear topographic features. Any divergence from this pattern may be due locally to the modifying influence of the foliation or other joint sets.

At the outlet of Deer Lake several joint sets cut the bedrock. The predominant joint sets strike N. 50°–85° E. and dip from 40° W. to vertical. Another major joint set strikes N. 75°–85° W. and is vertical. A minor joint set strikes N. 50° W. and dips 40° E. Lesser joint sets have attitudes that range from N. 30° to 40° W. with vertical dips to attitudes which are east-west and dip from 10° to 60° N. The attitudes of joint systems are shown on the geologic map (pl. 1). The foliation in the bedrock is conspicuous within the powersite area. The foliation strikes N. 20° E.–35° W. and is moderately steep to vertical. Some linear features such as reentrants in the cliffs above the shoreline are controlled by foliation. The foliation and joint sets appear tight in unweathered rock, and loss of water due to leakage may be negligible. Slickensides were noted at most localities; however, no crush zones were evident.

The west end of the Deer Lake basin was not examined by the field party. Careful examination of the aerial photographs indicates that graywacke is present and that the northeast-trending joint system controlled the development of the Deer Lake basin. All linear topographic features appear to be the result of erosion along major joint sets, local joints, or foliation. No faulting is evident.

DAMSITE

The damsite is 200 feet below the outlet of Deer Lake and just above the first rapids on Deer Creek. Both abutments and the channel section are underlain by low-grade metamorphic rocks which have been described as lineated and by schistose graywacke that contains interbedded argillite (Loney and others, 1964). The rocks show well-defined foliation, and they are cut by northeast-trending joints whose planar surfaces are encrusted with quartz.

The ground surface on both abutments rises sharply from lake level for about 20 feet and then slopes back at low gradient to rounded rock terraces that are covered by a thin mantle of soil and peat. The

left abutment rises gradually to the top of the ridge at an approximate altitude of 430 feet. The ridge trends northwest, and near the damsite it is cut by several small saddles above the altitude of 420 feet. Further west the ridge rises to an altitude of about 2,500 feet.

The right abutment flattens on a broad bench that is cut by small swales. From this bench the ground surface rises gradually in successively higher benches and culminates in a small peak at an altitude of about 510 feet. A deep, narrow southeast-trending saddle at an altitude of 424 feet separates the peak from the higher ground to the west. About 200 feet further west, another deep saddle at the altitude of 415 feet trends southwest through the drainage divide. The channel sections in the saddles are filled to an undetermined depth with large talus blocks from the adjacent canyon walls. Some of the talus blocks are as much as 4 feet in diameter.

The foundation and abutments are underlain by competent bedrock capable of supporting a dam 40 feet high with a crest length of 400 feet. The site is suitable for either a concrete gravity-type dam or an earthfill-type dam. A dam of greater height would require the construction of small auxiliary dams in the two deep saddles west of the right abutment which are at altitudes of about 425 feet and 415 feet, respectively. In these saddles the bedrock surface under the talus deposits probably would be below the raised level of the lake. Several core holes drilled at these localities are required to determine the profile of the foundation. The floor of the saddle can be excavated to bedrock and a small dam built to at least an altitude of 415 feet and with a crest length of 80 feet for the proper water-level regulation. Other saddles above the abutments could also serve as spillways, depending upon the height of the dam and the required reservoir capacity.

Most of the joints that cut bedrock are probably tight at depth and would not cause serious leakage. The major northeast-trending joint sets, however, may present a problem. These fractures appear to control the direction of topographic features such as the saddles and the deep canyon into which Deer Creek flows in spectacular falls, and at the damsite these joints may be open at depth and require grouting. Core drilling will be necessary to determine how deep those fractures extend and whether excessive leakage can be expected.

Slickensides are evidence of movement along some of the joints, but no large faults are present in the damsite area. The geologic map of the Deer Lake damsite and cross sections along the axes of the proposed damsite and auxiliary damsites are shown on plate 1.

RESERVOIR SITE

The reservoir area is underlain by competent graywacke. As stated, the field party did not examine the bedrock in the western part of the basin, but an air reconnaissance and careful examination of aerial photographs indicated that graywacke is probably present. Graywacke and argillite are exposed in almost continuous outcrops along the shoreline. The rock is siliceous and very resistant to erosion and rises in abrupt cliffs along the lake.

The reservoir trends northeast parallel to a predominant joint set. A major joint set strikes N. 50°–70° E. and dips from 70° E. to vertical. Another well-defined joint set strikes N. 50° W. and dips 60°–70° E. The strike of foliation in the bedrock ranges from N. 20° to 35° W., and the dip is nearly vertical. The systems of joints, or fractures, and foliation that cut the bedrock would not cause leakage from the reservoir. Most of the lineations observed in the basin are attributed to the systems of joints. No evidence of faulting was seen. The geology of the reservoir is shown on plate 1.

Because of the rugged terrain about the lake, landslide and talus deposits occur at the base of many of the steep slopes. Avalanche chutes are along some of the well-defined fractures. Locally, stream action or mass-gravity movement has concentrated fairly thick deposits of talus and rock detritus below the slide areas about the lake and in the upper lake basin. In general, most of the talus deposits in the basin are small, and the few streams which enter the lake have formed alluvial fans out on a steeply sloping lake bottom. The slide areas appear stable and should not cause any major problems if the lake level is raised by the construction of a dam. However, in the event of major earthquakes the alluvial-fan deposits could become subaqueous landslides and create waves which might be destructive.

The large cirque or hanging valley that contains the upper lake is connected to the western part of the Deer Lake basin by a narrow canyon. The upper lake is at the altitude of about 550 feet and is drained by a stream which drops precipitously to Deer Lake. The runoff of the upper lake as a recharge to Deer Lake is limited by the amount of melt water and precipitation.

TUNNEL ROUTE

The tunnel route could be located anywhere along the divide between Deer Lake and Mist Cove just north of the proposed damsite. The conduit would be all tunnel driven through rock similar lithologically to that already described at the damsite and in the reservoir. A major joint set that strikes northeast controls much of the drainage at this locality, and some lining in the tunnel might be required at places where

the conduit intersects these large fractures. The other joint systems are tight in the unweathered rocks. No evidence of faulting was observed at this locality.

Because the recharge area in Deer Lake is somewhat limited, a scheme based on raising the lake level by the construction of a dam and a drawdown below normal lake level would give maximum power capacity. The length of the tunnel would vary with the position of the intake and the mean head required. J. C. Dort (in Federal Power Commission and U.S. Forest Service, 1947) estimated a conduit length of 1,500 feet from the lake to a powerhouse site on Mist Cove. Under his plan a dam 40 feet high would raise the maximum water altitude of Deer Lake to 414 feet. If the conduit intake is 60 feet below normal lake level, a tunnel 1,000 feet long and a 500-foot penstock would give a mean head of about 364 feet at sea level.

POWERHOUSE SITE

Any location north or south of where Deer Creek flows into Mist Cove is favorable for a powerhouse site. The site south of the mouth of Deer Creek is more suitable because a terrace extends further inland here than at most places north of Deer Creek. The shoreline is underlain by graywacke and argillite, and the bedrock is well exposed along the wave-cut terrace. A powerhouse site at this locality would be 10–15 feet above mean sea level and would not be exposed to wave erosion.

The foliation and joint sets which cut the bedrock do not show shear or crush zones. No faulting is evident at the powerhouse site. In Chatham Strait just east of Mist Cove is an extension of a major fault that shows evidence of movement during the Tertiary Period (Twenhofel and Sainsbury, 1958). Epicenters of earthquakes have been recorded on this and another major fault along Peril Strait. Such evidence suggests that the powerhouse installations should be designed to give maximum protection against earthquakes and tsunamis.

CONSTRUCTION MATERIAL

No large sand and gravel deposits are in the Deer Lake area, and such material must be transported from other source areas or manufactured. Coarse aggregate is available by quarrying talus deposits along the lakeshore or in the upper valley. The low-grade metamorphic rocks are siliceous and very hard and break into angular fragments that resist weathering. Some of the thin-bedded argillite weathers into smaller rock fragments. The compressive strength of the more massive graywacke may approach that of some of the hardest sandstone. In decreasing order of abundance, quartz, quartzite, plagioclase, chert, and rock fragments are present in the graywacke.

The graywacke is suitable as coarse aggregate for concrete and rock fill. Small amounts of sand and gravel may be present in the talus deposits at the west end of Deer Lake. Fine material can be obtained by quarrying and crushing the bedrock at the damsite.

KASNYKU LAKE POWERSITE

WATERPOWER DEVELOPMENT

Development of the waterpower potential of Kasnyku Lake can be accomplished by the construction of a dam at the lake outlet to raise the lake level to the required storage capacity and by drawdown below the normal level of the lake. J. C. Dort (in Federal Power Commission and U.S. Forest Service, 1947) estimated the drainage area of the Kasnyku Lake basin to be 4.6 square miles and the surface area of Kasnyku Lake to be about 300 acres. He calculated the mean discharge rate at the lake outlet to be 65 cubic feet per second. The complete regulation of Kasnyku Lake would require a storage capacity of at least 27,000 acre-feet of water in the reservoir for which the power capacity is estimated at about 2,237 kilowatts. This storage capacity could be obtained by raising the lake surface 50 feet and by a maximum regulation by drawdown to a depth 40 feet below the normal lake level.

An alternate plan would be to build a dam to raise the lake surface 100 feet. The increased head would result in a power capacity of 4,900 kilowatts.

TOPOGRAPHY

Kasnyku Lake is in the northern part of Baranof Island, approximately 6 miles north of Baranof. The lake lies in a narrow bifurcate ice-eroded basin with steep to vertical walls. The basin is about 2.5 miles wide and 3 miles long. The main basin extends northeast and is connected to Waterfall Cove by a deep, narrow canyon about 1 mile long. From a point midway on Kasnyku Lake, a tributary basin extends nearly 2 miles to the southeast. A smaller lake occupies this part of the basin.

The walls of the basin rise steeply above Kasnyku Lake to the top of a drainage divide, which has an average altitude of about 2,000 feet. The divide area culminates in several higher peaks west of Kasnyku Lake at an altitude of 3,500 feet. Snowfields and small valley glaciers are in the higher mountains to the west.

The water-surface altitude of Kasnyku Lake was 595 feet on August 11, 1957, and the maximum observed depth was about 393 feet. Kasnyku Creek flows northeast from the lake beneath talus deposits to a small pond 0.3 mile below the lake outlet. From the pond, the creek flows through a V-shaped canyon to the coast, where it plunges in a series of spectacular waterfalls into Waterfall Cove. The top of the falls is at an altitude of 454 feet.

The damsite is on Kasnyku Creek immediately below the outlet of the lake. The bottom of the canyon is narrow and is covered by coalescing talus fans. The height of the talus cones above the canyon floor ranges from 20 feet to as much as 150 feet in the larger slides. The surface of the talus deposits near the abutments rises steeply to the base of the outcropping bedrock and then the slope becomes steeper to the top of the drainage divide. About 400 feet of relief occurs in the canyon at the proposed damsite. Scattered stands of spruce and hemlock and heavy thickets of devilsclub and alder cover the slopes and ridges.

A small stream at the head of the southeast arm of the basin drains the lake at the altitude of 662 feet; it is the major tributary to Kasnyku Lake. The lake is about 700 feet wide and 2,200 feet long and is of undetermined depth. The basin is concave to the west and is bordered by steep cirque walls with as much as 1,500 feet of relief. Several small lakes in the higher cirques feed into the lower lake. The slopes and the floor of the basin are covered by talus deposits.

GEOLOGY

BEDROCK

A large quartz diorite pluton of Jurassic and Cretaceous age underlies Baranof Island in an area that extends from Kasnyku Bay south to Cascade Bay. It is intruded into schist and phyllites of the Kelp Bay Group of Triassic or Jurassic age (Berg and Hinckley, 1963; Loney and others, 1963). The Cretaceous and Jurassic quartz diorite is exposed around Kasnyku Lake and in the canyon of Kasnyku Creek. Associated with it are lesser amounts of diorite and amphibolite. Recently determined lead-alpha and potassium-argon ages of plutonic rocks on Baranof Island suggest a probable Eocene or Oligocene age (Loney and others, 1967).

The quartz diorite is massive, hard, light gray, and medium to coarse grained and has pronounced jointing. Foliation is indistinct except locally, where it seems mostly due to the alignment of the dark minerals. The diorite has an equigranular texture and consists chiefly of biotite and plagioclase (oligoclase and andesine) and minor amounts of hornblende, quartz, and potassic feldspar. Common accessory minerals are apatite, zircon, magnetite, and some hematite. Rutile grains and needles occur in the biotite. Alteration of biotite to chlorite is common.

Numerous quartz-diorite dikes from 5 inches to 2 feet wide cut the diorite. The dikes do not show any preferred orientation. Of two dike specimens examined microscopically, one sample from the head of Kasnyku Lake has a hypidiomorphic granular texture and consists of plagioclase (chiefly andesine), biotite, and quartz and lesser amounts of sericite. Apatite, magnetite, and zircon are common accessory minerals. Quartz makes up more than 5 percent of the constituents and is visible in the hand specimen. There is some alteration of the biotite to chlorite. Another sample taken from a dike near the outlet of Kasnyku Lake is a white fine-textured granitic rock that consists of potassic feldspar and quartz and lesser amounts of sericite and biotite. The accessory minerals are apatite, zircon, and magnetite.

Several thick bands of amphibolite occur as inclusions in the diorite along the medial part of Kasnyku Lake. These bands, which are 10–50 feet wide, strike north to northwest and dip steeply. They are dark grayish green and fine to medium grained and show pronounced lineation. They contain abundant hornblende and biotite and lesser amounts of feldspar. Pyrite, magnetite, and spinel are the principal accessory minerals. Segregation layering is in both the amphibolite and the diorite. The high percentages of calcium and magnesium indicate that the amphibolite may have been formed by metamorphism of impure calcareous and dolomitic sediments. The mineral composition of the amphibolite is similar to the diorite, but the amphibolite seems to contain greater percentages of hornblende and plagioclase and a lesser amount of biotite. Some of the hornblende and biotite are altered to chlorite and epidote. The chemical analyses of rock samples collected in the powersite area are shown in table 1.

UNCONSOLIDATED DEPOSITS

The channel section at the damsite and the lower walls of the canyon are overlain by deposits of talus of undetermined thickness.

TABLE 1.—*Chemical composition, in percent, of six rock samples from the Kasnyku Lake powersite, southeastern Alaska*

[Analysts: P. Elmore, S. Botts, and L. Artis, U.S. Geol. Survey]

	1	2	3	4	5	6
SiO_2	70. 5	74. 8	69. 5	70. 2	70. 0	53. 0
Al_2O_3	16. 6	14. 7	16. 1	15. 7	14. 7	16. 7
Fe_2O_3	. 23	. 00	. 34	. 34	. 38	. 52
FeO	1. 7	. 48	2. 6	2. 6	2. 2	7. 8
MgO	. 10	. 1	. 2	. 6	. 9	7. 6
CaO	4. 1	1. 7	4. 1	3. 7	4. 6	7. 7
Na_2O	4. 2	5. 0	3. 6	4. 1	2. 7	3. 6
K_2O	. 95	2. 1	1. 2	1. 4	2. 4	. 32
H_2O-	. 03	. 00	. 03	. 04	. 06	. 00
H_2O+	. 76	. 63	1. 1	. 84	1. 5	. 75
TiO_2	. 21	. 02	. 28	. 42	. 27	1. 4
P_2O_5	. 25	. 31	. 61	. 21	. 12	. 16
MnO	. 03	. 00	. 06	. 04	. 04	. 25
CO_2	. 15	. 11	. 16	. 11	. 09	. 09
Total	99. 81	99. 95	99. 88	100. 30	99. 96	99. 89

LOCALITY

1. Quartz diorite from right abutment at damsite.
2. Quartz diorite from right abutment of alternate damsite.
3. Quartz diorite from left abutment at damsite.
4. Quartz diorite from east side of Kasnyku Lake adjacent to amphibolite.
5. Quartz diorite from head of Kasnyku Lake.
6. Amphibolite from medial west side of Kasnyku Lake.

Bedrock in the canyon walls slopes at about 40° and if projected below the floor of the canyon would converge at depths between 40 and 60 feet. The talus deposits are essentially continuous coalescing alluvial cones that rise to as much as 150 feet in height above the canyon floor. They consist chiefly of large blocks of igneous rock as much as 10 feet in diameter and also of smaller blocks which are in the floor of the canyon. The material in the talus deposits is homogeneous and would provide good crushed aggregate for the dam.

Rockslides have formed a continuous talus apron along the lower slopes of the canyon. These slides in the avalanche chutes along the upper part of the canyon may be a hazard. Also, the larger talus cones

occur near the damsite. Many of the fans are covered in part by growths of alder brush and salmonberry. At present these slides appear stabilized, but movement of heavy equipment and blasting may trigger rock avalanches.

Large landslide deposits are at the head of Kasnyku Lake and in the southeast-trending tributary basin. These deposits cover the base of steep cliffs and consist of large angular boulders, cobbles, and smaller fragments of diorite. Some finer material is present where streams have reworked the coarse detritus in small alluvial fans that are built out from the shore of the lake and along the drainage channel in the tributary valley. At this last locality the most likely source for gravel is the reworked glacial material and landslide detritus deposited by the large stream in a narrow alluvial plain. A cursory examination of this deposit at the mouth of the stream indicated that the material ranges in size from coarse sand to cobbles; however, the deposit appears small.

STRUCTURE

Northern Baranof Island is bordered by great northwest-trending lineaments that are probably the traces of major faults (Twenhofel and Sainsbury, 1958). The Chatham Strait lineament extends along the east side of Baranof Island and is probably the most conspicuous linear feature in southeastern Alaska. Another linear feature, the Peril Strait lineament, is a major fault that separates Baranof Island from Chichagof Island and is an offshoot of the Chatham Strait fault. Both lineaments are near Kasnyku Bay. Although no evidence of faulting was observed in the map area, smaller scale features such as prominent joint systems are probably related to the major faults. The most conspicuous joint system strikes northeast, and a less conspicuous joint system strikes northwest; the joints dip at high angles. Some of the igneous rocks such as the quartz diorite and the amphibolite bands associated with the diorite appear to trend parallel to the joint sets.

The canyon of Kasnyku Creek, as well as the drainage basin of Kasnyku Lake, is eroded along a strongly defined northeast-trending joint set. The southeast arm of the basin lies along a northwest-trending joint set. The attitudes of joint sets vary widely within the map area. Major joint sets strike N. 50°–75° E. and dip 55°–70° E. and N. 45°–65° W. and dip 65°–80° E. Minor joint sets strike N. 70°–80° E. and dip 65° W. and N. 5°–15° W. and dip 20°–50° W. Another minor joint set strikes N. 35° E., dips vertically, and shows evidence of slickensiding along planar surfaces.

Foliation in the quartz diorite is generally indistinct and is due chiefly to the alinement of ferromagnesian minerals. Some sheeting was observed in the diorite at the head of Kasnyku Lake and in the massive cliff southwest of the lake outlet. These minor structures do not present a major problem, and leakage along these partings should be negligible. There is evidence of faulting within the damsite area. Slickensides observed along some planar surfaces reflect slight movement that is possibly related to cooling and contraction within the diorite.

A drainage basin just north of Kasnyku Lake, which is linear and conspicuous on the aerial photographs, trends northeast. Similarly, the drainage basin southwest of Kasnyku Lake shows a pronounced northwest lineation. These major topographic features may be the result of erosion along major joints or possibly along faults.

DAMSITE

The storage capacity of Kasnyku Lake would be obtained by the construction of a dam at the lake outlet. The dam could be located approximately 100 feet below the outlet or at the alternate site about 600 feet below the outlet. Competent quartz diorite is exposed in the abutments at an altitude of about 650 feet, and both abutments rise in steep slopes above the talus deposits. The predominant joint set strikes N. 30°–50° E. and dips from 45° E. to vertical. A minor joint set strikes N. 35° W. and dips steeply. The joints are spaced 8–12 inches apart and appear tight on the weathered surface. The geology, which is similar at both sites, is shown on plate 2.

At both damsites the lower parts of the abutments and the channels are covered by deposits of talus of undetermined thickness. The unconsolidated material is coarse landslide detritus that is too permeable to be grouted with cement. Kasnyku Creek flows beneath the floor of the canyon at the damsites. By projecting the slope of the abutments into the subsurface, it is estimated that at least 40 feet of talus must overlie the bedrock. The canyon floor is about 100 feet wide at the damsite, and the fill must be excavated to bedrock, so that the base of the dam can be constructed on a stable foundation. Most of the talus cones head in chutes which contribute the main supply of detritus. The axes of the damsites are on abutments where there is minimum danger from rockslides.

A gravity-type concrete dam about 100 feet high would have a crest altitude at approximately 700 feet and a crest length of 420 feet. A 100-foot rise in the lake level would give a storage capacity of about 60,000 acre-feet and would double the storage capacity in the reservoir.

The recharge capabilities in the drainage basin are slight due to the small size of the basin and to the lack of major tributaries; the small lake in the southeast arm of the basin provides the major recharge to Kasnyku Lake. Because no glaciers are in the upper part of the basin, the runoff fluctuates widely with the amount of rain and melt water.

An alternate plan for providing nearly similar storage capacity is to construct a dam 60 feet high that has a crest length of 350 feet and a drawdown of 40 feet below normal lake level. The alternate plan is more economical because a smaller dam would cost less. Kasnyku Lake has a maximum depth of approximately 400 feet, so it is possible to increase the drawdown capacity by varying the altitude of the tunnel intake below the lake level. The lake bottom west of the outlet drops abruptly to maximum depth, and a favorable location of the conduit intake could be anywhere along this shoreline. If the damsite is not considered feasible for the construction of a dam because of the permeable channel section, the possibility of creating storage capacity by drawdown alone should not be eliminated.

RESERVOIR SITE

The drainage basin is underlain by competent bedrock that is similar to the quartz diorite at the damsite. The diorite locally includes small elongate bodies of amphibolite, and at places near the head of Kasnyku Lake it is intruded by thin light-gray quartz diorite dikes which contain abundant sericite and euhedral prisms of orthoclase.

Elongate bodies of amphibolite that strike N. 10°–15° W. and dip 35°–50° W. crop out along the west shore of the southeast arm. A wide band of amphibolite crops out on the east side of the lake and trends southeast to a point where it is concealed by surficial deposits. The contact of the amphibolite with the diorite is irregular and interlayered, and field evidence indicates that the amphibolite is older and is assimilated into the diorite. Some of the amphibolite bodies that are exposed on either side of the lake appear to be alined and may be a continuation of the same outcrops.

Foliation is not a characteristic of the massive quartz diorite, but where the foliation is apparent, the crude alinement of the ferromagnesian minerals is usually due to flow. However, by contrast the amphibolite is strongly lineated.

The major joint sets that cut the biotite diorite in the reservoir area strike N. 45°–70° E. and dip 65°–80° E., and N. 30°–45° W. and dip 40°–70° W. Other minor joint sets strike N. 20°–30° E. and dip 10°–55° W., and N. 15° E. and dip 45°–75° E. A few slickensides were noted along planar surfaces of a joint set that strikes N. 65°–75° E. and dips

west. The sheeting that was observed in the quartz diorite at several localities about the basin may be related in part to glacial rebound or to the release of load pressure by erosion. The partings in the bedrock are tight and should not cause leakage in the reservoir. The geology of the reservoir is shown on plate 2.

TUNNEL ROUTE

A suitable tunnel route that has a portal on the north shore of Kasnyku Lake near the lake outlet extends to tidewater at Ell Cove just north of Waterfall Cove. The tunnel can be cut through competent quartz diorite that underlies the ridge north of the damsite. A tunnel along this route would be approximately 2,900 feet long and would convey water to the powerhouse installation through a penstock about 1,400 feet long.

It would not be necessary to line the tunnel except possibly where it intersects major joints. These joints may cause some leakage in the tunnel, especially at places where there has been some movement along the planar surfaces. Most joints appear tight in the unweathered bedrock and should not cause any major difficulty. Some of the major northeast-trending joints along which most of the topographic features are developed may extend to greater depths than indicated by the cursory geologic examination at the surface. All large linear features within the mapped area that were examined on the ground and on the aerial photographs were determined to be joints and not faults. However, major faults probably occur in Chatham Strait east of the map area and in Peril Strait to the north; small faults may be in the drainage basins adjacent to Kasnyku Lake. The design of the tunnel and the intake installations should be such as to withstand possible earth movements along such faults.

POWERHOUSE SITE

The powerhouse site was not examined on the ground. Aerial reconnaissance and examination of aerial photographs indicate that bedrock similar to the quartz diorite in the reservoir area and at the damsite is present. The coastline is rugged and indented by fiords, and a wave-cut terrace extends along much of the shoreline. At Ell Cove the terrace extends inland some distance and rises gradually to the base of the steeply sloping upland. The powerhouse installation would be high enough above sea level to escape possible seismic sea waves generated by earthquakes. The powerhouse site is accessible by boat or by float-equipped aircraft.

CONSTRUCTION MATERIAL

Small deposits of fine unconsolidated material such as sand and gravel may be present in the southeast-trending tributary valley between the upper lake and Kasnyku Lake. Generally, the gravel deposits are coarse and composed chiefly of cobbles and landslide detritus. Part of the material which shows some sorting appears to have been deposited by melt water. Coarse material is also available in the talus deposits that cover the floor and the lower slope of the tributary valley. Talus deposits are present at other localities about Kasnyku Lake, but the excavation of these deposits may be hazardous due to the steepness of the slope on which the deposits occur. The location of these surficial deposits are shown on plate 2.

The coarse material from the extensive coalescing talus deposits in the narrow canyon below the damsite can be crushed and utilized for dam construction. These deposits are composed of homogeneous quartz diorite whose chemical composition is such that corrosive action would be minimized if the material was used as concrete aggregate. Large deposits of sand and gravel are not available within the basin, and such material must be transported from other areas.

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