Geologic Reconnaissance of the West Creek Damsite near Skagway, Alaska

GEOLOGICAL SURVEY BULLETIN 1211-A

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By JAMES E. CALLAHAN *and* RUSSELL G. WAYLAND

GEOLOGY OF WATER POWER SITES IN ALASKA

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A description of the geologic conditions which might affect the feasibility of powersite development on West Creek, a tributary of the Taiya River northwest of Skagway, Alaska

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GEOLOGIC RECONNAISSANCE OF THE WEST CREEK DAMSITE NEAR SKAGWAY, ALASKA

By James E. Callahan and Russell G. Wayland

ABSTRACT

The proposed West Creek damsite is about 6 air miles northwest of Skagway on the southernmost large tributary of the Taiya River from the west. The damsite lies at a sharp bend in the valley of West Creek, a typical glacial trough, and the site is well situated topographically for a concrete arch or gravity dam. The left abutment is formed by a low bedrock ridge extending into the center of the valley from the north wall, and the right abutment is essentially part of the south valley wall. The stream has cut a relatively deep and narrow gorge into the bedrock.

Bedrock at the damsite consists of a strong massive homogeneous granodiorite capable of supporting a dam of any practical size. Three sets of joints cut the granodiorite, two of which strike northeast with steep southerly to vertical dips. The other set trends northwestward with consistently vertical dips. The northeastward-striking joints intersect the axis of the dam at high angles and also trend through the left abutment.

A persistent lineation, possibly a fault related to the active Denali fault system, crosses West Creek about three-fourths of a mile downstream from the damsite. Considering this possible fault and the recorded earthquake epicenters near the damsite, the dam should be designed to withstand earthquakes of maximum severity.

The reservoir is underlain by unconsolidated sand and gravel deposits of glaciofluvial origin, lacustrine silts, and probably some till. Alluvial fans extend into the valley from both walls. Because the reservoir area is surrounded by high mountains composed of impermeable and relatively undisturbed granitic rock, leakage from the reservoir is unlikely.

A tunnel through the granodiorite southeast of the right abutment would probably be the most practical means of diversion from the reservoir area to a powerhouse in the Taiya River valley. Such a tunnel could be unlined except where it crosses the possible fault and some of the more persistent joints.

Construction materials available in the reservoir area include gravel aggregate containing varied sizes probably interbedded with lacustrine silts that are suitable for an impervious core in an earth-fill dam. Large angular blocks of granitic rock suitable for riprap might be obtained without quarrying from the alluvial-fan deposits.

INTRODUCTION

A reconnaissance geological examination of a possible damsite and reservoir area on West Creek was made in August 1962, by the authors to furnish geologic information for use in evaluating the waterpower resources of the public lands. The field examination was made in conjunction with a topographic survey party consisting of G. C. Giles, hydraulic engineer; L. Pease, D. Jamison, C. Payne and G. Smetzer.

GEOGRAPHY

West Creek is the local name for the southernmost large tributary flowing into the Taiya River from the west. The proposed damsite is about 6 air miles northwest of Skagway, Alaska (fig. 1) and is about 2 miles upstream from the confluence of West Creek and the Taiya River. The mouth of West Creek is readily accessible by an all-weather graveled road from Skagway. The damsite, however, could be reached only by foot or helicopter in 1962. The stream is too swift to navigate with small boats, and the damsite area is too densely forested for the use of fixed-wing aircraft.

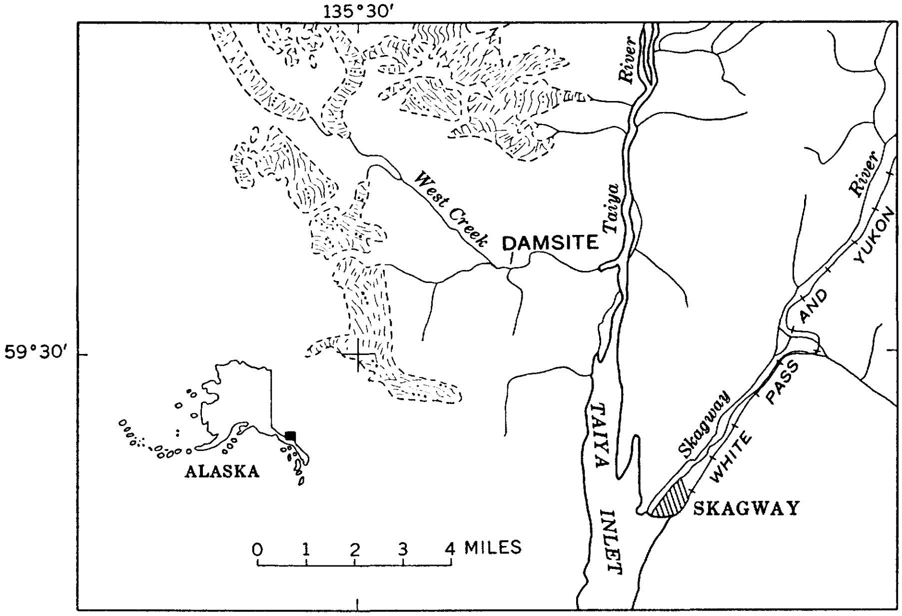

FIGURE 1.—Index map of the Skagway, Alaska, area showing the location of the proposed damsite on West Creek.

The proposed damsite and reservoir areas are included on the Skagway 1:250,000 scale Reconnaissance Topographic Map, on the Skagway C–2 1:63,360 scale quadrangle, and on U.S. Air Force aerial photographs SEA 80–055, 80–056, and 80–057, flown July 11, 1948, and SEA 140–116, 140–117, and 140–118 flown August 25, 1948. The scale of the photographs is approximately 1:40,000 at sea level.

TOPOGRAPHY AND DRAINAGE

West Creek originates in and flows through the severely glaciated mountains of the Coast Range of southeastern Alaska. The stream is about 6 miles long from the glacier where it originates to the mouth, and it drains an area of roughly 39 square miles. Approximately one-third of the drainage basin is covered by glaciers and ice fields. The total relief within the drainage area exceeds 7,000 feet, the altitudes ranging from less than 100 feet at the confluence of West Creek and the Taiya River to about 7,500 feet at the head of the glacier which feeds the stream. West Creek flows along the floor of a steep-walled glacial trough 4,000 to 5,500 feet deep. The valley walls have been extensively modified by tributary glaciers and to a lesser extent by postglacial stream action. In the reservoir area above the damsite (pl. 1) the valley floor is fairly flat and is formed on an undetermined thickness of glaciofluvial and lacustrine deposits. Upper West Creek flows over a broad flood plain at a mean altitude of about 650 feet, and has the typical braided channel of a glacial stream. At and below the damsite the stream has cut into bedrock and its gradient is much steeper. At the time of the field investigation during August 1962, the stream was carrying a heavy silt load.

The topography of the damsite is shown on plate 1. The left abutment consists of a ridge extending from the north wall into the central part of the valley. The right abutment is a a part of the south wall of the main valley. A dam with a maximum height of 165 feet (780-foot crest altitude), would be possible without auxiliary structures along alinement *A–A′* (pl. 1). With two relatively low wing dikes (*B* and *C*, pl. 1) in the saddles upstream from the dam, the height could be increased to 195 feet (810-foot crest altitude). For the purpose of this report, a height of 185 feet (800-foot crest altitude) will be assumed. The two saddles seem topographically suitable for natural spillways. The overflow would return to West Creek more than half a mile below the toe of the dam.

PREVIOUS INVESTIGATIONS

The Skagway area was part of the area covered in the geological reconnaissance of southeastern Alaska by Buddington and Chapin

(1929). More detailed work on the Coast Range intrusives was done in the Berner's Bay and Eagle River regions by Knopf (1911, 1912). No detailed mapping has been done in the immediate vicinity of Skagway, but much of the general discussion and conclusions of Buddington and Chapin (1929) and Knopf (1911, p. 22; 1912, p. 23–24) regarding the structure, petrography and origin of the Coast Range batholith is applicable to the intrusive rock that underlies the damsite and reservoir areas.

PRESENT INVESTIGATION

The present investigation consisted of a field examination of the damsite. A traverse was made along the crest of the ridge forming the left abutment, another on the north bank of West Creek through the gorge, and another on the right abutment to an altitude of 850 or 900 feet in the upper part of the gorge. Bedrock is concealed for the most part by soil cover and dense vegetation, particularly on the right abutment, but observed areas of bedrock outcrop are shown on plate 1. The topographic base map was not available at the time of the field examination, so that the outcrop areas indicated on plate 1 are generalized from field notes and the aerial photographs. The photographs were also used to determine some of the general structural features and to aid in delineating unconsolidated deposits in the reservoir area.

REGIONAL GEOLOGY

The damsite and reservoir areas are in the Coast Range batholith of southeastern Alaska. The batholith is an intrusive complex of Jurassic or Cretaceous age. The period of emplacement or of successive intrusions possibly extended over much of both Jurassic and Cretaceous time. Rocks of the batholith range in composition from gabbro to granite. The predominant rock types are granodiorite, quartz monzonite, and quartz diorite. According to Buddington and Chapin (1929, p. 178–179) the western part of the batholith is quartz diorite, whereas the core consists mainly of granodiorite, quartz monzonite, quartz diorite and minor amounts of more mafic rocks. Inclusions of metamorphic country rock such as schists, injection gneisses, and reaction gneisses, occur throughout the batholith. The inclusions range in size from small shreds to belts several miles in length. Buddington and Chapin (1929) mapped a belt of "layered gneiss" extending northwest from Skagway to a point on West Creek below the damsite. No foliated rock was observed in the damsite area during the present investigation.

Buddington and Chapin (1929, p. 231) state that the rocks of the mainland batholith are prevailingly gneissoid. They attribute most of the gneissic structure to stresses, flow currents and assimilation of foliated country rock prior to consolidation of the magma. They attribute some of the banding, however, to stresses subsequent to solidification, particularly near the borders of the intrusives. Gneissic banding is poorly developed or absent in many localities. The igneous rocks observed during this investigation, both at the damsite and along the east side of Taiya Inlet, are massive and homogeneous.

Most of the lineations seen on aerial photographs of the vicinity of the damsite are less than 2 miles long and correspond in direction to the strike of joints measured in outcrops. The lineations were plotted on the aerial photographs and later transposed to a base map (pl. 1). One lineation which can be traced about 7 miles by aerial photographs crosses West Creek below the damsite. It is assumed to be a normal fault dipping to the west. Twenhofel and Sainsbury (1958) interpret this lineation and several others nearby as splits from the much larger Chatham Strait lineament. The Chatham Strait lineament is part of the Denali fault system, which extends in a great arc some 1,600 miles through Canada and central Alaska to Bristol Bay. The Denali fault and probably the Chatham Strait lineament are known to have been active since the Tertiary period. Fault scarps in recent deposits and earthquake epicenters along the lineaments indicate continued activity to the present time.

GLACIATION

During Pleistocene time, most of the Coast Range was buried beneath the Cordilleran ice sheet. The depth of the ice varied from place to place throughout the region, as is evidenced by the different altitudes to which glacial smoothing and rounding is observed. In the West Creek area, valley walls and mountain spurs are smooth and rounded to an altitude of 3,500 to 4,000 feet. Above this altitude the peaks and ridges have a rugged serrate form resulting from Alpine-type glaciation. At its height, the ice sheet filled preexisting stream valleys, and scoured them to the characteristic U-shaped troughs. Many of the valleys are still occupied by remnant valley glaciers.

The glacier that occupied the valley of West Creek was able to cut down more deeply into bedrock in its upper reaches than it did at and below the damsite, so that it cut an elongate basin above the damsite. As the glacier retreated up the valley its front probably stood for some time at or near the damsite because of the bedrock high that forms the left abutment and the abrupt change in course of the valley at that point. When the level of the ice fell below the height of the left abutment, melt water drained across the abutment, probably through the saddles. As the glacier continued receding it probably left a recessional moraine near the damsite, which impounded water in a proglacial lake. Some of the coarse material deposited as moraines along the edge of the ice was reworked and deposited on the lake bottom, and glacial rock flour was deposited in the east end of the basin above the damsite.

The retreat of the ice toward its present position was interrupted by minor advances from time to time. The overflow from the proglacial lake gradually removed the remainder of the lateral and recessional moraine and cut into bedrock to form the present gorge.

EARTHQUAKE HISTORY

Between 1899 and 1952, nine earthquakes of intensity between 5 and 6 on the Modified Mercalli Scale were recorded in the area between Juneau and the Alaska-Canada Border north of Skagway and Haines (Heck and Eppley, 1958, p. 72–78). The epicenters of these were concentrated along the Chatham Strait lineament described above. Severe earthquakes in 1899 and in 1958 centered in the Lituya Bay-Yakutat Bay area were felt strongly at Skagway and Haines.

Because the proposed damsite is in an area of strong seismic activity and near suspected lines of present-day crustal movement, the dam and all appurtenant works should be designed to withstand earthquakes of maximum severity and should be founded on firm bedrock rather than on unconsolidated material.

DAMSITE

The suggested alinement (*A–A′*, pl. 1) seems to be suitable for a masonry dam of sufficient height to raise the water level to an altitude of 800 feet or more. Along this alinement, bedrock crops out at and near the top of the knob on the left abutment, at the present water level of West Creek, and on the steep slope immediately above the creek on the right abutment. The intervening cover along this alinement consists of soil, float and loose joint blocks, and dense undergrowth. The thickness of the cover probably does not exceed 10 to 15 feet.

BEDROCK

All outcrops and float observed at the damsite were granodiorite except for a small outcrop of diorite on the south side of the easternmost knob of the left abutment. The relationship of the diorite to the granodiorite was obscured by heavy vegetation. The rocks are massive and unweathered except for a slight discoloration extending one-quarter to one-half inch into exposed surfaces. Samples of the granodiorite were taken from two outcrops on the left abutment. The petrographic description in the following section is based on microscope determinations made by oil-immersion methods supplemented by measuring extinction angles of albite twins in plagioclase.

GRANODIORITE

The granodiorite is light gray, medium to coarse grained, and has a "salt and pepper" distribution of light and dark minerals in hand specimen. Dark minerals comprise 25 to 30 percent of the rock. Feldspars occur in subhedral to anhedral grains 1 to 3 mm in diameter. The quartz is anhedral and has roughly the same grain size as the feldspar. Biotite occurs in euhedral to subhedral plates and booklets 1 to 6 mm in diameter and as much as 3 mm thick. The hornblende is in prisms as much as 1 cm in length and 2 mm in diameter.

The average composition of the two samples collected from the left abutment is given below. For comparison, the range in composition of granodiorite of southeastern Alaska described by Buddington and Chapin (1929, p. 175) also is given.

	Average of 2 samples from West Creek (percent)	*Range of granodiorites, of southeastern Alaska (percent)*
Plagioclase (andesine, An_{40})	40	38–60
Potassium feldspar (microcline and orthoclase)	13	9–28
Quartz	22	15–30
Biotite (brown)	21	8–25 (biotite and hornblende)
Hornblende	4	

The most common accessory mineral is apatite. Zircon and an opaque mineral are also present.

DIORITE

A sample of the diorite was taken from the outcrop on the left abutment. It is a dark-gray fine- to medium-grained slightly porphyritic rock in hand specimen. Euhedral to subhedral feldspar crystals 2 to 2½ mm in diameter occur in a groundmass of hornblende, biotite, quartz and smaller feldspar grains. A few hornblende crystals reach a length of 3 or 4 mm. The approximate mineral composition of the rock is:

	Percent		*Percent*
Plagioclase (andesine, An_{40})	59	Biotite	14
Potassium feldspar	1	Hornblende	17
Quartz	9		

Apatite is relatively abundant and occurs as euhedral rod-shaped inclusions in all the major constituent minerals. Zircon occurs sparingly, but in relatively large euhedral or subhedral crystals.

The diorite may be a xenolith from an intrusive body older than the granodiorite or an assimilation product, or possibly a dike. Significant difference in the foundation properties of the granodiorite and the diorite is unlikely.

In summary, the bedrock in the damsite area is a competent unweathered massive and homogeneous granitic rock. Except where jointed or fractured, it should furnish an excellent foundation for any type of structure. Its strength should be constant in all directions because of the random orientation and distribution of the mineral grains. The rock is practically impermeable except for movement of fluid along joints. None of the mineral components are susceptible to or conducive of undesirable chemical or mechanical effects.

UNCONSOLIDATED DEPOSITS

Other than soil cover and float, unconsolidated material in the damsite area consists of a small amount of terrace gravel exposed between axis *A–A′* (pl. 1) and the narrow constriction downstream in the middle of the gorge. The terrace gravels are probably less than 15 feet thick. Possibly, alluvium partly fills the gorge at axis *A–A′* where the creek follows a joint direction. The thickness of overburden will not prevent the placement of a dam on firm bedrock along the full length of axis *A–A′* (pl. 1).

STRUCTURE

The joint system in the granodiorite is well developed and consists of steeply dipping or vertical conjugate joints typical of massive granitic rocks. As indicated by the equal area diagram (fig. 2) of 60 joint poles, the system consists of two northeastward-trending sets, one striking N. 60°–80° E., the other striking N. 40°–50° E., and both dipping from 65° south to vertical. A third set strikes about N. 45° W. and has consistently vertical dips. The northeastward-striking joints are most abundant, and can be traced as far as 2 miles on the aerial photographs (pl. 1). Spacing between joints is variable, but the average is on the order of 10 to 20 feet. No slickensides or crushed rock were observed along any of the joints in the immediate damsite area.

Sheeting is another type of fracture found in large bodies of intrusive rock. It is common at West Creek, particularly in the large outcrops of granodiorite on and near the tops of the glaciated knobs on the left abutment. The sheeting fractures are generally slightly curved or irregular, tend to parallel the ground surface and are spaced from 3 to 5 feet apart at the surface. They are thought to be a result of the release of load resulting from erosion (Billings, 1954, p. 121–123). Generally, the spacing of this type of fracture increases with depth. The sheeting fractures observed appeared reasonably tight except where joint blocks have worked loose.

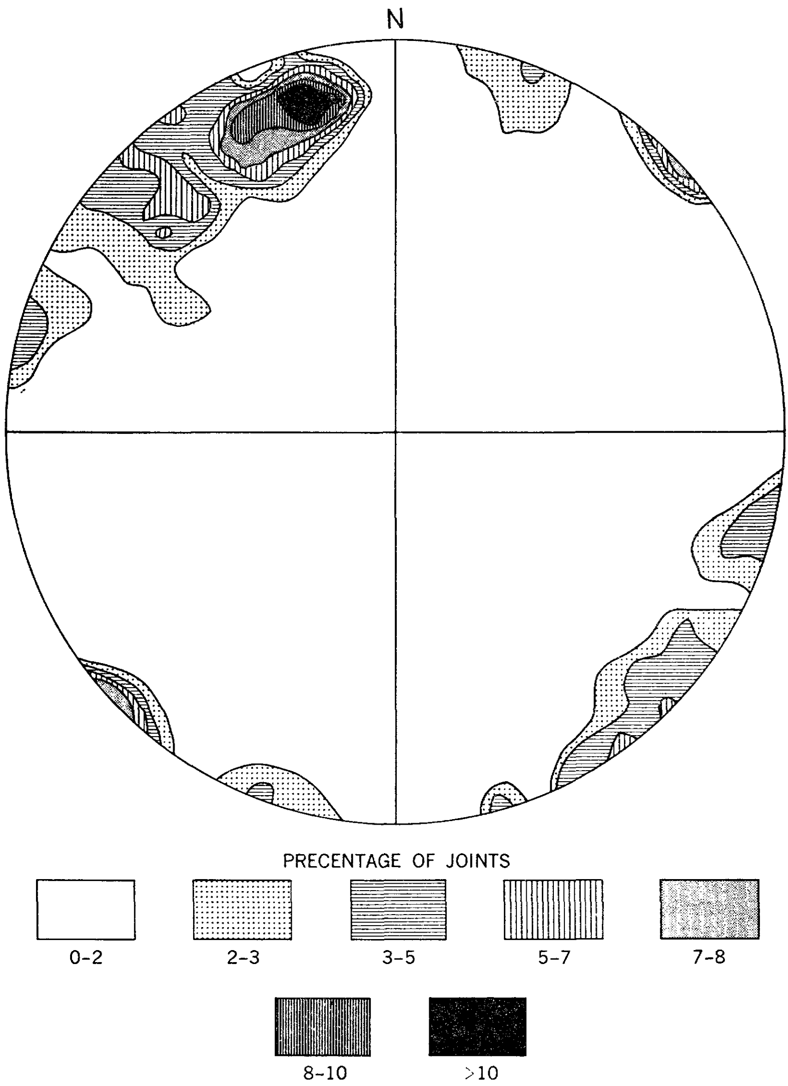

FIGURE 2—Equal-area diagram of poles of 60 joints measured in West Creek damsite area. Poles plotted on lower hemisphere. Contoured on percentage of joints per 1 percent of area of circle.

In the design, construction and maintenance of a dam, the northeastward-striking joints could present some problems. The course of West Creek in the upper part of the gorge parallels the major joint set (N. 60°–80° E.). The direction of thrust of an arch dam would be roughly parallel to the joint direction. The design of such a dam should take possible local slippage along the joints into consideration. Leakage under the dam along joints belonging to the major set should also be considered. Leakage is also likely along joints of both northeastward-trending sets through the left abutment, particularly in the saddle areas where both ice plucking and glaciofluviatile erosion were joint controlled. Leakage might also be expected along the gulch east of the right abutment that roughly parallels the major joint direction. Only drilling and pressure testing would determine whether joints and sheeting fractures are open at depth.

The stability of the left abutment during and after excavation might be locally affected by the southward-dipping joints of the major set unless care is taken to prevent undercutting.

The area below the damsite where the trace of the suspected fault crosses West Creek was not visited. Although slippage along the fault would not directly affect the dam or reservoir, it is related to an active fault system. Its proximity to the damsite should be considered in the earthquake design of the dam.

RESERVOIR SITE

With a water-surface altitude of 800 feet, the reservoir impounded by a dam along axis A–A′ on West Creek would have a length of slightly more than 3½ miles, and an average width of slightly less than half a mile.

The bedrock surrounding the reservoir area and underlying the unconsolidated deposits on the valley floor probably does not differ markedly from that observed at the damsite. Except for a few pebbles and cobbles of fine-grained reddish porphyritic andesite, the gravels in the channel of West Creek immediately above the damsite consist of igneous rock similar to the bedrock exposed in the damsite area. The andesite may have been derived from dikes in the bedrock in the drainage area of West Creek.

The thickness of unconsolidated material in the basin above the damsite is not known. Judged from a projection of the valley walls in profile, a thickness of at least 250 or 300 feet is likely. In addition to the sand and gravel deposits in the stream channel, a 4- to 5-foot bed of fine sand or silt overlying gravel occurs in the stream bank immediately above the gorge. This was probably deposited in the most recent lake to occupy the basin. As it is likely that a series of lakes of various sizes and depths existed, more beds of fine-grained material interbedded with sand and gravel probably underlie the east end of the basin. Although most of the morainal material left by the retreating glacier has been removed or reworked by postglacial stream activity, some till probably remains buried beneath or interbedded with the alluvium in the reservoir area.

Alluvial fans are at several places along both sides of the valley.

Some of the lineaments in the mountain masses surrounding the damsite and reservoir area are as much as 2 miles long, but none appear to be continuous from the valley of West Creek to neighboring drainages. Even if the joints are of such length, probably they are not open at a depth sufficient to cause serious leakage from the reservoir except in the immediate damsite area. The unconsolidated deposits on the valley floor rest on bedrock. As they are confined to the reservoir area, leakage from the reservoir through permeable beds would not be possible.

A long-range problem to be considered is the silting of the reservoir by glacial rock flour. West Creek carried a moderately heavy silt load in August. However, this was during a period of warm wet weather. The small glaciers now in the drainage area seem to be retreating. Most of the remaining moraine is at the upper end of the valley. Little coarse unconsolidated material is left above the reservoir, but even small landslides and avalanches might create waves of considerable magnitude.

CONDUIT ROUTE AND POWERHOUSE SITE

A tunnel (pl. 1) driven through bedrock for a distance of about 1½ miles from the reservoir to a powerhouse near sea level in the Taiya River valley, just south of the mouth of West Creek, might be preferable to a surface conduit constructed along the valley of West Creek. The creek valley below the damsite is narrow and steep sided, with at least one large and relatively recent avalanche scar on the north side. A tunnel driven through the bedrock could probably be unlined for much of its length and would not be subject to snow avalanches, rock slides, freezing, and other hazards which beset mountainside conduits in this environment. Avalanches, rock slides, and rock falls would be particularly likely considering the seismic history of the area. The tunnel route would probably be in massive, competent, and impermeable igneous rock similar to that at the damsite for its entire length. Earthquakes would have little effect on a tunnel except in a case of actual movement along a fault crossing the tunnel. Those parts of the tunnel which might be subject to collapse would probably require a lining in any event to prevent leakage.

The tunnel as projected would intersect the suspected fault at depth somewhere to the west of its trace at the surface. The fault is likely to cause water problems during construction, particularly if a wide crushed or sheared zone is involved. Leakage may be a problem if the tunnel is left unlined in the section crossed by the fault. Little evidence of postglacial movement, such as fresh scarps or offsets in recent alluvium or stream channels, can be observed along the fault on aerial photographs, but considering its possible relationship to larger active structures, a careful surface and subsurface examination of the fault trace should be made.

The tunnel route also intersects several other lineations which parallel the two northeastward-trending joint sets of the area. The distance separating the tunnel from the valley wall of West Creek should be made great enough to minimize leakage along these joints. Concrete lining in the tunnel may be necessary locally.

A powerhouse located at the base of the west wall of the Taiya River valley could be built on sound granodiorite.

CONSTRUCTION MATERIALS

The reservoir area is the nearest potential source to the damsite for unconsolidated material suitable for coarse and fine aggregate, impervious fill or riprap. Another source for construction materials is the Taiya River valley, but it is unlikely that the materials there would be superior to those found in the reservoir area.

The alluvium along West Creek observed above the damsite ranges from fine sand to 6-inch cobbles. The gravel is generally round to subround, the sand angular. A progressive increase in the maximum grain size and angularity might be expected upstream and toward the valley walls in the vicinity of tributaries. None of the stream deposits observed seem to contain significant fractions of silt or clay-size particles. The andesite observed in the stream gravel could be reactive with high-alkali cements if used for concrete aggregate, but the percentage of andesite present is probably too small to eliminate the gravel as a desirable aggregate.

Further study of the recent lacustrine deposit above the damsite and also the possible silt and rock flour deposits from earlier lake stages may show sufficient extent and texture in these sediments to provide impervious core material for use in an earth-fill dam.

None of the alluvial cones along the valley walls were examined, but considering the steepness of the valley walls, it is possible that large angular blocks of granodiorite or closely related rock suitable for riprap could be obtained without stone quarrying.

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