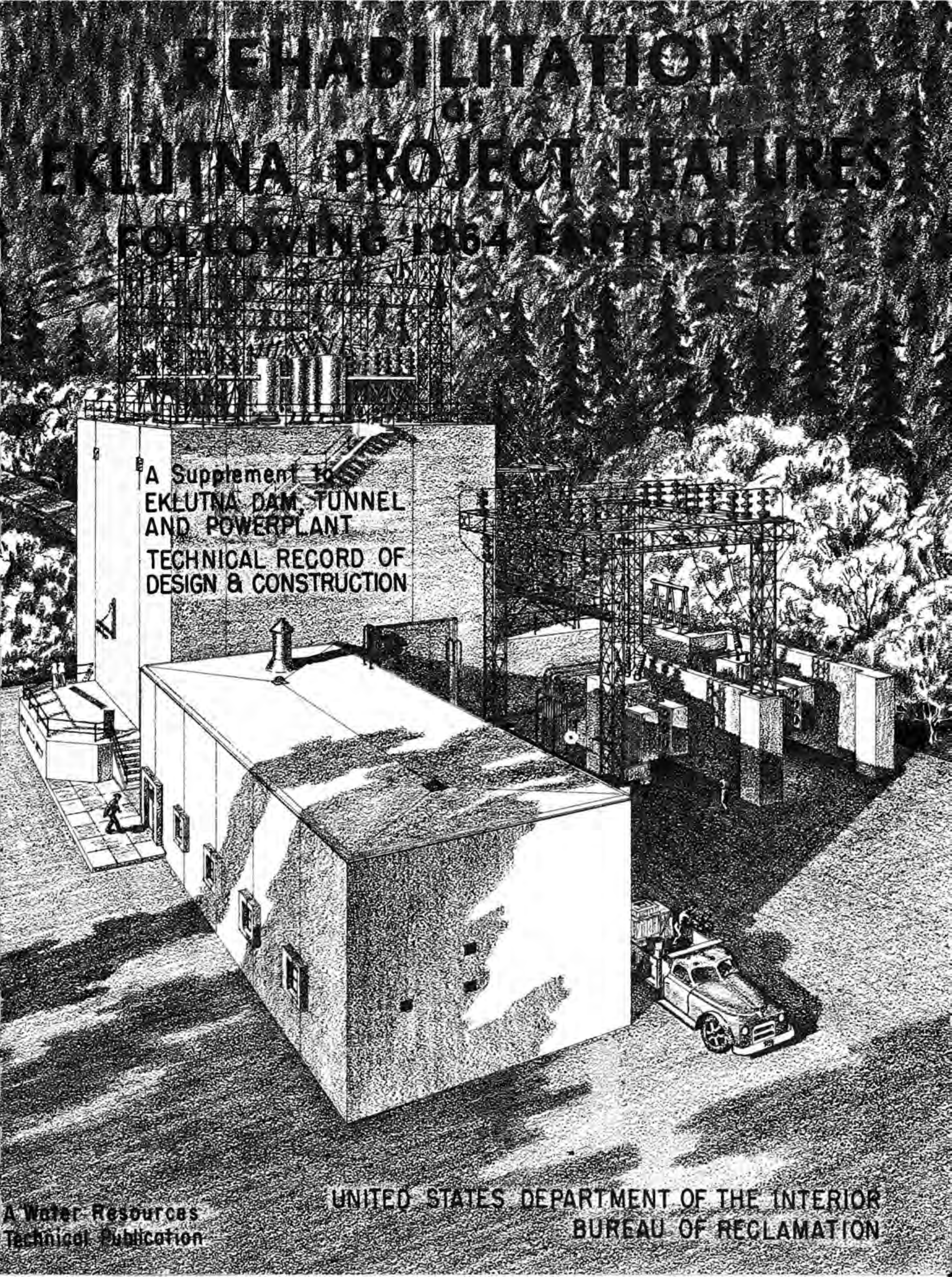
REHABILITATION OF EKLUTNA PROJECT FEATURES FOLLOWING 1964 EARTHQUAKE



A Supplement to
EKLUTNA DAM, TUNNEL AND POWERPLANT
TECHNICAL RECORD OF DESIGN & CONSTRUCTION

A Water Resources Technical Publication

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

IMPORTANT MESSAGE!

ALASKA POWER ADMINISTRATION ESTABLISHED

The Department of the Interior recently established an Alaska Power Administration to chart the future course of Federal participation in the development of water, power and related resources in Alaska. The order establishing the new Bureau under the supervision and direction of Assistant Secretary Kenneth Holum transferred Reclamation facilities to the new administration effective June 16, 1967. Its responsibilities include the operation and maintenance of the Eklutna project and the Crater-Long Lakes division of the Snettisham project, as well as the overall promotion of the development of water and power resources in the State of Alaska.

Because the text of this publication was in an advanced stage of preparation at the time of the above transfer, it was completed and published without reference to the change other than this note.

UNITED STATES
DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF RECLAMATION

Floyd E. Dominy, Commissioner
B. P. Bellport, Chief Engineer

REHABILITATION OF EKLUTNA PROJECT FEATURES FOLLOWING EARTHQUAKE OF MARCH 1964

A Supplement to

EKLUTNA DAM, TUNNEL AND POWERPLANT

TECHNICAL RECORD OF DESIGN AND CONSTRUCTION, MARCH 1958

Constructed 1951-1955
Rehabilitated 1964-1965

Eklutna Project
Alaska

Denver, Colorado
June 1967

Price $3.60

REHABILITATION OF EKLUTNA PROJECT FEATURES
FOLLOWING EARTHQUAKE OF MARCH 1964
Eklutna Project--Alaska

General Information

Purpose: To restore electric power to the Anchorage, Alaska, area for both civilian consumption and national defense installations after its disruption by the earthquake of March 27, 1964.

Construction dates: 1964-1965

Reservoir (as modified)

Name: Eklutna Lake

Location: Approximately 10 miles (16 kilometers) southeast of Eklutna Powerplant, and 30 miles (48 kilometers) northeast of Anchorage, Alaska.

Reservoir statistics:

- Total live capacity: 213,271 acre-feet (263,070,000 cubic meters)
- Active capacity: 174,798 acre-feet (215,613,000 cubic meters)
- Present inactive capacity: 38,473 acre-feet (47,456,000 cubic meters)
- Surface area (at total capacity): 3,420 acres (1,384 hectares)
- High-water elevation (spillway crest): 871.0 feet (265.48 meters)
- Length: 7 miles (11.3 kilometers)
- Width: 0.7 mile (1.13 kilometers)
- Depth: 200 feet (61.0 meters)

Dam (as replaced)

Type: Earth and rock fill

Foundation: Firm glacial till

Slopes: 3 to 1 upstream, 2 to 1 downstream

Slope protection: No special slope protection; rockfill (zone 3) was placed in 3-foot (0.9 meter) layers on both upstream and downstream faces.

Crest length: 815 feet (248.41 meters)

Crest width: 30 feet (9.14 meters)

Crest elevation: 891.0 feet (271.58 meters)

Volume: 85,000 cubic yards (65,000 cubic meters)

Spillway (as replaced)

Location: On right bank but almost midway between abutments of dam

Type: An ungated overflow crest with a rectangular reinforced concrete conduit through the dam and a stilling basin energy dissipator.

Crest elevation: 871.00 feet (265.48 meters)

Crest width: 18 feet (5.49 meters)

Capacity: 3,315 second-feet with reservoir at maximum (surcharge) elevation 884.8.

Intake Structure (as replaced)

Location: Eklutna Lake bottom

Type: Rectangular reinforced concrete box structure, open and protected by trashracks on its top, front, and two sides.

Dimensions: Trashracked portion about 23 feet (7.01 meters) wide, 20 feet (6.10 meters) high, and 22 feet (6.71 meters) long in direction of conduit flow; 42 feet 4 inches (12.90 meters) in overall length.

Elevation of invert: 793.6 feet (241.9 meters) which is 77.4 feet (23.59 meters) below the dam spillway crest.

Inlet channel: 100 feet (30.48 meters) wide, about 720 feet (220 meters) long. (Original intake structure and portions of original intake conduit remain in inlet channel.)

(Note: The following features have not been changed by the work discussed in this supplement, but are redescribed here in order to complete the pertinent information concerning the powerplant, tunnel, and related works.)

Eklutna Tunnel

Type: Circular, concrete-lined, pressure type

Inside diameter: 9 feet (2.74 meters)

Length: 23,550 feet (7,178.0 meters)

Hydraulic properties:
- Area: 63.62 square feet (5.91 square meters)
- Velocity: 10.06 feet per second (3.07 meters per second)
- Capacity: 640 second-feet (18.12 cubic meters per second)

Slope: 0.00341 (80-foot (24.38-meter) difference in elevation between inlet and the outlet gate at surge tank)

Surge Tank

Location: 22,805 feet (6,950.96 meters) downstream from bulkhead gate shaft and directly over tunnel
Height above tunnel: 176 feet (53.64 meters)
Inside diameter: 30 feet (9.14 meters)
Wall thickness: 18 inches (0.46 meter)
Type: Restricted orifice

Penstock

Location: Downstream of surge tank
Length: 1,088 feet (331.62 meters)
Variable diameters: 91-, 83-, and 75-inch (231.1-, 210.8-, and 190.5-centimeter) outside diameters
Type: Welded and coupled steel pipe encased in concrete
Plate thickness: 5/16 inch (0.79 centimeter) for initial section and variable up to 1-1/2 inches (3.81 centimeters) at terminal section
Profile: Descends 864 feet (263.35 meters) at an angle of 53° and then a Horizontal run of 501 feet (152.70 meters)

Powerplant

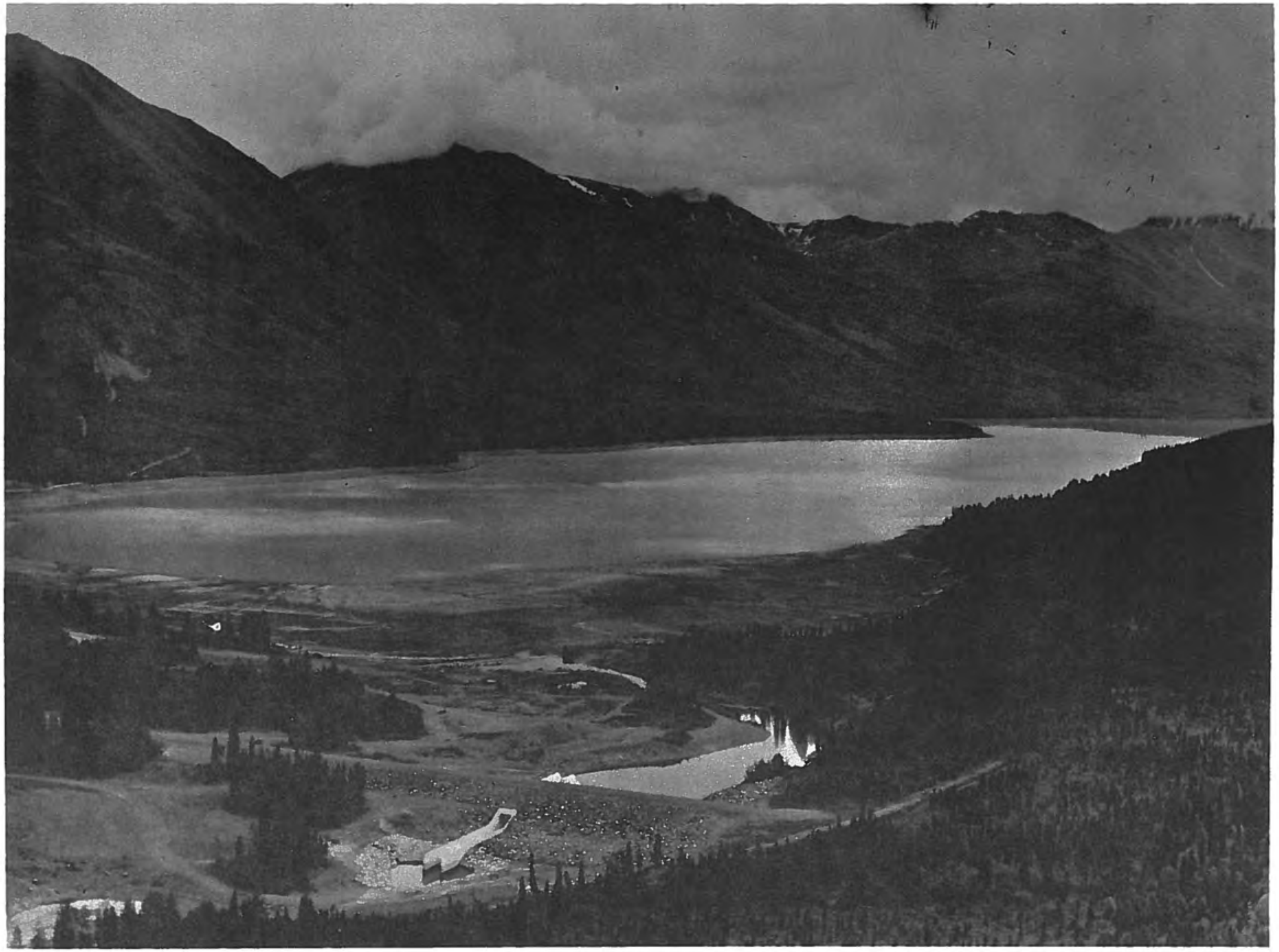
Location: Adjacent to Glenn Highway, 34 miles (54.72 kilometers) northeast of Anchorage, Alaska
Type: Reinforced concrete
Maximum head: 850 feet (259.08 meters) as originally constructed; 865 feet (263.65 meters) obtained with new dam.
Number of units: 2
Installed capacity: 33,334 kilovolt-amperes
Turbines: Francis type, 25,000 horsepower at a rated speed of 600 revolutions per minute and an 800-foot (243.84-meter) effective head
Generators: Vertical-shaft type, 16,667 kilovolt-amperes at 90-percent power factor 3 phase, 60 cycles, 6,900 volts
Transformers: Two main power transformers, 3-phase, 60-cycle, forced-air cooled, 20,000 kilovolt-amperes, 6,600 to 115,000 grounded wye-volts

Switchyard

Location: At three levels, on and adjacent to the powerplant (roof elevation 92.50 (28.19 meters), intermediate roof elevation 58.54 (17.84 meters), and ground level elevation 41.25 (12.57 meters))
Number of units: Two 115-kilovolt bays
One 12.47-kilovolt bay

Tailrace

Location: Extending north from powerplant under the Glenn Highway
Type: Combination pressure type and open channel. A reinforced concrete pressure conduit 209 feet (63.70 meters) long and of varying widths and depths discharges into an open channel with a bottom width of 25 feet (7.62 meters), side slopes of 2 to 1, a depth of 12.5 feet (3.81 meters), and a length of about 2,000 feet (610 meters), which conveys the water into the Knik River.



Frontispiece.--Aerial view of the new Eklutna Dam, Eklutna Lake, and the Chugach mountain range. The level of the lake is considerably below its maximum elevation. P783-D-58608.

FOREWORD

Technical records of design and construction, to which this publication is related by reference, are a series of publications which record the planning, design, construction, and initial operation of Bureau of Reclamation structures.

This supplement to the technical record of design and construction for Eklutna Dam, Tunnel and Powerplant discusses the rehabilitation of the Eklutna project features following the severe Alaska earthquake of March 27, 1964. The supplement is divided into three parts. Part I is devoted to brief descriptions of the features as originally designed and as later rehabilitated, a brief account of the inspections and assessment of the earthquake damage, a summary of rehabilitation costs, and geology particularly in relation to the earthquake. Part II contains two chapters on design, one dealing with the replacement of the intake structure and the repair of the conduit, and the other discussing the new dam and spillway. Part III contains three chapters related to construction, one on contract administration, one on emergency work to restore and maintain power generation immediately following the earthquake, and one on major repairs to the intake conduit and replacement of the dam, spillway, and intake structure.

This supplement was prepared by the Technical and Foreign Services Branch of the Office of Chief Engineer in Denver, Colo., from final design reports submitted by the design branches, final construction reports and cost information submitted by the field offices, and various other reports. Acknowledgment is gratefully made to the designers and field personnel for their contributions to this work.

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PART I--INTRODUCTION

CHAPTER I. HISTORY AND DESCRIPTION

1. Necessity for Rehabilitation. As one of the lesser effects of the severe earthquake which occurred in the vicinity of Anchorage, Alaska, at 5:36 p.m. on March 27, 1964, considerable damage was sustained by the Eklutna Powerplant and appurtenant works. The intensity of the earthquake was reported to be between 8.4 and 8.6 on the Richter scale. As soon as possible after the earthquake, the Bureau of Reclamation undertook a program of temporary repair and rehabilitation to restore the powerplant and pressure tunnel to normal operation and to insure, as far as possible, an adequate, dependable water supply for the Eklutna Powerplant for the indefinite future. This publication presents an account of this work.

2. Location and Purpose of Eklutna Project. In order to familiarize the reader with the general nature and purpose of the Eklutna project, and in order to promote a better understanding of the operation of each segment of the project, selected maps, schematic diagrams, and explanatory material contained in the original publication[1] are included in this publication.

The Eklutna project (fig. 1) is a 30,000-kilowatt hydroelectric power development designed and constructed by the Bureau of Reclamation to bring urgently needed electric power to the rapidly expanding area at Anchorage, Alaska. The project, the first major development by the Bureau of Reclamation outside the continental United States, was constructed during the 4-year period between 1951 and 1955.

The Eklutna Powerplant (fig. 2) is on the Glenn Highway between Anchorage and Palmer, Alaska, about 35 miles northeast of Anchorage. The Eklutna project area includes the Willow Creek mining district on the north, the Matanuska Valley on the east, and the city of Anchorage and environs to Turnagain Arm on the south. Cook Inlet, a branch of the Gulf of Alaska, lies to the west. The area is a northern reach of the Pacific Mountain system, the parallel ranges of which enter Alaska through British Columbia, Canada, and embodies two large flats--a valley floor and a coastal plain. The Cook Inlet and Chugach Mountains almost isolate these areas from each other; they are connected by a narrow strip of land bordered by a branch of the inlet--Knik Arm, a tidal estuary--and the mountains.

Anchorage lies on a low bluff overlooking Cook Inlet, and is bounded on the north, south, and west by arms of the sea. To the east is a low plain extending to the Chugach Mountains. This enclosed area comprises about 75 square miles. Matanuska Valley, through which flow the Matanuska and Knik Rivers, is roughly 50 by 16 miles, and is almost surrounded by the Alaska, Talkeetna, and Chugach Ranges.

Trending northwest from the Chugach Mountains to Knik Arm is the Eklutna Creek, which descends through a steep-sided, troughlike, glaciated valley about 27 miles long. Rugged peaks up to 8200 feet in elevation rise sharply above short valleys tributary to the creek.

The project is for power production only. Firm energy has been estimated at 143 million kilowatt-hours annually. Nonfirm energy, available only during certain hours in summer and early fall, is estimated to be more than 16 million kilowatt-hours in the average year. Transmission lines north to Palmer and south to Anchorage have been constructed, along with substation facilities. These lines operate at 115 kilovolts.

3. Brief Description of Eklutna Dams. There have been three dams constructed at the Eklutna site, each of which in its time served to store water and provide head for power production. These dams are briefly described below:

(a) *Initial Structure.*--The first dam to provide water for power generation was built by private interests in 1929 on top of a natural glacial dam. The latter was left by an alpine glacier about 7 miles long which, upon receding, formed the glacial dam and

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1/ "Technical Record of Design and Construction for Eklutna Dam, Tunnel, and Powerplant," Bureau of Reclamation, March 1958.

Figure 1.--Aerial photograph of Eklutna project showing relationship of features.
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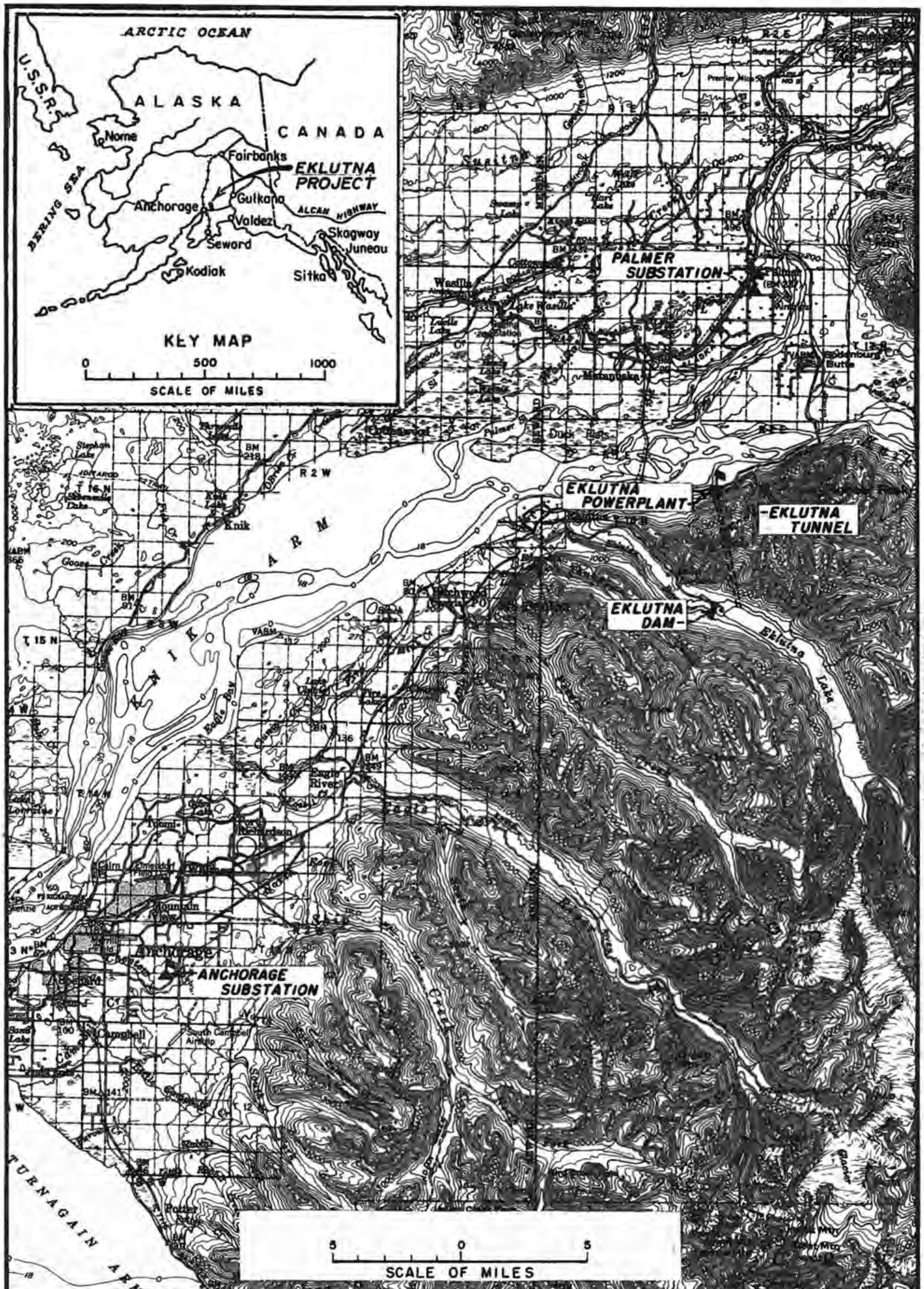


Figure 2.--Location map--Eklutna project.

Eklutna Lake behind it. The lake overflowed through Eklutna Creek below the dam. The natural glacial dam was raised with brush, clay, moss, logs, lumber, and rocks to provide a water supply for a small powerplant which was placed in operation near Eklutna Village, about 8 miles downstream from the dam.

This initial dam was not very successful, because when the lake water level rose 4 or 5 feet above the level held by the natural dam the slightest leak allowed this water to escape. Consequently, wood piling was driven across the mouth of the overflow channel to permit storage of water to a depth of 3 or 4 feet above the natural lake level.

(b) *Structure Existing at Time of Earthquake.*--In the fall of 1939 an earth and rock fill structure was built incorporating portions of the initial structure. This dam had 15 open bays, each 10 feet wide (total width 150 feet) which could be flash-boarded to elevation 871.0, and a gated section with 19 spillway gates, each 6 feet 6 inches high by 5 feet wide, to control discharge and thereby provide a more dependable water supply for the existing powerplant. The crest of the spillway gates, with the gates in the closed position, was at elevation 867.5, the same as the crest of the ungated, open bay section.

The dam was purchased by the city of Anchorage in 1943 and was sold to the Federal Government at the time the Bureau's Eklutna project was being built. In 1952, when the Bureau constructed the pressure tunnel through Goat Mountain to the new Eklutna Powerplant, this dam was strengthened and reinforced. Principal improvements consisted of placing additional earthfill embankment material on the existing embankment, driving and anchoring additional sheet piling, and placing riprap on the upstream and downstream faces.

Dimensionally, this dam as modified in 1952 had a crest length of 555 feet, a crest width of 15 feet, and a crest elevation of 875.0. It had 2 to 1 side slopes both upstream and downstream, and a volume of 5,000 cubic yards. The 19 spillway gates were considered to be in such poor condition, due to aging, that they were required to be left in the closed position at all times.

This structure, generally referred to in this publication as the existing structure, was still in place after the earthquake. However, investigation revealed that it could not be considered safe, so it was decided to replace it with a new structure about 1,400 feet downstream. Gates and excess timbers were removed from the existing structure to make it inoperative.

(c) *Replacement Dam Constructed After Earthquake.*--The replacement dam, constructed in 1965, consists of an earth and rock fill embankment with a crest length of 815 feet, a crest width of 30 feet, and a crest elevation of 891.0. It has a 3 to 1 upstream slope, a 2 to 1 downstream slope, and a volume of 85,000 cubic yards. An ungated overflow spillway with a crest length of 18 feet and a crest elevation of 871.0 is incorporated in the dam. Detailed dimensions and physical features of the dam and spillway are given in sections 18 and 31, respectively.

4. <u>Power Conduit and Appurtenances</u>. Water is conveyed northward from Eklutna Lake to the Eklutna Powerplant through a power conduit about 4-1/2 miles long excavated through Goat Mountain (see figs. 3 through 6). The principal elements of the conduit and appurtenances are described below. The dimensions are as originally constructed, and principal changes incorporated as a result of the repair and rehabilitation are indicated in the discussion. Figure 5 shows a schematic plan and profile of Eklutna project power features as originally constructed, and figure 6 shows the effects of the rehabilitation following the earthquake.

(a) *Intake Structure.*--Diversion from the lake is made through an inlet channel, 100 feet wide and originally about 500 feet long, excavated at the lake bottom at elevation 800 (about 70 feet below the maximum lake surface elevation). In the original construction, an intake structure 133 feet 8 inches long extended from the intake channel. The upstream portion of the intake structure comprised a trashrack structure 112 feet long, built of rectangular precast concrete sections of varying depths. Each was 26 feet 8 inches wide and 37 feet long. Immediately downstream from the trashrack structure was a precast concrete transition section, 14 feet 2 inches long. The inside of this transition section tapered from a rectangular reinforced concrete section 9 feet by 22 feet 8 inches to a circular section 9 feet in diameter. At the end of the square-to-round transition section there was a bulkhead section 7 feet 6 inches long. Slots were provided

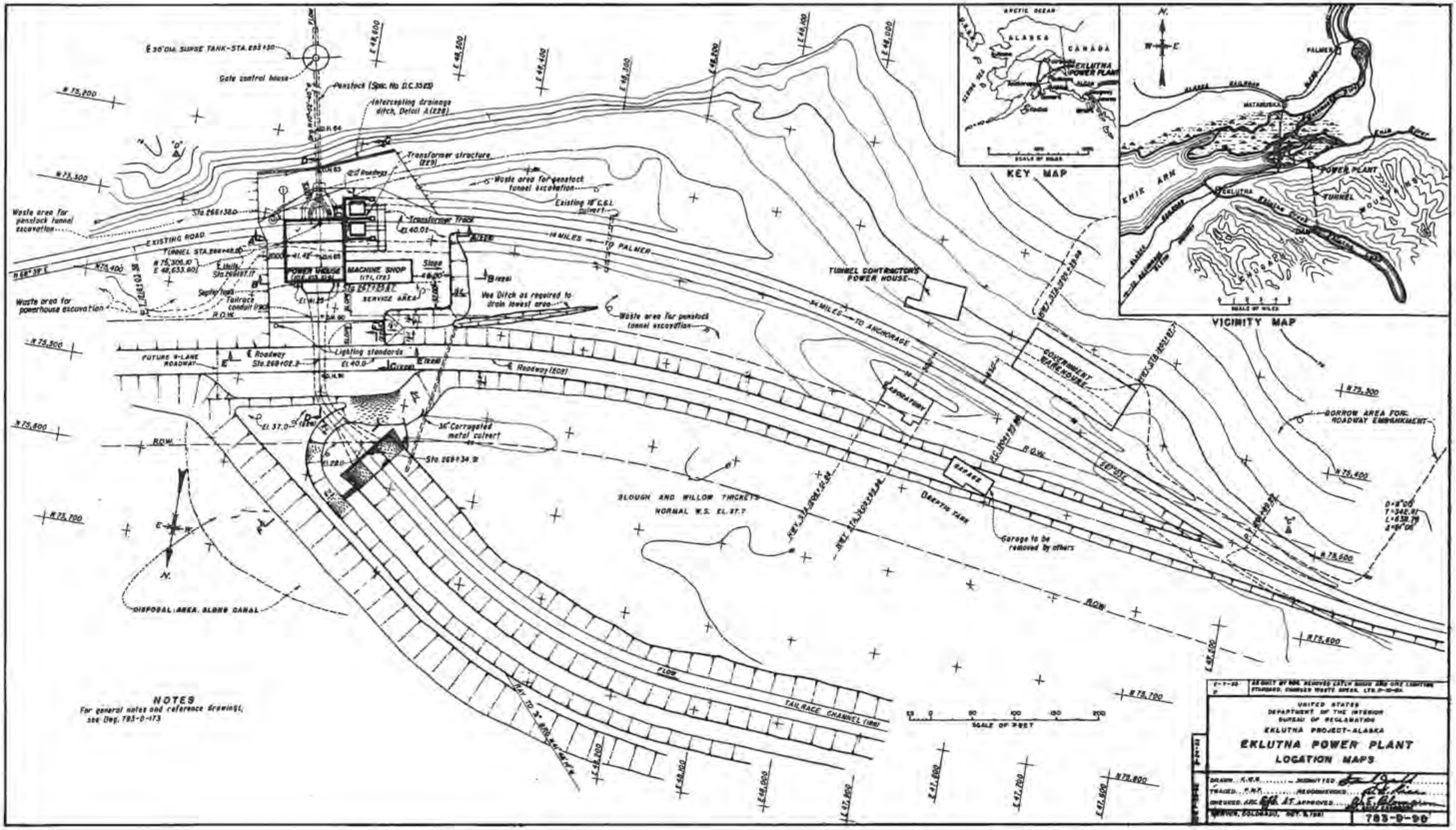


Figure 3. --Eklutna Powerplant location maps.

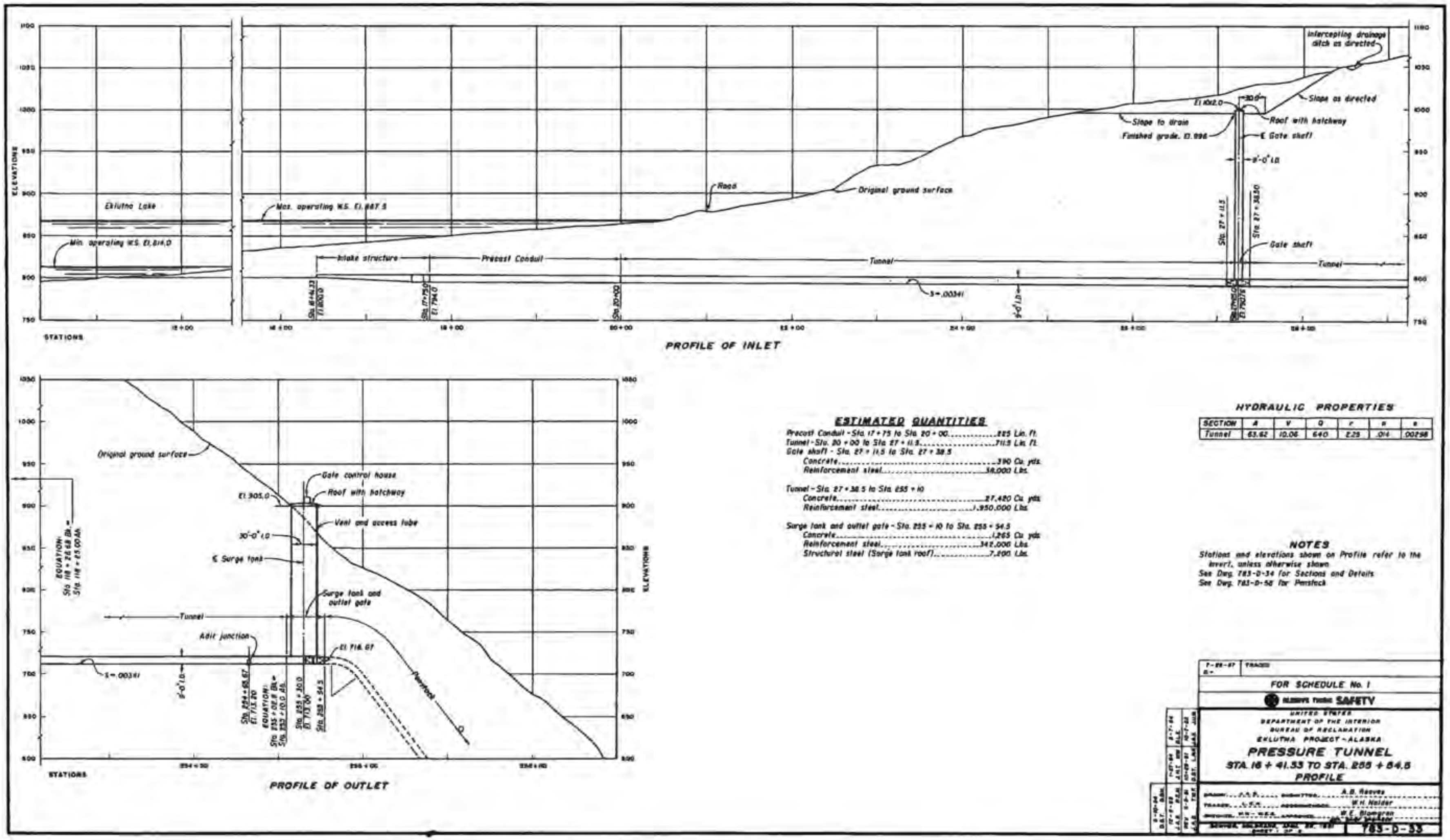


Figure 4. --Profile of power conduit as originally constructed (including intake structure, intake conduit, pressure tunnel, gate shaft, and surge tank) from station 16+41. 33 to station 255+54. 5.

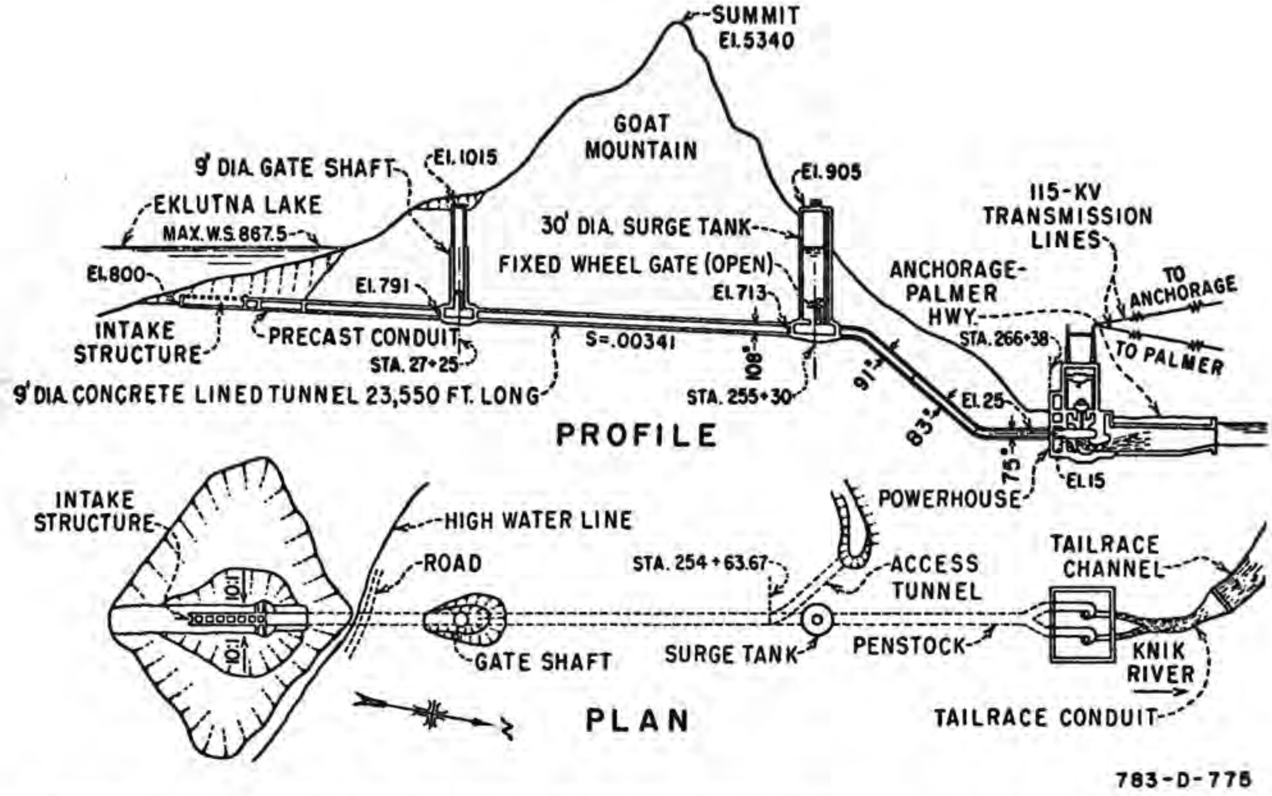


Figure 5. --Schematic plan and profile of Eklutna project features before 1964 earthquake.

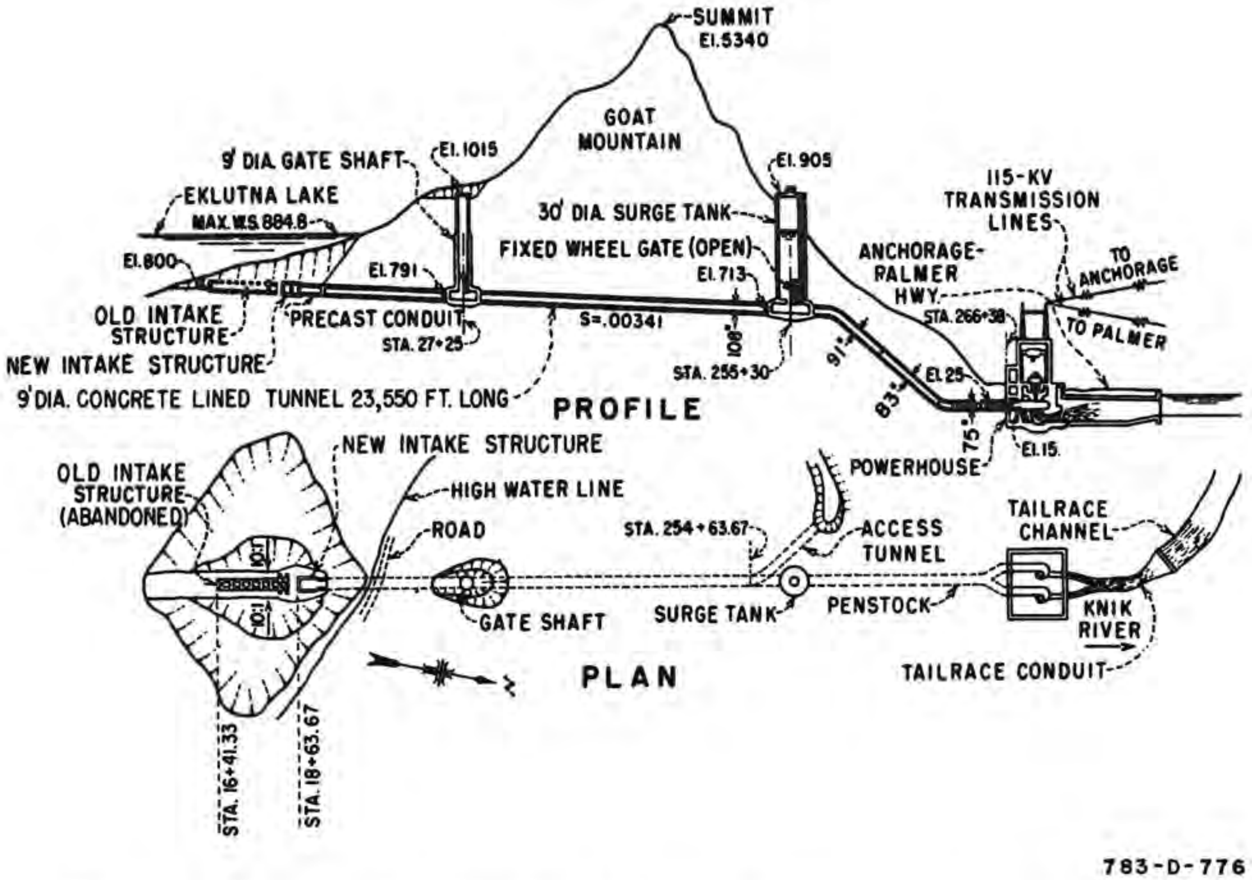


Figure 6. --Schematic plan and profile of Eklutna project features after rehabilitation following earthquake damage.

in the bulkhead section for either stop planks or a fabricated bulkhead to be used in the event of an emergency or for inspection purposes. From the end of the bulkhead section there was constructed a 9-foot inside-diameter precast concrete pipe 225 feet long extending to the entrance of Eklutna Tunnel (subsec. (b)). The pipe has a wall thickness of 12 inches. It was cast in 16-foot sections, each section weighing about 40 tons.

The earthquake so severely disarranged the intake structure, the transition section, the bulkhead section, and the upstream 16-foot sections of precast concrete pipe that eight of these sections had to be removed or abandoned and a new intake structure constructed for the pressure tunnel. The new intake structure connects to the remaining six precast pipe sections which have been repaired under specifications No. DC-6212. (For details of construction, see sec. 60.)

(b) *Tunnel*. --A circular, concrete-lined pressure tunnel 9 feet inside diameter and 23,550 feet (4.46 miles) long conveys water from Eklutna Lake to the penstocks leading to the powerplant. The capacity of the tunnel is 640 second-feet at a velocity of 10.06 feet per second, the slope of the invert being 0.00341.

The tunnel terminates in a surge tank installed directly over the tunnel 22,805 feet downstream from the bulkhead gate shaft. The surge tank, of the restricted-orifice type, has an inside diameter of 30 feet, a wall thickness of 18 inches, and extends 176 feet above the tunnel.

The tunnel section beneath the surge tank contains one 9-foot-long round-to-square transition and a similar square-to-round transition spaced 4 feet 6 inches apart along the centerline. The 4-foot 6-inch rectangular separation serves as a gate slot for the fixed-wheel gate which is used for emergency closure of the tunnel in the event of damage to the penstocks below or the turbine in the powerplant and for unwatering the penstock for inspection and maintenance.

A tunnel adit is located at the outlet end of the tunnel near the surge tank. The adit is essentially the same size as the main tunnel and is approximately 300 feet long. The purpose of the adit is to provide one means of access to the tunnel for inspection and maintenance purposes. It also acts as a free-flow conduit in conveying drainage water from the tunnel when entrance into the tunnel is necessary. Access from the adit to the tunnel is by means of a watertight door.

(c) *Penstock* --Extending from the surge tank at the end of the Eklutna Tunnel is the power penstock which conveys water to the powerplant turbines. The overall length of the penstock is about 1,088 feet, installed in 30-foot sections. The penstock is a variable-diameter (91-, 83-, and 75-inch-outside-diameter) welded and coupled steel pipe encased in concrete in a tunnel extending from the surge tank to the powerplant. Plate thickness of the penstock varies from 5/16 inch at the initial section to 1-1/2 inches at the terminal section. In profile, the penstock roughly parallels the mountainside, descending for approximately 864 feet at an angle of 53°; it then levels off and continues through a horizontal section about 501 feet long.

The penstock bifurcates into two 51-inch-diameter 23-foot-long branches at the powerplant which are connected to the spiral cases of the turbines. A 66-inch butterfly valve is installed in each penstock branch upstream from the turbines to provide means of unwatering the turbines for servicing or maintenance. These valves also serve as emergency shutoff valves in the event of damage to the turbines. Access to the penstock interior is obtained through the vent at the surge tank, through manholes in the powerplant, and through the tunnel adit.

5. Powerplant and Switchyard. The powerplant is a reinforced concrete structure 149 feet long housing two vertical-shaft generating units. The turbines are of the Francis type and are rated at 25,000 horsepower at a speed of 600 revolutions per minute and an 800-foot effective head. The generators are rated at 16,667 kilovolt-amperes, 3 phase, 60 cycles, 6,900 volts. The maximum operating head is 850 feet. There are two main power transformers rated at 3 phase, 60 cycles, forced-oil and forced-air-cooled, 20,000 kilovolt-amperes, 6,600 to 115,000 grounded wye-volts.

The switching equipment for the powerplant is located at three different elevations. The switchyard equipment itself, consisting of the power circuit breakers, disconnecting switches, and main buses, is on the roof of the powerplant at elevation 92.50. The main power transformers that "step up" the generator low voltage are located in the transformer bay adjacent to and southwest of the powerplant structure at elevation 41.25. The high-voltage bushings of these main power transformers are connected to the main switching equipment located on the roof at elevation 92.50.

The 115-kilovolt bus structure on the powerplant roof consists of two bays to supply the 115-kilovolt lines to the cities of Palmer and Anchorage. In addition, there is a 12.47-kilovolt line which supplies power to the Government camp from a small transformer energized from the low-voltage generator leads. This transformer is in the transformer bay adjacent to and south of the powerplant structure at elevation 41.25.

6. Tailrace. Water discharged from the draft tubes of the turbines in the powerplant enters a 209-foot-long pressure tailrace conduit through which the water is conducted under the Glenn Highway to an open tailrace channel which discharges into the Knik River.

The tailrace conduit is made up of rectangular, reinforced concrete transition sections having varying widths and depths. The terminal section of the conduit is 50 feet long and flares outward in the downstream direction from a width of 14 feet 6 inches to a width of 46 feet 6 inches. This terminal section is also of varying depth and has five openings separated by 10-inch walls through which the water passes into the tailrace channel. Stoplog slots are provided at the outlet of the conduit. The stoplogs are available for use when it is necessary to dewater the conduit or to unwater both draft tubes at the same time.

The banks of the open tailrace channel are built on a 2 to 1 slope and are lined with riprap at its junction with the tailrace conduit. The channel has a top width of about 75 feet, a bottom width of 25 feet, a depth of about 12 feet 6 inches, and a length of about 2,000 feet.

7. Assessment of Earthquake Damage. (a) *Powerplant.*--A quick survey of the powerplant and switchyard by project personnel immediately following the earthquake at 5:36 p.m. on March 27, 1964, indicated no apparent damage to either of the two generating units; but it revealed major damage to two 115-kilovolt air circuit breakers and bushing-type transformers serving the Anchorage and Palmer lines. The circuit breakers are located on the powerhouse roof at elevation 91.50. The free-standing hollow porcelain insulator columns, which are part of the circuit breakers, broke at the base, causing complete collapse of the contact mechanisms on the two breakers. Also, the two 20,000-kv.-a. power transformers, located in the transformer bay southwest of the powerhouse at elevation 41.25, had shifted on their rails and had sunk several inches, as had the camp line transformer. After the initial survey, the generator, which had been stopped for examination, was started and station service restored at 5:55 p.m. A temporary bypass was installed around the damaged equipment and the Anchorage line was energized through a bus tie switch at 10:10 p.m. Service was restored to Palmer at about 10 a.m. the next day.

Water pressures at the turbines of the powerplant fluctuated during the night of March 27 and during the next day, indicating that some disruption of the facilities had occurred. A considerable amount of debris was noted in the tailrace at this time. At 2:40 p.m. on March 28, a shear pin failed on unit 1 wicket gate drive, forcing a shutdown of the powerplant. This shutdown was the first of a series of stoppages required to make repairs and to remove rock and debris from the intake structure, pressure tunnel, penstock, wicket gates, and spiral cases. After emergency repairs to the wicket gate drive, operation continued on an intermittent, reduced output basis until May 9, 1964, when emergency repairs of the power conduit were undertaken. There were many shear pin failures during this time, but a half-screen of 2-inch mesh chain link fencing installed between the butterfly valve and the spiral case of each unit was effective in intercepting many of the rocks before they got to the wicket gates and turbine runners. Also, it was early learned that the large rocks did not move through the tunnel if the total load was kept below 18,000 kilowatts (equivalent to a water velocity of about 5 feet per second). Consequently, this load limit was maintained so far as possible.

(b) *Conduit and Intake Structure.*--Following the determination that debris had gotten into the tunnel and penstocks serving the powerplant, an underwater survey was made on April 19, 1964, under a negotiated contract by Associated Divers of Anchorage, Alaska, at the intake structure and conduit at Eklutna Lake. This survey revealed that one joint in the precast concrete intake conduit was badly damaged, and it was decided that this joint should be repaired and further inspection of the intake structure, conduit, and tunnel should be made immediately. Accordingly, on May 5, 1964, a contract (specifications No. DC-6112) was negotiated with Peter Kiewit Sons' Co., in Anchorage to do this work.

On May 9, 1964, the pressure tunnel was unwatered by the contractor and an extensive inspection was made of the entire waterway, including an underwater inspection of the intake structure and the precast conduit upstream from the tunnel headgate. This inspection revealed that some of the conduit joints had been separated by as much as 10 inches and some of the conduit sections had been laterally displaced. It was subsequently determined that the movement resulted from a consolidation of materials in Eklutna Lake induced by the earthquake. The intake structure had moved approximately 44 inches toward the lake; and tensional forces in the precast conduit produced by this horizontal shift had caused separation of 10 of the 15 bell-and-spigot joints in the conduit (see fig. 18). The opening of these joints allowed a quantity of rock, gravel, and debris estimated at 1,200 cubic yards to enter this pipe and be deposited throughout some 3-1/4 miles of the pressure tunnel. The debris was cleaned from the tunnel and temporary repairs were made to the conduit sections. The details of this work are given in chapter VI. Permanent repairs were made later as discussed in chapter VII.

(c) *Tailrace.*--During the period when the powerplant was shut down for repair of the intake, the 209-foot-long pressure tailrace conduit was inspected and cleaned. Cross-section measurements revealed a total of 110 cubic yards of rock and mud in the conduit, most of which is presumed to have been deposited following the break in the precast pipe section of the tunnel intake. The inspection also revealed considerable shifting of the sections nearest the powerplant. General area subsidence raised the high-tide water level at the tailrace outlet approximately 3 feet.

Severe cracking of the ground surface (fig. 32) developed in the area adjacent to and parallel with the 2,000-foot-long open canal section of the tailrace. The cracks varied in width from a few inches to 5 feet and had the effect of squeezing in the sides of the channel. The invert was irregularly mantled by gravelly debris ranging in depth from a few inches to several feet.

(d) *Other Power Facilities.*--The preliminary survey that was made following the earthquake revealed, in addition to the damage at Eklutna Powerplant (subsec. (a)), considerable damage to equipment at Anchorage Substation, Palmer Substation, and the Eklutna-Palmer transmission line, and minor damage to Reed Substation. One pole structure and two conductor spans in the Eklutna-Palmer transmission line were destroyed by a snowslide; three 115-kilovolt lightning arresters at Anchorage Substation were damaged; and one 115-kilovolt bushing at Palmer Substation was damaged. Repairs were immediately made to the equipment as discussed in chapter VI.

(e) *Eklutna Dam.*--Eklutna Dam suffered considerable earthquake damage, but an interesting observation with respect to this is that the damage did not appear for several weeks following the earthquake. The frozen ground near the surface apparently moved as a mass during the earthquake, and it was not until much later when the ground thawed that it was found the earthquake had consolidated the alluvial materials and left a void under the dam. This void caused settlement and cracking of the spillway and leakage through the dam, necessitating construction of a new dam and spillway. The design of these features is discussed in chapter IV and their construction in chapter VII.

(f) *Automotive Repair Shop and Other Structures.*--The ground beneath the north end of the automotive repair shop, a wood frame structure, settled up to 1 foot and moved approximately 10 inches horizontally along a tensional crack, which destroyed the floor and radiant heating system in the floor slab. Lighting fixtures were torn loose from the wall. This structure had to be rebuilt at another location (see sec. 43).

A number of other structures suffered minor damage. These included the machine shop, adjacent to the powerhouse (the different periods of oscillation of these two structures caused interconnecting drainage and electrical systems to be sheared); the warehouse; the project office; and some camp housing facilities.

(g) *Powerplant Yard and Roadways.* --Cracks up to a foot in width and several feet deep (fig. 7) developed from a point west of the garage, extending eastward adjacent to the north wall of the warehouse, thence across the roadway to the project office building. Cracks also extended from the garage to the southwest corner of the warehouse. A similar but much larger crack occurred in State Highway No. 1 opposite the entrance to the project area. Backfilling the pavement cracks was a continuing operation for several weeks as adjustment--believed to have been caused by the mechanics of thawing--along the cracks continued to take place.

(h) *Features Not Damaged.* --As previously indicated, the powerhouse, which was supported on piles driven to bedrock (graywacke) was not visibly damaged by the earthquake. Other features apparently not damaged included the gate shaft, the pressure tunnel, the penstock, the surge tank, and the anchor block (fig. 5).

The concrete gate shaft, at station 27+25, was founded on competent rock and was reinforced to withstand internal bursting pressures. Possible vertical deflections of the shaft due to earthquake were provided for by a number of horizontal joints. No damage to this structure was discernible.

Though much of the rock through which the 9-foot-diameter pressure tunnel was drilled is quite badly broken, with numerous minor fault planes, no structural damage to the tunnel was found. Considerable quantities of water were encountered entering the tunnel through gate leakage, tunnel flap valves, and joint leakage, but these were not earthquake related.

The entire length of the penstock tunnel was excavated in weathered rock except for a portion at the lower end where the tunnel section emerged to overburden material. This reach of tunnel was designed as a length of conduit supported at one end by the tunnel rock and at the other end by a pile-supported anchor block, or bent. The penstock is of variable diameter, from 75 to 91 inches, and is of steel pipe encased in concrete. It is 1,088 feet long.

The reinforced concrete surge tank, 30 feet in internal diameter and rising 176 feet above the tunnel, was constructed in badly fractured though reasonably stable rock. It was supported for its full height by 8-inch wide-flange H-beam structural-steel supports on 4-foot centers. The surge tank is located at the downstream end of the pressure tunnel, station 225+30.

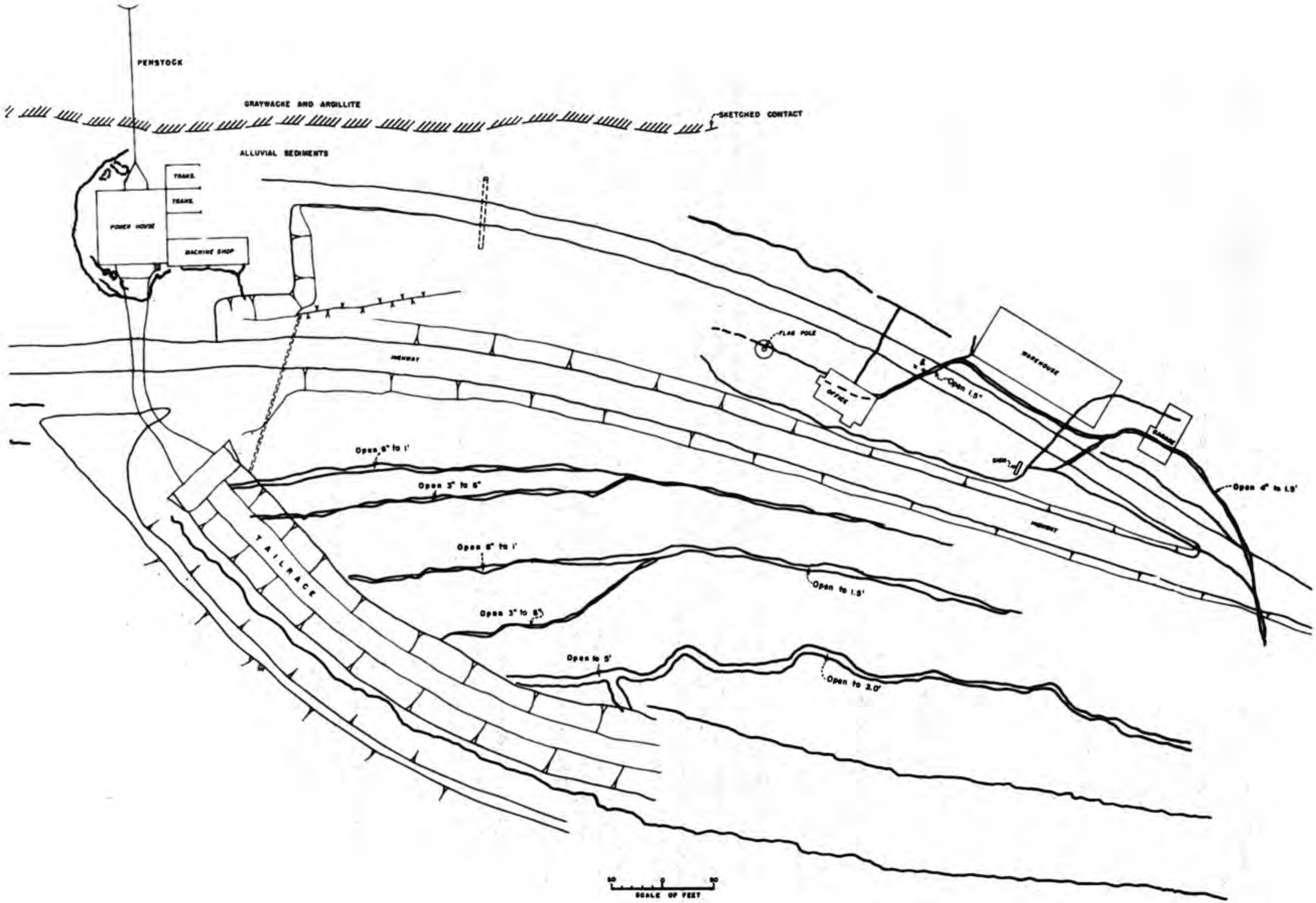
All evidence indicated that the penstock, surge tank, pile-supported anchor block, and powerhouse oscillated as an integral part of the area. Very little relative movement occurred between these features, although prominent surface settlement occurred in the anchor block area. A maximum residual separation of 1/16 to 1/8 inch was measured in the penstock ports of the powerhouse wall.

8. Cost Summary. The following tabulation summarizes the cost of the emergency work occasioned by the Alaska earthquake of 1964, the cost of rehabilitation of the intake structure and conduit for the pressure tunnel, and the cost of replacement of Eklutna Dam and spillway. A more detailed cost summary including contracts and purchase orders is given as appendix A.

Direct Costs

Construction by contract1/	$2,259,311	
Materials furnished by Government1/	87,678	
Purchased power1/	9,177	
Labor by Government forces1/	111,245	
Subtotal		$2,467,411
Service facilities		3,217

1/Shown in detail in appendix A.



783-D-779

Figure 7. --Sketch map of major earthquake cracks in Eklutna Powerplant area.

Indirect Costs

Designs and specifications--Denver	$ 91,180	
Engineering and inspection	129,991	
Administration and general expense	185,502	
Subtotal		$ 406,673
Total cost of emergency construction, rehabilitation of intake structure and conduit, and replacement of Eklutna Dam and spillway		$2,877,301

CHAPTER II. GEOLOGICAL CONSIDERATIONS

9. Geology of the Eklutna Area. The Knik River (fig. 8), Eklutna Lake, and Eklutna Creek lie in old glacial valleys covered with glacial till ranging in size from rock flour to large boulders. Where glacial and more recent streams have reworked this material, it has been sorted and somewhat bedded. In local areas, layers of nearly pure silt and clay are found interbedded with layers of coarser material. In the present stream channels and flood plain of the Knik River, well-rounded gravel and clean sand are found to a depth of at least 15 feet. Several intermittent advances of alpine glaciers have left glacial terrace remnants at high elevations along the Eklutna Creek Valley. The steep-sided valleys and flat flood plain area above the confluence of the Knik and Matanuska Rivers also are evidence of a long period of glacial erosion.

Figure 8. --The Knik Glacier--One of the many active glaciers in the Chugach Mountains. P783-908-234.

10. Geology of New Eklutna Project Features. Geologic data relating to the various Eklutna project features have been given in a previous Bureau publication. 1/ Also, M. H. Logan, in Geological Professional Paper 545-A, 2/ gives a detailed discussion of the geology of the various features in relation to the earthquake damage incurred. Figure 9, following, shows the topography and surface geology of the project features. Some general information and geologic data relating to the rehabilitation of the intake structure and replacement of the dam are given in the following subsections.

(a) *Intake Structure.* --Surface topography and bedrock contours obtained in 1951 from seismic data in the vicinity of the intake structure are shown on figure 10. Although foundation conditions in the area of the intake structure and conduit were well documented during the original investigations in 1951, three additional holes (DHI-10, -11, and -12, see fig. 11) were drilled along the conduit line in September and October 1964 in an effort to detect possible fracturing or shattering of the compact glacial till as a result of the earthquake. This exploration revealed no significant changes in the till foundation, and no evidence of foundation failure was observed during excavation for the new structure. Absence of structural damage to the existing intake structure and conduit segments is indicative that the glacial till foundation itself did not fail during the earthquake, but consolidation of the bedding material under these structures resulted in a horizontal movement toward the lake accompanied by a lesser amount of vertical displacement.

The new intake structure rests in firm glacial till. This material is a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders. It is extremely compact, and ripping was necessary before it could be removed by a dozer blade or dragline bucket. The location of exploration holes and surface geology in the area of the intake structure, as obtained in 1951 and amplified in 1964, are shown on figure 11.

(b) *Dam.* --The foundation exploration for a structure to replace Eklutna Dam began in August 1964 at a site near the downstream toe of the existing dam. An exploration program contemplating nine drill holes was formulated to determine the stratigraphic sequence of materials, competency of these materials, depth of stripping, and depth of the cutoff trench. Two of these holes (DH-1 and -2) were completed in the right abutment area and penetrated 30 to 50 feet of soft, wet silts and clays overlying firm, well-compacted glacial till. As the soft silts and clays were considered incompetent to support the proposed structures, the site was abandoned in favor of a location approximately 1,400 feet downstream. The selected site had previously been considered for a high dam and was investigated in 1951 by a series of drill holes and test pits (fig. 12). Two additional holes (DHS-13 and -14) were completed along the proposed spillway alinement in October 1964. The locations of both the 1951 and the 1964 exploration holes, as well as the surface geology, borrow area, and rock source, are indicated on figure 13.

The foundation at the selected site consists of firm glacial till with occasional thin, discontinuous lenses of sand and clay. The till is overlain on both abutments by a bed of gravelly clay ranging from 4 to 15 feet in thickness. This material has little stability when wet and numerous small slumps were evident in the area of the left abutment prior to construction of the dam. These slumps resulted from seasonal saturation of the gravelly clay by water from muskeg swamps on the gently sloping bench above the damsite. Much of this clay was removed by excavation of the cutoff trench, and drains were provided to intercept water from the muskeg swamp. The clay was completely removed along the spillway alinement so this structure would rest on firm glacial till.

1/ "Technical Record of Design and Construction for Eklutna Dam, Tunnel, and Powerplant," Bureau of Reclamation, March 1958.
2/ Logan, M. H., "Effect of the Earthquake of March 27, 1964, on the Eklutna Hydroelectric Project, Anchorage, Alaska," Geological Professional Paper 545-A, U.S. Geological Survey, 1967.

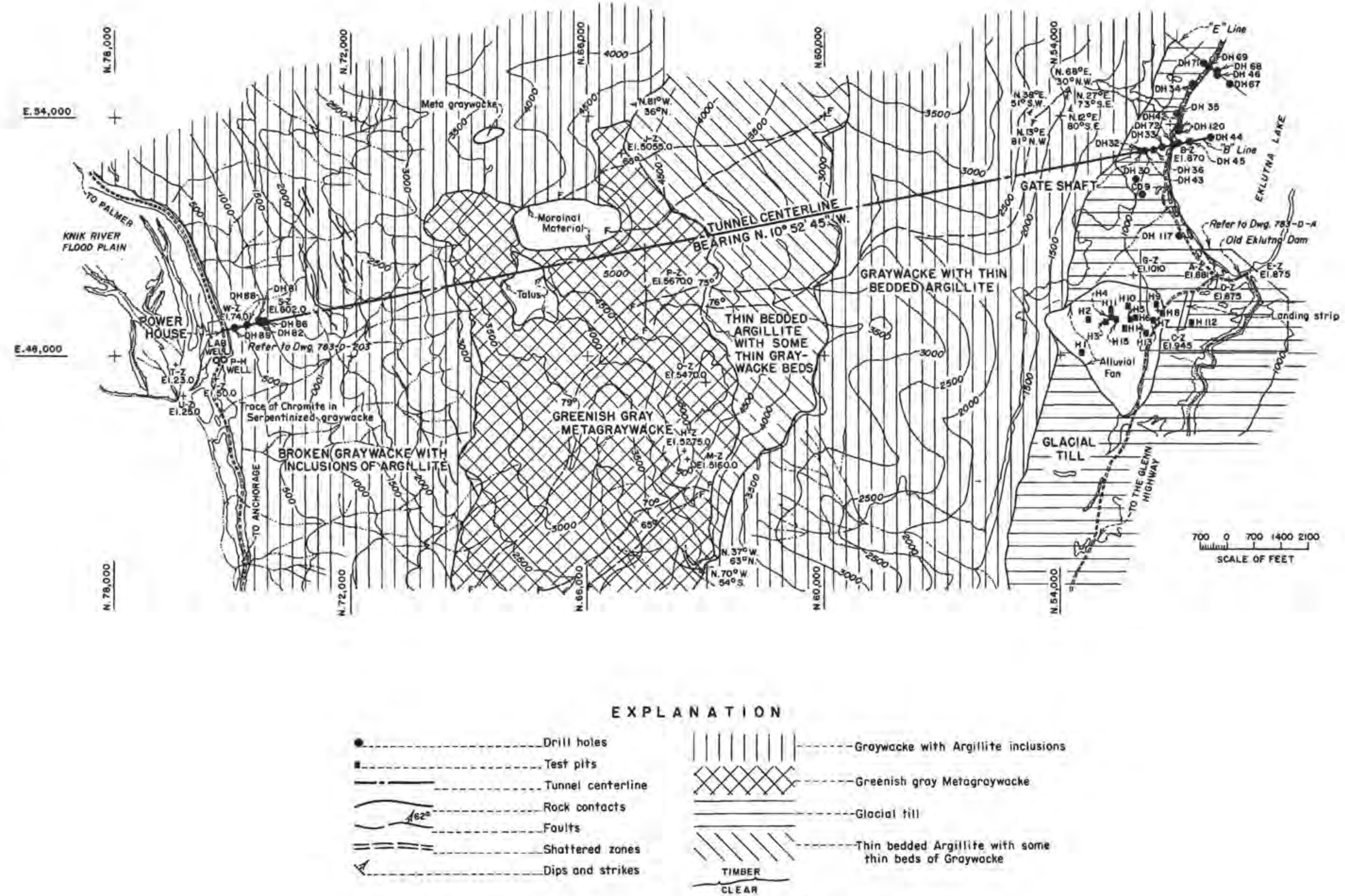


Figure 9. --Topography and surface geology of Eklutna project.

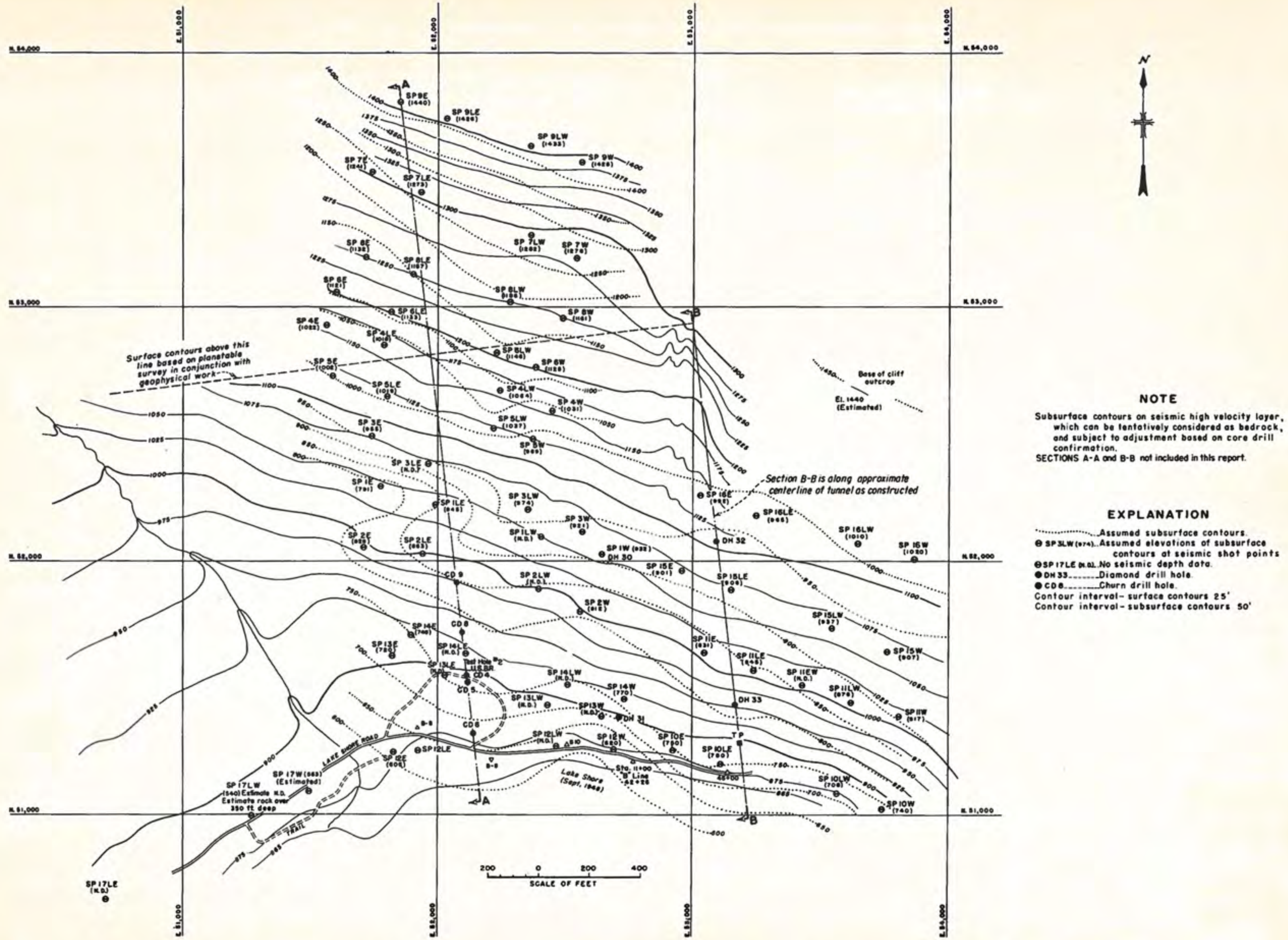


Figure 10.--Bedrock contours from seismic data for intake area, as obtained in 1951. From drawing No. 783-908-3.

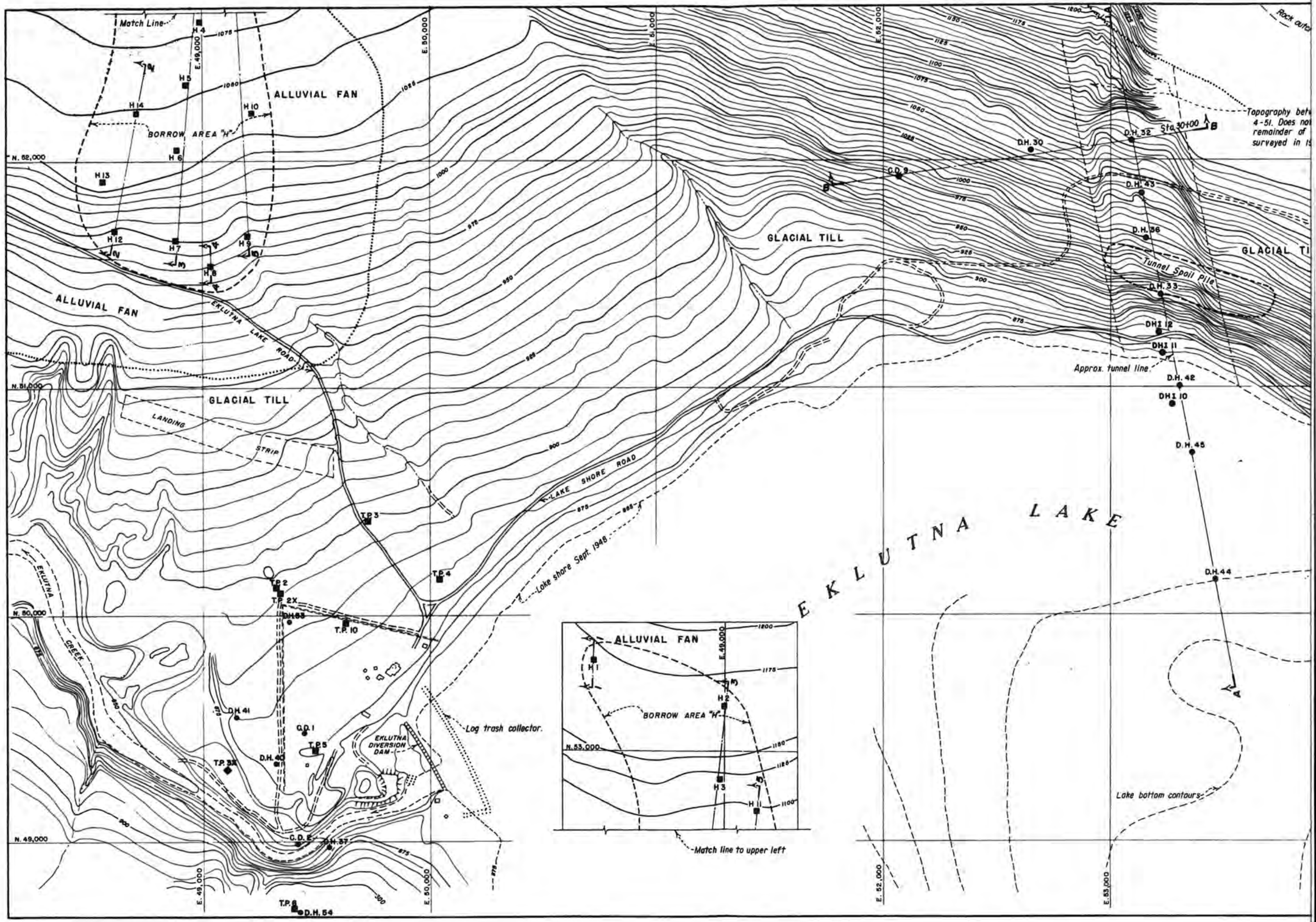


Figure 11.--Pressure tunnel inlet--Location
obtained in 1951 and a

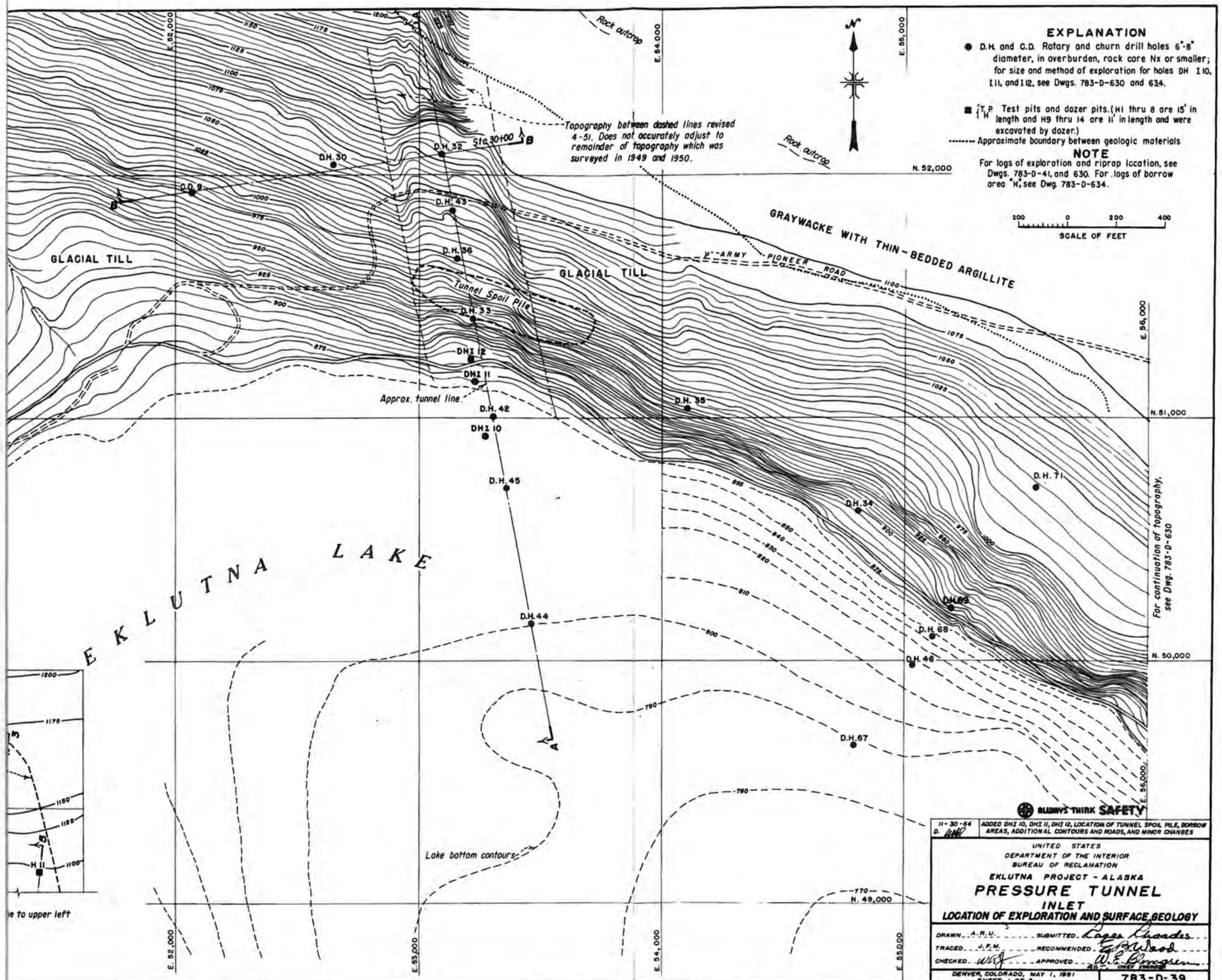


Figure 11. --Pressure tunnel inlet--Location of exploration and surface geology as obtained in 1951 and amplified in 1964.

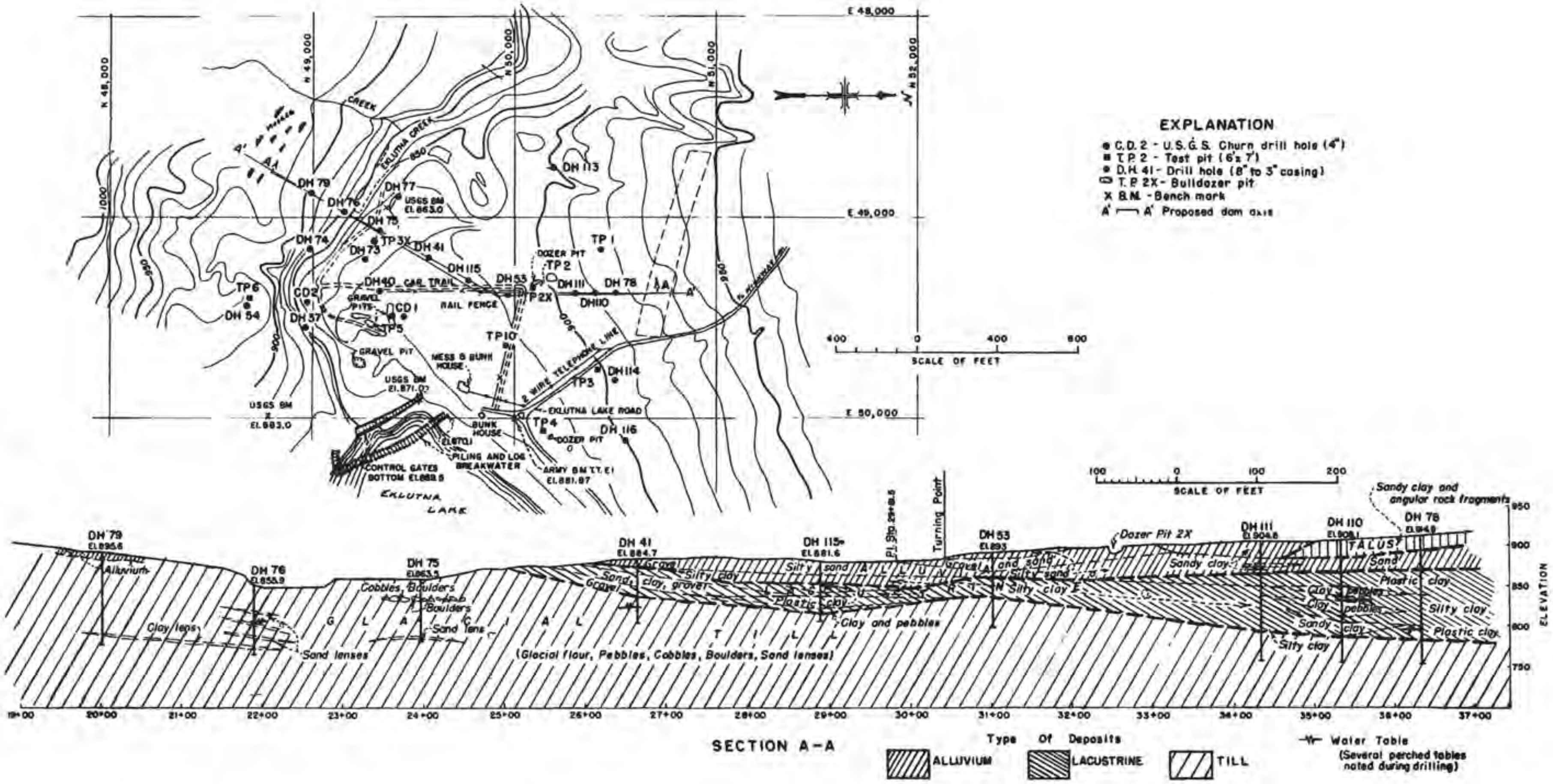


Figure 12. --Location of exploration and a geologic section made in 1951 in the damsite area. From drawing No. 783-D-604.

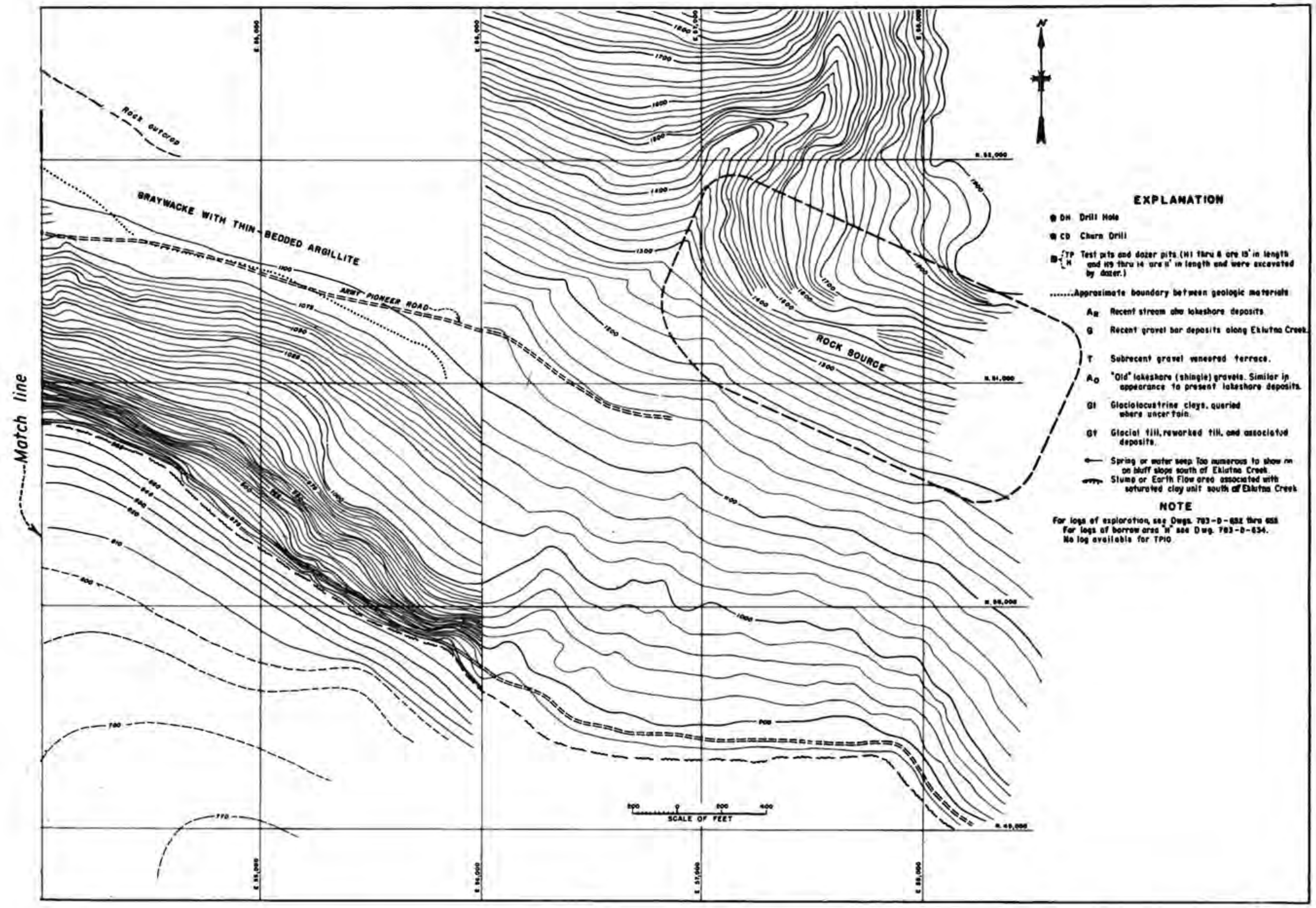


Figure 13.--Topography, surface geology, location of exploration (both 1951 and 1964), borrow area, and rock source for the replacement dam. (Sheet 1 of 2.) From drawing No. 783-D-651.

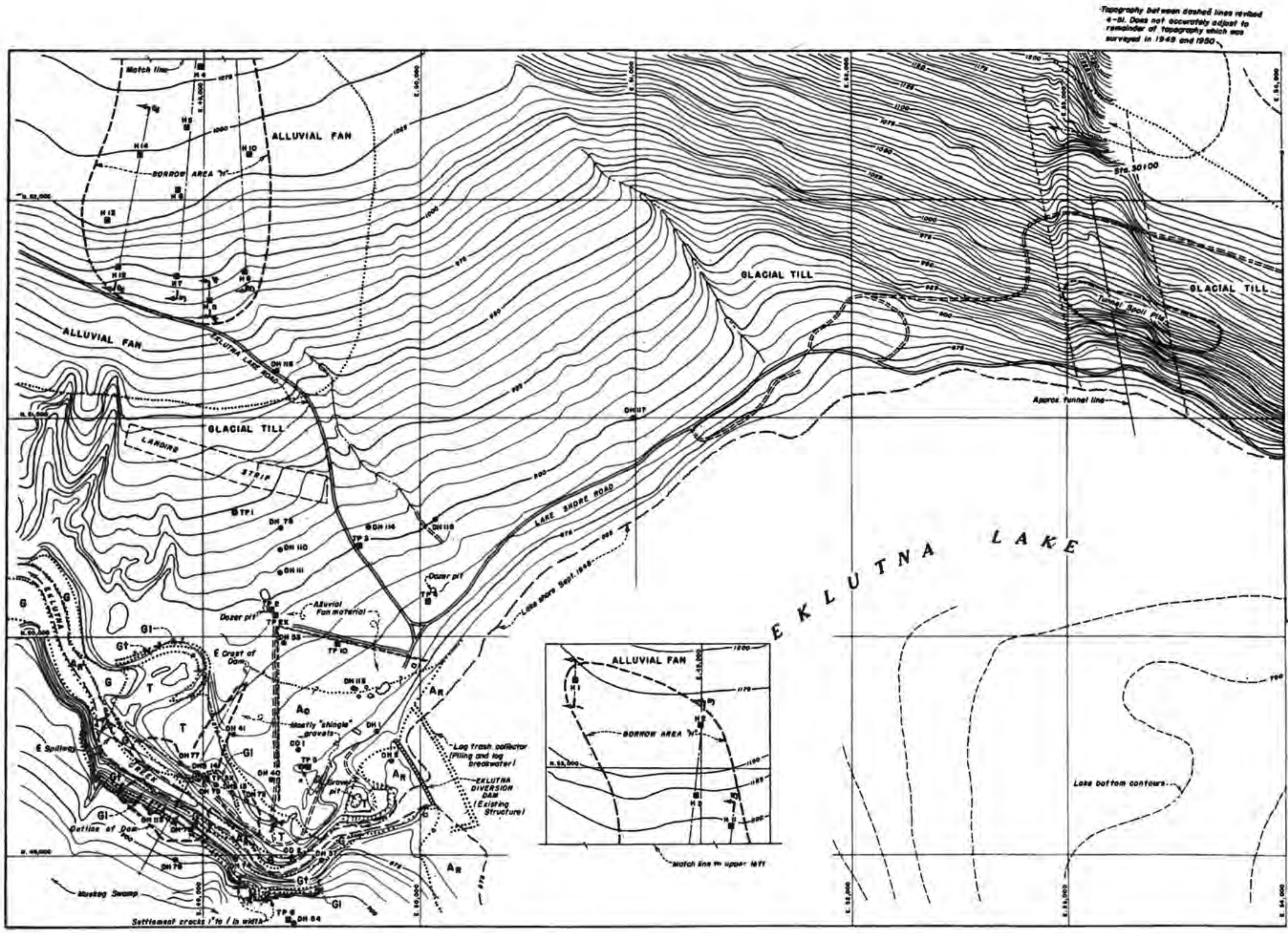
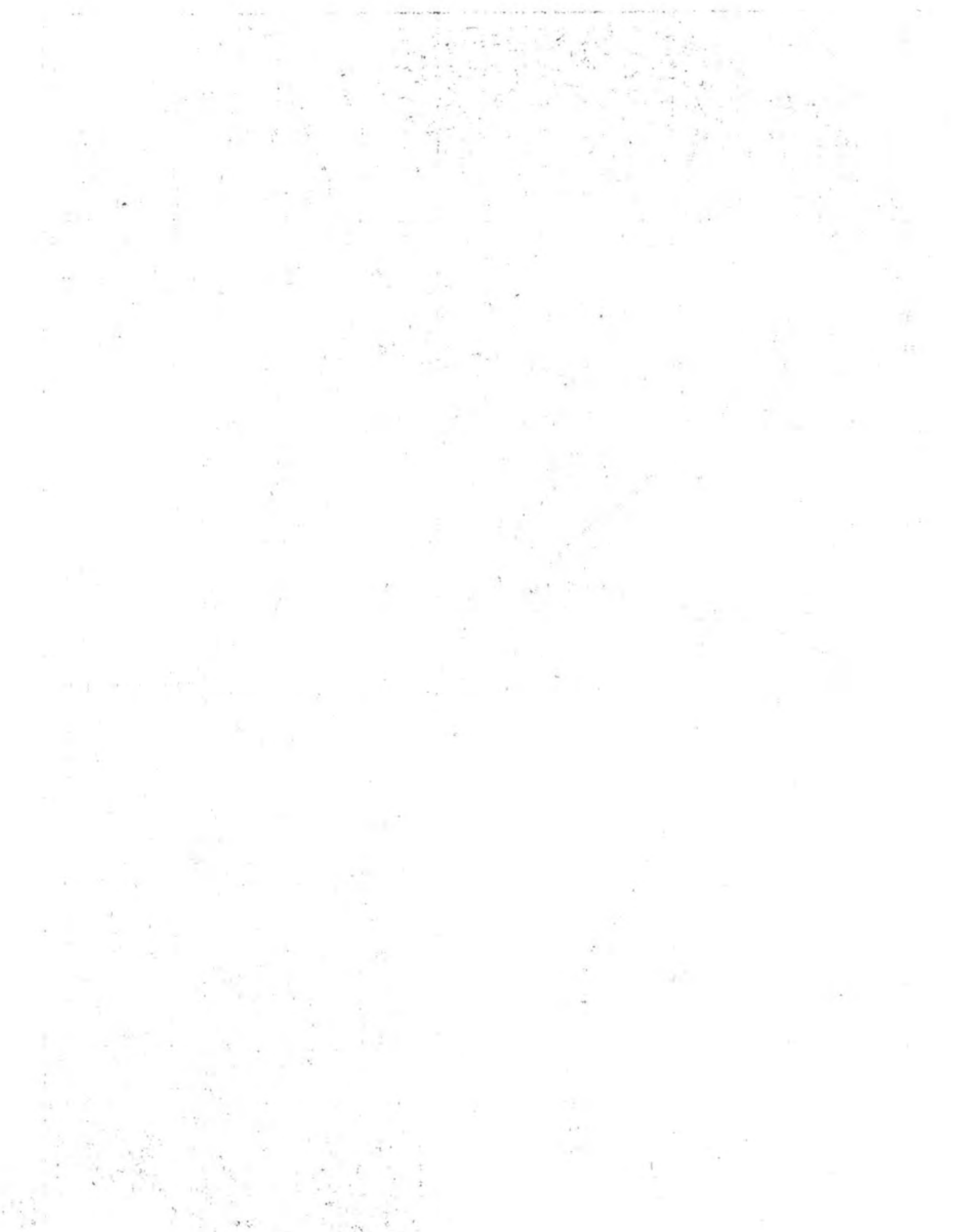


Figure 13. --Topography, surface geology, location of exploration (both 1951 and 1964), borrow area, and rock source for the replacement dam. (Sheet 2 of 2.) From drawing No. 783-D-651.



PART II
DESIGN

PART II--DESIGN

CHAPTER III. *Design*--REPLACEMENT OF INTAKE STRUCTURE AND REPAIR OF CONDUIT

11. General. The original arrangement of the inlet for Eklutna Tunnel, which provides water for Eklutna Powerplant, has been described in subsection 4(a), and an account of the post-earthquake investigations is given in subsection 7(b). An indication of the severity of the earthquake in the vicinity of the inlet may be obtained from figure 14, which shows major cracks along the shoreline of the lake. As indicated in the second reference cited, the earthquake caused displacement of the intake structure and disarrangement of some of the sections and joints in the 9-foot-inside-diameter (108-inch) precast concrete conduit. This disarrangement was so severe, and the potential for future disturbance was so great, as to necessitate ultimate removal or abandonment of 8 of the 14 sections of conduit and construction of a new intake structure about 222 feet downstream from the original structure. The separated joints in the six conduit sections that were not removed or abandoned were repaired. Four of the conduit sections and the original intake structure were left in place.

This chapter discusses the design of the new intake structure and the permanent repair of the conduit. An account of the temporary emergency repairs to the conduit, which were made earlier, is given in chapter VI.

12. Intake Structure. The original intake structure was a precast concrete horizontal structure 112 feet long and 26 feet 8 inches wide with trashracked openings only on top (subsec. 4(a)). The original intake structure and the precast concrete conduit had been placed under water on a prepared sand and gravel bedding in 1953; and investigation after the earthquake revealed that the earthquake had caused the shoreline materials, and the intake structure and precast conduit, to gravitate toward the center of the lake, thus opening the joints between many of the conduit sections and permitting large quantities of sand

Figure 14. --View of shoreline of Eklutna Lake in the vicinity of the intake structure after the earthquake. Intake structure is located at left center of photograph on shoreline. P783-D-44348-A.

and gravel to enter the conduit. Accordingly, in the design of the replacement intake structure, the new structure was keyed well into the more compact glacial till below the structure so as to deter any similar future movement, and was located closer to the shoreline to reduce the number of conduit sections and to permit adequate working space inside a cofferdam which was necessary for unwatering the site.

The new intake structure is much more compact than the original one. It consists of a rectangular reinforced concrete box structure, open and protected by trashracks on its top, front, and two sides. The trashracked portion is about 23 feet wide, 20 feet high, and 22 feet long in the direction of conduit flow. Overall length of the structure is 42 feet 4 inches. A bulkhead opening is provided for emergency closure of the conduit. The intake-structure is shown on figures 15, 16, and 17. Rock riprap 24 inches thick on 6 inches of gravel bedding was placed on a portion of the slopes adjacent to the inlet structure where it was felt that some protection against erosion was advisable. (See fig. 15.)

The new intake structure was constructed under specifications No. DC-6212.

13. Trashracks. (a) *General Description.*--To protect the powerplant turbines from oversize trash, six side trashrack sections, approximately 8.75 feet wide by 13.75 feet high, and four top trashrack sections, approximately 8.75 feet wide by 7.92 feet long, as shown on figure 17, were furnished under specifications No. DC-6212. Each of the six side trashracks provides a clear opening for the outlet works of 8 feet by 13 feet 6 inches, and each of the four top trashracks provides a clear opening of 8 by 8 feet.

The six side trashrack sections are installed in the vertical slots, and the four top sections are laid in recesses on top of the intake structure and tied down by clamp bars. The racks consist of 1-1/2- by 1/2-inch trash bars supported by 1-inch-thick load carrying members which transmit the load to the side members. The 1-1/2-inch clear opening between trash bars is considered sufficient protection for the turbines. The estimated weight of the 10 trashracks is 33,500 pounds.

(b) *Design.*--The trashracks were designed to permit a flow of 640 second-feet at a velocity of 1 foot per second through the net trashrack inlet area. The inlet structure was designed for a differential head of 20 feet at normal stresses; and the trashracks were designed for the same head but at a tensile stress of 36,000 pounds per square inch. This selection of stresses was used so the trashracks would reach their point of failure before the structure failed. The trashracks are removable in the event repairs or replacement become necessary.

14. Precast Concrete Conduit. It has been mentioned that the earthquake caused longitudinal separation of the joints of the precast concrete conduit as well as lateral displacement of some of them. A tabulation of the conduit joints showing their various displacements is included as figure 18. Specifications No. DC-6212 included removal of four precast concrete conduit sections (four additional sections and the original intake structure were abandoned but not removed) and repair of the damaged joints in the six conduit sections which were retained.

The specifications contemplated that the joints would be repaired by encasement in concrete collars, and a sketch illustrating the proposed repair of these joints by this method is shown as figure 19. Subsequent to preparation of specifications No. DC-6212, however, an alternative method was approved for repair of the conduit joints as discussed below. This method was permitted because it was believed to be more economical and would require less time than the originally specified method, and time was a very important consideration.

The alternative method consisted of the installation of expandable stainless steel rings inside the pipe at the joints. The rings were 1/2 inch thick and 20 inches wide. One-inch bolts with four nuts and beveled washers were provided to expand the ring against the inside of the pipe; and after expansion the rings would be welded in place. Irregularities between the rings and the inside of the pipe were to be filled with dry-pack mortar. The alternative method is illustrated in figure 20. Specifications for repair by this method were issued concurrently with specifications No. DC-6212 as supplemental notice No. 1. The contractor elected to use this alternative method as discussed in section 60.

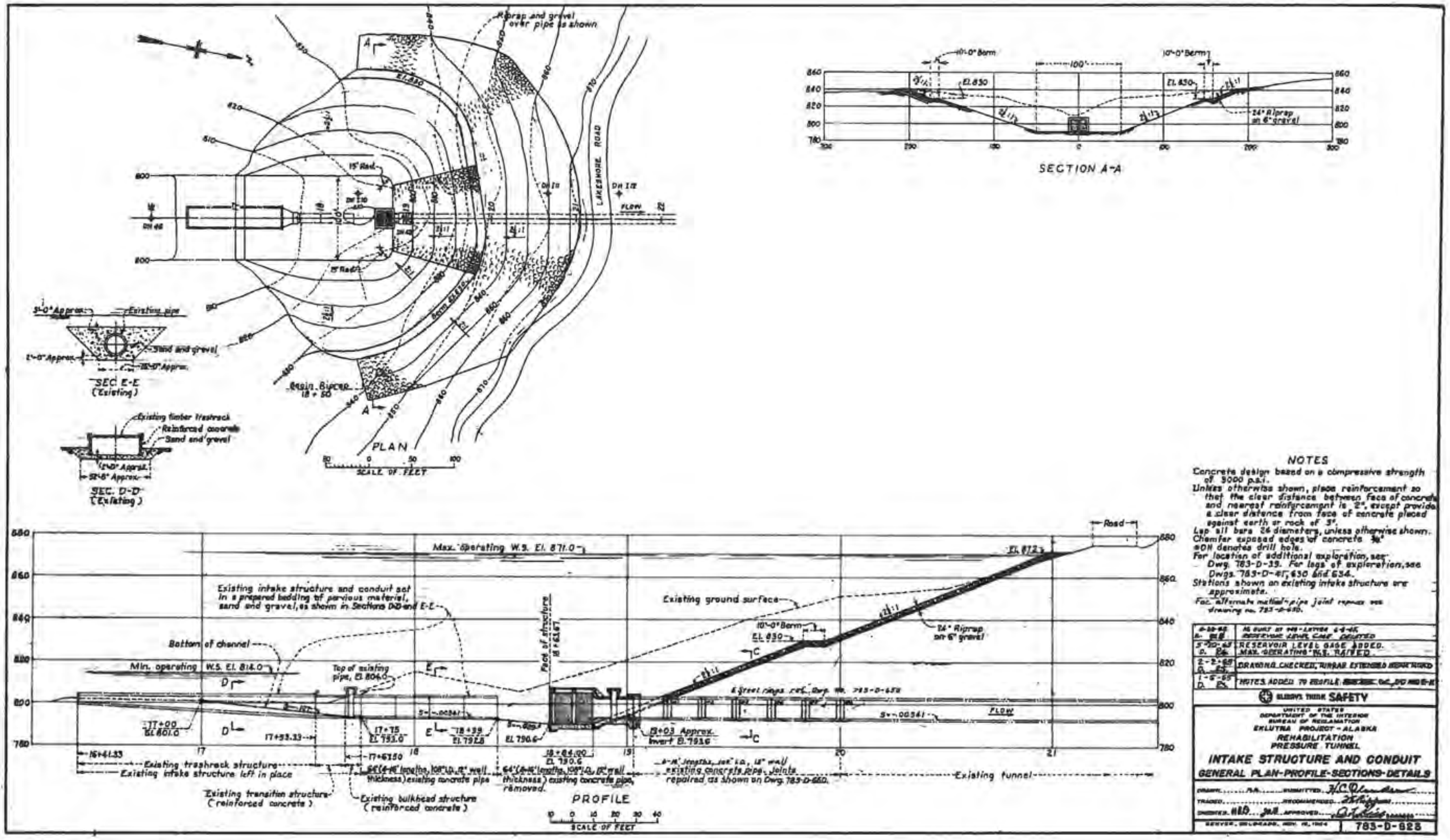


Figure 15. --Plan and elevation of new intake structure and rehabilitated conduit. From drawing No. 783-D-623, revised June 30, 1965.

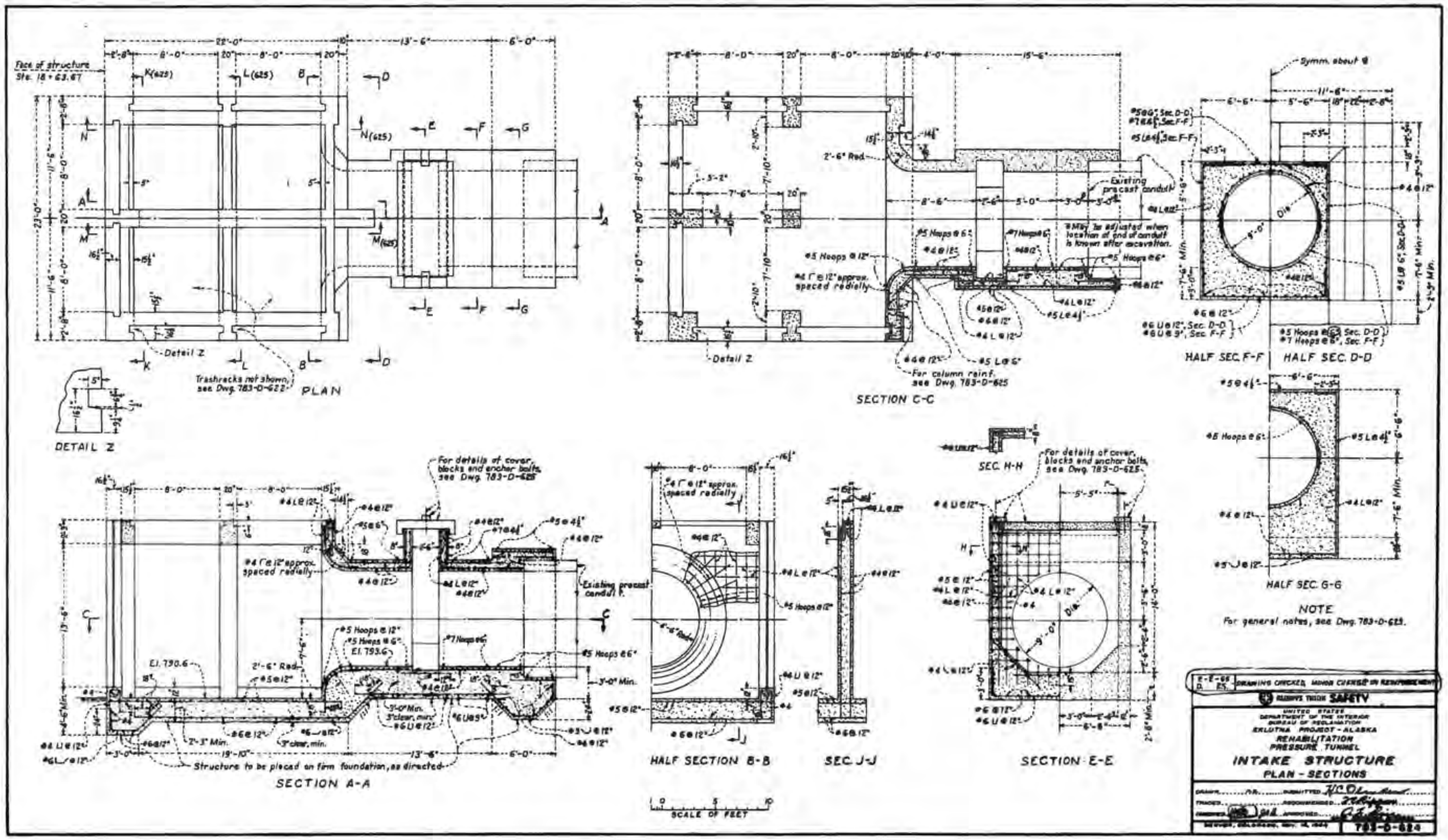


Figure 16. --Plan and sections of new intake structure.

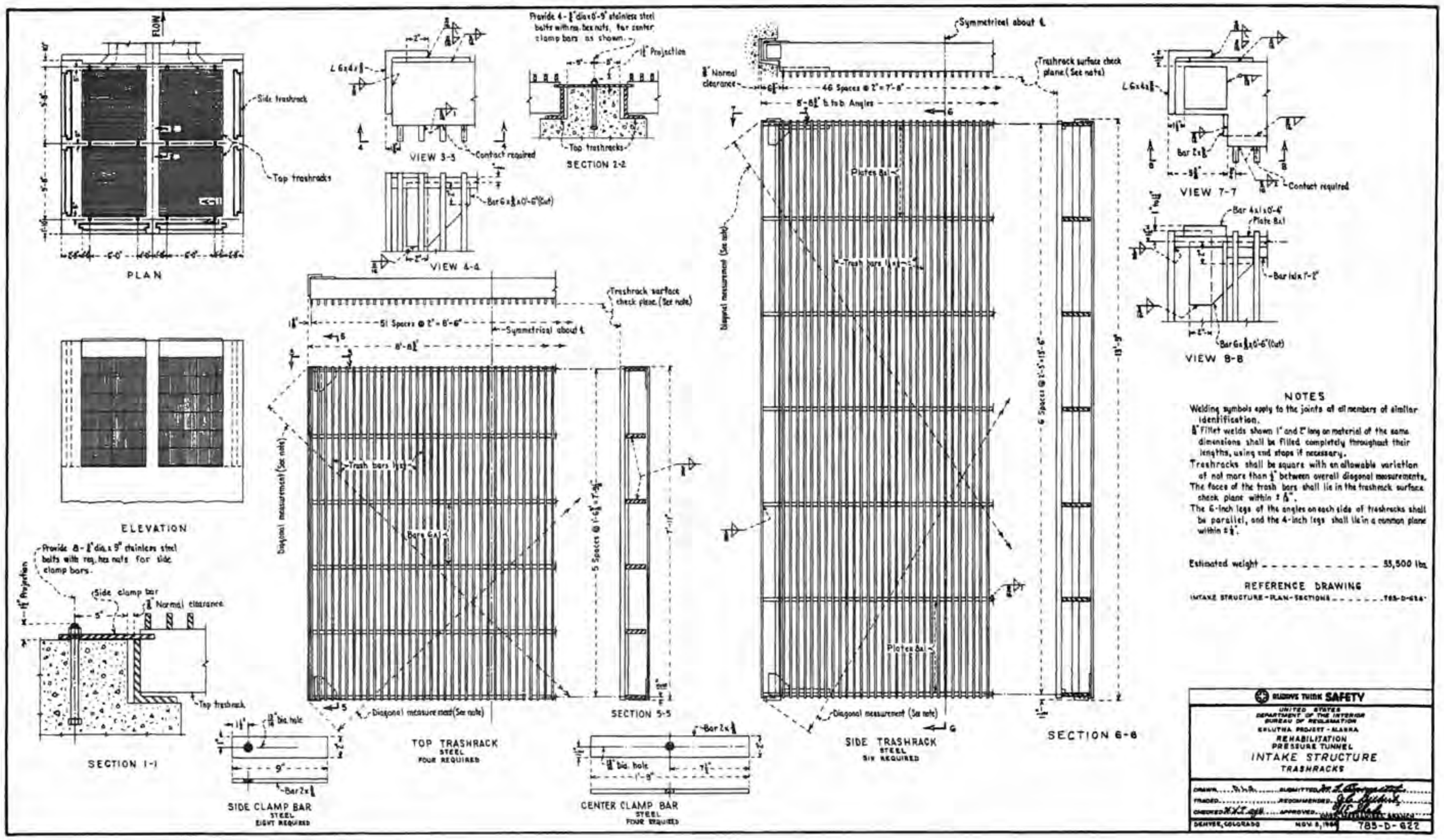
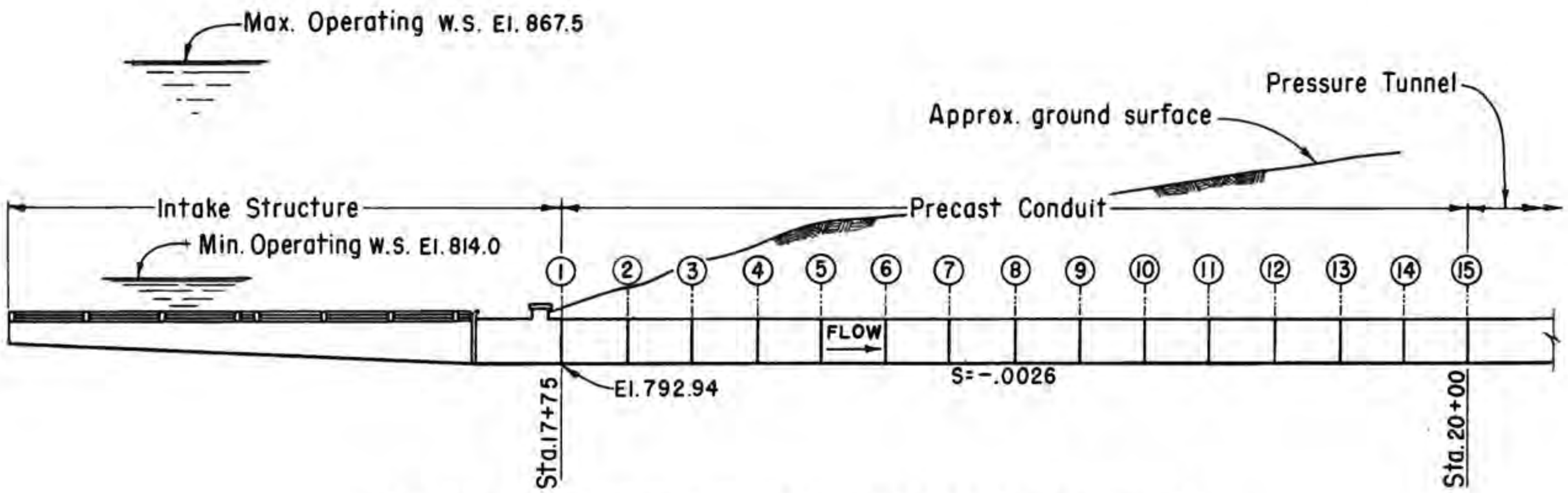
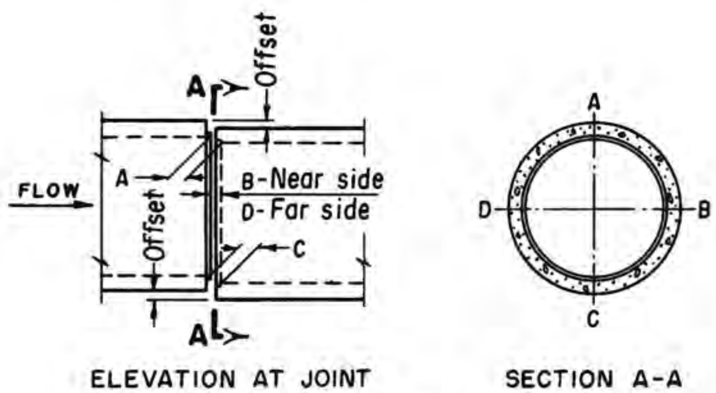


Figure 17. --Trashracks for the new intake structure.



INTAKE STRUCTURE AND PRECAST CONDUIT
ELEVATION



PRECAST CONDUIT

PRECAST CONDUIT											
JOINT SEPARATIONS					OFFSET	JOINT SEPARATIONS					OFFSET
JOINT	A	B	C	D		JOINT	A	B	C	D	
1	1 7/8"	1 1/8"	3/8"	1 1/8"	0	9	1 3/4"	2"		1 3/4"	0
2	1"	1/2"	5/8"	7/8"	0	10	3 1/2"	3 1/4"	2"	2 1/2"	0
3	1 1/4"	1"	1 3/8"	1 1/2"	0	11	3"	3 1/2"		3 3/4"	0
4	1 1/4"	1 1/2"	1 3/4"	1 1/2"	0	12	1 1/2"	1 3/4"	2"	1 1/2"	0
5	2 1/2"	1 7/8"	7/8"	1 5/8"	0	13	2 3/4"	2 1/2"	1 1/2"	1 1/2"	0
6	10"	10"		10"	4"	14	3/4"	1 1/4"		1 1/4"	1
7	6 1/2"	6 3/4"		8"	4 1/2"	15	2 3/4"	2 1/8"		1 1/2"	0
8	3 3/4"	3"		3 3/4"	0						

783-D-773

Figure 18.--Eklutna Powerplant intake structure and conduit--Joint separations after earthquake. From drawing No. 783-D-773.

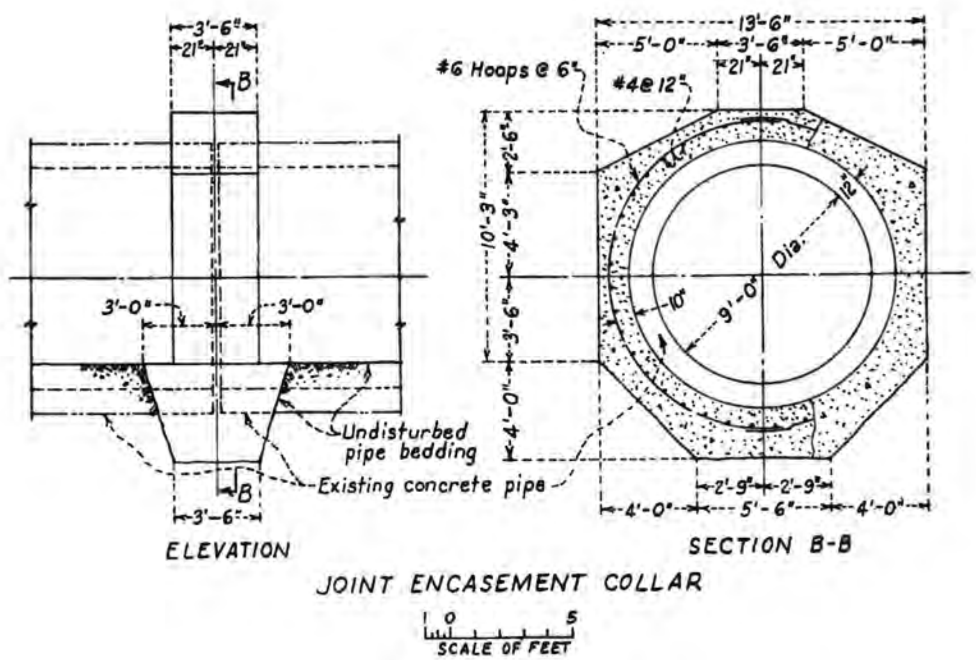


Figure 19.--Sketch illustrating method of making joint repairs for precast concrete pipe conduit as originally included in the specifications. From drawing No. 783-D-771.

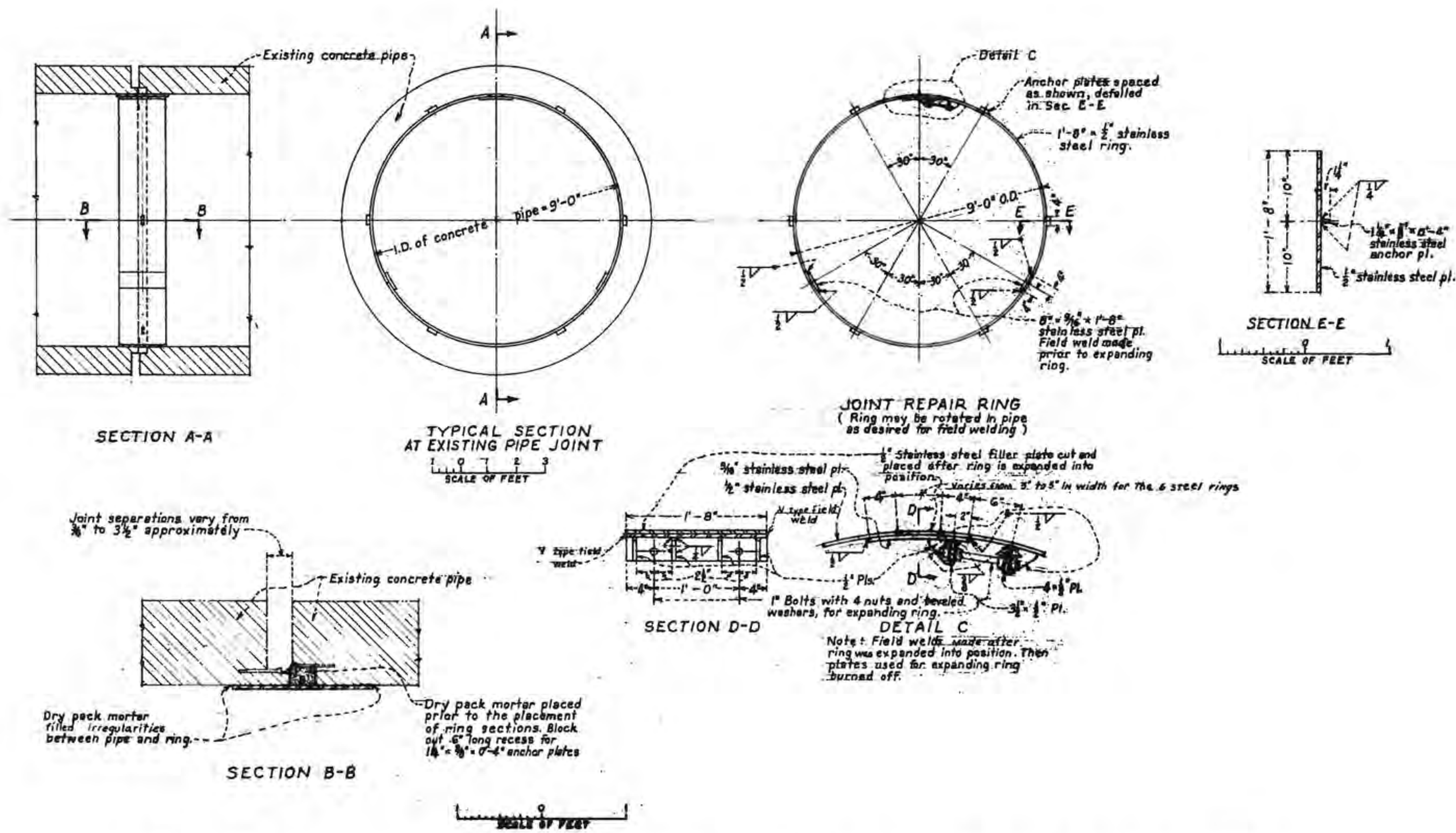


Figure 20.--Sections illustrating alternative method of making joint repairs for precast concrete conduit. This method was permitted by supplemental notice and was actually used by the contractor. From drawing No. 783-D-650.

CHAPTER IV. Design--EARTH DAM AND SPILLWAY

A. Earth Dam

15. Condition of Existing Dam. Immediately following the earthquake of March 27, 1964, the existing low dam at the outlet of Eklutna Lake was inspected by project forces. This inspection and subsequent early inspections revealed no apparent damage. The frozen ground near the surface apparently moved as a mass during the earthquake and no cracks were formed in the area of the dam and spillway. Later inspections, however, revealed that some consolidation of the alluvium beneath the frozen layer had occurred resulting in the development of a void. By July 1964, it became apparent that the upper layers of alluvium under the spillway gate structure had begun to subside into the void. Two cracks approximately 1 inch in width had developed--one in the base of the spillway slab and one in the sill of the gate structure. Also, a large part of the base slab obviously did not have foundation support as a result of the void. Figure 21 is a view of the spillway gate structure.

A representative was sent from the Denver office to inspect this damage and to determine what temporary repairs should be made and how the spillway could be operated (if at all) until permanent repairs could be made. He determined that the spillway could not safely resist water pressure against the gates, and that it would be unsafe to hold the reservoir water level above elevation 859.39 (the bottom of the gates). He concluded that the gates should be kept open until the structure could be replaced or repaired. Subsequent studies indicated that instead of repairing the existing dam and spillway, it would be less expensive to build a new replacement dam and spillway near the downstream toe of the existing structure.

16. Location of Replacement Dam. Explorations for a replacement dam near the location of the existing dam revealed highly plastic clay in the foundation which would not support the spillway structure. However, a suitable foundation for the spillway was found

Figure 21. --View of spillway gate structure of existing dam. P783-906-2358NA.

about 1,400 feet downstream. The downstream location also simplified the diversion of Eklutna Creek; and construction there would not interfere with the operation of Eklutna Lake.

17. Conference on Replacement Dam. On August 25, 1964, design and planning engineers from the Denver office and representatives from the Alaska District headquarters met to discuss the practicability of increasing the capacity of the lake or altering the turbines or generators to provide additional peaking capacity. It was determined that it would be impracticable to consider the design of the new Eklutna Dam in such a way that the capacity of the lake could be materially increased either initially or in the future. Also, changes at the generating plant would require a shutdown of the project, which could not be tolerated for several years--or until sufficient additional generating capacity was available in the area. Accordingly, the replacement dam was built with the spillway crest only 3.5 feet higher than the existing spillway, or to elevation 871.0, which raised the active storage capacity from 160,000 acre-feet to 175,000 acre-feet, or about 10 percent. However, the crest of the new dam itself was raised 16 feet, which had the effect of greatly increasing the surcharge storage capacity in the event of flood.

18. Principal Features of Replacement Dam. The principal features involved in the construction of the replacement structure for Eklutna Dam were an earth and rock fill dam embankment and a reinforced concrete spillway structure. The arrangement of the features is shown on figure 22, and the location of the replacement dam with relation to Eklutna Lake, Eklutna Tunnel, the existing dam, and the dam embankment borrow areas is shown on figure 13.

The dam embankment is approximately 815 feet long at the crest. It has a crest width of 30 feet and a crest elevation of 891.0, which is approximately 51 feet above the streambed. The dam has a 3 to 1 upstream slope and a 2 to 1 downstream slope. A rockfill berm at elevation 856.5 extends for a distance of 83 feet downstream from the dam to provide increased stability. The berm is about 15 feet thick and is a continuation of a rockfill slope protection on the left abutment, which it was considered might be subject to movement. A cutoff trench excavated to firm clayey soil is provided just upstream of the centerline of the dam, as described in subsection 19(b).

The zone 1 portion of the dam embankment consists of a central impervious core of selected clay, silt, sand, and gravel compacted by tamping rollers to 6-inch layers. Flanking the zone 1 portion both upstream and downstream is a zone 2 portion consisting of selected sand, gravel, and cobbles compacted in 12-inch layers by the treads of a crawler tractor. The outer or zone 3 portions of the dam embankment consist of rockfill material to 36-inch maximum size placed in 3-foot layers. There is no special slope protection other than that afforded by the zone 3 rockfill on the faces of the dam and the left abutment.

The spillway consists of an approach channel, an inlet structure, a rectangular conduit, and a chute and stilling basin. The ungated crest of the spillway is constructed in the inlet structure. (See sec. 32.)

19. Foundation Treatment. (a) *Stripping.*--The area to be occupied by zoned embankment materials was stripped of organic material, soil containing roots larger than one-fourth inch in diameter, loose rock and other objectionable material.

The slump areas under and adjacent to the left abutment of the dam were stabilized by stripping the area back on a slope of 3 to 1 and draining it through a blanket of sand, gravel, and rockfill. The graded area was extended upstream and downstream to provide a foundation for the left abutment blankets shown on section A-A of figure 22.

(b) *Cutoff Trench.*--A continuous cutoff trench was provided beginning at station 1+00 and ending at station 9+00. The trench was designed to intercept pervious strata near the ground surface. The maximum depth of the trench was specified to be 20 feet from the surface of the stripped foundation. Pervious strata below this depth are blanketed by overlying soil to the extent that they were not considered a hazard to the dam. A minimum depth of cutoff trench of 5 feet was specified to key the zone 1 material into the foundation.

20. Materials. (a) *General.*--The materials distribution chart for replacement of Eklutna Dam, figure 23, shows the sources of materials and their utilization in the embankment.

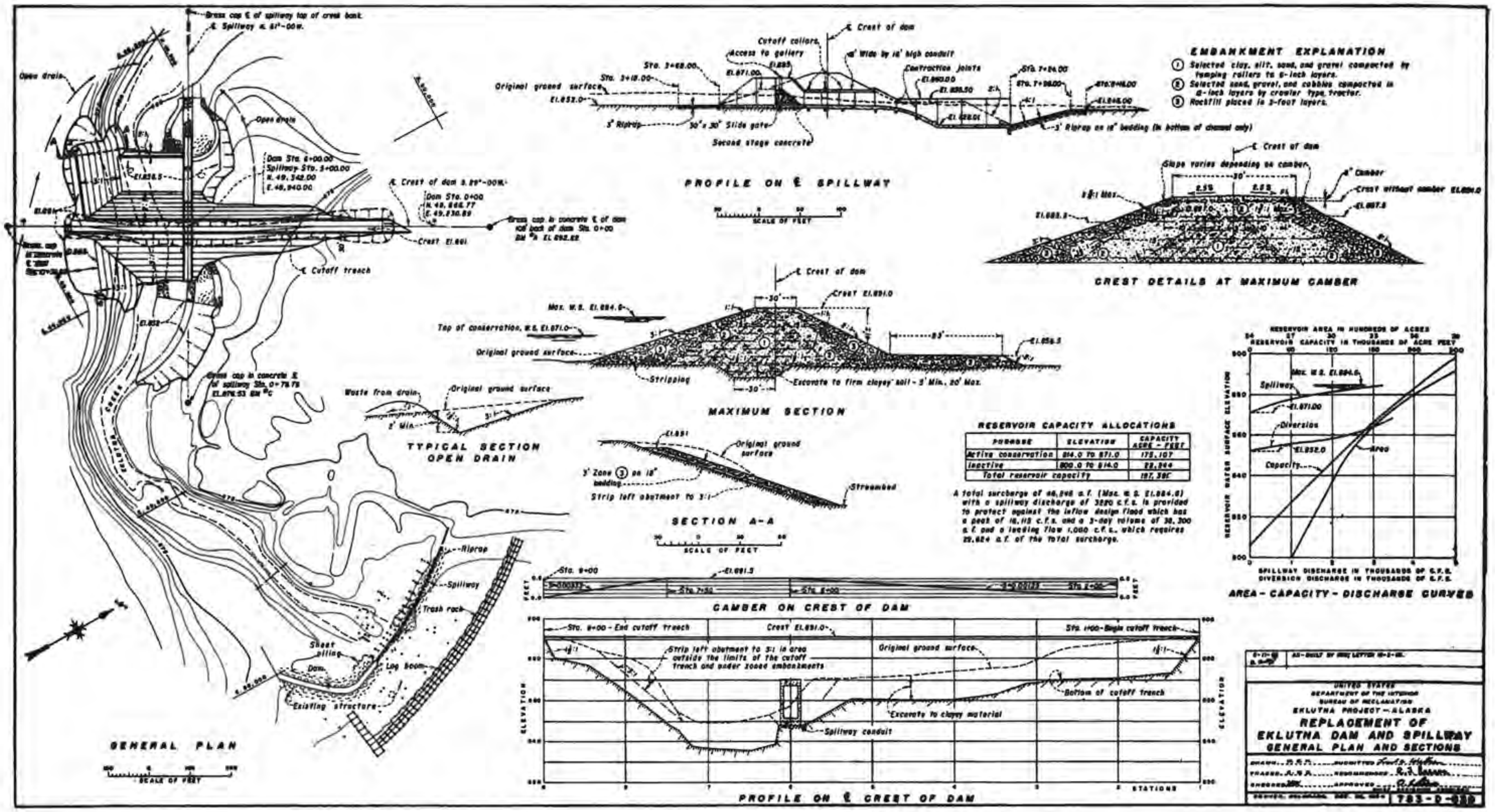
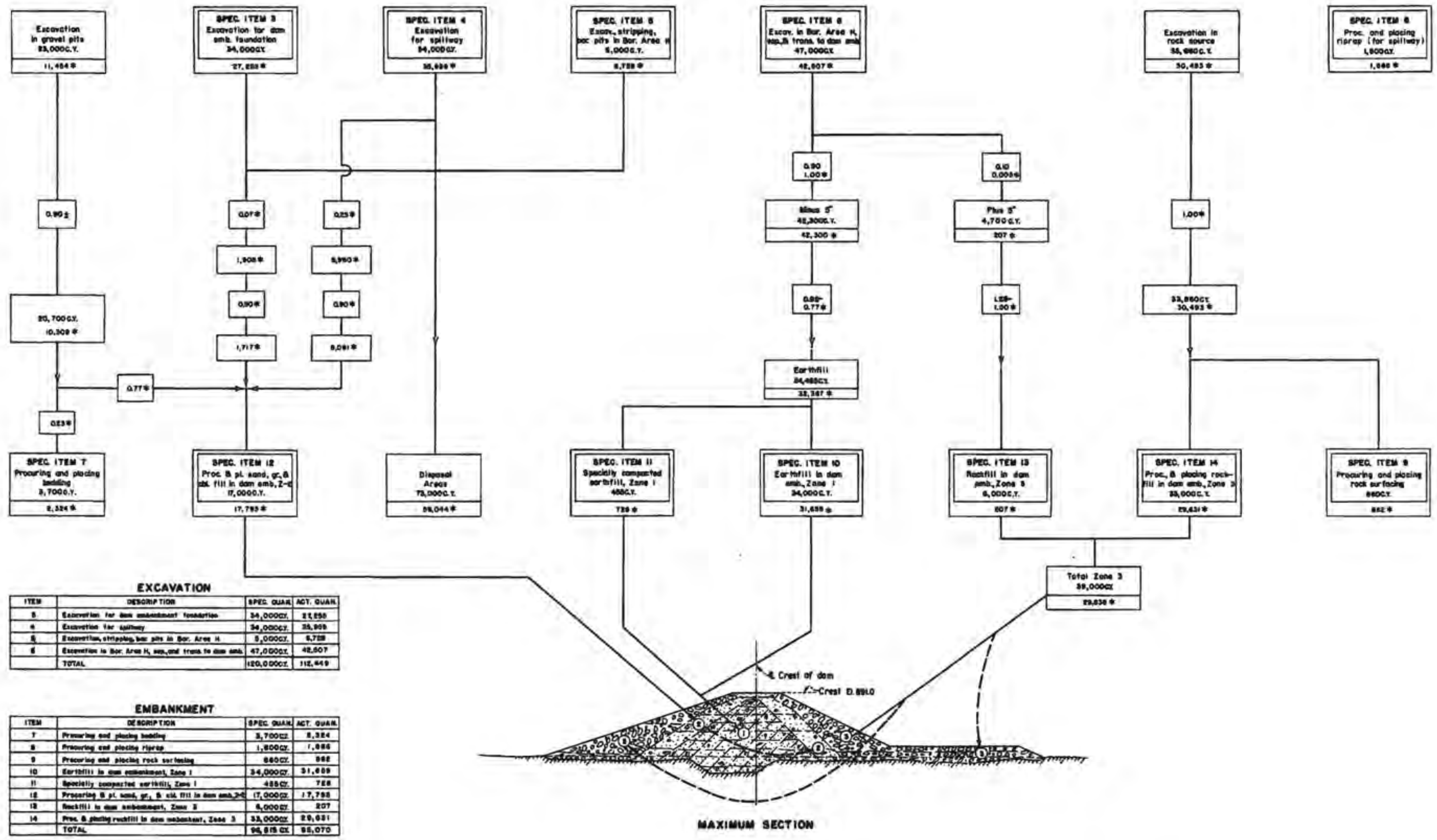


Figure 22. --General plan and sections for replacement of Eklutna Dam and spillway.



EXCAVATION

ITEM	DESCRIPTION	SPEC. QUAN.	ACT. QUAN.
3	Excavation for dam embankment foundation	34,000C.Y.	27,250
4	Excavation for spillway	34,000C.Y.	35,959
5	Excavation, stripping, bor. pits in Bor. Area H	5,000C.Y.	5,728
6	Excavation in Bor. Area H, sep., and trans. to dam emb.	47,000C.Y.	42,507
	TOTAL	120,000C.Y.	112,449

EMBANKMENT

ITEM	DESCRIPTION	SPEC. QUAN.	ACT. QUAN.
7	Procuring and placing bedding	3,700C.Y.	2,324
8	Procuring and placing riprap	1,800C.Y.	1,886
9	Procuring and placing rock surfacing	660C.Y.	862
10	Earthfill in dam embankment, Zone 1	34,000C.Y.	31,659
11	Specially compacted earthfill, Zone 1	455C.Y.	728
12	Procuring & pl. sand, gr., & cbl. fill in dam emb., Z-2	17,000C.Y.	17,793
13	Rockfill in dam embankment, Zone 3	6,000C.Y.	207
14	Proc. & placing rockfill in dam embankment, Zone 3	33,000C.Y.	29,631
	TOTAL	96,615 C.Y.	95,070

Figure 23.--Materials distribution for replacement dam. From drawing No. 783-D-660.

(b) *Required Excavation.* --The specifications did not require the use of any materials obtained from required excavation for the foundation of the dam and for the spillway structure. This material was expected to be a mixture of gravel and glacial till containing considerable organic matter and oversize particles at or near a saturated condition. Draining and processing of this material was not expected to be practicable. Accordingly, all required excavation was estimated to be wasted in disposal areas near the dam. But, as the materials distribution chart indicates, the required excavation produced better material than had been anticipated, and provided a substantial percentage of the required sand and gravel fill.

(c) *Zone 1 Borrow Area.* --Material excavated from borrow area H was processed to remove plus 5-inch rock from the silty sand or silty clay material for zone 1 of the embankment. This oversize material was used for portions of zone 3. Control of the separation process and depth and location of excavation in the borrow pits was exercised to the extent necessary to insure a blending of the various clay, silt, sand, and gravel strata into a uniform impervious material. Based on the test pit data and the Bureau's experience with similar material, the oversize material was estimated to average 10 percent of the excavation quantity, and the shrinkage factor of the zone 1 material was estimated to be approximately 0.82.

(d) *Stripping in Borrow Area H.* --Stripping in this borrow area was limited to the borrow pits actually used and to depths sufficient to remove all vegetation, humus material, and major root systems (roots larger than about one-fourth inch in diameter).

(e) *Zone 2.* --Sand, gravel, and cobbles for zone 2 were obtained from gravel bars along Eklutna Creek and from required excavation. Costs of stripping or selecting to obtain suitable material were included in the cost of the fill. Borrow area limits were not designated because specific gravel bars were not outlined in the design data. There was therefore no reason to exclude any source containing suitable material if it was at least 200 feet from the dam. (Material 200 feet or less from the dam was excluded by the specifications.)

(f) *Zone 3.* --Zone 3 rockfill was to be obtained from oversize material from the earthfill separation plant, and from talus deposits in the rock source. For estimating purposes, 10 percent of the separated material from borrow area H was assumed to be plus 5-inch cobbles and rock having a swell factor of 1.28.

21. Zoning. (a) *General.* --The area was explored for construction materials in 1951, in connection with designs for a dam having about three times the volume of the replacement dam. These investigations outlined an alluvial fan containing a silty, clayey, bouldery soil that could be processed to produce impervious material; talus deposits containing potential rockfill; and sand and gravel deposits of submarginal quality described as shingle gravel. In 1964, investigators of the site outlined gravel bars along Eklutna Creek that contained limited quantities of sand and gravel with more acceptable characteristics than the shingle gravel.

The stripping and processing required to produce zone 1 earthfill was estimated to make its cost nearly equal to that for gaining access to and hauling out rockfill, zone 3; or for stripping of gravel bars along the river for zone 2. Consequently, it appeared that no one of the three zones had any great economic advantage over the others as far as materials were concerned.

From a stability standpoint, the embankment was so low that no inherent stability problem was anticipated even though a weak foundation underlies the site. However, in view of the arctic conditions prevailing at this location, a rocky, porous outer shell was desirable to insure permanence of the neatlines and grades of the outer slope under arctic freezing and thawing cycles, without frequent maintenance.

Based on preceding considerations, the embankment was zoned to have a minimum impervious earthfill core, zone 1; outer shells of talus rock, zone 3; with core and shell zones separated by a transition zone of minimum width, zone 2. Zone 2 is composed of sand and gravel of a gradation that will prevent the movement of fines from the earthfill into the rockfill.

(b) *Zone 1 Clay, Silt, Sand, and Gravel.* --Zone 1 material provides an impervious water barrier for the dam. All zone 1 material was obtained from borrow area H and was processed through the separation plant. The operations of the borrow area and separation plant were conducted in such a manner that various strata of clay, silt, sand, and gravel were blended into a uniform impervious material and the plus 5-inch rock was removed from the material before it was brought to the fill.

(c) *Zone 2 Sand, Gravel, and Cobbles; and Bedding.* --Materials for zone 2 in the embankment and the bedding material in the left abutment blankets are selected sand and gravel having a gradation that will prevent the movement of fines from the underlying material into the rockfill.

Section A-A (fig. 22) shows the left abutment blankets upstream and downstream from the dam. The 18-inch layer of bedding shown in section A-A is continuous above approximate elevation 850 from zone 2 to the upstream and downstream edge of the blankets, so there is no direct contact between zone 3 and the left abutment.

(d) *Zone 3 Rockfill.* --Zone 3 is composed of rockfill consisting of plus 5-inch material from the zone 1 separation plant, supplemented by material from the rock source. The larger rock fragments were selected for upstream slope protection. The design of the structure was based on the assumption that zone 3 would be highly pervious; consequently, rockfill containing enough fines to fill the voids was unacceptable.

22. Slope Protection. Eklutna Dam occupies a position that is sheltered from Eklutna Lake by the topography and existing structures; consequently, the rockfill was considered to provide adequate slope protection. No special riprap layer was provided.

23. Placement Limits. Because of the remote location of this structure, it was desirable to maintain good construction control. Owing to the small quantity of material involved, the frequency of testing was greater than that recommended by the Earth Manual,1/ which is one field density test for each 1,000 cubic yards of zone 1 material placed. Also, because of the small amount of material involved, it was required that at least five record percolation-settlement tests be run, or about one test for every 6,000 cubic yards of material.

In addition to the minimum testing program, particular attention was to be given to the roller compaction to insure that it was accomplished in accordance with the specifications. Regardless of the low fill height, placement moisture content was to be controlled to average no more than optimum. The specifications requirement for material separation acted as a partial control on this factor, since it is doubtful that the processing could be accomplished at water contents greater than optimum. On the other hand, placing of the material in a condition more than 3 percent dry of optimum was to be avoided.

No difficulties were anticipated in placing zone 2 sand, gravel, and cobblefill. Control was to be largely by visual inspection with particular attention given to the thickness of lift and the specified compactive effort. Four or five field density tests were to be made, however, for record purposes.

No control tests were required for zone 3 rockfill. Visual inspection was to be directed toward obtaining a good distribution of rock sizes and to limiting the amount of fines (minus No. 4 material) to less than the amount that would completely fill the voids in the plus No. 4 material.

B. Hydrologic Requirements

24. Design Flood Studies. The design storm was based on an inplace analysis and maximization of the September 16-17, 1951 storm. A retention loss rate of 0.15 inch per hour was applied to increments of the design storm to determine the runoff. (See fig. 24.) The excess precipitation was applied to a unit hydrograph, and a base flow of 1,000 second-feet was added to the first peak of the total hydrograph. The time interval between major storms in this area is about 4 days. Accordingly, a recurring flood was started 4 days after the start of the design rainflood. The combined inflow design flood had a peak flow of 16,115 second-feet, a 3-day volume of 38,300 acre-feet, and a 7-1/2-day volume of 64,200 acre-feet, which was used in the final design of Eklutna Dam.

1/Earth Manual, first edition revised, Bureau of Reclamation, 1963.

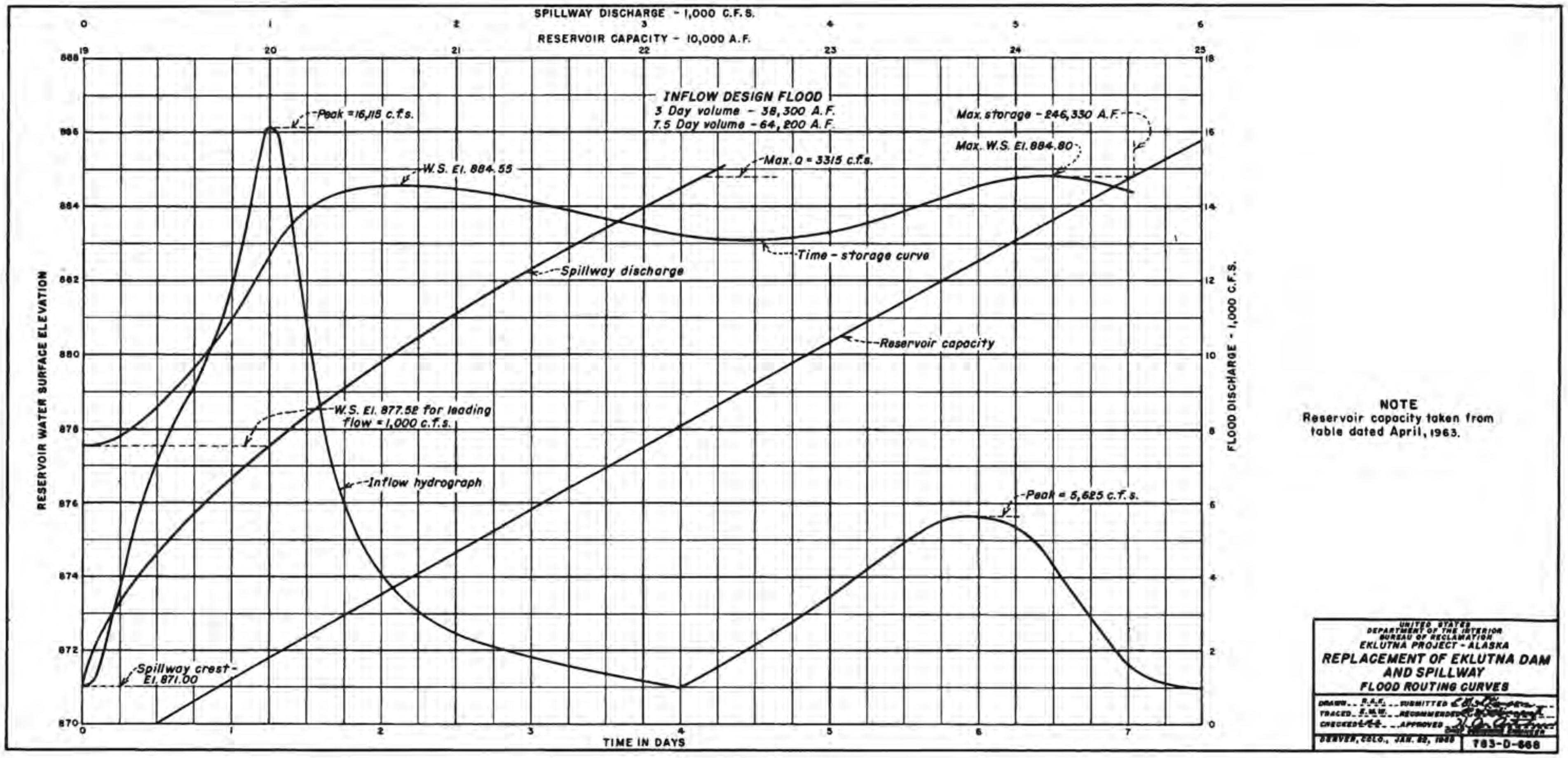


Figure 24. --Spillway flood routing curves for the replacement dam.

25. Flood Routing. A graphical flood routing of the inflow design flood, which is followed by a smaller flood, is shown on figure 24. At the maximum reservoir water surface elevation of 884.8, the selected spillway will discharge 3,315 second-feet, and 49,301 acre-feet of water will be stored in the surcharge pool with 6.2 feet of freeboard remaining below the dam crest.

26. Reservoir Storage Allocations. After construction of the new Eklutna Dam, the reservoir storage allocations were established as indicated below. (Note: These as-built capacities are somewhat different than those shown on the flood-routing curves, figure 24.)

Purpose	Reservoir surface elevation, feet	Storage, acre-feet1/	
		Increment	Total5/
Surcharge	871.0 to 2/884.8	49,301	--
Conservation	814.0 to 3/871.0	174,798	213,271
Inactive	4/800.0 to 814.0	38,473	38,473

1/From area-capacity tables dated May 1966.
2/Top of flood storage (with freeboard of 6.2 feet)
3/Elevation of spillway crest.
4/Floor of intake channel leading to pressure tunnel.
5/Live storage only. Dead storage has not been evaluated, but it has been estimated that the original lake capacity below elevation 800.0 will be sufficient to take 100 years of sediment accumulation without appreciable encroachment on active storage space.

27. Tailwater and Degradation Studies. Field data collected to perform these studies include the laying out and sounding of 23 cross sections in the reach extending about 1,790 feet below the dam axis and about 1,130 feet above. Rating tables and discharge measurement notes were obtained for the Geological Survey gaging station on Eklutna Creek near Palmer, located about 1,030 feet above the dam axis. The discharge measurement notes covered discharges ranging from 500 to 1,550 second-feet at this station. Roughness coefficients were estimated to be 0.040 for the main channel and 0.150 in the highly vegetated portions of the channel. Field observations of the channel bed indicated the sediments averaged 4 inches in diameter. A series of water surface profiles to determine the tailwater curve was computed for discharges in the range of 200 to 3,200 second-feet. An electronic computer was used for these calculations. The tailwater rating curve was plotted for the section at the base of the spillway outlet. An analysis was made to determine the stability of the river channel downstream from the spillway outlet. Using the armoring technique with a dominant discharge of 1,000 second-feet and a mean sediment diameter of 4 inches, the channel degradation below the outlet was found to be negligible.

C. Spillway Design

28. Preparation of Specifications Design. Because of the urgency of placing Eklutna Powerplant back into full operation, no definite plan report was prepared and the design went directly into the specifications stage. The urgency of the work and the remoteness of the location also dictated that the specifications drawings be used as the final construction drawings, and this plan was followed. The final designs and specifications drawings were prepared in 1964 and 1965.

29. The Problem of Permafrost. Eklutna Dam lies close to the permafrost line which crosses Alaska. Although permafrost probably does not occur at Eklutna Lake because of the warmth of the lake body, it was thought wise to review literature on construction in cold climates before deciding on the type of structure for the new spillway.

The following material in the Bureau of Reclamation library was found to contain pertinent information on the subject of construction on frozen soil:

(1) Gibbs, H. J., "Soil Engineering in Frost Areas--A summary of the summer session at Massachusett Institute of Technology," Soils Engineering Laboratory Report No. EM-510, Bureau of Reclamation, June 11 to 21, 1957 (unpublished).

(2) Tsytovich, N. A., "Bases and Foundations on Frozen Soil," National Academy of Sciences, National Research Council Publication 804, Highway Research Board Report No. 58.

(3) Tsytovich, N. A., and Sumgen, M. I., "Principles of Mechanics of Frozen Ground." U.S. Army Snow, Ice, and Permafrost Research Establishment; Corps of Engineers - Translation 19.

These references provided information that proved very useful in the spillway design.

30. Design Criteria. In addition to handling the inflow design flood indicated by the flood routing studies (sec. 25), it was determined that the type of structure selected must have the following functions or capabilities:

(1) It must have structural strength to resist frost action.

(2) It must be capable of being used for diversion during construction of the dam and converted for use as a spillway after diversion.

(3) It must be able to pass brush and trees.

(4) Within the above limits, it must be simple to construct and economical.

The specifications structure selected represents the judgment of the designers for a structure satisfying the above criteria.

31. General Description of Spillway Design. The reinforced concrete spillway consists of an inlet structure 105.54 feet long, a rectangular conduit section 83.80 feet long, a chute 77.66 feet long, and a stilling basin 89.00 feet long. A general plan and sections of the spillway are shown on figure 25. The entire structure is straight in alinement, and it has a constant width of 18 feet and a total length of 356 feet. The entrance structure contains a second-stage concrete overflow crest and an adit for access to the hoist that controls a 30- by 30-inch drainage outlet gate in the bottom of the crest section. The floor of the stilling basin is about 43 feet below the spillway crest. The stilling basin discharges the flow into Eklutna Creek. The spillway details are shown on figures 26 through 30.

32. Design Capacity. The spillway crest is located at the top of the conservation pool, elevation 871.0. For the reservoir water surface at maximum elevation 884.8, the spillway has a discharge capacity of 3,315 second-feet. The theoretical discharge curve for the spillway is shown on figure 25. Discharges were computed using the formula $Q = CLH^{3/2}$, with values of C ranging from 3.087 at zero head to 3.60 at maximum head.

33. Hydraulic Design of Spillway. (a) *Inlet Structure.*--The inlet approach channel has riprap on the bottom and on the cut slope for a distance of 50 feet upstream from the concrete structure. This riprap is to provide protection from erosion at the inlet to the concrete structure. The inlet sidewalls were extended upstream 29.5 feet at elevation 885.0 to keep the immediate effects of the surface drawdown away from the crest.

The crest, upstream from its axis, was designed to approximate the undernappe of a sheet of water flowing over a sharp-crested weir with a vertical face. Downstream from the axis of the crest, the desired shape is approximated by the equation $x^2 = 27y$. The velocity of flow approaching the crest was computed as 5.7 feet per second at maximum discharge. The inlet structure and crest are shown on figures 26 and 27.

(b) *Rectangular Conduit, Chute, and Stilling Basin.*--The underside of the conduit roof was set 16.0 feet above the surface of the floor. This allows 11.5 feet of clearance above the maximum theoretical water surface for the passage of tree limbs, roots, and brush. The water surface profile was computed using Manning's equation:

$$v = \frac{1.486\, r^{2/3}\, s^{1/2}}{n}$$

where:

v = the velocity of the flow,
n = the coefficient of roughness, assumed in this instance as 0.014,
r = the hydraulic radius, and
s = the slope of the energy gradient.

The 40-foot vertical curve of the chute was designed to assure floor pressures above atmospheric for the most adverse conditions, using a value of n equal to 0.008.

The stilling basin uses the energy dissipation characteristics of the hydraulic jump. Chute blocks at the beginning of the basin and a dentated sill at the end give additional stilling effects through diffusion and impact. The hydraulic jump characteristics were determined from the theory of conjugate stages of flow derived from the force-momentum equation. For computing the theoretical depth of jump, the following equation was used:

$$d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2 v_1^2 d_1}{g}}$$

where:

d_1 = conjugate depth before the hydraulic jump,
d_2 = conjugate depth after the hydraulic jump,
v_1 = velocity of supercritical flow before the hydraulic jump, and
g = acceleration of gravity.

The following basin dimensions and flow characteristics for a discharge of 3,315 second-feet were determined:

Velocity of flow entering basin, v_1 (based on n = 0.008)	= 55.8 feet per second
Maximum assumed tailwater elevation (channel does not degrade)	= 851.5
Depth before jump, d_1	= 3.30 feet
Theoretical conjugate depth, d_2	= 23.68 feet
Theoretical jump height, d_2-d_1	= 20.38 feet
Tailwater depth, 0.99 d_2	= 23.50 feet
Stilling basin floor elevation	= 828.0
Length of basin, 3.95 d_2	= 93.5 feet (89.0 used)
Elevation of stilling basin walls	= 860.0

Engineering Monograph No. 25 2/ was used in the design of the stilling basin, including determining dimensions of the chute blocks and dentated end sill.

34. Structural Design of Spillway. (a) *Foundation.*--The entire spillway rests on glacial till. Logs of drill holes along the spillway centerline indicate this material at foundation elevation to be similar to clayey gravel (GC) and silty gravel (GM). The drill logs classify the material as a heterogeneous mixture of compacted clay, silt, sand, gravel, and cobbles. About 10 to 20 percent is low to medium plastic fines.

Although the foundation material has been classified in the drill logs as one containing clay, a petrographic analysis of the material in the Denver laboratory was able to determine that there was little if any clay present. The material was, however, very similar in appearance to clay, resulting in the clay classification. The laboratory classified the material as a cohesive silt which dries to a firm mass without the shrinkage cracks that clay produces. After drying, the material does not disaggregate readily when immersed in water.

2/ "Hydraulic Design of Stilling Basins and Bucket Energy Dissipators," Engineering Monograph No. 25, Bureau of Reclamation, September 1958.

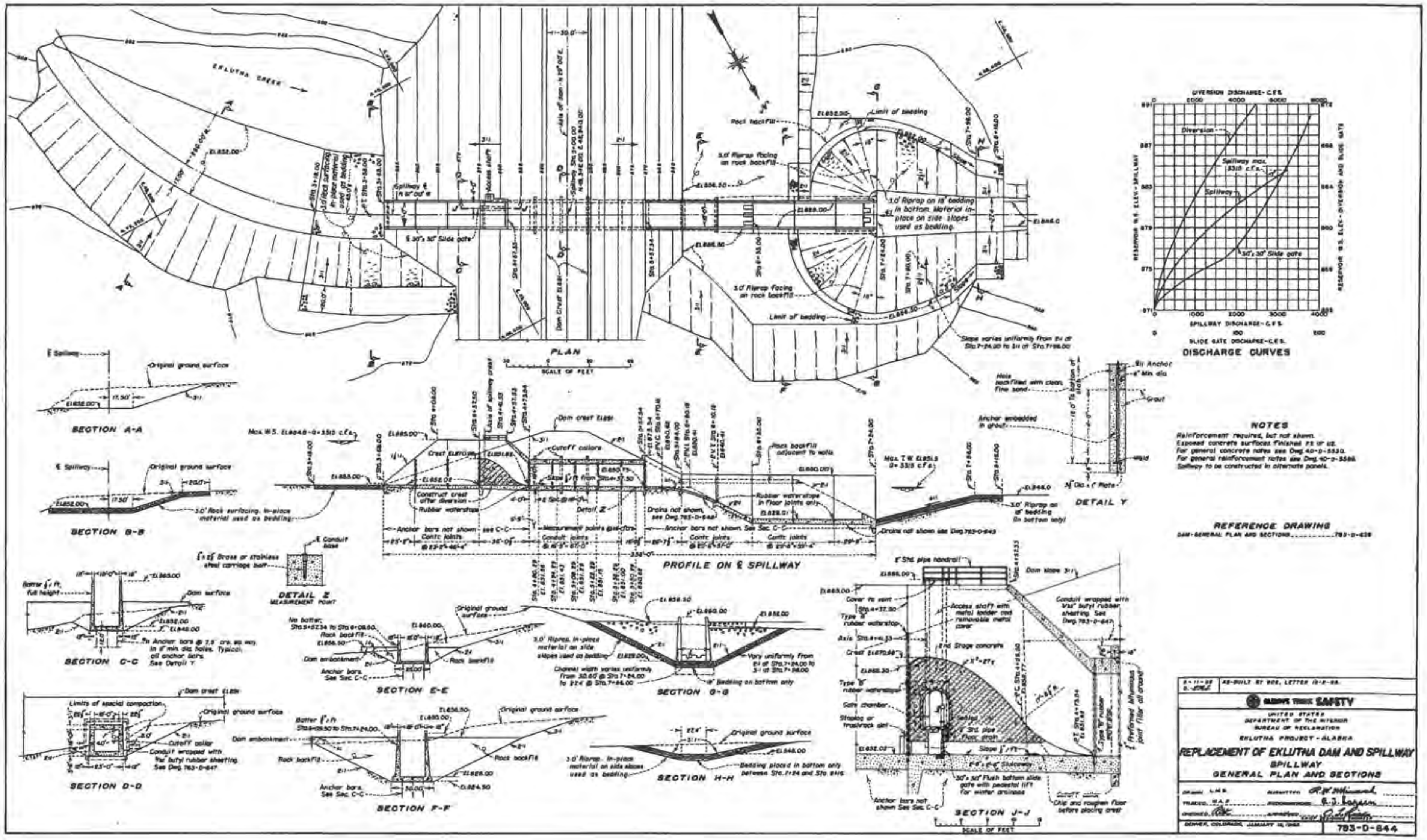


Figure 25. --General plan and sections for spillway of the new dam.

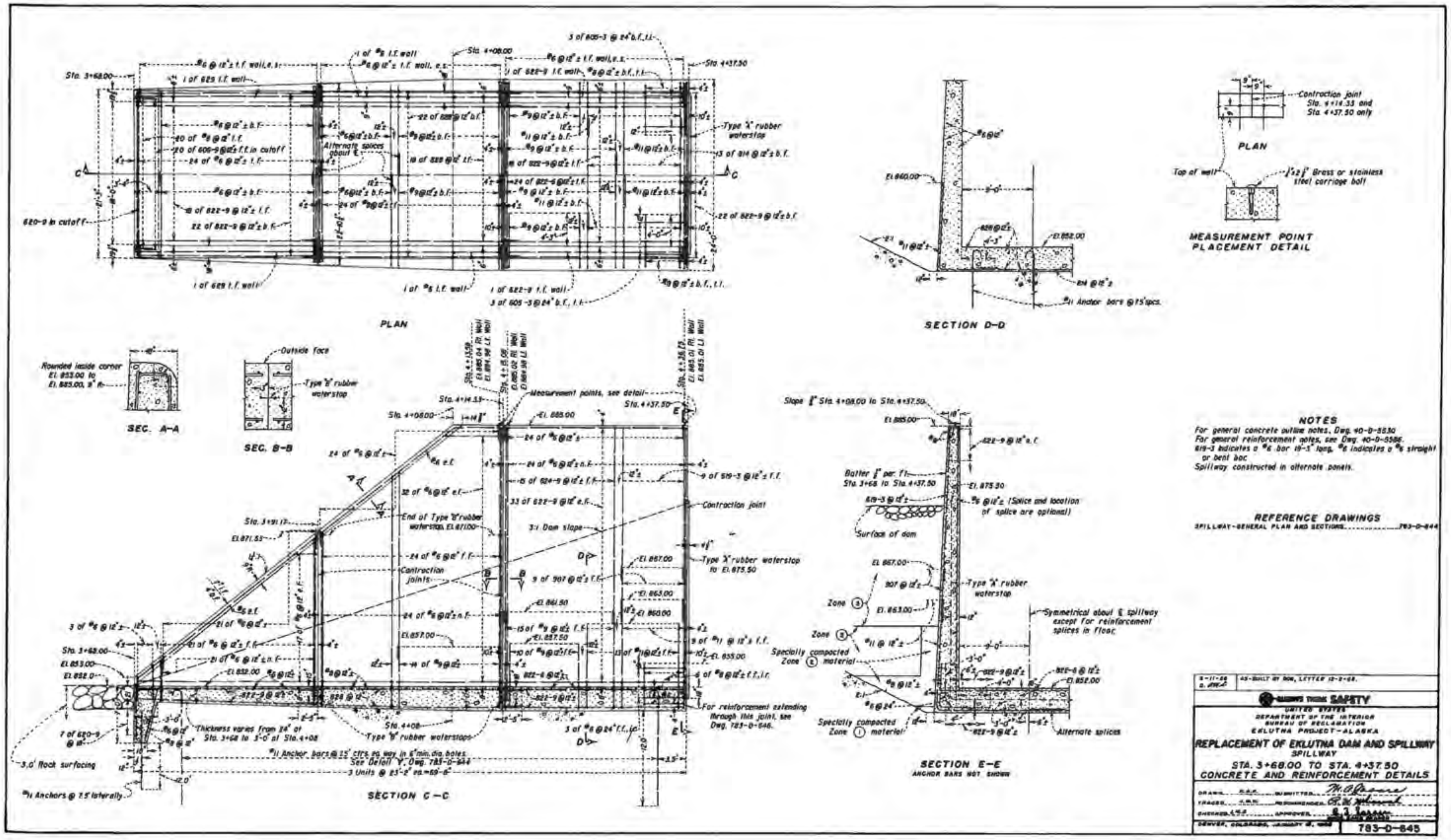


Figure 26. --Spillway design details--Station 3+68. 00 to station 4+37. 50.

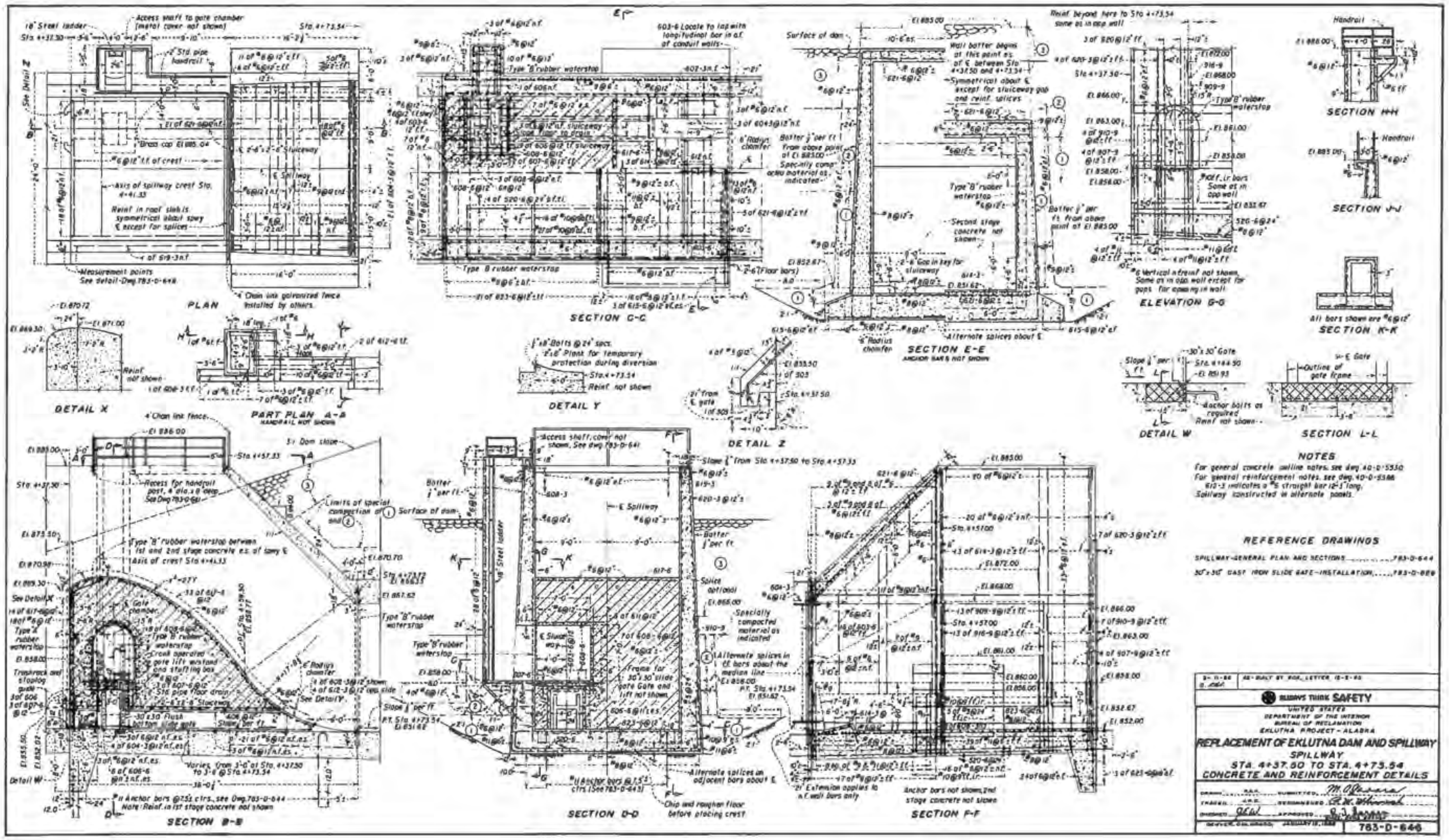


Figure 27. --Spillway design details--Station 4+37. 50 to station 4+73. 54.

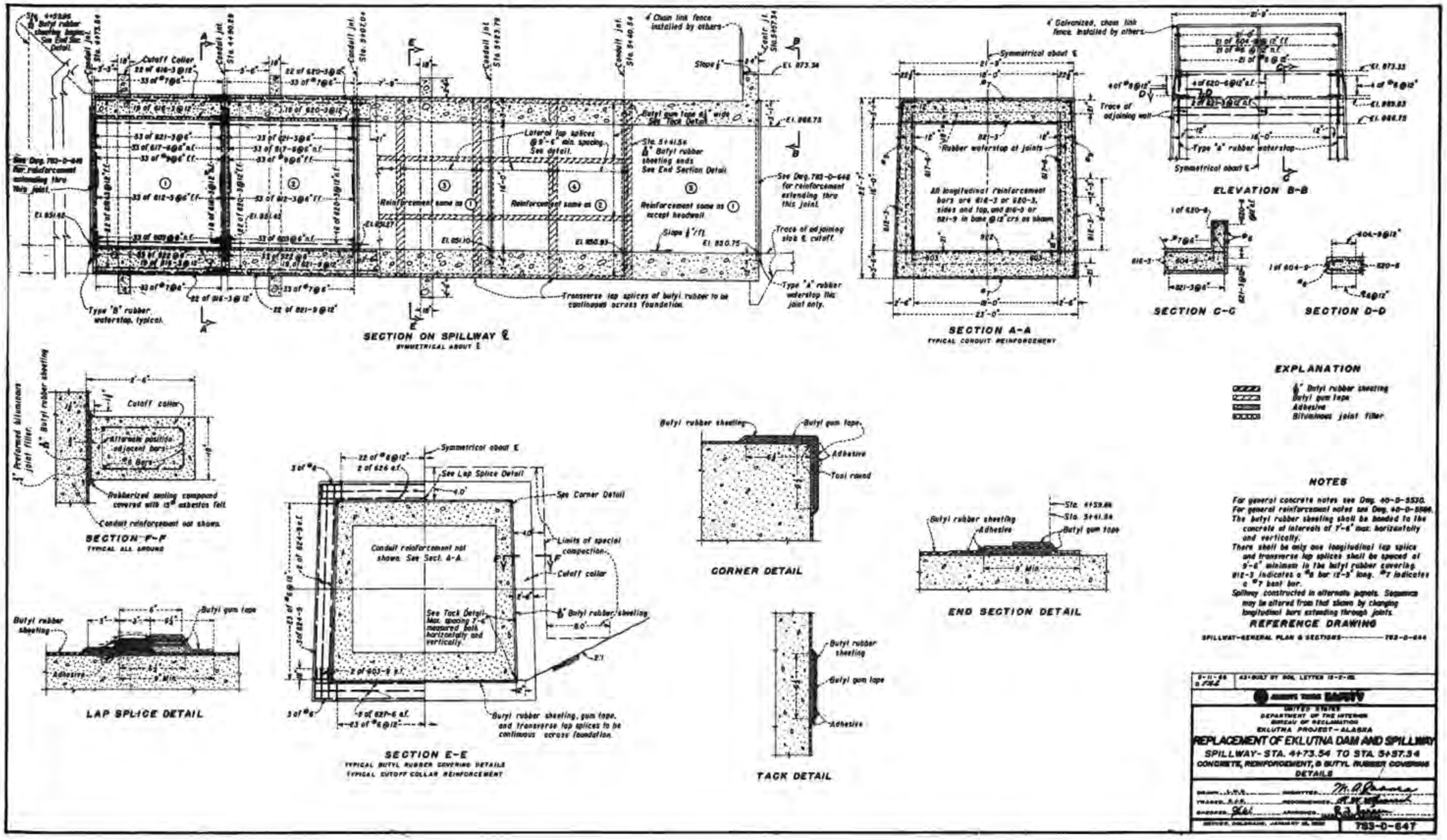


Figure 28. --Spillway design details--Station 4+73. 54 to station 5+57. 34.

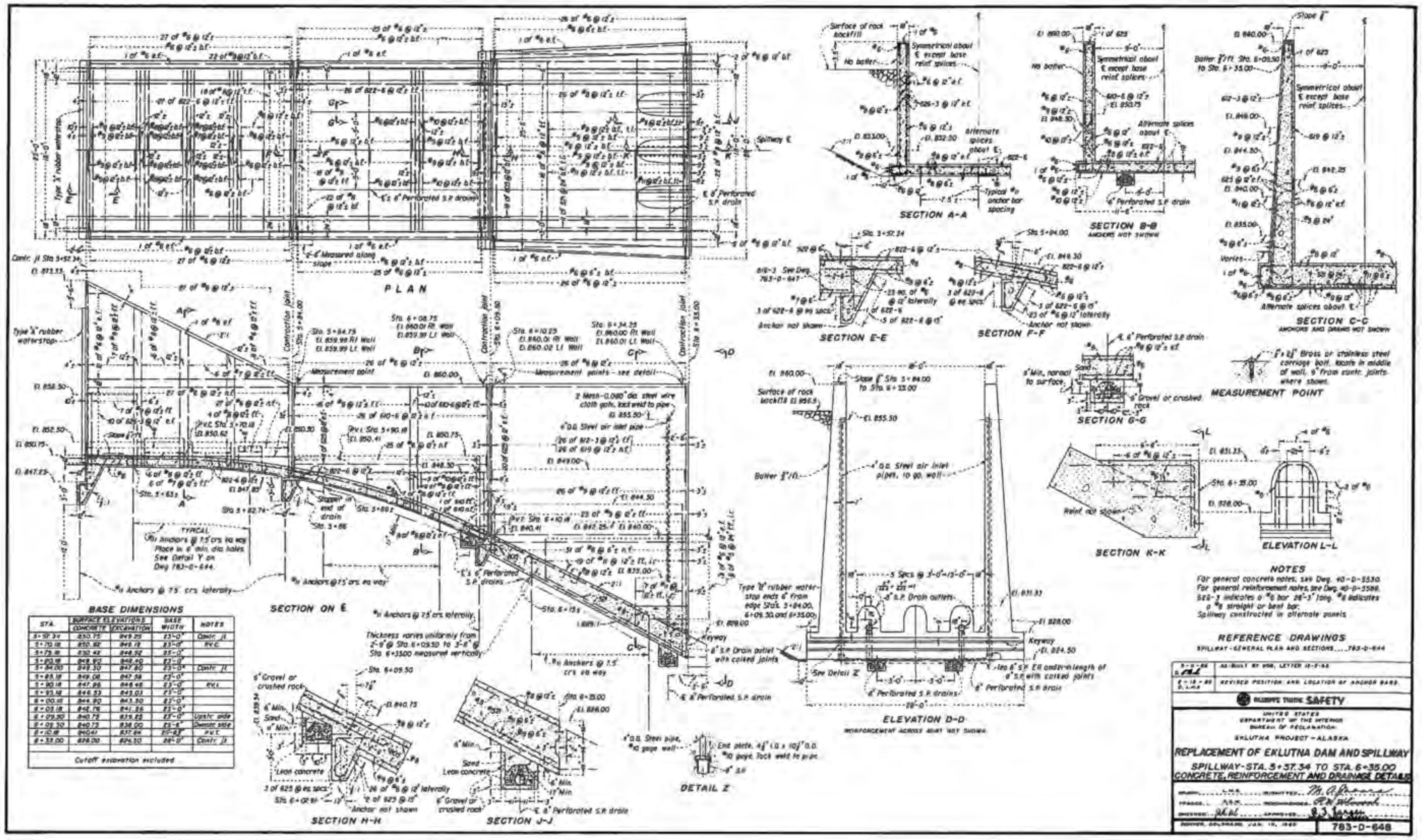


Figure 29. --Spillway design details--Station 5+57. 34 to station 6+35. 00.

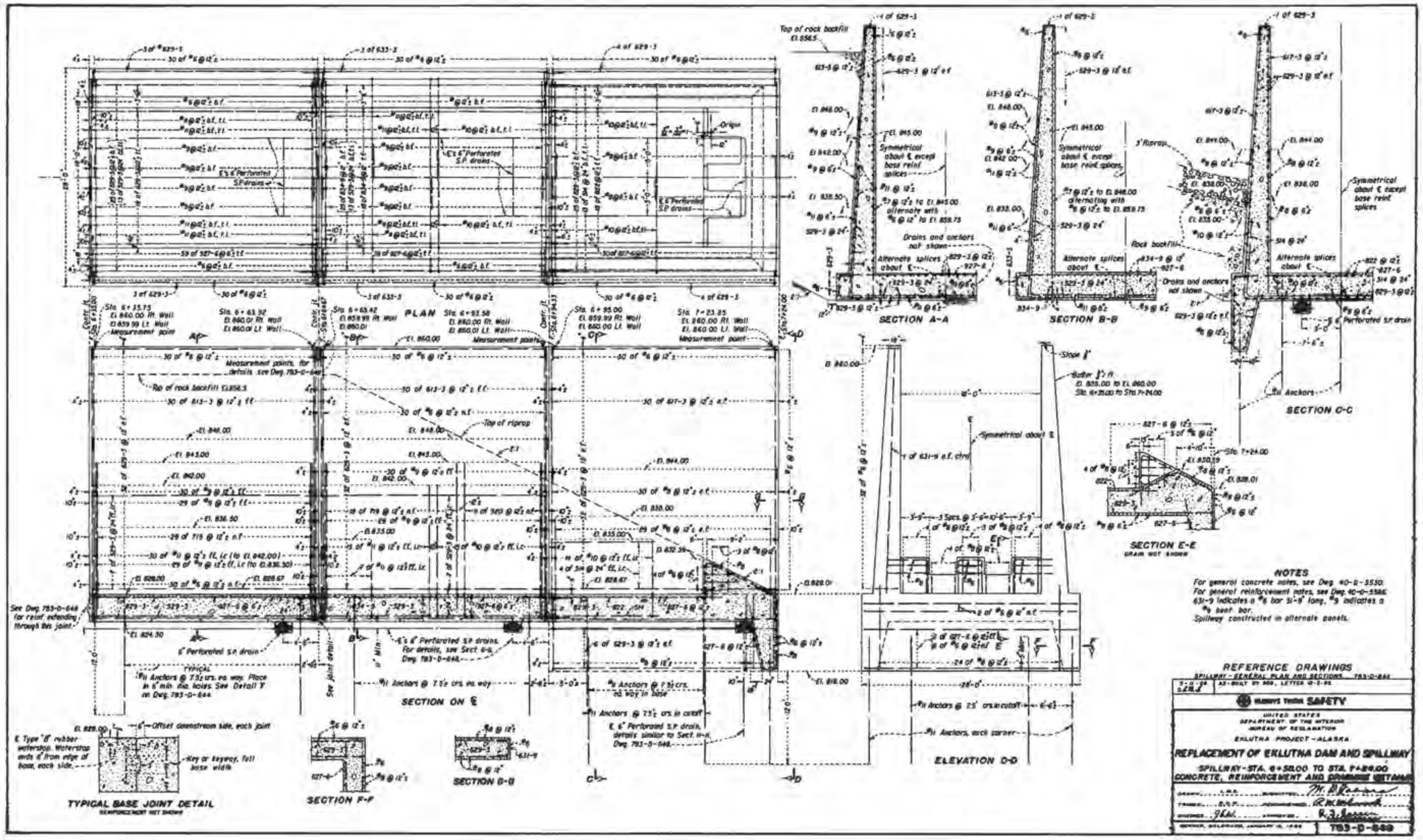


Figure 30. --Spillway design details--Station 6+35. 00 to station 7+24. 00.

The foundation is considered adequate to support the specifications type of structure.

(b) *Drainage.*--It was believed that the percentage of fine silty material may give this foundation a tendency for frost heave if ground moisture is available. Provisions were incorporated in the design to minimize available ground moisture as follows:

(1) The floor of the inlet structure and that of the rectangular conduit were kept at as high an elevation as possible above the minimum tailwater elevation, and still permit diversion.

(2) An open drain trench was excavated in the hillside on the right abutment to lead surface drainage water away from the structure downstream from the dam crest.

(3) Late in the fall or early winter, water is trapped in the reservoir bottom between the old Eklutna Dam and the new dam. A 30- by 30-inch drainage outlet gate was provided in the base of the spillway crest to drain out this water each year at the proper time. This water, approximately 7 feet deep, would permit detrimental frost action against the toe of the new dam and at the spillway inlet. This gate is not a typical reservoir outlet and is supplied only for drainage.

35. Backfill and Frost Action. The zoning of the backfill adjacent to the spillway walls and at the rectangular conduit section matches the zoning of the dam. The zone 2 material (selected sand, gravel, and cobbles) and the zone 3 material (rockfill) were considered to be free-draining and should impose no frost action. Free-draining rock backfill was specified along the chute and stilling basin walls to alleviate frost action.

The zone 1 material (selected clay, sand, and gravel) was placed and compacted with a definite moisture content. The material is not free-draining and is expected to be subject to frost action. Since the crest and upstream portion of the spillway lie within the zone 1 area, a rectangular box-type closed conduit was constructed through the dam to provide structural strength against frost action. A circular conduit would have afforded greater strength, but the spillway is too short to provide reasonable transitions from the rectangular crest to a circular conduit and back to a rectangular stilling basin. Sidewalls for an open channel would not be considered as strong as the rectangular conduit.

Detail Y, figure 25, shows the frost anchors used under the spillway floor slabs to protect them from frost heave. (The structure has sufficient weight to resist differential hydrostatic uplift, so anchors were not needed for this purpose.) Details for the installation of frost anchors were adapted from the literature listed in section 29. Fine-grained sand was placed around the deformed reinforcing steel anchor bar to fill the drilled hole in the foundation material. The bar was given two coats of rustproof paint of a type that would not destroy the bonding capabilities of the bar. The bottom of the bar is embedded in concrete located below the frostline and the top is embedded in the concrete of the floor slab. The anchorage results from the foundation material freezing to the sand which in turn freezes to the anchor bar. The frozen adhesion of the sand to the bar is believed to be higher than the frozen adhesion of the foundation material to concrete if the latter were placed around the bar instead of sand. This type of anchor is practical for use in frozen ground.

The following additional precautions were taken to aid the structure against frost heave or thrust:

(1) All walls were given a batter to add vertical load against heaving.

(2) Longitudinal reinforcement was extended through all contraction joints in the floor slab and in the joints of the sidewalls and roof of the conduit section, to aid in distributing localized frost action.

(3) The maximum allowable shear of 60 pounds per square inch was kept a distance of d/2 from the support instead of a distance of d from the support as allowed in ACI 318-63 3/ (where d is the distance from extreme compression fiber to the centroid of the tension reinforcement). The shear was thus kept smaller to handle unpredictable loadings.

3/ "Building Code Requirements for Reinforced Concrete," ACI 318-63, American Concrete Institute Standard, 1963.

(4) The minimum total thickness of primary concrete members was set at 18 inches.

36. Allowable Working Stresses. Allowable working stresses for normal loading conditions were assumed as follows:

(a) *Concrete.* --

Minimum compressive strength, f_c', in pounds per square inch inch at 28 days	3,000
(Modular ratio n = 9.2)	
Flexure, f_c, in pounds per square inch.	1,350
Shear, v_c, at a distance d/2 from the support (no web reinforcement allowed), in pounds per square inch	60
Bond (as allowed in chapter 13 of ACI 318-63 3/)	

(b) *Reinforcement.* --

Tension, f_s, in pounds per square inch.	20,000

For special loadings, it was permitted to increase the above tabulated allowable stresses by one-third as indicated for separate loadings.

37. Weight of Materials. Unit weights of materials were assumed as follows:

	Pounds per cubic foot
Dry fill:	
Riprap and rock backfill.	100
Zone 2 material	110
Zone 1 material	120
Saturated fill:	
Riprap and rock backfill.	125
Zone 2 material	130
Zone 1 material	135
Concrete	150
Water	62.5

Horizontal pressures were computed by the equivalent fluid pressure theory as follows:

	Pounds per cubic foot
Dry fill:	
Riprap and rock backfill.	30
Zone 2 material	35
Zone 1 material	40
Saturated fill:	
Riprap and rock backfill.	75
Zone 2 material	80
Zone 1 material	85

38. Design Loadings. The following design loadings were assumed:

(a) *Inlet Channel.* --

Condition (1). Embankment loads dry.

3/ Op. cit. p. 49

Condition (2). Embankment loads saturated below crest level. No water in inlet channel. Embankment loads dry above crest level.

Condition (3). No water in inlet channel. Embankment loads dry for full height. Construction surcharge of 133 pounds per square foot, uniform for full height. One-third increase in allowable stresses.

(b) *Rectangular Conduit.* --Saturated zone 1 material throughout.

(c) *Chute and Stilling Basin.*--

Condition (1). Dry rock backfill.

Condition (2). Dry rock backfill with construction surcharge of 135 pounds per square foot, uniform for full height. One-third increase in allowable stresses.

Condition (3). Rock backfill saturated to tailwater elevation of 856.0. Dry rock backfill above elevation 856.0. Spillway at maximum discharge with water in basin following hydraulic jump profile. Normal stresses.

Condition (4). Basin with surging discharge profile.

a. Water surface outside at elevation 851.5, inside at elevation 841.5.

b. Water surface outside at elevation 851.5, inside at elevation 856.5. One-third increase in allowable stresses.

Condition (5). Ice load. Ice assumed 3 feet thick exerting 6,500 pounds per lineal foot on inside of walls at elevation 846.0. Normal stresses.

(d) *Special Design Loadings.* --Increase horizontal embankment loads 20 percent on any part of the spillway for earthquake loading under normal conditions. One-third increase in allowable stresses.

Add footing to inlet channel at crest structure to equalize base pressures at junction of crest structure and conduit section with no water against crest.

39. Special Protective Measures for Spillway Conduit Section. A butyl-rubber wrapping 3/32 inch thick was placed around the conduit section to prevent loss of foundation or embankment material through cracks in the conduit should cracking occur. (See fig. 28.)

Perforated sewer pipe drains discharging in the downstream face of the chute blocks were installed to aid in relieving uplift pressure under the floor slab during discharge conditions.

PART III
CONSTRUCTION

PART III--CONSTRUCTION

CHAPTER V. *Construction*--CONTRACT ADMINISTRATION

A. Emergency Work Following Earthquake

40. Specifications No. DC-6112--Repair of Earthquake Damage to Precast Concrete Intake Conduit. Temporary repair to a damaged joint of the precast concrete pipe intake conduit and examination for other damage was accomplished under specifications No. DC-6112 under a contract with the Peter Kiewit Sons' Co. The contract, No. 14-06-D-5098, was negotiated in Anchorage, Alaska, on May 5, 1964. Work began immediately and was completed on June 25, 1964. (See subsec. 7(b).)

Order for changes No. 1 was negotiated with the contractor for the removal of accumulations of sand, gravel, and debris which were found in the intake conduit and pressure tunnel leading to the powerplant penstock.

Examination of the interior of the precast concrete conduit revealed that most of the conduit sections had suffered some joint separation as a result of the earthquake. Accordingly, order for changes No. 2 was negotiated with the contractor for the temporary repair of the nine additional damaged joints. This work was performed underwater by divers.

Contract costs under specifications No. DC-6112 by Peter Kiewit Sons' Co. came to $338,623, which included a negotiated adjustment in the contract price based on the contractor's actual costs. Project force-account costs for earthquake rehabilitation totaled $224,479, making the total cost of the temporary rehabilitation $563,102 through June 30, 1964.

A pay item breakdown for work performed under specifications No. DC-6112 is shown as appendix B.

B. Major Rehabilitation and Replacement Work

41. Specifications No. DC-6212--Rehabilitation of Intake Structure and Conduit for Pressure Tunnel. Eight bids were submitted on January 21, 1965, at Anchorage, Alaska, for replacement of the intake structure and repair of the conduit for the pressure tunnel under specifications No. DC-6212. The bids ranged from 56.8 to 128.8 percent of the engineer's estimate. Manson-Osberg Co., a joint venture consisting of Manson Constuction and Engineering Co. and Osberg Construction Co., Seattle, Wash., submitted the low bid of $633,631 and was awarded contract No. 14-06-D-5444 by telegraph on February 1, 1965. Notice to proceed was received by the contractor on February 12. Work began on February 26 and was completed and accepted on May 14, 1965.

As indicated in section 14, specifications No. DC-6212 contemplated permanent repair of the damaged joints of the precast concrete conduit by means of concrete collars, but concurrently with issuance of specifications, supplemental notice No. 1 was issued permitting repair of the joints by means of expandable stainless steel rings. The contractor selected the latter alternative.

A pay item breakdown for work performed under specifications No. DC-6212 is shown as appendix C.

42. Specifications No. DC-6240--Replacement of Eklutna Dam. Bids for replacement of Eklutna Dam under specifications No. DC-6240, were opened in Anchorage, Alaska, on March 16, 1965. Six bids were received. The three lowest bids and the engineer's estimate are listed below:

(1) A & B Construction Co, Helena, Mont.	$1,233,470
(2) Associated Engineers and Contractors, Inc., Seattle, Wash.	$1,288,976
(3) Norcoast Constructions, Inc., Seattle, Wash.	$1,338,270
(4) Engineer's estimate	$1,117,430

Contract No. 14-06-D-5494 was awarded to A & B Construction Co., the low bidder, on March 26, 1965. A construction period of 550 days was allowed in the specifications for completion of the contract. Notice to proceed was received by the contractor on April 6, 1965, fixing the completion date as October 8, 1966. Work was completed on November 15, 1965, 327 days ahead of the allowed completion date.

A pay item breakdown for work performed under specifications No. DC-6240 is shown as appendix D.

C. Minor Construction Work

43. Specifications No. DC-6270--Automotive Repair Shop. Fourteen bids were submitted on April 22, 1965, at Anchorage, Alaska, for construction of an automotive repair shop under specifications No. DC-6270. The bids ranged from a low of 96.2 percent of the engineer's estimate to a high of 161 percent. Holiday Construction Co., Inc., Spenard, Alaska, was the low bidder at $72,437.15 and was awarded contract No. 14-06-D-5596 on May 12, 1965. Notice to proceed was received by the contractor late on May 18 and was considered to have arrived on May 19. Time allowed for completion of the contract was 175 days, fixing the completion date at November 10, 1965.

Work to be performed under the contract consisted of earthwork, concrete work and constructing a 40- by 60-foot prefabricated automotive repair shop building, complete with plumbing, heating, electric, sewage disposal and gasoline dispensing facilities; dismantling and disposing of an existing 26- by 56-foot garage building and existing dispensing system; removing certain items of plumbing fixtures, an air system, an automotive hoist, and a water pumping unit and reinstalling in the new automotive repair shop; and connecting the water pumping unit to an existing well. As work progressed it was determined that a well in the new building would be more advantageous to the Government than piping water from the existing well. Order for changes No. 1 provided for a new well at the location of the pump in the new building at no additional cost to the Government.

The garage which the new automotove repair shop replaced, spanned a subsidence crack and incurred major damage in the earthquake. The new structure (fig. 31) was therefore moved away from this crack and rotated in a direction similar to that of the warehouse. Work under the contract started June 2 with excavation for the sewerline. The excavated materials were moved to the building site area. The concrete footings were placed and after a delay due to late receipt of the heating cable the floor was constructed. Progress was very sporadic due to delays in receiving materials. The prefabricated steel building was received early in August and erected promptly. Other materials including overhead lights and interior partitions were received late in October, but installation was slow. Interior painting and installation of the overhead doors were delayed and there was a rush to complete all work during the remaining days of the contract period. All work under the contract was accepted as complete on November 10, 1965.

The final estimate was in the amount of $73,633.95. The release on the contract and final estimate were signed by the contractor on November 23, 1965.

D. Organization, Wage Rates, Safety, Etc.

44. Government Organization. Administration of the construction contracts was conducted by an organization under the project construction engineer (GS-14) who was assisted by an office engineer (GS-13) and a field engineer (GS-13). The project construction engineer's organization was divided into office and field forces. The latter consisted of an inspection unit and a laboratory unit.

The office force, consisting of the office engineer, a technician, and a typist, was responsible for checking survey notes; computing quantities; and preparing contractors' monthly and final estimates, orders for changes, progress charts and reports, safety reports, and schedules. Also, this staff checked field reports and compiled data therefrom in addition to doing photographic work and classification of photographs, correspondence, timekeeping, procurement of supplies and materials, and other office work required in connection with the construction contracts.

Figure 31.--New automotive repair shop. P783-908 C&R-192A, September 3, 1965.

The field forces were under the direction of the field engineer, who supervised the inspection and laboratory units. The inspection unit was initially concerned with excavation, clearing, and concrete construction. Members of the group alternated duties of checking excavation pay lines, reinforcing steel, and concrete placement. Survey and layout work was also performed by this group. When concrete construction was nearly complete, embankment construction was started and continued to completion of the project. The laboratory unit consisted of a materials inspector and a laboratory technician. This unit was responsible for the control of all testing of embankment materials, aggregates and other concrete ingredients.

45. Contractors' Organizations. Contractors' organizational structures for work under specifications Nos. DC-6112 and DC-6212 were not reported.

(a) *Specifications No. DC-6240--Replacement of Eklutna Dam.*--The A & B Construction Co., the prime contractor working under this contract, was headed by two superintendents. One was in charge of all concrete construction; the other handled all office engineering in connection with procurement of materials, subcontracts, and all other office phases of the work.

When concrete construction was completed, the concrete superintendent left this job for other work; the office superintendent, however, remained as the contractor's representative until completion of the job.

The prime contractor let three subcontracts for portions of the work required by these specifications. The subcontractors and their work are listed below:

(1) Hermon Bros. Co., Palmer, Alaska, performed earth excavation, and placed zones 1, 2, and 3 embankment, rockfill, riprap and bedding.

(2) Fowler Steel Co., Anchorage, Alaska, hauled all reinforcing steel to the jobsite, and placed and tied all reinforcing bars for the spillway.

(3) United Geophysical Co., Anchorage, Alaska (suboffice) drilled all holes for anchor bars.

Employment by the prime contractor began on April 5, 1965, with four men on duty. Employment by the prime contractor, the earthwork subcontractor, and the steel subcontractor was fairly uniform from July 1 through September. Peak employment for the prime contractor occurred during August with 27 employees. However, peak employment for the entire job was in September with 37 employees for the 4 companies. Concrete work was completed September 30; after that date the earthwork subcontractor increased the number of his employees, so that his maximum employment occurred in October.

46. Construction Equipment. The A & B Construction Co., contractor for replacement of Eklutna Dam under specifications No. DC-6240, rented pumps, trucks and other miscellaneous items locally. Fowler Steel Co., the subcontractor for delivering and placing reinforcing steel, depended upon the prime contractor for assistance in lifting heavy loads. The drilling company furnished their own truck-mounted drilling rig. The prime contractor used his equipment to move and place the rig in position to drill on slopes. Major equipment used by the prime contractor and the earthwork subcontractor is listed below:

A & B Construction Co.--Prime Contractor

Quantity	Item	Size or capacity1/
1	Front-end rubber-tired loader with backhoe attachment	1-1/2 cu. yd.
1	Motor crane	--
1	Dump truck	5 cu. yd.
2	Ready mix trucks	7 cu. yd.
1	Pump	4 in.
1	Pump	2 in.
1	Pump	1-1/2 in.
1	Air compressor	--

Hermon Bros. Construction Co.--Subcontractor
(Earth Moving)

Quantity	Item	Size or capacity1/
2	Crawler tractors with dozer attachments	93 hp.
2	Crawler tractors with dozer attachments	270 hp.
1	Crawler tractor	270 hp.
2	Scrapers	12 cu. yd.
3	Rubber-tired motorized scrapers	21 cu. yd.
1	Front-end articulating loader	5-1/2 cu. yd.
1	Front-end articulating loader	2-3/4 cu. yd.
1	Front-end loader	--
6	Dump trucks	12 cu. yd.
1	Motor patrol	115 hp.
1	Water truck	--
1	Fuel truck	--
1	Compacting tamping roller	2-drum
1	Portable aggregate separator with feeder	5-in. screen
1	Air compressor	--

1/Where the type and size or capacity of a particular make and model of equipment were not stated in the original report, these have been obtained from current construction equipment catalogs. As specifications for a particular model may vary from year to year, some minor discrepancies may exist between the reported size or capacity and that of the equipment actually used.

(Rock Quarry)

Quantity	Item	Size or capacity
1	Air compressor	--
1	Rotary air compressor	600 c. f. m.
1	Crawler-mounted compressed-air drill	10-ft. carriage

United Geophysical Co.--Drilling Subcontractor

1	Truck-mounted drilling rig	--

Construction equipment for other contractors is listed or described with construction operations.

47. Safety--Government Forces. No Government employees were injured during the rehabilitation of this project. Vehicles operated by Government employees traveled 42,118 miles with no accidents.

48. Safety--Contractors' Forces. (a) *Specifications No. DC-6212--Rehabilitation of Intake Structure and Conduit.*--The contractor under these specifications was required to provide a safety engineer. Under his direction, in cooperation with Government forces, an excellent safety record was established. Manson-Osberg Co. completed all work with no disabling accidents or lost time injuries. This accomplishment of an accident-free job was believed due primarily to the initiative of the contractor in providing a vigorous safety program and enforcement of the safety provisions.

(b) *Specifications No. DC-6240--Replacement of Eklutna Dam.*--The contractor under these specifications submitted a safety program which provided for weekly (toolbox) and monthly safety meetings, first-aid and medical facilities, sanitary drinking water and toilet facilities, protective equipment for employees, inspection of equipment, protection to the public, and accident reporting procedure. This program was approved by the Denver office. The contractor and all subcontractors were safety conscious and cooperated wholeheartedly in the safety program. Toolbox meetings began June 14 and continued weekly thereafter. Subjects discussed were pertinent to the work at hand.

One lost time accident occurred resulting in 10 days lost time. A carpenter fell 16 feet onto lumber and a concrete slab, injuring his left heel and back. Owing to this one accident the frequency rate at the end of the job was 31.49 and the severity rate 314.9. Employees of the contractor and his subcontractors had a total of 31,756 man-hours of employment.

49. Labor Relations and Wage Rates. (a) *General.*--All labor on the project was obtained through the various craft unions, most of whom had a steward on the job. Wages for ironworkers and carpenters had been increased by approximately 8-1/2 percent through union negotiation before the start of this construction. Also, on July 1, 1965, the laborers received an increase of 6 percent.

(b) *Specifications No. DC-6212--Rehabilitation of Intake Structure and Conduit.*--No labor relations difficulties were experienced by the contractor on this contract.

(c) *Specifications No. DC-6240--Replacement of Eklutna Dam.*--A minor strike resulted from a disagreement between the contractor under these specifications and the unions concerned, as to which craft should place the butyl-rubber membrane around the concrete spillway conduit. However, after only 1 day's strike this dispute was settled.

The contractor advised the labor unions that under his contract nondiscrimination in employment was required. No discrimination was noted on account of race, color, creed, or national origin.

(d) *Wage Rates.* --In general, the wage rates paid on these contracts were higher than specifications requirements owing to negotiations having been made with the various unions after the wage rate decision. Wage rates for specifications Nos. DC-6112 and DC-6212 were not specifically reported, but the following tabulation shows the basic wage rates and subsequent wage rates which were effective under specifications No. DC-6240, for replacement of Eklutna Dam:

Classification	Hourly rate
Carpenter foreman	$6.44
Carpenter	5.85
Crane operator (crawler type)	5.94
Crane oiler	5.34
Tractor operator	6.29
Teamster (ready mix 7-9 cu. yd.)	5.83
Mechanic (heavy duty)	5.97
Bulldozer operator	5.86
Driller (wagon)	5.63
Ironworker (reinforcement)	6.30
Laborer (prior to 7-1-65)	4.84
Laborer (after 7-1-65)	5.13
Cement mason	6.26
Laborer (concrete)	5.25
Drilling machines, core, cable, rotary and exploration	5.88

50. Factors Affecting Construction Progress. During the early stages of the work under specifications No. DC-6240, the weather had very little effect on progress. Drizzling rain sometimes accompanied by wind was the rule rather than the exception. However, this did not deter the carpenter work, placement of concrete, or dam and spillway excavation. In late September after zone 1 operations had started, rains occurred which rendered the zone 1 material too wet to process. Several workdays were lost, but wind and sunshine operated to condition the material sufficient to permit a new start early in October. During October conditions changed almost daily and completion of the work during 1965 appeared unlikely at times. However, clear, cold weather predominated during the last month of work. In general, weather conditions hindered progress very little.

A minor labor difficulty delayed the work on the Eklutna Dam replacement for 1 day. There were no other significant hindrances to construction progress.

CHAPTER VI. *Construction* --EMERGENCY WORK FOLLOWING EARTHQUAKE

A. Repairs to Electrical Equipment and Facilities

51. General. Immediately following the Alaska earthquake at 5:36 p.m. on March 27, 1964, Eklutna project forces made an inspection of the powerplant and related facilities to assess the damage sustained. A brief summary of this damage is given in section 7. Most obvious was major damage to two 115-kilovolt air circuit breakers and bushing-type transformers serving the Anchorage and Palmer lines.

As indicated in the above reference, after a brief shutdown for inspection, station service was resumed at 5:55 p.m.; and the damaged circuit breakers were bypassed and other repairs made permitting resumption of service to Anchorage and Palmer by 10 a.m. the next day. Owing to the urgency of the situation, it was impossible at that time to conduct extensive tests on each piece of equipment. However, project personnel proceeded with caution and gradually raised the generated voltage from zero to its normal value. After the initial emergency work had been performed, the following work was accomplished on the electrical equipment and installations.

(a) *Eklutna Powerplant*.--Apparently because the Eklutna Powerplant was founded on piles, which were driven to bedrock (graywacke), only minor damage was sustained to the powerplant as a result of the earthquake. Most damage was to the switchyard equipment on the powerhouse roof. Considerable cracking was sustained by the tailrace channel as shown in figure 32.

Two 121X auxiliary relays on the main control panel in the control room burned out. This was believed caused by the mechanical failure of the 115-kilovolt air circuit breakers on the powerhouse roof, mentioned above. Auxiliary contacts on the circuit breakers could not open to interrupt the operating current in these relays and they became overheated. Both relays were replaced by similar units purchased and air-freighted from Westinghouse Electric.

Figure 32.--General view of Eklutna Powerplant after the earthquake. Cracks up to 5 feet wide along the banks of the 2,000-foot tailrace channel are clearly visible below the powerplant. The cracks had the effect of squeezing in the sides of the channel. The channel was cleaned by means of both blasting and dragline operation. P783-D-44504A.

The main 20,000-kv.-a. unit transformers, which had settled and moved from 3 to 5 inches on the track when tack-welded rail stops broke loose, and the Government camp transformer, which had settled badly, were raised and leveled. Broken conduit connections to the main transformers were repaired (see fig. 33). Also, the conduit entrance fitting for the low-voltage leads of the Government camp transformer was temporarily repaired pending receipt of a replacement unit.

The tap changers of all three transformers were operated and found to function freely. (Lacking internal inspection, this was a fairly good indication that the core and coils had not shifted in the case.) The oil levels in the bushings and tanks were normal, as were also the temperatures.

The three transformers and the cables from the unit circuit breakers to the main transformers were given Doble tests, results of which were satisfactory. Also, tests of the oil in all three transformers indicated a dielectric strength of more than 30 kilovolts.

Using undamaged parts from the two 115-kilovolt circuit breakers, and spare parts at hand, one complete circuit breaker was assembled and placed in operation. Another circuit breaker, which had been dismantled and flown to Alaska from the Gering Substation in Nebraska, was assembled and put in operation. Both of these circuit breakers were given Doble tests. Consistent results were obtained for the various interrupters and for the three poles of the circuit breaker shipped from Gering. Test results from the other circuit breaker were not as consistent, but no information was available as to the permissible variation for this equipment.

None of the switchyard structures appeared to have been racked or twisted, and all disconnecting switches were undamaged and operated easily.

The 115-kilovolt lightning arrestors and capacitor potential devices appeared to be undamaged. This equipment did not receive a Doble test, as it was considered more important to test the more vulnerable and more expensive equipment during the short time that the Doble test set was available.

Figure 33.--View of 20,000-kv.-a. transformer conduit and terminal box showing damage caused by movement of the transformer during the earthquake. Rail stops, consisting of 1/4-inch by 1-inch-wide steel bars, were tack-welded to the rails. The welds broke and allowed the transformer to move on the rails. P783-906-2254NA, April 6, 1964.

Only one electrical conduit was known to have been broken by the shifting of the machine shop with respect to the main powerplant, and that conduit is not in use. Other conduits and the circuit breaker air lines were protected at the building junction by embedded sleeves which permitted some movement or bending of the conduit.

The battery rack at Eklutna is equipped with sideboards, and therefore no damage resulted to this equipment. Individual cells had shifted slightly, but they were easily repositioned. With the exception of two auxiliary relays, no damage to the powerplant instrumentation or relays was found.

(b) *Anchorage Substation.*--The power transformers, which had shifted as much as 7 or 8 inches on their pads, were repositioned. Terminal boxes were damaged to a minor extent by movement with respect to the embedded conduit, but this was remedied when the transformers were repositioned. The conduit connection to one transformer was broken at the ground level and was replaced. Three 115-kilovolt lightning arrestors which were broken were removed and new arrestors were ordered. Operation without arrestors is not considered particularly serious in this area since lightning incidence is very low. Tests of the oil in these transformers indicated a dielectric strength of more than 30 kilovolts.

When the transformer shifted, a great amount of force was exerted by the low-voltage connections on the 34.5-kilovolt bushings. One bushing on one transformer was left leaning at a small angle from its usual position. It was at first assumed that this bushing was damaged, but project personnel decided that the tank cover was bent by the force of the earthquake and that the bushing was likely not damaged. It was decided that when the transformer could be taken out of service to install new arrestors, a further check would be made. It was considered that Doble testing of these transformers might not be possible, since the test set may not be available when a transformer outage can be scheduled. However, they would be meggered. The oil levels in the transformer bushings and tanks were normal, as were also the transformer temperatures and pressures.

No damage occurred to relays, instruments, or control wiring. The station battery rack had been installed with sideboards; consequently, there was some shifting of the cells but no damage. However, the entire rack moved slightly on the control house floor.

All circuit breakers operated properly; they were Doble-tested with satisfactory results. Also, all of the disconnecting switches operated satisfactorily. None of the structures, the control house, or the cable trench were damaged. Test equipment and miscellaneous tools and parts even remained on the shelves in the house. It is interesting to note that the 115-kilovolt arrestors in the CEA transformer are of a late type and were not damaged.

(c) *Palmer Substation.*--The transformer at the Palmer Substation shifted a small amount on its pad. Also, one 115-kilovolt bushing was found to be leaking oil badly; it was replaced by the spare and the damaged bushing was returned to the manufacturer for repair. This transformer was given a Doble test during the week of May 18, 1964.

Circuit breaker operation was checked and found to be satisfactory; the circuit breaker was given a Doble test. The transformer structures did not appear to be racked or twisted, and all disconnecting switches were intact and operated easily.

(d) *Transmission Lines.*--There was no damage to the 115-kilovolt Anchorage line, but the earthquake caused a snow and ice slide on the Palmer line near the Knik River bridge which swept away a three-pole guyed structure, No. 3/7, and an access road. This structure was located on the western edge of a large slide area but on top of a knoll. Previous slides had moved directly down the slope to a point just above the knoll and then veered off to the east. However, this slide was of such a volume and velocity that a portion of the material rolled directly over the knoll and destroyed the structure. The loss of this structure was accompanied by the loss of about 7,500 feet of 397,500-circular-mil ASCR conductor, comprising the three phases of the two adjacent spans. Replacement of structure No. 3/7 was complicated by inclement weather and the mass of snow and ice that had to be traversed. An Army helicopter from Fort Richardson was used to transport the poles to the site (fig. 34). The first of three poles was actually set by the helicopter crew, but efforts to set the remaining poles had to be abandoned because of the steepness of the mountainside. However, the helicopter was used to deliver the remaining poles to the site on the mountainside.

The repair of the transmission line was completed April 8 and service was restored April 16 upon completion of repair work on the air circuit breaker at the Eklutna Switchyard. During the period the Palmer line was out of service, power was delivered to the Palmer Substation from Reed Substation (Anchorage line tap) over the Matanuska Electric Association (MEA) 34.5-kilovolt line and the 12.47-kilovolt Palmer area distribution system. In order to carry the Palmer load through the limited capacity of the Reed Substation, it was necessary for the MEA to provide auxiliary cooling by means of truck-mounted fans.

(e) *Reed Substation.*--The transformer at this station is the property of the customer and was not damaged. The Bureau structures, switches, circuit breakers, instrument transformers and instruments also showed no evidence of damage.

52. Mechanical Equipment Problems. A number of secondary mechanical problems developed as a result of the earthquake including the clogging of spiral case and butterfly valve drainlines by rocks, frequent clogging of cooling water filters and coils with sand, and excessive wear of jet pump diffusers by the extremely abrasive glacial flour. The problem of rock moving into the spiral cases was eased by limiting the plant output when possible to 18,000 kilowatts, but the sand continued to be a problem until the plant was shut down and the intake repaired.

53. Turbine-Generator Unit Checks. As stated previously, the generating units did not sustain any apparent damage as the result of the earthquake. However, as a precaution, alinement checks and bearing clearance measurements were made by a maintenance specialist from Region 7. Bearing clearances were satisfactory. Unit 1 was found

Figure 34.--View of helicopter assisting in reconstruction of 115-kilovolt transmission line. An Army helicopter crew cooperated with Bureau of Reclamation and Matanuska Electric Association line crews in rebuilding a section of the 115-kilovolt line which was swept away by a snowslide released during the earthquake. P783-906-2312, April 3, 1964.

to be leaning downstream 0.00067 inch per foot compared with 0.00026 inch on unit 2. As a further precautionary measure, a half-screen of 2-inch mesh chain link fencing was installed between the butterfly valve and spiral case of each unit to intercept rocks before they got to the wicket gates and runners. These screens proved to be only partially effective as some rocks did pass over them. However, from early experience it was learned that the large rocks did not move through the tunnel if the total generating load was kept below 18,000 kilowatts (corresponding to a water velocity of approximately 5 feet per second). Therefore, until intake repairs could be made and the rocks removed from the tunnel, this load limit was maintained insofar as other plants were able to make up the balance of the system load.

From the time rocks were first found to be entering the spiral cases, unit 1 was assigned the bulk of the powerplant load in order to draw any rocks in the system in that direction, since this unit was scheduled for a major overhaul. (Unit 2 had been overhauled the year before.) Rocks lodging in the guide vanes and runners resulted in the loss of many wicket gate shear pins, necessitating a rush order for 24 pins from Newport News Ship and Drydock Co. and a special order for 6 pins fabricated in Region 7.

B. Emergency Repairs to Intake Conduit and Cleanup of Pressure Tunnel

54. Initial Inspection by Divers. When misoperation of the generators following the Alaska earthquake of March 27, 1964, revealed that foreign materials had found their way into the pressure tunnel and penstocks, a contract was negotiated with Associated Divers of Anchorage to make an underwater survey of the intake structure and as much as possible of the precast concrete intake conduit to ascertain the extent of the damage. The divers did not enter the conduit. (See subsec. 7(b).)

This inspection, which was made on April 19, 1964, revealed no damage to the trashrack, but a diver discovered a gaping crater or conelike hole in the lake bottom over the precast concrete pipe section near the conduit inlet at approximately station 19+00 (see figs. 4 and 5). A 10-inch opening in an exposed precast pipe joint was discovered at the bottom of the cone. The cone was approximately 40 feet across the top and 15 to 20 feet deep.

After the underwater survey, it was decided, as soon as a complete shutdown could be tolerated, to repair the damaged section of the intake conduit and make a detailed inspection of the intake structure, conduit, 4-1/2-mile pressure tunnel, and penstocks. The headgate would be closed to permit unwatering the tunnel and penstocks to facilitate inspection.

55. Detailed Inspections. By the first of May, the Chugach Electric Association, city of Anchorage, and Elmendorf Air Force Base had their generating plants sufficiently restored so that they were reasonably sure of being able to handle the total area load for an extended period, thus permitting a complete shutdown of Eklutna Powerplant for a thorough inspection of the waterway. On May 5, a representative from the Denver office negotiated contract No. 14-06-D-5098 with Peter Kiewit Sons' Co. in Anchorage in the amount of $133,859.17 for a detailed inspection and repair on a time-and-material basis of known damage to the precast conduit section of the tunnel intake. At the time of the negotiation, only one joint was known to be open.

On May 9, 1964, the Eklutna Powerplant was shut down and preparations for unwatering of the tunnel began. Divers were sent into the headgate shaft before the gate was lowered to determine the condition of the gate slot (see fig. 35). The divers found deposits of sand and rock, 1 to 2 feet in depth, both upstream and downstream of the gate as well as at the gate pocket. Divers working in 40 feet of water required approximately 12 hours to clear the gate so it could be seated.

(a) *Inspection of Pressure Tunnel*.--As soon as the headgate could be closed, unwatering procedures were completed and an inspection team including the Alaska District Manager walked the entire 4-1/2-mile length of the pressure tunnel to ascertain the quantity of rock in the tunnel and appraise any other damage. Rock was found deposited approximately 12 to 18 inches deep and rather uniformly distributed from the headgate (station 27+25) to station 103+00 (see fig. 45). From station 103+00 to station 235+00 the rock

Figure 35.--Bureau and contractor personnel lowering diving gear into headgate shaft in preparation for investigation of conditions in and around the headgate seat prior to unwatering tunnel. P783-906-2319, May 9, 1964.

was deposited in a series of bars of varying depth. The last mile was relatively free of debris. Cross-section measurements indicated there was a total of 1,500 to 2,000 cubic yards of material ranging from sand to an occasional rock of football size, with the greatest portion being under 1 inch in diameter. No structural damage to the tunnel was found.

(b) *Inspection of Penstocks.*--On May 18 a representative from the Denver office and the Alaska District Manager made an inspection of the penstock from the base of the surge tank, elevation 716.67, to the powerplant at elevation 24.0. This 863-foot length of penstock slopes at an angle of 53° with the horizontal making an inspection difficult. A rather unique method of descending through this 6-foot-diameter pipe was devised. The penstock was filled with water, using the tunnel leakage water, and after it was filled, the leakage was diverted out through the adit tunnel door and a two-man liferaft was floated down the penstock (see fig. 36). The desired rate of descent of the raft was controlled by releasing water from the penstock by use of the butterfly valves, wicket gates, and drainlines. Instructions to obtain the desired water discharge were given from the raft to the plant by a combination of telephone and radio. The entire penstock from the tunnel to the generating units appeared to have been free from any permanent deformation caused by the earthquake. Fineline cracks in the overlapped painted surfaces at the coupled sleeve joints did, however, indicate that unusual pipe vibration had occurred.

(c) *Inspection of Intake Structure, Conduit, and Upstream End of Pressure Tunnel.*--At the time of the negotiations with Peter Kiewit Sons' Co., it was intended that their work would be limited to the repair of the one known opened joint of the precast concrete intake conduit and inspection and cleaning of the 1,000 feet of tunnel from the trashrack to the upstream face of the headgate (see figs. 4 and 5). Bureau force-account labor would clean the 4-1/2 miles downstream from the headgate (see subsec. 57(a)).

Figure 36. --A two-man rubber raft being used for internal inspection of the 863-foot-long penstock which slopes at an angle of 53° with the horizontal. Descent of the raft was controlled by releasing water from the penstock drainlines. P783-906-2315, May 18, 1964.

While force-account labor was working in the unwatered tunnel, Peter Kiewit Sons' Co. began emergency underwater repair work on the known break in the intake pipe, and began a detailed inspection of the inside of the precast pipe section between the end of the drilled tunnel and the underwater intake. Entrance to the lakebed portion of the tunnel was through an underwater manhole in the transition section at station 17+75 (see fig. 15). Six divers and their tenders were employed on a three-shift basis, with two divers working on each shift. However, during the final inspection, when it was required that they move through the entire 1,000 feet to the headgate, four divers were used to assist in handling the extended air lines.

Inspection by the divers revealed that a total of 10 of the 15 bell-and-spigot joints had opened, some as much as 10 inches. An order for changes covering repair of the additional joint separations was therefore negotiated with the contractor. A sketch of the affected sections of conduit and a chart showing their joint separations is shown as figure 18. The final inspection also revealed that approximately 25 cubic yards of rock was distributed throughout the 500-foot portion of the tunnel just upstream of the headgate, which could not be removed by divers.

56. Emergency Repairs to Precast Intake Conduit. Representatives from the Denver office were sent to Eklutna to work out with other Bureau personnel and the contractor, Peter Kiewit Sons' Co., the most expeditious temporary method of sealing the joints of the precast concrete pipe.

(a) *Initial Operations.* --When the representatives from the Denver office arrived, a steel caisson had been lowered into the backfill material at joint 6, though not with complete success, as it refused to go down the last 2 feet. Because of difficulties encountered in lowering the caisson at joint 6, the decision had been made to attempt uncovering joint 7 without using a caisson. This work was then in progress. The crew consisted of

2 divers with about 10 supporting crafts for each of the 3 shifts. The divers were installing short curved steel plates on the inside across the opening at joint 6, securing them by 16-inch bolts and strong-backs outside the joint. These plates were installed around three-fourths of the circumference leaving a space at the top to allow muck to be moved from the inside of the pipe. The divers reported that there were triangular openings at the ends of each plate. Also, it was believed future shifting of the pipe sections could result in loosening of the bolts and plates. Therefore, the method was later abandoned and the plates removed in favor of the method of closure described below. An 8-inch airlift pump was used to remove sand and rocks from above joint 7 and also from within the pipe.

(b) *Adopted Procedure.*--Discussions were held among Bureau personnel, contractor personnel, and one of the more experienced divers to find the best means of sealing the separated pipe joints. Many suggestions were considered. It was finally decided to install expandable steel rings inside the pipe. Rings 12 inches wide would be used at the eight joints having separations of 2 to 4 inches without offsets. Double 12-inch rings with flanges would be used at joints 6 and 7, which were separated 10 and 8 inches, respectively, and were offset about 4 inches. Each ring would be rolled to fit the 9-foot inside diameter of the pipe, and would be made in four segments of 1/4-inch plates to keep the weight of each piece less than 100 pounds, the maximum weight it was considered the divers could handle. The rings were ordered from the Superior Machine Shop in Anchorage, where a plate roll was available.

Removal of sand and gravel from within the pipe, and from above joint 7 ran into difficulty. Fair progress was made until May 24, when a high wind and waves caused a sand slide that filled over joint 7, partially filled the caisson at joint 6, and filled the inside of the pipe at both of these joints. The same storm undermined piling supporting the contractor's crane, which was almost lost in the lake. After the crane was withdrawn to higher ground, its boom was too short, so the contractor was forced to obtain a larger crane to complete the work.

At this point, it was decided to build a second caisson to be used at joint 7. This also was ordered from Superior Machine Shop, and given priority over the expanding rings. The contractor continued to remove sand and gravel from inside the pipe and from above joint 7.

On the morning of May 26, a diver was successful in cleaning sand from the top of joint 7 and in placing a 7-foot circular arc of steel plate over the joint. Additional circular pieces 4 feet long were later pushed down at each end of the 7-foot plate. However, sand continued to slide into joint 7 and had to be pumped out of the pipe. The following evening a diver discovered that one of the 4-foot curved plates had been pushed down into the sand about a foot away from the joint. It was pulled out and replaced at the joint; and the inflow of sand immediately lessened. On May 28, a top section of expandable ring was suspended inside joint 7; but a new sand slide made it necessary to remove the section on swing shift.

On the morning of May 29, 17 sandbags were placed around the steel plates at joint 7 and a number of large rocks which protruded through the joint were removed. Swing shift divers commenced installation of the steel rings in joint 7. The large caisson was delivered at 9 p.m. This time, however, the complete double ring was successfully installed; so the caisson was not used. The closing of joint 7 was completed on May 30; and this made it possible to clean all sand out of the pipe in that area and to gain unimpaired access to all other joints in the precast concrete section. Installation of the single 12-inch rings in joints 5, 8, 9, 10, 11, 12, 13, and 15 proceeded at a rate of nearly two rings per shift.

On May 31, the graveyard shift completed installation of the last rings, except the double ring for joint 6 which was still in the shop. This ring was installed the following day, except the top pieces which were left out to permit removal of some additional gravel.

It was concluded that the expanding steel rings installed at separated joints in the precast concrete pipe at the inlet to Eklutna Tunnel, as shown on figures 37 and 38, would

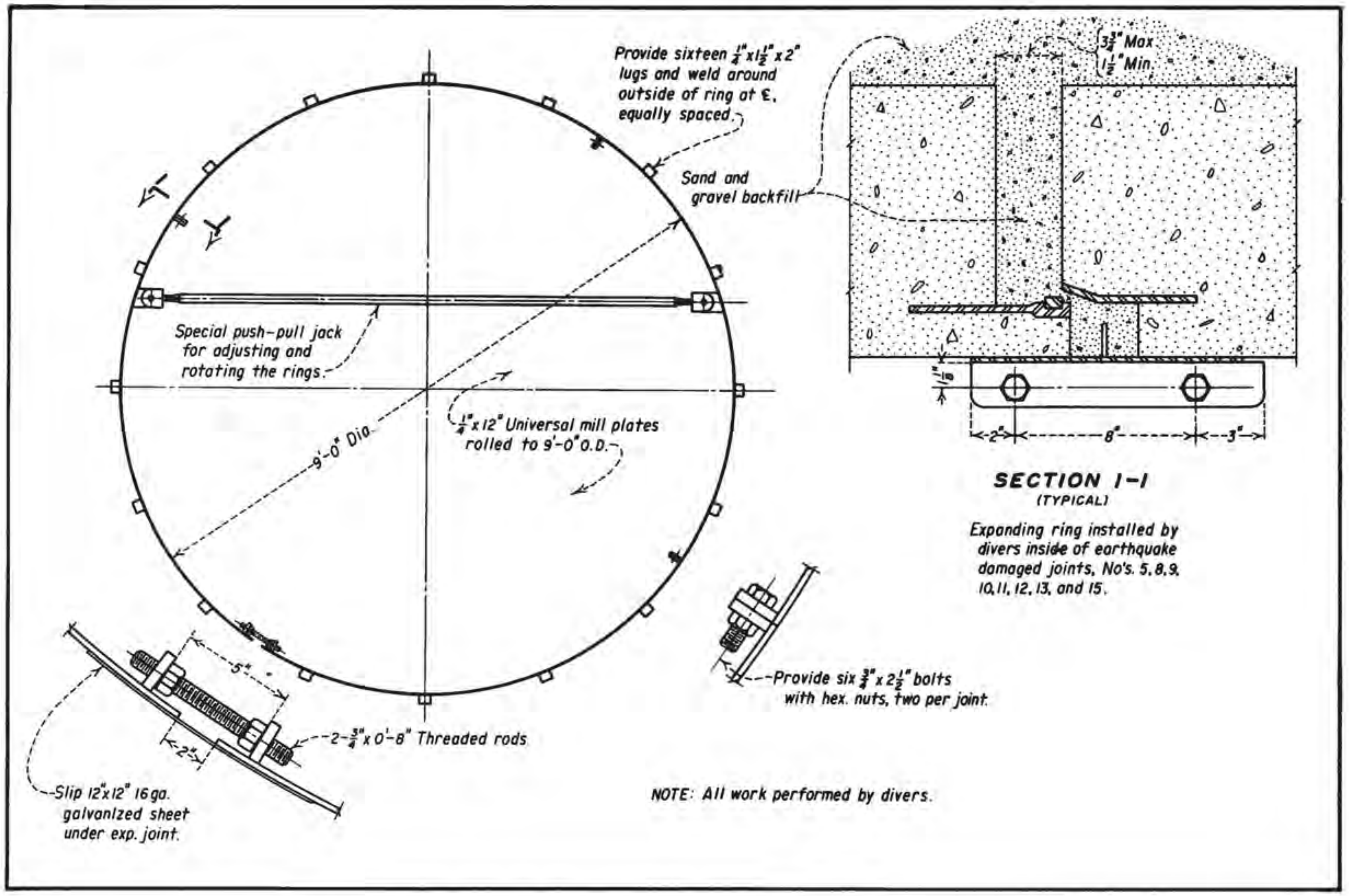


Figure 37. --Steel expandable ring used for temporary repair of joints between sections of intake structure conduit (typical case). From drawing No. 783-D-774.

Figure 38. --View of an expandable steel ring fabricated by the contractor for installation by divers as a means of making emergency repairs to the precast concrete tunnel intake pipe. A single ring was used where there was no offset at the damaged joint. Where an offset existed, two rings were installed back-to-back. P783-906-2335, June 1964.

effectively prevent entrance of backfill material into the power conduit so long as there was no further appreciable movement of the concrete sections. The repair was considered temporary only. It was very expensive--as all construction work in this area is expensive; but it permitted power production until permanent corrective work could be undertaken.

57. Cleanup of Pressure Tunnel. (a) *By Force Account*.--The approach to the tunnel mucking operation by force-account crews was complicated by the fact that access to the tunnel at each end had dimensional limitations of less than 3 feet in width (see figs. 39 and 40). Also, there was a considerable flow of water from headgate leakage, tunnel flap valves, and joint leakage. Rock removal operations were started on a two-shift basis from both ends using wheelbarrows and sluicing methods through the adit tunnel entrance downstream, and wheelbarrows and a 1/4-cubic-yard bucket operating through the 220-foot headgate shaft at the upstream end.

Figure 41 shows a movable plywood dam being used to cause the head developed by the leakage water to move debris toward the adit.

By the end of the first week of rock removal activity by force-account hand labor, the rate of progress and daily cost indicated that mechanical means would have to be employed if the job was to be completed within a reasonable time. (Downtime for the Eklutna Powerplant is estimated to cost $4,000 per day.)

(b) *By Contractor Forces*.--Since Peter Kiewit Sons' Co. was well experienced in tunnel mucking operations and had equipment available, it was decided to negotiate an order for changes to their contract calling for removal of the rock from the first 3-1/2 miles of tunnel in addition to that deposited upstream of the headgate. Mobilization for this phase of the work was slow and tedious, as all equipment had to be broken down or cut into pieces

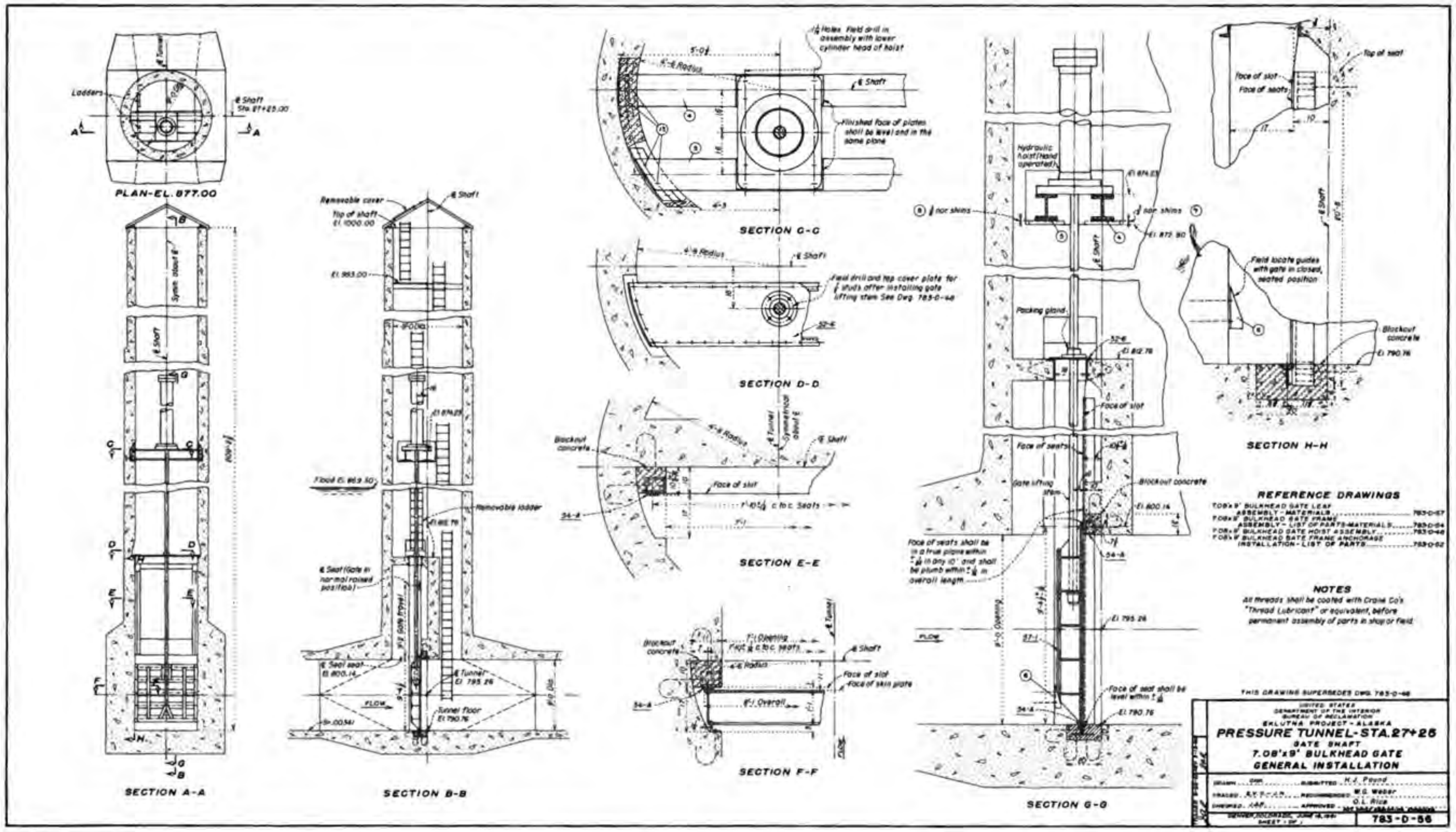


Figure 39. --General installation of bulkhead gate in pressure tunnel--Station 27+25 (gate shaft).

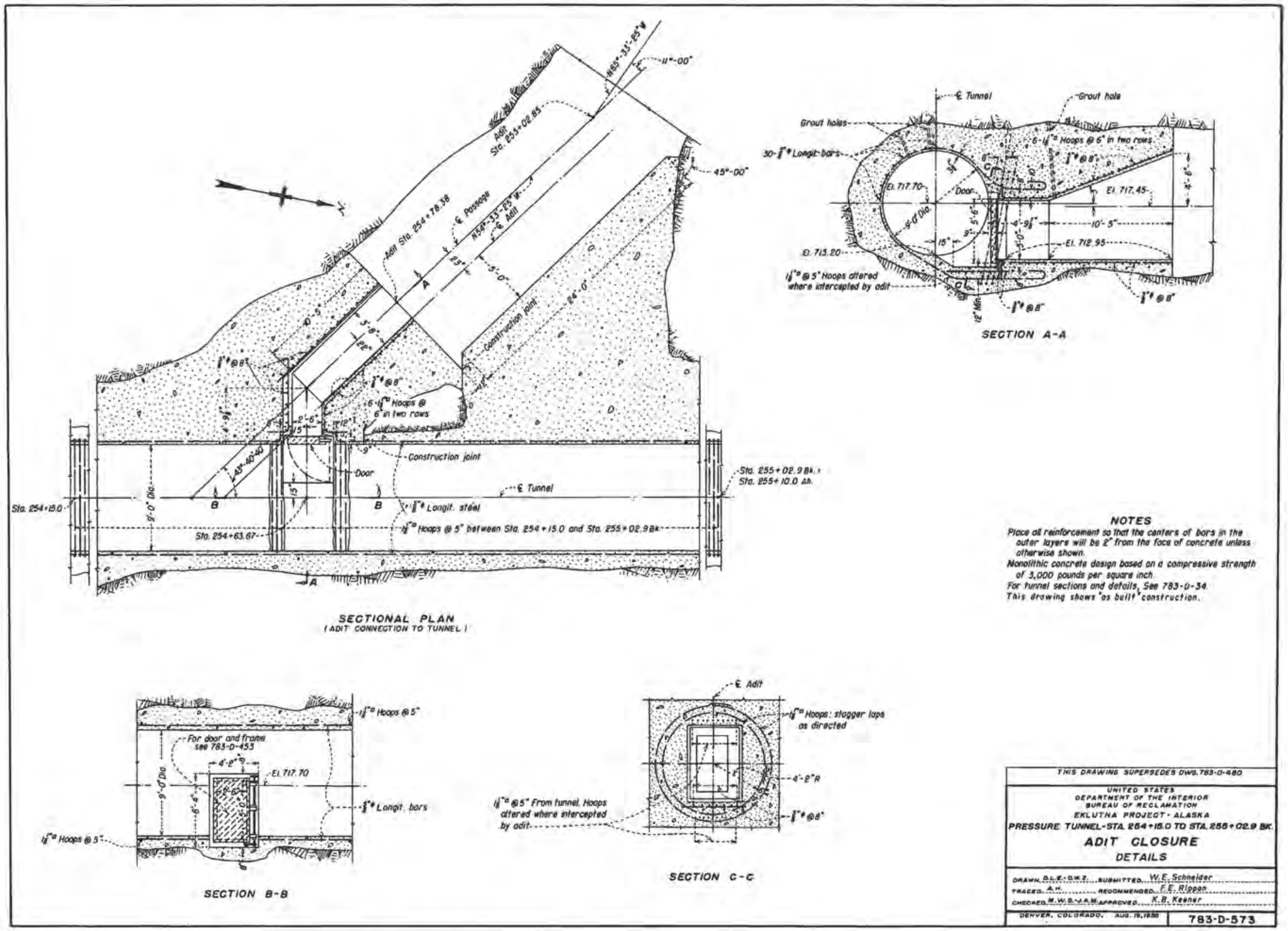


Figure 40. --Details of adit closure for pressure tunnel--Station 254. 15 to station 255. 02. 9 Bk.

which could be passed through the narrow space at the bottom of the headgate shaft (see figs. 42 and 43). Bureau force-account crews were withdrawn for work in the tailrace and other critical areas after having reached station 32+00 from the headgate end and station 189+00 from the adit door end of the tunnel. (See fig. 4.)

The contractor's mechanical mucking operations were accomplished using a diesel-powered 1-1/2-cubic-yard haul unit and a slusher and drag-bucket combination (see figs. 44 and 45). The empty drag bucket was drawn into the gravel debris by a cable attached to a gin pole which was jacked against the sides of the tunnel. The loaded drag bucket was drawn into the loading chute of the slusher unit, which discharged the material into the haul unit. The haul unit then delivered its load upstream to the headgate shaft where the rock was lifted to the surface in a 3/4-cubic-yard bucket by a 45-ton motor crane.

Rock removal progress in the early stages was limited by the travel time of the 3/4-cubic-yard mucking bucket up the 220-foot gate shaft. As the slusher worked its way further into the tunnel, the travel time of the haul unit became the controlling factor with round trips eventually taking approximately 45 minutes. Peak yardage was obtained on the seventh day of operation with an average of 50 buckets or approximately 40 cubic yards per shift. As the contractor approached station 100+00 and a lighter concentration of material, advancing the heavy slusher became a more critical operation, so force-account crews were again put to work from the downstream end. After 48 shifts, the contractor met the Bureau forces at station 157+00 at 12:30 a.m. on June 21. Figure 46 shows the second of two approximately equal piles of sand and rock removed from the headgate end of the tunnel.

Following final cleanup and demobilization of the mucking equipment, three heavy chain link screens 4 feet high were installed at approximately 100-foot intervals downstream from the headgate. Each screen was made up of 2-inch mesh wire with an additional strand interwoven to reduce the effective opening to 1 inch. (See fig. 47.) The headgate was partially opened until the tunnel and penstock were filled and then immediately closed and the tunnel dewatered sufficiently to permit examination of the screens. No rock had collected at the first screen at station 28+50, although the wire mesh was bulged somewhat, indicating there had been some impact. One to two cubic yards of rock were found deposited behind the second screen at station 29+50, but nothing was found to have lodged on the third screen at station 30+50.

After this small amount of rock was removed, the tunnel was again filled and the powerplant placed into operation for a period of 48 hours picking up all possible customer load in the hope that the remaining rock would be washed through the headgate and deposited against the screens. Following this 48-hour operation, the tunnel was again unwatered and approximately 23 cubic yards of gravel was found deposited, and as before, almost all of it had lodged behind the second and third screens. Less than 1 cubic yard had been carried a short distance beyond the third screen. A second 48-hour generating period was conducted, and this time only 2 cubic yards of gravel was collected, so it was assumed that the lake section of the tunnel had been cleared of debris and on July 2 the powerplant was returned to normal operation.

58. Tunnel Cleanup Equipment. Following is a list of the principal items of equipment used by Peter Kiewit Sons' Co. in their mucking operations in the pressure tunnel:

Quantity	Item	Size or capacity
1	Haul unit, diesel-powered	1-1/2 cu. yd.
1	Electric slusher, with 20-kilowatt diesel-powered generator	15 hp.
1	Drag bucket	3/4 cu. yd.
1	Belt conveyor, electrically driven	--
1	Electric pump	2,500 g.p.m.
1	Motor crane	45 ton
1	Generator, diesel-driven	100 kw.
1	Exhaust fan	15 hp., 3,600 r.p.m.

Figure 41.--View of tunnel mucking operation by Bureau force-account employees. Sand and rock is being moved toward the adit tunnel by means of a movable plywood dam utilizing the head developed by the leakage water to assist motivation. P783-906-2326, May 1964.

Figure 42.--View of diesel-powered 1-1/2-cubic-yard haul unit being dismantled prior to lowering it into the tunnel through the headgate shaft. P783-906-2343, June 1964.

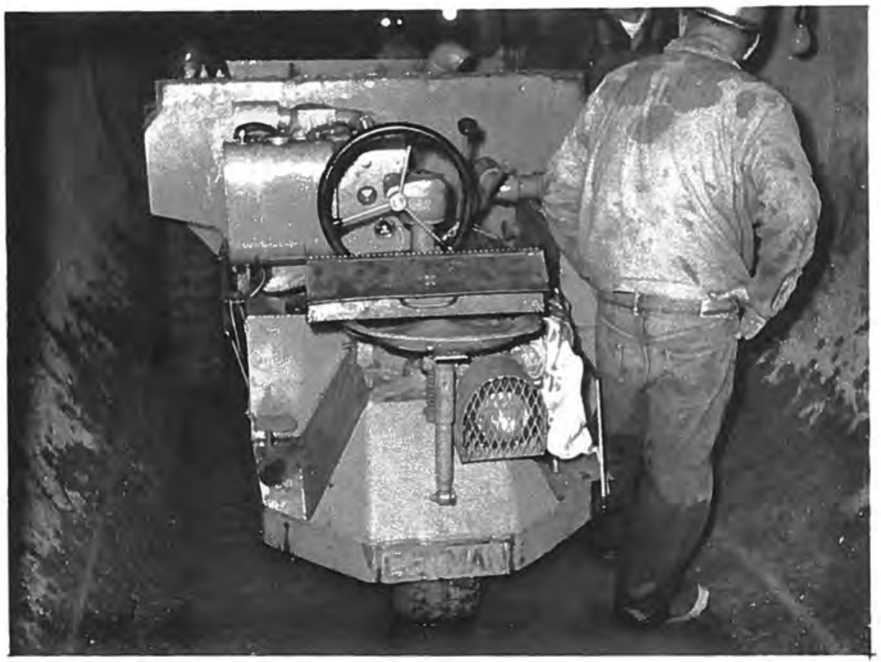


Figure 43.--View of the haul unit being reassembled in the 9-foot-diameter tunnel. P783-906-2344, June 1964.

Figure 44.--View of loading chute and drag bucket of the 15-horsepower electric slusher unit used by the contractor to remove accumulated gravel from the pressure tunnel. P783-906-2349, June 1964.

Figure 45.--Accumulation of debris in pressure tunnel as a result of earthquake damage to precast concrete intake conduit. Rock in foreground is typical of that deposited throughout 3-1/2 miles of the tunnel. View is looking upstream toward the loading end of the slusher unit. The drag bucket is being drawn toward the slusher from the gin pole in the center of the picture. P783-906-2351, June 1964.

(a) *Ventilation Problem.*--The exhaust fan, listed above, was installed at the adit door in the lower end of the pressure tunnel, to assure adequate ventilation of the tunnel at all times. Natural ventilation was good at times, but atmospheric changes during the course of the day could retard or even reverse the natural airflow. Carbon monoxide buildup in the tunnel atmosphere was a constant threat and was checked closely by Bureau inspectors on each shift.

Figure 46.--View showing the second of two approximately equal piles of sand and rock removed through the headgate shaft during tunnel mucking operations. The water spilling from the pipe at the left is the discharge from a high-lift pump installed behind the gate shaft and represents the leakage through the headgate seals. P783-906-2355, June 1964.

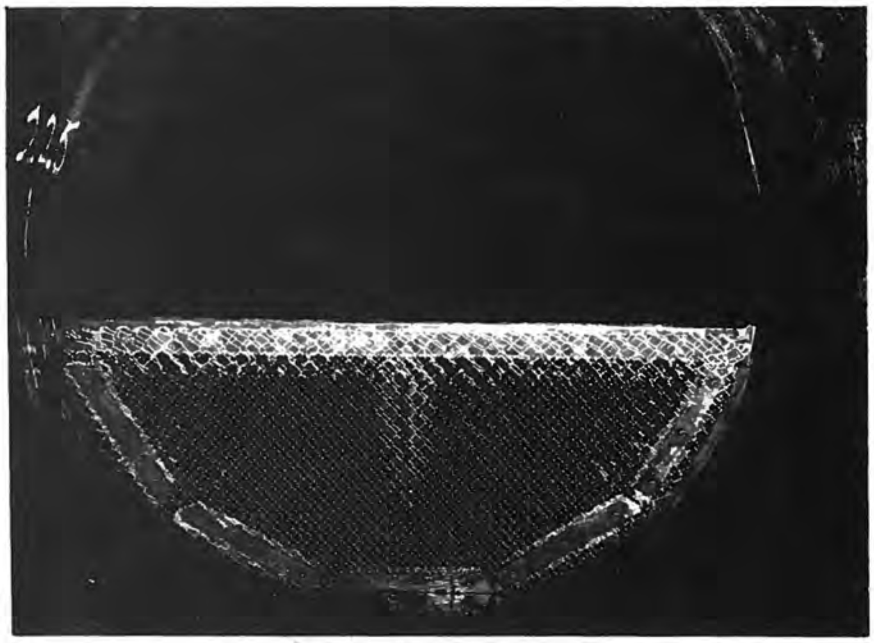


Figure 47.--View of the second of three 4-foot-high screens installed at intervals of approximately 100 feet below the headgate. The screens were installed by the contractor after the sand and rock was removed from the 4-1/2-mile tunnel. They were designed to stop the rock which remained in the tunnel between the headgate and the trashrack and which could not be readily removed by divers. P783-906-2356, June 1964.

CHAPTER VII. Construction --MAJOR REHABILITATION AND REPLACEMENT WORK

A. Replacement of Intake Structure and Repairs to Conduit

59. General. The replacement of the intake structure and permanent repair of the conduit leading to the pressure tunnel above Eklutna Powerplant were accomplished by Manson-Osberg Co., under specifications No. DC-6212, between February and May 1965 (see sec. 41).

Components of the work required by the contract included caring for lake water and unwatering the site during construction; removing a portion of the existing precast concrete pipe conduit at the intake of the pressure tunnel; earthwork and construction for a new intake structure and for installing stainless steel joint repair rings between sections of the remaining precast concrete conduit or construction of concrete encasements about these pipe joints; furnishing and installing trashracks for the new intake structure; and placement of riprap in the excavation area to elevation 872.0.

60. Intake Structure and Conduit for Pressure Tunnel. The contractor, Manson-Osberg Co., began to move in equipment on February 26, 1965. Ice 25 inches in thickness which had accumulated on the bank of Eklutna Lake above the inlet between elevations 847 and 812 was removed starting on March 1, using a ripper and three crawler-tractor bulldozers.

Excavation above the berm on the backslope above the intake (elevation 830) was started and the wet material was hauled to a waste area about 300 yards to the east of the centerline of the intake. Work on the cofferdam was started March 15 (fig. 48) and the area was ready to be drained on March 25. The tunnel was drained slowly during the day and the following night, so that on March 26 all water inside the cofferdam had drained out, exposing the intake structure and conduit (figs. 49 and 50). The cofferdam, which was 400 feet long, was built up to a crest width of 40 feet and a top elevation of 823.5. Pumping from a sump about 20 feet left of station 17+60 continued until construction was completed.

Figure 48.--General view of construction of cofferdam and excavation for the new intake structure. P783-908 C&R-7A, March 23, 1965.

Figure 49.--View showing exposed top side (trashracked side) of original intake structure after removal of water. P783-908 C&R-17A, March 26, 1965.

Figure 50.--Two damaged joints on the existing 9-foot-diameter precast concrete conduit. P783-908 C&R-27A, March 21, 1965.

The inside joint rings which had been installed by divers immediately after the earthquake to exclude further sand and gravel intrusion (see sec. 56) were stripped off and four damaged sections of the concrete conduit were removed. Four additional sections adjacent to the original intake structure, together with the intake structure, were abandoned but left in place, as may be seen in figure 51. The six remaining pipe joints, which had been separated by the earthquake from 3/4 inch to about 3-1/2 inches, were sandblasted and dry-packed with concrete. Then the stainless steel joint repair rings, which the contractor elected to provide in lieu of concrete encasements about the joints (see sec. 14), were installed. Three long screw jacks were used to facilitate installation of the rings. Some difficulties were encountered in fitting these rings, owing to irregularities in the shape of the existing pipe, but the work was completed by April 28, 1965. A view of one of the steel rings during installation is shown in figure 52.

Concurrently with the work on the conduit, forms for the intake structure were prefabricated and were set in place on April 12. Also, the reinforcing steel was erected and concrete was placed in the base and the remainder of the intake structure (fig. 53). The trashracks arrived and were installed by April 30. Figure 54 shows the completed intake structure in front of the abandoned portion of conduit and the original intake structure.

Final grading and placement of bedding and riprap below elevation 820 (along the slope of the bank above the inlet as seen on figure 55) was accomplished concurrently with the concrete work for the intake structure. The bedding material was obtained from a pit located about 900 feet to the right, or southeast of the tunnel centerline along the lakeshore road. Riprap rock was obtained from a source about 1 mile east of the intake along the lakeshore road.

Beginning on May 2, water was pumped from Eklutna Lake to the inlet structure area enclosed by the cofferdam. By the following evening the water had filled the area to elevation 803, and removal of the cofferdam was started the next day. By May 5 enough material had been removed from the cofferdam to permit the water depth to equalize on either side. Removal of the cofferdam was completed by May 7 and all work under this contract was accepted as complete on May 14, 1965.

The operation of the powerplant was resumed with the production of power by one generator at 8 a.m. on May 18, 1965.

B. Replacement of Dam and Spillway

61. General. Replacement of Eklutna Dam and the spillway structure was accomplished by A & B Construction Co., of Helena, Mont., under specifications No. DC-6240 between April and November 1965. A photograph of the completed dam is shown in figure 56. The contract completion date was October 8, 1966; but the contractor's proposed construction program estimated completion of all work by December 31, 1965.

The new dam is an earth and rock fill structure having three zones composed of compacted material of varying porosity. A detailed description of the dam is found in section 18, and a general plan and sections are shown on figure 22.

The spillway for the new Eklutna Dam consists of an approach channel; an inlet structure with the crest of the spillway built into it; a rectangular reinforced concrete conduit; and a chute and stilling basin. A description of the spillway structure is given in section 31.

62. Clearing Site and Removing Existing Structures. The prime contractor performed all clearing operations. Work started on April 6, 1965, and clearing in the dam construction area was essentially completed by May 1. Clearing in borrow area H, the source of impervious zone 1 material, and removal of existing structures were performed intermittently, the latter being nearly completed by September 1. One 96-horsepower crawler-tractor bulldozer, chain saws, and small tools were utilized by the clearing crew which consisted of one tractor operator and two laborers. Areas utilized for permanent construction, stockpiles, and borrow pits were cleared of all vegetation and debris. Areas outside of the above, but within the reservoir area below elevation 870 between the replacement damsite and the existing dam, were cleared of all growth more than 5 feet high and having a butt diameter of more than 2 inches. All timber structures, including timber gates with their stems and handwheels, were removed from the area of the existing dam.

Figure 51.--General view of abandoned intake structure and conduit in the background and new intake structure nearing completion in the foreground. P783-908 C&R-54A, April 28, 1965.

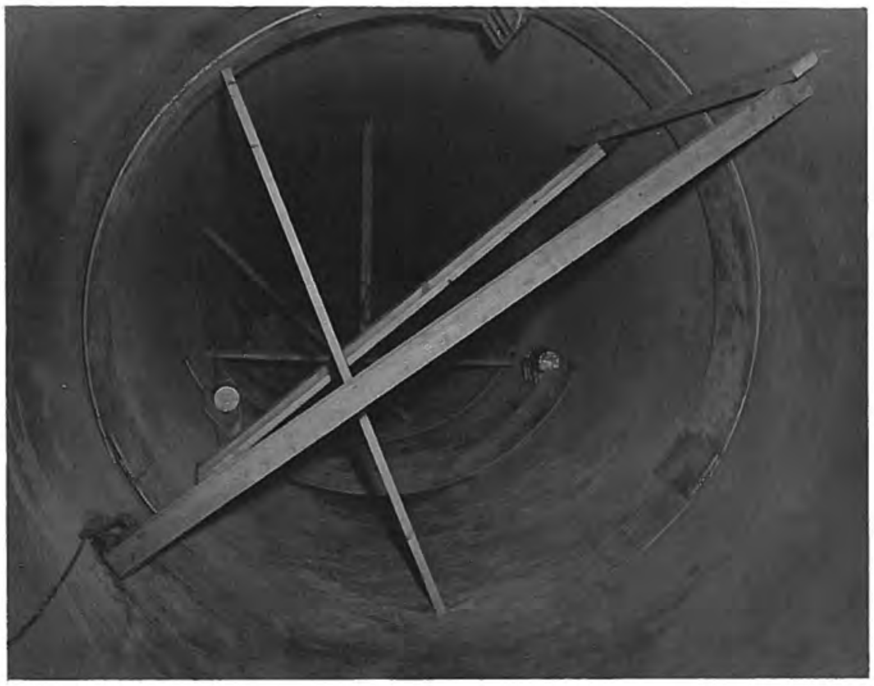


Figure 52.--View showing installation of steel rings inside the 9-foot-diameter precast concrete conduit. P783-908 C&R-48A, April 16, 1965.

Figure 53.--New intake structure with concrete work completed and ready for installation of trashracks on the top, sides, and front. P783-908 C&R-65A, April 30, 1965.

Figure 54.--Completed new intake structure in front of abandoned portion of conduit and old intake structure. P783-D-48322NA, May 3, 1965.

Figure 55. --Completed riprap in place on the backslope to the new intake structure. P783-908 C&R-83A, May 18, 1965.

Figure 56. View of completed Eklutna Dam, showing the upstream face and the spillway inlet. P783-D-58572, August 1967.

Piles, trees, etc., in this area were cut off 6 inches above the ground and fallen trees and logs more than 4 inches in diameter were removed by the contractor. To accelerate burning of the stacked timber, the contractor utilized large fans operated by gasoline engines.

63. Unwatering Site. The original water control plan submitted by the contractor included construction of a cofferdam in front of the existing dam gates. However, it was called to his attention that the gates must not be lowered, as the existing structure was unsafe (sec. 15). The contractor determined that excavation of a channel around the construction area would provide ample protection in case of an unusual rise in the lake level. Accordingly, a new plan was submitted and approved. This plan allocated a lump-sum price of $90,000 as follows:

Preconstruction unwatering	$ 4,500
Construction unwatering.	68,000
Rehabilitation of area	17,500

As it developed, no problem was encountered with the level of the water in Eklutna Lake. As a result of the initial drawdown during the winter of 1964-65, the lake stood at elevation 812.0 on March 23, 1965, and rose to elevation 814.75 by May 18, a period during which no power was generated. With generation of power the lake level fell to 813.5 by June 19. A fairly steady rise began at this time, raising the level to elevation 826.0 on August 1 and to elevation 846.7 by September 30. A very gradual rise continued through October 15 to elevation 847.2. Thereafter, the level dropped slowly and was at elevation 844.5 on November 15, 1965, the completion date. The gates on the old Eklutna Dam were kept open all spring and summer and were removed in August of 1965.

The contractor constructed a drain on the left abutment and dug other temporary ditches to prevent erosion in the cutoff trench and to prevent drainage water from entering the construction area. The flow of Eklutna Creek was diverted along the toe of the left abutment during construction of the spillway. Sumps were placed adjacent to the upstream side of the core trench and at the inlet of the spillway. After embankment construction began, water was pumped over the left abutment to the drain. After the core trench was backfilled, new sumps were dug adjacent to the spillway inlet, and pumping continued throughout the remainder of the construction period. Also, it was necessary to unwater the stilling basin area periodically as rains occurred.

1. *Earthwork*

64. Excavation. Earthwork operations for the new Eklutna Dam were started in April 1965, when the contractor started stripping and excavating for the spillway and right abutment portion of the cutoff trench. Subsequently, A & B Construction Co. issued two subcontracts to Hermon Brothers Co., Palmer, Alaska, for the remainder of the earthwork and rock and riprap portions of the dam. The depth of cut in the spillway varied from 5 to 35 feet, and in the cutoff trench from 0 to 15 feet. Two 270-horsepower crawler tractors pulling 15-cubic-yard scrapers were used to excavate for the spillway structure. Total spillway excavation was 35,959 cubic yards, a portion of which was used later for zone 2. Concurrently with the spillway excavation a major portion of the stripping and excavation on the left abutment was performed (fig. 57).

Following excavation for the spillway structure, earthwork operations were suspended to allow the concreting operations to proceed. Concrete placement had progressed sufficiently by the end of August to allow the contractor to complete the excavation of the left abutment and the remainder of the cutoff trench. Total yardage excavated from the cutoff trench and left abutment was 27,255 cubic yards, including stripping. The bulk of this excavated material was wasted. Work progressed steadily on excavation and spillway construction; but embankment work was delayed until completion of the concrete conduit section of the spillway on September 1, 1965. The entire spillway structure was completed by September 30. At this time the earthwork subcontractor accelerated his work by adding more men and equipment, but his efforts were partially offset by cold weather and snow early in October.

65. Embankment Materials. The earth embankment at the new Eklutna Dam consists of three zones: zone 1, an impervious water barrier for the dam; zone 2, a semipervious zone of sand and gravel; and zone 3, an outer pervious shell of rock.

Figure 57.--Excavating operations on the left abutment of the new dam. P783-908 C&R-121A, June 10, 1965.

The zone 1 portion of the embankment consists of material excavated from the area designated as borrow area H located about one-half mile north of the damsite. This material is a mixture of clay, silt, gravel, and cobbles up to 5 inches in maximum size.

The zone 2 portion of the dam embankment consists of materials from the spillway excavation and from river bottom areas above and below the centerline of the dam. The materials are a mixture of sand, gravel, and cobbles.

The zone 3 portion of the dam embankment consists mainly of materials from the designated rock source located about 2 miles east of the dam. The material ranged from 3 to 36 inches in size.

66. Borrow Area Operations. Operations in borrow area H, which was the source of zone 1 material for the impervious water barrier, began by clearing the area of trees and stripping the topsoil. The underlying material consisted of layers of clay-silt, sand and gravel. The various layers were cut through by a bulldozer blade and partially blended before they entered the separator which removed the oversize and further blended the material. (See fig. 58.) This machine was set up in a central location. The natural moisture content was found to be sufficient in the material and therefore no additional water was required. Oversize material was stockpiled for use in the zone 3 portion of the dam. Material from stripping was pushed aside to be spread and leveled in the pit after excavation was complete.

During the latter period of construction the quality of the material began to deteriorate to the extent that the rock and sand contents were considered too high for the material to be suitable for the impervious core. A new borrow area was therefore opened south of the designated area, and just south of the airstrip. A section was cleared and a small amount of material was excavated, but the new source was abandoned due to excessive amounts of sand and low plasticity of the fines. The material was also excessively wet.

Figure 58.--Gravel processing plant, or separator, located in borrow area H. P783-908 C&R-122A, June 10, 1965.

Operations were resumed in the original borrow area, with great care being taken to keep the quality of material as high as possible. At this stage of construction use of the separator was discontinued and the material was loaded directly, as there was virtually no material being retained on the 5-inch screen.

For excavation in the borrow area, one 93-horsepower crawler tractor and one 270-horsepower crawler tractor equipped with dozer blades were used to push zone 1 material to the separator with 5-inch screen. After use of the separator was discontinued, one of the larger dozers was used as a pusher to assist the rubber-tired motorized scrapers in loading.

67. Embankment Placing Operations. Three 300-horsepower rubber-tired motorized scrapers each with a rated capacity of 21 cubic yards transported the zone 1 (impervious) material from borrow area H to the embankment (see fig. 59).

Placing and compacting of the zone 1 portion of the dam (sec. 65) was started in the cutoff trench. The material was hauled to the fill, dumped in lifts, leveled with a 93-horsepower crawler-tractor dozer, and compacted by rolling. Each lift was subjected to 12 passes of a two-drum, 40,000-pound compacting roller pulled by a 270-horsepower crawler tractor.

The zone 2 (semipervious) portion of the dam embankment (sec. 65) was placed in lifts about 12 inches thick. The material was spread with a 270-horsepower crawler-tractor dozer and compacted by four passes of the tractor treads. The moisture content was generally satisfactory for compaction. Gradation tests were performed on the zone 2 material to determine its suitability.

That portion of the fill adjacent to the structure (zones 1 and 2) was hand placed. A front-end loader pushed material to the area where it was hand shoveled into place and

Figure 59. --Placement of zone 1 embankment on the dam.
P783-908 C&R-194A, September 14, 1965.

compacted using two gasoline-powered tampers. Control tests were taken which showed this method to be adequate so long as the lifts were kept thin (3 to 5 inches thick after compaction).

The rock for the zone 3 portion of the dam (sec. 65) was blasted loose and loaded in dump trucks using a 2-3/4-cubic-yard front-end loader. Five dump trucks were used to transport the rock from the quarry to the embankment where it was spread with a heavy-duty dozer (a small amount of material was obtained from the separation plant in borrow area H). The material was well graded from 3 to 36 inches in size. Inspectors made visual inspection of the rock to see that it met specifications requirements for quality and size for use in zone 3.

All work on Eklutna Dam was completed and final acceptance made on November 15, 1965, 327 days ahead of the contract completion date and 46 days ahead of the contractor's own schedule. A photograph of the completed dam is shown in figure 56.

68. Riprap Protection for Spillway. The riprap for protection of the outlet channel of the spillway consisted of rock from the Alaska Railroad quarry at Eklutna Village (see fig. 60). The material was hauled from the quarry to the dam by truck and was placed with a 270-horsepower crawler-tractor dozer. The rock ranged from about 8 to 36 inches in diameter.

69. Bedding Material. Bedding material for the riprap was procured from the streambed downstream from the stilling basin. This material was used on the left abutment both upstream and downstream of the dam, and in the outlet of the stilling basin in the streambed area. (See fig. 25.) The natural ground surface material on the inlet channel and on the side slopes between the end of the stilling basin and the end of the riprap area was tested for gradation and found to be in conformance with specifications requirements for bedding. Consequently, in these areas, rock surfacing and riprap were placed directly on the natural ground. Gradation tests for suitability were made on bedding for the riprap and also on the zone 3 material on the left abutment. The tests were satisfactory.

Figure 60. --View of the downstream face of the completed dam and spillway. P783-908 C&R-211NA, October 21, 1965.

70. Earthwork Control. One field density test was performed for approximately each 1,000 cubic yards of zone 1 material. The density test holes were 7 inches in diameter by 12 to 14 inches deep. Ottawa sand poured through a cone device was used for volume determination. Owing to the congested conditions it was difficult to work out a schedule for taking tests without interferring with the contractor's operations. Therefore, the time available during the contractor's normal shutdown periods was utilized as much as possible for these tests.

Considerable difficulty was experienced in making this test because the density hole squeezed inward during the test; thus the volume indicated was less than it should have been, and the density based on this volume was too high. This difficulty was overcome by constructing a special platform which supported the operator's weight approximately 3 feet from the density plate, and exercising extreme care during excavation of the hole. It was also found that digging a shelf for the operator to stand about 6 inches lower than the top of the hole helped prevent deformation of the hole.

One percolation test was performed for approximately each 6,000 cubic yards of fill. A total of five tests were made by the Corps of Engineers laboratory in Anchorage, and a sample was sent to the Bureau's Denver laboratory for a large permeability test to be used for comparison.

2. *Concrete work*

71. General. The only concrete construction related to the dam was in the spillway structure, since no river outlet other than the pressure tunnel intake was provided.

The prime contractor, after having completed the main excavation for the rectangular reinforced concrete spillway conduit, began the installation of the anchor bars that was specified to secure the spillway conduit to its foundation. After an unsuccessful attempt at drilling the anchor bar holes with a piledriver, the contractor subcontracted this work to United Geophysical Co., who performed the work with a truck-mounted rig using a rotary bit. Work began on June 7 and was completed by June 30, 1965. To expedite the work, a crane was used to support the rig while drilling holes on the slope. (See fig 61.) Since only a short period of time was needed to drill each hole, this procedure saved considerable time which might otherwise have been required for blocking up the rig before each drilling operation. The prime contractor installed the 130 anchor bars and performed the grouting operation. The bars were 1-3/8 inches in diameter and ranged from 13 to 16 feet in length. (See fig. 62.)

A drainage system was installed by the prime contractor under the spillway chute and stilling basin floors. Perforated 6-inch-diameter sewer pipe laid on a 3-inch-thick lean concrete pad and covered by a 6-inch gravel envelope was used in both the transverse drains and the longitudinal drains, except that the outlet cross drain utilized 8-inch-diameter perforated sewer pipe.. The concrete pads were placed without forming. Drain outlets were 8-inch-diameter sewer pipe rising in the chute blocks at the lower end of the chute section. Four-inch-outside-diameter steel air inlet pipes rising in the chute walls to elevation 855.50 opened into the stilling basin.

A summary of the concrete placed in the spillway is shown below:

Specifications item	Description	Cubic yards	Unit price
20	Concrete in spillway floors	792.82	$ 80.00
21	Concrete in spillway walls	1,104.63	140.00
22	Concrete in spillway conduit and cutoff collars	873.06	180.00
23	Second-stage concrete in spillway crest	231.66	180.00
Total		3,002.17	

72. <u>Forms and Reinforcing Steel</u>. Forms for the spillway were constructed using 4- by 8-foot panels constructed of 2- by 6-inch studs placed on 16-inch centers with 3/4-inch plywood facing. (See fig. 63.) Carpenters placed sections of these forms by nailing them to each other. Walers were then applied to line up and strengthen the forms. This practice did not require the continuous use of a crane during construction of the forms, as carpenters could move small panels into place manually except on the higher portions of the structure. Erection of forms for the first placement of concrete on the spillway began on June 10, 1965, in the first upstream floor section.

The steel subcontractor, Fowler Steel Co., Anchorage, Alaska, began placing reinforcement bars, and the initial concrete was placed in this section on June 17. All reinforcing steel was manufactured by Bethlehem Steel Corp. With a few minor exceptions, all bars were bent and properly cut for use in the spillway structure before shipment from the fabricator. The subcontractor handled all the steel, which was brought to Anchorage by ship. Their employees hauled the steel to the damsite, unloaded it and placed it in the forms, after which it was inspected. A summary of reinforcing steel, including anchor bars, used in the work is as follows:

Section	From station	To station	Weight of steel, pounds
Inlet	3+68	4+37.50	50,618
Crest	4+37.50	4+73.54	62,828
Conduit	4+73.54	5+57.34	106,937
Chute	5+57.34	6+35.00	70,479
Stilling basin	6+35.00	7+24.00	146,443
Total			437,305

In addition to the above quantities, 382 pounds of steel were required for the steel plates welded to the bottom of the anchor bars.

The foundation for the entire structure was quite uniform and no difficulty was experienced due to poor foundation materials. The spillway floors were completed by August 18, and all conduit sections and cutoff collars were completed during August. The chute and stilling basin walls and second-stage concrete in the inlet section were placed during September and all concrete work was completed by September 30. Concrete in the crest section was placed without forms on the downstream side, the water-cement ratio being reduced to 0.45 for this concrete.

73. Concrete Control. (a) *Aggregates.*--The contractor set up a batching plant on the right abutment upstream from the new damsite. The plant consisted of a three-bin unit with a total capacity of 24 cubic yards for two sizes of coarse aggregate and sand (see fig. 64). The coarse aggregate was separated into No. 4 to 3/4-inch and 3/4- to 1-1/2-inch sizes.

The bins were charged by dropping the coarse aggregate onto a sloping 3/16-inch screen from the bucket of a front-end loader. The sand was dropped into a chute which carried it to the proper bin. The sand and aggregates were weighed cumulatively in a 3/4-cubic-yard-capacity bin which ran on a track under the three-bin unit. The scales had three beams, one for each size of material. The weighing bin was charged by the operator, who released the scale beam for each size of material, then opened the door in the bottom of the bin until the proper weight was indicated by a large dial with a pointer which indicated over, under, or proper weight. The mixing water was pumped from a springfed pool and measured through a watermeter.

Coarse aggregates and sand from the Merrill Field pit were furnished by Anchorage Sand and Gravel Co. of Anchorage, Alaska. One 20-cubic-yard truck delivered the sand and aggregates which were stockpiled at the site. The sand and coarse aggregates were tested by the testing laboratory of the Corps of Engineers, North Pacific Division.

(b) *Cement.*--A type II cement was furnished by Kaiser Cement and Gypsum Corp. of Anchorage, Alaska. It was manufactured by Permanente Cement Co., Bellingham, Wash., and shipped to Anchorage, by barge. The bulk cement was delivered to the job on a 110-barrel-capacity truck and blown into the cement silo by compressed air. The cement was weighed in an individual hopper by a separate scale used only for the cement. The cement certifications were furnished by the chief plant chemist from Bellingham, Wash.

(c) *Batching, Mixing, and Placing.*--Two transit mixers were used on this project. The capacity of the mixers was 7-1/2 cubic yards but each unit mixed only 6 cubic yards of concrete. The charging speed was from 12 to 17 revolutions per minute, the mixing speed was from 4 to 9 revolutions per minute, and the agitating speed was from 2 to 6 revolutions per minute. Each mixer was equipped with a revolution counter which was reset to zero after each load was charged. Variability of constituents tests were run on the mixers. The concrete was transported a distance of approximately 300 yards and discharged into a 3/4-cubic-yard bucket which was lifted by a crane. The concrete was then deposited into the forms and consolidated by electric vibrators.

(d) *Air Entrainment.*--Two brands of air-entraining agent were used by the contractor. One brand was supplied by the Hunt Process Co., Los Angeles, Calif., and the other by

Figure 61.--Drill rig supported by motor crane while drilling holes for anchor bars on the spillway. P783-908 C&R-142NA, June 25, 1965.

Figure 62.--Anchor bars in place on the spillway structure subgrade. P783-908 C&R-113A, June 10, 1965.

Figure 63.--Forming and steel reinforcement in the spillway stilling basin. P783-908 C&R-158NA, July 23, 1965.

Figure 64.--Contractor's batching plant located at the damsite. P783-908 C&R-130A, June 16, 1965.

Protex Industries, Inc., Denver, Colo. Both agents appeared to give the same percentage of entrained air without adjustment in the quantity added to the mix.

(e) *Curing.*--The concrete was cured with a white-pigmented curing compound sprayed on immediately after the forms were stripped. (See fig. 65.) The curing compound was manufactured by the Hunt Process Co., Los Angeles, Calif.

(f) *Concrete Mixes and Testing.*--The average concrete mixes as used on the entire spillway for two water-cement ratios are as follows:

Maximum size of aggregate, inches	Water, lb. per cu. yd.	Cement, lb. per cu. yd.	Percent of entrained air	Sand		Gravel	
				lb. per cu. yd.	Sp. gr.	No. 4 to 3/4 in. lb. per cu. yd.	3/4 to 1-1/2 in. lb. per cu. yd.
Water-Cement Ratio = 0.46							
1-1/2	230	500	4.5	1,118	2.70	1,019	1,151
Water-Cement Ratio = 0.51							
1-1/2	230	460	4.5	1,130	2.70	1,031	1,162

The concrete test cylinders were made at the jobsite. They were cured in a water tank until taken to the testing laboratory of the Corps of Engineers, North Pacific Division, in Anchorage, Alaska, where they were cured in a fog room at 73.5° F. and 95 percent relative humidity. The cylinders were tested by the Corps of Engineers. A summary of compressive strength tests follows:

Maximum size of aggregate, inches	7-day tests				28-day tests				90-day tests			
	No. of cyls.	Strength, p.s.i. Avg.	Max.	Min.	No. of cyls.	Strength, p.s.i. Avg.	Max.	Min.	No. of cyls.	Strength, p.s.i. Avg.	Max.	Min.
Water-Cement Ratio = 0.46												
1-1/2	22	3,810	5,090	2,530	16	4,895	5,920	3,870	3	5,613	6,000	4,980
Water-Cement Ratio = 0.51												
1-1/2	14	3,465	4,810	2,120	25	4,775	5,780	3,770	1	4,770	4,770	4,770

74. Watertight Protection for Spillway Conduit. The specifications required that the concrete spillway conduit be covered with a 3/32-inch-thick butyl-rubber covering to produce a continuous watertight protection along the barrel section from station 4+59.86 to station 5+41.54 (see fig. 66).

The butyl-rubber covering was prepared by Staff Industries, Upper Montclair, N. J., from material manufactured by the Goodyear Tire and Rubber Co., New Bedford, Mass. The material came in rolls of proper width to make the designated lap splice and of sufficient length to completely encircle the conduit section of the spillway. There were many delays in applying the covering, since no splicing or tacking could be accomplished in damp or wet weather. The material was difficult to handle on the sloping section without wrinkling.

3. *Gates and Metalwork*

75. General. A 30-inch-square cast iron slide gate with flush bottom closure was installed in the bottom of the crest section of the spillway as a winter drainage outlet.

Figure 65. --Concrete placements on the inlet and conduit sections of the spillway nearing completion. P783-908 C&R-172NA, August 19, 1965.

Figure 66. --Butyl-rubber covering in place on the conduit section of the spillway. P783-908 C&R-184A. September 2, 1965.

It was necessary to drill an aperture about 4 inches into the gate chamber roof above the stem in order to provide enough clearance for the gate stem at full opening. The gate stem was enclosed by an 8-inch-diameter steel pipe. Painting was completed on October 20. Heat was applied on the painted areas until the paint was completely dry.

The drainage outlet trashrack (fig. 25) was installed during October. Painting was also accomplished at this time; heaters were used to dry the paint owing to the cold weather.

The handrail and ladders were procured by the contractor and installed in the crest section of the spillway immediately after the concrete was cured. Painting was accomplished early in October. The handrails were enclosed in a plastic tent and heaters were operated during the drying period.

APPENDIX

APPENDIX A

Cost summary for emergency work, rehabilitation, and reconstruction of certain Eklutna project features occasioned by Alaska earthquake of 1964 (data submitted by district office March 30, 1967):

A. Emergency Work and Replacement of Automotive Repair Shop

Construction Contracts

Specifications number	Item, contractor, and contract number	Total cost to the Government
DC-6112	Repair of earthquake damage to Eklutna tunnel--Peter Kiewit Sons' Co., contract No. 14-06-D-5098	$338,623
DC-6270	Construction and completion of the automotive repair shop--Holiday Construction Co., Inc., contract No. 14-06-D-5596	73,634
	Total, Construction Contracts	$412,257

Supply Contracts and Purchase Orders

Invitation number	Item, contractor, and contract number	Total cost to the Government
(D)A-69,455A	Turbine shaft sleeves and parts--Newport News Shipbuilding and Dry Dock Co., contract No. 14-06-D-5154	$ 2,820
64-1193	Equipment rental (pump, hose, compressor)--Lottsfeldt and Kyzer, contract No. 14-06-0906-22	1,121
64-1194	Equipment rental (pump and hose)--Shaw Tool Rentals, contract No. 14-06-0906-23 . .	113
64-1195	Equipment rental (pump and hose)--McDowell-Woodland Co., Inc., contract No. 14-06-0906-24.	3,082
64-1196	Electric pump rental--Equipment, Inc., contract No. 14-06-0906-25.	265
64-1197	Equipment rental (pump, gas engine)--Bud's Service, contract No. 14-06-0906-26	132
64-1113	Inspection of intake structure--Associated Divers, Inc., by U.S. Corps of Engineers, contract No. 64-76.	8,737
65-390	Diving service to recover diamond drill and associated equipment and inspection of Eklutna Tunnel intake--Associated Divers, Inc., contract No. 14-06-0906-27	3,448
65-878	Replacement (Gering circuit breaker)--Brown Boveri Corp., purchase order No. 703-65-483	14,688

A. Emergency Work and Replacement of Automotive Repair Shop--Continued

Supply Contracts and Purchase Orders--Continued

Invitation number	Item, contractor, and contract number	Total cost to the Government
65-405	Equipment rental of compressor hose (gate shaft)--Woodland Equipment Co., Inc., contract No. 14-06-0906-29	$ 664
65-1406	Equipment rental (compressor)--Woodland Equipment Co., Inc., contract No. 14-06-0906-30	149
DS-6309 66-657	Supplemental control and photogrammetric compilation of topographic map of Eklutna Lake--Air Photo Tech. Inc., contract No. 14-06-D-5667	6,430
	Miscellaneous purchase orders	37,733
	Total, Supply Contracts and Purchase Orders	$ 79,382
	Total, Contractual Costs	$491,639

Noncontractual Costs

Purchased power	$ 9,177
Labor by Government forces	111,245
Indirect costs:	
Designs and specifications (Denver)	22,513
Engineering and inspection	13,824
Administrative and general expense	20,516
Total, Noncontractual Costs	$177,275
Total Cost of Emergency Work and Replacement of Automative Repair Shop	$668,914

B. Replacement of Intake Structure and Repairs to Intake Conduit

Construction Contract

Specifications number	Item, contractor and contract number	Total cost to the Government
DC-6212	Rehabilitation of intake structure and conduit for pressure tunnel--Manson-Osberg Co., contract No. 14-06-D-5444	$652,416
	Total, Construction Contract	$652,416

Supply Contracts and Purchase Orders

Miscellaneous purchase orders	$ 2,289
Total, Purchase Orders	$ 2,289
Total, Contractual Costs	$654,705

APPENDIX A--Continued

B. Replacement of Intake Structure and Repairs to Intake Conduit--Continued

Noncontractual Costs

	Total cost to the Government
Indirect Costs:	
Designs and specifications (Denver)	$ 29,663
Engineering and inspection	23,194
Administrative and general expense	80,847
Total, Noncontractual Costs	$ 133,704
Total Cost of Replacement of Intake Structure and Repairs to Intake Conduit	$ 788,409

C. Replacement of Eklutna Dam and Spillway

Construction Contract

Specifications number	Item, contractor, and contract number	Total cost to the Government
DC-6240	Eklutna Dam and spillway--A & B Construction Co., contract No. 14-06-D-5494 . . .	$1,194,638
	Total, Construction Contract	$1,194,638

Supply Contracts and Purchase Orders

	Miscellaneous purchase orders	$ 6,007
	Total, Purchase Orders	$ 6,007
	Total, Contractual Costs	$1,200,645

Noncontractual Costs

Service facilities	$ 3,217
Indirect costs:	
Designs and specifications	39,004
Engineering and inspection	92,973
Administration and general expense	84,139
Total, Noncontractual Costs	$ 219,333
Total Cost of Replacement of Eklutna Dam and Spillway .	$1,419,978

Recapitulation:	
Cost of Emergency Work and Replacement of Automotive Repair Shop	$ 668,914
Cost of Replacement of Intake Structure and Repairs to Intake Conduit	788,409
Cost of Replacement of Eklutna Dam and Spillway	1,419,978
Total Cost of Emergency Work, Rehabilitation, and Reconstruction of Eklutna Project Features	$2,877,301

APPENDIX B

Construction costs by pay items--Repair of earthquake damage to precast concrete conduit for Eklutna Tunnel intake--Specifications No. DC-6112, contract No. 14-06-D-5098:

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Negotiated emergency contract on cost-plus basis		Lump sum	$385,947.47	$385,947.47
	Negotiated adjustment in contract price based on contractor's actual costs			-47,324.47	-47,324.47
	Total--Net Payments			$338,623.00	$338,623.00

APPENDIX C

Construction costs by pay items--Rehabilitation of intake structure and conduit for Eklutna Pressure Tunnel--Specifications No. DC-6212, contract No. 14-06-D-5444:

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
1	Care of lake water and removal of water at construction site (see breakdown below)		Lump sum	$200,631	--
	Dewatering:				
	Move in and set up pumping equipment	100%	Lump sum	25,000	$ 25,000
	Operate pumping equipment	100%	Lump sum	43,000	43,000
	Move out pumping equipment	100%	Lump sum	10,000	10,000
	Cofferdam:				
	Construct cofferdam	100%	Lump sum	82,631	82,631
	Remove cofferdam and waste material	100%	Lump sum	40,000	40,000
2	Earthwork	100%	Lump sum	215,000	215,000
3	Riprap	4,845.9	cu. yd.	20	96,918
4	Gravel bedding for riprap	1,186.7	cu. yd.	10	11,867
5	Concrete	100%	Lump sum	80,000	80,000
6	Removing four 108-inch-diameter precast-concrete pipe units and pipe joint rings	100%	Lump sum	13,000	13,000
7	Furnishing and installing trashracks	100%	Lump sum	35,000	35,000
	Total--Net Payments				$652,416

APPENDIX D

Construction costs by pay items--Replacement of Eklutna Dam--Specifications No. DC-6240, contract No. 14-06-D-5494:

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
1	Care of water during construction and removal of water from foundations. The water control plan included the following:		Lump sum	$90,000.00	--
	(a) Preconstruction dewatering including open drains, earthfill dike, test holes, and availability of local dewatering equipment	100%	Lump sum	4,500.00	$ 4,500.00
	(b) Construction dewatering including open drains, trenching, sumping, and lake overflow diversion	100%	Lump sum	68,000.00	68,000.00
	(c) Rehabilitate area including backfilling of drains, channels, trenches, and sumps and removal of dikes and general cleanup	100%	Lump sum	17,500.00	17,500.00
2	Clearing site and removing existing structures	100%	Lump sum	40,000.00	40,000.00
3	Excavation for dam embankment foundation	27,255	cu. yd.	2.50	68,137.50
4	Excavation for spillway	35,959	cu. yd.	2.50	89,897.50
5	Excavation, stripping borrow pits in borrow area H	6,728	cu. yd.	0.75	5,046.00
6	Excavation in borrow area H, separation, and transportation to dam embankment	42,507	cu. yd.	2.10	89,264.70
7	Procuring and placing bedding	2,323.66	cu. yd.	6.00	13,941.96
8	Procuring and placing riprap	1,866.26	cu. yd.	15.00	27,993.90
9	Procuring and placing rock surfacing	861.9	cu. yd.	6.00	5,171.40

APPENDIX D--Continued

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
10	Earthfill in dam embankment, zone 1	31,659	cu. yd.	$ 0.32	$ 10,130.88
11	Specially compacted earthfill, zone 1	727.6	cu. yd.	8.00	5,820.80
12	Procuring and placing sand, gravel, and cobble fill in dam embankment, zone 2	17,793	cu. yd.	1.28	22,775.04
13	Rockfill in dam embankment, zone 3	207	cu. yd.	0.40	82.80
14	Procuring and placing rockfill in dam embankment, zone 3	29,630.8	cu. yd.	4.00	118,523.20
15	Drilling holes for anchor bars and installing bars in place	1,625.0	lin. ft.	4.00	6,500.00
	Furnishing the following sizes of perforated sewer pipes and constructing drains:				
16	6-inch diameter	304.3	lin. ft.	18.00	5,477.40
17	8-inch diameter	20.0	lin. ft.	18.00	360.00
18	Furnishing and handling cement	4,149.90	bbl.	13.00	53,948.70
19	Furnishing and placing reinforcement bars	437,687	lb.	0.25	109,421.75
20	Concrete in spillway floors	792.82	cu. yd.	80.00	63,425.60
21	Concrete in spillway walls	1,104.63	cu. yd.	140.00	154,648.20
22	Concrete in spillway conduit and cutoff collars	873.06	cu. yd.	180.00	157,150.80
23	Second-stage concrete in spillway crest	231.66	cu. yd.	180.00	41,698.80
	Furnishing and placing rubber waterstop of the following types:				
24	Type A	129.46	lin. ft.	5.00	647.30
25	Type B	732.60	lin. ft.	5.00	3,663.00

APPENDIX D--Continued

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
26	Furnishing and placing butyl-rubber covering	852.8	sq. yd.	$ 4.00	$ 3,411.20
27	Furnishing and installing one 30- by 30-inch cast iron slide gate, lift, stuffing box, and lift support	100%	Lump sum	3,500.00	3,500.00
28	Furnishing and installing metalwork	100%	Lump sum	3,500.00	3,500.00
29	Furnishing and installing steel air inlet pipe and drain complete with accessories	100%	Lump sum	500.00	500.00
	Total--Net Payments				$1,194,638.43

APPENDIX E

Chronology of events related to rehabilitation of Eklutna project features following earthquake of March 1964:

Date	Event
March 27, 5:36 p.m., 1964	Earthquake shocks began.
March 28, 1964	First shutdown of Eklutna Powerplant for repairs began.
April 19, 1964	An underwater inspection by divers was made of damage to intake structure trashrack and intake pipe.
May 5, 1964	Contract No. 14-06-D-5098 was negotiated with Peter Kiewit Sons' Co. in Anchorage, Alaska, in the amount of $133,859.17 for a detailed inspection and repair, on a time and material basis, of the precast concrete conduit pipe of the tunnel intake.
May 9, 1964	Eklutna Powerplant was shut down and preparations began toward unwatering the power tunnel. Divers were sent into the headgate shaft to determine the condition of the gate slot. The removal of rock and sand from the tunnel began under the combined efforts of both the contractor's forces and the Government force-account crews.
June 21, 1964	Government forces and the contractor's mucking workmen met at station 157+00, thus ending the actual debris cleanout work in the tunnel.
January 19, 1965	The project construction engineer arrived at the project on a temporary assignment.
January 21, 1965	Bids for rehabilitation (replacement) of the intake structure under specifications No. DC-6212 were opened at Anchorage, Alaska. Eight bids were received. The apparent low bidder was Manson-Osberg Co., Seattle, Wash., in the amount of $633,631.00.
February 1, 1965	Manson-Osberg Co. was awarded the contract for rehabilitation of the intake structure and conduit for the pressure tunnel under specifications No. DC-6212.
February 12, 1965	Notice to proceed was issued and received by the contractor for work under specifications No. DC-6212.
February 26, 1965	Manson-Osberg Co. moved in the initial equipment.
March 1, 1965	Actual construction under specifications No. DC-6212 began with removal of ice from the excavation area.
March 16, 1965	Bids for replacement of Eklutna Dam under specifications No. DC-6240 were opened at Anchorage, Alaska. Six bids were received. The apparent low bid was submitted by A & B Construction Co., Helena, Mont., in the amount of $1,233,470.00.
March 22, 1965	By this date all Government personnel had arrived at the project construction engineer's office in Eagle River, Alaska.

Date	Event
March 26, 1965	The powerplant was shut down, the tunnel was drained, and work on the intake structure began.
March 26, 1965	The A & B Construction Co., Helena, Mont., was awarded the contract for replacement of Eklutna Dam, under specifications No. DC-6240.
April 5, 1965	A telegram giving notice to proceed was issued for specifications No. DC-6240 and was received by the contractor on April 6, 1965.
April 7, 1965	The dam contractor began clearing operations.
April 22, 1965	Bids for construction of an automotive repair shop under specifications No. DC-6270 were opened at Anchorage, Alaska. Fourteen bids were received. The apparent low bid was submitted by Holiday Construction Co., Spenard, Alaska, in the amount of $72,437.15.
May 12, 1965	The Holiday Construction Co. was awarded the contract for construction of the automotive repair shop under specifications No. DC-6270.
May 14, 1965	The contract for rehabilitation of the intake structure and conduit for the pressure tunnel was accepted as complete by the project construction engineer.
May 18, 1965	Manson-Osberg Co. signed a release on contract for rehabilitation of the intake structure and conduit.
May 18, 1965	Notice to proceed issued and received by the contractor for work under specifications No. DC-6270, automotive repair shop.
May 18, 1965	Power generation was resumed by Eklutna Powerplant after a shutdown of 54 days.
June 2, 1965	Excavation work started for the automotive repair shop.
June 7, 1965	The drilling subcontractor started drilling of anchor bar holes for Eklutna Dam.
June 12, 1965	The earthwork subcontractor abandoned earthwork to allow completion of the spillway conduit section.
June 13, 1965	The contractor for replacement of Eklutna Dam began concrete construction in the spillway.
June 30, 1965	The subcontractor completed drilling of anchor bar holes in the spillway.
August 17, 1965	The contractor completed placement of the conduit section of the spillway.
August 25, 1965	The earthwork subcontractor resumed work.
September 4, 1965	The earthwork subcontractor began placement and compaction of zone 1 material in the embankment.
September 30, 1965	The contractor completed all concrete placement for the spillway structure.

APPENDIX E--Continued

Date	Event
October 1, 1965	The contractor started hauling zone 3 and rockfill material from the rock source to the embankment.
October 5, 1965	Heavy rain and snow slowed progress on earthwork for Eklutna Dam.
October 20, 1965	The earthwork subcontractor completed placement of zone 1 material.
October 21, 1965	The contractor started hauling riprap from the Alaska Railroad quarry near the town of Eklutna.
October 26, 1965	The earthwork subcontractor completed placement of zone 2 material.
October 29, 1965	The earthwork subcontractor completed hauling and placement of riprap.
November 10, 1965	The earthwork subcontractor completed hauling and placement of zone 3 material.
November 10, 1965	The automotive repair shop was completed and accepted.
November 15, 1965	All work under the contract for replacement of Eklutna Dam was accepted as complete.
November 18, 1965	All work under specifications Nos. DC-6212 and DC-6240, was transferred from construction status to O&M status.
November 22, 1965	The A & B Construction Co. signed a release on contract for replacement of Eklutna Dam.
November 23, 1965	The Holiday Construction Co. signed a release on contract for the automotive repair shop.

APPENDIX F

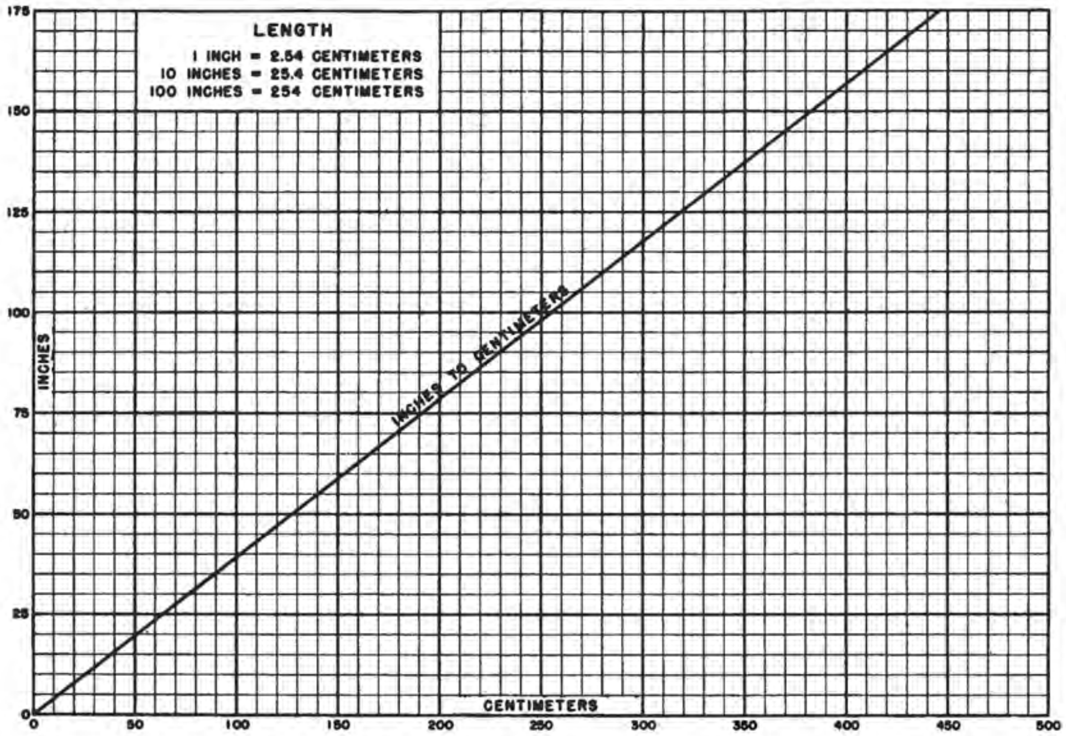
Conversion factors--English to metric system of measurement:

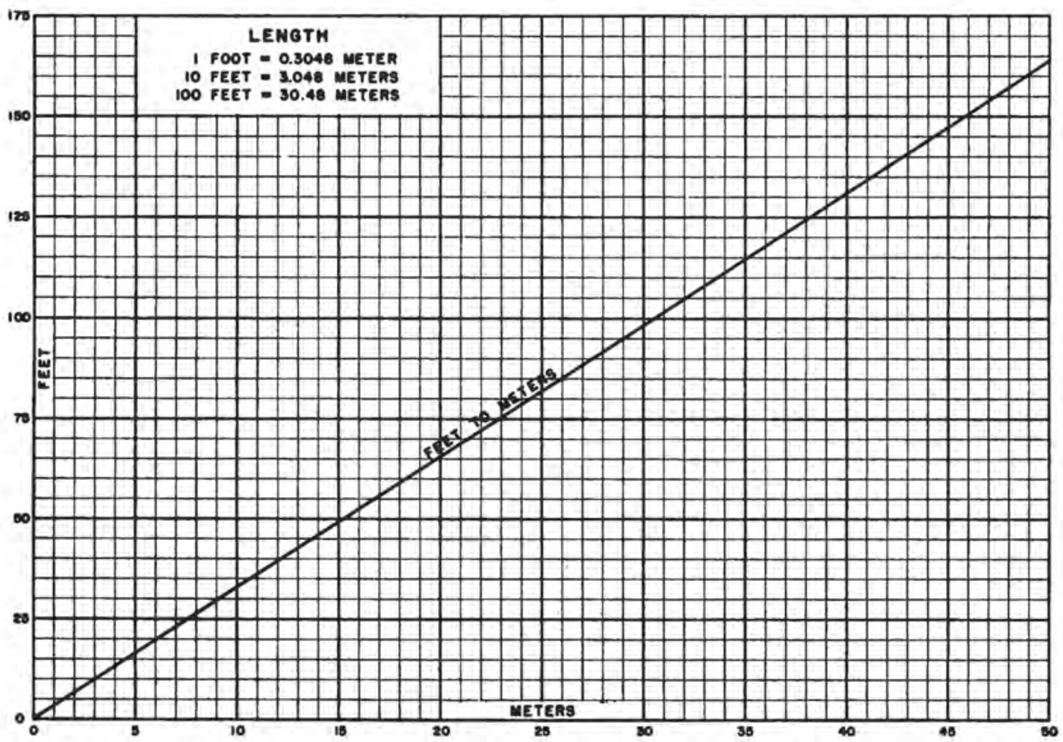
Quantity	English unit	Multiply by	To get metric equivalent
Length	inches	2.54*	centimeters
	feet	30.48*	centimeters
		0.3048*	meters
		0.0003048	kilometers
	yards	0.9144*	meters
	miles	1,609.3	meters
		1.6093	kilometers
Area	square inches	6.4516*	square centimeters
	square feet	929.03	square centimeters
	square yards	0.83613	square meters
	acres	0.40469	hectares
		4,046.9	square meters
		0.0040469	square kilometers
	square miles	2.5898	square kilometers
Volume	gallons	3,785.4	cubic centimeters
		0.0037854	cubic meters
		3.7854	liters
	acre-feet	1,233.5	cubic meters
		1,233,500.	liters
	cubic inches	16.387	cubic centimeters
	cubic feet	0.028317	cubic meters
	cubic yards	0.76455	cubic meters
		764.55	liters
Velocity	feet/second	0.3048*	meters/second
	miles/hour	1.6093	kilometers/hour
Acceleration	feet/second x second	0.3048*	meters/second x second
Discharge	cubic feet/second or second-feet	0.028317	cubic meters/second
Weight	pounds	0.45359	kilograms
	tons (2,000 pounds)	0.90718	tons (metric)

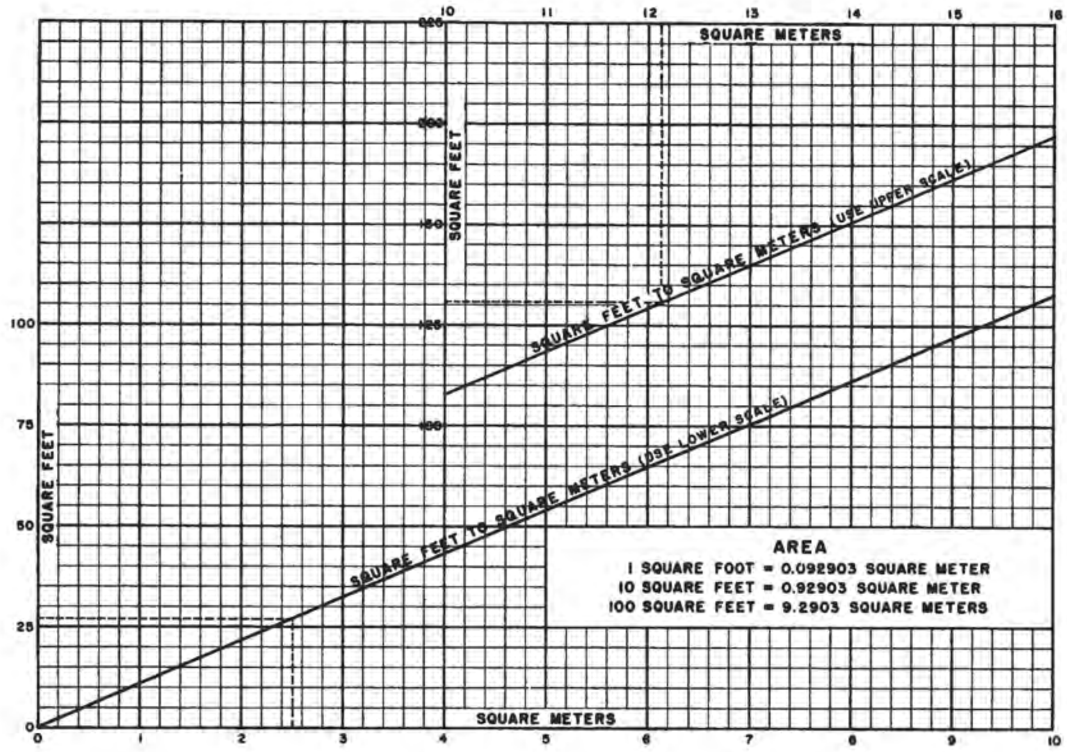
*Exact value.

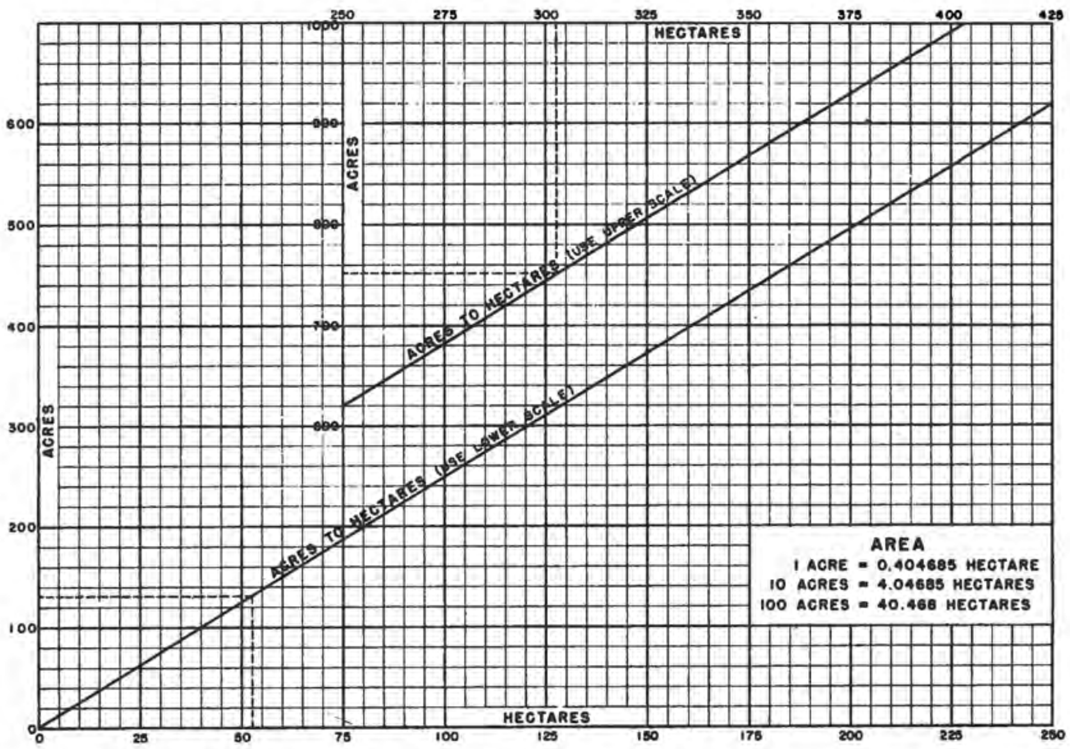
APPENDIX G

Charts for conversion of English to metric system of measurement.

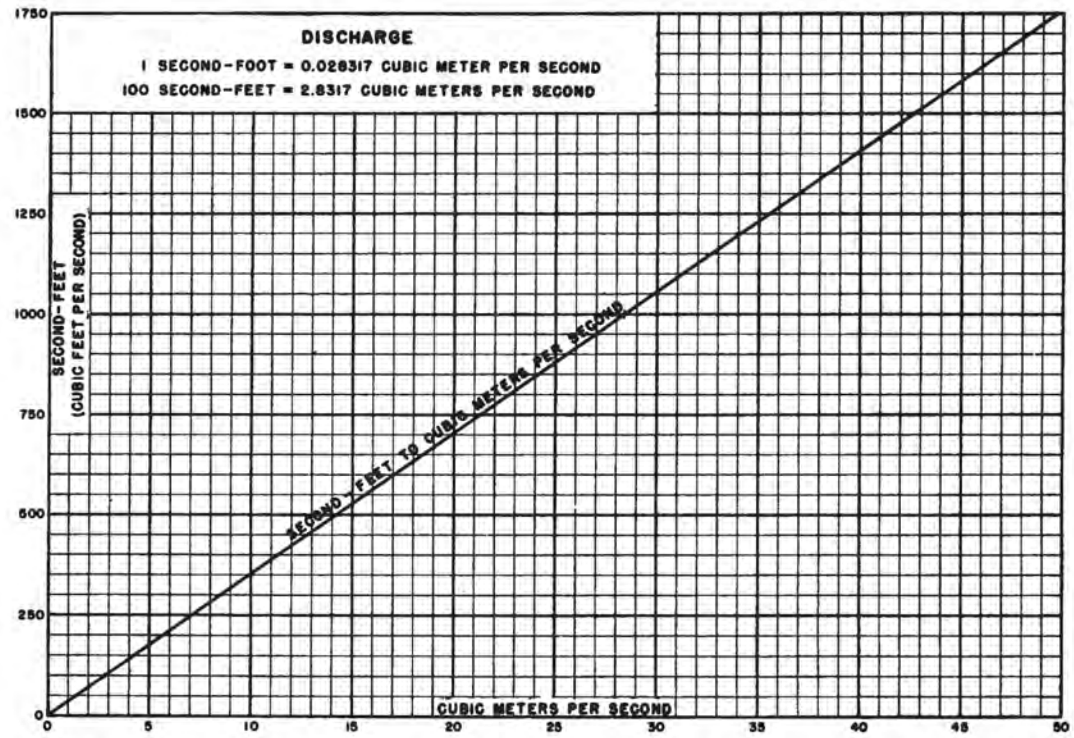


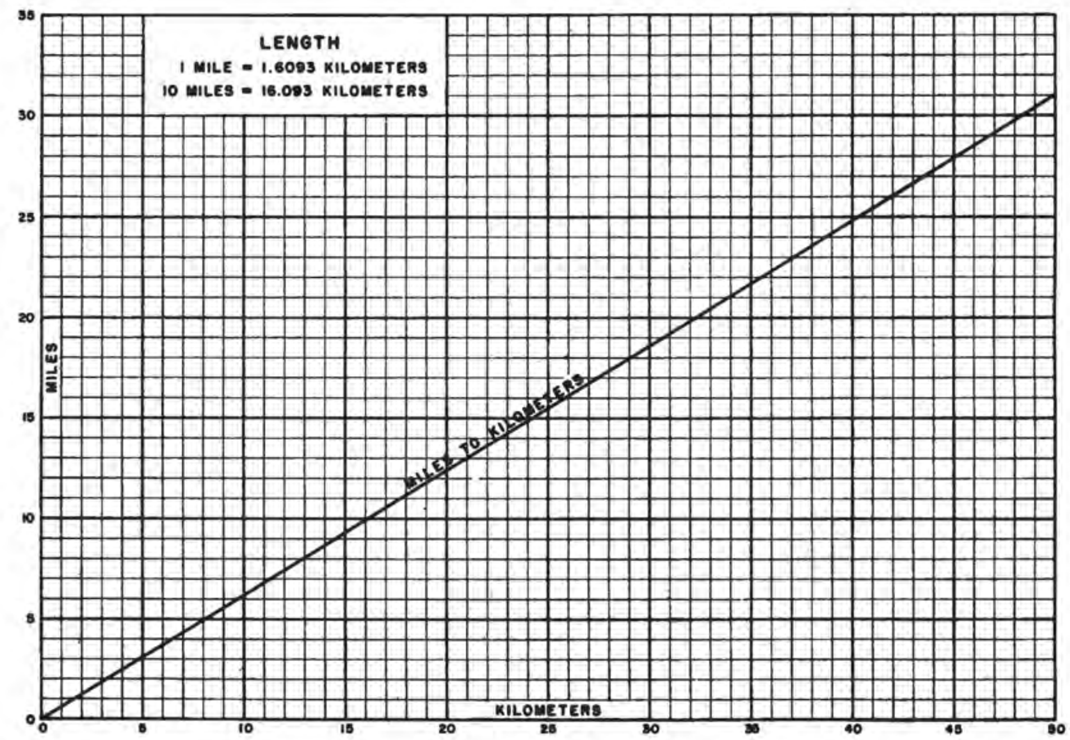


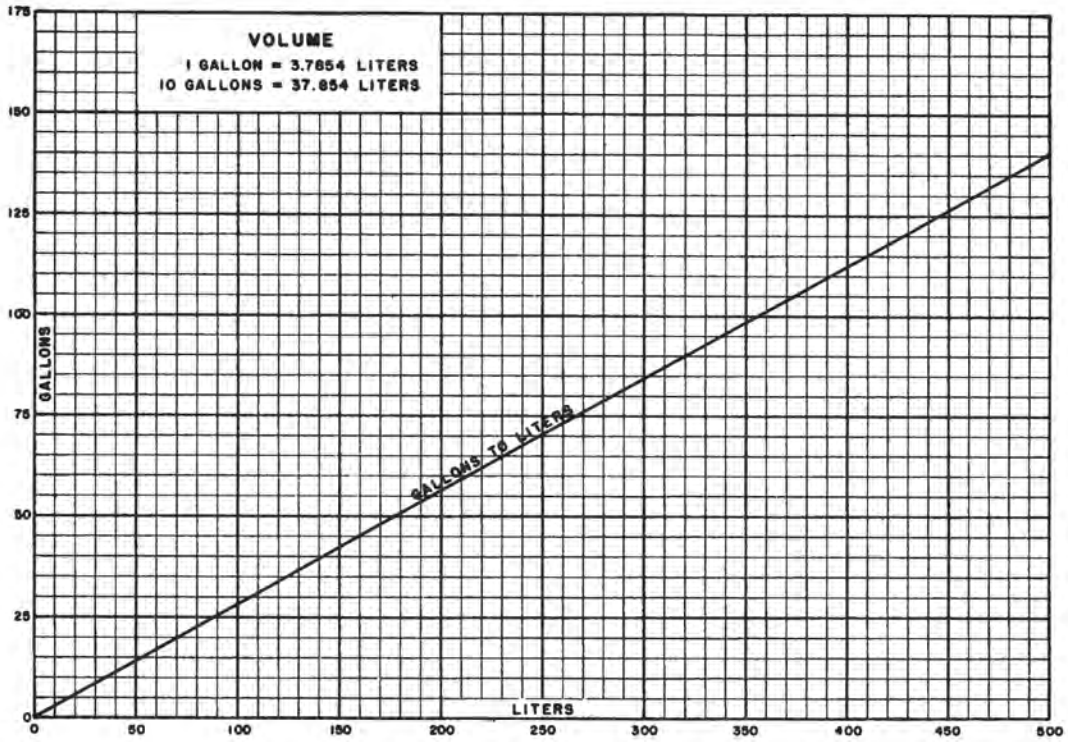

SQUARE METERS
SQUARE FEET
SQUARE FEET TO SQUARE METERS (USE UPPER SCALE)
SQUARE FEET TO SQUARE METERS (USE LOWER SCALE)
SQUARE FEET
AREA
1 SQUARE FOOT = 0.092903 SQUARE METER
10 SQUARE FEET = 0.92903 SQUARE METER
100 SQUARE FEET = 9.2903 SQUARE METERS
SQUARE METERS

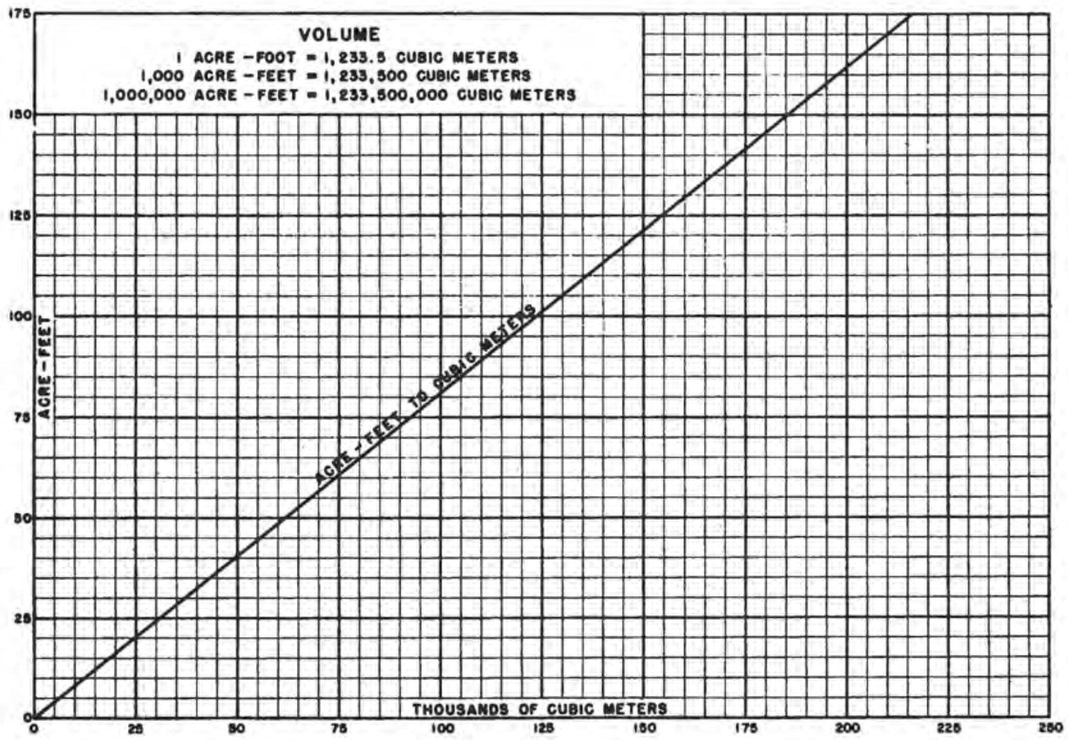

HECTARES
ACRES
ACRES TO HECTARES (USE UPPER SCALE)
ACRES TO HECTARES (USE LOWER SCALE)
ACRES
AREA
1 ACRE = 0.404685 HECTARE
10 ACRES = 4.04685 HECTARES
100 ACRES = 40.468 HECTARES
HECTARES

APPENDIX G--Continued






VOLUME
1 GALLON = 3.7854 LITERS
10 GALLONS = 37.854 LITERS
GALLONS
LITERS
GALLONS TO LITERS
0
25
50
75
100
125
150
175
0
50
100
150
200
250
300
350
400
450
500


VOLUME
1 ACRE-FOOT = 1,233.5 CUBIC METERS
1,000 ACRE-FEET = 1,233,500 CUBIC METERS
1,000,000 ACRE-FEET = 1,233,500,000 CUBIC METERS
ACRE-FEET
THOUSANDS OF CUBIC METERS
ACRE-FEET TO CUBIC METERS
0
25
50
75
100
125
150
175
0
25
50
75
100
125
150
175
200
225
250

APPENDIX H

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"Eklutna and the Alaska Earthquake," A Report by the Alaska District Office, Bureau of Reclamation, Juneau, Alaska, first issued December 1964, reissued June 1966.

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"Specifications No. DC-6240, Replacement of Eklutna Dam, Eklutna Project, Alaska," March 1965.

GPO 837-418

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Title	Price	Foreign postage
Anchor Dam (1962)	$ 3.95	$1.00
Bonham and Cottonwood Pipelines and Molina Powerplants (1964)	5.25	1.30
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Volume II - Dams and Reservoirs	2.75	0.70
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Volume IV - Power and Pumping Plants	3.75	0.90
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Delta-Mendota Canal (1959)	3.20	0.80
Eklutna Dam and Powerplant (1958)	4.30	1.05
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Equalizing Reservoir Dams and the Feeder Canal (1954)	2/	
Folsom Powerplant and Switchyard (1960)	2.85	0.70
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Fremont Canyon Powerplant and Power Conduit (1963)	7.75	1.95
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Glendo Dam and Powerplant (1961)	10.35	2.60
Heart Butte Dam (1952)	2/	
Helena Valley Pumping Plant and Tunnel (1961)	3.10	0.80
Hungry Horse Dam and Powerplant (1958)	4.85	1.20
Jamestown Dam (1957)	1.60	0.40
Kortes Dam and Powerplant (1959)	6.85	1.70
Long Lake Dam and Main Canal (1955)	2/	
Medicine Creek Dam (1955)	2/	
Monticello Dam (1959)	2.60	0.65
Navajo Dam (1966)	5.35	1.35
Nimbus Dam, Powerplant, and Fish Hatchery (1960)	4.25	1.05
O'Sullivan Dam (1954)	2/	
Palisades Dam and Powerplant (1960)	10.00	2.50
Platora Dam (1954)	2/	
Potholes East Canal (1958)	2.10	0.50
Prineville Dam (1963)	3.55	0.90
Rogue River Basin Project (1962)	9.35	2.35
Sherman Dam (1964)	3.50	0.90
Steinaker Dam (1963)	4.00	1.00
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Trinity River Division Features (1965)		
Volume I - Design (1965)	7.00	1.75
Volume II - Construction (1966)	10.30	2.60
Twin Buttes Dam (1964)	4.85	1.20
Willard Dam (1967)	4.25	1.05

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