Southcentral Railbelt Area, Alaska
Upper Susitna River Basin

SUPPLEMENTAL FEASIBILITY REPORT

HYDROELECTRIC POWER
and related purposes

U.S. Department of the Army
Alaska District
Corps of Engineers

Appendix
Part 1

Anchorage, Alaska

1979

SOUTHCENTRAL RAILBELT AREA, ALASKA
UPPER SUSITNA RIVER BASIN
SUPPLEMENTAL FEASIBILITY REPORT

APPENDIX - PART I

Section A - Hydrology
Section B - Project Description and Cost Estimates
Section C - Power Studies and Economics
Section D - Foundations and Materials
Section E - Environmental Assessment
Section F - Recreational Assessment

Prepared by the
Alaska District, Corps of Engineers
Department of the Army

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SECTION A

HYDROLOGY

The 1976 Interim Feasibility Study was based on 25 years of historical streamflow records. Data through 1977 has been added, extending the period of historical streamflow to 28 years. The annual runoff for the additional 3-year period was 96 percent of the long-term average.

Power capabilities of the hydroelectric projects were reevaluated on the basis of the extended period of record. The results of this analysis appear in Section C, Power Studies and Economics.

SECTION B

PROJECT DESCRIPTION AND COST ESTIMATES

SECTION B

PROJECT DESCRIPTION AND COST ESTIMATES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

SUMMARY OF CHANGES

GENERAL

Field surveys during 1978 revealed that topography for Watana dam shown in the 1976 Interim Feasibility Report was 15 feet higher than actual conditions. Data in this report has base elevations corrected to the 1978 topography. Only plates or text revised for this submittal will reflect the new elevations which are 15 feet lower. The top of dam is now shown at elevation 2,195 feet and normal pool at elevation 2,185 feet.

Quantities and cost estimates have been revised and updated to October 1978 levels. The cost for Watana dam and reservoir (first-added) is $1,765,000,000 versus $1,088,000,000 in the 1976 report. The cost for Devil Canyon dam and reservoir (second-added) is $823,000,000 (concrete gravity) and $665,000,000 (concrete arch) versus $432,000,000 (concrete arch) in the 1976 report.

A construction schedule reanalysis resulted in the extension of the construction period from 10 to 14 years. Initial power-on-line is anticipated in 1994.

WATANA

The main dam cross section was revised to best utilize materials as determined in 1978 field investigations. A grouting gallery was added under a portion of the dam.

The spillway was moved laterally and revised to take better advantage of rocklines and to discharge directly into Tsusena Creek at stream level.

The outlet works were revised to improve hydraulic layout and access into the intake structures.

The diversion tunnel portals were relocated in better rock based upon information obtained from the exploration program.

The power intake selective withdrawal system was revised to be more comparable with those currently in use at other projects.

Rock excavation quantities in the 1976 report were based on a continuous cut slope. Foundation explorations concluded that the rock cuts should be terraced. Data in this report is based upon rock cuts that are compatible with this latest field information.

As a result of new and more accurate topography, the length of the dam has changed; therefore, total embankment quantities have increased.

DEVIL CANYON

A gravity dam was evaluated and is presented with an overdam spillway, and the diversion structure modified to be more compatible with a gravity structure.

Elevator access was provided to the powerplant instead of a road access tunnel.

The power intake selective withdrawal system was revised to be more comparable with those currently in use at other projects.

The general plan showing the locations of the two dams is on Plate B-1.

DAM

The crest length of the dam has changed from 3,450 feet to 3,765 feet, based upon new topography.

As a result of explorations in the river bottom, the foundation excavation has been revised. The river alluvium will be removed to bedrock under the dam. A grout gallery, excavated into rock, has been added to insure adequate treatment of the permanently frozen bedrock.

The 1976 Interim Feasibility Report presented an earthfill dam utilizing local gravel deposits for shell material. Explorations have revealed that there are insufficient gravel deposits within economic haul distances. Since a large amount of sound rock will be generated from spillway excavation and an excellent quarry source is available immediately adjacent to the damsite, the design has been revised to substitute rockfill for gravel in the upstream and downstream shells. Field explorations revealed an abundance of glacial till in the area suitable for use as core material. For this reason, a semipervious zone has been added to use the less expensive glacial material rather than quarried rock. The filters have also been revised to take advantage of adequate quantities of gravelly sand and the readily available rock quarry (see Plate B-3). The gravelly sand from Borrow Pit E, near the mouth of Tsusena Creek, will be used for the fine filter, and rockfill, in the smaller sizes from the quarry, will be used for the coarse filter. Details of the revisions are discussed in Appendix D, Foundations and Materials.

SPILLWAY

The saddle spillway centerline has been moved approximately 800 feet southwest (see Plates B-2 and B-5). The foundation explorations more definitely located top of rock in this area; therefore, the spillway was relocated to insure construction in rock. Crest gate widths were reduced from 59 feet to 55 feet after additional hydraulic calculations. The concrete lined downstream channel section was lengthened from 150 feet to 800 feet to protect against rock plucking caused by high water velocities. The length of channel divergence was revised from 930 feet downstream of the crest to 1,360 feet to improve hydraulics. The spillway channel slope was revised, requiring excavation its full length, so that it emerges at the Tsusena Creek level to reduce environmental damage expected from the 400-foot vertical water drop over natural terrain with the original spillway design. This substantially increases excavation; however, almost all of the material will be used in the dam embankment.

OUTLET WORKS

The intake structures were moved, shifting the high level intake structure away from the dam embankment, realining both intake tunnels to improve connections to the diversion tunnels and changing the access shafts from within the embankment to tunnels through the right abutment rock upstream of the dam (see Plates B-4 and B-6). This improves access, eliminates problems associated with a structural shaft in the embankment, and reduces susceptibility to damage from seismic events. The high level intake invert was raised to restrict operating heads on gates to under 250 feet.

DIVERSION FEATURES AND OPERATION

The two diversion tunnels were lengthened, both upstream and downstream, to locate the portals in better rock as a result of exploration data obtained in 1978. The roller gates for controlling the diversion tunnels have been deleted because stream regulation is not required during diversion. Wheeled bulkhead gates will be used to close one tunnel at a time during periods that closures are required. The diversion tunnel inverts have been raised to reduce cofferdamming and dewatering requirements at tunnel portals. Cofferdam height will remain unchanged since there is outlet control of diversion tunnel flows up to cofferdam design flood. The scheme of tunnel plugging and water control during pool filling has not changed. See Plate B-6 for plug and fill valve details.

PENSTOCKS AND WATERWAYS

The selective withdrawal system, designed to select water at elevations within the reservoir which will allow meeting downstream water quality requirements, has been revised to be more comparable with those currently in use on other projects. This revision requires a larger concrete structure on the upstream face of the dam to accommodate the gates, trashracks, bulkheads, and operating equipment.

DEVIL CANYON

MAIN DAM

A concrete gravity dam (see Plates B-7 and B-8) is substituted in this report for the double curvature thin arch structure of the 1976 Interim Feasibility Report. The thin arch dam's structural integrity is dependent on the adequacy and integrity of the rock abutments. Foundation investigations to date have raised no doubts concerning the abutment rock structures but are inadequate to clearly establish abutment conditions. The necessary horizontal drill holes at the vertical canyon walls were estimated to be so costly that to proceed in the summer of 1978 would have prevented obtaining other required foundation data at Watana damsite with the funds available. A careful reevaluation of the situation indicated a study of the more conservative and technically feasible gravity structure should be made. The concrete gravity structure is economically feasible. The required foundation investigations will be conducted during the preconstruction advance engineering and design period and the less expensive arch structure will be constructed if adequate foundation conditions exists.

The gravity section will be 650 feet high from bottom of excavation, based on indications that the rock is fractured near the surface. The crest remains at elevation 1,455 feet. The concrete crest length will be 1,590 feet and the earthfill portion will have a 720-foot crest length.

No field explorations were conducted at this site under the 1978 program except for three refraction seismograph lines. This information, combined with the borings data collected by the Bureau of Reclamation that was discussed in the initial report, is the basis of the foundation design for the site.

SPILLWAY

The gravity dam will have a central gated overdam spillway discharging into the existing river channel.

DIVERSION STRUCTURE

The diversion tunnel has been lengthened from 1,150 feet to 1,230 feet because of the longer gravity dam base length. Since flow regulation during diversion is not required, the intake gates have been replaced with wheeled bulkhead gates. Regulation of Watana reservoir to release water into Devil Canyon reservoir will be utilized to fill the reservoir to the low level outlets in a matter of hours after diversion tunnel closure. Proper timing will allow maintaining of downstream flows with minimum interruption.

POWERPLANT

The access tunnel to the powerplant has been replaced with a housed vertical entrance shaft and elevator. This shaft will be 20 feet by 30 feet wide by 548 feet deep and will house an elevator capable of lifting the largest items required in the powerhouse. The 185-foot long access tunnel will connect the access shaft to the powerplant. The elevator will provide equipment, personnel, and vehicular access to the powerplant level at elevation 907 feet.

PENSTOCKS AND WATERWAYS

The selective withdrawal system has been revised to be more comparable with those currently in use at other projects. The system has been designed to select water at elevations within the reservoir which will allow meeting downstream water quality requirements. This revision required a larger concrete structure on the upstream face of the dam to accommodate the gates, trashrack, bulkheads, and operating equipment.

CONSTRUCTION SCHEDULE

GENERAL

The construction period has been reanalyzed and extended from 10 to 14 years. The Watana dam and powerplant will take 10 years to construct, an increase of 4 years over the previous schedule. The Devil Canyon project construction will require 8 years rather than the previously reported 5 years. There will be 4 years of overlapping construction to meet power-on-line dates. The schedule is portrayed graphically on Figure B-1.

DIVERSION PLANS

The Watana diversion works construction and stream diversion period has been extended to 3 years, from the previously reported 2 years, because the construction access to the tunnel portals requires extensive rock cuts and additional time. The start of construction of the diversion works for the Devil Canyon dam has been delayed from the 5th to the 7th year of Watana construction because it is dependent on stream regulation by the upstream Watana dam.

MAIN DAMS

Foundation preparation at Watana is delayed to the 4th year as a result of the extended diversion requirements which delay the start of cofferdam construction. Watana embankment construction is scheduled to begin in the 5th year and continue into the 10th, now requiring 6 years instead of the previously reported 3 years, based on construction seasons of 5 months with daily placement rates of 80,000 cubic yards. Water impoundment starts in the 8th year with power-on-line in October of the 10th year. The reservoir filling would continue beyond the power-on-line date and is dependent on inflow and power generation.

Foundation preparation for Devil Canyon dam would start in the 9th year, a delay from the earlier reported 7th year of Watana dam construction. Concrete placement and dam completion would start in the 10th year, requiring 5 years, an increase of 2 years over the earlier schedule. Impoundment would begin in the 13th year with reservoir filling completed by October of the 14th year.

POWER-ON-LINE

The scheduled power-on-line dates are 1994 for Watana and 1998 for Devil Canyon compared to those previously scheduled in 1986 and 1990, respectively. These dates include the result of the changes in scheduled

Congessional construction authorization from July 1980 to October 1984 and the reanalyzed construction schedule. The construction schedule in the 1976 report was based on an authorization for construction, while the Chief of Engineer's Report recommended authorization for Phase I AE&D. This recommendation incorporated 4 years for study prior to seeking construction authorization.

TRANSMISSION LINE

Transmission line construction is scheduled to be completed in 1991, making it available to tie the Anchorage and Fairbanks areas together in advance of Watana power-on-line.

COST ESTIMATES

DETAILED COST ESTIMATES

Tables B-1 and B-2 present the cost estimates for Watana and Devil Canyon.

The estimates are presented in as much detail as possible based on the concept drawings. Unit cost for a major items also includes minor items that will appear as bid items as the design progresses.

Extensive use has been made of bid abstracts from similar projects constructed in the western United States and Canada. All abstracted costs have been escalated to the October 1978 level and an additional factor applied to reflect the higher cost of construction in Alaska.

The Alaska Power Administration (APA) prepared the transmission line cost estimate and have updated the estimate to the October 1978 level. The transmission line cost estimate includes all structures, equipment and transformers for the switchyards and substations for Watana, Devil Canyon, Fairbanks, and Anchorage. The transmission line cost is shown in Table B-1, Watana.

The transformers listed under "Switchyard" in Tables B-1 and B-2 are located in an underground transformer chamber adjacent to the powerhouse. The cables listed connect the transformers to potheads located in the switchyard.

The APA estimate did not include earthwork for the switchyards. This cost is shown under "Switchyard" in Tables B-1 and B-2.

The following lists the estimated January 1975 cost and the October 1978 cost.

	Jan 1975 ($1,000)	Oct 1978 ($1,000)
Watana	$1,088,000	$1,765,000
Devil Canyon		
Thin Arch Dam	432,000	665,000
Concrete Gravity Dam	---	823,000

The project cost used in the economic analysis includes Watana and the concrete gravity dam plan at Devil Canyon. The total cost is $2,588,000,000.

CONTINGENCIES

Watana Dam

The total estimated contingencies for Watana dam are $245,917,000, or 18 percent of the estimated Watana construction cost. The main dam, the largest single feature of Watana project, has a contingency of 15 percent, or $58,178,000. This is a relatively uncomplicated earth and rockfill structure. The 1978 exploration program established foundation conditions and sources of suitable embankment materials in sufficient quantities to construct the dam. The overburden is minimal and foundation rock exposed over much of the site. Radical changes in foundation conditions and borrow sources are not anticipated.

The design approach for the spillway is conservative for a relatively uncomplicated structure. Fifteen percent contingencies, or $20,528,000, were estimated.

The outlet works estimate includes 20 percent contingencies, or $7,016,000. The estimate includes 100 percent lining of the diversion and outlet tunnels. If rock quality is good, some of the lining may be deleted.

The power intake works estimate includes 20 percent contingencies, or $40,772,000.

The powerhouse estimate includes 20 percent contingencies or $13,294,000. The underground powerhouse interior feature requirements are known from comparison with other projects and a careful review of this item.

Turbines, generators, accessory electrical equipment, and miscellaneous powerplant equipment are estimated with 15 percent contingencies. These are known features with quantities and basic costs furnished by experienced powerhouse design personnel.

The tailrace tunnels are assumed to be 100 percent concrete lined. If the rock quality is good, some of these lining requirements may be deleted. Contingencies for this feature are 15 percent.

Twenty percent contingencies were used for transmission facilities. The transmission system estimate was prepared by the Alaska Power Administration with consultation with Bonneville Power Administration.

Contingencies of 20 percent were used for roads and bridges. Assumptions on foundations assume extensive tundra removal and replacement with nonfrost susceptable fill which requires large borrow quantities for replacement.

The construction facility requirements have been reviewed and compared with facilities required for similar structures on similar projects such as Dworshak, Mica and Oroville. The Trans Alaska Oil Pipeline construction camp experience was also reviewed. Diversion tunnels are assumed to be fully lined and rock support assumptions during tunneling have been conservative. Careful analyses of means of diversion and procedures have been made. Contingencies for construction facilities are 20 percent.

Devil Canyon Dam

The total contingencies used for the Devil Canyon gravity dam estimate are $120,551,000, or 20 percent of the Devil Canyon construction costs. Contingencies for all features are the same percentages as for Watana dam for the same reasons, except that contingencies for the main dam, spillway, and auxiliary dam features have been increased to 20 percent.

Twenty percent contingencies were used for the main dam. Assumptions on foundation excavation and preparation for a gravity dam are conservative. Both abutments are exposed rock. The concrete gravity structure is relatively simple with known features. Aggregate locations and quantities available have been established.

The auxiliary earthfill and concrete dam was estimated at 20 percent contingencies. The borrow source is known, partially explored, and quantities determined. This is a simple, uncomplicated structure. Foundation excavation and preparation assumptions are conservative.

The total contingencies for the thin arch dam alternate are $103,756,000 or 21.2 percent of the updated total estimated construction cost of $665,000,000.

In general, the contingencies used for this project are based on intensive study and comparison with cost histories and experience with other projects.

The Office of Management and Budget (OMB) has questioned the contingencies used based on a 36 percent overrun on the Snettisham project. The project cost estimate for the Snettisham project was $41,500,000 for fiscal year 1967, the first year of construction. This estimate included the Long Lake phase of project development, camp facilities, the transmission system, and related features. The Crater Lake phase of project development was added in fiscal year 1973, but design and construction were subsequently deferred.

The estimate submitted to Congress for fiscal year 1976 was $98,540,000, of which $22,132,000 was a price level adjustment, reflecting a 35 percent cost overrun; however, with deferment of the Crater Lake phase, total expenditures through fiscal year 1978 are $81,386,975, an actual cost overrun of $17,754,975, or 22 percent. This cost overrun includes the temporary repair and subsequent permanent relocation of a failed portion of the transmission line. Environmental considerations dictated its original location in an area of unanticipated and unknown extreme winds and ice conditions not previously encountered on any transmission line in North America. The increased cost for the transmission line temporary repairs and permanent relocation was $9,976,000 of the overrun, reducing the remainder of the overrun to $7,778,985 or 10 percent. This information is reflected in the General Accounting Office Report to Congress on Financial Status of Major Civil Acquisitions - December 31, 1975, dated 24 February 1975.

TABLE B-1--DETAILED COST ESTIMATE
WATANA DAM AND RESERVOIR ELEVATION 2185
OCTOBER 1978 PRICE LEVEL
(FIRST-ADDED)

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
01	LANDS AND DAMAGES				
	Reservoir				
	Public domain	AC	2,560	195.00	500
	Private land	AC	99,170	186.00	18,446
	Site and other	AC	1,080	185.00	200
	Access road	AC	780	186.00	145
	Transmission facilities	AC	3,965	965.00	3,826
	Recreation	AC	90	222.00	20
	Mining claims	EA	4	8,000.00	32
	Subtotal				23,169
	Contingencies 20%				4,634
	Government administrative costs				880
	TOTAL LANDS AND DAMAGES				(28,683)
	Construction cost				28,000
	Economic cost				(500)
03	RESERVOIR				
	Mob and Prep	LS	1		204
	Clearing	AC	5,100	800.00	4,080
	Contingencies 20%				857
	TOTAL, RESERVOIR				5,000
04	DAMS				
04.1	MAIN DAM				
	Excavation common				
	Left abutment	CY	1,466,000	5.00	7,330
	Right abutment	CY	1,292,000	5.00	6,460
	River channel	CY	1,547,000	5.00	7,735
	Rock Excavation				
	Left abutment	CY	616,000	18.00	11,088
	Right abutment	CY	428,000	18.00	7,704
	River channel	CY	198,000	18.00	3,564
	Drainage system	LF	135,000	35.00	4,725
	Foundation preparation	SY	114,000	35.00	3,990
	Drilling-grouting	LF	145,000	50.00	7,250
	Care of water and pumping	LS	1		2,000
	Mobilization and Prepatory work	LS	1		19,000
	Instrumentation	LS	1		960
	Clearing grubbing	AC	111	3,500.00	389

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.1	MAIN DAM (Cont'd)				
	Embankment				
	Semi Pervious				
	From stockpile	CY	1,335,000	3.50	4,673
	From req. excavation	CY	4,743,000	1.00	4,743
	Impervious				
	From req. excavation	CY	3,342,000	1.00	3,342
	From borrow	CY	4,031,000	4.00	16,124
	Rock				
	From abutments				
	Req. excavation	CY	1,123,000	.75	842
	Stockpile	CY	420,000	3.25	1,365
	From Spillway Req. exca.	CY	13,693,000	.75	10,270
	From roads (stockpile)	CY	2,348,000	3.25	7,631
	From grout gallery	CY	36,000	.75	27
	From stockpile misc.	CY	800,000	3.25	2,600
	From borrow	CY	17,876,000	9.00	160,884
	Filters from borrow	CY	7,822,000	8.00	65,576
	Riprap	CY	223,000	22.00	4,906
	Grout gallery				
	Excavation	CY	26,700	75.00	2,003
	Concrete (roof-sides)	CY	19,000	375.00	7,125
	Cement	Cwt	87,000	8.00	696
	Reinforcement	LB	6,793,000	.55	3,736
	Concrete floor steps, landings, etc	CY	2,750	500.00	1,375
	Ventilation				375
	Access tunnel from Powerhouse				
	Excavation rock	CY	10,768	190.00	2,046
	Concrete	CY	6,528	600.00	3,917
	Cement	Cwt	26,109	8.00	209
	Resteel	LB	2,164,000	.55	1,190
	Subtotal				387,850
	Contingencies 15%				58,178
	TOTAL, MAIN DAM				446,000
04.2	SPILLWAY				
	Clearing & stripping	AC	158	2,500.00	395
	Foundation prep.	SY	33,700	50.00	1,685
	Excavation				
	Common	CY	10,568,000	2.00	21,136

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.2	SPILLWAY				
	Rock	CY	10,533,000	8.00	84,264
	Concrete				
	Mass	CY	16,900	100.00	1,690
	Structural	CY	9,750	500.00	4,875
	Lining	CY	15,600	450.00	7,020
	Cement	Cwt	182,500	8.00	1,460
	Reinforcement	Lb	1,123,000	.55	618
	Drill & grout for anchors	LF	17,200	20.00	344
	Tainter gates 1200000# gate hoists	EA	3	1,250,000.00	3,750
	Stoplogs (400000#)	LS	1		600
	Spillway bridges (55'L by 26'W) (3EA)	LS	1		500
	Drainage	LS	1		2,000
	Mob-Prep	LS	1		6,517
	Subtotal				136,854
	Contingencies 15%				20,528
	TOTAL, SPILLWAY				157,000
04.3	OUTLET WORKS				
	Excavation				
	Common	CY	35,700	15.00	536
	Rock	CY	115,400	50.00	5,770
	Tunnel 25 Ø				
	45° slope	CY	29,400	190.00	5,586
	Vertical	CY	1,880	140.00	263
	Horizontal	CY	4,250	125.00	531
	Concrete				
	Lining				
	45° slope	CY	6,000	600.00	3,600
	Rebar	LB	322,000	.55	177
	Vertical	CY	350	500.00	175
	Rebar	LB	14,100	.55	8
	Horizontal	CY	820	300.00	246
	Rebar	LB	33,100	.55	18
	Structural	CY	9,600	600.00	5,760
	Rebar	LB	900,000	.55	495
	Rockbolts				
	In vertical face				
	Drill & grout bolts (92,200 LB)	LF	21,400	20.00	428

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.3	OUTLET WORKS				
	45° Slope	LF	4,800	20.00	96
	Horizontal	LF	4,400	20.00	88
	Tainter gates (4)	LB	496,000	3.00	1,488
	Slide gates (4)	LB	2,200,000	3.00	6,600
	Trashracks (2)	LB	64,800	2.00	130
	Cement	Cwt	110,700	8.00	886
	Elevators (50-ton)	LS	2	250,000.00	500
	Mob and Prep work	LS	1		1,700
	Subtotal				35,081
	Contingencies 20%				7,016
	TOTAL, OUTLET WORKS				42,000
04.4	POWER INTAKE WORKS				
	Mob and Prep Work	LS	1		9,700
	Intake structure				
	Excavation (rock)	CY	222,000	30.00	6,660
	Foundation preparation	SY	3,700	50.00	185
	Mass concrete	CY	39,500	100.00	3,950
	Structural concrete	CY	102,900	500.00	51,450
	Cement	Cwt	555,600	8.00	4,445
	Resteel	LB	9,372,000	.55	5,155
	Emb. metal	LB	35,000	4.50	158
	Trash rack	LB	938,000	2.00	1,876
	Stairs	LS	1		100
	Elevator	LS	1		300
	Bulkhead gates	LB	3,860,000	2.00	7,720
	Stoplogs	LB	1,594,000	2.00	3,188
	Electrical and mechanical work	LS	1		2,250
	Truck crane	LS	1		300
	Bridge	LS	1		3,500
	Trash boom	LS	1		425
	Tunnel excavation	CY	95,100	175.00	16,643
	Concrete	CY	35,200	350.00	12,320
	Cement	Cwt	140,800	8.00	1,126
	Resteel	LB	483,000	.55	266
	Steel liner	LB	24,350,000	2.70	65,745
	Bonnetted gates	EA	3	1,800,000.00	5,400
	Log Boom	LS	1		500

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.4	POWER INTAKE WORKS (Cont'd)				
	Electrical and mechanical work	LS	1		500
	Subtotal				203,862
	Contingencies 20%				40,772
	TOTAL, POWER INTAKE WORKS				245,000
	TOTAL DAMS				890,000
07	POWERPLANT				
07.1	POWERHOUSE				
	Mob and prep work	LS	1		3,000
	Rock excavation, tunnels, P.H. chamber, transformer chamber, etc	CY	202,000	75.00	15,150
	Concrete	CY	57,600	500.00	28,800
	Cement	Cwt	261,000	8.00	2,088
	Reinforcement	LB	6,912,000	.55	3,802
	Architectural features	LS			1,500
	Elevators	LS	1		600
	Mechancial and electrical work	LS	1		5,000
	Structural steel	LB	1,250,000	2.00	2,500
	Misc. Metalwork	LB	150,000	4.50	675
	Draft tube bulkhead gates - guides	LS	1		750
	Rock bolts	LF	8,445	30.00	253
	Steel sets	LB	102,000	2.00	204
	600 ton bridge crane	LS	1		1,000
	30 ton bridge crane	LS	1		250
	Airshaft (transformer chamber) 3' DIA 880'	LS	1		900
	Subtotal				66,472
	Contingencies 20%				13,294
	TOTAL, POWERHOUSE				80,000

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT (Cont'd)				
07.2	TURBINES AND GENERATORS				
	Turbines	LS	1		18,900
	Governors	LS	1		814
	Generators	LS	1		21,600
	Subtotal				41,314
	Contingencies 15%				6,197
	TOTAL, TURBINES AND GENERATORS				48,000
07.3	ACCESSORY ELECTRICAL EQUIPMENT				
	Accessory Electrical Equipment	LS	1		3,532
	Contingencies 15%				530
	TOTAL, ACCESSORY ELECTRICAL EQUIPMENT				4,000
07.4	MISCELLANEOUS POWERPLANT EQUIPMENT				
	Miscellaneous Powerplant Equipment	LS	1		1,716
	Contingencies 15%				257
	TOTAL, MISCELLANEOUS POWERPLANT EQUIPMENT				2,000
07.5	TAILRACE				
	Mob and Prep Work	LS	1		2,400
	Tunnel excavation	CY	233,000	85.00	19,805
	Concrete lining	CY	28,200	250.00	7,050
	Cement	Cwt	112,800	8.00	902
	Reinforcement	LB	5,202,000	.55	2,861
	Rock bolts	LF	51,000	20.00	1,020
	Steel sets	LB	1,115,000	1.50	1,673
	Outlet Portal				
	Excavation rock	CY	2,500	75.00	188
	Concrete	CY	450	500.00	225
	Cement	Cwt	1,800	8.00	14
	Reinforcement	LB	207,000	.55	114
	Stoplogs-steel	LB	737,100	1.50	1,106
	Tailrace channel				
	Excavation rock	CY	176,300	50.00	8,815
	Concrete	CY	4,425	300.00	1,328
	Cement	Cwt	17,700	8.00	142
	Reinforcement	LB	177,000	.55	97
	Anchor bars #9	LF	5,700	15.00	86

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT (Cont'd)				
07.5	TAILRACE (Cont'd)				
	Cofferdam	LS	1		2,000
	Subtotal				49,826
	Contingencies 20%				9,965
	TOTAL, TAILRACE				60,000
07.6	SWITCHYARD				
	Transformers	LS	1		5,434
	Insulated cables	LS	1		2,832
	Earthwork	LS	1		1,300
	Subtotal				9,566
	Contingencies 20%				1,913
	TOTAL, SWITCHYARD				11,000
07.7	TRANSMISSION FACILITIES				
	Transmission facilities	LS	1		255,000
	Contingencies 20%				51,000
	TOTAL, TRANSMISSION FACILITIES				306,000
	TOTAL, POWERPLANT				511,000
08	ROADS AND BRIDGES				
	Permanent Access Road - 27 miles (Highway No. 3 to Devil Canyon)				
	Clearing and grubbing	AC	135	1,500.00	203
	Excavation				
	Rock	CY	200,000	20.00	4,000
	Common	CY	60,000	3.00	180
	Embankment	CY	890,000	3.50	3,115
	Riprap	CY	2,700	30.00	81
	Road surfacing (crushed)	CY	216,000	15.00	3,240
	Bridges	LS	1		15,000
	Culverts and guardrail	LS	1		1,250
	Permanent Access Road - 37 miles (Devil Canyon to Watana)				
	Clearing	AC	195	1,500.00	293
	Excavation				
	Rock	CY	300,000	20.00	6,000
	Common	CY	90,000	3.00	270

TABLE B-1--DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
08	ROADS AND BRIDGES (Cont'd)				
	Embankment	CY	1,244,000	3.50	4,354
	Riprap	CY	3,800	30.00	114
	Road surfacing (crushed)	CY	304,000	15.00	4,560
	Bridges	LS	1		5,000
	Culverts and guardrail	LS	1		2,250
	Permanent on-site roads				
	Power plant access tunnel	LS	1		15,459
	Power plant access road	LS	1		1,971
	Dam crest road	LS	1		125
	Mob and prep	LS	1		3,500
	Spillway access road	LS	1		560
	Switchyard access road	LS	1		300
	Road to operating facility	LS	1		300
	Power intake structure access road	LS	1		375
	Airstrip access road	LS	1		650
	Subtotal				73,150
	Contingencies 20%				14,630
	TOTAL, ROAD AND BRIDGES				88,000
14	RECREATION FACILITIES				
	Site D				
	Camp units (tent camp)	EA	10	3,000.00	30
	Vault toilets	EA	2	3,000.00	6
	Subtotal				36
	Contingencies 20%				7
	Total Site D				43
	Site E				
	Trail system	MI	12	15,000.00	180
	Contingencies 20%				36
	Total Site E				216
	TOTAL, RECREATION FACILITIES				1,000
19	BUILDINGS, GROUND, AND UTILITIES				
	Living quarters and O&M facilities	LS	1		2,500

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
19	BUILDINGS, GROUNDS, AND UTILITIES (Cont'd)				
	Visitor facilities				
	Visitor building	LS	1		100
	Parking area	SF	12,000	3.00	36
	Boat ramp	LS	1		200
	Vault toilets	EA	2	3,000.00	6
	Runway facility	LS	1		250
	Subtotal				3,192
	Contingencies 20%				638
	TOTAL, BUILDINGS, GROUNDS, AND UTILITIES				4,000
20	PERMANENT OPERATING EQUIPMENT				
	Operating Equipment and Facilities	LS	1		2,500
	Contingencies 20%				500
	TOTAL, PERMANENT OPERATING EQUIPMENT				3,000
50	CONSTRUCTION FACILITIES				
	Diversion tunnels				
	D.S. Bulkhead	LS	1		75
	Excavation				
	Common	CY	37,700	15.00	566
	Rock	CY	173,600	50.00	8,680
	Tunnel 33 H.S.	CY	336,200	90.00	30,258
	Concrete				
	Lining	CY	58,350	275.00	16,046
	Reinforcement	LB	3,155,000	.55	1,735
	Structural	CY	9,150	500.00	4,575
	Reinforcement	LB	1,045,000	.55	575
	Rock bolts				
	Vertical face	LF	24,900	20.00	498
	Tunnel roof	LF	40,000	20.00	800
	Bulkheads	LS	1		900
	Cement	Cwt	386,700	8.00	3,094
	Plug tunnels	LS	1		1,352
	Care of water	LS	1		1,250
	Mob and prep work	LS	1		3,500
	Subtotal				73,924
	Contingencies 20%				14,785
	TOTAL, CONSTRUCTION FACILITIES				89,000

TABLE B-1--DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
TOTAL CONSTRUCTION COST					1,619,000
ENGINEERING AND DESIGN 4%					65,000
SUPERVISION AND ADMINISTRATION 5%					81,000
TOTAL PROJECT COST WATANA DAM AND RESERVOIR ELEVATION 2185 (First-Added)					1,765,000

TABLE B-2--DETAILED COST ESTIMATE

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

OCTOBER 1978 PRICE LEVEL
(SECOND-ADDED)

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
01	LAND AND DAMAGES				
	Reservoir				
	Public Domain				(0)
	State & Private Land				14,160
	Mining Claim				8
	Subtotal				14,168
	Contingencies 20%				2,834
	Government Administrative Cost				558
	TOTAL, LAND AND DAMAGES				18,000
	Construction Cost				18,000
	Economic Cost				18,000
03	RESERVOIR				
	Mob-Prep Work				77
	Clearing	AC	1,920	800.00	1,536
	Subtotal				1,613
	Contingencies 20%				323
	TOTAL, RESERVOIR				2,000
04	DAMS				
04.1	MAIN DAM				
	Excavation Rock	CY	476,400	20.00	9,528
	Excavation common	CY	89,400	5.00	447
	Exterior mass concrete	CY	256,100	80.00	20,488
	Interior mass concrete	CY	2,138,000	75.00	160,350
	Structural concrete (dam structure)	CY	8,883	475.00	4,219
	Concrete (spillway)	CY	18,600	450.00	8,370
	Post cooling	LS	1		8,000
	Instrumentation	LS	1		900
	Pier & spillway rebar	Lb	3,255,000	.55	1,790
	Taintor gates	EA	2	1,500,000.00	3,000
	Bridges	LS	1		700
	Prevention or water pollution	LS	1		1,000

TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.1	MAIN DAM (Cont'd)				
	Scaling canyon walls	LS	1		1,000
	Stoplog, complete	LS	1		1,000
	Gantry crane	LS	1		750
	Elevator	LS	1		600
	Stairways	LS	1		686
	Rock bolts	LS	1		1,500
	Electrical and mechancial work	LS	1		1,500
	Miscellaneous metalwork	Lb	2,500	4.50	11
	Foundation treatment	LF	400,000	5.56	2,224
	Drilling and grouting	LF	70,000	50.00	3,500
	Drilling drainage holes	LF	52,500	35.00	1,838
	Concrete for parapet and overhang	CY	3,352	500.00	1,676
	Resteel	Lb	4,296,115	.55	2,363
	Slide gates, frames, guides and operators	Sets	4	1,350,000.00	5,400
	Chain link fence	LF	1,845	20.00	37
	Resteel for sluce conduits	Lb	891,560	.55	490
	Exploratory tunnels (excavation)	CY	3,500	400.00	1,400
	Rock bolts	LF	50,000	20.00	1,000
	Contraction joint & cooling system grouting	LS	1		2,750
	Cement	Cwt	7,441,000	8.00	59,528
	Mob and Prep	LS	1		15,400
	Subtotal				323,445
	Contingencies 20%				64,689
	TOTAL, MAIN DAM				388,000
04.4	POWER INTAKE WORKS				
	Mob and Prep	LS	1		4,496
	Excavation				
	Open cut	CY	7,200	75.00	540
	Tunnels	CY	34,400	175.00	6,020
	Concrete				
	Mass	CY	7,300	100.00	730
	Structural and backfill	CY	10,430	500.00	5,215
	Cement	Cwt	74,000	8.00	592
	Reinforcing steel	Lb	2,478,000	.55	1,363
	Penstocks	Lb	9,582,270	2.25	21,560

TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.4	POWER INTAKE WORKS (Cont'd)				
	Bonnetted gates and controls	EA	4	1,800,000.00	7,200
	Stoplogs, (936000#)	LS	1		1,875
	Trashracks (421,000# each)	EA	2	1.50	1,263
	Intake selector gate tower				
	Excavation rock	CY	7,400	50.00	370
	Concrete structural	CY	47,100	500.00	23,550
	Cement	Cwt	188,400	8.00	1,507
	Reinforcement	Lb	7,065,000	.55	3,886
	Selector gates(1,500,000#)	EA	4	3,375,000.00	13,500
	Subtotal				94,417
	Contingencies 20%				18,883
	TOTAL, POWER INTAKE WORKS				113,000
04.5	AUXILIARY DAM (EARTH FILL AND CONCRETE)				
	Mob and Prep	LS	1		312
	Excavation				
	Dam foundation	CY	100,000	6.00	600
	Foundation prepareation	SY	2,100	50.00	105
	Dam embankment	CY	835,000	6.00	5,010
	Drilling and grouting	LF	8,800	60.00	528
	Subtotal				6,555
	Contingencies 20%				1,311
	TOTAL, AUXILIARY DAM				8,000
	TOTAL, DAMS				509,000
07	POWERPLANT				
07.1	POWERHOUSE				
	Mob and Prep work	LS	1		2,000
	Excavation, rock	CY	208,400	75.00	15,630
	Concrete	CY	22,000	500.00	11,000
	Cement	Cwt	88,000	8.00	704
	Reinforcing steel	Lbs	5,400,000	.55	2,970
	Architectural features	LS	1		1,500

TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT				
07.1	POWERHOUSE (Cont'd)				
	Elevator	LS	1		200
	Mechancial and electrical work	LS	1		4,812
	Structural steel	Lb	1,200,000	2.25	
	Miscellaneous metalwork	Lb	150,000	4.50	675
	Subtotal				42,191
	Contingencies 20%				8,438
	TOTAL, POWERHOUSE				51,000
07.2	TURBINES AND GENERATORS				
	Turbines	LS	1		20,250
	Governors	LS	1		1,053
	Generators	LS	1		22,950
	Subtotal				44,253
	Contingencies 15%				6,638
	TOTAL, TURBINES AND GENERATORS				51,000
07.3	ACCESSORY ELECTRICAL EQUIPMENT				
	Accessory Electrical Equipment	LS	1		2,512
	Contingencies 15%				377
	TOTAL, ACCESSORY ELECTRICAL EQUIPMENT				3,000
07.4	MISCELLANEOUS POWERPLANT EQUIPMENT				
	Miscellaneous Powerplant Equipment	LS	1		1,798
	Contingencies 15%				270
	TOTAL, MISCELLANEOUS POWERPLANT EQUIPMENT				2,000
07.5	TAILRACE				
	Mob and Prep	LS	1		766
	Excavation tunnel	CY	74,500	85.00	6,333
	Concrete	CY	17,500	300.00	5,250
	Cement	Cwt	70,200	8.00	562
	Resteel	Lb	3,029,000	.55	1,666
	Draft tube bulkhead gate and guides	LS	1		700
	Tailrace tunnel stoplogs (370,000#)	LS	1		800
	Subtotal				16,077
	Contingencies 20%				3,215
	TOTAL, TAILRACE				19,000

TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT				
07.6	SWITCHYARD				
	Transformers	LS	1		6,545
	Insulated cables	LS	1		3,312
	Excavation				
	Rock	CY	36,000	20.00	720
	Common	CY	75,000	5.00	375
	Embankment	CY	470,000	4.00	1,880
	Subtotal				12,832
	Contingencies 20%				2,566
	TOTAL, SWITCHYARD				15,000
	TOTAL, POWERPLANT				141,000
08	ROADS AND BRIDGES				
	Mob and Prep	LS	1		400
	On-site road				
	Clearing and earthwork	Mile	2.3	300,000.00	690
	Paving	Mile	2.3	110,000.00	253
	Culverts	LF	850	100.00	85
	Powerhouse and tailrace access	LS			6,000
	Road to operating facility	Mile	2	125,000.00	250
	Portals	EA	2	500,000.00	1,000
	Subtotal				8,678
	Contingencies 20%				1,736
	TOTAL, ROADS AND BRIDGES				10,000
14	RECREATION FACILITIES				
	Site A				
	(Boat access only)				
	Boat dock	EA	1	40,000.00	40
	Camping units	EA	10	3,000.00	30
	Two-vault toilets	EA	2	3,000.00	6
	Subtotal				76
	Contingencies 20%				15
	Total Site A				91
	Site B				
	Access road	Mile	0.5	150,000.00	75
	Overnight camps	EA	50	4,000.00	200

TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
14	RECREATION FACILITIES				
	Site B (Cont'd)				
	Comfort stations	EA	2	60,000.00	120
	Power	LS	1		40
	Sewage	LS	1		75
	Subtotal				510
	Contingencies 20%				102
	Total Site B				612
	Site C				
	Trailhead picnic area access road	Mile	.2	150,000.00	30
	Picnic units w/parking	EA	12	3,000.00	36
	Trail system	Mile	30	15,000.00	450
	Two-vault toilets	EA	2	3,000.00	6
	Subtotal				522
	Contingencies 20%				104
	Total Site C				626
	TOTAL, RECREATION FACILITIES				1,000
19	BUILDINGS, GROUND, AND UTILITIES				
	Living quarters and O&M facilities	LS	1		2,500
	Visitor facilities				
	Visitor buildings	LS	1		300
	Parking Area	LS	1		70
	Boat ramp	LS			220
	Vault toilets	EA	2	3,000.00	6
	Subtotal				3,496
	Contingencies 20%				699
	TOTAL, BUILDINGS, GROUNDS, AND UTILITIES				4,000
20	PERMANENT OPERATING EQUIPMENT				
	Operating Equipment and facilities	LS	1		2,200
	Contingencies 20%				440
	TOTAL, PERMANENT OPERATING EQUIPMENT				3,000

TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
50	CONSTRUCTION FACILITIES				
	Mob and Prep work	LS	1		1,885
	Coffer dams				
	Sheet pile	Ton	1,024	1,500.00	1,536
	Earth fill	CY	38,000	15.00	570
	Pumping	LS	1		3,500
	Remove Coffer dams	LS	1		600
	Diversion workds				
	Tunnel excavation	CY	35,700	100.00	3,570
	Concrete	CY	9,200	300.00	2,760
	Cement	Cwt	36,800	8.00	294
	Reinforcement	Lb	1,564,000	.55	860
	Steel sets	Lb	157,000	3.00	471
	Rock bolts	EA	1,150	300.00	345
	Tunnel Plug				
	Concrete	CY	1,100	600.00	660
	Cement	Cwt	4,400	8.00	35
	Reinforcement	Lb	187,000	.55	103
	Diversion Intake Structure				
	Excavation rock	CY	104,000	30.00	3,120
	Concrete structural	CY	3,800	500.00	1,900
	Cement	Cwt	15,200	8.00	122
	Reinforcement	Lb	380,000	.55	209
	Bulkhead	Lb	960,000	1.50	1,440
	Approach Channel Lining				
	Concrete	CY	1,600	300.00	480
	Cement	Cwt	6,400	8.00	51
	Reinforcement	Lb	80,000	.55	44
	Diversion Outlet Structure				
	Excavation Rock	CY	274,000	50.00	13,700
	Concrete	CY	1,100	500.00	550
	Cement	Cwt	4,400	8.00	35
	Reinforcement	Lb	110,000	.55	61
	Stoplogs	Lb	100,000	1.50	150
	Outlet Channel Lining				
	Concrete	CY	900	500.00	450
	Cement	Cwt	3,600	8.00	29
	Reinforcement	Lb	45,000	.55	25
	Subtotal				39,555
	Contingencies 20%				7,911
	TOTAL, CONSTRUCTION FACILITIES				47,000

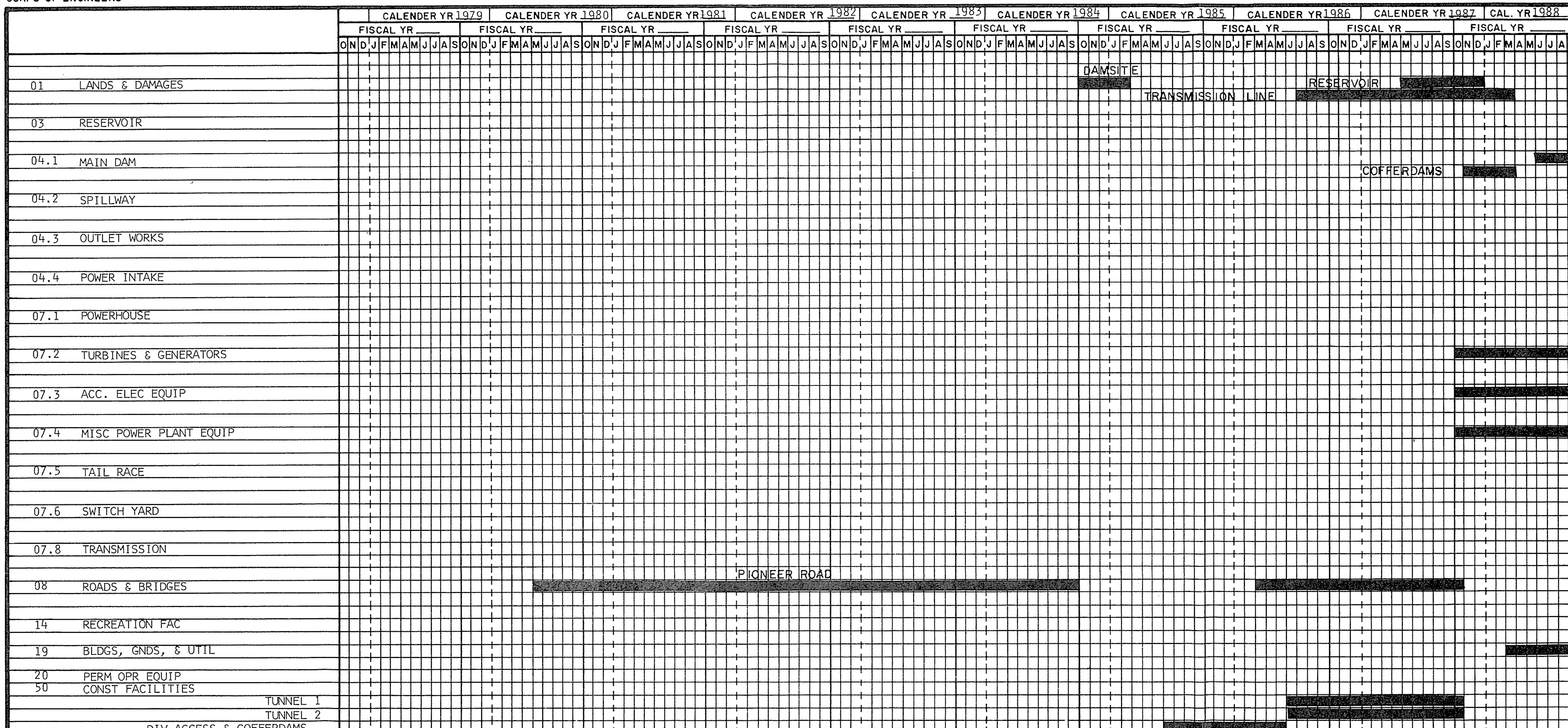
TABLE B-2--DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450, GRAVITY DAM

Cost Account Number	Description or Item	Unit	Quantity	Unit Cost ($)	Total Cost ($1,000)
	TOTAL, CONSTRUCTION COST				735,000
30	ENGINEERING AND DESIGN 7%				51,000
31	SUPERVISION AND ADMINISTRATION 5%				37,000
	TOTAL PROJECT COST DEVIL CANYON DAM AND RESERVOIR ELEVATION 1450, GRAVITY DAM (SECOND-ADDED)				823,000

CORPS OF ENGINEERS

U.S. ARMY



WATANA DAM PROJECT

DEVIL CANYON DAM PROJECT

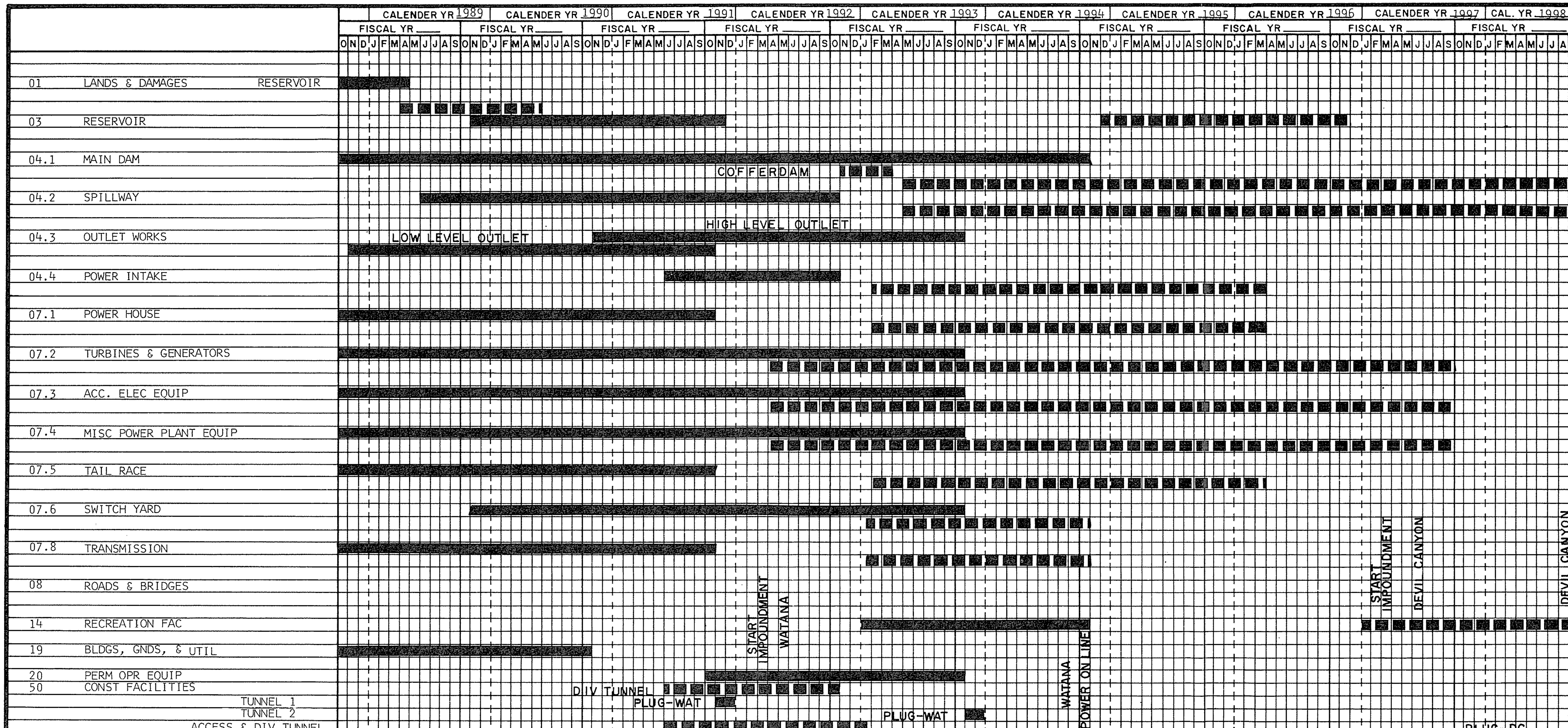
FIGURE B-1
CONSTRUCTION SCHEDULE
SHEET 1 OF 2

NPA FORM 104
APR 75

400-77

CORPS OF ENGINEERS

U.S. ARMY



WATANA DAM PROJECT

DEVIL CANYON DAM PROJECT

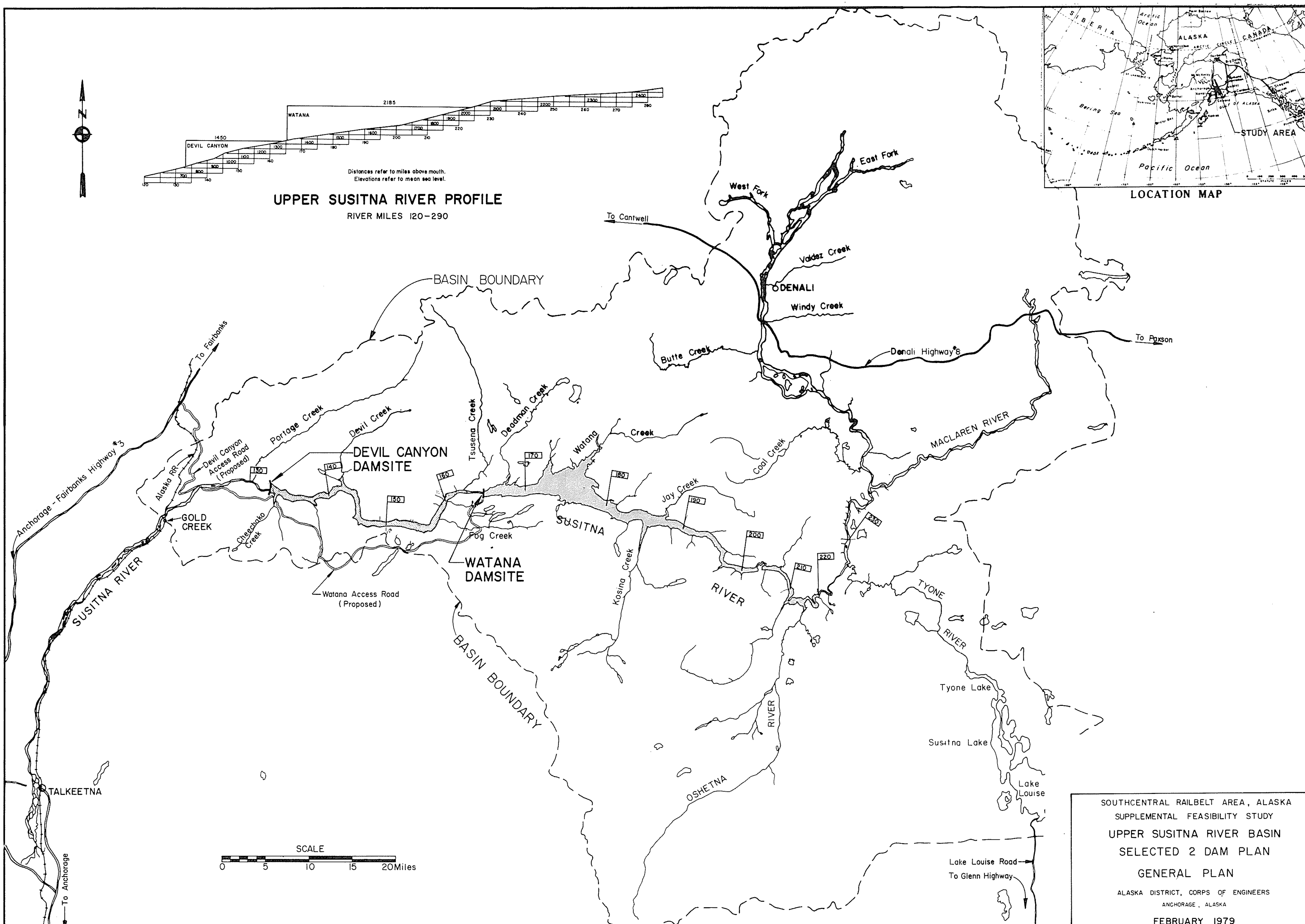
FIGURE B-1

CONSTRUCTION SCHEDULE

SHEET 2 OF 2

NPA FORM 104
APR 75

400-77



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
SELECTED 2 DAM PLAN
GENERAL PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

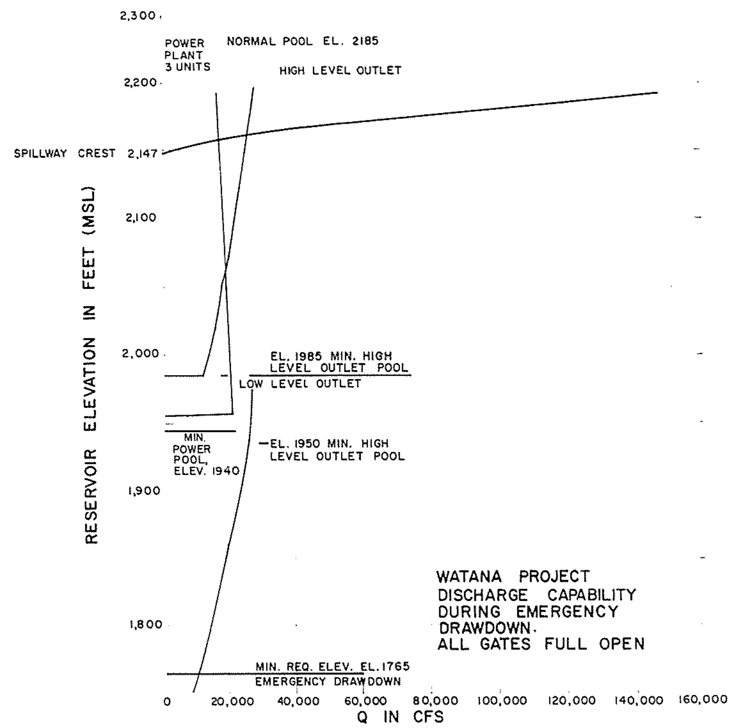
FEBRUARY 1979

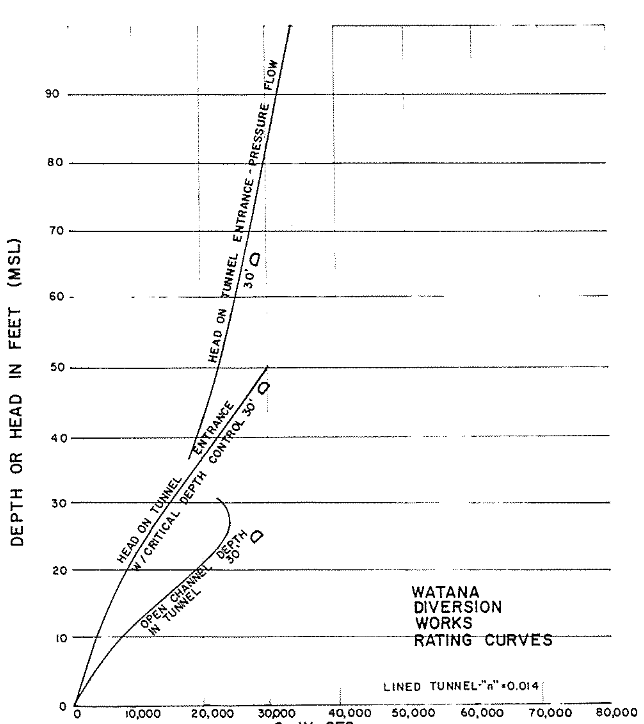
PLATE B-1

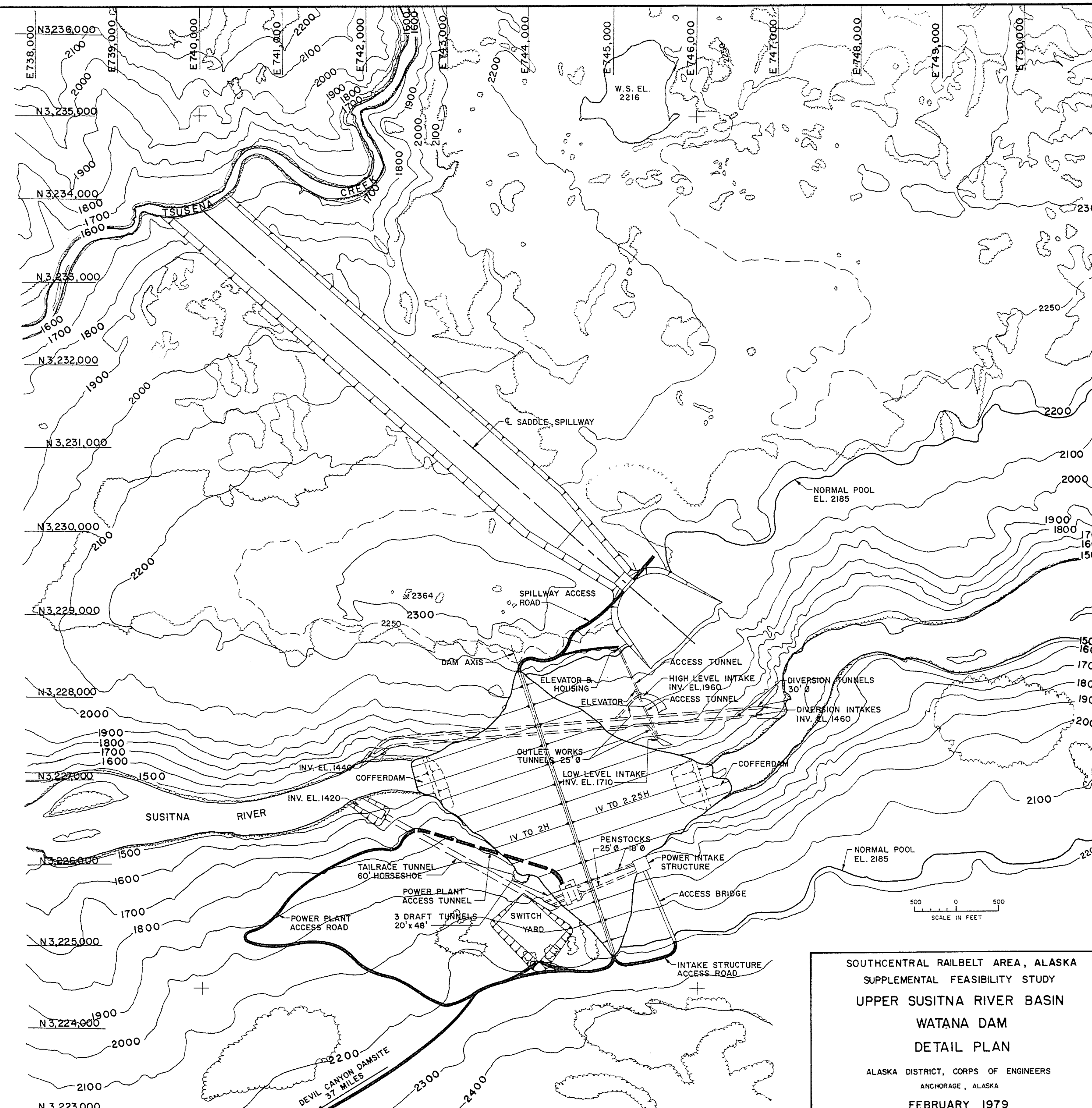
1032-79

NOTES:

1. TOPOGRAPHIC CONTOURS ARE BASED ON AERIAL PHOTOGRAPHY DATED 10 JUNE 1978. VERTICAL DATUM IS MEAN SEA LEVEL (MSL)







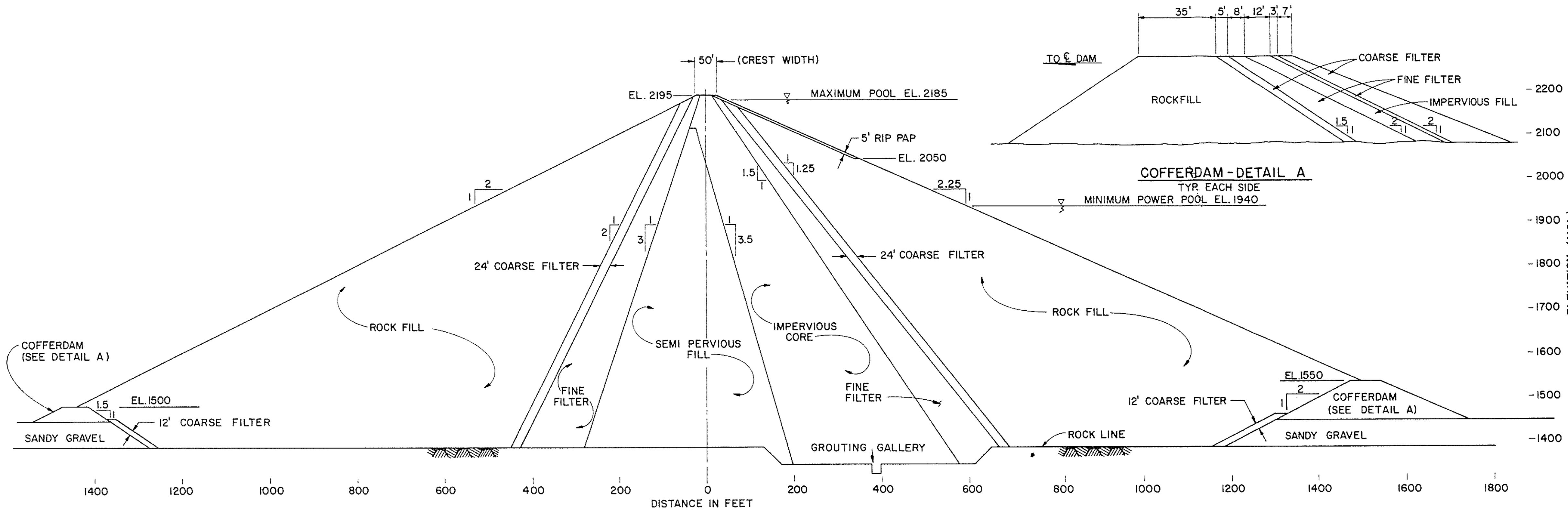
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAM
DETAIL PLAN

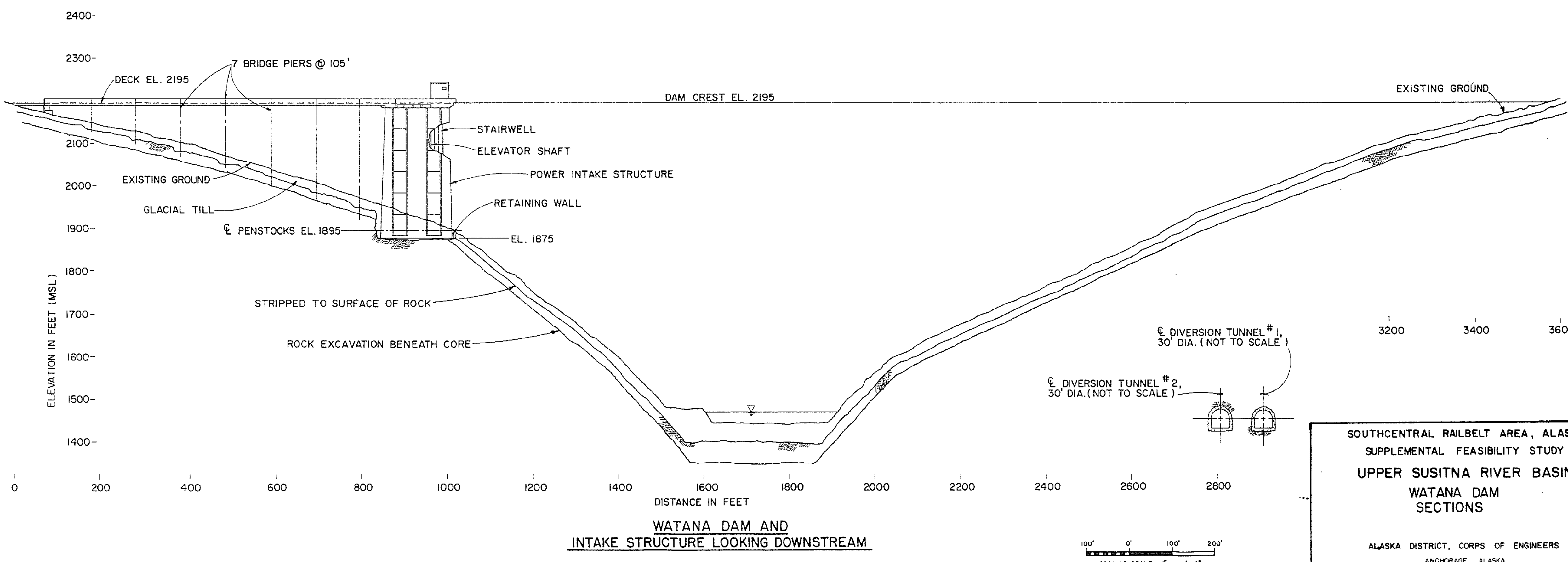
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

FEBRUARY 1979

EUGENE DIETZGEN COMPANY



TYPICAL SECTION



WATANA DAM AND INTAKE STRUCTURE LOOKING DOWNSTREAM

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

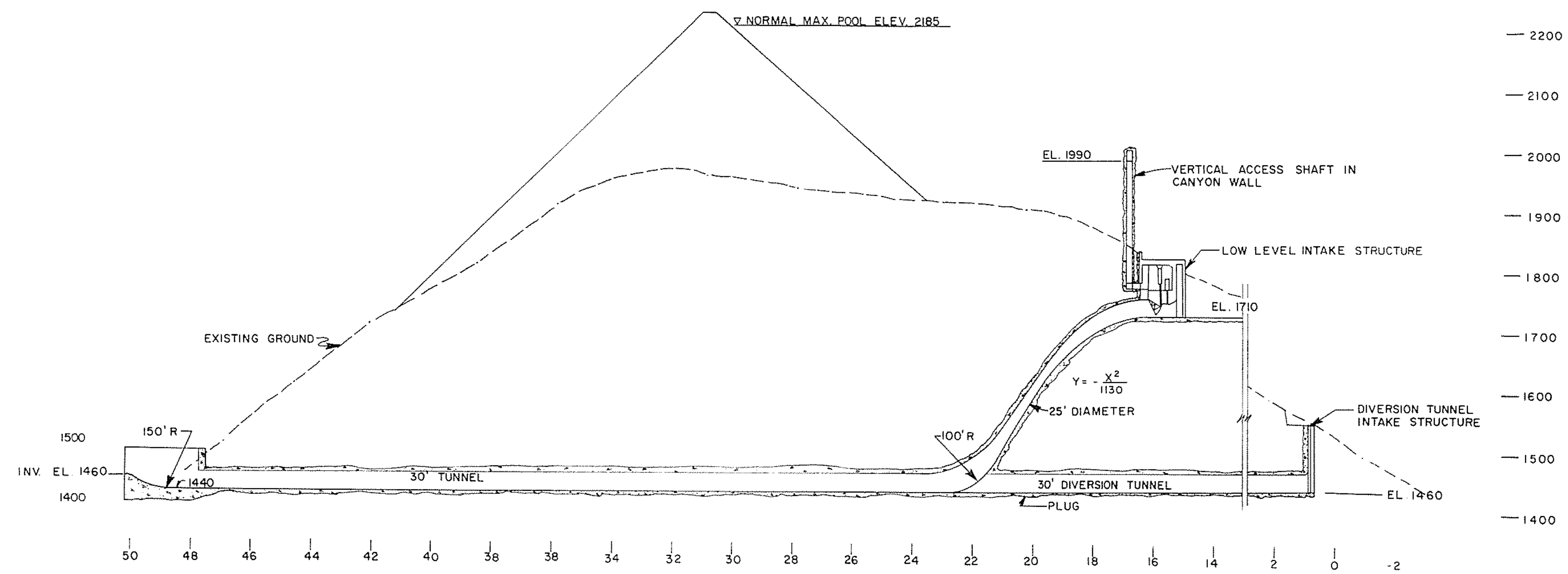
UPPER SUSITNA RIVER BASIN

WATANA DAM SECTIONS

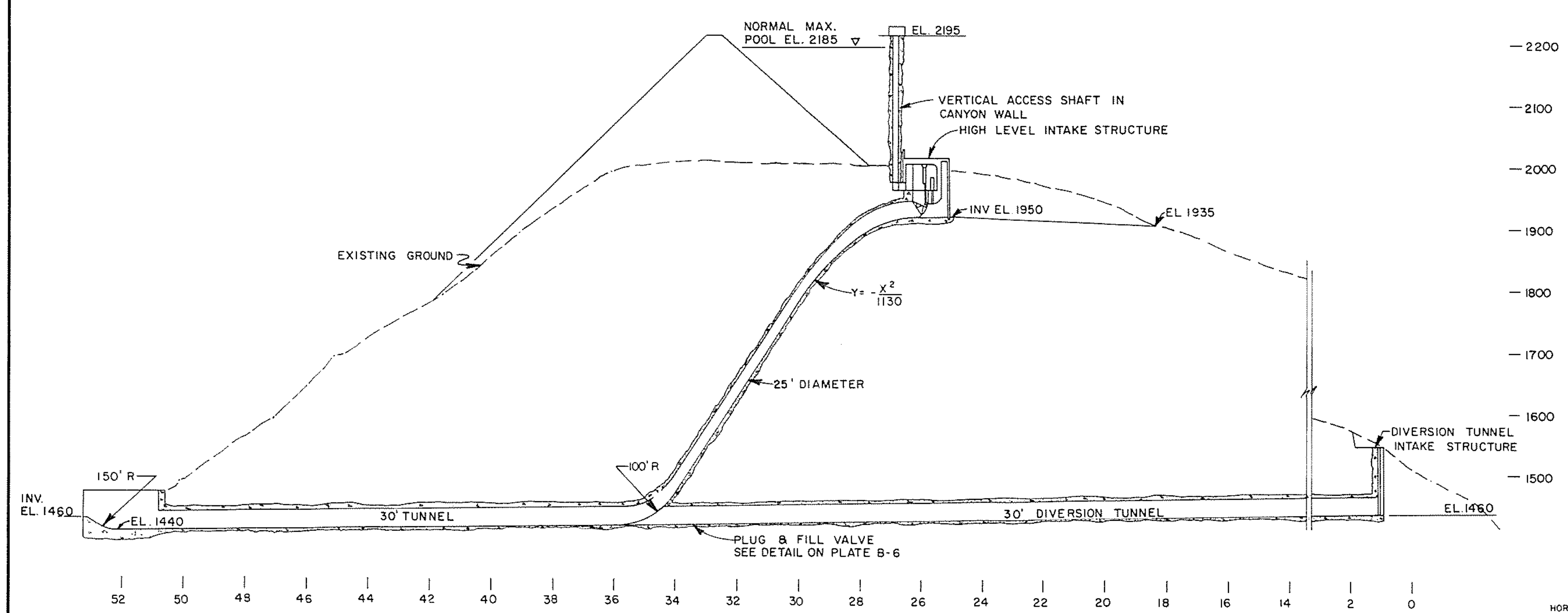
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

FEBRUARY 1979

NOTE:
THE HIGH AND LOW LEVEL INTAKE STRUCTURES ARE PLOTTED AT TWICE NORMAL SCALE FOR CLARITY.



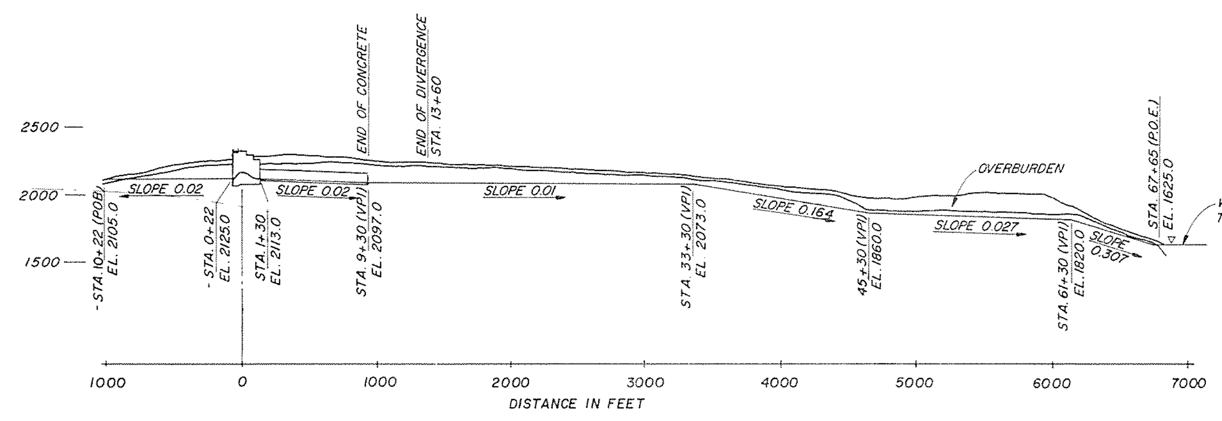
PROFILE LOW LEVEL OUTLET & DIVERSION TUNNEL #2



PROFILE HIGH LEVEL OUTLET & DIVERSION TUNNEL #1

HORZ: GRAPHIC SCALE: IN FEET (0, 200, 400, 600)
VERT: GRAPHIC SCALE: IN FEET (0, 100, 200, 300)

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
PROFILES
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
FEBRUARY 1979



SADDLE SPILLWAY ℄ PROFILE

SCALE IN FEET

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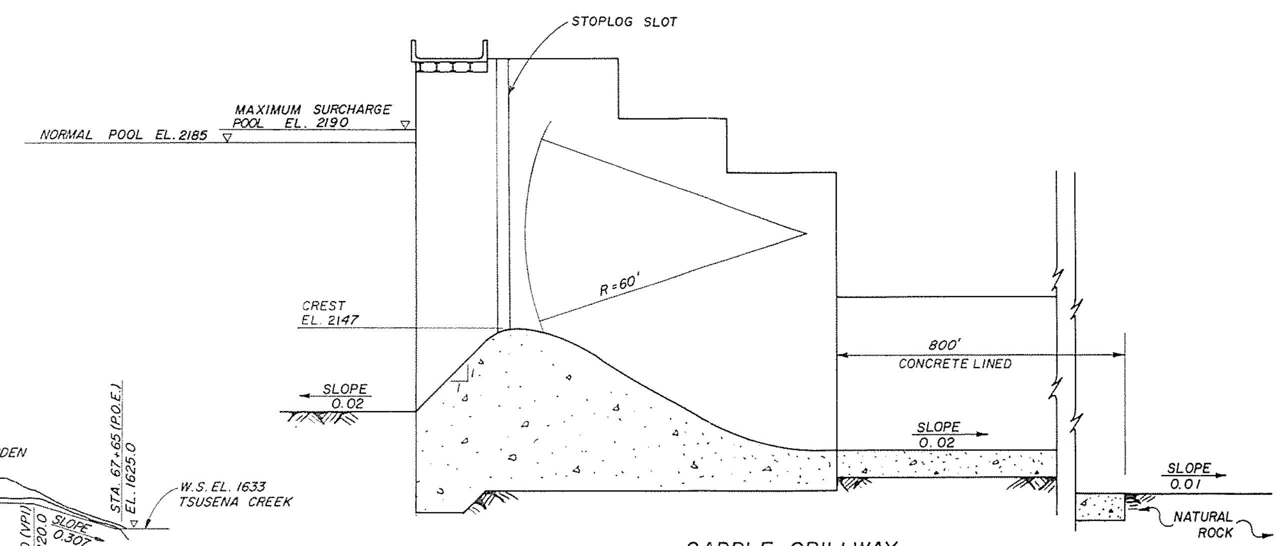
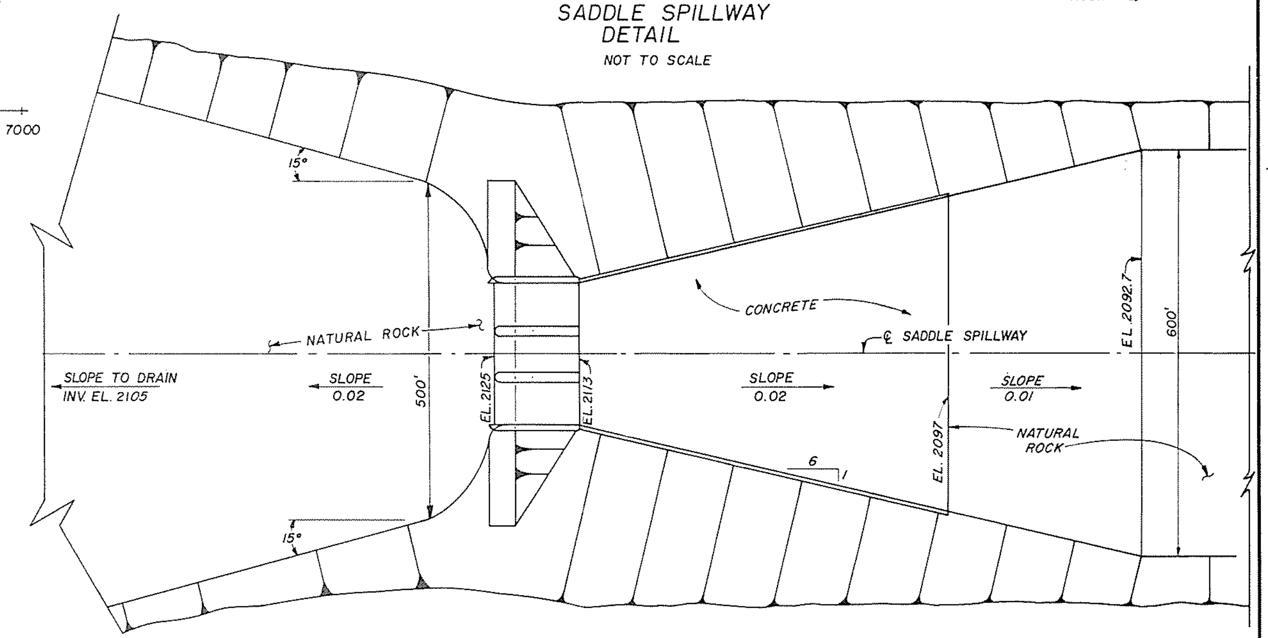


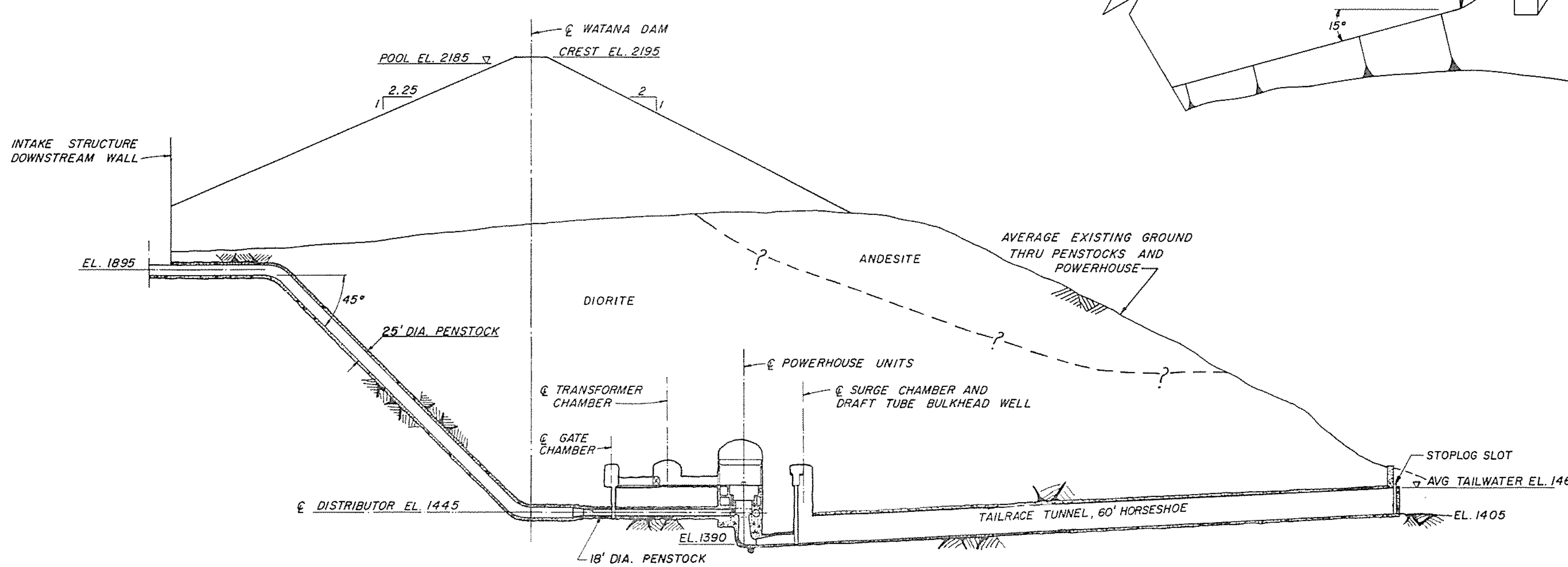
SADDLE SPILLWAY
DETAIL

NOT TO SCALE



SADDLE SPILLWAY
SECTION A-A

NOT TO SCALE



PENSTOCK ℄ PROFILE

NOT TO SCALE

SOUTHCENTRAL RAILBELT AREA, ALASKA

SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

WATANA DAM

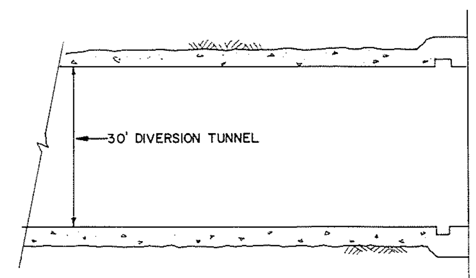
SADDLE SPILLWAY AND PENSTOCK

PROFILES, SECTIONS AND DETAILS

ALASKA DISTRICT, CORPS OF ENGINEERS

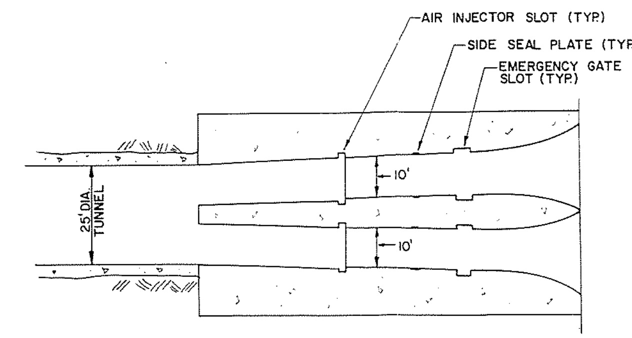
ANCHORAGE, ALASKA

FEBRUARY 1979



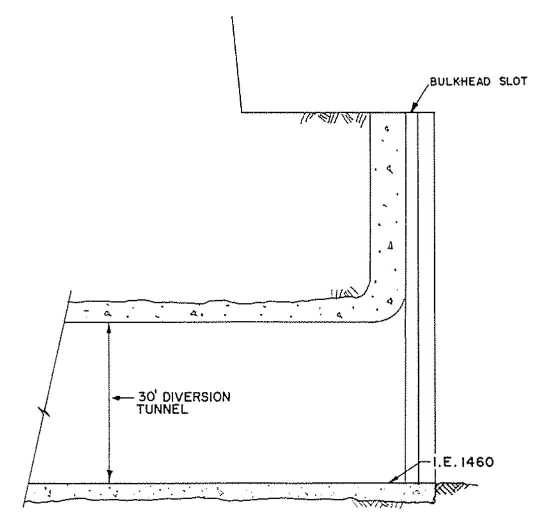
DIVERSION TUNNELS #1 AND #2 INTAKE STRUCTURE

PLAN @ EL. 1485



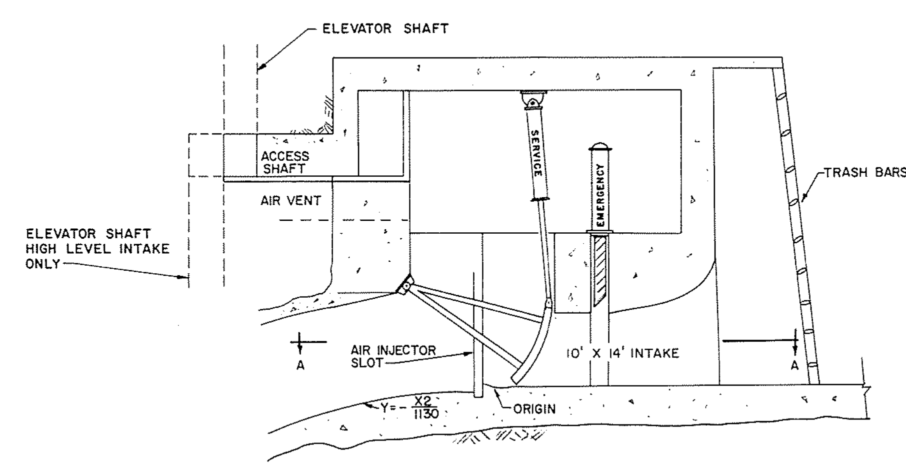
HIGH AND LOW LEVEL INTAKE

PLAN @ A-A



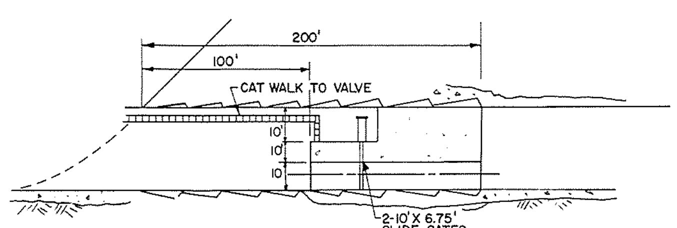
DIVERSION TUNNELS #1 AND #2 INTAKE STRUCTURE

SECTION



HIGH AND LOW LEVEL INTAKES

SECTION



PLUG AND FILL VALVE DETAIL

NOT TO SCALE

SOUTHCENTRAL RAILBELT AREA, ALASKA

SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

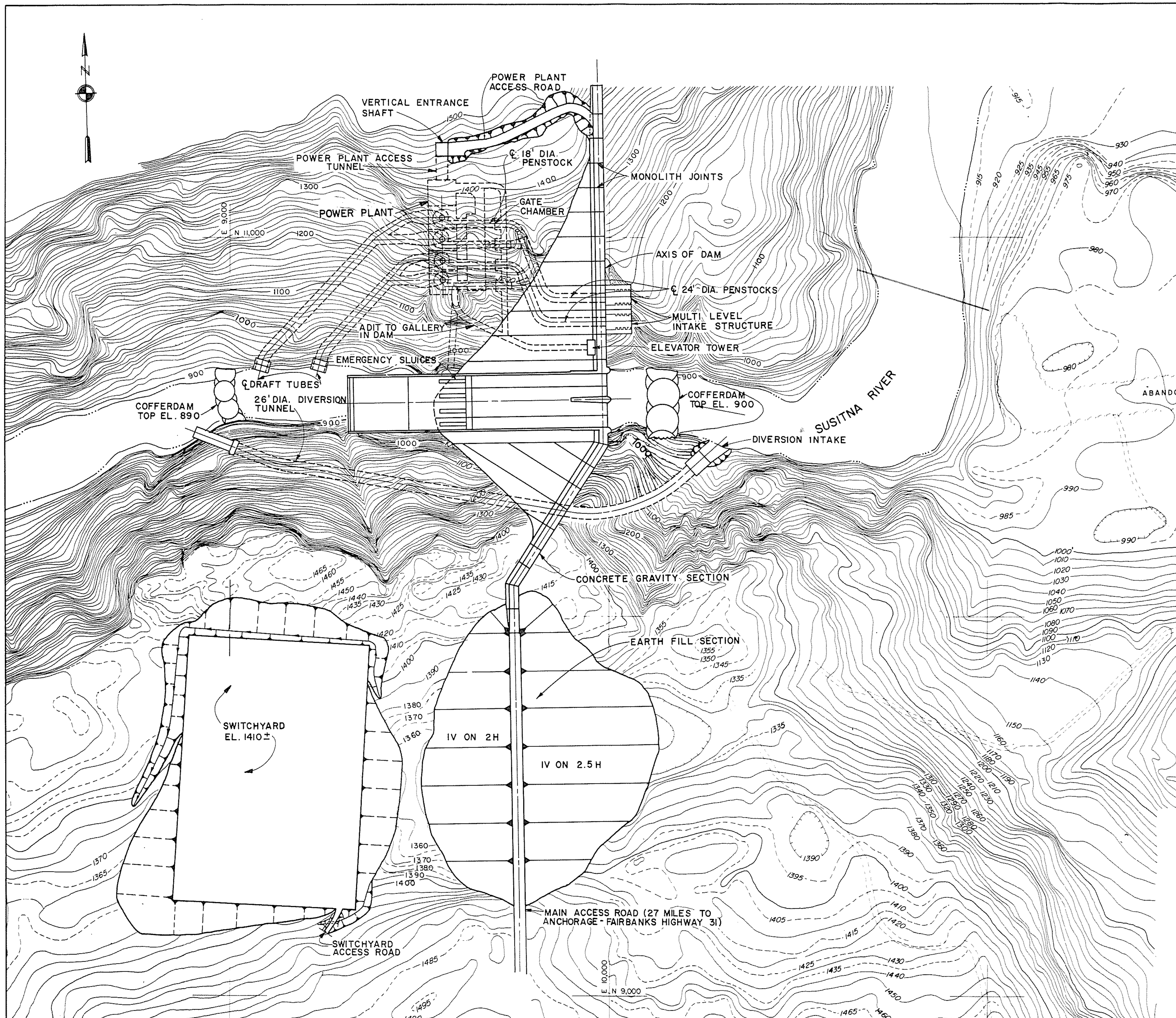
WATANA DAM

DETAILS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

FEBRUARY 1979



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

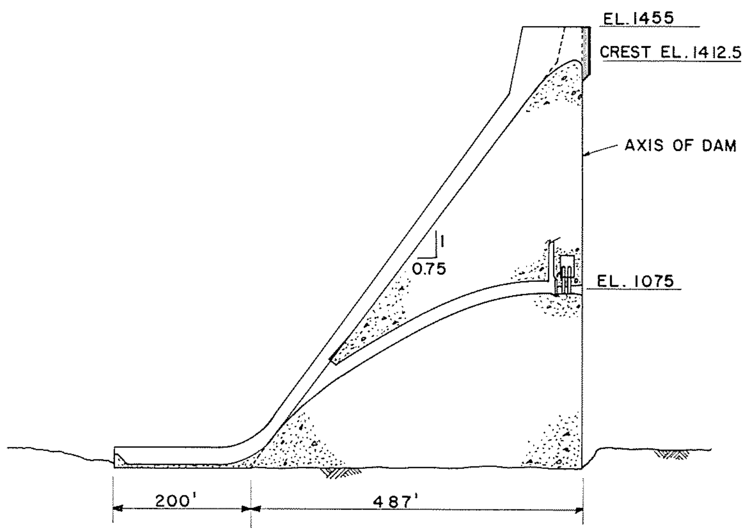
UPPER SUSITNA RIVER BASIN

DEVIL CANYON DAM
CONCRETE GRAVITY DAM
DETAIL PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

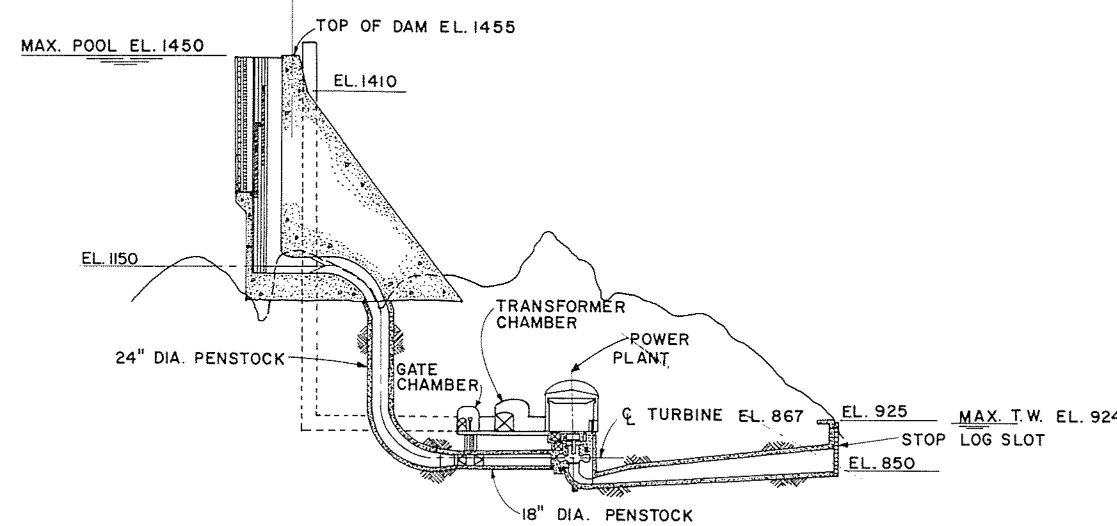
FEBRUARY 1979

PLATE B-7

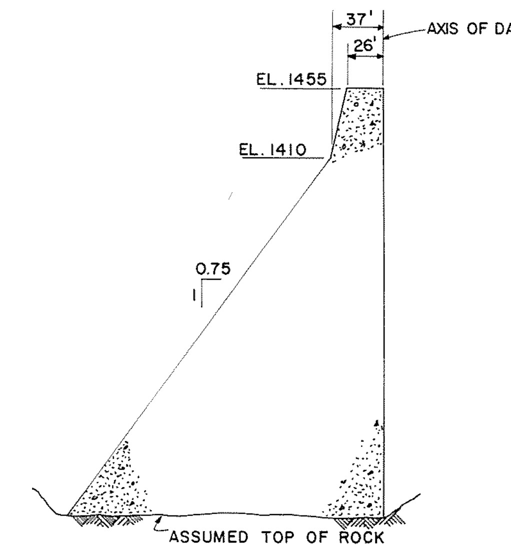


SPILLWAY SECTION

GRAPHIC SCALE: 1" = 100'-0"

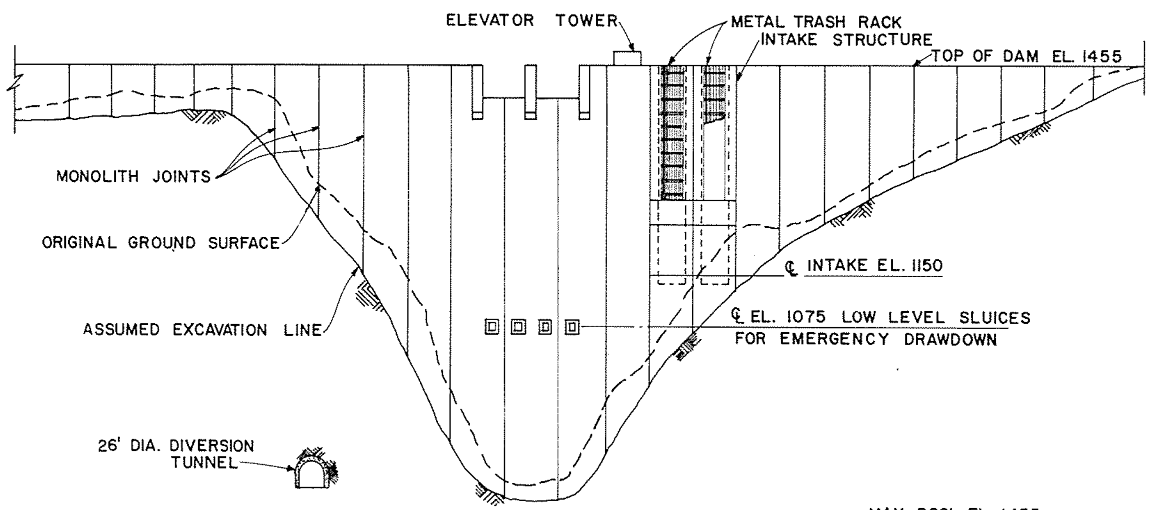


SECTION THRU PENSTOCK AND POWER PLANT
SCALE: 1" = 100'

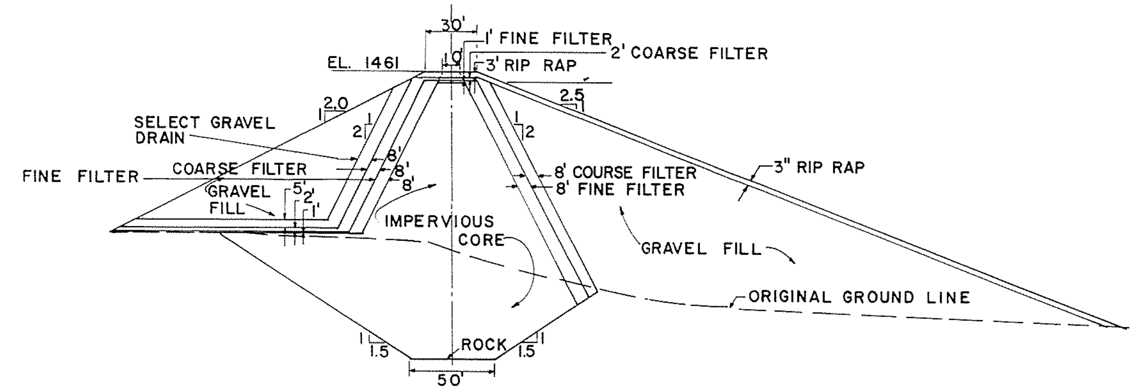


TYPICAL NON-OVERFLOW SECTION

GRAPHIC SCALE: 1" = 50'-0"

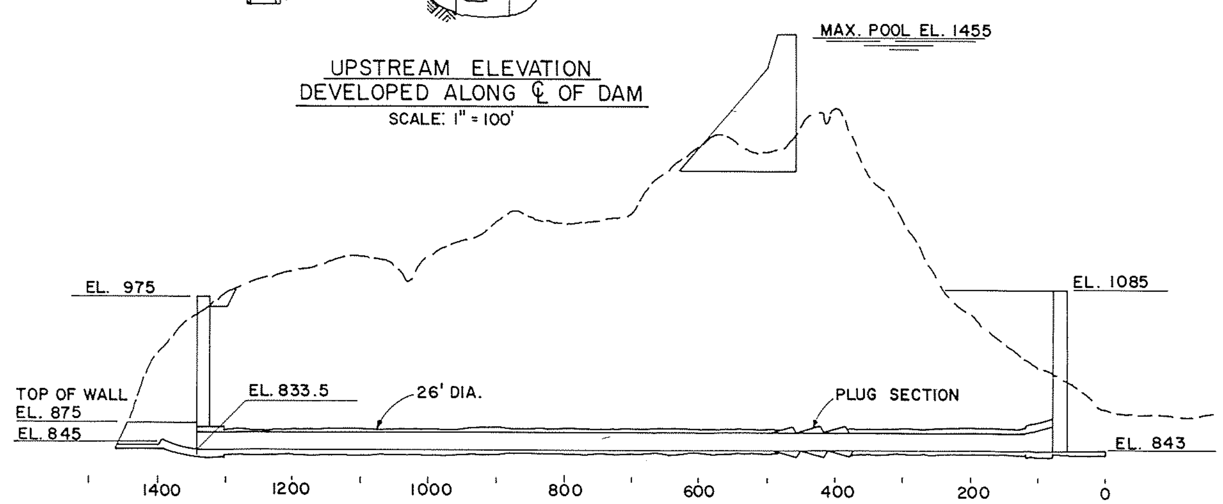


UPSTREAM ELEVATION
DEVELOPED ALONG ℄ OF DAM
SCALE: 1" = 100'



DEVIL CANYON AUXILIARY EARTH FILL DAM

GRAPHIC SCALE: 1" = 40'-0"



DIVERSON TUNNEL PROFILE
SCALE: 1" = 100'

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
DEVIL CANYON DAM
CONCRETE GRAVITY DAM
ELEVATION AND SECTIONS
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
FEBRUARY 1979

EUGENE DIETZGEN COMPANY

SECTION C

POWER STUDIES AND ECONOMICS

SECTION C

POWER STUDIES AND ECONOMICS

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

LIST OF TABLES

LIST OF TABLES (cont)

LIST OF FIGURES

LIST OF PLATES

EXHIBITS

SUMMARY OF CHANGES

This section updates benefit calculations and the determination of the project's economic justification presented in the 1976 Interim Feasibility Report. Economic trends and power usage continue to indicate that significant amounts of new generation will be required in the railbelt area of southcentral Alaska. A new load forecasting methodology and the three additional years of historical data result in slightly decreased peak load projections. The estimated costs of both the hydroelectric project and the coal-fired alternative have risen significantly since 1975. Under the base case set of assumptions, hydroelectric development in the upper Susitna River basin continues to appear economically justified. The 1978 updated benefit-cost ratio of the proposed development is 1.4 compared to the earlier estimate of 1.3.

STUDY AREA ECONOMY

SUMMARY OF CHANGES

The economic base analysis presented in the 1976 Interim Feasibility Report was based on the market area's economic performance through 1974. Fears of a severe post-pipeline depression in Alaska have been largely dissipated by the sustained performance of the State's economy in the 2 years since the pipeline phased down in 1976. In 1977, higher production levels were reached in the forest products, fisheries, and agricultural industries when compared to 1976. The State's financial institutions reached record high levels in 1977 in deposits, loans, and total assets. In addition, more houses and commercial and industrial buildings were constructed in 1977 than during any previous year. In fact, by excluding contract construction employment (under which pipeline workers were classified), there appears to have been a net increase in 1977 of 1,500 nonagricultural jobs in Alaska.

INTRODUCTION

The discussion that follows both augments and updates the economic base analysis of the 1976 report. It is based on three primary sources. One is a detailed analysis of the southcentral Alaska economy between 1965 and 1975. This work was done by the Institute of Social and Economic Research of the University of Alaska for the Southcentral Level B Study. Two other reports, one by the State's Department of Commerce and Economic Development and the other by the Department of Labor, provide information on the performance of the economy since 1975. Some of the population and income estimates through 1974 presented here differ from the estimates reported in the 1976 Interim Feasibility Report. These differences result from recent efforts by the State and others to develop a consistent data base.

HUMAN RESOURCES

The rapid economic growth in the Railbelt area of Alaska and in Alaska as a whole has resulted in substantial immigration of people seeking jobs in the Alaskan economy. Table C-1 summarizes population growth in the study area and in the state as a whole.

TABLE C-1

STUDY AREA POPULATION AS PERCENT OF TOTAL

Year	Total Alaska	Study Area	Percent of Total
1960	226,167	149,186	66
1970	302,361	209,178	69
1973	330,365	234,768	71
1974	351,159	245,846	70
1975	404,634	290,522	72
1976	413,289	301,250	73

Source: State of Alaska Department of Commerce and Economic Development, The Alaskan Economy, Year-End Performance Report 1977.

There are two major economic motivating factors which explain the large population increase. One is the fact that real incomes have been rising in Alaska faster than the rate in the U.S. as a whole. This is an indication that Alaska has been a region of improving economic opportunity in comparison to nationwide averages. In addition, individuals see explicit opportunities in the growth in employment. 1/ The Alaska Department of Labor estimates that net migration accounted for a 73,000 increase in resident population between 1970 and 1975, about 72 percent of the increase, while natural increase accounted for only 29,000, or about 28 percent of the total.

EMPLOYMENT

Employment shares of major industrial categories are presented in Table C-2. As can be seen, some significant changes in employment percentages have taken place over the past 5 years. In 1973, government claimed by far the largest share (38 percent) of total employment with services and retail trade a distant second at 14 percent. By 1978, Government's share declined to 30 percent. Manufacturing is the only other sector to show a significant decline - its share drops from 8.5 percent to 7 percent. Mining, construction, and services show the largest gains.

1/ Institute for Social and Economic Research, University of Alaska, Southcentral Alaska's Economy 1965-75, draft report.

TABLE C-2

INDUSTRY EMPLOYMENT SHARES
(Percent)

Industry	1973	1978 (Projection)
Mining	1.79	3.06
Manufacturing	8.50	7.11
Government	37.75	30.49
Construction	7.09	10.02
Retail Trade	13.60	14.02
Wholesale Trade	3.10	3.40
Finance, Insurance and Real Estate	3.86	4.87
Transportation	2.40	2.46
Communications	2.40	2.46
Public Utilities	0.92	0.78

Source: Alaska Department of Labor, Alaska Economic Outlook to 1985, July 1978.

Data for 1977 indicates that while the mid-year completion of the trans-Alaska oil pipeline had an impact on the State's economy, it has not been as severe as expected. As a result of the large decrease in contract construction employment, total nonagricultural employment declined accordingly. The decline in nonagricultural employment, however, was less than that of contract construction, indicating a previously unexpected economic stability.

PERSONAL INCOME

Total personal income is defined as the sum of wage and salary income, proprietor's income, dividends, interest and rental income, and transfer payments. Subtracted from this are personal contributions for social insurance. Once total personal income is compiled, it is then adjusted by the residency of the worker.

From statehood in 1959 through 1973, there has been stable growth in the State's personal income, paralleling the national trends. Alaska's per capita income estimate increased 86 percent from $2,498 in 1959 to $4,644 in 1970 while the U.S. average rose 83 percent from $2,167 to $3,966 respectively during this same time period. This trend continued through 1973 with Alaska's per capita income rising an additional 28 percent while the national level rose 27 percent.

Since 1973 per capita income in Alaska has demonstrated a phenomenal rate of growth. In 1974 it increased 17 percent to $7,117 while in 1975 the reported increase was 33 percent to $9,440. During 1976 the annual rate of increase slowed considerably to 10 percent, boosting per capita income to $10,415. Correspondingly, on the national level it increased 9 percent in 1974, 8 percent in 1975, and 9 percent in 1976.

Clearly, Alaska's resident personal income has increased substantially the past few years. The State's economy has received a tremendous boost from construction of the oil pipeline, Native land claims, outer continental oil development, and government expenditures. With the completion of the oil pipeline, personal income of Alaskans is initially declining in real terms. As additional projects come on line in the future, the rate of growth in real personal income will again turn positive.

TABLE C-3

TOTAL PERSONAL INCOME IN ALASKA, 1970-1977

Year	Personal Income (In billions of $)
1970	1.3
1971	1.5
1972	1.6
1973	1.9
1974	2.4
1975	3.3
1976	3.8
1977	3.9

Source: Alaska Department of Commerce and Economic Development, The Alaska Economy, Year-End Performance Report 1977.

AGGREGATE ECONOMIC PERFORMANCE

It has generally been assumed that there existed a direct cause and effect relationship between pipeline construction and the State's economic expansion. Preliminary data for 1977 indicate that while pipeline construction employment declined during the year, it did not trigger massive layoffs in other nonpipeline sectors of the State's economy. Indeed, even with an annual average loss of 11,300 construction workers, total employment in Alaska for 1977 declined by only about 9,700 workers, or less than 6 percent, from the historic high level in 1976. Refer to Table C-4.

Obviously, there have been other factors which have contributed significantly to the State's recent economic expansion. By the end of September 1977, over $348 million had passed through the Alaska Native Fund to the Native corporations. Of this amount, a considerable portion had been invested in Alaska businesses and industry. In addition, public sector expenditures by Federal, State, and local governments have demonstrated dramatic increases in recent years, and mineral exploration activity has continued at a strong pace. These and other sources of nonpipeline economic stimulation have occurred during the pipeline construction time period and they appear to have played a significant role in expanding and strengthening Alaska's economy.

The forest products industry, after considerable expansion in 1976 from the previous depressed levels, maintained a stable high level of activity in 1977. Pulp and lumber production remained constant in 1977 although the production of wood chips declined significantly as a result of world market conditions. Japan, the major purchaser of Alaska's forest products, continues to be hampered by the slow recovery of its national economy, especially in its residential housing sector.

The State's commercial fisheries industry greatly surpassed all expectations during 1977. The salmon harvest was the highest since 1970 with strong returns of pink salmon to the southern portion of southeast Alaska and with good returns to most other areas of the State. Generally, the shellfish harvest and prices paid to fishermen were higher than in 1976.

As a result of the overall increases in 1977's fin and shellfish harvest, higher employment levels were stimulated in the State's fish processing sector.

Investment in hard rock mineral exploration increased substantially during 1977 to an estimated record high of $60 million. Oil exploration continued with 33 wildcat and step-out wells drilled in 1977, representing nearly a threefold increase in activity over the 1976 total. Major oil discoveries were announced in 1977 at Point Thompson and Flaxman Island (located east of Prudhoe Bay), indicating the possibility of additional North Slope oil and gas fields of significant scale. In October 1977, the Lower Cook Inlet lease sale was held in Anchorage.

TABLE C-4

ALASKA ECONOMIC INDICATORS

	1970	1971	1972	1973	1974	1975	1976	1977e
Resident Population (000)	302.4	312.9	324.3	330.4	351.2	404.6	413.3	N.A.
Civilian Labor Force #(000)	87.2	92.9	98.6	103.8	119.5	148.5	158.0	158.9
Employment #(000)	81.1	85.4	90.5	95.2	110.3	138.5	145.0	136.4
Nonagricultural Employment (000). . .	92.5	97.6	104.2	109.9	128.2	161.3	171.7	162.0
Number Unemployed #(000).	6.0	7.5	8.0	8.6	9.2	10.0	13.0	20.5
Wage & Salary Payments ($000,000) . .	$1,253	$1,359	$1,471	$1,621	$2,167	$3,449	$4,247	$3,737
Resident Personal Income *($000,000).	$1,412	$1,563	$1,698	$2,006	$2,429	$3,443	$3,979	$4,000
Anchorage CPI (1967 = 100).	109.6	112.6	115.9	120.8	133.9	152.3	164.1	175.7
Percent Change in CPI	3.5	3.0	2.7	4.2	10.9	13.8	7.8	7.1

N.A. = Not Available
e = Estimate
# = Current Population Survey Basis
* = Place of Residence Basis

Source: Alaska Department of Commerce and Economic Development, The Alaska Economy, Year-End Performance Report 1977.

Although drilling results in the Gulf of Alaska have been disappointing to date, other oil and gas exploration activities are continuing on the National Petroleum Reserve Alaska (old PET-4) and on Native corporation lands.

PRESENT AND HISTORICAL POWER REQUIREMENTS

This section presents the existing and planned generating capacities of the railbelt area as of 1977 along with generating resources that are planned for the near future. Also shown are the historical net generation estimates through 1977.

TABLE C-5

SUMMARY OF EXISTING GENERATING CAPACITY

	Installed Capacity (MW)				
	Hydro	Diesel	Gas Turbine	Steam Turbine	Total
Anchorage-Cook Inlet Area:					
Utility System	45.0	27.5	435.1	14.5	522.1
National Defense	-	9.2	-	40.5	49.7
Self-Supplied Industries	-	11.3	15.2	37.5	64.0
SUBTOTAL	45.0	48.0	450.3	92.5	635.8
Fairbanks-Tanana Valley Area:					
Utility Systems	-	35.1	203.1	53.5	291.7
National Defense	-	14.0	-	63.0	77.0
SUBTOTAL	0	49.1	203.1	116.5	368.7
TOTAL	45.0	97.1	653.4	209.0	1004.5

Source: Alaska Power Administration, "Power Market Analysis," January 1979. Anchorage-Cook Inlet figures include the Valdez-Glennallen area which totals 56.8 MW.

The total 1977 installed capacity of 1,004.5 MW represents a 45 percent increase over the 692 MW of installed capacity that existed in 1974.

TABLE C-6

NEAR-TERM PLANNED RESOURCES

	Year	Installed Capacity (MW) Gas Turbine	Steam Turbine	Total
Anchorage-Cook Inlet Utilities	1978	66.7	-	66.7
	1979	113.7	-	113.7
	1980	100.0	-	100.0
	1981	18.0	-	18.0
	1982	100.0	-	100.0
	1984	18.0	400.0	418.0
SUBTOTAL		416.4	400.0	816.4
Fairbanks-Tanana Valley Utilities	1982	-	104.0	104.0
TOTAL		416.4	504.0	920.4

Source: Battelle Pacific Northwest Laboratories, "Alaskan Electric Power: An Analysis of Future Requirements and Supply Alternatives for the Railbelt Region," March 1978.

TABLE C-7

HISTORICAL NET GENERATION (GWH)

Year	Anchorage-Cook Inlet Area Util	Nat. Def	Indu	Fairbanks-Tanana Valley Area Util	Nat. Def	Indu	Total
1970	744.1	156.2	1.7	239.3	203.5	-	1,344.8
1971	886.9	161.2	25.0(e)1/	275.5	201.4	-	1,550.0
1972	1,003.8	166.5	45.3	306.7	203.3	-	1,725.6
1973	1,108.5	160.6	45.3(e)	323.7	200.0	-	1,838.1
1974	1,189.7	155.1	45.3	353.8	197.0	-	1,940.9
1975	1,413.0	132.8	45.3(e)	450.8	204.4	-	2,246.3
1976	1,615.3	140.3	45.3(e)	468.5	217.5	-	2,486.9
1977	1,790.1	130.6	69.5	482.9	206.8	-	2,679.9

1/ (e): estimated industrial load, revised by APA, January 1979.

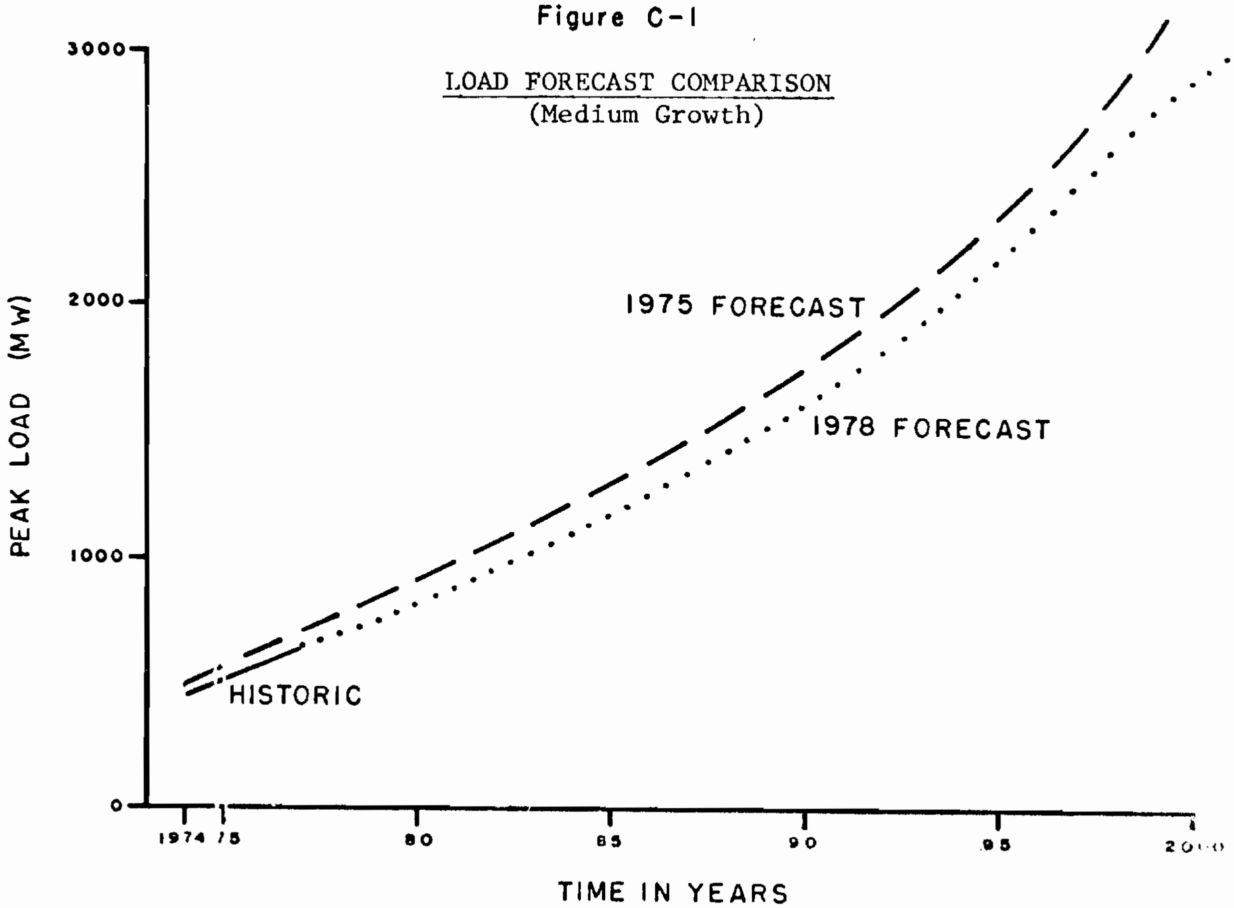
Source: APA, Upper Susitna Project Marketability Analysis, November 1978.

SUMMARY OF CHANGES

The forecasted demand for electrical power presented in this section constitutes a downward revision from those estimates used in the 1976 Interim Feasibility Report. The cumulative changes are due to the use of a different forecast methodology, 3 additional years of historical data, and generally more conservative economic development assumptions. The extent of change in the forecasts, however, is not great. For instance, the midrange forecast of peak load for the year 2000 has been revised to 2,852 MW, a 10 percent decrease from the earlier estimate of 3,170 MW (refer to Figure C-1). The most noticeable change occurs in the high range forecast which was reduced 36 percent in the year 2000.

Additionally, the revised forecast has been extended an additional 25 years to 2025 in order to facilitate longer range planning.

Figure C-1



FORECAST METHODOLOGY

The Alaska Power Administration (APA) has used a simplified end-use model to forecast future power requirements, augmented by trend analysis and an econometric model. Total power demand has been categorized into three primary end uses: the residential/commercial/industrial loads supplied by electric utilities, the national defense installation sector, and the self-supplied industrial component.

Those factors in each category that best explain historical trends in energy use were identified. In the utility sector, those explanatory variables are population and per capita use. Population was forecasted with the help of a committee of experts using a regional econometric model, while per capita use estimates are an extrapolation of past trends adjusted to account for anticipated departures from those trends. National defense needs are assumed to depend on the level of military activity and the number of military personnel in the study area. Future self-supplied industrial power requirements are based on explicit assumptions regarding future economic development and the energy needs associated with such development.

POPULATION AND ECONOMIC ACTIVITY FORECAST

The most important sector in terms of magnitude of electrical energy use is the utility sector, and population is the key factor in this sector's future power requirements. Population forecasts in turn, are highly dependent upon assumptions of future economic activity. Economic activity assumptions are also important because they have a direct impact on energy requirements in the self-supplied industrial sector.

The population and economic activity assumptions used in this forecast are based on a draft report of the Economics Task Force, Southcentral Alaska Water Resources Study, dated September 18, 1978. The report is entitled, Southcentral Alaska's Economy and Population, 1965-2025: A Base Study and Projection.

The report was a joint effort of economists, planners, and agency experts who were members of the Economics Task Force of the Southcentral Alaska Water Resources Study (Level B), being conducted by the Alaska Water Study Committee, a joint committee of Federal and State agencies, the Alaska Federation of Natives, the Alaska Municipal League, the Municipality of Anchorage, the Southcentral region borough governments, and regional Native corporations.

The projections reported relied on two long-run econometric models devised by economists from the University of Alaska Institute of Social and Economic Research and from the MIT-Harvard Joint Center for Urban Studies. Funding was provied by the National Science Foundation's Man in the Arctic Program (MAP). The two specific models used here were modifications of the Alaska State and regional models developed under that program. The models produced estimates of gross output, employment, income, and population for the years 1975-2000. Population and employment were disaggregated and extrapolated to the year 2025 by ISER researchers under Economics Task Force direction, and using Task Force concensus methodology. The data required to run the model were provided by various members of the Economics Task Force, the assumptions were reviewed by the Task Force, and the model outputs and tentative projections were reviewed for internal consistency and plausibility by ISER researchers and by the Task Force.

The use of the econometric model requires a set of assumptions related to the level and timing of development. The assumptions primarily consist of time series on employment and output in certain of the export-base industries and in government. Because of the importance of these assumptions to the electrical energy load forecast, they are presented here in full on pages C-13 through C-31 from the Economic Task Force Report.

<u>Assumptions Used to Produce Economic and Population Projections, 1975-2000</u>

The critical assumptions are organized into two scenarios which consist of all low-range assumptions taken together and, alternatively, all high-range assumptions taken together. The scenarios were intended to show a "reasonable" high and reasonable low development series of specific projects which together would offer about the broadest range of employment and population outcomes which could be foreseen. This does <u>not</u> mean that the Task Force predicts that all or any of the projects assumed will actually occur; on the contrary, there is a highly variable degree of uncertainty with respect to the level and timing of all developments in the scenarios. However, some projects were subjectively rated more likely than others, some unlikely, and some very unlikely. Task Force consensus assigned most of the more likely projects to the low development scenario, some of the less likely to the high development scenario, and the remainder were assumed not to occur within the time horizon of the study.

The resulting low and high scenarios should <u>not</u> be considered synonyms for the terms "minimum" and "maximum" development. The Task Force did not feel competent to say what the theoretical minimum or maximum <u>possible</u> level of economic development in Southcentral Alaska might be, since this could be influenced by Government policy at Federal, State, and local levels and by market developments beyond the power of anyone to predict at this time; nor would that exercise have been of much use to planners.

The assumptions are organized by industry and discussed in the following sections.

Agriculture: Agriculture is currently a marginal industry in Alaska, employing about 1,000 people statewide (depending upon the definition of part-time, family help, and proprietors). In southcentral Alaska, about 115 man-years per year are expended in agriculture. Under a set of very favorable public policy decisions and favorable markets, considerable further development might occur. Primary requirements include: public priority given to agricultural production in Alaska at the same level as petroleum, minerals, and marine products; active pursuit of statutes and programs to reserve and preserve agricultural lands; and public aid to innovative settlement and development techniques. In this case, the agricultural experts on the Task Force could foresee possible commercial agricultural employment of around 800 man-years in southcentral Alaska per year, and about 4,600 statewide by the year 2000, rising to 6,900 by 2025. This reflects the current emphasis on development of the Tanana Valley, rather than the southcentral area. Total statewide sales of agricultural products in the high case rise to about $400 million (1975 dollars) per year in the year 2000, and to about $500 million in 2025. Value of output in constant 1958 dollars rises to $51 million by 2000, about $8.5 million from southcentral. By the end of the study period in the high case, about 1.06 million acres would be cultivated for crops, and 5.2 million acres of range land utilized. (Currently, about 20,000 acres are used for crops and grass in the State, about 12-13 thousand in southcentral.)

In the low case, public priority is given to "national" and "public" interest in esthetic, recreational, subsistence, and wilderness values, tending to reduce the amount of land available for crops and reducing the access and usability of land for agriculture. In addition, public agricultural agencies and institutions which support agriculture are allowed to atrophy. In this case, and with market conditions continuing to be unfavorable to Alaskan agriculture, the southcentral industry output and commercial employment drops to zero as the land is subdivided for homesites and recreational use. Value of commercial output drops to zero by 1991, with only "amenity" (part-time, partly subsistence) output remaining.

Forestry: Aggregated in State statistics under Agriculture-Forestry-Fisheries, this is a tiny sector which employs about 22 people statewide. Virtually all employment in logging occurs in lumber and wood products manufacturing. Value added is likewise negligible. In the high case, this sector grows in proportion to growth in lumber and wood products. In the low case, it stays at current levels.

Fisheries: The fisheries sector primarily consists of persons actually engaged in fishing, but it is troublesome for several reasons. It is difficult to count fishermen since this is an industry in which proprietors do much of the work, often with unpaid family help, the work is seasonal in nature, and many out-of-state persons take part. This causes the State's employment statistics, based on employment covered by unemployment insurance, to be misleading. Likewise, multiple licenses and unfished licenses make fisherman licenses a misleading indicator. Area-of-catch statistics collected on fish landed in Alaska, together with independent data on crew size, by gear type, give a pretty good picture of total persons actually engaged in fishing. For southcentral Alaska (but including the Aleutian chain), annual average employment on this basis is about 2,000 persons, while it was 4,359 statewide in 1975. In the high case, it is assumed that in existing fisheries, expansion of fishing productivity would be offset by limited entry and labor-saving improvements in the fleet, leaving employment constant at existing levels despite a fourfold increase in the salmon catch. However, given very favorable conditions, major development of the American trawl fishery off Alaska's coast could result in 100 percent replacement of the foreign fishing effort inside the 200-mile limit by the year 2000, employing about 17.5 thousand persons in fishing statewide and 8.7 thousand (or 50 percent) in southcentral. This was considered to be a very speculative development; consequently, no bottomfishing development was considered in the low case, while existing fisheries just maintained current employment.

Output level of existing fisheries in the high case expands considerably, since the State is assumed to undertake an aggressive hatchery and habitat improvement program, together with the 200-mile economic zone. The combined effect is assumed to be a quadrupling of salmon catch, while shellfish remain at about existing levels. The expansion of the trawl fishery was assumed to result in a southcentral catch of 1.85 billion pounds per year, worth $361 million exvessel in the high case. In the low case, all fisheries maintain their approximate 1975 levels.

Mining, Including Oil and Gas: The mining sector is dominated by employment and output in oil and gas, with lesser amounts in coal, sand, and gravel, and a few persons engaged in precious metal exploration and extraction. For the State as a whole, oil and gas developments are expected to dwarf all other considerations in this industry. Within southcentral Alaska, an important local issue is the development of the Beluga coal field.

The developments in mining in the high case are assumed to be as follows: There is a small find of hydrocarbons in the Northern Gulf of Alaska, but no important production. If the mean expected reserves are found, peak production would be about 932 thousand barrels of oil per day in 1985, and peak gas production of 0.5 billion cubic feet per day in 1987. The Sadlerochit, Kuparuk River, and Lisburne formations at Prudhoe Bay all combine in the high case for a 1,785 million barrels/day flow of oil in 1985. In addition, the joint State/Federal offshore lease sale is assumed to contain oil and gas resources equivalent to total reserves of 1.9 billion barrels. There are also two lease sales--in the Northern Gulf of Alaska (Sale 55) and Western Gulf/Kodiak area (Sale 46)--which result in moderate sized oil finds. Peak oil production in the Northern Gulf is about 0.550 million barrels per day in 1986, and 0.515 million barrels per day in 1992 in the Western Gulf. Daily gas production peaks at 1.0 bcf/day in the Northern Gulf and 0.26 bcf/day in the Western Gulf. Coal production in the high case would begin in 1983, with full-scale mining of 730,000 tons of coal per year by 1984 to feed a mine-mouth powerplant, twice that amount by 1986 to feed a second plant, and development of 6 million tons/year exports by 1990. In the high case, employment peaks at slightly over 9,000 in 1984, subsequently declining to 8,200 in 1995, while output rises to $3.2 billion (constant 1958 dollars1/), tailing off to $2.6 billion.

Low case oil and gas development basically consists of development at or around Prudhoe Bay. There is exploration in all the areas noted in the previous case, but exploration turns up far fewer prospects worth developing. While the Kuparuk and Lisburne are developed in this case and there is a joint offshore sale, the Beaufort sale turns up only 0.8 billion barrels of reserves instead of 1.9 billion. The lower Cook Inlet turns up only a small find, while the northern and western regions of the Gulf of Alaska are dry and result in "exploration only" employment. Beluga coal is not developed in the low case. As a result of all this, statewide peak employment in mining rises to about 7,000 in 1984, dropping to less than 4,800 by the end of the century.

Within the region, exploration plus development of oil and gas employ almost 4,800 persons by 1984 in the high case, declining to almost one-fourth that number by 1993. Beluga coal adds about 220 workers by 1990, the first year of coal export. In the low case, the peak employment is only 2,700 persons in 1984, the peak year, declines sharply thereafter, and levels off at 1,200 after 1987.

Food Manufacturing: The food manufacturing industry in Alaska is dominated by seafood processing, a situation which is not expected to change in the near furure. In the high case, the projected fourfold increase in the output of the salmon fisheries implies about a doubling

1/ The 1958 base year was used for convenience since U.S. Department of Commerce estimates of gross product were in terms of 1958 dollars when the study began.

in employment required to process the salmon. Since it was the consensus of the Task Force that shellfish are at or near maximum sustained yield, the overall processing plant employment for existing fisheries is projected to increase about 25 percent. Also in the high case, by the year 2000 the 100 percent replacement of foreign bottom fish effort off Alaska results in a catch of 3.7 million metric tons per year, requiring estimated total processing employment of about 12,000 and short-term (5-month) seasonal employment of 21,211--for an annual average of 21,000 by 2000. However, we assumed that only about one-third of total catch would be processed in Alaska shore-based facilities, resulting in total Alaska shore-based employment of 3,759, half of whom are employed in southcentral, and affect the local economy. The remainder of the 21,000 work on processing vessels near shore and offshore, but their incomes probably would affect the Anchorage economy and the statewide economy to some degree. Output for this industry was estimated by taking the expected exvessel value and using the historic ratio of exvessel to wholesale value, and the ratio of value-added to wholesale value. In the high cases, the value of catch in existing fisheries was assumed to rise at the same rate as total catch, yielding $145 million in value added in 2000, while catch in the emergent trawl fishery was assumed to rise to $722 million (3.7 million metric tons), yielding about $167 million of value added in processing (all value added in constant 1958 dollars). In the low case, a growth rate of 1 percent per year was projected for total output, yielding $81.5 million per year value-added by 2000.

Lumber and Wood Products Manufacturing: The two critical assumptions for this industry are the annual cut of timber in the State, determined mostly by Forest Service allowable cut and Japanese market conditions, and whether any dimension sawmills are built in Alaska. In the high case, the annual cut by the year 2000 was assumed to be 1,260 million board feet (probably partly from Native lands), compared with 660 million in 1970. In the low case, the increase is to only 960 million. No new mills are built in either case. While not exactly proportional, the increase in employment is similar: in the high case, statewide employment rises to 3,834 from 2,176 in 1975; in the low case, the rise is from 2,176 to 3,280. The output of this industry was estimated by calculating the 1975 ratio of output per employee. This was assumed to escalate at its 1965-1975 rate of growth in the high case (about 1.66 percent), but stayed at 1975 levels in the low case.

Since almost all the prime timber likely to be exploited by an expanding industry is located outside the southcentral region, we assumed that outside of Anchorage, the employment of firms in this sector would escalate by about 1 percent per year in the low case, by 2.3 percent per year in the high case, which is about the same or less than the statewide rates. Employment was assumed constant in Anchorage.

Pulp and Paper Manufacturing: The growth in this sector is determined by most of the same factors as lumber and wood products. In neither case is there a pulp mill built in southcentral Alaska, so there is no employment or output in this sector within the region. In the State, the increase in total cut results in average employment increases of about 1.6 percent per year in the low case, 1.8 percent per year in the high, resulting in totals of 1,777 and 1,886, respectively. In the low case, productivity per worker remains at its 1975 value; in the high case, it increases at 2.76 percent annually, its 1965-1975 rate, resulting in value added of $88.2 million and $93.6 million, respectively, in the year 2000.

Other Manufacturing: This sector is an odd mixture of a wide variety of cottage industries, printing and publishing, and consumer goods manufacture, together with a few major petrochemical plants and refineries. The major possible sources of new employment in this sector were assumed to be the Alpetco royalty oil refinery-petrochemical complex, Alaska Pacific LNG plant, and whatever other LNG or gas treatment facilities might be associated with gas output from lower Cook Inlet and the Gulf of Alaska. In the high case, the total operating employment of these facilities was about 2,000 persons (mostly working for Alpetco). In the low case, the only source was Pacific LNG, employing about 60 persons. Statewide output in this sector was more of a problem since it was unclear how much the output to be added by any of the LNG plants might be. It was decided to subsume LNG value-added under mining, and in the high case, value-added in other manufacturing was estimated as the existing level of output, plus total revenues of Alpetco, minus cost of feedstocks, from the Alpetco pro forma financial projections of March 10, 1978. All the growth was entered outside of Anchorage. In the low case, the existing level of output was used.

Construction: For modeling purposes, it was only necessary to estimate total employment working on major projects exogenous to the economy, since the rest of construction is projected with the support sector and output is determined by employment in this sector in the models. In the high case, the significant projects within the region were assumed to be oil treatment and shipment facilities in the Gulf of Alaska and Kodiak subregions and the Kenai-Cook Inlet Census Division, small LNG facilities associated with the Northern Gulf and lower Cook Inlet development, a Beluga coal transshipment facility, Pacific LNG and Alpetco plants, and a new State capital in Willow. Outside the region, there is augmentation of TAPS pipeline capacity, the northwest Alaska gas pipeline is constructed, and field development facilities are projected for the Beaufort Sea and the Kuparuk and Lisburne formations. Statewide, total exogenous construction employment peaks at a total of about 14,000 in 1981, declining rapidly thereafter to less than 1,000 by 1991. In the region, the peak employment is a bit less than 7,000 in 1981.

The level of construction employment was considerably less in the low case, both because of fewer developments in oil and gas, and because several projects needing State support do not occur, e.g, Alpetco and the State capital move. In this case, the northwest Alaska pipeline is constructed, but the oil finds at Prudhoe Bay offshore areas are relatively small, as are those in lower Cook Inlet. The Kuparuk and Lisburne formations are developed, and the Pacific LNG plant is built. However, there is no new substantial augmentation to fish processing in the form of new plants to process bottom fish. In the low case, statewide peak employment in exogenous construction is about 9,500, while in the region it is about 1,800.

Federal Government: Federal Government employment has been growing very little over the last 10 years, with civilian increases about offset by decreases in military employment. The rate of civilian increase has been about 0.5 percent per year, and lacking the boost of any massive developments requiring Federal support, and lacking a new State capital, the likely rate of increase in Federal civilian employment for the low case is assumed to remain at 0.5 percent, increasing employment from 18,000 to 21,000 statewide, and from 10,900 to 12,250 in the region by 2000. In the high case, general development results in a doubling of the average rate of increase to about 1 percent per year in Federal Government in most of the State, and 1.2 percent per year in southcentral to reflect the State capital move. This increases statewide Federal civilian employment from 18,000 to 22,000, and regional employment from 10,900 to 14,500. Federal military employment is assumed to remain constant at 1975 levels in both the State and region.

State Government: State Government employment went through several revisions because of concern about State budgets. Historically, the rate of growth in this sector averaged 8.5 percent per year, a rate which most Task Force members believed was unlikely to continue. On the other hand, in the high case bottomfish development, major oil development, and the moving of the State capital to Willow were likely to result in fairly substantial increases in State employment. In the high case, it is assumed that 2,750 positions were transferred from Juneau to Willow and that total State Government employment would increase from 14,700 to about 39,000 in the year 2000, declining from around 7.6 percent of civilian wage and salary employment to about 7.2 percent. In the region, State employment bulks fairly large because of the State capital move, with the total from Anchorage and other southcentral combined moving from 5,400 to 14,900, or from 5.2 percent to 13.1 percent of total employment.

In the low case, it was assumed that government growth was restricted by lower development needs, by funding constraints or public opinion, and by the fact that the State capital did not move. Before 1985, State Government employment growth was held to about 2 percent per year, with zero growth thereafter. State employment as a result goes from 14,700 in 1975 to 19,159 in 2000, about 6.4 percent of civilian employment in the latter year. In the region, total State employment rises from 5,400 to 7,140 in 1985-2000, about 6.1 percent of civilian employment in 1975 and 3.1 percent in the year 2000.

Local Government: Local government was assumed to be influenced in the future by many of the same factors influencing the rate of growth in State employment. The historic rate from 1965 to 1975 was 10.5 percent (10.1 percent in southcentral), partly a result of development of school systems and the transfer of State-operated rural schools in the unorganized borough to local control. Due to increasing numbers of functions being performed at the local level and rural development in the high case, statewide growth was expected to be faster than in southcentral, where local governments are already well organized. Due to the moving of the State capital and due to local government response to fishing and oil, local government employment was projected to sustain about a 4 percent per year growth rate outside the region and about 3.4 percent within the southcentral region. This meant a statewide increase in local employment from 14,200 in 1975 to 34,900 in 2000. In the low case, since the State capital does not move and State-local transfers are expected to be sharply curtailed after 1985, the assumed rates of growth are about 2 percent until 1985 and about 1 percent thereafter. Total employment in local government goes from 14,200 in 1975 to 20,100 in 2000. Within the region, local government in the high case grows from about 8,100 to about 18,600. In the low case, regional local government employment grows from 8,100 to 11,300.

Miscellaneous Assumptions: In the model, Alaskan wage rates are determined in most industries as a function of Alaskan prices and U.S. average weekly wages in the private economy, deflated by the U.S. Consumer Price Index for Urban Clerical Workers. (Both the latter series are published by the Bureau of Labor Statistics.) Alaskan prices are in turn determined as a function of U.S. prices and local demand conditions, reflected by changes in employment. Finally, migration to Alaska is calculated as a function of the change in employment opportunities and relative per capita income in Alaska, compared to the rest of the country. In order to project a "high" and "low" scenario, the economics Task Force reexamined the assumptions usually used to run the model for impact-assessment purposes in Alaska and concluded that "high" or "low" growth could occur because of movements of the economy outside the State as well as inside the State. In particular, the rates of growth of U.S. disposable personal income per capita (2.0 percent) and wages (1.2 percent) appeared a bit optimistic for the low case. Therefore, in the low case, "pessimistic" forecasts by Data Resources, Inc. were used: 1.0 percent per annum average increase in real wages and 1.77 percent average increase in real disposable personal income per capita. These two changes had little influence.

Government expenditures other than wages and salaries directly influence output in the construction sector. To avoid having to make a series of complex assumptions of doubtful validity concerning government capital spending programs, the Task Force assumed other Government spending increased proportionately to Government employment.

Finally, the Task Force recognized that some of the service, public utilities, and transporation employment in the southcentral area would not be local-serving employment at all. Particularly, employment in these sectors for Alyeska Pipeline Service Company and Beluga coal extraction would be essentially exogenous to the local economy. Consequently, an exogenous component was added for employment in these three sectors to adjust for the employment by Alyeska and by Beluga.

These assumptions are summarized in Table C-8.

Assumptions Used to Estimate Employment and Populations, 2000-2025

The Task Force was charged with estimating total employment and population after the year 2000, but the econometric models' results were doubtful that far in the future. The Task Force instead developed some educated guesses concerning the Alaskan economy in the post-2000 period, and these were used to extrapolate the year 2000 results to 2025.

Basically, the same methodology was used as above. The basic sector employment was projected by individual industry, a relationship between nonbasic and basic employment was assumed, and then a relationship between population and employment assumed and projected.

Basic employmemt was projected as follows: Since there were no significant additional prospects for oil development in southcentral Alaska after 2000, this sector was assumed to stabilize at its year 2000 level, replacing old fields with some additional development. This was true in both cases. Exogenous construction tends to follow oil development, so it, too, was left at its year 2000 level. Federal civilian employment continued to grow to serve the expanding post-2000 population; by 1.2 percent per year in the high case and 0.5-0.6 percent in the low case. State and local government continued to grow at the rates projected for their respective cases from 1975 to 2000, with fairly rapid expansion in the high case, and virtually no expansion in the low case. Agriculture continued to expand after 2000 in the high case, with some significant opening up of lands. There was no post-2000 development in the low case. Since manufacturing of fish products, lumber, wood, and pulp was assumed to fully utilize the available resources (as in the high case), or its growth was restricted by external institutional market factors (as in the low case), the level

TABLE C-8

DEVELOPMENT ASSUMPTIONS

SECTORS	HIGH	LOW
Exogenous Construction Employment	1. Oil treatment and shipment facilities: Gulf of Alaska Kodiak Kenai - Cook Inlet	
	2. Small LNG facilites in: Lower Cook Inlet North Gulf of Alaska	
	3. Beluga coal developed and tranship facility	
	4. State capital built at Willow	
	5. ALPETCO built on Kenai Peninsula	
	6. Pacific LNG built on Kenai Peninsula	Pacific LNG built on Kenai Peninsula
	7. Northwest Gas Pipeline built	Northwest Gas Pipeline built
	8. TAPS expanded	
	9. Facilties developed for Kaparuk and Lisburne at Prudhoe Bay	Facilites developed for Kaparuk and Lisburne at Prudhoe Bay
	10. Major Beaufort Sea oil discovery	Small oil find offshore
	11. Peak employment of 7,000 in 1981 in Southcentral, 14,000 Statewide	Peak employment of 1,800 in Southcentral, 9,500 Statewide

TABLE C-8 (cont)

SECTORS		HIGH	LOW
Agriculture Employment	1.	Major development: 800 man-years by 2000 in Southcentral, 4,600 Statewide, 6,400 by 2025	Zero employment by 1990
Agriculture Value of Output	1.	1958 dollars: 8.5 million in Southcentral by 2000, 51 million Statewide	Amenity only
Forestry Employment	1.	Essentially none	Essentially none
Forestry Value of Output	1.	Negligible increase	Negligible increase
Fishery Employment	1.	No increase in existing fisheries	No increase in existing fisheries
	2.	17,500 increase in bottom fishing Statewide, 8,750 in Southcentral by 2000	No bottom fish development
Fisheries Value of Output	1.	Salmon quadruples by 2000	No increase in salmon
	2.	No increase in shellfish	No increase in shellfish
	3.	Bottom fish: 722 million 1958 dollars Statewide by 2000, 361 million Southcentral	No bottom fish development

TABLE C-8 (cont)

SECTORS		HIGH	LOW
Pulp and Paper Manufacturing Employment	1.	Employment increases by 1.8% per year, to 1,886 by 2000 Statewide	Employment increases by 1.6% per year, to 1,777 by 2000 Statewide
	2.	No employment in Southcentral	No employment in Southcentral
	3.	Value added of $93.6 million by 2000	Value added of $88.2 million by 2000
Pulp and Paper Value of Output	1.	Real output per employee grows at 2.76% Statewide	Real output per employee remains constant
	2.	Employment does not grow in Southcentral	
Outer Manufacturing Employment	1.	Dominated by petroleum industry	Only increase is for Pacific LNG, employing 60 people
	2.	Increases reflect employment by ALPETCO, Pacific LNG, and two small LNG plants	
	3.	Total employment of 2,000	
Other Manufacturing Value of Output	1.	Existing level, plus additons from ALPETCO	Existing level of output

TABLE C-8 (cont)

SECTORS		HIGH	LOW
Lumber and Wood Products Manufacturing Employment	1.	Annual cut by 2000 is 1,260 million board feet	Annual cut by 2000 is 960 million board feet
	2.	No new mills	No new mills
	3.	Statewide rises to 3,834	Statewise rises to 3,280
	4.	Other Southcentral employment increases 2.3% per year	Other Southcentral employment increases 1% per year
	5.	Employment constant in Anchorage	Employment constant in Anchorage
Lumber and Wood Products Value of Output	1.	Real output per employee grows at 1.659% per year	Output per employee does not grow
Food Manufacturing Employment	1.	Fourfold increase in output of salmon fisheries	Existing fisheries stay at existing levels
	2.	Doubling of salmon processing employment	
	3.	Existing fisheries plant employment increases 25%	
	4.	By 2000, 100% replacement of foreign bottomfish effort	No bottomfish development
	5.	3.7 million metric tons/year catch by 2000	

TABLE C-8 (cont)

SECTORS	HIGH	LOW
Food Manufacturing Employment (cont)	6. Total processing employment of 12,000 by 2000	
	7. Short-term (5-month) processing employment of 21,211	
	8. Annual processing employment average of 21,000 by 2000	
	9. Total Alaska shore-based employment of 3,759, 1/2 in Southcentral	
Food Manufacturing Value of Output	1. Existing fisheries value added (1958 $) $145 million by 2000	Growth at 1% per year for total output, $81.5 million per year value added by 2000
	2. Trawl fishery catch rises to 3.7 million metric tons, $722 million, $167 million value added in processing	No enhancement of fisheries output
Mining Oil and Gas Employment	1. Development of Kaparuk River sand and Lisburne formation, 1.785 million barrels/day in 1985	Development of Kaparuk River sands and Lisburne formation
	2. 1.0 billion barrels developed offshore Prudhoe Bay	0.8 billion barrels developed offshore Prudhoe Bay
	3. North Gulf of Alaska: .550 million barrels/day in 1986	No find in North Gulf of Alaska

TABLE C-8 (cont)

SECTORS	HIGH	LOW
Mining Oil and Gas Employment (cont)	4. West Gulf/Kodiak Area: .515 million barrels/day in 1992	No find in West Gulf/Kodiak Area
	5. 1.0 BCF/day gas production in North Gulf of Alaska	No gas production in North Gulf of Alaska
	6. .26 BCF/day gas production in West Gulf/Kodiak Area	No gas production in West Gulf/Kodiak Area
	7. Coal production begins in 1983: 730,000 tons/year by 1984 to feed mine mouth plant; 1,460,000 tons/year by 1986 to feed second plant; 6 million tons/year exports by 1990	No Beluga coal development
	8. 9,000 employed in 1984 Statewide 8,200 employed in 1995 Statewide	7,000 employed in 1984 Statewide 4,800 employed in 2000 Statewide
	9. North Gulf of Alaska: 932,000 barrels of oil per day by 1985, 0.5 billion cubic feet per day in 1987	
	10. 4,800 employed regionwide by 1984, declining thereafter	2,700 employed in 1984 regionwide declines sharply thereafter
	11. 220 employed by Beluga coal by 1990	
Value of Hard Mineral Production	1. Present levels plus output of Beluga coal	Present levels

TABLE C-8 (cont)

SECTORS		HIGH	LOW
Value of Oil and Gas Production	1.	Production is multiplied times estimated wellhead values of $17.00/bbl ($1.80/MCF for gas), new fields only in Southcentral 1/	Production is multiplied times estimated wellhead values of $7.50/bbl (1.40/MCF for gas), new fields only in Southcentral 1/
	2.	Prudhoe and other North Slope production starts at $5.32/bbl and 25¢/MCF in 1977, with oil rising to $29.28 by 2000 1/	Prudhoe and other North Slope production starts at $5.20/bbl and 25¢/MCF in 1977, with oil rising to $29.28 by 2000 1/
Federal Government Employment	1.	Rises at 1.2% per year in Southcentral, 10,857 to 14,500 by 2000	Rises at 0.5% per year in Southcentral, 10,900 to 12,250 by 2000
	2.	Rises at 1% per year outside Southcentral	Rises at 0.5% per year outside Southcentral
Total Local Government Employment	1.	4% growth rate outside the region	2% growth rate until 1985, 1% thereafter
	2.	3.4% growth rate within Southcentral region	
	3.	Statewide increase from 14,200 to 34,900 in 2000	Statewide increase from 14,200 to 20,100 in 2000
	4.	Southcentral region increase from 8,100 to 18,600	Southcentral region increase from 8,100 to 11,300
Total Local and State Government Expenditures	1.	Proportional to increase in wages and salaries of Government workers	Proportional to increase in wages and salaries of Government workers

1/ Estimates are in current dollars incorporating a 5 percent annual rate of inflation.

TABLE C-8 (cont)

SECTORS		HIGH	LOW
Total State Government Employment	1.	2,750 positions transferred from Juneau to Willow, 1982-1984	
	2.	Total employment increases from 14,700 to 38,000 in 2000	Total employment increase from 14,700 to 19,159 in 2000
	3.	Declines from 7.6% of civilian wage and salary employment to about 7.2% by 2000	Declines to 6.4% of civilian employment by 2000
	4.	Southcentral employment increases from 5,400 to 14,900, or from 5.2% to 13.1% of total employment	Southcentral employment rises from 5,400 to 7,140, from 6.1% of civilian employment to 3.1% by 2000
	5.	Statewide rate of employment growth is about 5.4% per year	Before 1985, government employment growth held to 2% per year, with zero growth thereafter
Value of Facilities Oil and Gas Production, Transportation	1.	Based on Dept. of Revenue, Alaska's Oil and Gas Tax Structure, February 1977, Page IV, 23, thru 1985, declined at 5% per year thereafter	Based on Dept. of Revenue, Alaska's Oil and Gas Tax Structure, February 1977, Page IV, 23, thru 1985, declined at 5% per year thereafter
Value of Facilities, Manufacturing	1.	Includes estimated value of LNG and Petrochemical facilities for local property tax	Includes value of Pacific LNG facilities

TABLE C-8 (cont)

SECTORS		HIGH	LOW
Exogenous Transporation and Services Employment	1.	Estimated Alyeska employees in these sectors, plus 40 workers at the Beluga coal transshipment facilities	Alyeska workforce only
Rate of Growth of Disposable Personal Income Per Capita and Wages	1.	Income - 2%	Income - 1.77%
	2.	Wages - 1.2%	Wages - 1.0%

of employment in these industries was held constant at the year 2000 level. Fishing itself was assumed to replace 10 percent of the foreign bottomfishing effort after 2000 by the year 2025 in the low case, but there was assumed to be no change in the traditional fisheries beyond their year 2000 level. In other manufacturing, the year 2000 employment level was sustained, except that nonpetrochemical "other" manufacturing was projected to double after the year 2000 to serve local markets in the high case.

In projecting the nonbasic/basic ratio, somewhat different procedures were used for Anchroage and the rest of the region. In Other Southcentral, the year 2000 regional ratio of nonbasic to basic employment was multiplied times regional basic employment each year out to 2025 and disaggregated, using year 2000 proportions, which permitted proportional growth in the nonbasic sector in each subregion after the year 2000. In the high case, the nonbasic/basic ratio was assumed to converge to the existing 1975 U.S. ratio by 2025, but it was found to be already there by 2000. In Anchorage, it was recognized that much of the "support sector" employment in fact serves statewide needs in transportation, financial services, etc. Therefore, an estimate was made of local-serving nonbasic employment by multiplying the statewide nonbasic/basic ratio by local basic sector employment. The remainder was designated "statewide-serving" nonbasic employment, which was assumed to grow at the same rate as basic employment because Anchorage statewide services in both the basic sector and this part of the nonbasic sector can be assumed to grow in response to similar statewide demands for central offices and general support services. With the Anchorage economy relatively mature by that time, it is more difficult to argue that statewide-serving nonbasic firms would continue to grow faster than their counterparts in the basic industries after 2000 than before 2000.

Finally, civilian non-Native population not employed in exogenous construction was estimated using year 2000 population/employment ratios at the regional level and allocated to subregions using year 2000 proportions. Any assumption other than proportional population growth among subregions after 2000 was judged too difficult to defend, since so little is known about the character of Alaska's economy at that point. To this was added exogenous construction employment (no growth). Native population (2 percent growth per year), and military (no growth).

FORECAST RESULTS

The Level B population forecast for the Anchorage-Cook Inlet subregion was adopted by APA for estimating power requirements without any modification. APA applied projected statewide growth rates to the Fairbanks-Tanana Valley area to develop population forecasts for that region. The resulting population projections upon which the load forecast is based are presented in Table C-9. The figures include national defense personnel. Actual population growth will likely fall within the limits established by the high and low forecasts. The APA population and load forecasts are discussed at length in Section G, Marketability Analysis.

TABLE C-9

POPULATION ESTIMATES

Year	Anchorage-Cook Inlet		Fairbanks-Tanana Valley		Statewide	
	Low	High	Low	High	Low	High
1980	239,200	247,200	60,390	62,020	500,225	513,766
1985	260,900	320,000	68,010	77,350	563,303	640,718
1990	299,200	407,100	74,660	95,370	618,397	790,042
1995	353,000	499,200	82,130	114,360	680,286	947,312
2000	424,400	651,300	89,700	139,760	743,034	1,157,730
2025	491,100	904,000	99,040	179,240	820,369	1,484,784

UTILITY SECTOR

The midrange net generation forecast from 1977 to 1980 was based on the average annual growth rate between 1973 and 1977. This rate was adjusted upward and downward by 20 percent to establish the 1980 high and low forecasts respectively. Beyond 1980, the high and low case net generation is estimated by multiplying forecasted population by projected per capita use. Between 1973 and 1977, per capita use of electricity grew at an annual rate of 3.8 percent in Anchorage and 9.4 percent in Fairbanks. The lower Anchorage growth rate was adopted as the basis of the per capita use trend. Increasing electrification is assumed to be partly offset by increasing effectiveness of conservation programs, resulting in a gradually slower rate of growth in per capita use. The future rate of growth in per capita use was projected to decline as shown in Table C-10.

In order to test the validity of this methodology for estimating per capita power consumption, comparable regions in the Pacific Northwest were examined. The Eugene metropolitan area, Oregon, (population 150,450) as well as the Richland-Kennewick SMSA, Washington, (population 100,100) were selected on the basis of their similarity in population and commercial/industrial characteristics to the railbelt area (i.e., substantial population coupled with relatively little heavy industry).

In the period from 1970-1977 per capita electricity use increased by an average of 5.4 percent and 7.1 percent for Eugene and the Richland-Kennewick SMSA, respectively. This compares to a 3.8 percent per capita growth rate for Anchorage (1973-1977). Furthermore, the power sales anticipated by the utilities which serve Eugene and the Richland-Kennewick SMSA, coupled with the population projections for these two regions, reveal an ever increasing rate of per capita consumption. Clearly, these utilities make little or no provision for energy conservation.

In 1977, per capita use in Eugene and the Richland-Kennewick SMSA was 13,424 kWh and 17,297 kWh, respectively. These current rates meet or exceed the high forecast for Alaska in the 1980-1985 period. Without doubt, Alaska holds a considerable potential for increased electrification.

Pacific Northwest current per capita consumption (excluding aluminum and others that buy at bus bar) is 13,550 kWh/yr.

TABLE C-10

PER CAPITA USE PROJECTIONS

	Low		Mid-Range	High	
Period	Rate (%)	Forecast (KWH/Cap)	Rate (%)	Rate (%)	Forecast (KWH/Cap)
1980-1985	2.5	11,000	3.5	4.5	13,800
1985-1990	2.0	12,400	3.0	3.5	16,300
1990-1995	1.5	13,100	2.5	3.0	18,900
1995-2000	1.0	13,800	2.0	2.5	21,400
2000-2025	0	13,800	1.0	2.0	35,000

With the high and low population forecasts and with high, mid, and low per capita use assumptions, six different net generation forecasts were calculated. From these, the high population-high energy use and the low population-low energy use combinations were used for the high and low range net generation forecasts. The midrange utility sector forecast came from averaging the high population-low energy use and the low population-high energy use forecasts.

The resulting forecasts are shown in Tables C-12 through C-14. Peak load forecasts were calculated from projected net generation using a 50 percent load factor.

NATIONAL DEFENSE SECTOR

The forecast for this relatively minor sector is based on historical data from Army and Air Force installations in the railbelt area. Zero growth is assumed for the midrange forecast. For the high range, growth at 1 percent per year is assumed, while the low range forecast is based on a decline of 1 percent annually (see Tables C-12 through C-14).

SELF-SUPPLIED INDUSTRIES SECTOR

This category of load is comprised of those existing industries that generate their own power, along with all similar type facilities expected to be constructed in the future. It is likely that such industries would purchase power and energy if available at reasonable cost. The specific assumptions for this sector are based on Battelle's March 1978 report entitled Alaskan Electric Power, An Analysis of Future Requirements and Supply Alternatives for the Railbelt Region.

The high range of development includes an existing chemical plant, LNG plant and refinery, along with a new LNG plant, refinery, coal gasification plant, mining and mineral processing plants, timber industry, capital city, and some large energy intensive industry. This set of assumptions coincides with the Level B Study Task Force high case development assumptions with two exceptions. Coal gasification and an energy intensive industry were included by APA because informed judgement indicates their definite potential. Their impact on population and economic activity is relatively minor but their effect on peak load requirements could be substantial.

The University of Alaska and Battelle completed a study entitled Energy Intensive Industries for Alaska in September 1978. The study evaluated a number of energy intensive industries that might be attracted to the State as a consequence of the availability of its large and diversified sources of primary energy. For a number of economic reasons, it was concluded that the availability of energy resources per se would not be sufficient to overcome the higher capital, operating and marketing costs for a world scale primary industry located in the State. However, it was also concluded that of all industries examined, the primary aluminium metal industry appeared to be the most likely to succeed in Alaska. It was further concluded that a large electroprocess industry would have important implications to Alaska's electric power supply planning. The viability of such an industry is contingent upon the availability of low cost hydropower. For these reasons, the development assumptions for the high range case include some large energy intensive industry.

The assumed peak load requirements in the year 2000 are presented in Table C-11. The midrange forecast is the same as the high range except that the large energy intensive industry (aluminium smelter) is excluded. The low range further excludes the new capital city. There is also some reduction of peak load requirements of the mid and low range cases. The resulting forecast is shown on Tables C-12 through C-14.

TABLE C-11

SELF-SUPPLIED INDUSTRY SECTOR ASSUMPTIONS, 2000
(High Range)

Type of Load	Load (MW)
Existing Facilities:	
Chemical Plant	26.0
LNG Plant	0.6
Refinery	2.4
Timber	5.0
New Facilities:	
LNG Plant	17.0
Refinery	15.5
Aluminium Smelter	280.0
Coal Gasification Plant	250.0
Mining and Mineral Processing Plant	50.0
Timber	7.0
New City	30.0
Total Peak Load	683.5

TABLE C-12

TOTAL POWER AND ENERGY REQUIREMENTS

Anchorage-Cook Inlet Area and Fairbanks-Tanana Valley Area Combined

Peak Power

	1977 MW 1/	1980 MW	1985 MW	1990 MW	1995 MW	2000 MW	2025 MW
TOTAL							
High		890	1,671	2,360	3,278	4,645	10,422
Median	650	829	1,162	1,592	2,134	2,852	4,796
Low		769	961	1,177	1,449	1,783	2,146

Annual Energy

	GWH 1/	GWH	GWH	GWH	GWH	GWH	GWH
TOTAL							
High		3,928	7,636	10,684	14,844	20,936	47,054
Median	2,681	3,663	5,133	7,078	9,528	12,738	21,578
Low		3,391	4,256	5,219	6,430	7,890	9,630

1/ Thousand KW = MW
Million KWH = GWH

Source: Alaska Power Administration, Department of Energy

TABLE C-13

ANCHORAGE-COOK INLET AREA POWER AND ENERGY REQUIREMENTS

Peak Power

	1977 MW 1/	1980 MW	1985 MW	1990 MW	1995 MW	2000 MW	2025 MW
UTILITY							
High		620	1,000	1,515	2,150	3,180	7,240
Median	424	570	810	1,115	1,500	2,045	3,370
Low		525	650	820	1,040	1,320	1,520
NATIONAL DEFENSE							
High		31	32	34	36	38	48
Median	41	30	30	30	30	30	30
Low		29	28	26	24	24	18
INDUSTRIAL							
High		32	344	399	541	683	1,615
Median	25	32	64	119	199	278	660
Low		27	59	70	87	104	250
TOTAL							
High		683	1,376	1,948	2,727	3,901	8,903
Median	490	632	904	1,264	1,729	2,353	4,060
Low		581	737	916	1,151	1,448	1,788

Annual Energy

	GWH 1/	GWH	GWH	GWH	GWH	GWH	GWH
UTILITY							
High		2,720	4,390	6,630	9,430	13,920	31,700
Median	1,790	2,500	3,530	4,880	6,570	8,960	14,750
Low		2,300	2,840	3,690	4,560	5,770	6,670
NATIONAL DEFENSE							
High		135	142	149	157	165	211
Median	131	131	131	131	131	131	131
Low		127	121	115	105	104	81
INDUSTRIAL							
High		170	1,810	2,100	2,840	3,590	8,490
Median	70	170	340	630	1,050	1,460	3,470
Low		141	312	370	460	550	1,310
TOTAL							
High		3,025	6,342	8,879	12,427	17,675	40,401
Median	1,991	2,801	4,001	5,641	7,751	10,551	18,351
Low		2,568	3,273	4,075	5,125	6,424	8,061

1/ Thousand KW = MW   Million KWH = GWH

Source: Alaska Power Administration, Department of Energy

TABLE C-14

FAIRBANKS-TANANA VALLEY AREA POWER AND ENERGY REQUIREMENTS

Peak Power

	1977 MW 1/	1980 MW	1985 MW	1990 MW	1995 MW	2000 MW	2025 MW
UTILITY							
High		158	244	358	495	685	1,443
Median	119	150	211	281	358	452	689
Low		142	180	219	258	297	329
NATIONAL DEFENSE							
High		49	51	54	56	59	76
Median	41	47	47	47	47	47	47
Low		46	44	42	40	38	29
TOTAL							
High		207	295	412	551	744	1,519
Median	160	197	258	328	405	499	736
Low		188	224	261	298	335	358

Annual Energy

	GWH 1/	GWH	GWH	GWH	GWH	GWH	GWH
UTILITY							
High		690	1,070	1,570	2,170	3,000	6,320
Median	483	655	925	1,230	1,570	1,980	3,020
Low		620	790	960	1,130	1,300	1,440
NATIONAL DEFENSE							
High		213	224	235	247	260	333
Median	207	207	207	207	207	207	207
Low		203	193	184	175	166	129
TOTAL							
High		903	1,294	1,805	2,417	3,260	6,653
Median	690	862	1,132	1,437	1,777	2,187	3,227
Low		823	983	1,144	1,305	1,466	1,569

1/ Thousand KW = MW   Million KWH = GWH

Source: Alaska Power Administration, Department of Energy

CREDIT FOR ENERGY AND CAPACITY

The amount of project power for which benefit can be claimed depends on both the project's capability and the market requirements. The latter, in turn, is a function of total loads and the mix of available generating resources. The determination of this "usable" energy and capacity from the Susitna project is based on a load/resource analysis conducted by Battelle Pacific Northwest Laboratories for APA.

The load/resource analysis matches forecasted electric power requirements with appropriate generating capacity additions. The computer aided analysis schedules new plant additions, keeps track of older plant retirements, and computes the loading of installed capacity on a year-by-year basis over the period 1978 to 2011.

The analyses are based on the load forecasts and the existing and planned generating resources described in the previous sections. Reserve margins of 25 percent for noninterconnected load centers and 20 percent for the interconnected systems are assumed. The results of the load/resource analysis are in terms of net deliverable capacity and energy after deductions for anticipated transmission losses. The load/resource analysis methodology recognizes construction schedule constraints by not allowing call-up of new generation or transmission capacity that could not be made available. For purposes of this analysis, the following economic facility lifetimes have been assumed:

Type	Years
Coal-fired Thermal Generation	35
Oil-fired Steam Generation	35
Gas-fired Combustion Turbine	20
Oil-fired Combustion Turbine	20
Hydroelectric Generation	50 1/

At the end of its economic life, the facility is retired from service.

Generating plant availability can be expressed in terms of plant utilization factors (PUF's), which are primarily dependent upon plant type and plant age. For new capacity and most types of existing capacity, the following maximum PUF's are assumed:

1/ While the payback period for financial calculations is 50 years, the physical life of a hydroelectric project is typically in excess of 100 years. The effect of this discrepancy is insignificant because there are only 53 MW of hydro capacity.

Type	Maximum PUF
Hydro	0.50
Stream Electric	0.75
Combustion Turbine	0.50
Diesel	0.10

Plants are allowed to run at the maximum PUF from the start, except for new coal-fired steam electric plants which generally experience lower plant utilization in the first few years and also toward the end of their economic lives.

Hydroelectric generation systems, as a result of their storage ability and conservative ratings, can make additional power available for peaking and it is assumed they can be scheduled at 115 percent of design capacity for this service, except during the critical hydraulic period when head limits plant output.

The results of the base case are presented as Exhibit C-1. In those years when Susitna hydropower is available, the total system's surplus capacity in any given year is subtracted from Susitna hydro capability in that year to give the actual amount of Susitna capacity that is usable. The remainder of the Susitna capacity is considered temporarily surplus to the needs of the market area and no capacity benefit is claimed. For instance, refer to Exhibit C-1, Watana POL in 1994 and the midrange load forecast. In 1995-96 (Pages C-1-13 and C-1-14), adding Anchorage and Fairbanks, Watana is on line with 703 MW dependable capacity and 808 MW overload capacity. The combined Anchorage and Fairbanks surplus peak capacity in that year is 543 MW. 1/ Therefore, only 265 MW, or 808 less 543, is usable Susitna capacity. Although no benefits are claimed for the hydro capacity that appears surplus to the needs of the market area, that capacity in actuality would be utilized to generate power. This would result in older thermal generation being placed in a cold reserve status. This, in turn, extends the useful life of these temporarily retired plants and postpones the need for future capacity additions. Though real, the monetary benefits attributable to this postponement of new capaicty are minor and has been ignored in this analysis.

For both the medium and high range load growth cases, additional coal-fired generation would have to be installed after Watana completion

1/ The load resource analysis shows 101 MW surplus in Fairbanks, but this must be adjusted down by 25 MW to account for the 25 MW steam plant that comes on line subsequent to Watana.

but before Devil Canyon power would be available. Unfortunately, due to construction timing requirements, Devil Canyon cannot be advanced in order to postpone the coal-fired addition.

Once the Susitna project's dependable capacity is fully absorbed by increasing peak load requirements, there is the opportunity to capitalize on the hydroelectric projects' capability to produce additional peaking capacity on an intermittent basis. This additional capacity is available when the net power head exceeds the critical head. (The critical head is where rated capacity is available at full gate opening.) The amount of additional capacity increases with head until the full 15 percent overload is reached. This occurs at full gate and average head (where generator output is maximum), which is at about 630 feet for Watana and 545 feet at Devil Canyon, as can be seen on Figure C-2. Figure C-3 shows that the head at Watana exceeds 630 feet about 75 percent of the time. Because the power pool at Devil Canyon is almost never drafted, Devil Canyon head is sufficient to produce 15 percent overload essentially 100 percent of the time.

Since this interruptible capacity cannot be guaranteed, its value is typically less than that for dependable capacity. In keeping with accepted practice, interruptible capacity, when needed to meet peak load requirements, is valued at 50 percent of dependable capacity. 1/ For purposes of benefit calculations, Watana is credited with 15 percent of its at-market dependable capacity, or 103 MW of interruptible capacity. (Since the full amount is available only 75 percent of the time, the figure is adjusted downward to 77 MW.) The comparable figure for Devil Canyon is 100 MW, which brings the combined project's interruptible capacity to 177 MW for benefit calculation.

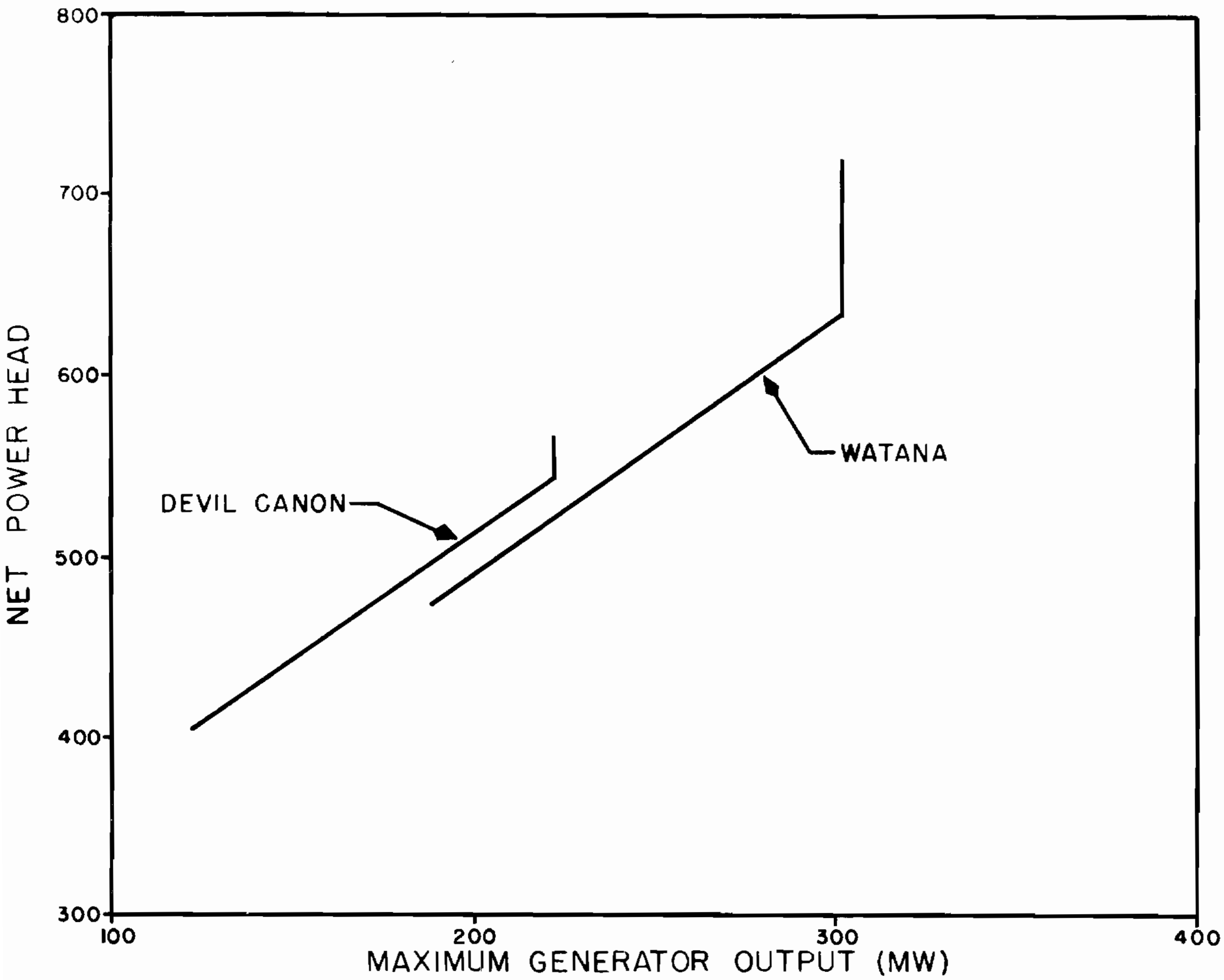
Again referring to the load resource analyses in Exhibit C-1 (Pages C-1-13 through C-1-18), it can be seen that the Susitna project's energy is fully utilized as it becomes available. There is no surplus energy because thermal plant utilization factors are reduced to take advantage of the less expensive hydro energy. Therefore, unlike Susitna capacity benefits which are only claimed through assimilation into the system, all Susitna energy is useful and benefits can be claimed for all of it.

The value of this hydro energy depends upon the type of generation that would otherwise be producing the energy in the absence of the hydroelectric generation. Part of the hydro energy goes to meet the growth in demand for energy over time. In the absence of the hydroelectric project, this load growth would be met by new coal-fired

1/ Department of the Army, Office of the Chief of Engineers, Digest of Water Resources Policies, p. A-129.

Figure C-2

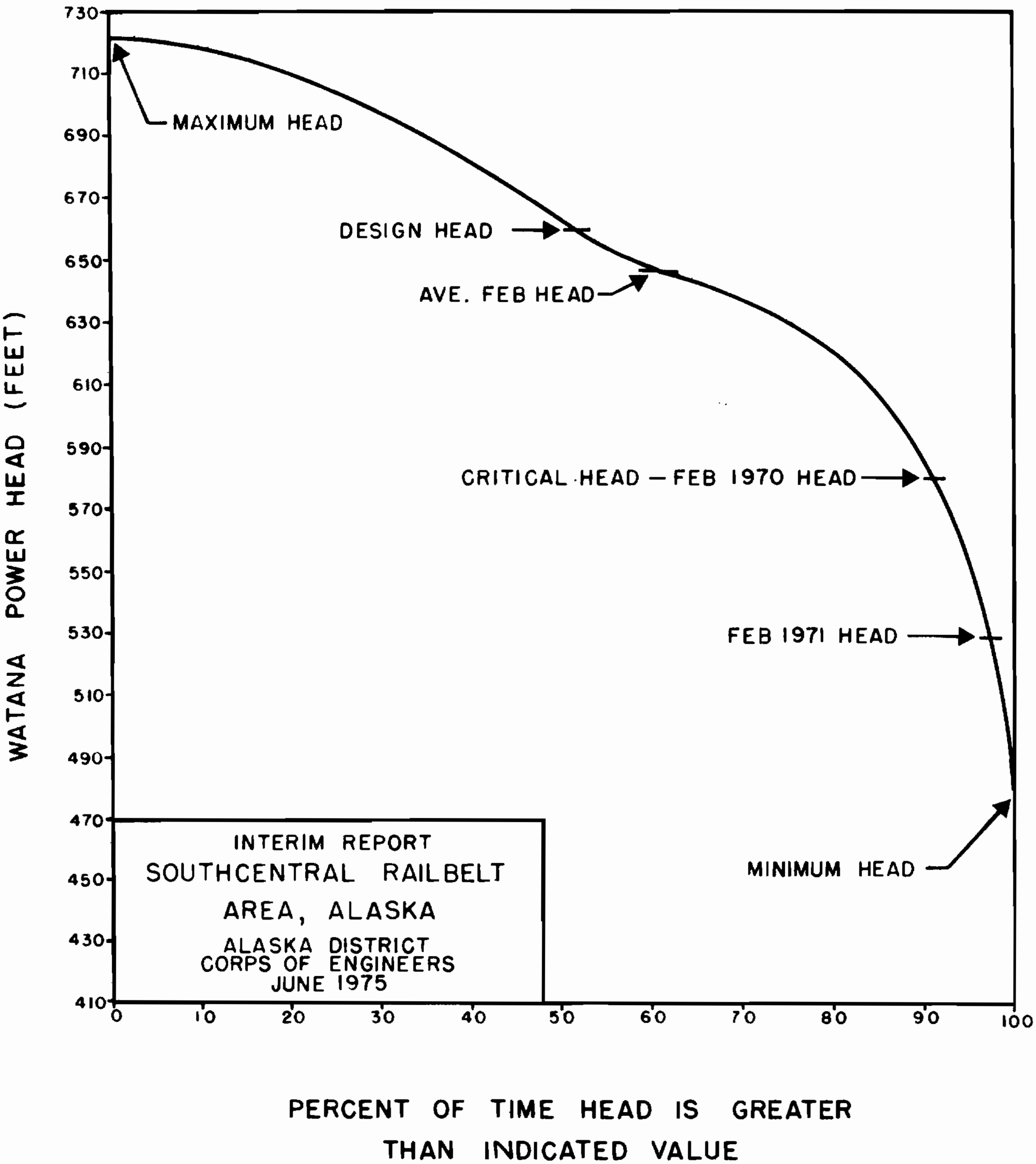
DEVIL CANYON AND WATANA
UNIT MAXIMUM PERFORMANCES



INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

Figure C-3

ANNUAL HEAD DURATION CURVE
WATANA RESERVOIR



generation, and the value of this portion of the hydro energy is therefore the cost of coal-fired energy. The remainder of the hydro energy displaces more costly thermal generation. While the existing thermal plants continue to provide peak load capacity, the utilization of the plants decline. This displaced energy is comprised of several types of generation: coal-fired steam, oil-fired and gas-fired plants, and diesel plants, each having its unique energy cost. The value of the hydro energy produced in any year, then, is a composite value determined by the relative shares of generation type that would be producing energy in the absence of the hydro.

The load-resource analysis shows that the great majority of the displaced generation is coal-fired, since the plant utilization factors of the diesel, gas, and oil-fired plants were already reduced prior to Susitna hydropower availability. This results in a composite energy value that, in the most extreme year, is only 5 percent greater than the coal-fired energy value. Within 12 years after power-on-line, all Susitna energy goes toward meeting load growth and is therefore valued entirely at the coal-fired value. Because the effect on project justification is so minor over the 100-year economic life, the benefit of the hydro energy has been calculated using the coal-fired energy value, not the slightly higher composite energy value.

The usable capacity and energy for the midrange forecast with interconnection in 1991, Watana power-on-line in 1994 followed by Devil Canyon in 1998 is presented in Table C-15 and is portrayed graphically on Figures C-4 and C-5. The usable capacity analysis results for the various cases analyzed appear as Exhibit C-3 and are presented graphically in Exhibit C-2. Shown are cases for the low and high-range load forecasts, as well as for delayed power-on-line dates.

TABLE C-15

USABLE CAPACITY AND ENERGY, BASE CASE

Year	Dependable Capacity (MW)	Interruptible Capacity (MW)	Prime Energy	Secondary Energy
1994 *	27	0	2,997	0 **
1995	265	0	3,058	397
1996	680	0	3,058	397
1997	680	0	3,058	397
1998 #	950	0	6,057	397 **
1999	1,035	0	6,057	785
2000	1,231	0	6,057	785
2001	1,347	1	6,057	785
2002 ##	1,347	177	6,057	785

* Watana power-on-line with interconnection.
** Less than full energy availabe due to reservoir filling.
\# Devil Canyon power-on-line.
\## Full utilization of Susitna power.

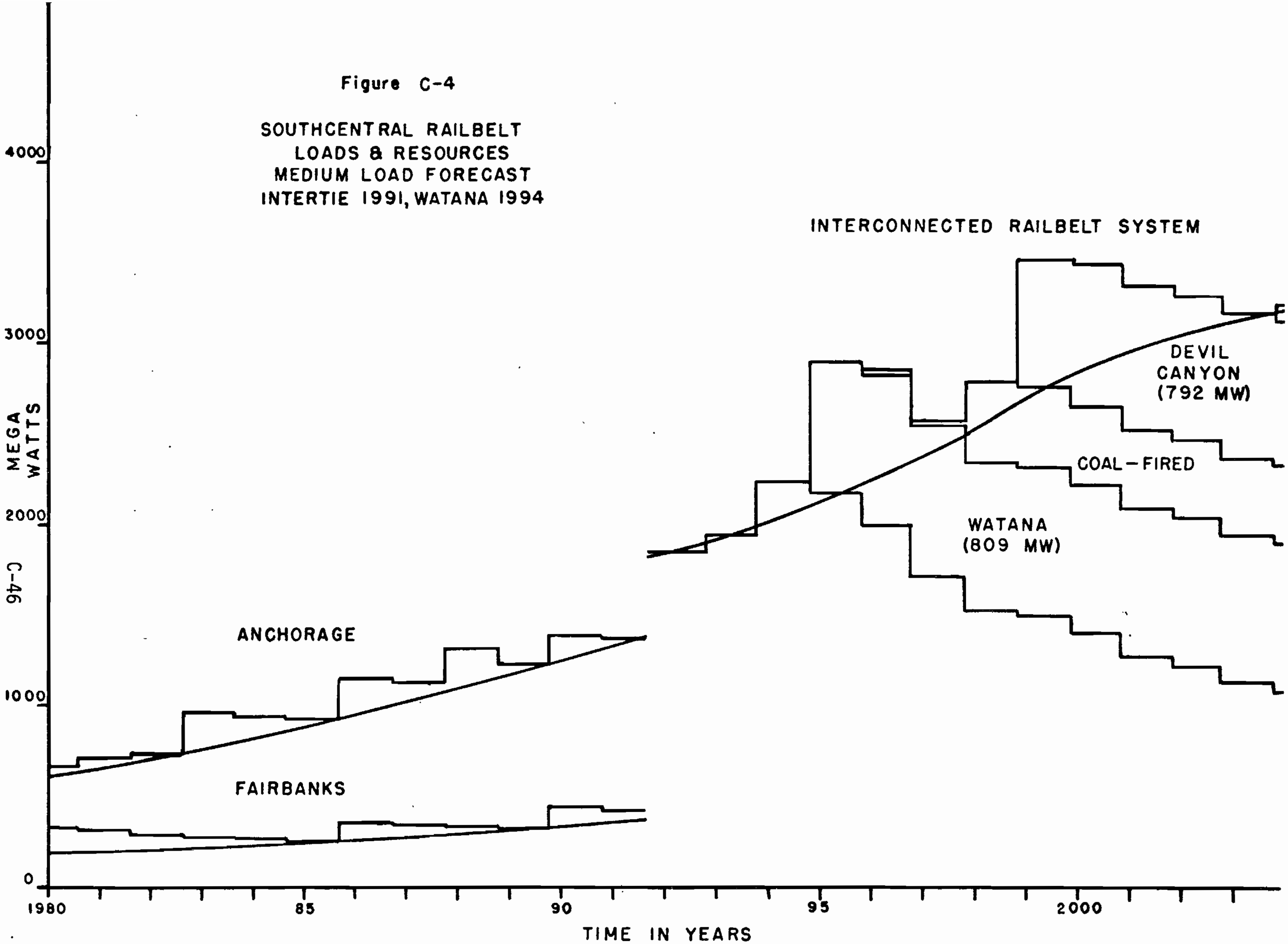


Figure C-4

SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
MEDIUM LOAD FORECAST
INTERTIE 1991, WATANA 1994

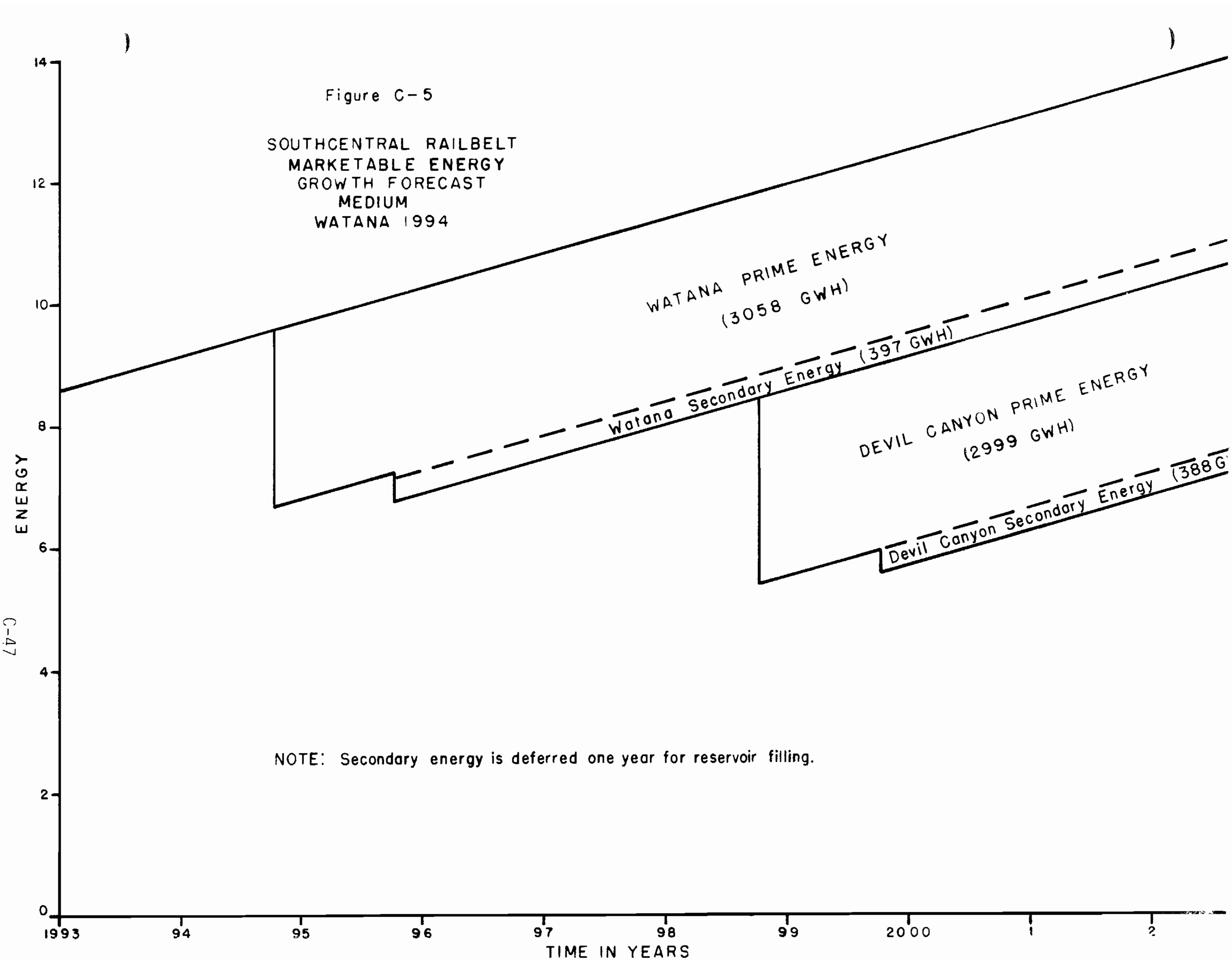


Figure C-5
SOUTHCENTRAL RAILBELT
MARKETABLE ENERGY
GROWTH FORECAST
MEDIUM
WATANA 1994
WATANA PRIME ENERGY
(3058 GWH)
Watana Secondary Energy (397 GWH)
DEVIL CANYON PRIME ENERGY
(2999 GWH)
Devil Canyon Secondary Energy (388 G
NOTE: Secondary energy is deferred one year for reservoir filling.
ENERGY
14
12
10
8
6
4
2
0
1993
94
95
96
97
98
99
2000
1
2
TIME IN YEARS

POWER CAPABILITIES

The installed capacities at Devil Canyon and Watana reservoirs were selected based upon the project firm annual energy produced in a 28-year period of historical streamflow (1950-1977). This period included three new years of streamflow, in addition to the 25 years used in the original scoping analysis prepared in 1975. An updated seasonal load curve prepared by APA was used in the new simulated operation study.

The addition of the 3-year period of recorded streamflows resulted in changes to the average annual and firm annual energy capability amounting to less than 2 percent. The annual runoff for the 3-year period is 96 percent of the long-term average. Therefore, no adjustment in the original energy capabilities is considered necessary. The power generating capabilities for the project are given in Table C-16.

TABLE C-16

AT-SITE POWER CAPABILITIES

	Devil Canyon	Watana	Total
Installed Capacity, MW	689	703	1,392
Peaking Capacity, MW	792	809	1,601
Dependable Capacity, MW	689	703	1,392
Average Annual Energy, 10^3 MWh	3,410	3,480	6,890
Firm Annual Energy, 10^3 MWh	3,020	3,080	6,100
Secondary Energy, 10^3 MWh	390	400	790
Average Annual Spilled Energy, 10^3 MWh	31	44	75
Plant Factor - Percent 1/	50	50	50

1/ Based on firm annual energy.

The driest year of record was 1969, which was estimated to have a 1,000 year return period based upon a Log Pearson Type III probability distribution, with an average annual runoff at Devil Canyon of 5,600 cubic feet per second, or 59 percent of average. The second driest year of record (1950) had a return period of 20 years with an average annual runoff of 7,340 cubic feet per second. The 100-year average annual low flow is estimated to be 6,500 cubic feet per second or 68 percent of average. The 10 month period immediately following the 100-year low flow would likely be the most critical power period to be encountered in the life of the project.

The project dependable capacity is based upon the firm annual energy and is equal to the installed capacity. The project firm annual energy using the 28-year record of historical flows occurred in 1971. During May of that year total project storage was reduced to its lowest level of the entire period (230,000 acre-feet or 3 percent of usable storage). The annual energy produced by the project in 1971 was approximately 6,100,000 megawatt hours.

The maximum peaking capacity for both powerplants is 115 percent of installed or rated capacity at 0.9 power factor. This 15 percent overload capability was assumed to be available only at or near maximum head on each unit for routing purposes.

The large storage capacity of Watana reservoir provides nearly full river control. Spills occurred in 8 of the 28 years of record and were only about 1 percent of the average annual project energy.

The transmission losses have been estimated by APA to be 3.2 percent on-peak and 0.7 percent for the long-term average. The at-market power capabilities are shown in Table C-17.

TABLE C-17

AT-MARKET POWER CAPABILITY

	At-Site	Losses	At-Market
Installed Capacity, MW	1,392	45	1,347
Peaking Capacity, MW	1,601	51	1,550
Dependable Capacity, MW	1,392	45	1,347
Average Annual Energy, 10^3 MWh	6,890	48	6,842
Firm Annual Energy, 10^3 MWh	6,100	43	6,057
Secondary Energy, 10^3 MWh	790	6	784

SEASONAL RESERVOIR OPERATION

The 1978 update of the simulated operation study did not result in any substantial revisions to the overall pattern of project operation. The general criterion as before was to maintain Devil Canyon reservoir at maximum pool to realize the greatest possible head on that reservoir. During the winter, withdrawals were made from Watana storage to meet the system power demand. Devil Canyon storage was used only after the supply in Watana reservoir was exhausted.

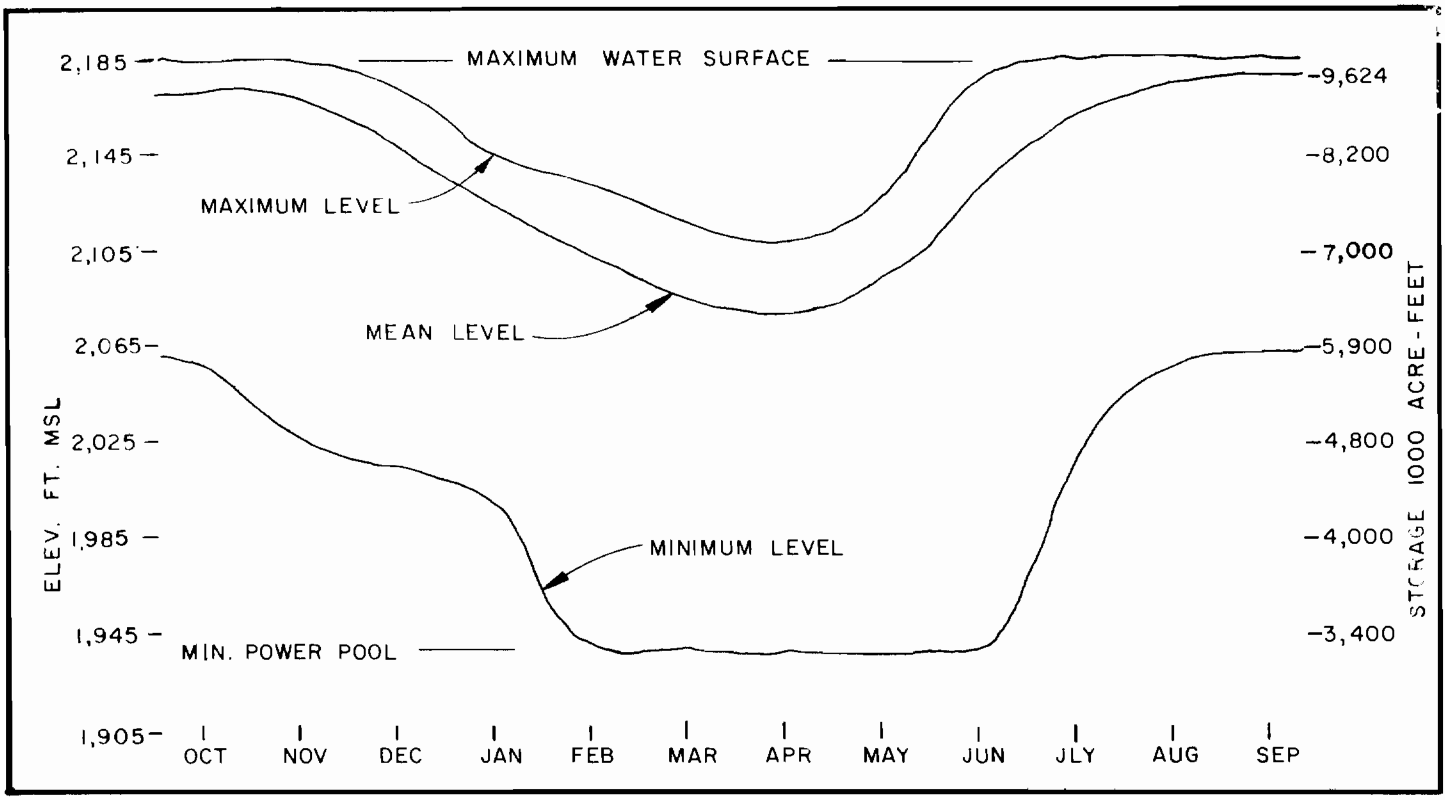
The general characteristics of the Watana operation are shown in Figure C-6. The pool elevations shown have been adjusted in accordance with the topographic information obtained in the 1978 field surveys at the Watana damsite. In years of average streamflow the maximum drawdown on Watana reservoir was about 100 feet. The reservoir reached minimum active pool (elevation 1,940 feet) on only two occasions in the 28-year period.

In the simulated operation, one criteria was to fill Watana reservoir on September 30 each year. This was not possible, however, in 13 of 28 years of record. In such years of reduced streamflow, it proved to be inefficient to draw the Watana pool to a low level on September 30 in order to meet the system load requirement. If the reservoir was consistently drawn below elevation 2,100 feet (storage = 6,700,000 acre-feet) on September 30 each year, the resulting head loss was of such magnitude that the project was unable to recover sufficiently to meet minimum system load requirements, even in years with above average runoff. The minimum September 30 carry-over for Watana reservoir was therefore set at 6,700,000 acre-feet for the updated 1978 simulated operation studies. The generation and water storage levels for Devil Canyon and Watana reservoirs for the entire 28-year period of record are shown on Plates C-1 and C-2.

The spring and summer filling operation for Watana reservoir in the operation studies was guided only by a fixed flood control rule curve. In later scoping studies this operation could be improved somewhat through the use of a variable rule curve based upon both 7-day and seasonal volume forecasts.

In the simulated operation, only the releases necessary for minimum generation requirements were made until the month when the reservoir would fill or encroach the flood space. Only during that month could the excess runoff be used to generate secondary energy. The method of operation results in unnecessary spillage of water.

In order to obtain a more realistic estimate of the spill frequency at Watana reservoir, a separate study was conducted. In this study the daily inflow to Watana reservoir was estimated using the records from the stream gage at Gold Creek. It was assumed that the full hydraulic capability of the Watana turbines could be used for 15 days in advance of the spills observed in the other simulation study. In addition, for 5 days in advance of the spills, the outlet tunnel with discharge capacity of 30,000 cfs was used to maintain the pool below



NOTE: DATA FROM OPERATIONAL STUDY OF AVERAGE MONTHLY STREAMFLOW FOR PERIOD OF RECORD 1950-1977 WITH JAN 1976 SELECTED PROJECT PLAN.

Figure C—6

OPERATING LEVELS

WATANA RESERVOIR

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

OCTOBER 1978

the crest of the spillway as much as possible. When the inflows exceeded the discharge capacity of both the powerplant and the outlet works and the reservoir reached full pool, the spillway, of course, had to be used.

The results of the study are shown in Figure C-7. The curve on the right indicates the frequency of spills if the outlet tunnel is not used; the curve on the left assumes both the powerplant and the outlet tunnel are used. The curve illustrates that the spillway at Watana reservoir would be used approximately once in 10 years.

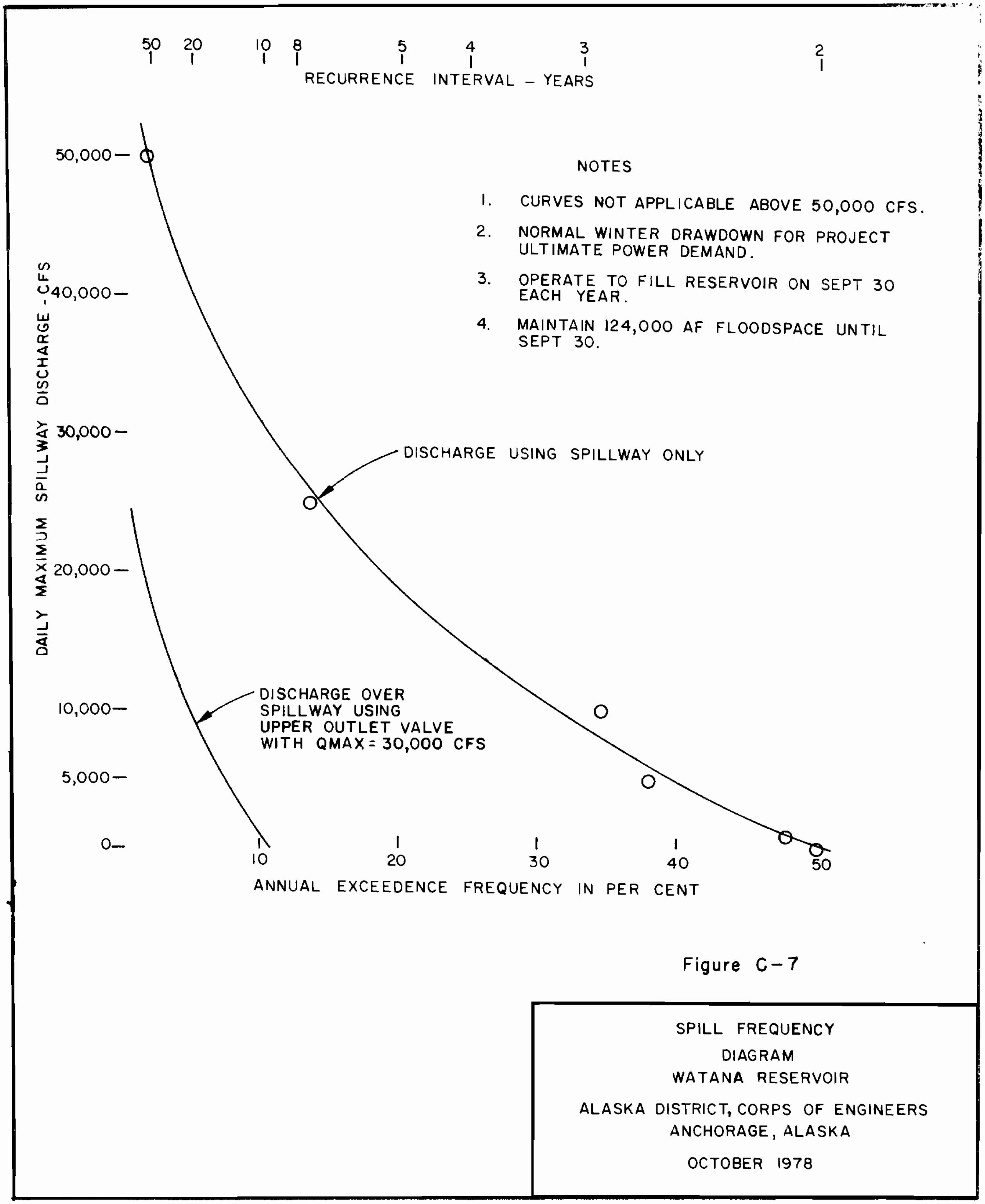

50
20
10
8
5
4
3
2
RECURRENCE INTERVAL - YEARS
NOTES
1. CURVES NOT APPLICABLE ABOVE 50,000 CFS.
2. NORMAL WINTER DRAWDOWN FOR PROJECT ULTIMATE POWER DEMAND.
3. OPERATE TO FILL RESERVOIR ON SEPT 30 EACH YEAR.
4. MAINTAIN 124,000 AF FLOODSPACE UNTIL SEPT 30.
DAILY MAXIMUM SPILLWAY DISCHARGE - CFS
50,000
40,000
30,000
20,000
10,000
5,000
0
DISCHARGE USING SPILLWAY ONLY
DISCHARGE OVER SPILLWAY USING UPPER OUTLET VALVE WITH QMAX = 30,000 CFS
10
20
30
40
50
ANNUAL EXCEEDENCE FREQUENCY IN PER CENT
SPILL FREQUENCY DIAGRAM
WATANA RESERVOIR
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
OCTOBER 1978

Figure C-7

ECONOMIC ANALYSIS

COSTS - THE BASE CASE

A detailed construction cost estimate for Watana, Devil Canyon, and the connecting transmission systems is presented in Section B, Project Description and Cost Estimates. It is expected that construction will begin in 1984, the transmission intertie would be complete in 1991, Watana would be complete in 1994, and Devil Canyon would be complete in 1998. Total estimated first cost of Devil Canyon and Watana plus the transmission system is $2.588 billion.

Interest During Construction (IDC)

The interest charged on money expended during the construction period is considered an additional cost of the construction phase. Simple interest is calculated at 6-7/8 percent for each year's expenditure and added to first cost to establish the investment cost.

System Annual Costs

Expenditures and IDC made after the October 1994 POL date of Watana are discounted to 1994. The resultant total investment cost is then transformed into an equivalent average annual fixed cost by applying the appropriate capital recovery factor associated with the 6-7/8 percent interest rate and 100-year project life.

Annual Operations, Maintenance, and Replacement

Operations, maintenance, and replacement costs estimated by APA are added to the average annual costs to obtain a total average annual cost of $228 million. See Table C-18.

HYDROPOWER BENEFITS

Power Values and Alternative Costs

The power values and alternative costs for use in power benefit calculations were developed by the San Francisco Regional Office of the Federal Energy Regulatory Commission (FERC), an agency of the Department of Energy. A copy of the letter forwarding the power values is included in Exhibit C-7. The method of analysis used by the FERC staff in developing the power values is explained in Hydroelectric Power Evaluation, by the Federal Power Commission (FPC), dated March 1968. The calculations were based on a 50 percent plant factor for the upper Susitna basin projects. Based on future load estimates, FERC

TABLE C-18

ANNUAL COST COMPUTATIONS
(in thousands of dollars)

	Watana			Devil Canyon Gravity Dam				
Year	Expenditure	Accumulated Expenditure	IDC	Expenditure	Present Worth of Expenditure	Accumulated Expenditure	IDC	Present Worth of IDC
1984	30,500		1,048					
1985	107,000	30,500	5,775					
1986	114,000	137,500	13,372					
1987	159,000	251,500	22,756					
1988	218,500	410,500	35,733					
1989	214,000	629,000	50,600					
1990	248,000	843,000	66,481					
1991	258,000	1,091,000	83,875					
1992	223,000	1,349,000	100,409	39,000	39,000		1,341	1,341
1993	161,000	1,572,000	113,609	98,500	98,500	39,000	6,067	6,067
1994	32,000	1,733,000	120,244	117,000	117,000	137,500	13,475	13,475
1995	1,765,000	1,765,000	613,902	137,000	128,187	254,500	23,581	22,064
1996				144,000	126,070	391,500	38,191	33,436
1997				158,000	129,428	535,500	43,622	35,734
1998				129,500	99,258	693,500	53,505	41,010
				823,000	737,443	823,000	179,782	153,127

	Watana	Devil Canyon	Total Watana & Devil Canyon
Construction Cost	$1,765,000	$737,443	$2,502,443
I.D.C.	613,902	153,127	767,029
Investment Cost	$2,378,902	$890,570	$3,269,472
Interest and Amortization	$ 163,761	$ 61,307	$ 225,068
Operation, Maintenance, and Replacement	2,620	700	3,320
Average Annual Cost	$ 166,381	$ 62,007	$ 228,388

assumed that the output of the proposed hydropower project would be utilized between the two major railbelt area load centers in the ratio of 80 percent to Anchorage-Kenai and 20 percent to Fairbanks-Tanana Valley.

Power values are provided for two generation alternatives at each of the load centers. An oil-fired combined cycle plant located near Anchorage and a mine-mouth coal-fired steam-electric generating plant located near the Beluga coal fields are considered as alternatives to hydropower for the Anchorage-Kenai area. For the Fairbanks load center, an oil-fired regenerative combustion turbine plant near Fairbanks and a mine-mouth coal-fired steam-electric plant near Healy are suggested as the proper alternative power sources. FERC notes that the agency is unable to state that either is the most probable source, despite the oil-fired alternatives appearing less expensive.

Whereas in 1975 FPC presented gas-fired generation as a possible alternative, it is no longer considered a viable option because of national policy and, specifically, the National Energy Act.

The Anchorage area coal-fired power values are based on a two unit, 450 MW plant with a service life of 30 years. The heat rate is 10,000 BTU/kwh and the annual plant factor is 55 percent. The investment cost estimate is $1,240 per kilowatt, while the cost of fuel is estimated at $1.10 per million BTU. Included in the estimate are baghouse filters and SO_2 scrubbers at $187 per kilowatt and cooling towers at $35 per kW. These are July 1978 costs, and neither inflation nor fuel cost escalation are considered.

The coal-fired alternative at Fairbanks is a two unit 230 MW plant, also with a 30 year service life. Its heat rate is 10,500 BTU/Kwh and has a 55 percent plant factor. The estimated investment cost is $1,475 per kilowatt and the fuel cost is assumed to be $.80 per million BTU. Included in this estimate are electrostatic precipitators and SO_2 scrubbers at $357 per kW and cooling towers at $44 per kW. Again, these are the costs as of July 1978.

Financing for the Anchorage alternative is a combination of 75 percent REA and 25 percent municipal. In Fairbanks, the assumption is that financing would be provided by the Alaska Power Authority.

The composite capacity value of the coal-fired alternative is $186.58 per kilowatt-year. The corresponding energy value is 12.76 mills per kWh. This and other sets of power values are shown in more detail in Exhibit C-4.

Natural Gas Alternative

In not providing power values for a gas-fired thermal alternative, FERC indicates its agreement with APA and the Corps of Engineers that natural gas is not an appropriate long-term alternative to hydropower in the Anchorage area. This is in keeping with the National Energy Act which prohibits such use in base-load plants with very limited exception.

The strongest argument against the use of natural gas for electrical generation is the national energy policy, but limited Cook Inlet supplies offer additional rationale. Since the Office of Management and Budget specifically commented on the Cook Inlet gas supply situation, updated information has been gathered.

The estimated Cook Inlet natural gas balance through the year 2000 is presented in Table C-19. The reserve estimates are based on an analysis entitled "Estimated Recoverable Gas Reserves from Gas Fields in the Cook Inlet Area" by the State Division of Oil and Gas Conservation, April 13, 1978. Division analysts believe that more detailed study would likely result in as much as a 20 percent increase in the estimate for three fields. 1/ This correction would result in an increase of 436 BCF over the 13 April 1978 estimate of 3,776 BCF. Not included in the Division's estimate are approximately 216 BCF of Kenai Field gas that has been leased for reservoir pressure maintenance. This gas will be returned in future years and will be available for sale. The adjusted estimate of recoverable Cook Inlet gas reserves is therefore 4,428 BCF. The Alaska Division of Mineral and Energy Management estimates potential additional resources of about 7 trillion cubic feet; such estimates are speculative with little agreement among experts.

Approximately 3,698 BCF, or 84 percent of those reserves are presently committed to Alaskan and export uses. Table C-20 presents the estimated reserves and commitments by field. The Pacific Alaska LNG contracts, amounting to 952 BCF, have lapsed as a result of failure to gain FERC approval of the project. The approval has been delayed largely due to the PALNG's inability to gain gas committments sufficient to operate at required scale. PALNG continues to explore for gas in Cook Inlet and eventual FERC approval is anticipated. PALNG expects the lapsed contracts to be readily reinstated with an extended deadline for project approval and some renegotiation of price. The PALNG lapsed contracts are therefore considered committments for this analysis.

1/ Conversation with staff of the Division of Oil and Gas Conservation, 27 September 1978.

There has been an unwillingness on the part of natural gas owners to enter into contracts for the provision of gas during a period of rapidly escalating gas prices and great uncertainty regarding gas price deregulation. Additional commitments are anticipated as the pricing structure stabilizes.

In 1976, 34 percent of Alaska's total energy consumption was provided by Cook Inlet natural gas. The uses are detailed in Table C-21. In the same year, 54 percent of Alaska's electrical generation was provided by Cook Inlet gas. Natural gas is exported in large quantities in the form of both LNG (liquified natural gas) and ammonia-urea fertilizer. Comparing consumption in 1976 with the previous year, natural gas use was up 12 percent with the largest increase, 18 percent, in electricity generation.

Projections of natural gas consumption levels between 1980 and 2000 were developed in a study for the Alaska Royalty Oil and Gas Development Advisory Board and the 1978 Alaska State Legislature. The report, published in January 1978, is entitled Oil and Gas Consumption in Alaska, 1976-2000. A base case projection of gas demands is presented and possible departures from the base case are analyzed. Over the entire period, natural gas use is forecasted to grow at 2 percent annually. This low rate is attributable to the base case assumptions of prohibition on the use of gas in new electricity generating facilities in the mid-1980's and only moderate increases in industrial use. As a result, use of gas in 1980 is 238 billion cubic feet, up from 165 BCF in 1976. By 2000 its has risen to 267 BCF, reflecting the fact that most of the growth in natural gas consumption is assumed to occur in the near term and in the industrial sector.

The forecast shows gas use in space heating to be the most rapidly growing demand throughout the period at 5 percent. Gas use in electricity generation remains essentially constant, while industrial use of gas rises sharply in the near future, but further increases are assumed to be zero because of supply constraints. The base case assumes population growth of about 3 percent annually, per capita demand somewhat moderated by high energy prices, and no significant new industrial consumers of large amounts of gas.

The sensitivity of the projection to changes in several of the assumptions was tested. All resulted in increased demand relative to the base case. Two of the possible scenarios are of special interest and appear in Table C-19.

One possibility is the continued use of gas in new electricity generating units in Anchorage after the mid-1980's. By 1990 this would add about 23 BCF annually to gas demands for electric power, essentially doubling gas use by that sector. This would add 10 percent to total gas requirements in that year and increase the overall growth rate in gas consumption from 2 percent up to 3 percent for the projection period.

The active proposal to liquify Cook Inlet natural gas for transport to California is a second scenario of interest. As noted earlier, required FERC approvals have yet to be given, but PALNG continues to actively explore for additional Cook Inlet gas and to plan for construction of facilities beginning in 1980. This proposal would require about 80 BCF annually in its initial phase. Were adequate reserves available, this would be essentially doubled to 161.6 BCF annually. Over a period of 15 years (assuming a start in 1985) such a project would thus require from 1,200 to 2,424 BCF of Cook Inlet gas.

Another source of Cook Inlet gas demand forecasts is Natural Gas Demand and Supply to the Year 2000 in the Cook Inlet Basin of South Central Alaska, a November 1977 report compiled by the Stanford Research Institute (SRI) for Pacific Alaska LNG Company. The SRI forecast is somewhat higher than that previously discussed. This difference is accounted for primarily in the industrial component, where SRI does not limit growth as was done in the 1978 base case forecast to accommodate anticipated supply constraints. The SRI intermediate forecast is presented along with the other three scenarios in Table C-19.

Summing the annual estimates of Cook Inlet demand requirements from 1976 to 2000 results in total estimated requirements of 5,211 BCF in the base case. The addition of Pacific Alaska LNG increases the forecast to 6,411 BCF or 7,635 BCF depending on the scope of the operation. The addition to the base case of new gas-fired electrical generation increases the forecast to 5,743 BCF. The SRI intermediate forecast of total demand over the period is 8,232 BCF, which includes full scale PALNG, but no new gas-fired generation.

Estimated proven Cook Inlet gas reserves are inadequate to meet the requirements in all forecasted cases. The deficit through the year 2000 varies from a low of 783 BCF in the base case to 3,804 BCF in the SRI intermediate forecast (see Table C-19). The use of Cook Inlet gas for new gas-fired electrical generation after 1985 would increase the year 2000 deficit by about 532 BCF.

There may or may not be sufficient undiscovered gas reserves in the Cook Inlet area to meet the anticipated deficit. Estimates of undiscovered reserves range from 6-29 trillion cubic feet. Because the Cook Inlet gas supply has historically far exceeded local demand and because

TABLE C-19

COOK INLET NATURAL GAS BALANCE
1977 to 2000 1/
(Billion Cubic Feet)

	Base Case	LNG to California (80 BCF/161 BCF Annually)	New Gas Generation in Anchorage (79 BCF Annually in 2000)	SRI Intermediate Case
Demand				
(A) Estimated Requirements	5,211	6,411/7,635 2/	5,743 3/	8,232 4/
(B) Committed Reserve 5/	3,698	3,698	3,698	3,698
(C) Remaining Requirements 6/	1,513	2,713/3,937	2,105	4,534
Supply				
(D) Estimated Recoverable Reserves 7/	4,428	4,428	4,428	4,428
(E) Uncommitted Reserves 8/	730	730	730	730
(F) Undiscovered Reserves 9/	?	?	?	?
Balance				
(G) Deficit (Not Including Possible Undiscovered Reserves) 10/	783	1,983/3,207	1,375	3,804

NOTES TO TABLE C-19:

1/ Based on "Oil and Gas Consumption in Alaska, 1976-2000," January 1978 by the Division of Energy and Power Development and the Division of Minerals and Energy Management, Table IV.1, with modifications explained below.

2/ Base case requirements plus additional LNG export from 1985 to 2000 of either 80 BCF annually or 161 BCF annually.

3/ Gas use in new gas-fired electrical generation increases from zero in 1985 to 79 BCF annually in 2000.

4/ Intermediate case without additional gas-fired electrical generation from "Natural Gas Demand and Supply to the Year 2000 in the Cook Inlet Basin of southcentral Alaska," November 1977 by the Stanford Research Institute for Pacific Alaska LNG Company, Table II.

5/ See Table 2.

6/ (C) = (A) - (B)

7/ See Table 2.

8/ (E) = (D) - (B)

9/ Estimates range from 6 to 29 trillion cubic feet but are too speculative for purposes of power planning.

10/ (G) = (A) - (D) or (C) - (E)

TABLE C-20

COOK INLET NATURAL GAS RESERVES AND COMMITTMENTS

Field	Source 1/	Committed (BCF)	Total Reserves 2/ (BCF)
Beaver Creek	PALNG	112	239
Beluga River	DOGC, PALNG	1,003	1,057
Birch Hill			11
Falls Creek			13
Ivan River	PALNG	101	101
Kenai	DOGC	1,708	1,785 3/ 4/
Lewis River	PALNG	22	90
McArthur River	DOGC, PALNG	87	140 3/
Nicolai Creek			17
North Cook Inlet	DOGC	666	912 3/
North Fork			12
Sterling			23
Swanson River			0
West Forelands			20
West Fork			8
TOTAL		3,698	4,428

NOTES:

1/ DOGC is short for "Summary of Gas Sales Contracts, Cook Inlet Area, March 15, 1976" by the Division of Oil and Gas Conservation. PALNG refers to data provided by Len McLean of Pacific Alaska LNG Company in an interview on 4 October 1978.

2/ The total reserve estimates are taken from "Estimated Recoverable Gas Reserves from Gas Fields in the Cook Inlet Area," April 13, 1978 by the State Division of Oil and Gas Conservation. The report was augmented by information provided by Lonnie Smith, Chief Petroleum Engineer, DOGC, in an interview on 28 September 1978.

3/ Includes a 20 percent increase over estimate contained in April 13, 1978 DOGC report on the basis of new information available to DOGC.

4/ Includes 216 BCF leased for reservoir pressure maintenance that was not included in the DOGC report.

TABLE C-21

1976 ALASKA GAS USE 1/

Use	Quantity (MMCF)
Final Consumption (Heating)	16,804
Electrical Generation	29,284
Extraction and Processing Uses	137,880 2/
Exports	87,765 3/
TOTAL	271,733

NOTES:

1/ Source is "Oil and Gas Consumption in Alaska, 1976-2000," January 1978.

2/ 26,798 MMCF production related; 111,082 MMCF reinjected, much of which can be eventually recovered.

3/ 63,509 MMCF for LNG; 24,256 MMCF for ammonia-urea.

until recently there has been no substantial export market, the Cook Inlet area has not yet been extensively explored for natural gas. Despite the possibilities, the speculative reserves are inappropriate for consideration in power planning. Regardless of availability, however, the worldwide competition for natural gas will escalate the price of gas to levels which will likely make new gas-fired base load generation uneconomic in the face of large available supplies of coal and hydropower potential.

Oil-Fired Generation Alternative

As noted previously, FERC provided power values based on both oil-fired and coal-fired generation for both Anchorage and Fairbanks. The National Energy Act generally prohibits the use of oil as fuel in new large-scale base load generating plants. The act also includes, however, several provisions under which a utility may be exempted from the restrictions on use of oil. Under the law, companies may be exempted from the fuel-switching requirement for new plants if they can prove it would be overly costly, environmentally unsound, or impossible because of insufficient or unavailable supplies of coal or other fuels at the plant's location.

Proposed regulations to implement the coal-conversion portion of the energy bill have been issued by the Department of Energy. 1/ To gain an exemption on cost grounds, for instance, a company would have to prove that a coal or alternate fuel plant was much more expensive than the oil or gas plant. Under the proposed rules, coal plants costing 30 to 80 percent more than oil or gas plants would not necessarily be considered too costly to avoid mandatory conversion. Based on the FERC-provided power values, annual costs for coal-fired generation are approximately 40 percent higher than for oil-fired. This is based on a 50 percent plant utilization factor and includes capital expenses as well as the costs for operation and fuels.

To gain an environmental exemption under the proposed rules, companies would be required to produce decisions from the Environmental Protection Agency or State agencies proving that coal plants would be environmentally unacceptable. Although some proposed plant sites in Alaska are extremely sensitive, such as at Healy adjacent to Mt. McKinley Park, there is no evidence that acceptable sites cannot be found.

To gain an exemption based on fuel availability at a plant's location, a utility would have to show it fully considered a range of alternative sites, including sites outside the utility's traditional service area. The substantial proven coal resources at both Healy and Beluga argue against using this rationale in seeking an exemption.

1/ As reported in the Wall Street Journal, November 14, 1978, p 14.

To gain an exemption based on an inability to raise capital, a company would have to show that the added capital needed to burn coal or alternate fuels, instead of oil or gas, equals 25 percent or more of the annual average capital budget.

In writing these regulations, it is clear that the administration's intent is to severly limit the scope of exemptions and place a heavy burden of proof on utilities seeking an exemption. Based on the proposed regulations, it would appear that railbelt utilities would have a difficult time obtaining exemption for new base load plants. The Alaska Power Administration, Department of Energy, agrees with this assessment. The APA Administrator, Robert J. Cross, writes that "(APA's) finding is that exemptions don't seem all that permanent or pertinent in terms of a large new hydro project coming on line in 1992. I just don't see the logic of the oil assumption in benefit determinations for 100-years of power from a major new hydro project." 1/ Also agreeing that oil is an inappropriate alternative for benefit calculation is the State's Alaska Power Authority. The Power Authority's Executive Director, Eric P. Yould, states that, "oil-fired generation for the railbelt area may not be acceptable either for legal and regulatory reasons or from the standpoint of fuel availability." 2/ He notes further that Golden Valley Electric Cooperative at Fairbanks recently analyzed the coal versus oil-fired generation question. GVEA has determined that the coal-fired generation alternative is preferable to oil if capital costs are not prohibitive. The full text of both pieces of correspondence are contained in Exhibit C-7.

Based on the foregoing, coal-fired generation has been selected as the most likely and appropriate alternative against which to compare the Susitna hydroelectric proposal. Coal is therefore the basis for the base case benefit calculations. Oil-fired generation is addressed in the sensitivity analysis.

Derivation of Power Benefits - The Base Case

Annual power benefits were computed by applying the unit value of capacity and energy to the usable output of the hydropower project. Benefits were computed for each year of the 100-year economic life of the project and were then discounted to the base date to determine the combined present worth. The base date in all cases is the power-on-line date of the Watana project. The prescribed Federal discount rate of 6-7/8 percent was used. The last step of the calculations

1/ Robert J. Cross, Administrator, Alaska Power Administration in a memo to FERC dated 9 November 1978.

2/ Eric P. Yould, Executive Director, Alaska Power Authority in a letter to Colonel George Robertson dated 17 November 1978.

entailed the conversion of the present worth value to an equivalent average annual benefit, again using the 6-7/8 percent discount rate. The results of the computer-aided calculations are shown in Exhibit C-5.

For the base case, which included coal-fired power values, the median load forecast, power-on-line dates of 1994 and 1998 for the two stages of development, transmission line completion in 1991, public/non-Federal financing of the thermal alternative, and stable prices, the average annual power benefits are estimated at $289 million. For Watana alone, the corresponding figure is $158 million.

OTHER BENEFITS

Recreation

Recreation-day values for 1978 were researched in order to check the need for changing the values as originally reported in the 1976 Interim Feasibility Report. A review of other projects such as the Chena Lakes Project at Fairbanks indicated that the former values are typical of 1978 visitor-day recreation values and remain unchanged. Therefore, the average annual benefit for recreation is $300,000.

Flood Control

The extent of damage prevention from downstream flooding remains unchanged. The dollar value of those losses has been adjusted to reflect the time elapsed since the original estimate. The annual benefits for flood control are $65,000.

Employment

When otherwise unemployed labor resources are used in the construction of a project, the economic cost of those resources is less than the prevailing wage rate. Conceptually, this adjustment can be made either by an appropriate reduction to the project's cost or by an increase in project benefits. The latter approach has been adopted by Corps of Engineers regulations.

The labor area for this project is to be Anchorage and Fairbanks. The proposed project will be located in an unpopulated area and will draw heavily from these two population centers. Alaska is designated by the U.S. Department of Labor as an area of substantial and persistent unemployment.

The present labor force in the Anchorage/Fairbanks area is 114,800, with approximately 12,534 in the construction industry. With an average 10,443 unemployed, approximately 25 percent or 2,610 are construction labor. The possibility of a gas pipeline project and the capital relocation will affect the availability of otherwise unemployed workers to the Susitna project. The adjustment depends on whether these projects occur prior to or concurrent with the Susitna project.

During the oil pipeline construction a preferential hire law was in force which directed pipeline contractors to hire qualified Alaska residents in preference to nonresidents. The Alaska Department of Labor reports that during construction of the oil pipeline the average percent of manpower requirements drawn from within Alaska was 40 to 50 percent. The proposed upper Susitna hydro project is much smaller than was the oil pipeline project. It is thought that an 80 percent local hire goal could easily be met. The proposed gas pipeline project is planned to begin in the early 1980's and completion is anticipated before Susitna construction begins.

Estimated yearly manpower expenditures for construction of the Devil Canyon and Watana dams and the transmission line are shown in Table C-22. These figures were derived by estimating the labor cost associated with each major feature of the project, net of contingencies. Overall, 38 percent of project costs are estimated to be labor expenses.

TABLE C-22

MANPOWER EXPENDITURES
($1,000)

Year	Skilled	Unskilled	Total	Percent of Total
1984	8,307	2,077	10,384	1.2
1985	28,378	7,094	35,472	4.1
1986	30,454	7,614	38,068	4.4
1987	42,221	10,555	52,776	6.1
1988	58,140	14,535	72,675	8.4
1989	57,448	14,362	71,810	8.3
1990	66,446	16,611	83,057	9.6
1991	69,214	17,304	86,518	10.0
1992	69,906	17,477	87,383	10.1
1993	69,214	17,304	86,518	10.0
1994	40,144	10,036	50,180	5.8
1995	36,683	9,171	45,854	5.3
1996	38,760	9,690	48,450	5.6
1997	42,221	10,555	52,776	6.1
1998	34,607	8,651	43,259	5.0
	692,143	173,036	865,179	100.0

Approximately 6 percent of these labor expenses are attributable to the contractors' supervisory and managerial functions. Of the remaining $813 million labor costs, 80 percent are expected to be paid to locally hired labor. Of this total an estimated 20 percent or $130,000,000 will be for unskilled labor, while 80 percent or $521,000,000 will be for skilled labor. Following the recommendations of Draft ER 1105-2-354, the proportion of labor costs claimed as employment benefits for skilled and unskilled categories are 40 percent and 55 percent respectively.

Using an interest rate of 6-7/8 percent, each year's benefits are present-worth to POL. Then, using the summation of all years, the appropriate capital recovery factor is applied to obtain the annual employment benefit for each category of workers (skilled and unskilled). The annual skilled labor benefit is $17,562,000 and the annual unskilled labor benefit is $6,037,000. Thus, the total employment benefit for the Susitna project is $23,599,000.

Similar procedures have been applied to the coal-fired and oil-fired generation alternatives to estimate their respective employment benefits. This is in keeping with Draft ER 1105-2-354 which directs that employment impacts of each alternative plan are to be assessed. The estimated labor portion of the total project cost was calculated using FERC investment cost data and labor percentages for the planned Healy II coal-fired plant. At a composite (Anchorage-Fairbanks) investment cost of $1,287 per kilowatt, the total cost of coal-fired plant construction, equivalent in output to the Susitna project, is $2,060,487,000. This total amount was scheduled over the planning period to reflect capacity additions indicated by the load-resource analysis medium range case.

According to Stanley Consultants, the engineering firm that has developed the plans for Healy II on behalf of Golden Valley Electric, approximately 40 percent of construction costs are payments to labor. 1/ Using the same proportion of skilled and unskilled labor as was used with the hydro project calculations and the same discounting procedures, the average annual equivalent employment benefit for the coal-fired generation alternative is $19,635,000. 2/ The comparable figure for the oil-fired alternative is $5,203,000. These estimates are presented for rough comparison only since they do not reflect a detailed study of labor requirements for thermal plant construction. Since, on average, a more skilled workes is required for construction of the thermal plant and since such a worker would probably not be available locally, the thermal alternative employment benefit estimate is probably somewhat overstated.

1/ Per conversation with Stanley Consultants, 20 December 1978.
2/ This amount incorporates a 20 percent reduction to account for contingency factors in the cost estimates, thus insuring comparability with the hydro project.

The thermal alternatives are procedurally defined to have power benefits equal to plan costs. The crediting of employment benefits, therefore, results in the thermal alternatives each having positive net benefits equal in magnitude to the employment benefit.

Intertie Benefits

The original feasibility report discussed the value of interconnected load centers made possible by the construction of a transmission line between Anchorage and Fairbanks. It was noted that intertie benefits arise from two aspects of interconnection, shared reserves and energy transfer.

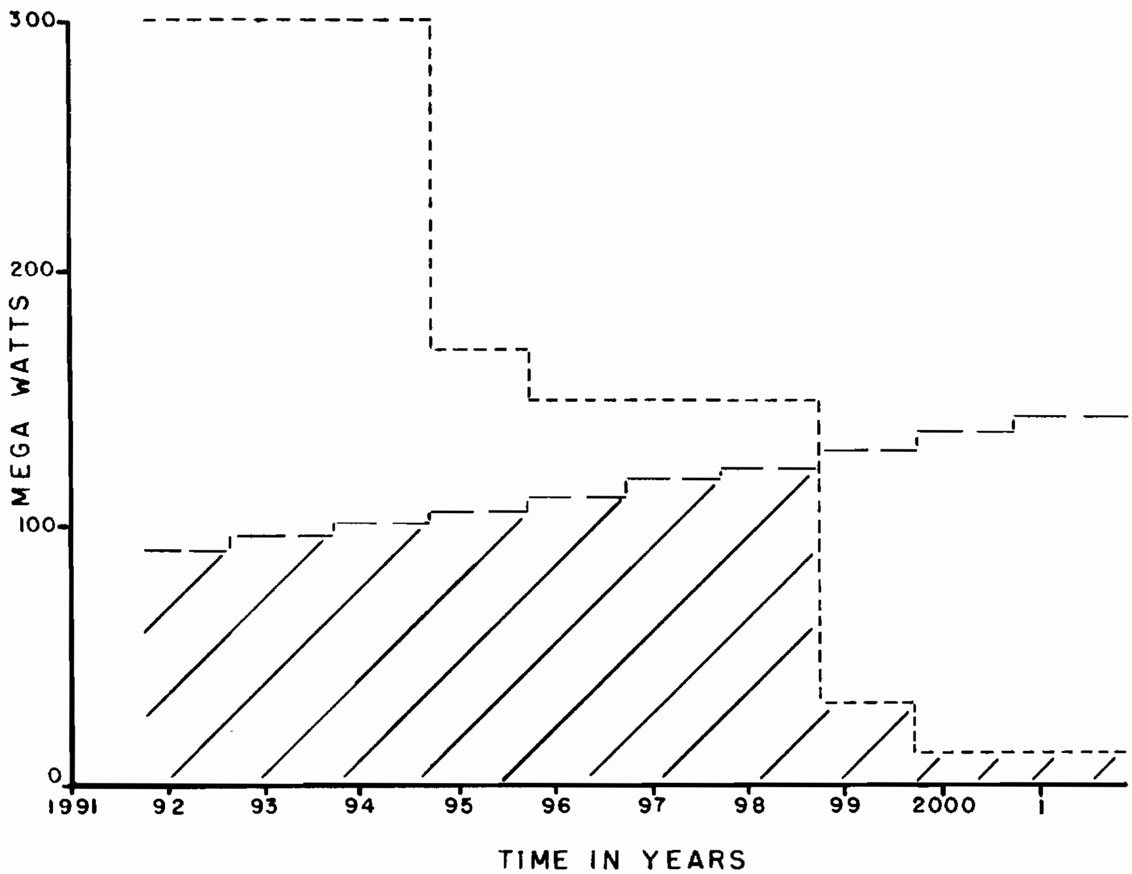
The load-resource analysis has demonstrated that capacity additions can be postponed as a result of reduced reserve requirements in an interconnected system. Since the reserve margin effectively increases the amount of generating capacity in place at any given time, it contributes costs to the system. Therefore a reduction in that reserve margin will reduce cost. Realizing that a more refined analysis of desired reserve margins will be needed at a later date, APA now estimates that a 25 percent margin would be required without interconnection while only 20 percent reserves would be needed with interconnected load centers. These estimates are based largely on the experience in other market areas.

The flexibility afforded by the transmission line decreases as the line becomes loaded with Susitna power. The reserve reduction capability is limited by the unused portion of the line segment with the least capacity - that portion from Devil Canyon to Fairbanks. When the line is completed and before Watana power production begins, a full 300 MW capacity is available in the line. 1/ This is reduced as time goes on by the amount of Susitna capacity allocated to the Fairbanks load center. The capacity savings due to interconnection for each year, then, is the lesser of unused line capacity and the 5 percent reserve differential applied to the total peak load requirement. This is shown graphically in Figure C-8, and the results are presented in Table C-23. Each year's capacity saving is valued at the capacity value of a coal-fired steam plant as provided by FERC, $170 per kW. The values are discounted at 6-7/8 percent to give the present worth as of the Watana power-on-line date. The 100-year capital recovery factor is then applied to the summation to give the equivalent annual capacity benefit from interconnection.

1/ This figure is not an absolute maximum capacity, but rather a reasonable limit for the Devil Canyon-Fairbanks segment based on acceptable line loss.

Figure C-8

TRANSMISSION LINE CAPACITY CREDIT



------ Unused Capacity

— — — 5 % Reserve Differential Applied To Total Peak Load Requirements.

TABLE C-23

INTERTIE CAPACITY BENEFITS

Year	Capacity Saving (MW)	Capacity Value ($1,000)	Present Worth ($1,000)
1991	90	15,300	18,700
1992	96	16,300	18,600
1993	101	17,200	18,400
1994	107	18,200	18,200
1995	114	19,400	18,200
1996	121	20,600	18,000
1997	128	21,800	17,900
1998	30	5,100	3,900
1999 through 2041	12	2,000	27,300
Total ($1,000)			$159,200
Annual Benefit ($1,000)			$ 10,959

The other aspect of interconnection discussed in the original feasibility report was the capability for transfer of energy from the low energy cost producing load center to the high cost area. The transfer allows a cost saving equal to the differential cost of energy production for the amount transferred. Estimates in 1975 indicated that energy could be transferred from Anchorage to Fairbanks for a cost saving of 2.48 mills/kWh. The 1978 estimates by FERC indicate that coal will be cheaper in Fairbanks than in Anchorage with the result that Fairbanks energy would be 2.65 mills/kWh cheaper than that produced by coal plants in Anchorage. This reversal in 3 years highlights the volatility of this cost differential. For instance, if new coal plants had to be located at some distance from the Healy coal fields due to their proximity to Mt. McKinley National Park's clean air, the additional cost for transporting the coal would essentially eliminate any energy cost differential. Therefore, although the opportunity remains to take advantage of energy cost differentials through the transfer of energy, no energy transfer benefits are claimed because of the possibility that energy production costs in the two load centers might well be almost equal.

PLAN JUSTIFICATION - THE BASE CASE

A summary of project costs and benefits for the proposed two stage development as well as for Watana alone are presented in Tables C-24 and C-25. The base case set of assumptions applies.

TABLE C-24

AVERAGE ANNUAL COSTS

Development	Interest & Amortization ($1,000)	O, M & R ($1,000)	Total (Rounded) ($1,000)
Watana	163,761	2,620	166,381
Watana and Devil Canyon	225,068	3,320	228,388

TABLE C-25

AVERAGE ANNUAL BENEFITS

	Watana ($1,000)	Watana and Devil Canyon ($1,000)
Power	163,958	288,700
Recreation	100	300
Flood Control	65	65
Intertie	10,959	10,959
Employment	18,654	23,599
Total	193,736	323,623

Benefits and costs are compared in Table C-26.

TABLE C-26

PLAN JUSTIFICATION

	Watana	Watana and Devil Canyon	Devil Canyon Last Added
Annual Costs ($1,000)	166,381	228,388	63,007
Annual Benefitis ($1,000)	193,736	323,623	129,887
Net Benefits ($1,000)	27,355	95,235	67,880
Benefit Cost Ratio	1.16	1.42	2.09

These figures indicate that, given the base case assumptions, the Watana-Devil Canyon system is economically justified; the Watana project first added is economically feasible by itself; and Devil Canyon is incrementally justified on a last added basis.

SENSITIVITY OF PROJECT JUSTIFICATION

This section presents the results of various sensitivity tests conducted to determine the impact on the project's economic justification of possible departures from the basic set of assumptions that underlie the calculation of benefits and costs. Each test was conducted using the same procedures as described earlier in this section, but with certain specific assumptions altered as outlined in the following paragraphs.

Comparability Test

The power values for the base case are computed using the most likely means of financing the various thermal alternatives. These included municipal, REA, and Alaska Power Authority financing. This test examines project justification when the power values are calculated on the basis of thermal alternative financing at the same rate applied to the hydropower alternative, the Federal discount rate of 6-7/8 percent. Using power values based on Federal financing, the average annual power benefits are $264 million, a decrease of 9 percent. The hydro project costs and nonpower benefits are already based on the Federal discount rate and therefore remain unchanged. The effect on project justification is noticeable; net benefits fall from $95 million to $71 million, while the justification ratio becomes 1.31.

With Federal financing, Watana alone offers net benefits of $14 million and a justification ratio of 1.08.

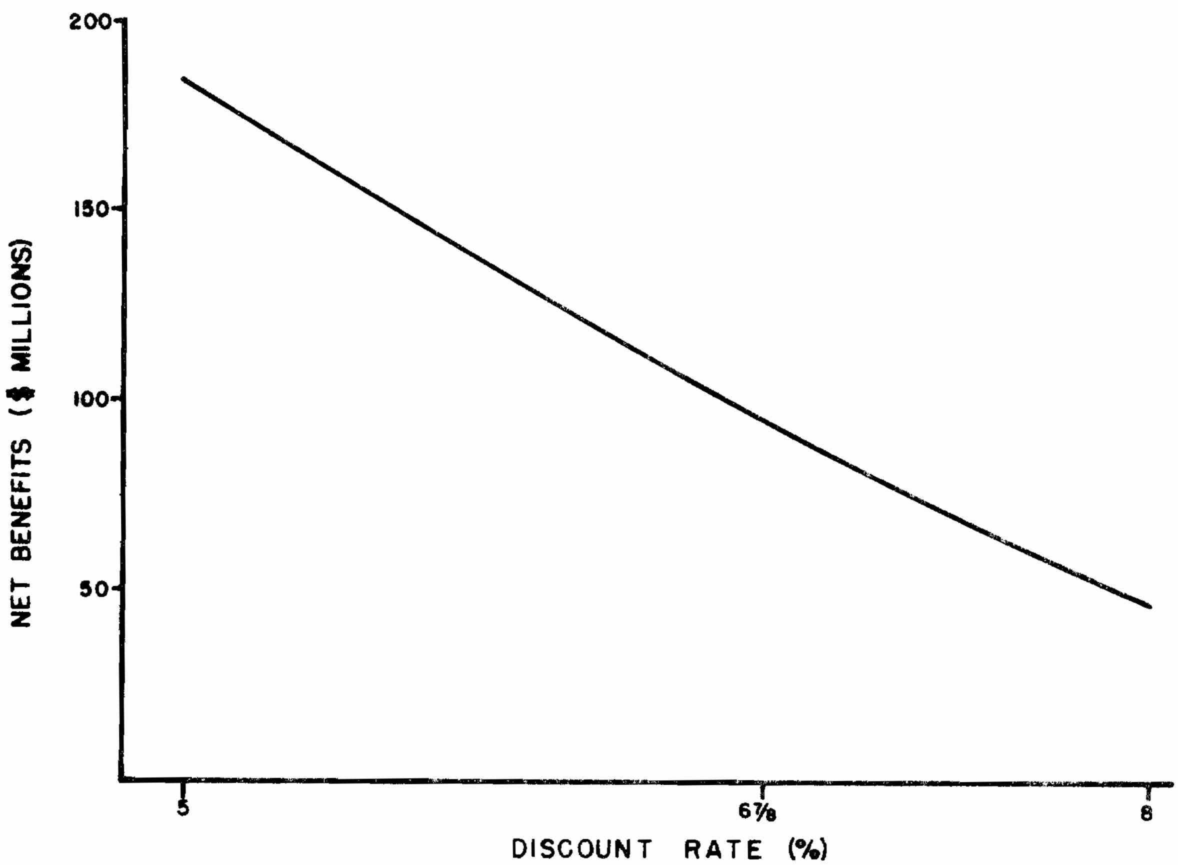
Alternate Discount Rates

The rate at which future project benefits are discounted and at which interest during construction is calculated can affect the comparison of projects. The discount rate to be used in the evaluation of Federal water resource projects is established annually and is pegged to the interest rate on long-term government bonds. This serves as an approximation of the opportunity cost of Federal funds. The established rate has risen to the current value of 6-7/8 percent, reflecting the influence of inflation.

In order to determine the magnitude of impact a different discount rate would have on the project's economic justification, benefits and costs were recalculated using interest rates lower and higher than the established rate. With a discount rate of 5 percent, annual costs decline while benefits increase. Net benefits rise from $95 million in the base case to $180 million, and the benefit-cost ratio becomes 2.14. With an 8 percent rate, the effects are reversed. Net benefits fall to $42 million with a benefit-cost ratio of 1.15. Refer to Figure C-9. It can be concluded that the project's economic justification is sensitive to changes in the discount rate. The effects would be dampered, however, if the costs of the alternative generation mode were similarly calculated using the alternate rates.

Figure C-9

PLAN JUSTIFICATION, ALTERNATE DISCOUNT RATES



Variations in the Load Forecast and Project Timing

The base case set of assumptions incorporates the mid-range load forecast because it has been judged to reflect the most likely future power requirements. The actual demand for electrical power, however, will almost certainly depart from the mid-range forecast, and it is important to determine how such departures can effect the viability of the project. A significant departure on the low side could have several results. The first, and most likely, would entail a planned delay in the start of project construction when it became apparent that the load was not growing as rapidly as expected. Another possibility would be that the departure from anticipated growth only becomes apparent after construction has already begun. In this case, the construction period would be stretched out so that the project is not completed until the project's power is needed. A third possibility would be to postpone or cancel other generating resource additions with shorter lead times. The last and potentially most damaging possible circumstance would entail the sudden slackening of load growth immediately after the project was completed.

If, on the other hand, the load requirements grow more rapidly than expected, Susitna power would be needed earlier than presently planned. The Watana project, however, probably cannot be completed any earlier than the planned 1994 power-on-line date, and the Devil Canyon project cannot be completed earlier than 4 years after Watana.

To assess the impacts of these various circumstances, the load-resource analysis was conducted using the low and high range forecasts. With the low range forecast, the initial project continues to be required as soon as it is available, ie., 1994. A coal-fired steam plant addition in 1997 is no longer needed, but Devil Canyon is still required in 1998. The net effect is that Susitna capacity is absorbed at a slower rate, and power benefits fall 3 percent to $280 million. Net benefits become $87 million and the benefit-cost ratio is 1.38.

As noted above, the most damaging possibility in terms of project economics would occur if there was a sudden decrease in the rate of load growth immediately after power-on-line. This would mean that Susitna power would be needed less rapidly, and less Susitna capacity would be usable in the early years. In the base case, Susitna power is fully absorbed in the railbelt system by 2002. The annual growth rate in peak load during the period between power-on-line and 2002 is 4.6 percent. In the low-load growth case, Susitna power is absorbed over a longer period, between 1994 and 2010. The annual growth rate in peak load for this case is 1.9 percent. Additional cases were analyzed to determine how low the growth rate would have to be before the power benefits declined to the point that the project would no longer be economically justified. The annual rate of growth in peak load requirements would have to suddenly fall to 0.8 percent and remain at that rate indefinitely before project costs would exceed benefits. With load growth dependent upon both population and per capita use changes, there is no evidence to suggest that such a low growth rate is reasonable.

Despite the greater peak load requirements of the high range forecast, there is no opportunity to advance project construction since the projects cannot be brought on line prior to 1994 and 1998.

Using the high-range load forecast results in more rapid utilization of Susitna power and an increase of $12 million in net benefits. The benefit-cost ratio becomes 1.47.

Construction Delays

The base case analysis is predicated on a 14-year combined construction schedule. Watana construction is planned to take 10 years and Devil Canyon 8 years. There is overlapping construction to meet load requirements.

Construction delays are possible for any of a number of reasons. Project economics have been analyzed to assess the impact such delays would have on project justification. A 2-year construction delay was adopted for analysis. The effect of the delay is to postpone power-on-line and increase interest during construction. If fossil fuel costs are escalating, the delay also increases the value of power produced. With stable prices, a 2-year construction delay causes annual costs to rise to $245 million and net benefits to fall to $75 million, with a benefit-cost ratio of 1.31. It would require a delay of at least 9 years before the Susitna project's net benefits would fall as low as those of the coal-fired alternative.

Alternate Investment Cost Estimates for Coal-Fired Plants

The Alaska Power Administration has provided independent estimates of coal-fired generation costs that serve as useful comparisons to those estimates provided by the Federal Energy Regulatory Commission. APA data primarily reflects experience in the lower 48 states with adjustment to reflect Alaska price levels, smaller sized plants, and construction conditions. The basic reference is the Comparative Study of Coal and Nuclear Generation Options in the Pacific Northwest, June 1977 by the Washington Public Power Supply System (WPPSS).

APA's estimate is premised on powerplant locations near mining operations at Beluga and Healy. Plants of 200 MW and 500 MW are examined. The investment costs, which include construction and interest during construction assume that flue gas desulpherization would be required. Mid-1976 costs from the WPPSS study were increased to October 1978 using the Handy-Whitman Steamplant cost trends and a 1.8 Alaska factor to account for cost differentials. The resulting composite investment cost estimate of $1,644 per kilowatt for the 450 and 230 MW plants in Anchorage and Fairbanks respectively was used in the calculation of power values in lieu of the FERC composite estimate of $1,299 per kilowatt. This resulted in an increased capacity value. See Exhibit C-4. Using the adjusted value results in a $40 million increase in the power benefit. Net benefits rise to $135 million, and the benefit-cost ratio becomes 1.59.

Oil-Fired Thermal Alternative

As discussed in a previous section, oil-fired generation is not the most appropriate alternative for derivation of power values. National energy policy priorities strongly suggest that coal-fired generation is the likely and proper alternative to hydropower in the mid-1990's and beyond. Since oil-fired power values were provided by FERC along with coal values, however, and since the Office of Management and Budget raised questions specifically addressing the sensitivity of project justification to oil prices, power benefits were also calculated using oil-fired power values.

In Anchorage, FERC reports that the likely oil-fired alternative is a combined cycle plant consisting of four units of 105 MW each. The service life is 30 years, and the heat rate is 8,350 BTU/kWh. The investment cost is estimated at $360 per kilowatt, while the oil fuel cost is $3.00 per million BTU.

For Fairbanks, the oil-fired alternative is a regenerative combustion turbine with four 60 MW units. The service life is again 30 years, while the heat rate in this case is 10,000 BTU/kWh. The investment cost is $265 per kilowatt, and fuel is estimated at $2.00 per million BTU.

The composite railbelt oil-fired power values with public, non-Federal financing are $43.95 per kilowatt and 26.92 mills per kilowatt hour. Power benefits amount to $212 million which is 27 percent less than the base case. The corresponding benefit-cost ratio is 1.08, with net benefits of $18 million.

Inflation

The economic evaluation procedures normally followed in Federal water resource studies ignore the effects of inflation and escalation. 1/ The implicit assumption is that price level changes will impact equally on all alternatives being compared. In time of relatively stable prices, this is a reasonable simplifying assumption.

Ever since the 1930's, however, there has been an accelerating rise in costs in the United States. Nationwide, the annual increase in construction costs from 1970 to 1976 approximated 10 percent. The Anchorage composite consumer price index has increased at an annual rate of 4 percent since 1960 and at almost 7 percent since 1970. In spite of possible temporary periods of price stability, it appears that substantial inflation may become a regular aspect of the economic scene. The extent and persistence of inflationary trends indicates the need to examine their effect on the comparison between hydroelectric and thermal generation.

Inflation does not affect hydro and thermal alternatives equally because there is a differential susceptibility to rising prices. The extent of these differential impacts is determined by adjusting the capacity and energy values as well as the hydro project costs to account for inflation. A distinction has to be made between interest and amortization costs on the one hand and all other charges on the other, because the affect of inflation on these two categories of expenditure is quite different. The latter category is addressed first.

A multiplier is developed for adjustment of annual charges associated with operating costs, fuel costs, insurance, interim replacements, and taxes. Expenditures for these items are continually susceptible to rising prices. The initial annual expenditure associated with these cost components in the base year is the value used in the standard method of computing power values. With inflation, a higher figure must be used, since the annual expenditures increase from year to year. The assumed rate of inflation, the duration of the assumed inflation, and the discount rate together determine how large the increase will be. The appropriate adjustment multiplier is found by computing the sum of the present values of the inflated payments, and dividing that by the sum of the present values of the yearly payments without inflation. The resulting quotient is the multiplier by which the fixed initial payment of the standard method must be adjusted to take inflation into account.

1/ Throughout this report, "inflation" refers to increases in the general price level, while "escalation" refers to real price changes or changes over and above increases in the general price level.

For this analysis, inflation is assumed to prevail for a period of 15 years beyond the initial project's power-on-line date. This period of inflation is assumed to be followed by a period of stable prices to the end of the 100 year economic life of the project. 1/ Inflation rates of 3 and 5 percent have been adopted as reasonable values with which to explore the magnitude of inflationary impact. The corresponding annual expenditure multipliers for a discount rate of 6-7/8 percent are 1.34 and 1.64.

The second type of cost to examine is the interest and amortization charge. During the life of a hydroelectric project, an alternative thermal plan with a life of only 30 to 35 years will have to be replaced at least twice. Each time it is replaced, its cost will have risen in keeping with the compound rate of inflation. The multiplier reflecting the increase in these capital expenditures resulting from inflation is found by dividing the present worth of the interest and amortization with inflation affecting future replacements by their present worth without inflation. Again, inflation is confined to the first 15 years beyond power-on-line with stable prices assumed thereafter. The multipliers are 1.08 for 3 percent inflation and 1.15 for a 5 percent rate.

TABLE C-27

INFLATION ADJUSTMENT MULTIPLIERS
(6-7/8 percent discount rate, 30 year thermal plant life, 15 year period of inflation)

	Inflation Rate	
	3%	5%
Cost Category		
Variable Costs	1.34	1.64
Capital Expenses	1.08	1.15

These multipliers are then applied to the various cost components of the power values and to the elements of the hydro project cost as shown in Exhibit C-4. Note that the multiplier for interest and amortization of the hydro project is unity. This occurs because the hydro project does not have to be replaced during the period of analysis and is therefore not susceptable to inflating prices.

1/ Inflation in the years prior to power-on-line is ignored because there is little differential inflation impact before costs are actually incurred. Battelle in Alaskan Electric Power, March 1978, page 6-3, reports that prices for thermal powerplants have risen since 1970 at almost exactly the same rate as that for hydroelectric facilities.

Fuel Escalation

In deriving power values for use in benefit analysis, FERC uses present day costs for the fuel requirements of the thermal plant. Even after inflation is taken into account, this procedure is not equitable in a period of substantial fuel cost escalation, when fuel prices rise faster than the general price level. Whereas a hydro development will continue to produce its energy from falling water without cost, a thermal plant depends on fossil fuels that are susceptible to real price increases as well as to inflationary trends. Depleting supplies, intensified environmental controls, cartelized production, and the need to go further and deeper for supplies all tend to boost prices at rates higher than inflation.

Fuel Oil: As a practical matter the world oil market is controlled by the Organization of Petroleum Exporting Countries (OPEC). The OPEC cartel pricing strategy appears to be based on their perception of the marginal costs of production of their nearest competitor. This policy is intended to maximize their long-term profits. 1/

In the future OPEC's most probable strategy (assuming the cartel can be sustained and no other super-giant oil fields are found or alternative lower cost technologies are developed) will be to escalate its prices paralleling the market rate of interest occurring in its western world market area. The market rate of interest sets the basis from which OPEC can measure its opportunity cost and escalates at approximately 3 percentage points higher than the general inflation rate as measured by the GNP deflator. Thus for a general 5 percent per annum inflation rate, the OPEC oil price increase rate would be expected to be about 8 percent per annum.

If Mexico enters the continental market as a major source, it will probably shave prices slightly to gain market entry by displacing Middle East crude, but then generally trade at OPEC's world market price.

Another possibility is the collapse of the OPEC cartel. Iran and Saudia Arabia, the largest oil producers in OPEC, are committed along with many other OPEC nations to rapid economic development programs. These programs are dependent upon oil export revenues for their funding. Under the umbrella of OPEC's pricing policy, there is opportunity and strong incentive to develop substantial new productive capacity both within and outside the cartel. The increase in capacity imposes

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1/ This discussion of fuel price behavior is based largely on a March 1978 report by Battelle Pacific Northwest Laboratories entitled, Alaska Electric Power, An Analysis of Future Requirements and Supply for the Railbelt Region and on discussions with Ward Swift of Battelle.

downward pressure on prices. To offset this pressue and maintain the cartel price, production must be cut back somewhat; principally this will fall on the largest producers, Iran and Saudia Arabia in this case. Thus they are caught in a dilemma between a declining market share and the need for export earnings for developmental programs. This situation could lead to price wars to regain market shares and thus the collapse of OPEC as an effective cartel.

Price cutting has a theoretical floor - the marginal cost of producing the level of output demanded at such a market price. This would likely be determined by Mexico, the North Sea producers and the costs of increased production in Iran. All of the conditions contributing to the initial cartelization would still be present, a highly concentrated market and very inelastic commodity demand. Thus a collapse might only be temporary and under this scenario, world prices could become rather volatile.

Given the many vested (U.S. and foreign) interests in maintaining oil prices, a major downward break in oil prices is not likely. As a case in point, if Saudi Arabia went back to pre-1973 prices, and could satisfy demand, (not likely at those prices) both North Sea and North Slope production could be shut in.

Given that scenario and without governmental intervention, U.S. and other nations' dependence on foreign oil would increase markedly, domestic exploration and field development would be severely cut back, and consumption would increase. Although existence of contingency policies to respond to such a case are unknown, it is hard to visualize that very rigorous governmental intervention would not occur either through import quotas or duties that would maintain the economic viability of the domestic industries.

In 1977, the domestic refinery acquisition cost of domestic crude was about 35 percent less than that of foreign crude ($9.20 per bbl versus $14.10 per bbl). A price decline of greater than 35 percent is deemed highly unlikely for the reasons outlined above.

Coal: Coal prices in Alaska appear much more predictable due to the absence of regulation and the currently limited influence of marketability factors.

Two sources of coal supply for the railbelt region are most pertinent to this analysis:

1. The Healy coal field is currently being mined by the Usibelli Coal Company at about 700,000 tons/year with plans for expansion to 1.5 million tons per year. This mine currently supplies the Golden Valley Electric Association (GVEA) plant located at Healy and the Fairbanks Municipal Utility System in Fairbanks.

2. A potential future coal source is the Beluga field in the Cook Inlet region. The latter field is known to contain very substantial reserves but the new mine development required will be costly due to lack of transporation facilities and mine supporting infrastructure.

The Healy coal field is the obvious supplier for future interior generation based on coal. Recent cost of coal delivered by truck to the GVEA Healy plant is $0.80/MMBTU and by rail at Fairbanks, $1.15/ MMBTU. 1/ Although the Healy site may be able to expand to perhaps 200 MW capacity, its location 4.5 miles from Mt. McKinley National Park may restrict further development due to air quality considerations. Thus further coal fired expansion in the upper railbelt most probably will necessitate plant location in the Nenana area along the rail line. In this case, additional costs above mine mouth costs, will be incurred including tipple costs (approximately $0.11 per MMBTU currently) and Alaska Railroad tariffs. The latter may be reduced if unit trains were to be employed.

The Usibelli Coal Mine, Inc. has indicated that they expect their prices to rise at about 7 percent per annum. This pricing schedule appears reasonable if it is assumed that a 5 percent per annum general inflation rate continues and a 2 percentage point markup escalation is appropriate for the resource owner.

The Beluga/Susitna coal field is an obvious source of supply for coal fired generation. The reserves are very large and capable of supporting a world scale mine for export and mine mouth power generation. The coal is subbituminous (Rank C) and of relatively low heating value (7,100 BTU/lb) at run-of-mine but quite low in sulfur (0.15 percent typical). Coal preparation including washing and drying could raise the heating value to 9,000 BTU/lb. Some of the coal will be of too low a quality for export but would nevertheless be suitable for mine mouth power generation.

Fuel Cost Assumptions

To calculate the impact of relative changes in the price of fuels on project feasibility, adjustments are made to the power values upon which the calculation of power benefits is based. The period from 1978 to the initial project power-on-line date is looked at separately from the period after POL. For the initial period, the estimated 1978 fuel price is compounded at the assumed annual escalation rate to give the anticipated constant dollar fuel cost at the time of power-on-line. The energy and capacity values are then recalculated using standard FERC procedures. For the post-POL period, a multiplier is used to adjust the energy value using procedures identical to those used to adjust for inflation. The period of escalation is limited to the years prior to the 30th year after power-on-line. Thirty years corresponds to the service life of the initial thermal plant.

1/ September, 1978

Three sample cases are analysed. First, for both coal and oil, there is an assumption that fuel costs escalate at 2 percent per year between 1978 and the 30th year after power-on-line, after which there is no additional escalation. The 2 percent rate is selected as representative of long-term real price increases arising from depleting, more distant sources, increasing environmental safeguards in extraction, processing and handling, and anticipated producing nation pricing policy. (Refer to the previous discussion of fuel price trends.)

The second case looks at no escalation prior to power-on-line followed by a 30-year period of 2 percent annual escalation. This case is designed to reflect the possibility of a near-term softening of the market for oil due to slackening demand or increased supply in the short-term.

The final case explores the impact of real oil price declines prior to power-on-line. An immediate 35 percent drop in price is assumed, with no change in price thereafter. This scenario is included to show the possible effect on project justification of a breakup of the OPEC cartel. Exhibit C-4 shows how these various adjustments are made to the energy value provided by FERC.

Test Results

The results of the sensitivity tests for inflation and escalation are presented on Figures C-10 and C-11. Two percent annual escalation in the price of coal results in a 55 percent increase in net benefits and the benefit-cost ratio becomes 1.64. In the most extreme coal-fired case, 2 percent fuel escalation with 5 percent inflation, the benefit-cost ratio rises to 2.17. The worst case analyzed in terms of project justification is with the oil-fired alternative and a sudden 35 percent drop in oil prices. The resulting benefit-cost ratio is 0.85.

Summary

In summary, it has been shown that the benefit-cost ratio is sensitive to the source of financing, to the discount rate, to the type of alternative generation, to construction delays, and to inflation and fuel cost escalation. It is relatively insensitive, on the other hand, to variations in load requirement forecasts. Under the full range of forecasts, Susitna hydropower is needed as soon as it is available.

Despite the sensitivity of project economics to many of these parameters, the degree of sensitivity is not sufficient to make the project uneconomic, except in one case. Only if oil-fired generation were to be considered the appropriate long-term alternative to hydropower and if the price of oil were to suddenly fall drastically as a result of world market forces would net benefits of Susitna hydropower development be less than those of the thermal generation alternative.

Figure C-10

SENSITIVITY TO INFLATION AND ESCALATION—COAL

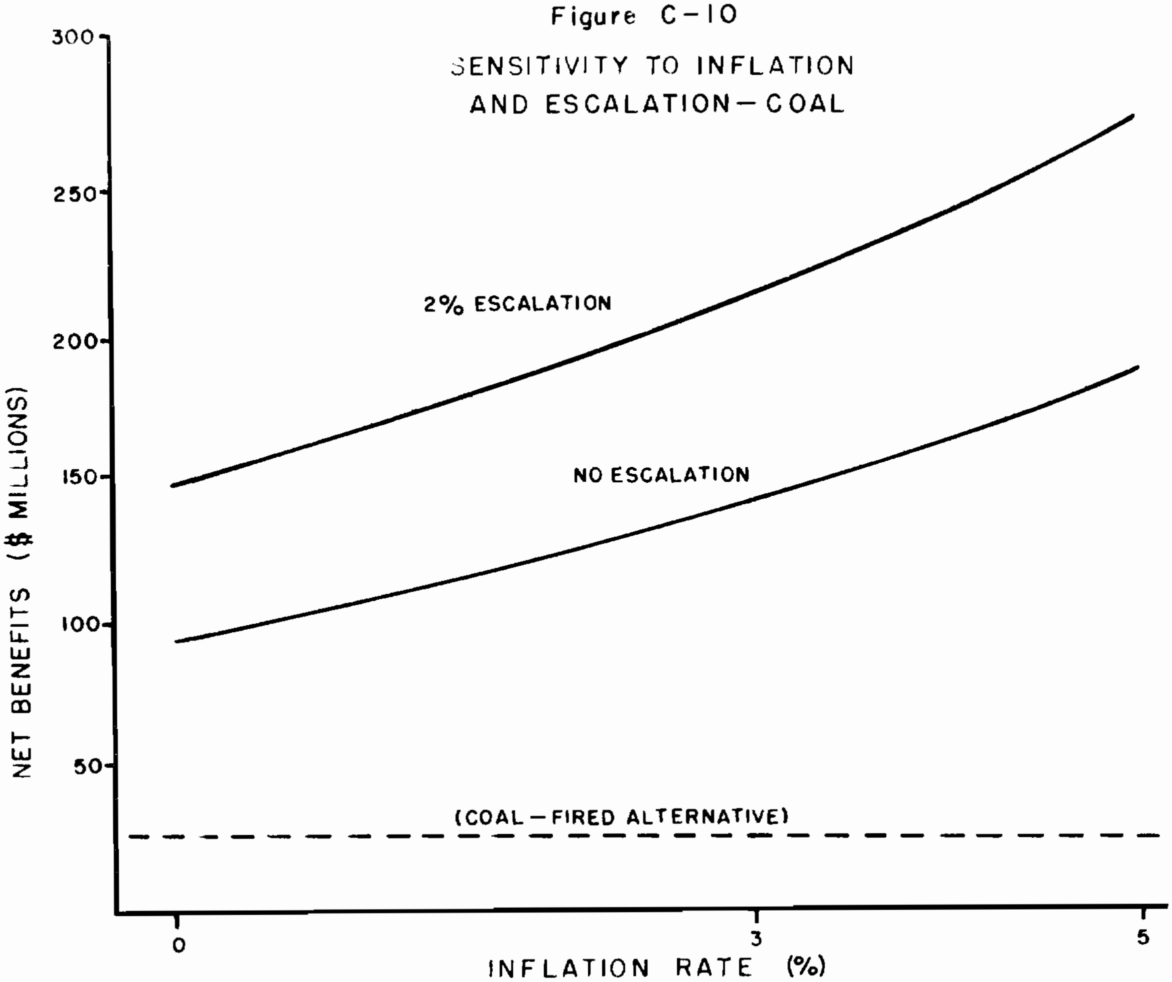
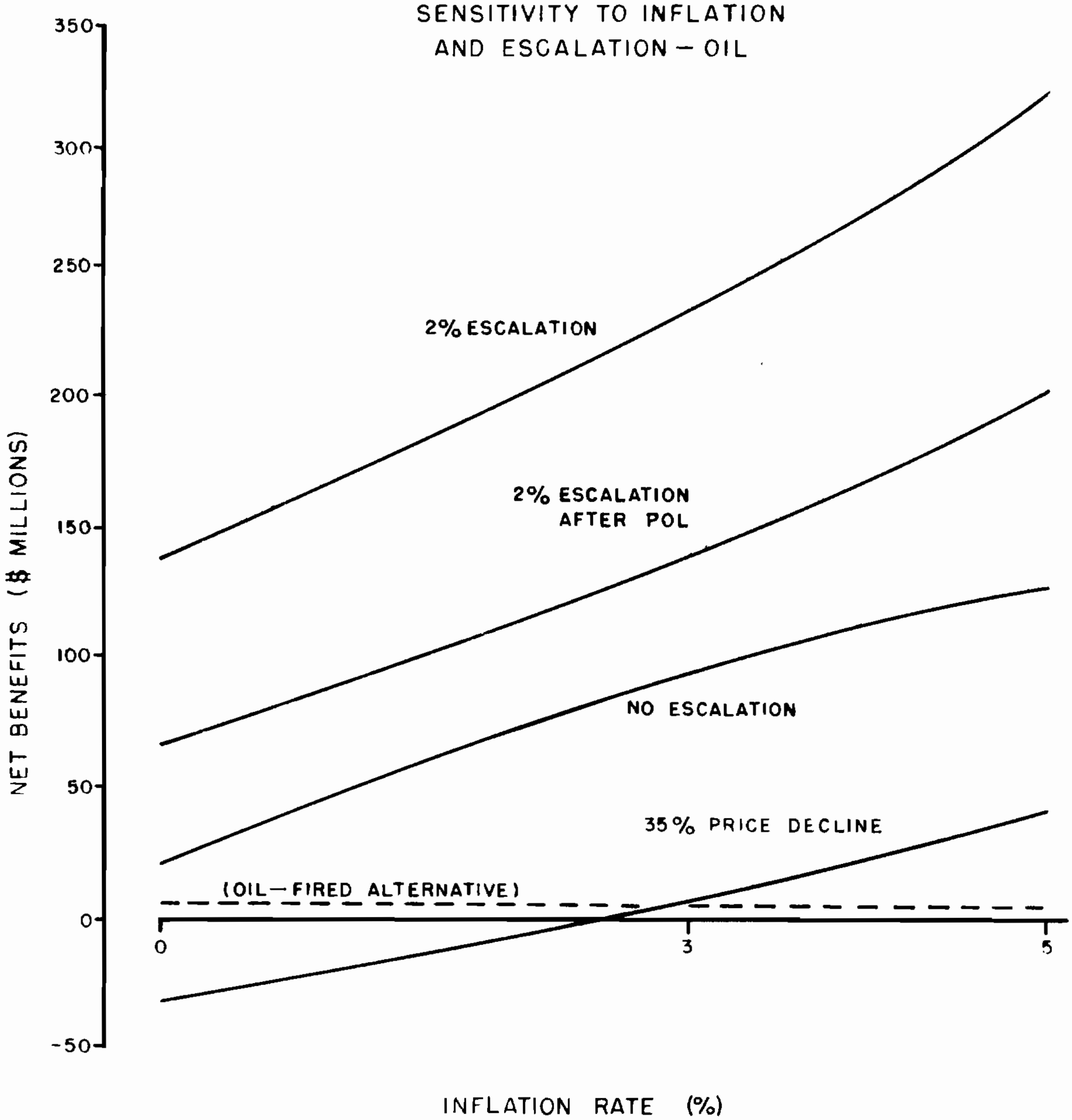
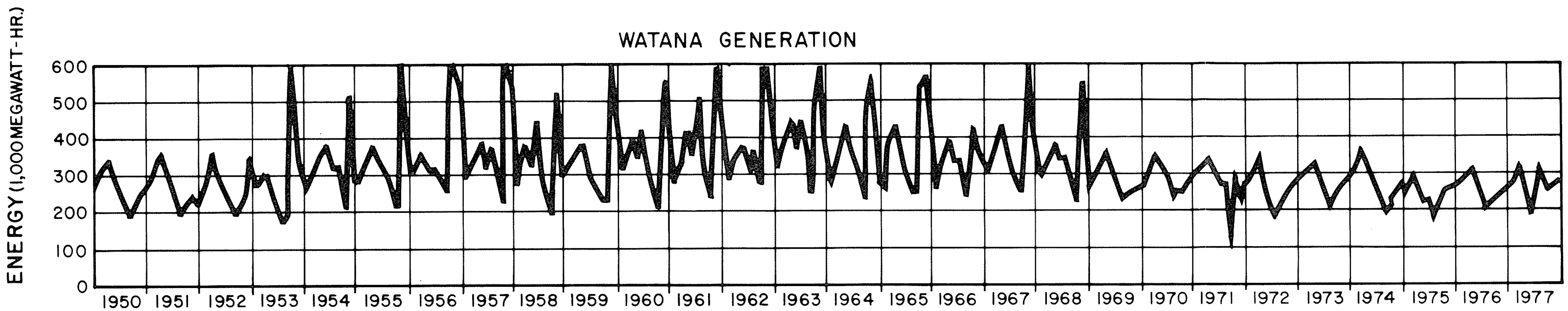


Figure C-11

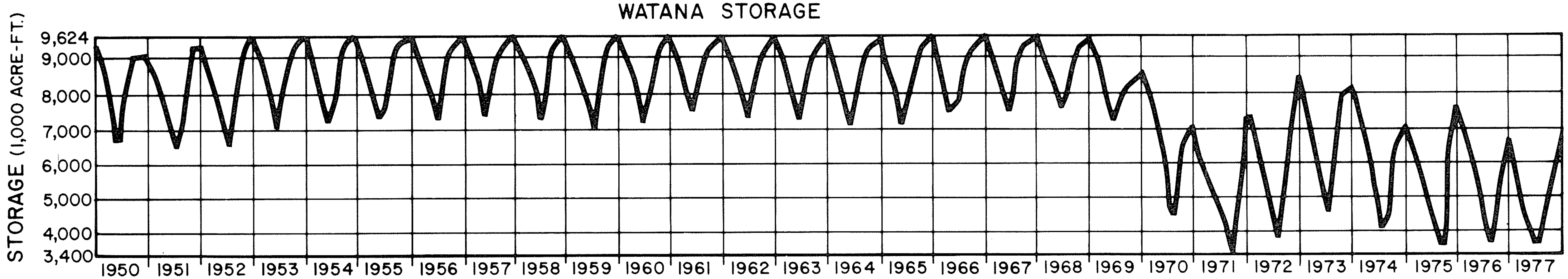
SENSITIVITY TO INFLATION AND ESCALATION – OIL



WATANA GENERATION



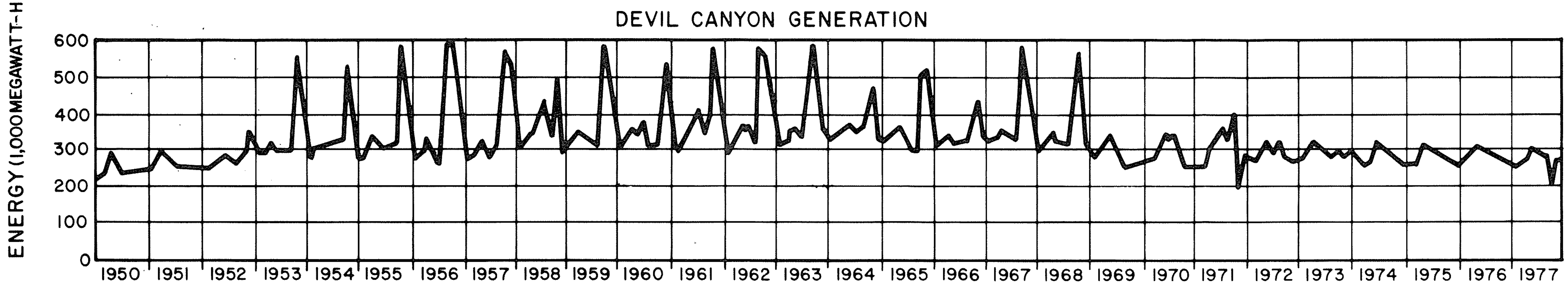
WATANA STORAGE

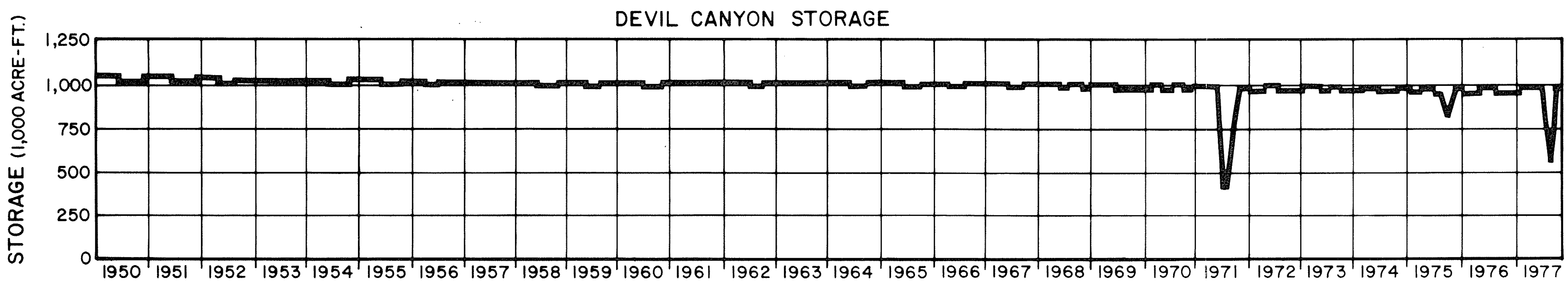


SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
RESERVOIR OPERATION & ENERGY OUTPUT
WATANA DAM

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
NOVEMBER, 1978





SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

RESERVOIR OPERATION & ENERGY OUTPUT
DEVIL CANYON DAM

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
NOVEMBER, 1978

EXHIBIT C-1

LOAD RESOURCE ANALYSES

NSUFFICIENT PLANTS IN 1978-1979

NSUFFICIENT PLANTS IN 1978-1979

PLANNED ADDITION IN 1979-1980: CEA B 9	ANCH	32.	0.50	TURB	1980.
PLANNED ADDITION IN 1979-1980: AMLP-6 7	ANCH	62.	0.50	TURB	1980.

NSUFFICIENT PLANTS IN 1979-1980

NSUFFICIENT PLANTS IN 1979-1980

PLANNED ADDITION IN 1980-1981: X-1	ANCH	100.	0.50	TURB	1981.
PLANNED RETIREMENT IN 1980-1981: HEA	ANCH	2.	0.10	DIES	1981.
PLANNED ADDITION IN 1981-1982: CEA-BL4	ANCH	18.	0.50	TURB	1982.

NSUFFICIENT PLANTS IN 1981-1982

NSUFFICIENT PLANTS IN 1981-1982

PLANNED ADDITION IN 1982-1983: X-2	ANCH	100.	0.50	TURB	1983.
PLANNED RETIREMENT IN 1982-1983: AMLP-D	ANCH	2.	0.10	DIES	1983.
PLANNED RETIREMENT IN 1982-1983: AMLP-1	ANCH	15.	0.50	TURB	1983.
NEEDED ADDITION IN 1982-1983: COALA1	PSEA1	200.	0.75	STEA	1983.
PLANNED RETIREMENT IN 1983-1984: CEA-BL1	ANCH	8.	0.50	TURB	1984.
PLANNED RETIREMENT IN 1983-1984: CHENA4	FAIR	5.	0.50	TURB	1984.
PLANNED ADDITION IN 1984-1985: CEA-BL5	ANCH	18.	0.50	TURB	1985.
PLANNED RETIREMENT IN 1984-1985: AMLP-2	ANCH	15.	0.50	TURB	1985.
PLANNED RETIREMENT IN 1984-1985: GVEA	FAIR	24.	0.10	DIES	1985.
PLANNED ADDITION IN 1985-1986: BRADLEY LK	ANCH	70.	0.50	HYDR	1986.
PLANNED ADDITION IN 1985-1986: NATIONAL D.	ANCH	7.	0.75	STEA	1986.
PLANNED RETIREMENT IN 1985-1986: SES	ANCH	3.	0.10	DIES	1986.
PLANNED RETIREMENT IN 1985-1986: CEA-INT1-2	ANCH	31.	0.50	TURB	1986.
PLANNED RETIREMENT IN 1985-1986: NATIONAL D.	ANCH	7.	0.10	DIES	1986.
NEEDED ADDITION IN 1985-1986: COALA2	PSEA2	200.	0.75	STEA	1983.
NEEDED ADDITION IN 1985-1986: HEALY 2	PSEF1	100.	0.75	STEA	1978.
PLANNED RETIREMENT IN 1987-1988: CEA-KNIK	ANCH	15.	0.50	STEA	1988.
NEEDED ADDITION IN 1987-1988: COALA3	PSEA3	200.	0.75	STEA	1984.
PLANNED ADDITION IN 1988-1989: NATIONAL D.	FAIR	14.	0.75	STEA	1989.
PLANNED RETIREMENT IN 1988-1989: CEA-B1-2	ANCH	33.	0.50	TURB	1989.
PLANNED RETIREMENT IN 1988-1989: FMUS-123	FAIR	9.	0.75	STEA	1989.
PLANNED RETIREMENT IN 1988-1989: AMLP-3	ANCH	19.	0.50	TURB	1989.
PLANNED RETIREMENT IN 1988-1989: FMUS-D-123	FAIR	8.	0.10	DIES	1989.
PLANNED RETIREMENT IN 1988-1989: INDUSTRIAL	ANCH	12.	0.50	TURB	1989.
PLANNED RETIREMENT IN 1988-1989: NATIONAL D.	FAIR	14.	0.10	DIES	1989.
NEEDED ADDITION IN 1989-1990: COALA4	PSEA4	200.	0.75	STEA	1984.
NEEDED ADDITION IN 1989-1990: COALF1	PSEF1	100.	0.75	STEA	1985.
PLANNED ADDITION IN 1990-1991: NATIONAL D.	FAIR	32.	0.75	STEA	1991.
PLANNED RETIREMENT IN 1990-1991: NATIONAL D.	FAIR	32.	0.75	STEA	1991.
PLANNED ADDITION IN 1991-1992: NATIONAL D.	ANCH	43.	0.75	STEA	1992.
PLANNED RETIREMENT IN 1991-1992: CEA-INT3	ANCH	18.	0.50	TURB	1992.
PLANNED RETIREMENT IN 1991-1992: NATIONAL D.	ANCH	41.	0.75	STEA	1992.
PLANNED RETIREMENT IN 1991-1992: NATIONAL D.	ANCH	2.	0.10	DIES	1992.
PLANNED RETIREMENT IN 1992-1993: AMLP-4	ANCH	32.	0.50	TURB	1993.
PLANNED RETIREMENT IN 1992-1993: GVEA	FAIR	40.	0.50	TURB	1993.
PLANNED RETIREMENT IN 1992-1993: CEA-BL2	ANCH	18.	0.50	TURB	1993.
NEEDED ADDITION IN 1992-1993: COALA5	PSEA5	200.	0.75	STEA	1984.
PLANNED RETIREMENT IN 1993-1994: HEA	ANCH	0.	0.10	DIES	1994.
PLANNED RETIREMENT IN 1993-1994: CEA-BL3	ANCH	55.	0.50	TURB	1994.

NEEDED ADDITION IN	1993-1994: COALA6	PSEA6	400.	0.75	STEA	1984.
UPPER SUSITNA ADDED	1994-1995: WATANA-1	HYDRO	611.	0.56	HYDR	1995.
PLANNED ADDITION IN	1995-1996: NATIONAL D.	FAIR	25.	0.75	STEA	1996.
UPPER SUSITNA ADDED	1995-1996: WATANA-2	HYDRO	92.	0.56	HYDR	1996.
PLANNED RETIREMENT IN	1995-1996: HEA	ANCH	7.	0.50	TURB	1996.
PLANNED RETIREMENT IN	1995-1996: AMLP-56	ANCH	53.	0.50	TURB	1996.
PLANNED RETIREMENT IN	1995-1996: CEA-95	ANCH	65.	0.50	TURB	1996.
PLANNED RETIREMENT IN	1995-1996: NATIONAL D.	FAIR	25.	0.75	STEA	1996.
PLANNED RETIREMENT IN	1996-1997: CHENA 6	FAIR	24.	0.50	TURB	1997.
PLANNED RETIREMENT IN	1996-1997: SES	ANCH	2.	0.50	DIES	1997.
PLANNED RETIREMENT IN	1996-1997: CEA-B4	ANCH	9.	0.50	TURB	1997.
PLANNED RETIREMENT IN	1996-1997: CEAB6789	ANCH	200.	0.50	TURB	1997.
PLANNED RETIREMENT IN	1997-1998: N.POLE 1&2	FAIR	140.	0.50	TURB	1998.
NEEDED ADDITION IN	1997-1998: COALA7	PSEA7	400.	0.75	STEA	1984.
UPPER SUSITNA ADDED	1996-1999: DEVIL CAN-1	HYDRO	600.	0.56	HYDR	1999.
PLANNED RETIREMENT IN	1496-1999: CEA-BL3	ANCH	18.	0.50	TURB	1999.
UPPER SUSITNA ADDED	1999-2000: DEVIL CAN-2	HYDRO	89.	0.56	HYDR	2000.
PLANNED RETIREMENT IN	1999-2000: AMLP-6&7	ANCH	82.	0.50	TURB	2000.
PLANNED RETIREMENT IN	2000-2001: CEA-X-1	ANCH	100.	0.50	TURB	2001.
PLANNED RETIREMENT IN	2001-2002: CEA-BL4	ANCH	18.	0.50	TURB	2002.
PLANNED RETIREMENT IN	2002-2003: CEA-X-2	ANCH	100.	0.50	TURB	2003.
PLANNED RETIREMENT IN	2002-2003: HEALY1	FAIR	25.	0.75	STEA	2003.
NEEDED ADDITION IN	2003-2004: COALF2	PSEF2	100.	0.75	STEA	1985.
PLANNED RETIREMENT IN	2004-2005: CEA-BL5	ANCH	18.	0.50	TURB	2005.
NEEDED ADDITION IN	2004-2005: COALF3	PSEF3	100.	0.75	STEA	1985.
PLANNED RETIREMENT IN	2005-2006: CHENA5	FAIR	20.	0.75	STEA	2006.
NEEDED ADDITION IN	2005-2006: COALA8	PSEA8	400.	0.75	STEA	1984.
NEEDED ADDITION IN	2009-2010: COALA9	PSEA9	400.	0.75	STEA	1984.

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 19[illegible]2.
NOTES:NOV. 30, 1978 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	1978-1979				1979-1980				1980-1981			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	585.			2531.	632.			2801.	686.			3041.
RESOURCES												
EXISTING												
HYDRO	53.	.50	.50	204.	53.	.50	.50	204.	53.	.50	.50	204.
STEAM/ELEC	51.	.75	.75	332.	51.	.75	.75	332.	51.	.75	.75	332.
COMB.TURBINE	575.	.50	.40	2034.	575.	.50	.36	1810.	689.	.50	.35	2113.
DIESEL	19.	.15	.00	0.	19.	.15	.00	0.	19.	.15	.00	0.
TOTAL	698.			2569.	698.			2346.	812.			2649.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	114.	.50	.50	497.	100.	.50	.50	438.
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	2.	.00	.00	0.
GROSS RESOURCES	698.			2569.	812.			2843.	910.			3087.
CAP RES. MARGIN	0.193				0.284				0.326			
RESERVE REQ.	146.				158.				172.			
LOSSES	29.			38.	32.			42.	34.			46.
NET RESOURCES	523.			2531.	622.			2801.	704.			3041.
TRANSFERED	0.				0.				0.			
SURPLUS	-62.			0.	-10.			0.	18.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	1978-1979				1979-1980				1980-1981			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	184.			804.	197.			862.	209.			916.
RESOURCES												
EXISTING												
HYDRO	0.	.50	.50	0.	0.	.50	.50	0.	0.	.50	.50	0.
STEAM/ELEC	110.	.75	.66	633.	110.	.75	.72	692.	110.	.75	.75	723.
COMB.TURBINE	209.	.50	.10	183.	209.	.50	.10	183.	209.	.50	.11	207.
DIESEL	46.	.10	.00	0.	46.	.10	.00	0.	46.	.10	.00	0.
TOTAL	365.			816.	365.			875.	365.			930.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	365.			816.	365.			875.	365.			930.
CAP RES. MARGIN	0.983				0.852				0.746			
RESERVE REQ.	46.				49.				52.			
LOSSES	9.			12.	10.			13.	10.			14.
NET RESOURCES	310.			804.	306.			862.	302.			916.
TRANSFERED	0.				0.				0.			
SURPLUS	126.			0.	109.			0.	93.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	1981-1982 PEAK	1981-1982 MPUF	1981-1982 APUF	1981-1982 ENERGY	1982-1983 PEAK	1982-1983 MPUF	1982-1983 APUF	1982-1983 ENERGY	1983-1984 PEAK	1983-1984 MPUF	1983-1984 APUF	1983-1984 ENERGY
REQUIREMENTS	741.			3281.	795.			3521.	850.			3761.
RESOURCES												
EXISTING												
HYDRO	53.	.50	.50	204.	53.	.50	.50	204.	53.	.50	.50	204.
STEAM/ELEC	51.	.75	.75	332.	51.	.75	.75	332.	251.	.75	.42	923.
COMB.TURBINE	789.	.50	.39	2716.	807.	.50	.32	2250.	691.	.50	.35	2691.
DIESEL	17.	.15	.00	0.	17.	.15	.00	0.	15.	.15	.00	0.
TOTAL	910.			3251.	928.			2785.	1210.			3817.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	200.	.75	.20	350.	-	-	-	-
COMB.TURBINE	18.	.50	.50	79.	100.	.50	.50	438.	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	15.	.00	.00	0.	8.	.00	.00	0.
DIESEL	-	-	-	-	2.	.00	.00	0.	-	-	-	-
GROSS RESOURCES	928.			3330.	1210.			3574.	1202.			3817.
CAP RES. MARGIN	0.252				0.523				0.414			
RESERVE REQ.	185.				199.				213.			
LOSSES	37.			49.	40.			53.	43.			56.
NET RESOURCES	706.			3281.	972.			3521.	947.			3761.
TRANSFERED	0.				0.				0.			
SURPLUS	-35.			0.	177.			0.	97.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	1981-1982				1982-1983				1983-1984			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	221.			970.	233.			1024.	245.			1078.
RESOURCES												
EXISTING												
HYDRO	0.	.50	.50	0.	0.	.50	.50	0.	0.	.50	.50	0.
STEAM/ELEC	110.	.75	.75	723.	110.	.75	.75	723.	110.	.75	.75	723.
COMB.TURBINE	209.	.50	.14	262.	209.	.50	.17	317.	209.	.50	.21	371.
DIESEL	46.	.10	.00	0.	46.	.10	.00	0.	46.	.10	.00	0.
TOTAL	365.			985.	365.			1039.	365.			1094.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	5.	.00	.00	0.
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	365.			985.	365.			1039.	360.			1094.
CAP RES. MARGIN	0.651				0.566				0.467			
RESERVE REQ.	55.				58.				61.			
LOSSES	11.			15.	12.			15.	12.			16.
NET RESOURCES	299.			970.	295.			1024.	286.			1078.
TRANSFERED	0.				0.				0.			
SURPLUS	78.			0.	62.			0.	41.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
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APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1982.
NOTES:NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1984-1985				1985-1986				1986-1987			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	904.			4001.	976.			4329.	1046.			4657.
RESOURCES												
EXISTING												
HYDRO	53.	.50	.50	204.	53.	.50	.50	204.	134.	.50	.50	510.
STEAM/ELEC	251.	.75	.53	1164.	251.	.75	.64	1405.	458.	.75	.56	2259.
COMB.TURBINE	883.	.50	.34	2615.	886.	.50	.28	2116.	655.	.50	.26	1958.
DIESEL	15.	.15	.00	0.	15.	.15	.00	0.	5.	.15	.00	0.
TOTAL	1202.			3982.	1205.			3724.	1452.			4727.
ADDITIONS												
HYDRO	-	-	-	-	81.	.50	.50	307.	-	-	-	-
STEAM/ELEC	-	-	-	-	207.	.75	.20	363.	-	-	-	-
COMB.TURBINE	18.	.50	.50	79.	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	15.	.00	.00	0.	31.	.00	.00	0.	-	-	-	-
DIESEL	-	-	-	-	10.	.00	.00	0.	-	-	-	-
GROSS RESOURCES	1205.			4061.	1452.			4394.	1452.			4727.
CAP RES. MARGIN	0.333				0.488				0.385			
RESERVE REQ.	226.				244.				262.			
LOSSES	45.			60.	49.			65.	52.			70.
NET RESOURCES	934.			4001.	1159.			4329.	1138.			4657.
TRANSFERED	0.				0.				0.			
SURPLUS	30.			0.	183.			0.	90.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
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APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 A/ U.S.-1994.

C R I T I C A L   P E R I O D

	1984-1985 PEAK	1984-1985 MPUF	1984-1985 APUF	1984-1985 ENERGY	1985-1986 PEAK	1985-1986 MPUF	1985-1986 APUF	1985-1986 ENERGY	1986-1987 PEAK	1986-1987 MPUF	1986-1987 APUF	1986-1987 ENERGY
REQUIREMENTS	258.			1132.	272.			1193.	286.			1254.
RESOURCES												
EXISTING												
HYDRO	0.	.50	.50	0.	0.	.50	.50	0.	0.	.50	.50	0.
STEAM/ELEC	110.	.75	.75	723.	110.	.75	.75	723.	210.	.75	.55	1018.
COMB.TURBINE	204.	.50	.24	426.	204.	.50	.18	313.	204.	.50	.14	254.
DIESEL	46.	.10	.00	0.	22.	.10	.00	0.	22.	.10	.00	0.
TOTAL	360.			1149.	336.			1036.	436.			1273.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	100.	.75	.20	175.	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	24.	.00	.00	0.	-	-	-	-	-	-	-	-
GROSS RESOURCES	336.			1149.	436.			1211.	436.			1273.
CAP RES. MARGIN	0.300				0.601				0.523			
RESERVE REQ.	65.				68.				72.			
LOSSES	13.			17.	14.			18.	14.			19.
NET RESOURCES	258.			1132.	354.			1193.	350.			1254.
TRANSFERED	0.				0.				0.			
SURPLUS	0.			0.	82.			0.	64.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
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APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	1987-1988				1988-1989				1989-1990			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	1120.			4985.	1192.			5313.	1264.			5641.
RESOURCES												
EXISTING												
HYDRO	134.	.50	.50	510.	134.	.50	.50	510.	134.	.50	.50	510.
STEAM/ELEC	458.	.75	.63	2413.	643.	.75	.58	3254.	643.	.75	.66	3745.
COMB.TURBINE	855.	.50	.24	1786.	855.	.50	.23	1628.	791.	.50	.16	1120.
DIESEL	5.	.15	.00	0.	5.	.15	.00	0.	5.	.15	.00	0.
TOTAL	1452.			4709.	1637.			5393.	1573.			5375.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	200.	.75	.20	350.	-	-	-	-	200.	.75	.20	350.
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	15.	.00	.00	0.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	64.	.00	.00	0.	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	1637.			5060.	1573.			5393.	1773.			5726.
CAP RES. MARGIN	0.462				0.320				0.403			
RESERVE REQ.	280.				298.				316.			
LOSSES	56.			75.	60.			80.	63.			85.
NET RESOURCES	1301.			4985.	1216.			5313.	1394.			5641.
TRANSFERED	0.				0.				0.			
SURPLUS	181.			0.	24.			0.	130.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES:NOV. 30, 1978 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	1987-1988 PEAK	MPUF	APUF	ENERGY	1988-1989 PEAK	MPUF	APUF	ENERGY	1989-1990 PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	300.			1315.	314.			1376.	328.			1437.
RESOURCES												
EXISTING												
HYDRO	0.	.50	.50	0.	0.	.50	.50	0.	0.	.50	.50	0.
STEAM/ELEC	210.	.75	.62	1139.	210.	.75	.68	1194.	216.	.75	.59	1105.
COMB.TURBINE	204.	.50	.11	196.	204.	.50	.10	178.	204.	.50	.10	178.
DIESEL	22.	.10	.00	0.	22.	.10	.00	0.	0.	.10	.00	0.
TOTAL	436.			1335.	436.			1372.	419.			1283.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	14.	.75	.20	25.	100.	.75	.20	175.
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	9.	.00	.00	0.	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	22.	.00	.00	0.	-	-	-	-
GROSS RESOURCES	436.			1335.	419.			1397.	519.			1459.
CAP RES. MARGIN	0.452				0.334				0.582			
RESERVE REQ.	75.				79.				82.			
LOSSES	15.			20.	16.			21.	16.			22.
NET RESOURCES	346.			1315.	325.			1376.	421.			1437.
TRANSFERED	0.				0.				0.			
SURPLUS	46.			0.	11.			0.	93.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES:NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1990-1991 PEAK	1990-1991 MPUF	1990-1991 APUF	1990-1991 ENERGY	1991-1992 PEAK	1991-1992 MPUF	1991-1992 APUF	1991-1992 ENERGY	1992-1993 PEAK	1992-1993 MPUF	1992-1993 APUF	1992-1993 ENERGY
REQUIREMENTS	1357.			6063.	1450.			6485.	1543.			6907.
RESOURCES												
EXISTING												
HYDRO	134.	.50	.50	510.	134.	.50	.50	510.	134.	.50	.50	510.
STEAM/ELEC	843.	.75	.62	4577.	843.	.75	.68	4793.	845.	.75	.70	5159.
COMB.TURBINE	791.	.50	.15	1067.	791.	.50	.18	1205.	773.	.50	.16	991.
DIESEL	5.	.15	.00	0.	5.	.15	.00	0.	3.	.15	.00	0.
TOTAL	1773.			6154.	1773.			6508.	1755.			6660.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	43.	.75	.20	74.	200.	.75	.20	350.
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	81.	.00	.00	0.	-	-	-	-
COMB.TURBINE	-	-	-	-	16.	.00	.00	0.	50.	.00	.00	0.
DIESEL	-	-	-	-	2.	.00	.00	0.	-	-	-	-
GROSS RESOURCES	1773.			6154.	1755.			6582.	1906.			7011.
CAP RES. MARGIN	0.307				0.211				0.235			
RESERVE REQ.	339.				290.				309.			
LOSSES	68.			91.	73.			97.	77.			104.
NET RESOURCES	1366.			6063.	1393.			6485.	1520.			6907.
TRANSFERED	0.				57.				0.			
SURPLUS	9.			0.	0.			0.	-23.			0.

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AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES:NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1990-1991				1991-1992				1992-1993			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	343.			1505.	358.			1573.	374.			1641.
RESOURCES												
EXISTING												
HYDRO	0.	.50	.50	0.	0.	.50	.50	0.	0.	.50	.50	0.
STEAM/ELEC	316.	.75	.53	1293.	316.	.75	.51	1418.	316.	.75	.55	1522.
COMB.TURBINE	204.	.50	.10	178.	204.	.50	.10	178.	204.	.50	.10	143.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	519.			1472.	519.			1597.	519.			1666.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	32.	.75	.20	56.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	32.	.00	.00	0.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	40.	.00	.00	0.
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	519.			1528.	519.			1597.	479.			1666.
CAP RES. MARGIN	0.513				0.450				0.281			
RESERVE REQ.	86.				72.				75.			
LOSSES	17.			23.	18.			24.	19.			25.
NET RESOURCES	416.			1505.	430.			1573.	386.			1641.
TRANSFERED	0.				-57.				0.			
SURPLUS	73.			0.	14.			0.	12.			0.

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AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1993-1994				1994-1995				1995-1996			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	1636.			7329.	1729.			7751.	1654.			8311.
RESOURCES												
EXISTING												
HYDRO	134.	.50	.50	510.	134.	.50	.50	510.	706.	.55	.55	2949.
STEAM/ELEC	1045.	.75	.62	5642.	1445.	.75	.34	4333.	1445.	.75	.37	4641.
COMB.TURBINE	724.	.50	.10	586.	669.	.50	.10	586.	669.	.50	.10	477.
DIESEL	3.	.15	.00	0.	3.	.15	.00	0.	3.	.15	.00	0.
TOTAL	1906.			6738.	2251.			5429.	2822.			8067.
ADDITIONS												
HYDRO	-	-	-	-	572.	.56	.56	2438.	86.	.56	.56	369.
STEAM/ELEC	400.	.75	.20	701.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	55.	.00	.00	0.	-	-	-	-	125.	.00	.00	0.
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	2251.			7439.	2822.			7667.	2784.			8436.
CAP RES. MARGIN	0.376				0.632				0.502			
RESERVE REQ.	327.				346.				371.			
LOSSES	82.			110.	86.			116.	93.			125.
NET RESOURCES	1842.			7329.	2390.			7751.	2321.			8311.
TRANSFERED	-7.				0.				0.			
SURPLUS	199.			0.	661.			0.	467.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
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AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1993-1994				1994-1995				1995-1996			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	389.			1709.	405.			1777.	423.			1859.
RESOURCES												
EXISTING												
HYDRO	0.	.50	.50	0.	0.	.50	.50	0.	131.	.56	.56	559.
STEAM/ELEC	316.	.75	.53	1591.	316.	.75	.40	1101.	316.	.75	.42	1059.
COMB.TURBINE	164.	.50	.10	143.	164.	.50	.10	143.	164.	.50	.10	143.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	479.			1735.	479.			1245.	610.			1761.
ADDITIONS												
HYDRO	-	-	-	-	131.	.56	.56	559.	19.	.56	.56	82.
STEAM/ELEC	-	-	-	-	-	-	-	-	25.	.75	.20	43.
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	25.	.00	.00	0.
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	479.			1735.	610.			1804.	629.			1887.
CAP RES. MARGIN	0.231				0.506				0.488			
RESERVE REQ.	76.				81.				85.			
LOSSES	19.			26.	20.			27.	21.			28.
NET RESOURCES	382.			1709.	509.			1777.	524.			1859.
TRANSFERED	7.				0.				0.			
SURPLUS	0.			0.	104.			0.	101.			0.

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AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1996-1997 PEAK	1996-1997 MPUF	1996-1997 APUF	1996-1997 ENERGY	1997-1998 PEAK	1997-1998 MPUF	1997-1998 APUF	1997-1998 ENERGY	1998-1999 PEAK	1998-1999 MPUF	1998-1999 APUF	1998-1999 ENERGY
REQUIREMENTS	1979.			8671.	2103.			9431.	2228.			9991.
RESOURCES												
EXISTING												
HYDRO	792.	.55	.55	3317.	792.	.55	.55	3317.	792.	.55	.55	3317.
STEAM/ELEC	1445.	.75	.43	5393.	1445.	.75	.42	5261.	1845.	.75	.25	4115.
COMB.TURBINE	545.	.50	.10	294.	335.	.50	.10	294.	335.	.50	.10	278.
DIESEL	3.	.15	.00	0.	0.	.15	.00	0.	0.	.15	.00	0.
TOTAL	2784.			9004.	2572.			8872.	2972.			7710.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	570.	.56	.56	2431.
STEAM/ELEC	-	-	-	-	400.	.75	.20	701.	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	210.	.00	.00	0.	-	-	-	-	18.	.00	.00	0.
DIESEL	2.	.00	.00	0.	-	-	-	-	-	-	-	-
GROSS RESOURCES	2572.			9004.	2972.			9572.	3524.			10141.
CAP RES. MARGIN	0.300				0.413				0.582			
RESERVE REQ.	396.				421.				446.			
LOSSES	99.			133.	105.			141.	111.			150.
NET RESOURCES	2078.			8871.	2447.			9431.	2967.			9991.
TRANSFERED	0.				-110.				-14.			
SURPLUS	99.			0.	233.			0.	725.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
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ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1996-1997 PEAK	MPUF	APUF	ENERGY	1997-1998 PEAK	MPUF	APUF	ENERGY	1998-1999 PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	442.			1941.	461.			2023.	480.			2105.
RESOURCES												
EXISTING												
HYDRO	150.	.56	.56	642.	150.	.56	.56	642.	150.	.56	.56	642.
STEAM/ELEC	316.	.75	.44	1206.	316.	.75	.51	1412.	316.	.75	.36	983.
COMB.TURBINE	164.	.50	.10	123.	140.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	629.			1970.	606.			2053.	466.			1624.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	120.	.56	.56	512.
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	24.	.00	.00	0.	140.	.00	.00	0.	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	606.			1970.	466.			2053.	586.			2137.
CAP RES. MARGIN	0.371				0.011				0.221			
RESERVE REQ.	88.				92.				96.			
LOSSES	22.			29.	23.			30.	24.			32.
NET RESOURCES	495.			1941.	351.			2023.	466.			2105.
TRANSFERED	0.				110.				14.			
SURPLUS	53.			0.	0.			0.	0.			0.

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AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES:NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1999-2000 PEAK	MPUF	APUF	ENERGY	2000-2001 PEAK	MPUF	APUF	ENERGY	2001-2002 PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	2353.			10551.	2421.			10863.	2490.			11175.
RESOURCES												
EXISTING												
HYDRO	1362.	.55	.55	5749.	1447.	.55	.55	6110.	1447.	.55	.55	6110.
STEAM/ELEC	1845.	.75	.27	4393.	1845.	.75	.30	4797.	1845.	.75	.32	5129.
COMB.TURBINE	317.	.50	.10	206.	236.	.50	.10	119.	136.	.50	.10	103.
DIESEL	0.	.15	.00	0.	0.	.15	.00	0.	0.	.15	.00	0.
TOTAL	3524.			10348.	3528.			11026.	3428.			11343.
ADDITIONS												
HYDRO	85.	.56	.56	362.	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	82.	.00	.00	0.	100.	.00	.00	0.	18.	.00	.00	0.
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	3528.			10709.	3428.			11026.	3410.			11343.
CAP RES. MARGIN	0.499				0.416				0.369			
RESERVE REQ.	471.				484.				498.			
LOSSES	118.			158.	121.			163.	125.			168.
NET RESOURCES	2939.			10551.	2822.			10863.	2787.			11175.
TRANSFERED	-20.				-31.				-44.			
SURPLUS	566.			0.	370.			0.	253.			0.

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AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	1999-2000				2000-2001				2001-2002			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	499.			2187.	508.			2229.	518.			2270.
RESOURCES												
EXISTING												
HYDRO	270.	.56	.56	1154.	288.	.56	.56	1229.	288.	.56	.56	1229.
STEAM/ELEC	316.	.75	.36	991.	316.	.75	.37	1034.	316.	.75	.39	1075.
COMB.TURBINE	0.	.50	.00	0.	0.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	586.			2145.	604.			2262.	604.			2304.
ADDITIONS												
HYDRO	18.	.56	.56	75.	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	604.			2220.	604.			2262.	604.			2304.
CAP RES. MARGIN	0.209				0.188				0.165			
RESERVE REQ.	100.				102.				104.			
LOSSES	25.			33.	25.			33.	26.			34.
NET RESOURCES	479.			2187.	477.			2229.	474.			2270.
TRANSFERED	20.				31.				44.			
SURPLUS	0.			0.	0.			0.	0.			0.

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AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	2002-2003				2003-2004				2004-2005			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	2558.			11487.	2626.			11799.	2694.			12111.
RESOURCES												
EXISTING												
HYDRO	1447.	.55	.55	6110.	1447.	.55	.55	6110.	1447.	.55	.55	6110.
STEAM/ELEC	1845.	.75	.34	5534.	1845.	.75	.36	5850.	1845.	.75	.38	6183.
COMB.TURBINE	118.	.50	.10	15.	18.	.50	.10	15.	18.	.50	.10	0.
DIESEL	0.	.15	.00	0.	0.	.15	.00	0.	0.	.15	.00	0.
TOTAL	3410.			11659.	3310.			11976.	3310.			12293.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	100.	.00	.00	0.	-	-	-	-	18.	.00	.00	0.
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	3310.			11659.	3310.			11976.	3292.			12293.
CAP RES. MARGIN	0.294				0.260				0.222			
RESERVE REQ.	512.				525.				539.			
LOSSES	128.			172.	131.			177.	135.			182.
NET RESOURCES	2670.			11487.	2653.			11799.	2618.			12111.
TRANSFERED	-80.				0.				76.			
SURPLUS	32.			0.	27.			0.	0.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1976 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	2002-2003 PEAK	MPUF	APUF	ENERGY	2003-2004 PEAK	MPUF	APUF	ENERGY	2004-2005 PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	527.			2312.	537.			2353.	546.			2395.
RESOURCES												
EXISTING												
HYDRO	288.	.56	.56	1229.	288.	.56	.56	1229.	288.	.56	.56	1229.
STEAM/ELEC	316.	.75	.44	1116.	291.	.75	.39	984.	391.	.75	.30	1027.
COMB.TURBINE	0.	.50	.10	0.	0.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	604.			2347.	579.			2213.	679.			2256.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	100.	.75	.20	175.	100.	.75	.20	175.
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	25.	.00	.00	0.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	579.			2347.	679.			2388.	779.			2431.
CAP RES. MARGIN	0.098				0.264				0.426			
RESERVE REQ.	105.				107.				109.			
LOSSES	26.			35.	27.			35.	27.			36.
NET RESOURCES	447.			2312.	544.			2353.	642.			2395.
TRANSFERED	80.				0.				-76.			
SURPLUS	0.			0.	7.			0.	20.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
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APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	2005-2006 PEAK	MPUF	APUF	ENERGY	2006-2007 PEAK	MPUF	APUF	ENERGY	2007-2008 PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	2763.			12423.	2831.			12735.	2899.			13047.
RESOURCES												
EXISTING												
HYDRO	1447.	.55	.55	6110.	1447.	.55	.55	6110.	1447.	.55	.55	6110.
STEAM/ELEC	1845.	.75	.36	5799.	2245.	.75	.35	6816.	2245.	.75	.36	7133.
COMB.TURBINE	0.	.50	.10	0.	0.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.15	.00	0.	0.	.15	.00	0.	0.	.15	.00	0.
TOTAL	3292.			11909.	3692.			12926.	3692.			13243.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	400.	.75	.20	701.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	3692.			12609.	3692.			12926.	3692.			13243.
CAP RES. MARGIN	0.336				0.304				0.273			
RESERVE REQ.	553.				566.				580.			
LOSSES	138.			186.	142.			191.	145.			196.
NET RESOURCES	3001.			12423.	2984.			12735.	2967.			13047.
TRANSFERED	0.				0.				0.			
SURPLUS	238.			0.	153.			0.	68.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: - -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1978 W/ U.S.-1994.

CRITICAL PERIOD

	2005-2006				2006-2007				2007-2008			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	556.			2437.	565.			2476.	575.			2520.
RESOURCES												
EXISTING												
HYDRO	288.	.56	.56	1229.	288.	.56	.56	1229.	288.	.56	.56	1229.
STEAM/ELEC	491.	.75	.30	1245.	471.	.75	.31	1286.	471.	.75	.32	1329.
COMB.TURBINE	0.	.50	.10	0.	0.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	779.			2474.	759.			2515.	759.			2556.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	20.	.00	.00	0.	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	759.			2474.	759.			2515.	759.			2558.
CAP RES. MARGIN	0.364				0.343				0.319			
RESERVE REQ.	111.				113.				115.			
LOSSES	28.			37.	28.			37.	29.			38.
NET RESOURCES	620.			2437.	617.			2478.	615.			2520.
TRANSFERED	0.				0.				0.			
SURPLUS	64.			0.	52.			0.	40.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: ANCHORAGE
ANCHORAGE CASE: 2 -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 19--2.
NOTES: NOV. 30, 1979 W/ U.S.-1[illegible].

CRITICAL PERIOD

	2008-2009 PEAK	MPUF	APUF	ENERGY	2009-2010 PEAK	MPUF	APUF	ENERGY	2010-2011 PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	2968.			13359.	3036.			13671.	3104.			13983.
RESOURCES												
EXISTING												
HYDRO	1447.	.55	.55	6110.	1447.	.55	.55	6110.	1447.	.55	.55	6110.
STEAM/ELEC	2245.	.75	.35	7450.	2245.	.75	.36	7065.	2645.	.75	.35	8083.
COMB.TURBINE	0.	.50	.10	0.	0.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.15	.00	0.	0.	.15	.00	0.	0.	.15	.00	0.
TOTAL	3692.			13559.	3692.			13175.	4092.			14193.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	400.	.75	.20	701.	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	3692.			13559.	4092.			13876.	4092.			14193.
CAP RES. MARGIN	0.244				0.348				0.318			
RESERVE REQ.	594.				607.				621.			
LOSSES	148.			200.	152.			205.	155.			210.
NET RESOURCES	2950.			13359.	3333.			13671.	3316.			13983.
TRANSFERED	18.				0.				0.			
SURPLUS	0.			0.	297.			0.	212.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

AREA: FAIRBANKS
FAIRBANKS CASE: [illegible] -- MEDIUM LOAD GROWTH
INTERTIE YEAR: 1992.
NOTES: NOV. 30, 1979 W/ U.S.-1994.

C R I T I C A L   P E R I O D

	2008-2009				2009-2010				2010-2011			
	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY	PEAK	MPUF	APUF	ENERGY
REQUIREMENTS	584.			2561.	594.			2603.	603.			2645.
RESOURCES												
EXISTING												
HYDRO	288.	.56	.56	1229.	288.	.56	.56	1229.	288.	.56	.56	1229.
STEAM/ELEC	471.	.75	.33	1371.	471.	.75	.34	1413.	471.	.75	.35	1456.
COMB.TURBINE	0.	.50	.10	0.	0.	.50	.10	0.	0.	.50	.10	0.
DIESEL	0.	.10	.00	0.	0.	.10	.00	0.	0.	.10	.00	0.
TOTAL	759.			2599.	759.			2642.	759.			2685.
ADDITIONS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
RETIREMENTS												
HYDRO	-	-	-	-	-	-	-	-	-	-	-	-
STEAM/ELEC	-	-	-	-	-	-	-	-	-	-	-	-
COMB.TURBINE	-	-	-	-	-	-	-	-	-	-	-	-
DIESEL	-	-	-	-	-	-	-	-	-	-	-	-
GROSS RESOURCES	759.			2599.	759.			2642.	759.			2685.
CAP RES. MARGIN	0.299				0.277				0.258			
RESERVE REQ.	117.				119.				121.			
LOSSES	29.			38.	30.			39.	30.			40.
NET RESOURCES	613.			2561.	610.			2603.	608.			2645.
TRANSFERED	-18.				0.				0.			
SURPLUS	10.			0.	16.			0.	5.			0.

PEAK -- PEAK LOAD/GENERATING CAPACITY REQUIREMENTS(MEGAWATTS)
MPUF -- MAXIMUM PLANT UTILIZATION FACTOR
APUF -- ACTUAL PLANT UTILIZATION FACTOR
ENERGY -- GENERATION/ANNUAL ENERGY REQUIREMENTS(MILLIONS OF KILOWATT-HOURS)

EXHIBIT C-2

LOAD RESOURCE ANALYSES (GRAPHS)

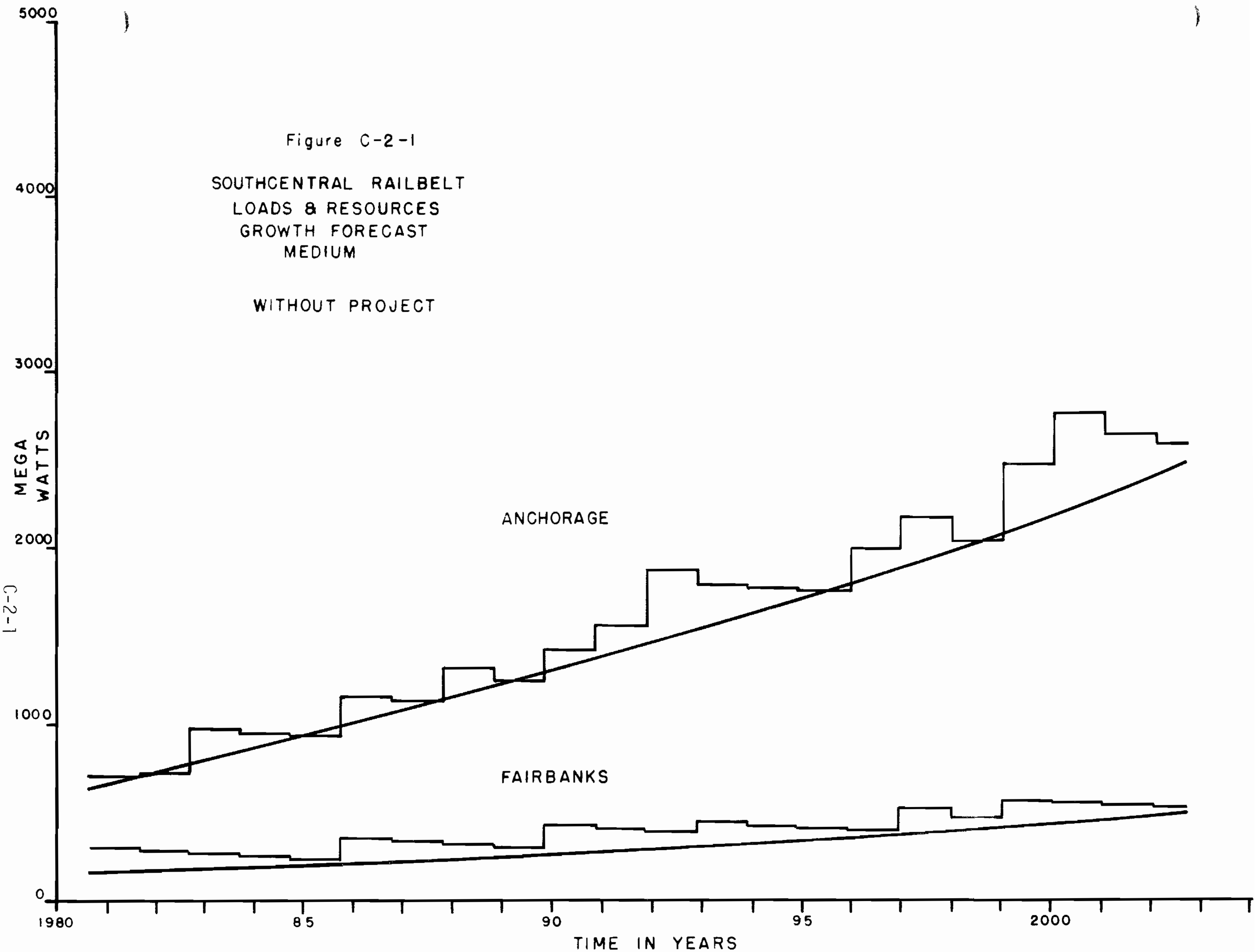
Figure C-2-1
SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
GROWTH FORECAST
MEDIUM
WITHOUT PROJECT
MEGA WATTS
5000
4000
3000
2000
1000
0
ANCHORAGE
FAIRBANKS
1980
85
90
95
2000
TIME IN YEARS

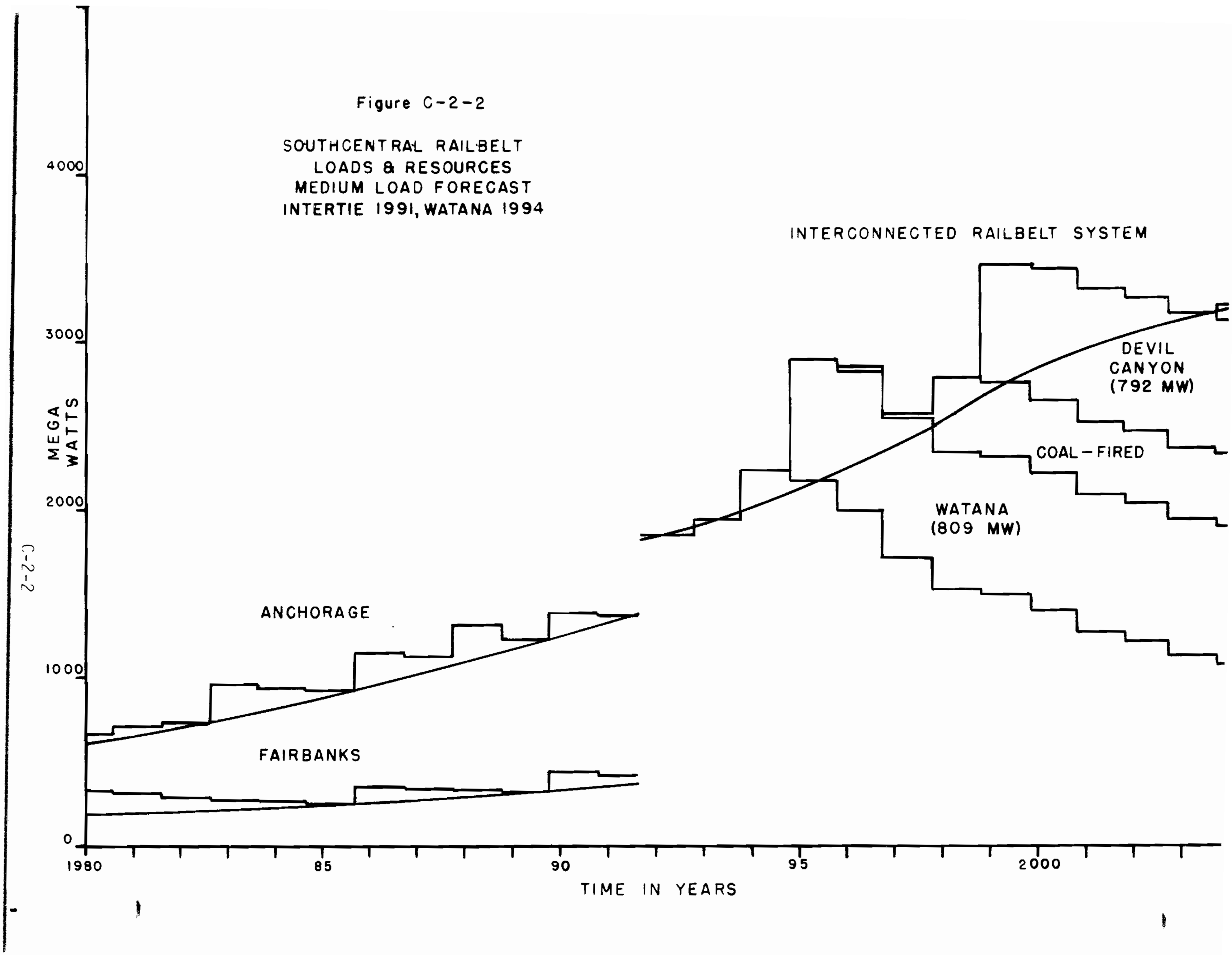

Figure C-2-2
SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
MEDIUM LOAD FORECAST
INTERTIE 1991, WATANA 1994
INTERCONNECTED RAILBELT SYSTEM
DEVIL
CANYON
(792 MW)
COAL-FIRED
WATANA
(809 MW)
ANCHORAGE
FAIRBANKS
MEGA WATTS
4000
3000
2000
1000
0
1980
85
90
95
2000
TIME IN YEARS

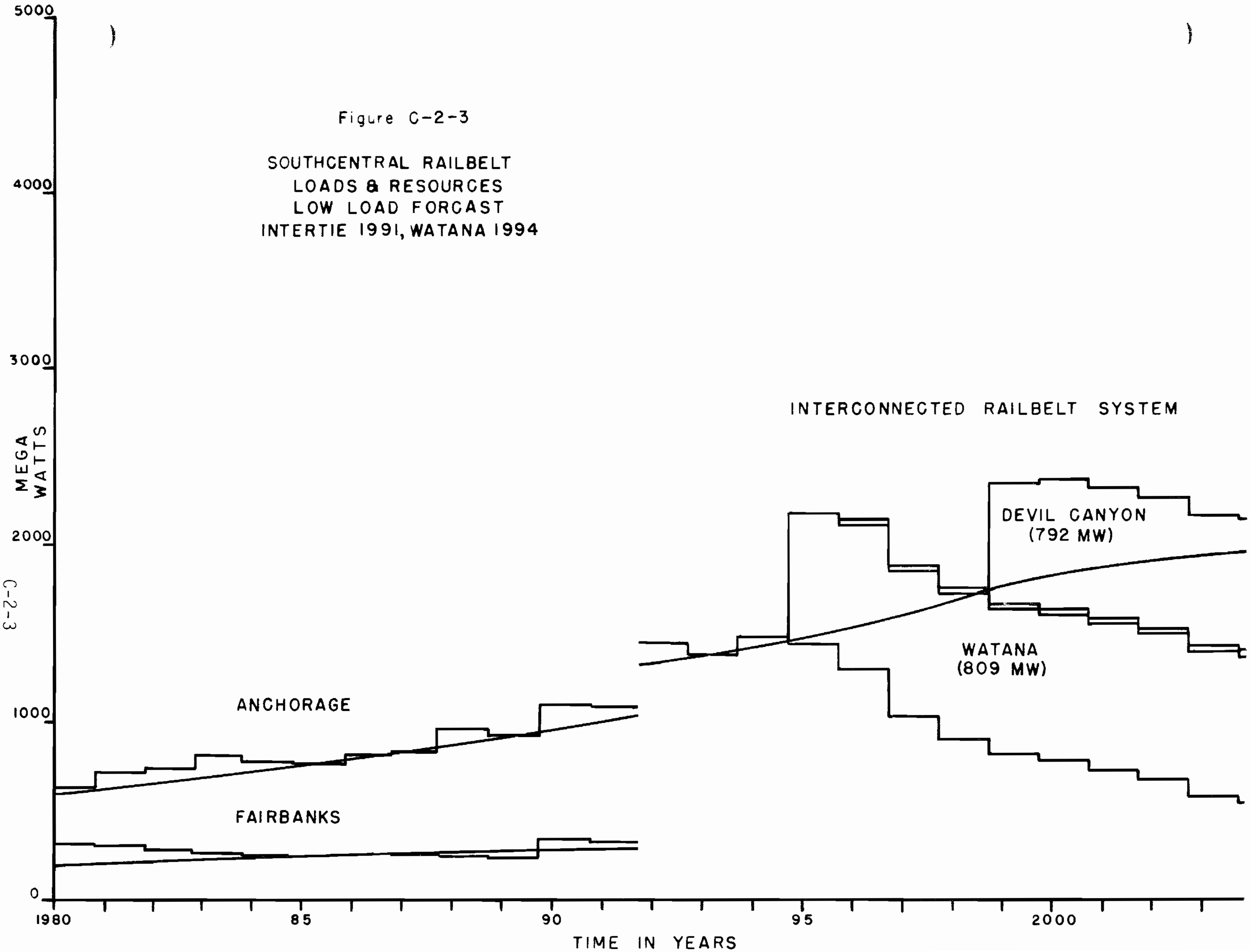
Figure C-2-3
SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
LOW LOAD FORCAST
INTERTIE 1991, WATANA 1994
MEGA WATTS
5000
4000
3000
2000
1000
0
INTERCONNECTED RAILBELT SYSTEM
DEVIL CANYON
(792 MW)
WATANA
(809 MW)
ANCHORAGE
FAIRBANKS
1980
85
90
95
2000
TIME IN YEARS

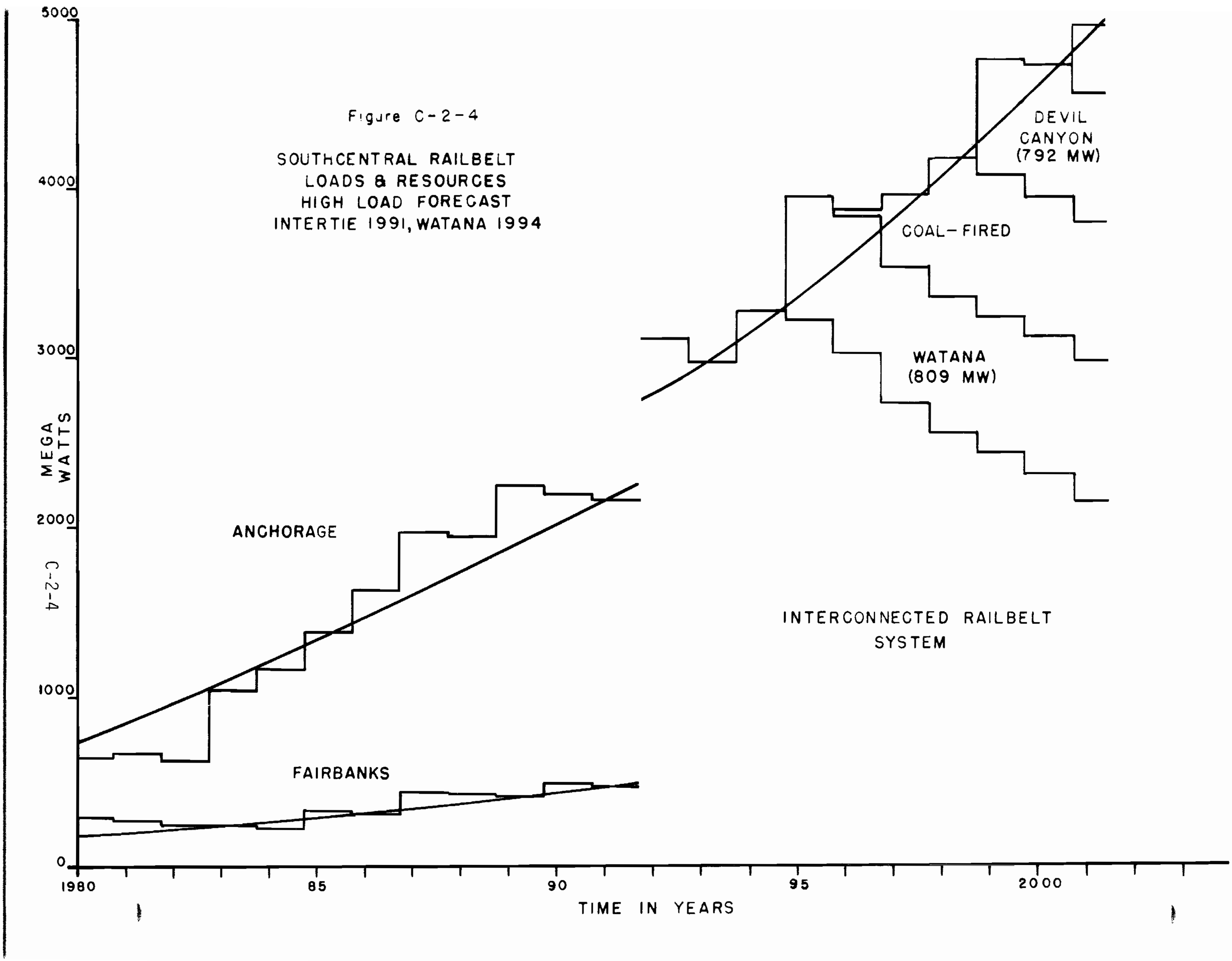
Figure C-2-4
SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
HIGH LOAD FORECAST
INTERTIE 1991, WATANA 1994
MEGA WATTS
5000
4000
3000
2000
1000
0
1980
85
90
95
2000
TIME IN YEARS
ANCHORAGE
FAIRBANKS
INTERCONNECTED RAILBELT
SYSTEM
DEVIL
CANYON
(792 MW)
COAL-FIRED
WATANA
(809 MW)

EXHIBIT C-3

USABLE CAPACITY SUMMARY

TABLE C-3-1

USABLE CAPACITY SUMMARY
(Dependable Capacity Only)

Year	94 1/, Low 2/	94, Med	94, High	96, Med
1994	0	27	99	
1995	214	265	533	
1996	533	680	680	160
1997	680	680	680	476
1998	*858	*950	*1,151	674
1999	1,023	1,035	1,347	680
2000	1,143	1,231		*731
2001	1,178	1,347		847
2002	1,321			1,069
2003	1,339			1,167
2004	1,347			1,281
2005				1,347

NOTES: 1/ Watana power-on-line and interconnection date.
2/ Low, Medium or High load forecast.
* Year of Devil Canyon power-on-line.

EXHIBIT C-4

POWER VALUE CALCULATIONS

TABLE C-4-1

COAL-FIRED, FERC VALUES
BASE CASE AND FUEL ESCALATION TO POL

Item of Cost	Anchorage		Fairbanks		(A) Base Case 1/	(B) Fuel Escalated to 1994 @ 2%
Interest & Amortization	110.77 X .80 =	$ 88.62	99.64 X .20 =	$19.93	$108.55	$108.55
Interim Replacements, Insurance, and Taxes	9.26 X .80 =	7.41	8.33 X .20 =	1.66	9.07	9.07
Annual Carrying Cost of Fuel Inventory	.91 X .80 =	.73	.48 X .20 =	.10	.83	1.20
Fixed Operating Costs	14.69 X .80 =	11.75	16.29 X .20 =	3.26	15.01	15.01
Administrative & General	5.65 X .80 =	4.52	6.68 X .20 =	1.34	5.86	5.86
Transmission Cost	30.25 X .80 =	24.20	30.50 X .20 =	6.10	30.30	30.30
Total Capacity Cost ($/Kw)		$137.23		$32.39	$169.62	$169.99
with Hydro Adjustment					186.58	186.99
Energy Fuel (mils/kWh)	11.00 X .80 =	$ 8.80	8.40 X .20 =	$ 1.68	$ 10.48	$ 14.39
Variable O&M	1.64 X .80 =	1.31	1.82 X .20 =	.37	1.68	1.68
Transmission Cost	.65 X .80 =	.52	.42 X .20 =	.08	.60	.60
Total Energy Cost (mil/Kwh)		$ 10.63		$ 2.13	$12.76	$ 16.67

1/ Base case is a composite value based on the weighted average of Anchorage and Fairbanks values. The 80-20 proportion is derived from the relative future estimated electrical needs of Anchorage and Fairbanks.

TABLE C-4-2
COAL-FIRED, FERC VALUES

Item of Cost	(C) With 3% Inflation	(D) With 5% Inflation	(E) With 2% Fuel Escalation 1/	(F) With 3% Inflation & 2% Fuel Escalation	(G) With 5% Inflation & 2% Fuel Escalation
Interest & Amortization	A X 1.08 = 117.23	A X 1.15 = 124.83	108.55	E X 1.08 = 117.23	E X 1.15 = 124.83
Interim Replacements, Insurance & Taxes	A X 1.34 = 12.15	A X 1.64 = 14.87	9.07	E X 1.34 = 12.15	E X 1.64 = 14.87
Annual Carrying Cost of Fuel Inventory	A X 1.34 = 1.11	A X 1.64 = 1.36	B X 1.32 = 1.58	E X 1.34 = 2.12	E X 1.64 = 2.59
Fixed Operating Costs	A X 1.34 = 20.23	A X 1.64 = 24.62	15.01	E X 1.34 = 20.11	E X 1.64 = 24.62
Administrative & General	A X 1.34 = 7.85	A X 1.64 = 9.61	5.86	E X 1.34 = 7.85	E X 1.64 = 9.61
Transmission Cost	30.30	30.30	30.30	30.30	30.30
Total Capacity Cost ($/Kw)	188.87	205.59	170.37	189.76	206.82
with Hydro Adjustment	207.76	226.15	187.41	208.74	227.50
Energy Fuel	A X 1.34 = 14.04	A X 1.64 = 17.19	B X 1.32 =18.99	E X 1.34 = 25.45	E X 1.64 = 31.14
Variable O&M	A X 1.34 = 2.25	A X 1.64 = 2.76	1.68	E X 1.34 = 2.25	E X 1.64 = 2.76
Transmission Cost	.60	.60	.60	.60	.60
Total Energy Cost (mil/Kwh)	16.89	20.55	21.27	28.30	34.50

1/ Fuel escalates from 1978 to POL and from POL through 30-year life of initial thermal plant.

TABLE C-4-3

COAL-FIRED, FEDERAL FINANCING, & APA INVESTMENT COST

Item of Cost	(H) Federal Financing	(I) APA Investment Cost	(J) APA With 3% Inflation & 2% Fuel Escalation
Interest & Amortization	101.73	137.77	148.79
Interim Replacements, Insurance & Taxes		11.51	15.42
Annual Carrying Cost of Fuel Inventory	.71	.83	1.78
Fixed Operating Costs	15.01	15.01	20.11
Administrative & General	5.86	5.86	7.85
Transmission Cost	26.93	30.30	30.30
Total Capacity Cost ($/Kw)	150.24	201.28	224.25
with Hydro Adjustment	165.26	221.41	246.68
Energy Fuel	10.48	10.48	21.40
Variable O&M	1.68	1.68	2.25
Transmission Cost	.60	.60	.60
Total Energy Cost (mil/Kwh)	12.76	12.76	24.25

TABLE C-4-4

OIL-FIRED, FERC VALUES

Item of Cost	(K) Fuel Escalation to 1994	(L) No Inflation, No Escalation
Interest & Amortization	29.22	29.22
Interim Replacements, Insurance & Taxes	2.55	2.55
Annual Carrying Cost of Fuel Inventory	2.52	1.75
Fixed Operating Costs	--	--
Administrative & General	2.98	2.98
Transmission Cost	5.36	5.36
Total Capacity Cost ($/Kw)	42.63	41.86
with Hydro Adjustment	44.76	43.95
Energy Fuel	33.28	24.24
Variable O&M	1.70	1.70
Transmission Cost	.98	.98
Total Energy Cost (mil/Kwh)	35.96	26.92

TABLE C-4-5
OIL-FIRED, FERC VALUES

Item of Cost	(M) With 3% Inflation	(N) With 5% Inflation	(P) With 2% Fuel Escalation	(Q) With 3% Inflation & 2% Fuel Escalation	(R) With 5% Inflation & 2% Fuel Escalation
Interest & Amortization	L X 1.08 = 31.56	L X 1.15 = 33.60	29.22	P X 1.08 = 31.56	P X 1.15 = 33.60
Interim Replacements, Insurance & Taxes	L X 1.34 = 3.42	L X 1.64 = 4.18	2.55	P X 1.34 = 3.42	P X 1.64 = 4.18
Annual Carrying Cost of Fuel Inventory	L X 1.34 = 2.35	L X 1.64 = 2.87	K X 1.32 = 3.33	P X 1.34 = 4.46	P X 1.64 = 5.46
Fixed Operating Costs	--	--	--	--	--
Administrative & General	L X 1.34 = 3.99	L X 1.64 = 4.89	2.98	P X 1.34 = 3.99	P X 1.64 = 4.89
Transmission Cost	5.36	5.36	5.36	5.36	5.36
Total Capacity Cost ($/Kw)	46.68	50.90	43.44	48.79	53.49
with Hydro Adjustment	49.01	53.45	45.61	51.23	56.16
Energy Fuel	L X 1.34 = 35.48	L X 1.64 = 39.75	K X 1.32 =43.93	P X 1.34 = 58.87	P X 1.64 = 72.05
Variable O&M	L X 1.34 = 2.28	L X 1.64 = 2.79	1.70	P X 1.34 = 2.28	P X 1.64 = 2.79
Transmission Cost	.98	.98	.98	.98	.98
Total Energy Cost (mil/Kwh)	38.74	43.52	46.61	62.13	75.82

TABLE C-4-6
OIL-FIRED, FERC VALUES, FUEL ESCALATION AFTER POL

Item of Cost	(S) Without Inflation	(T) With 3% Inflation & 2% Fuel Escalation	(U) With 5% Inflation & 2% Fuel Escalation
Interest & Amortization	29.22	S X 1.08 = 31.56	S X 1.15 = 33.60
Interim Replacements, Insurance & Taxes	2.55	S X 1.34 = 3.42	S X 1.64 = 4.18
Annual Carrying Cost of Fuel Inventory (2% Esc after POL)	L X 1.32 = 2.31	S X 1.34 = 3.10	S X 1.64 = 3.79
Fixed Operating Costs	--	--	--
Administrative & General	2.98	S X 1.34 = 3.99	S X 1.64 = 4.89
Transmission Cost	5.36	5.36	5.36
Total Capacity Cost ($/Kw)	42.42	47.43	51.82
with Hydro Adjustment	44.54	49.80	54.41
Energy Fuel (2% Esc after POL)	L X 1.32 = 32.00	S X 1.34 = 42.88	S X 1.64 = 52.48
Variable O&M	1.70	S X 1.34 = 2.28	S X 1.64 = 2.79
Transmission Cost	.98	.98	.98
Total Energy Cost (mil/Kwh)	34.68	46.14	56.25

TABLE C-4-7

OIL-FIRED, FERC VALUES, FUEL COST DECLINE OF 35%

Item of Cost	(V) Without Inflation	(W) With 3% Inflation & 2% Fuel Escalation	(X) With 5% Inflation & 2% Fuel Escalation
Interest & Amortization	29.22	V X 1.08 = 31.56	V X 1.15 = 33.60
Interim Replacements, Insurance & Taxes	2.55	V X 1.34 = 3.42	V X 1.64 = 4.18
Annual Carrying Cost of Fuel Inventory	1.19	V X 1.34 = 1.59	V X 1.64 = 1.95
Fixed Operating Costs	--	--	--
Administrative & General	2.98	V X 1.34 = 3.99	V X 1.64 = 4.89
Transmission Cost	5.36	5.36	5.36
Total Capacity Cost ($/Kw)	41.30	45.92	49.98
with Hydro Adjustment	43.37	48.22	52.48
Energy Fuel	15.77	V X 1.34 = 21.13	V X 1.64 = 25.86
Variable O&M	1.70	V X 1.34 = 2.28	V X 1.64 = 2.79
Transmission Cost	.98	.98	.98
Total Energy Cost (mil/Kwh)	18.45	24.39	29.63

TABLE C-4-8

HYDROPOWER COSTS WITH INFLATION
($1,000)

Cost Item	No Inflation	3% Inflation		5% Inflation	
Interest and Amortization	216,671	X 1	= 216,671	X 1	= 216,671
Operation and Maintenance	2,890	X 1.34 =	3,873	X 1.64 =	4,740
Replacement	430	X 1.34 =	576	X 1.64 =	705
Total	219,991		221,120		222,116

EXHIBIT C-5

POWER BENEFIT CALCULATIONS

WATANA AND DEVIL CANYON MID RANGE

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (KW)	PRESENT WORTH OF CAPACITY (KW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	4713.6	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	40495.3
1995	0.8755	265.0	232.0	43287.1	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	81883.5
1996	0.8192	680.0	557.0	103931.1	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	140044.7
1997	0.7665	680.0	521.2	97245.5	3058.0	2343.9	29907.7	397.0	304.3	3882.7	0.0	131036.0
1998	0.7172	950.0	681.3	127116.3	6057.0	4343.9	55427.8	397.0	284.7	3633.0	0.0	186179.0
1999	0.6710	1035.0	694.5	129583.2	6057.0	4064.4	51862.3	785.0	526.8	6721.5	0.0	188166.9
2000	0.6279	1231.0	772.9	144208.3	6057.0	3803.0	48526.1	785.0	492.9	6289.1	0.0	199023.5
2001	0.5875	1347.0	791.3	147646.7	6057.0	3558.3	45404.5	785.0	461.2	5884.5	54.9	198990.5
2002	0.5497	1347.0	740.4	138148.9	6057.0	3329.4	42483.8	785.0	431.5	5506.0	9076.6	195215.3
				935882.7			375519.3			40501.4	9131.4	1361034.7
2003												
2094	7.9766	1347.0	10744.5	2004703.7	6057.0	48314.2	616489.6	785.0	6261.6	79898.4	131712.2	2832803.9
PRESENT WORTH BENEFITS				2940586.5			992008.9			120399.7	140843.6	4193838.6
CRF=	0.0688 AV ANN BENEFITS =			202427.5			68289.1			8288.2	9695.6	288700.4

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	186.58	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	TOTALS---POWER VALUES & INTEREST
NEW SYSTEM				
WATANA AND DEVIL CANYON MID RANGE	202428.	68289.	8288.	288700.
NEW SYSTEM				

C-5-1

WATANA ALONE - COAL

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	4713.6	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	40495.3
1995	0.8755	265.0	232.0	43257.1	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	81883.5
1996	0.8192	680.0	557.0	103931.1	3058.0	2505.0	31963.9	397.0	325.2	4149.7	76.4	140121.1
1997	0.7665	680.0	521.2	97245.5	3058.0	2343.9	29907.7	397.0	304.3	3882.7	5505.8	136541.8
				249177.3			131814.8			12467.3	5582.2	399041.7
1998												
2094	11.1298	680.0	7568.3	1412089.4	3058.0	34035.0	434286.5	397.0	4418.5	56380.6	79949.2	1982705.7
PRESENT WORTH BENEFITS				1661266.8			566101.3			68847.9	85531.4	2381747.4
CRF=	0.0688 AV ANN BENEFITS =			114360.2			38969.9			4739.4	5887.9	163957.5

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

CAPACITY ENERGY SECONDARY INTEREST
1 186.58 12.76 12.76 0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

WATANA ALONE - COAL — 114360. 38970. 4739. 163958.

NEW SYSTEM

FEDERAL FINANCING

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	4175.0	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	39956.7
1995	0.8755	265.0	232.0	38340.6	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	76937.2
1996	0.8192	680.0	557.0	92055.2	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	128168.8
1997	0.7665	680.0	521.2	86133.5	3058.0	2343.9	29907.7	397.0	304.3	3882.7	0.0	119924.0
1998	0.7172	950.0	681.3	112592.8	6057.0	4343.9	55427.8	397.0	284.7	3633.0	0.0	171653.6
1999	0.6710	1035.0	694.5	114776.1	6057.0	4064.4	51862.3	785.0	526.8	6721.5	0.0	173359.8
2000	0.6279	1231.0	772.9	127730.0	6057.0	3803.0	48526.1	785.0	492.9	6289.1	0.0	182545.2
2001	0.5975	1347.0	791.3	130775.5	6057.0	3558.3	45404.5	785.0	461.2	5884.5	48.5	182113.1
2002	0.5497	1347.0	740.4	122363.0	6057.0	3329.4	42483.8	785.0	431.5	5506.0	8039.4	178392.2
				828941.9			375519.3			40501.4	8088.0	1253050.5
2003												
2094	7.9766	1347.0	10744.5	1775631.6	6057.0	48314.2	616489.6	785.0	6261.6	79898.4	116661.8	2588681.3
PRESENT WORTH BENEFITS				2604573.5			992008.9			120399.7	124749.7	3841731.8
CRF= 0.0688 AV ANN BENEFITS =				179296.7			68289.1			8288.2	8587.7	264461.6

CAPACITY VALUE = 165.26000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	165.26	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

FEDERAL FINANCING — 179297. 68289. 8288. 264462.

NEW SYSTEM

C-5-4

FEDERAL FINANCING - WATANA ALONE

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	4175.0	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	39956.7
1995	0.8755	265.0	232.0	38340.8	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	76937.2
1996	0.8192	680.0	557.0	92055.2	3058.0	2505.0	31963.9	397.0	325.2	4149.7	67.7	128236.4
1997	0.7665	680.0	521.2	86133.5	3058.0	2343.9	29907.7	397.0	304.3	3882.7	4876.7	124800.7
				220704.5			131814.8			12467.3	4944.4	369931.0
1998 2094	11.1298	680.0	7558.3	1250733.7	3058.0	34035.0	434286.5	397.0	4418.5	56380.6	70813.6	1812214.4
PRESENT WORTH BENEFITS				1471438.2			566101.3			68847.9	75758.0	2182145.4
CRF=	0.0688	AV ANN BENEFITS =		101292.6			38969.9			4739.4	5215.1	150217.1

CAPACITY VALUE = 165.26000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	165.26	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	TOTALS---POWER VALUES & INTEREST
NEW SYSTEM				
FEDERAL FINANCING - WATANA ALONE	101293.	38970.	4739.	150217.
NEW SYSTEM				

5% DISCOUNT RATE

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9524	27.0	25.7	4797.2	2997.0	2854.3	36420.7	0.0	0.0	0.0	0.0	41218.5
1995	0.9070	265.0	240.4	44546.9	3058.0	2773.7	35392.4	397.0	360.1	4594.8	0.0	84834.0
1996	0.8638	680.0	587.4	109598.9	3058.0	2641.6	33707.0	397.0	342.9	4376.0	0.0	147681.8
1997	0.8227	680.0	559.4	104379.9	3058.0	2515.8	32101.9	397.0	326.6	4167.6	0.0	140649.4
1998	0.7835	950.0	744.3	138890.8	6057.0	4745.8	60556.6	397.0	311.1	3969.1	0.0	203406.6
1999	0.7462	1035.0	772.3	144101.9	6057.0	4519.8	57673.0	785.0	585.8	7474.5	0.0	209249.4
2000	0.7107	1231.0	874.8	163229.3	6057.0	4304.6	54926.7	785.0	557.9	7118.6	0.0	225274.5
2001	0.6768	1347.0	911.7	170105.5	6057.0	4099.6	52311.1	785.0	531.3	6779.6	63.1	229259.3
2002	0.6446	1347.0	868.3	162005.2	6057.0	3904.4	49820.1	785.0	506.0	6456.8	10644.0	228926.1
				1041946.1			412909.5			44937.0	10707.1	1510499.6
2003												
2094	12.7401	1347.0	17160.9	3201880.6	6057.0	77166.7	984647.3	785.0	10001.0	127612.4	210368.5	4524508.8
PRESENT WORTH BENEFITS				4243826.6			1397556.8			172549.4	221075.7	6035008.4
CRF= 0.0504 AV ANN BENEFITS =				213817.3			70413.3			8693.6	11138.5	304062.7

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.05000

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	186.58	12.76	12.76	0.05000

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

5% DISCOUNT RATE — 213817. 70413. 8694. 304063.

NEW SYSTEM

8% DISCOUNT RATE

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	( )	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9259	27.0	[illegible]5.0	4664.5	2997.0	2775.0	35409.0	0.0	0.0	0.0	0.0	40073.5
1995	0.8573	265.0	2[illegible].2	42390.7	3058.0	2621.7	33453.4	397.0	340.4	4343.0	0.0	80186.5
1996	0.7938	690.0	5[illegible]9.8	100717.0	3058.0	2427.5	30975.4	397.0	315.2	4021.3	0.0	135713.7
1997	0.7350	650.0	4[illegible].8	93256.5	3058.0	2247.7	28680.9	397.0	291.8	3723.5	0.0	125660.9
1998	0.6806	950.0	6[illegible].6	120634.1	6057.0	4122.3	52600.5	397.0	270.2	3447.6	0.0	176682.1
1999	0.6302	1035.0	6[illegible]2.2	121692.2	6057.0	3816.9	48704.1	785.0	494.7	6312.2	0.0	176708.5
2000	0.5835	1231.0	7[illegible].3	134016.1	6057.0	3534.2	45096.4	785.0	458.0	5844.6	0.0	184957.1
2001	0.5403	1347.0	7[illegible]7.7	135782.1	6057.0	3272.4	41755.9	785.0	424.1	5411.7	50.4	183000.1
2002	0.5002	1347.0	6[illegible]3.8	125724.2	6057.0	3030.0	38662.9	785.0	392.7	5010.8	8260.3	177658.2
				878376.7			355338.6			38114.7	8310.7	1280640.6
2003												
2094	6.2474	1347.0	8415.3	1570124.4	6057.0	37840.7	482847.1	785.0	4904.2	62578.0	103159.6	2218709.1
PRESENT WORTH BENEFITS				2449001.1			838185.7			100692.7	111470.3	3499349.7
CRF= 0.0800 AV ANN BENEFITS =				196009.2			67085.3			8059.1	8921.7	280075.3

CAPACITY VALUE = 185.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.08000

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	186.58	12.76	12.76	0.08000

1

SYSTEM OF DEVELOPMENT
NEW SYSTEM
8% DISCOUNT RATE
NEW SYSTEM

CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

196009. 67085. 8059. 280075.

LOW LOAD GROWTH

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	0.0	0.0	0.0	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	35781.7
1995	0.8755	214.0	187.4	34955.3	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	73552.8
1996	0.8192	533.0	436.6	81463.7	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	117577.2
1997	0.7665	680.0	521.2	97245.5	3058.0	2343.9	29907.7	397.0	304.3	3882.7	0.0	131036.0
1998	0.7172	858.0	615.3	114807.9	6057.0	4343.9	55427.8	397.0	284.7	3633.0	0.0	173868.6
1999	0.6710	1023.0	686.5	128080.5	6057.0	4064.4	51862.3	785.0	526.8	6721.5	0.0	186664.5
2000	0.6279	1143.0	717.7	133899.3	6057.0	3803.0	48526.1	785.0	492.9	6289.1	0.0	188714.5
2001	0.5875	1178.0	692.0	129122.3	6057.0	3558.3	45404.5	785.0	461.2	5884.5	0.0	180411.4
2002	0.5497	1321.0	726.1	135482.4	6057.0	3329.4	42483.8	785.0	431.5	5506.0	0.0	183472.1
2003	0.5143	1339.0	688.7	128494.5	6057.0	3115.3	39750.9	785.0	403.7	5151.8	0.0	173397.2
2004	0.4812	1347.0	648.2	120947.0	6057.0	2914.9	37193.8	785.0	377.8	4820.4	1302.0	164263.2
2005	0.4503	1347.0	606.5	113166.5	6057.0	2727.4	34801.2	785.0	353.5	4510.3	2856.5	155334.9
2006	0.4213	1347.0	567.5	105887.1	6057.0	2551.9	32562.6	785.0	330.7	4220.2	3301.6	145971.4
2007	0.3942	1347.0	531.0	99075.	6057.0	2387.8	30467.9	785.0	309.5	3948.7	3751.2	137243.4
2008	0.3689	1347.0	496.9	92702.4	6057.0	2234.2	28508.0	785.0	289.6	3694.7	4129.3	129034.3
2009	0.3451	1347.0	464.9	86739.0	6057.0	2090.4	26674.1	785.0	270.9	3457.0	4475.4	121345.6
2010	0.3229	1347.0	435.0	81159.3	6057.0	1956.0	24958.2	785.0	253.5	3234.6	5332.3	114684.5
				1683230.1			630436.0			73539.1	25148.2	2412353.4
2011 2094	4.6783	1347.0	6301.7	1175764.2	6057.0	28336.4	361572.8	785.0	3672.5	46860.6	77249.5	1661447.2
PRESENT WORTH BENEFITS				2858994.3			992008.9			120399.7	102397.7	4073800.6
CRF=	0.0688 AV ANN BENEFITS =			196810.8			68289.1			8288.2	7049.0	280437.1

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	186.58	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM
LOW LOAD GROWTH 196811. 68289. 8288. 280437.
NEW SYSTEM

HIGH LOAD GROWTH

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	99.0	92.6	17283.2	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	53064.9
1995	0.8755	533.0	466.6	87064.3	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	125660.7
1996	0.8192	680.0	557.0	103931.1	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	140044.7
1997	0.7665	680.0	521.2	97245.5	3058.0	2343.9	29907.7	397.0	304.3	3982.7	0.0	131036.0
1998	0.7172	1151.0	825.5	154013.8	6057.0	4343.9	55427.6	397.0	284.7	3633.0	0.0	213074.6
1999	0.6710	1347.0	903.9	168646.0	6057.0	4064.4	51862.3	765.0	526.8	6721.5	11060.3	238310.0
				628163.9			239104.9			22821.8	11080.3	901190.8
2000												
2094	9.7416	1347.0	13122.0	2448296.7	6057.0	59005.0	752904.0	785.0	7647.2	97578.0	160856.9	3459635.6
PRESENT WORTH BENEFITS				3076480.6			992008.9			120399.7	171937.2	4360826.4
CRF=	0.0688 AV ANN BENEFITS =			211782.4			68289.1			8288.2	11836.0	300195.7

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

CAPACITY	ENERGY	SECONDARY	INTEREST
1 186.58	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM
HIGH LOAD GROWTH — 211782. 68289. 8288. 300196.
NEW SYSTEM

TWO YEAR CONSTRUCTION DELAY

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1996	0.9357	160.0	149.7	27932.4	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	63714.2
1997	0.8755	475.0	415.7	77753.5	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	116349.8
1998	0.8192	674.0	552.1	103014.1	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	139127.6
1999	0.7665	680.0	521.2	97245.5	3058.0	2343.9	29907.7	397.0	304.3	3882.7	0.0	131036.0
2000	0.7172	731.0	524.2	97814.2	6057.0	4343.9	55427.8	397.0	284.7	3633.0	0.0	156874.9
2001	0.6710	847.0	568.4	106045.4	6057.0	4064.4	51862.3	785.0	526.8	6721.5	0.0	164629.1
2002	0.6279	1069.0	671.2	125230.4	6057.0	3803.0	48526.1	785.0	492.9	6289.1	0.0	180045.6
2003	0.5875	1167.0	685.6	127916.6	6057.0	3558.3	45404.5	785.0	461.2	5884.5	0.0	179205.7
2004	0.5497	1281.0	704.1	131379.9	6057.0	3329.4	42483.8	785.0	431.5	5506.0	0.0	179369.7
2005	0.5143	1347.0	692.8	129262.2	6057.0	3115.3	39750.9	785.0	403.7	5151.8	2543.0	176707.9
2006	0.4812	1347.0	648.2	120947.0	6057.0	2914.9	37193.8	785.0	377.8	4820.4	6689.4	169650.6
2007	0.4503	1347.0	606.5	113166.8	6057.0	2727.4	34801.2	785.0	353.5	4510.3	7435.2	159913.6
				1257708.1			487265.2			54983.9	16667.6	1816620.8
2008												
2096	6.5307	1347.0	8796.9	1641327.7	6057.0	39556.7	504743.6	785.0	5126.6	65415.8	107837.8	2319325.0
PRESENT WORTH BENEFITS				2899035.8			992008.9			120399.7	124505.4	4135949.7
CRF=	0.0688	AV ANN BENEFITS =		199567.2			68289.1			8288.2	8570.8	284715.4

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875
1
CAPACITY ENERGY SECONDARY INTEREST
1 186.58 12.76 12.76 0.06875
1
SYSTEM OF DEVELOPMENT CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST
NEW SYSTEM
TWO YEAR CONSTRUCTION DELAY 199567. 68289. 8288. 284715.
NEW SYSTEM

APA INVESTMENT COST

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY ( )	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	5593.5	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	41375.2
1995	0.8755	265.0	232.0	51367.8	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	89964.2
1996	0.8192	680.0	557.0	123332.6	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	159446.1
1997	0.7665	680.0	521.2	115398.9	3058.0	2343.9	29907.7	397.0	304.3	3882.7	0.0	149189.4
1998	0.7172	950.0	681.3	150848.2	6057.0	4343.9	55427.8	397.0	284.7	3633.0	0.0	209909.0
1999	0.6710	1035.0	694.5	153773.3	6057.0	4064.4	51862.3	785.0	526.8	6721.5	0.0	212357.0
2000	0.6279	1231.0	772.9	171128.5	6057.0	3803.0	48526.1	785.0	492.9	6289.1	0.0	225943.7
2001	0.5875	1347.0	791.3	175208.8	6057.0	3558.3	45404.5	785.0	461.2	5884.5	65.0	226562.9
2002	0.5497	1347.0	740.4	163938.6	6057.0	3329.4	42483.8	785.0	431.5	5506.0	10771.0	222698.8
				1110589.5			375519.3			40501.4	10836.0	1537446.2
2003 2094	7.9766	1347.0	10744.5	2378933.7	6057.0	48314.2	616489.6	785.0	6261.6	79898.4	156299.7	3231621.3
PRESENT WORTH BENEFITS				3489523.2			992008.9			120399.7	167135.7	4769067.5
CRF= 0.0688 AV ANN BENEFITS =				240215.9			68289.1			8288.2	11505.5	328298.7

CAPACITY VALUE = 221.41000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	221.41	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

APA INVESTMENT COST — 240216. 68289. 8288. 328299.

NEW SYSTEM

APA INVESTMENT COST AND 2% ESCALATION AND 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	6231.9	2997.0	2804.2	68002.1	0.0	0.0	0.0	0.0	74234.0
1995	0.8755	265.0	232.0	57230.5	3058.0	2677.2	64922.8	397.0	347.6	8428.5	0.0	130581.8
1996	0.8192	680.0	557.0	137406.8	3055.0	2505.0	60746.4	397.0	325.2	7886.3	0.0	206041.5
1997	0.7665	680.0	521.2	128569.6	3058.0	2343.9	56838.8	397.0	304.3	7379.0	0.0	192797.4
1998	0.7172	950.0	681.3	168064.9	6057.0	4343.9	105338.9	397.0	284.7	6904.3	0.0	280308.1
1999	0.6710	1035.0	694.5	171323.7	6057.0	4064.4	98562.7	785.0	526.6	12773.9	0.0	282660.4
2000	0.6279	1231.0	772.9	190659.8	6057.0	3803.0	92222.4	785.0	492.9	11952.2	0.0	294834.4
2001	0.5875	1347.0	791.3	195205.7	6057.0	3558.3	86290.0	785.0	461.2	11183.4	72.5	292751.5
2002	0.5497	1347.0	740.4	182648.6	6057.0	3329.4	80739.1	785.0	431.5	10464.0	12000.3	285852.0
				1237343.5			713663.2			76971.6	12072.8	2040051.0
2003 2094	7.9766	1347.0	10744.5	2650446.5	6057.0	48314.2	1171620.1	785.0	6261.6	151844.4	174138.5	4148049.6
PRESENT WORTH BENEFITS				3887790.0			1885283.3			228816.1	186211.2	6188100.6
CRF= 0.0688 AV ANN BENEFITS =				267632.2			129781.3			15751.5	12818.6	425983.7

CAPACITY VALUE = 246.68000$/KW-YR
ENERGY VALUE = 24.25000MILLS/KWH
SECONDARY VALUE= 24.25000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	246.68	24.25	24.25	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

APA INVESTMENT COST AND 2% ESCALATION AND 3% INFLATION — 267632. 129781. 15752. 425984.

NEW SYSTEM

OIL FIRED ALTERNATIVE

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1110.3	2997.0	2804.2	75489.3	0.0	0.0	0.0	0.0	76599.7
1995	0.8755	265.0	232.0	10196.5	3058.0	2677.2	72071.0	397.0	347.6	9356.5	0.0	91624.0
1996	0.8192	680.0	557.0	24491.6	3058.0	2505.0	67434.8	397.0	325.2	8754.6	0.0	100671.0
1997	0.7665	680.0	521.2	22906.7	3058.0	2343.9	63096.9	397.0	304.3	8191.5	0.0	94195.1
1998	0.7172	950.0	681.3	29943.5	6057.0	4343.9	116937.0	397.0	284.7	7664.5	0.0	154545.0
1999	0.6710	1035.0	694.5	30524.1	6057.0	4064.4	109414.7	785.0	526.8	14180.4	0.0	154119.2
2000	0.6279	1231.0	772.9	33969.1	6057.0	3803.0	102376.4	785.0	492.9	13268.2	0.0	149613.7
2001	0.5875	1347.0	791.3	34779.0	6057.0	3556.3	95790.8	785.0	461.2	12414.7	12.9	142997.4
2002	0.5497	1347.0	740.4	32541.8	6057.0	3329.4	89628.8	785.0	431.5	11616.1	2138.0	135924.7
				220452.6			792239.7			85446.4	2151.0	1100289.7
2003												
2094	7.9766	1347.0	10744.5	472219.6	6057.0	48314.2	1300619.1	785.0	6261.6	168563.0	31025.6	1972427.3
PRESENT WORTH BENEFITS				692672.2			2092858.8			254009.4	33176.5	3072716.9
CRF= 0.0688 AV ANN BENEFITS =				47683.0			144070.7			17485.8	2283.8	211523.3

CAPACITY VALUE = 43.95000$/KW-YR
ENERGY VALUE = 26.92000MILLS/KWH
SECONDARY VALUE= 26.92000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	43.95	26.92	26.92	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST
NEW SYSTEM	
OIL FIRED ALTERNATIVE	47683. 144071. 17486. 211523.
NEW SYSTEM	

C-5-12

WATANA ALONE - OIL

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1110.3	2997.0	2804.2	75489.3	0.0	0.0	0.0	0.0	76599.7
1995	0.8755	265.0	232.0	10196.5	3056.0	2677.2	72071.0	397.0	347.6	9356.5	0.0	91624.0
1996	0.8192	680.0	557.0	24481.6	3058.0	2505.0	67434.8	397.0	325.2	8754.6	18.0	100689.0
1997	0.7665	680.0	521.2	22906.7	3058.0	2343.9	63096.9	397.0	304.3	8191.5	1296.9	95492.0
				58695.2			278092.0			26302.6	1314.9	364404.7
1998												
2094	11.1298	680.0	7568.3	332625.8	3058.0	34035.0	916222.0	397.0	4418.5	118947.1	18832.5	1386627.5
PRESENT WORTH BENEFITS				391321.0			1194314.1			145249.6	20147.4	1751032.1
CRF= 0.0688 AV ANN BENEFITS =				26938.2			82215.6			9998.9	1386.9	120539.6

CAPACITY VALUE = 43.95000$/KW-YR
ENERGY VALUE = 26.92000MILLS/KWH
SECONDARY VALUE= 26.92000MILLS/KWH
INTEREST RATE = 0.06875

1

CAPACITY	ENERGY	SECONDARY	INTEREST
1 43.95	26.92	26.92	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	TOTALS---POWER VALUES & INTEREST
NEW SYSTEM				
WATANA ALONE - OIL	26938.	82216.	9999.	120540.
NEW SYSTEM				

BASE CASE WITH 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	5248.7	2997.0	2804.2	47363.1	0.0	0.0	0.0	0.0	52611.8
1995	0.8755	265.0	232.0	48203.9	3058.0	2677.2	45218.4	397.0	347.6	5870.4	0.0	99289.7
1996	0.8192	680.0	557.0	115729.1	3058.0	2505.0	42309.6	397.0	325.2	5492.8	0.0	163531.4
1997	0.7565	690.0	521.2	108284.5	3058.0	2343.9	39587.9	397.0	304.3	5139.4	0.0	153011.9
1998	0.7172	950.0	681.3	141546.4	6057.0	4343.9	73368.0	397.0	284.7	4808.8	0.0	219725.2
1999	0.6710	1035.0	694.5	144293.1	6057.0	4064.4	68648.4	785.0	526.8	8897.0	0.0	221838.5
2000	0.6279	1231.0	772.9	160578.4	6057.0	3803.0	64232.4	785.0	492.9	8324.7	0.0	233135.5
2001	0.5875	1347.0	791.3	164407.1	6057.0	3558.3	60100.5	785.0	461.2	7789.2	61.0	232357.8
2002	0.5497	1347.0	740.4	153831.2	6057.0	3329.4	56234.4	785.0	431.5	7288.1	10106.9	227460.6
				1042121.3			497062.7			53610.3	10168.0	1602962.3
2003												
2091	7.9766	1347.0	10744.5	2232271.7	6057.0	48314.2	816027.4	785.0	6261.6	105758.9	146663.7	3300721.7
PRESENT WORTH BENEFITS				3274393.0			1313090.1			159369.2	156831.7	4903684.0
CRF= 0.0688 AV ANN BENEFITS =				225406.5			90392.0			10970.8	10796.2	337565.5

CAPACITY VALUE = 207.76000$/KW-YR
ENERGY VALUE = 16.89000MILLS/KWH
SECONDARY VALUE= 16.89000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	207.76	16.89	16.89	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

BASE CASE WITH 3% INFLATION — 225406. 90392. 10971. 337566.

NEW SYSTEM

BASE CASE WITH 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	5713.3	2997.0	2804.2	57626.5	0.0	0.0	0.0	0.0	63339.8
1995	0.8755	265.0	232.0	52467.5	3058.0	2677.2	55017.0	397.0	347.6	7142.5	0.0	114627.0
1996	0.8192	680.0	557.0	125972.9	3058.0	2505.0	51477.9	397.0	325.2	6683.0	0.0	134133.8
1997	0.7665	680.0	521.2	117869.4	3058.0	2343.9	48166.5	397.0	304.3	6253.1	0.0	172289.0
1998	0.7172	950.0	681.3	154077.6	6057.0	4343.9	89266.6	397.0	284.7	5850.9	0.0	249195.1
1999	0.6710	1035.0	694.5	157065.3	6057.0	4064.4	83524.3	785.0	526.8	10824.9	0.0	251414.5
2000	0.6279	1231.0	772.9	174792.1	6057.0	3803.0	78151.4	785.0	492.9	10128.6	0.0	263072.0
2001	0.5875	1347.0	791.3	178959.7	6057.0	3558.3	73124.1	785.0	461.2	9477.0	66.4	261627.2
2002	0.5497	1347.0	740.4	167447.6	6057.0	3329.4	68420.2	785.0	431.5	8867.4	11001.6	255736.8
				1134365.3			604774.3			65227.5	11068.0	1815435.1
2003												
2094	7.9766	1347.0	10744.5	2429862.5	6057.0	48314.2	992857.5	785.0	6261.6	128676.4	159645.8	3711042.2
PRESENT WORTH BENEFITS				3564227.8			1597631.8			193903.9	170713.8	5526477.3
CRF=	0.0688 AV ANN BENEFITS =			245358.5			109979.7			13348.2	11751.8	380438.1

CAPACITY VALUE = 226.15000$/KW-YR
ENERGY VALUE = 20.55000MILLS/KWH
SECONDARY VALUE= 20.55000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	226.15	20.55	20.55	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST

NEW SYSTEM

BASE CASE WITH 5% INFLATION — 245358. 109980. 13348. 380438.

NEW SYSTEM

BASE CASE WITH 2% ESCALATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	4734.6	2997.0	2804.2	59645.6	0.0	0.0	0.0	0.0	6438[illegible].1
1995	0.8755	265.0	232.0	43479.7	3058.0	2677.2	56944.6	397.0	347.6	7392.7	0.0	107817.1
1996	0.8192	680.0	557.0	104393.5	3058.0	2505.0	53281.5	397.0	325.2	6917.2	0.0	164592.2
1997	0.7665	680.0	521.2	97678.1	3058.0	2343.9	49854.1	397.0	304.3	6472.2	0.0	1540[illegible].4
1998	0.7172	950.0	681.3	127683.8	6057.0	4343.9	92394.1	397.0	284.7	6055.9	0.0	226133.8
1999	0.6710	1035.0	694.5	130159.6	6057.0	4064.4	86450.7	785.0	526.8	11204.2	0.0	227814.5
2000	0.6279	1231.0	772.9	144849.8	6057.0	3803.0	80889.5	785.0	492.9	10483.5	0.0	236222.8
2001	0.5875	1347.0	791.3	148303.5	6057.0	3558.3	75686.1	785.0	461.2	9809.1	55.0	233852.7
2002	0.5497	1347.0	740.4	136763.5	6057.0	3329.4	70817.4	785.0	431.5	9178.1	9117.0	227875.9
				940046.0			625963.5			67512.8	9172.0	1642694.4
2003												
2094	7.9766	1347.0	10744.5	2013621.6	6057.0	48314.2	1027643.7	785.0	6261.6	133184.8	132298.1	3306748.3
PRESENT WORTH BENEFITS				2953667.6			1653607.3			200697.6	141470.1	4949442.6
CRF=	0.0688 AV ANN BENEFITS =			203328.0			113833.0			13815.9	9738.7	340715.5

CAPACITY VALUE = 187.41000$/KW-YR
ENERGY VALUE = 21.27000MILLS/KWH
SECONDARY VALUE= 21.27000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	187.41	21.27	21.27	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
BASE CASE WITH 2% ESCALATION	203328.	113833.	13816.	9739.	340716.
NEW SYSTEM					

BASE CASE WITH 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	5713.3	2997.0	2804.2	57626.5	0.0	0.0	0.0	0.0	63339.8
1995	0.8755	265.0	232.0	52467.5	3058.0	2677.2	55017.0	397.0	347.6	7142.5	0.0	114627.0
1996	0.8192	680.0	557.0	125972.9	3058.0	2505.0	51477.9	397.0	325.2	6683.0	0.0	184133.8
1997	0.7665	680.0	521.2	117869.4	3058.0	2343.9	48166.5	397.0	304.3	6253.1	0.0	172289.0
1998	0.7172	950.0	681.3	154077.6	6057.0	4343.9	89266.6	397.0	284.7	5850.9	0.0	249195.1
1999	0.6710	1035.0	694.5	157065.3	6057.0	4064.4	83524.3	785.0	526.8	10824.9	0.0	251414.5
2000	0.6279	1231.0	772.9	174792.1	6057.0	3803.0	78151.4	785.0	492.9	10128.6	0.0	263072.0
2001	0.5875	1347.0	791.3	178959.7	6057.0	3558.3	73124.1	785.0	461.2	9477.0	66.4	261627.2
2002	0.5497	1347.0	740.4	167447.6	6057.0	3329.4	68420.2	785.0	431.5	8867.4	11001.6	255736.8
				1134365.3			604774.3			65227.5	11068.0	1815435.1
2003												
2094	7.9766	1347.0	10744.5	2429862.5	6057.0	48314.2	992857.5	785.0	6261.6	128676.4	159645.8	3711042.2
PRESENT WORTH BENEFITS				3564227.8			1597631.8			193903.9	170713.8	5526477.3
CRF=	0.0688	AV ANN BENEFITS =		245358.5			109979.7			13348.2	11751.8	380438.1

CAPACITY VALUE = 226.15000$/KW-YR
ENERGY VALUE = 20.55000MILLS/KWH
SECONDARY VALUE= 20.55000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	226.15	20.55	20.55	0.06875

1

SYSTEM OF DEVELOPMENT
NEW SYSTEM
BASE CASE WITH 5% INFLATION
NEW SYSTEM

CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST
245358. 109980. 13348. 380438.

BASE CASE WITH 2% ESCALATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	4734.6	2997.0	2804.2	59645.6	0.0	0.0	0.0	0.0	6438[illegible].1
1995	0.8755	265.0	232.0	43479.7	3058.0	2677.2	56944.6	397.0	347.6	7392.7	0.0	107817.1
1996	0.8192	680.0	557.0	104393.5	3058.0	2505.0	53281.5	397.0	325.2	6917.2	0.0	164592.2
1997	0.7665	680.0	521.2	97678.1	3058.0	2343.9	49854.1	397.0	304.3	6472.2	0.0	15400[illegible].4
1998	0.7172	950.0	681.3	127683.8	6057.0	4343.9	92394.1	397.0	284.7	6055.9	0.0	226133.8
1999	0.6710	1035.0	694.5	130159.6	6057.0	4064.4	86450.7	785.0	526.8	11204.2	0.0	227814.5
2000	0.6279	1231.0	772.9	144849.8	6057.0	3803.0	80889.5	785.0	492.9	10483.5	0.0	236222.8
2001	0.5875	1347.0	791.3	148303.5	6057.0	3558.3	75686.1	785.0	461.2	9809.1	55.0	233853.7
2002	0.5497	1347.0	740.4	138763.5	6057.0	3329.4	70817.4	785.0	431.5	9178.1	9117.0	227875.9
				940046.0			625963.5			67512.8	9172.0	1642694.4
2003												
2094	7.9766	1347.0	10744.5	2013621.6	6057.0	48314.2	1027643.7	785.0	6261.6	133184.8	132298.1	3306748.3
PRESENT WORTH BENEFITS				2953667.6			1653607.3			200697.6	141470.1	4949442.6
CRF=	0.0688 AV ANN BENEFITS =			203328.0			113833.0			13815.9	9738.7	340715.5

CAPACITY VALUE = 187.41000$/KW-YR
ENERGY VALUE = 21.27000MILLS/KWH
SECONDARY VALUE= 21.27000MILLS/KWH
INTEREST RATE = 0.06875

1

CAPACITY	ENERGY	SECONDARY	INTEREST
1 187.41	21.27	21.27	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
BASE CASE WITH 2% ESCALATION	203328.	113833.	13816.	9739.	340716.
NEW SYSTEM					

BASE CASE WITH 2% ESCALATION AND 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	5273.4	2997.0	2804.2	79359.2	0.0	0.0	0.0	0.0	[illegible]
1995	0.8755	265.0	232.0	48428.3	3058.0	2677.2	75765.5	397.0	347.6	9836.1	0.0	[illegible]
1996	0.8192	680.0	557.0	116275.0	3058.0	2505.0	70891.7	397.0	325.2	9203.4	0.0	[illegible]
1997	0.7665	680.0	521.2	108795.3	3058.0	2343.9	66331.4	397.0	304.3	8611.4	0.0	[illegible]
1998	0.7172	950.0	681.3	142216.1	6057.0	4343.9	122931.6	397.0	284.7	8057.4	0.0	[illegible]
1999	0.6710	1035.0	694.5	144973.7	6057.0	4064.4	115023.7	785.0	526.8	14907.3	0.0	[illegible]
2000	0.6279	1231.0	772.9	161335.8	6057.0	3803.0	107624.5	785.0	492.9	13948.4	0.0	[illegible]
2001	0.5875	1347.0	791.3	165182.6	6057.0	3558.3	100701.3	785.0	461.2	13051.1	61.3	[illegible]
2002	0.5497	1347.0	740.4	154556.8	6057.0	3329.4	94223.4	785.0	431.5	12211.6	10154.6	[illegible]
				1047037.0			832852.3			89826.7	10215.9	1979931.4
2003												
2094	7.9766	1347.0	10744.5	2242801.2	6057.0	48314.2	1367292.8	785.0	6261.6	177204.0	147355.5	3934653.6
PRESENT WORTH BENEFITS				3289838.2			2200145.1			267030.7	157571.5	5914585.5
CRF=	0.0688	AV ANN BENEFITS =		226469.7			151456.2			18382.2	10847.1	407155.2

CAPACITY VALUE = 208.74000$/KW-YR
ENERGY VALUE = 28.30000MILLS/KWH
SECONDARY VALUE= 28.30000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	208.74	28.30	28.30	0.06875

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SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
BASE CASE WITH 2% ESCALATION AND 3% INFLATION	226470.	151456.	18382.	10847.	407155.
NEW SYSTEM					

BASE CASE WITH 2 % ESCALATION AND 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	5747.4	2997.0	2804.2	96745.3	0.0	0.0	0.0	0.0	102492.6
1995	0.8755	265.0	232.0	52780.7	3058.0	2677.2	92364.3	397.0	347.6	11991.1	0.0	157136.1
1996	0.8192	680.0	557.0	126724.9	3058.0	2505.0	86422.8	397.0	325.2	11219.7	0.0	224367.4
1997	0.7665	680.0	521.2	118573.0	3058.0	2343.9	80663.4	397.0	304.3	10498.0	0.0	209734.4
1998	0.7172	950.0	681.3	154997.4	6057.0	4343.9	149863.6	397.0	284.7	9622.7	0.0	314483.6
1999	0.6710	1035.0	694.5	158002.9	6057.0	4064.4	140223.2	785.0	526.8	18173.2	0.0	316399.3
2000	0.6279	1231.0	772.9	175835.5	6057.0	3603.0	131203.0	785.0	492.9	17004.2	0.0	324042.7
2001	0.5875	1347.0	791.3	180028.0	6057.0	3558.3	122763.0	785.0	461.2	15910.3	66.8	318768.2
2002	0.5497	1347.0	740.4	168447.2	6057.0	3329.4	114866.0	785.0	431.5	14886.9	11067.2	309267.3
				1141136.9			1015314.6			109506.0	11134.1	2277091.6
2003												
2094	7.9766	1347.0	10744.5	2444367.6	6057.0	48314.2	1666841.0	785.0	6261.6	216026.1	160598.8	4487033.5
PRESENT WORTH BENEFITS				3585504.4			2682155.6			325532.1	171732.8	6764925.0
CRF= 0.0688 AV ANN BENEFITS =				246823.2			184637.4			22409.4	11821.9	465691.8

CAPACITY VALUE = 227.50000$/KW-YR
ENERGY VALUE = 34.50000MILLS/KWH
SECONDARY VALUE= 34.50000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	227.50	34.50	34.50	0.06875

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SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
BASE CASE WITH 2 % ESCALATION AND 5% INFLATION	246823.	184637.	22409.	11822.	465692.
NEW SYSTEM					

OIL FIRED WITH 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1238.1	2997.0	2804.2	108635.1	0.0	0.0	0.0	0.0	109873.3
1995	0.8755	265.0	232.0	11370.5	3058.0	2677.2	103715.8	397.0	347.6	13464.7	0.0	128551.0
1996	0.8192	650.0	557.0	27300.2	3058.0	2505.0	97044.0	397.0	325.2	12598.6	0.0	136942.8
1997	0.7665	680.0	521.2	25544.0	3058.0	2343.9	90801.4	397.0	304.3	11788.1	0.0	128133.6
1998	0.7172	950.0	681.3	33390.9	6057.0	4343.9	168281.6	397.0	284.7	11029.8	0.0	212702.3
1999	0.6710	1035.0	694.5	34038.3	6057.0	4064.4	157456.4	785.0	526.8	20406.7	0.0	211901.5
2000	0.6279	1231.0	772.9	37880.0	6057.0	3803.0	147327.7	785.0	492.9	19094.0	0.0	204301.6
2001	0.5875	1347.0	791.3	38783.2	6057.0	3558.3	137850.4	785.0	461.2	17865.7	14.4	194513.7
2002	0.5497	1347.0	740.4	36288.3	6057.0	3329.4	128982.9	785.0	431.5	16716.5	2384.2	184371.9
				245833.5			1140095.3			122964.1	2398.6	1511291.5
2003 2094	7.9766	1347.0	10744.5	526586.6	6057.0	48314.2	1871693.4	785.0	6261.6	242575.4	34597.6	2675453.0
PRESENT WORTH BENEFITS				772420.1			3011788.7			365539.6	36996.2	4186744.5
CRF=	0.0688 AV ANN BENEFITS =			53172.8			207329.0			25163.4	2546.8	288212.0

CAPACITY VALUE = 49.01000$/KW-YR
ENERGY VALUE = 38.74000MILLS/KWH
SECONDARY VALUE= 38.74000MILLS/KWH
INTEREST RATE = 0.06875

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CAPACITY ENERGY SECONDARY INTEREST
1 49.01 38.74 38.74 0.06875

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SYSTEM OF DEVELOPMENT
NEW SYSTEM
OIL FIRED WITH 3% INFLATION
NEW SYSTEM

CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST
53173. 207329. 25163. 288212.

OIL FIRED WITH 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1350.3	2997.0	2804.2	122039.2	0.0	0.0	0.0	0.0	123389.6
1995	0.8755	265.0	232.0	12400.6	3058.0	2677.2	116512.9	397.0	347.6	15126.1	0.0	144039.6
1996	0.8192	680.0	557.0	29773.4	3058.0	2505.0	109017.9	397.0	325.2	14153.1	0.0	152944.4
1997	0.7665	680.0	521.2	27858.1	3058.0	2343.9	102005.1	397.0	304.3	13242.6	0.0	143105.9
1998	0.7172	950.0	681.3	36415.9	6057.0	4343.9	189045.3	397.0	284.7	12390.8	0.0	237851.9
1999	0.6710	1035.0	694.5	37122.0	6057.0	4064.4	176884.5	785.0	526.8	22924.6	0.0	236931.1
2000	0.6279	1231.0	772.9	41311.7	6057.0	3803.0	165505.9	785.0	492.9	21449.9	0.0	228267.5
2001	0.5875	1347.0	791.3	42296.7	6057.0	3558.3	154859.4	785.0	461.2	20070.1	15.7	217241.8
2002	0.5497	1347.0	740.4	39575.5	6057.0	3329.4	144897.6	785.0	431.5	18779.0	2600.2	205852.7
				268104.5			1280767.9			138136.3	2615.9	1689624.5
2003												
2094	7.9766	1347.0	10744.5	574292.1	6057.0	48314.2	2102635.4	785.0	6261.6	272506.0	37731.9	2987165.4
PRESENT WORTH BENEFITS				842396.5			3383403.3			410642.3	40347.8	4676789.9
CRF= 0.0688 AV ANN BENEFITS =				57989.9			232910.7			28268.3	2777.5	321946.3

CAPACITY VALUE = 53.45000$/KW-YR
ENERGY VALUE = 43.52000MILLS/KWH
SECONDARY VALUE= 43.52000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	53.45	43.52	43.52	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	TOTALS---POWER VALUES & INTEREST
NEW SYSTEM				
OIL FIRED WITH 5% INFLATION	57990.	232911.	28268.	321946.
NEW SYSTEM				

OIL FIRED WITH 2% ESCALATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1152.3	2997.0	2804.2	130704.3	0.0	0.0	0.0	0.0	131856.5
1995	0.8755	265.0	232.0	10581.7	3058.0	2677.2	124785.6	397.0	347.6	16200.1	0.0	151567.3
1996	0.8192	680.0	557.0	25406.3	3058.0	2505.0	116758.4	397.0	325.2	15156.0	0.0	157322.6
1997	0.7665	680.0	521.2	23771.9	3058.0	2343.9	109247.6	397.0	304.3	14182.9	0.0	147202.5
1998	0.7172	950.0	681.3	31074.4	6057.0	4343.9	202467.8	397.0	284.7	13270.6	0.0	246812.8
1999	0.6710	1035.0	694.5	31677.0	6057.0	4064.4	189443.6	785.0	526.8	24552.3	0.0	2[illegible]5672.8
2000	0.6279	1231.0	772.9	35252.1	6057.0	3803.0	177257.2	785.0	492.9	22972.9	0.0	235482.2
2001	0.5875	1347.0	791.3	36092.6	6057.0	3558.3	165854.7	785.0	461.2	21495.1	13.4	223455.8
2002	0.5497	1347.0	740.4	33770.9	6057.0	3329.4	155185.6	785.0	431.5	20112.4	2218.8	211287.7
				228779.1			1371704.7			147944.2	2232.2	1750660.3
2003												
2094	7.9766	1347.0	10744.5	490055.4	6057.0	48314.2	2251926.4	785.0	6261.6	291854.4	32197.4	3066033.6
PRESENT WORTH BENEFITS				718834.5			3623631.1			439798.6	34429.6	4816693.9
CRF=	0.0688	AV ANN BENEFITS =		49484.0			249447.8			30275.4	2370.1	331577.2

CAPACITY VALUE = 45.61000$/KW-YR
ENERGY VALUE = 46.61000MILLS/KWH
SECONDARY VALUE= 46.61000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	45.61	46.61	46.61	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
OIL FIRED WITH 2% ESCALATION	49484.	249448.	30275.	2370.	331577.
NEW SYSTEM					

OIL FIRED WITH 2% ESCALATION AND 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	1294.2	2997.0	2804.2	174225.6	0.0	0.0	0.0	0.0	175519.8
1995	0.8755	265.0	232.0	11885.5	3058.0	2677.2	166336.1	397.0	347.6	21594.3	0.0	199816.0
1996	0.8192	680.0	557.0	28536.8	3058.0	2505.0	155636.1	397.0	325.2	20205.2	0.0	204378.1
1997	0.7665	680.0	521.2	26701.1	3058.0	2343.9	145624.5	397.0	304.3	18905.5	0.0	191231.0
1998	0.7172	950.0	681.3	34903.4	6057.0	4343.9	269884.7	397.0	284.7	17689.3	0.0	322477.4
1999	0.6710	1035.0	694.5	35580.2	6057.0	4064.4	252523.7	785.0	526.8	32727.6	0.0	320531.5
2000	0.6279	1231.0	772.9	39595.8	6057.0	3803.0	236279.5	785.0	492.9	[illegible]0622.3	0.0	306497.7
2001	0.5875	1347.0	791.3	40539.9	6057.0	3558.3	221080.2	785.0	[illegible]	[illegible]552.5	1[illegible].0	290287.7
2002	0.5497	1347.0	740.4	37932.1	6057.0	[illegible]29.4	206856.7	785.0	431.5	26809.3	2492.2	274092.3
				256969.0			1828449.2			197206.0	2507.2	2285131.4
2003 2094	7.9766	1347.0	10744.5	550439.3	6057.0	48314.2	3001763.3	785.0	6261.6	389034.9	36164.7	3977402.2
PRESENT WORTH BENEFITS				807408.3			4830212.4			586240.9	38672.0	6262533.6
CRF= 0.0688 AV ANN BENEFITS =				55581.3			332507.8			40356.3	2662.1	431107.6

CAPACITY VALUE = 51.23000$/KW-YR
ENERGY VALUE = 62.13000MILLS/KWH
SECONDARY VALUE= 62.13000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	51.23	62.13	62.13	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
OIL FIRED WITH 2% ESCALATION AND 3% INFLATION	55581.	332508.	40356.	2662.	431108.
NEW SYSTEM					

OIL FIRED WITH 2% ESCALATION AND 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	1418.8	2997.0	2604.2	212615.2	0.0	0.0	0.0	0.0	214034.0
1995	0.8755	265.0	232.0	13029.3	3058.0	2677.2	202987.4	397.0	347.6	26352.5	0.0	242369.2
1996	0.8192	680.0	557.0	31282.9	3058.0	2505.0	189929.7	397.0	325.2	24657.3	0.0	245870.0
1997	0.7665	680.0	521.2	29270.6	3058.0	2343.9	177712.0	397.0	304.3	23071.2	0.0	230053.8
1998	0.7172	950.0	681.3	38262.2	6057.0	4343.9	329352.3	397.0	284.7	21587.1	0.0	389201.6
1999	0.6710	1035.0	694.5	39004.1	6057.0	4064.4	308165.9	785.0	526.8	39939.0	0.0	387109.0
2000	0.6279	1231.0	772.9	43406.2	6057.0	3803.0	288342.4	785.0	492.9	37369.8	0.0	369118.4
2001	0.5875	1347.0	791.3	44441.2	6057.0	3558.3	269794.0	785.0	461.2	34965.9	16.5	349217.6
2002	0.5497	1347.0	740.4	41582.4	6057.0	3329.4	252438.9	785.0	431.5	32716.6	2732.0	329469.9
				281697.8			2231337.8			240659.3	2748.5	2756443.4
2003 2094	7.9766	1347.0	10744.5	603409.6	6057.0	48314.2	3663185.1	785.0	6261.6	474756.5	39645.0	4780996.2
PRESENT WORTH BENEFITS				885107.4			5894522.9			715415.8	42393.5	7537439.6
CRF= 0.0688 AV ANN BENEFITS =				60930.1			405774.1			49248.6	2918.3	518871.1

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CAPACITY VALUE =  56.16000$/KW-YR
ENERGY VALUE   =  75.82000MILLS/KWH
SECONDARY VALUE=  75.82000MILLS/KWH
INTEREST RATE  =   0.06875
1
  CAPACITY  ENERGY   SECONDARY INTEREST
 1     56.16     75.82      75.82   0.06875
1
SYSTEM OF DEVELOPMENT                                   CAPACITY ENERGY SECONDARY INTERRUPTABLE TOTALS
NEW SYSTEM
OIL FIRED WITH 2% ESCALATION AND 5% INFLATION            60930. 405774.  49249.   2918.       518871.
NEW SYSTEM
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OIL FIRED WITH 2% ESCALATION AFTER POL

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	1125.2	2997.0	2804.2	97250.0	0.0	0.0	0.0	0.0	98375.2
1995	0.8755	265.0	232.0	10333.4	3058.0	2677.2	92846.2	397.0	347.6	12053.6	0.0	115233.3
1996	0.8192	680.0	557.0	24810.2	3058.0	2505.0	86873.7	397.0	325.2	11278.2	0.0	122962.1
1997	0.7665	680.0	521.2	23214.2	3058.0	2343.9	81285.3	397.0	304.3	10552.7	0.0	115052.3
1998	0.7172	950.0	681.3	30345.4	6057.0	4343.9	150645.5	397.0	284.7	9873.9	0.0	190864.8
1999	0.6710	1035.0	694.5	30933.8	6057.0	4064.4	140954.8	785.0	526.8	18268.0	0.0	190156.7
2000	0.6279	1231.0	772.9	34425.1	6057.0	3803.0	131887.5	785.0	492.9	17092.9	0.0	183405.6
2001	0.5875	1347.0	791.3	35245.9	6057.0	3558.3	123403.5	785.0	461.2	15993.4	13.1	174655.9
2002	0.5497	1347.0	740.4	32978.6	6057.0	3329.4	115465.3	785.0	431.5	14964.5	2166.7	165575.2
				223412.0			1020611.9			110077.3	2179.8	1356281.1
2003												
2094	7.9766	1347.0	10744.5	478558.8	6057.0	48314.2	1675537.6	785.0	6261.6	217153.2	31442.1	2402691.7
PRESENT WORTH BENEFITS				701970.8			2696149.5			327230.6	33621.9	3758972.3
CRF=	0.0688	AV ANN BENEFITS =		48323.1			185600.7			22526.3	2314.5	258764.6

CAPACITY VALUE = 44.54000$/KW-YR
ENERGY VALUE = 34.68000MILLS/KWH
SECONDARY VALUE= 34.68000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	44.54	34.68	34.68	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
OIL FIRED WITH 2% ESCALATION AFTER POL	48323.	185601.	22526.	2315.	258765.
NEW SYSTEM					

OIL FIRED WITH 2% ESCALATION AFTER POL AND 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1258.1	2997.0	2804.2	129386.3	0.0	0.0	0.0	0.0	130544.4
1995	0.8755	265.0	232.0	11555.7	3058.0	2677.2	123527.3	397.0	347.6	16036.7	0.0	151117.7
1996	0.8192	680.0	557.0	27740.2	3058.0	2505.0	115581.1	397.0	325.2	15005.1	0.0	158326.4
1997	0.7665	680.0	521.2	25955.8	3058.0	2343.9	108146.0	397.0	304.3	14039.9	0.0	148141.7
1998	0.7172	950.0	681.3	33929.1	6057.0	4343.9	200426.2	397.0	284.7	13136.7	0.0	247492.0
1999	0.6710	1035.0	694.5	34587.0	6057.0	4064.4	187533.3	785.0	526.8	24304.7	0.0	246425.0
2000	0.6279	1231.0	772.9	38490.6	6057.0	3803.0	175469.8	785.0	492.9	22741.3	0.0	236701.6
2001	0.5875	1347.0	791.3	39408.3	6057.0	3558.3	164182.2	785.0	461.2	21278.4	14.6	224483.5
2002	0.5497	1347.0	740.4	36873.3	6057.0	3329.4	153620.8	785.0	431.5	19909.6	2422.6	212826.3
				249796.1			1357872.9			146452.4	2437.3	1756558.7
2003												
2094	7.9766	1347.0	10744.5	535074.7	6057.0	48314.2	2229218.7	785.0	6261.6	288911.5	35155.2	3086360.1
PRESENT WORTH BENEFITS				784870.9			3587091.6			435363.8	37592.5	4844918.8
CRF=	0.0688 AV ANN BENEFITS =			54029.9			246932.4			29970.1	2587.8	333520.2

CAPACITY VALUE = 49.80000$/KW-YR
ENERGY VALUE = 46.14000MILLS/KWH
SECONDARY VALUE= 46.14000MILLS/KWH
INTEREST RATE = 0.06875

1

CAPACITY	ENERGY	SECONDARY	INTEREST
1 49.80	46.14	46.14	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
OIL FIRED WITH 2% ESCALATION AFTER POL AND 3% INFLATION	54030.	246932.	29970.	2588.	333520.
NEW SYSTEM					

OIL FIRED WITH 2% ESCALATION AFTER POL AND 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	1374.6	2997.0	2804.2	157736.8	0.0	0.0	0.0	0.0	159111.4
1995	0.8755	265.0	232.0	12623.3	3058.0	2677.2	150594.0	397.0	347.6	19550.6	0.0	182767.9
1996	0.8192	680.0	557.0	30308.1	3058.0	2505.0	140906.7	397.0	325.2	18293.0	0.0	189507.8
1997	0.7665	680.0	521.2	28358.5	3058.0	2343.9	131842.5	397.0	304.3	17116.2	0.0	177317.3
1998	0.7172	950.0	681.3	37069.9	6057.0	4343.9	244342.8	397.0	284.7	16015.2	0.0	297427.9
1999	0.6710	1035.0	694.5	37788.7	6057.0	4064.4	228624.8	785.0	526.8	29630.3	0.0	296043.8
2000	0.6279	1231.0	772.9	42053.7	6057.0	3803.0	213917.9	785.0	492.9	27724.2	0.0	283695.8
2001	0.5875	1347.0	791.3	43056.4	6057.0	3558.3	200157.1	785.0	461.2	25940.8	16.0	269170.3
2002	0.5497	1347.0	740.4	40286.7	6057.0	3329.4	187281.5	785.0	431.5	24272.1	2646.9	254487.2
				272919.8			1655404.2			178542.4	2662.9	2109529.3
2003												
2094	7.9766	1347.0	10744.5	584606.8	6057.0	48314.2	2717675.6	785.0	6261.6	352216.5	38409.6	3692908.4
PRESENT WORTH BENEFITS				857526.6			4373079.8			530758.9	41072.5	5802437.8
CRF= 0.0688 AV ANN BENEFITS =				59031.4			301039.2			36537.0	2827.4	399435.0

CAPACITY VALUE = 54.41000$/KW-YR
ENERGY VALUE = 56.25000MILLS/KWH
SECONDARY VALUE= 56.25000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	54.41	56.25	56.25	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
OIL FIRED WITH 2% ESCALATION AFTER POL AND 5% INFLATION	59031.	301039.	36537.	2827.	399435.
NEW SYSTEM					

OIL-SUDDEN DROP OF 35%

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1095.7	2997.0	2804.2	51737.7	0.0	0.0	0.0	0.0	52833.3
1995	0.8755	265.0	232.0	10062.0	3058.0	2677.2	49394.8	397.0	347.6	6412.6	0.0	65869.4
1996	0.8192	680.0	557.0	24156.5	3058.0	2505.0	46217.4	397.0	325.2	6000.1	0.0	76376.0
1997	0.7665	680.0	521.2	22604.4	3058.0	2343.9	43244.3	397.0	304.3	5614.1	0.0	71462.9
1998	0.7172	950.0	681.3	29548.3	6057.0	4343.9	80144.4	397.0	284.7	5253.0	0.0	114945.7
1999	0.6710	1035.0	694.5	30121.3	6057.0	4064.4	74988.9	785.0	526.8	9718.7	0.0	114828.9
2000	0.6279	1231.0	772.9	33520.6	6057.0	3803.0	70165.1	785.0	492.9	9093.5	0.0	112779.4
2001	0.5875	1347.0	791.3	34320.1	6057.0	3558.3	65651.5	785.0	461.2	8508.6	12.7	108492.9
2002	0.5497	1347.0	740.4	32112.3	6057.0	3329.4	61428.3	785.0	431.5	7961.2	2109.8	103611.7
				217543.3			542972.6			58561.9	2122.6	821200.4
2003 2094	7.9766	1347.0	10744.5	465987.8	6057.0	48314.2	891397.6	785.0	6261.6	115527.0	30616.1	1503528.5
PRESENT WORTH BENEFITS				683531.1			1434370.2			174088.9	32738.7	2324728.9
CRF=	0.0688 AV ANN BENEFITS =			47053.7			98740.9			11984.1	2253.7	160032.4

CAPACITY VALUE = 43.37000$/KW-YR
ENERGY VALUE = 18.45000MILLS/KWH
SECONDARY VALUE= 18.45000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	43.37	18.45	18.45	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	TOTALS---POWER VALUES & INTEREST
NEW SYSTEM				
OIL-SUDDEN DROP OF 35%	47054.	98741.	11984.	160032.
NEW SYSTEM				

OIL-SUDDEN DROP OF 35% AND 3% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	INTERRUP CAPACITY BENEFITS	TOTAL BENEFITS
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
		(MW)	(MW)	($1000)	(GWH)	(GWH)	($1000)	(GWH)	(GWH)	($1000)	($1000)	($1000)
1994	0.9357	27.0	25.3	1218.2	2997.0	2804.2	68394.7	0.0	0.0	0.0	0.0	69612.9
1995	0.8755	265.0	232.0	11187.2	3058.0	2677.2	65297.6	397.0	347.6	8477.2	0.0	84961.9
1996	0.8192	680.0	557.0	26860.1	3058.0	2505.0	61097.1	397.0	325.2	7931.8	0.0	95889.1
1997	0.7665	680.0	521.2	25132.3	3058.0	2343.9	57166.9	397.0	304.3	7421.6	0.0	89720.6
1998	0.7172	950.0	681.3	32852.6	6057.0	4343.9	105947.0	397.0	284.7	6944.2	0.0	145743.8
1999	0.6710	1035.0	694.5	33489.7	6057.0	4064.4	99131.7	765.0	526.8	12847.7	0.0	145469.1
2000	0.6279	1231.0	772.9	37269.4	6057.0	3803.0	92754.8	785.0	492.9	12021.2	0.0	142045.4
2001	0.5875	1347.0	791.3	38158.0	6057.0	3558.3	86788.1	785.0	461.2	11247.9	14.2	136208.2
2002	0.5497	1347.0	740.4	35703.4	6057.0	3329.4	81205.3	785.0	431.5	10524.4	2345.8	129778.8
				241870.9			717783.3			77416.0	2359.9	1039430.1
2003												
2094	7.9766	1347.0	10744.5	518098.5	6057.0	48314.2	1178384.1	785.0	6261.6	152721.1	34039.9	1883243.6
PRESENT WORTH BENEFITS				759969.3			1896167.4			230137.1	36399.8	2922673.6
CRF=	0.0688 AV ANN BENEFITS =			52315.7			130530.6			15842.4	2505.7	201194.4

CAPACITY VALUE = 48.22000$/KW-YR
ENERGY VALUE = 24.39000MILLS/KWH
SECONDARY VALUE= 24.39000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	48.22	24.39	24.39	0.06875

1

SYSTEM OF DEVELOPMENT — CAPACITY ENERGY SECONDARY TOTALS---POWER VALUES & INTEREST
NEW SYSTEM
OIL-SUDDEN DROP OF 35% AND 3% INFLATION 52316. 130531. 15842. 201194.
NEW SYSTEM

OIL--SUDDEN DROP OF 35% AND 5% INFLATION

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	27.0	25.3	1325.8	2997.0	2804.2	83088.8	0.0	0.0	0.0	0.0	84414.6
1995	0.8755	265.0	232.0	12175.5	3058.0	2677.2	79326.2	397.0	347.6	10298.4	0.0	101800.2
1996	0.8192	680.0	557.0	29233.1	3058.0	2505.0	74223.4	397.0	325.2	9635.9	0.0	113092.4
1997	0.7665	680.0	521.2	27352.6	3058.0	2343.9	69448.8	397.0	304.3	9016.1	0.0	105817.4
1998	0.7172	950.0	681.3	35755.0	6057.0	4343.9	128708.9	397.0	284.7	8436.1	0.0	172900.0
1999	0.6710	1035.0	694.5	36448.3	6057.0	4064.4	120429.4	785.0	526.8	15607.9	0.0	172485.6
2000	0.6279	1231.0	772.9	40562.0	6057.0	3803.0	112682.5	785.0	492.9	14603.9	0.0	167848.3
2001	0.5875	1347.0	791.3	41529.1	6057.0	3558.3	105433.9	785.0	461.2	13664.5	15.4	160642.8
2002	0.5497	1347.0	740.4	38857.6	6057.0	3329.4	98651.6	785.0	431.5	12785.5	2553.0	152847.7
				263239.0			871993.4			94048.2	2568.4	1231849.0
2003												
2094	7.9766	1347.0	10744.5	563869.9	6057.0	48314.2	1431550.7	785.0	6261.6	185532.0	37047.1	2217999.8
PRESENT WORTH BENEFITS				827108.9			2303544.1			279580.2	39615.6	3449848.7
CRF=	0.0688	AV ANN BENEFITS =		56937.5			158574.1			19246.1	2727.1	237484.7

CAPACITY VALUE = 52.48000$/KW-YR
ENERGY VALUE = 29.63000MILLS/KWH
SECONDARY VALUE= 29.63000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	52.48	29.63	29.63	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	TOTALS---POWER VALUES & INTEREST
NEW SYSTEM				
OIL-SUDDEN DROP OF 35% AND 5% INFLATION	56937.	158574.	19246.	237485.
NEW SYSTEM				

C-5-29

MINIMUM LOAD GROWTH

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (GWH)	PRESENT WORTH FIRM ENERGY (GWH)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (GWH)	PRESENT WORTH SEC ENERGY (GWH)	SECONDARY ENERGY BENEFITS ($1000)	INTERRUP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1994	0.9357	0.0	0.0	0.0	2997.0	2804.2	35781.7	0.0	0.0	0.0	0.0	35781.7
1995	0.8755	107.0	93.7	17478.2	3058.0	2677.2	34161.4	397.0	347.6	4435.0	0.0	56074.6
1996	0.8192	366.0	299.8	55939.4	3058.0	2505.0	31963.9	397.0	325.2	4149.7	0.0	92053.0
1997	0.7665	530.0	406.2	75794.3	3058.0	2343.9	29907.7	397.0	304.3	3882.7	0.0	109584.8
1998	0.7172	546.0	391.6	73059.6	6057.0	4343.9	55427.8	397.0	284.7	3633.0	0.0	132120.3
1999	0.6710	651.0	436.8	81505.9	6057.0	4064.4	51862.3	785.0	526.8	6721.5	0.0	140089.7
2000	0.6279	764.0	479.7	89500.5	6057.0	3803.0	48526.1	785.0	492.9	6289.1	0.0	144315.7
2001	0.5875	792.0	465.3	86812.3	6057.0	3558.3	45404.5	785.0	461.2	5884.5	0.0	138101.4
2002	0.5497	927.0	509.6	95073.5	6057.0	3329.4	42483.8	785.0	431.5	5506.0	0.0	143063.3
2003	0.5143	938.0	482.4	90013.3	6057.0	3115.3	39750.9	785.0	403.7	5151.8	0.0	134916.0
2004	0.4812	968.0	465.8	86916.7	6057.0	2914.9	37193.8	785.0	377.8	4820.4	0.0	128930.9
2005	0.4503	999.0	449.8	83930.0	6057.0	2727.4	34801.2	785.0	353.5	4510.3	0.0	123241.5
2006	0.4213	1009.0	425.1	79317.1	6057.0	2551.9	32562.6	785.0	330.7	4220.2	0.0	116099.8
2007	0.3942	1020.0	402.1	75023.9	6057.0	2387.8	30467.9	785.0	309.5	3948.7	0.0	109440.5
2008	0.3689	1031.0	380.3	70954.8	6057.0	2234.2	28508.0	785.0	289.6	3694.7	0.0	103157.5
2009	0.3451	1043.0	360.0	67163.2	6057.0	2090.4	26674.1	785.0	270.9	3457.0	0.0	97294.3
2010	0.3229	1054.0	340.4	63505.5	6057.0	1956.0	24958.2	785.0	253.5	3234.6	0.0	91698.4
2011	0.3022	1061.0	320.6	59815.0	6057.0	1830.2	23352.7	785.0	237.2	3026.6	0.0	86194.3
2012	0.2827	1070.0	302.5	56442.0	6057.0	1712.4	21850.5	785.0	221.9	2831.9	0.0	81124.4
2013	0.2645	1077.0	284.9	53156.7	6057.0	1602.3	20444.9	785.0	207.7	2649.7	0.0	76251.4
2014	0.2475	1085.0	268.6	50106.7	6057.0	1499.2	19129.8	785.0	194.3	2479.3	0.0	71715.8
2015	0.2316	1095.0	253.6	47315.6	6057.0	1402.8	17899.2	785.0	181.8	2319.8	0.0	67534.6
2016	0.2167	1100.0	238.4	44474.1	6057.0	1312.5	16747.8	785.0	170.1	2170.5	0.0	63392.4
2017	0.2028	1108.0	224.7	41915.8	6057.0	1228.1	15670.4	785.0	159.2	2030.9	0.0	59617.2
2018	0.1897	1118.0	212.1	39573.4	6057.0	1149.1	14662.4	785.0	148.9	1900.3	0.0	56136.1
2019	0.1775	1124.0	199.5	37226.5	6057.0	1075.2	13719.2	785.0	139.3	1778.0	0.0	52723.7
				1622014.0			793913.0			94726.1	0.0	2510653.1
2020												
2094	2.5631	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PRESENT WORTH BENEFITS				1622014.0			793913.0			94726.1	0.0	2510653.1
CRF= 0.0688 AV ANN BENEFITS =				111658.1			54652.3			6520.9	0.0	172831.3

CAPACITY VALUE = 186.58000$/KW-YR
ENERGY VALUE = 12.76000MILLS/KWH
SECONDARY VALUE= 12.76000MILLS/KWH
INTEREST RATE = 0.06875

1

	CAPACITY	ENERGY	SECONDARY	INTEREST
1	186.58	12.76	12.76	0.06875

1

SYSTEM OF DEVELOPMENT	CAPACITY	ENERGY	SECONDARY	INTERRUPTABLE	TOTALS
NEW SYSTEM					
MINIMUM LOAD GROWTH	111658.	54652.	6521.	0.	172831.
NEW SYSTEM					

EXHIBIT C-6

INVESTMENT COST CALCULATIONS

TABLE C-6-1

INVESTMENT COST WITH 2 YEARS CONSTRUCTION DELAY
(in thousands of dollars)

	Watana			Devil Canyon Gravity Dam				
Year	Expenditure	Accumulated Expenditure	IDC	Expenditure	Present Worth of Expenditure	Accumulated Expenditure	IDC	Present Worth of IDC
1984	30,500		1,048					
1985	107,000	30,500	5,775					
1986	114,000	137,500	13,372					
1987	159,000	251,500	22,756					
1988	214,500	410,500	35,595					
1989	208,000	625,000	50,119					
1990	230,000	833,000	65,175					
1991	245,000	1,063,000	91,503					
1992	223,000	1,308,000	97,591					
1993	161,000	1,531,000	110,791					
1994	32,000	1,692,000	117,425	39,000	39,000		1,341	1,341
1995	25,000	1,724,000	119,384	98,500	98,500	39,000	6,067	6,067
1996	16,000	1,749,000	120,794	117,000	117,000	137,500	13,475	13,475
1997	1,765,000	1,765,000	851,328	137,000	128,187	254,500	23,581	22,064
1998				144,000	126,070	391,500	38,191	33,436
1999				158,000	129,428	535,500	43,622	35,734
2000				129,500	99,258	693,500	53,505	41,010
				823,000	737,443	823,000	179,784	153,127

	Watana	Devil Canyon	Total Watana & Devil Canyon
Construction Cost	$1,765,000	$737,443	$2,502,443
I.D.C.	851,328	153,127	1,004,455
Investment Cost	$2,616,328	$890,570	$3,506,898
Interest and Amortization	$ 180,106	$ 61,307	$ 241,413
Operation, Maintenance, and Replacement	2,620	700	3,320
Average Annual Cost	$ 182,726	$ 62,007	$ 244,733

TABLE C-6-2

INVESTMENT COST WITH 8% DISCOUNT RATE
(in thousands of dollars)

	Watana			Devil Canyon Gravity Dam				
Year	Expenditure	Accumulated Expenditure	IDC	Expenditure	Present Worth of Expenditure	Accumulated Expenditure	IDC	Present Worth of IDC
1984	30,500		1,220					
1985	107,000	30,500	6,720					
1986	114,000	137,500	15,560					
1987	159,000	251,500	26,480					
1988	218,500	410,500	41,580					
1989	214,000	629,000	58,920					
1990	248,000	843,000	77,360					
1991	258,000	1,091,000	97,600					
1992	223,000	1,349,000	116,840	39,000	39,000		1,560	1,560
1993	161,000	1,572,000	132,200	98,500	98,500	39,000	7,060	7,060
1994	32,000	1,733,000	139,920	117,000	117,000	137,500	15,680	15,680
1995	1,765,000	1,765,000	714,400	137,000	126,852	254,500	25,840	23,926
1996				144,000	123,457	391,500	37,080	31,790
1997				158,000	125,425	535,500	49,160	39,025
1998				129,500	95,186	693,500	60,660	44,587
				823,000	725,420	823,000	197,040	163,628

	Watana	Devil Canyon	Total Watana & Devil Canyon
Construction Cost	$1,765,000	$725,420	$2,490,420
I.D.C.	714,400	163,628	878,028
Investment Cost	$2,497,400	$889,048	$3,368,448
Interest and Amortization	$ 198,442	$ 71,156	$ 269,598
Operation, Maintenance, and Replacement	2,620	700	3,320
Average Annual Cost	$ 201,062	$ 71,856	$ 272,918

TABLE C-6-3

INVESTMENT COST WITH 5% DISCOUNT RATE
(in thousands of dollars)

	Watana			Devil Canyon Gravity Dam				
Year	Expenditure	Accumulated Expenditure	IDC	Expenditure	Present Worth of Expenditure	Accumulated Expenditure	IDC	Present Worth of IDC
1984	30,500		763					
1985	107,000	30,500	4,200					
1986	114,000	137,500	9,725					
1987	159,000	251,500	16,550					
1988	218,500	410,500	25,988					
1989	214,000	629,000	36,800					
1990	248,000	843,000	48,350					
1991	258,000	1,091,000	61,000					
1992	223,000	1,349,000	73,025	39,000	39,000		975	975
1993	161,000	1,572,000	82,625	98,500	98,500	39,000	4,413	4,413
1994	32,000	1,733,000	87,450	117,000	117,000	137,500	9,800	9,800
1995	1,765,000	1,765,000	446,476	137,000	130,476	254,500	19,575	18,643
1996				144,000	130,612	391,500	23,175	21,020
1997				158,000	136,486	535,500	30,725	26,541
1998				129,500	106,540	693,500	37,913	31,191
				823,000	758,614	823,000	126,576	112,583

	Watana	Devil Canyon	Total Watana & Devil Canyon
Construction Cost	$1,765,000	$758,614	$2,523,614
I.D.C.	446,476	112,583	559,059
Investment Cost	$2,211,476	$871,197	$3,082,673
Interest and Amortization	$ 111,421	$ 43,894	$ 155,315
Operation, Maintenance, and Replacement	2,620	700	3,320
Average Annual Cost	$ 114,041	$ 44,594	$ 158,635

TABLE C-6-4

INVESTMENT COST WITH ARCH DAM AT DEVIL CANYON
(in thousands of dollars)

	Watana			Devil Canyon Gravity Dam				
Year	Expenditure	Accumulated Expenditure	IDC	Expenditure	Present Worth of Expenditure	Accumulated Expenditure	IDC	Present Worth of IDC
1984	30,500		1,048					
1985	107,000	30,500	5,775					
1986	114,000	137,500	13,372					
1987	159,000	251,500	22,756					
1988	218,500	410,500	35,733					
1989	214,000	629,000	50,600					
1990	248,000	843,000	66,481					
1991	258,000	1,091,000	83,875					
1992	223,000	1,349,000	100,409	32,500	32,500		1,117	1,117
1993	161,000	1,572,000	113,609	61,000	61,000	32,500	4,331	4,331
1994	32,000	1,733,000	120,244	87,000	87,000	93,500	9,419	9,419
1995	1,765,000	1,765,000	613,902	113,000	105,731	180,500	16,294	15,246
1996				122,000	106,809	203,500	24,372	21,337
1997				148,500	121,646	415,500	33,670	27,581
1998				101,000	77,413	564,000	42,247	32,381
				665,000	592,009	665,000	131,449	111,412

	Watana	Devil Canyon	Total Watana & Devil Canyon
Construction Cost	$1,765,000	$592,099	$2,357,099
I.D.C.	613,902	111,412	725,314
Investment Cost	$2,378,902	$703,511	$3,082,413
Interest and Amortization	$ 163,761	$ 48,429	$ 212,190
Operation, Maintenance, and Replacement	2,620	700	3,320
Average Annual Cost	$ 166,381	$ 49,129	$ 215,510

EXHIBIT C-7

CORRESPONDENCE

FEDERAL ENERGY REGULATORY COMMISSION
REGIONAL OFFICE
555 BATTERY STREET, ROOM 415
SAN FRANCISCO, CA 94111

October 31, 1978

Colonel George R. Robertson
District Engineer
Alaska District, Corps of Engineers
P. O. Box 7002
Anchorage, Alaska 99510

Dear Colonel Robertson:

This is in response to your letter of April 14, 1978, in which you requested updated power values for use in your studies of the Upper Susitna River Basin. We regret that we were not able to provide the values earlier.

Attached Tables I through VI give details of our estimates. At Mr. Mohn's suggestion, an annual capacity factor of 50 percent was assumed for the Upper Susitna Basin projects.

At your request, we have provided a breakdown of our cost estimates in order that your staff may make sensitivity analyses of the effects of possible inflation of all components of the estimates including fuel cost escalation. Power values are provided based on estimated costs of power from two possible alternative thermal sources for both the Anchorage-Kenai and Fairbanks areas. An oil-fired combined cycle plant, located near Anchorage, and a mine-mouth coal-fired steam-electric generating plant located near the Beluga coal fields are considered as alternatives to hydro power for the Anchorage-Kenai area. For the Fairbanks area, an oil-fired regenerative combustion turbine plant near Fairbanks and a mine-mouth coal-fired steam-electric plant are believed to be the proper alternative power sources. A combined cycle plant alternative was not studied for Fairbanks because of its associated "ice fogging" problems and proximity to populated centers. Our estimates indicate that the combined-cycle plant near Anchorage and the regenerative combustion turbine plant near Fairbanks, respectively, are the least costly sources of power alternative to hydroelectric. However, we are not able to state that either is the most probable source.

As you know, there is significant speculation with respect to the practical and economic feasibility of the development of a coal mine in the Beluga area to serve a relatively small coal-fired steam-electric plant. To be feasible, it is probable that the field must be developed to provide coal for export in large quantities, or for added local use. It is not readily apparent to us that coal will be available near term to fuel a plant in the Beluga area. We have, nevertheless, included a power value based on the existence of such an installation in our estimates.

Coal is readily available in the Healy field near Fairbanks. Golden Valley Electric Association, Inc. has contracted for a consultant's study of the potential of installing additional coal-fired generation to its system. Coal-fired generation, according to our estimates, however, would be significantly more costly than that from a regenerative oil-fired combustion turbine.

The National Energy Act generally prohibits the use of oil or natural gas as fuel in large-scale base load generating plants. However, the Act also includes many provisions under which a utility may be exempted from the restrictions on use of oil. Exemptions may be obtained because of unavailability of coal, high cost of coal and associated facilities, site limitations, environmental requirements, and, most importantly, if the required use of coal would not allow the petitioner to obtain adequate capital for the financing of such a powerplant. Undoubtedly, rules regarding the above will be prescribed and interpretations of the Act will be made by proper authority. Care should be exercised in the selection of probable alternative power sources because of these exemption provisions. We suggest that inquiries be made of the intentions of local utility officials regarding possible requests for exemptions to the use of coal in lieu of other fuels in light of the high investment cost of coal-fired plants.

Pursuant to one of your requests, associated investment costs of pollution control equipment included in the total investment costs for coal-fired plants are given below. These costs include indirects and overheads as well as interest during construction.

(1) Fairbanks Area - Healy plant (PNF). Electrostatic precipitators and SO_2 scrubbers are estimated to cost \$357/kW, and cooling towers, \$44.20/kW. Costs at federal financing are slightly higher.

(2) Anchorage-Kenai Area - Beluga plant (PNF). Baghouse filters and SO_2 scrubbers are estimated to cost \$187/kW, and cooling towers, \$35/kW. Costs at federal financing are slightly lower.

Estimates of future loads are supplied the FERC on FPC Form 12E-2 by the four principal utilities operating in Fairbanks and Anchorage. These estimates show that in 1988 approximately 80 percent of the total electric needs of the so-called "railbelt area" will be in the Anchorage-Kenai area and 20 percent in the Fairbanks area. This division of requirements would probably be a useful guide in your allocation of Upper Susitna projects output.

These estimates of power values are subject to the approval of our Washington Office.

If we can be of further assistance, please advise.

Very truly yours,

Eugene Neblett
Regional Engineer

Attachments

TABLE I

Annual Fixed Charge Rates
Anchorage-Kenai Market Area

	Generating Stations and Substations	Steel Tower Transmission Lines
Service Life, years	30	50
REA Financing	%	%
Cost of Money	8.500	8.500
Depreciation (Sinking Fund)	0.805	0.146
Insurance	0.250	0.100
Taxes	0.350	0.350
Total, Fixed Charges	9.905	9.096
Use	9.91	9.10
Municipal Financing		
Cost of Money	6.250	6.250
Depreciation (Sinking Fund)	1.210	0.317
Insurance	0.250	0.100
Taxes	1.300	1.300
Total, Fixed Charges	9.010	7.967
Use	9.01	7.97
Composite - REA and Municipal 1/		
REA @ 75%	7.43	6.82
Municipal @ 25%	2.25	1.99
Total, Composite	9.68	8.81
Federal Financing		
Cost of Money	6.875	6.875
Depreciation (Sinking Fund)	1.083	0.257
Insurance 2/	-	-
Total, Fixed Charges	7.958	7.132
Use	7.96	7.13

1/ *Based on approximate proportion of total future loads in Anchorage-Kenai Market Area.*
2/ *Omitted at request of NPD, Corps of Engineers.*

TABLE II

Annual Fixed Charge Rates
Fairbanks Market Area

	Generating Stations and Substations	Steel Tower Transmission Lines
Service Life, Years	30	50
Public-nonfederal Financing 1/	%	%
Cost of Money	5.750	5.750
Depreciation (Sinking Fund)	1.322	0.374
Insurance	0.250	0.250
Taxes	-	-
Total, Fixed Charges	7.322	6.374
Use	7.32	6.37
Federal Financing		
Cost of Money	6.875	6.875
Depreciation (Sinking Fund)	1.083	0.257
Insurance 2/	-	-
Total, Fixed Charges	7.958	7.132
Use	7.96	7.13

1/ *Alaska Power Authority financing assumed.*

2/ *Omitted at request of NPD, Corps of Engineers.*

TABLE III

Hydroelectric Plant Power Values At Market
Anchorage-Kenai Area
(Costs as of 7/1/78)

			Coal-fired Generating Plant	
A.	Plant Description			
	Capacity	MW	450	
	Unit Size	MW	225	
	Service Life	Years	30	
	Heat Rate	Btu/kWh	10 000	
	Fuel Cost	¢/10^6 Btu	110	
	Annual Plant Factor	%	55	
			Financing	
			Pub.-nonfed.1/	Federal
B.	Investment Cost	$/kW	1 240	1 220
C.	Annual Capacity Cost at Plant		$/kW-yr.	
	Fixed Charges		120.03	97.11
	Fuel Inventory		0.91	0.75
	Fixed O&M		14.69	14.69
	Administrative and General		5.65	5.65
	Annual Capacity Cost at Generator Bus		141.28	118.20
D.	Energy Cost		mills/kWh	
	Fuel		11.00	11.00
	Variable O&M		1.64	1.64
	Energy Costs at Generator Bus		12.64	12.64

TABLE III (cont'd.)

Hydroelectric Plant Power Values At Market
Anchorage-Kenai Area
(Costs as of 7/1/78)

	Coal-fired Generating Plant		
	Financing		
	Pub.-nonfed.	Federal	
	--- $/kW-yr. ---		mills/kWh
E. Cost of Thermal Plant Output at Generator Bus	141.28	118.20	12.64
F. Plant to Market Thermal Plant Transmission Costs - 230 kV			
1. Step-up substation			
(a) Fixed charges	2.50	2.04	
(b) O&M and Adm. & Gen.	0.53	0.53	
2. Transmission Lines			
(a) Fixed charges	10.97	8.79	
(b) O&M and Adm. & Gen.	2.56	2.53	
3. Receiving Station			
(a) Fixed charges	1.83	1.50	
(b) O&M and Adm. & Gen.	0.39	0.39	
4. Losses			
(a) Capacity	11.45	9.58	
(b) Energy			0.65
G. Cost of Thermal Power Delivered at Market			
1. Capacity	171.51	143.56	
2. Energy			13.29
H. Hydro-thermal Capacity and Energy Value Adjustments			
1. Capacity	17.15	14.36	
2. Energy			- 2/
I. Value of Hydro Plant Output Delivered at Market			
1. Capacity	188.66	157.92	
2. Energy			13.29

1/ *REA, 75%; Municipal, 25%.*
2/ *Negligible.*

TABLE IV

Hydroelectric Plant Power Values At Market
Anchorage-Kenai Area
(Costs as of 7/1/78)

			Combined Cycle Generating Plant	
A.	Plant Description			
	Capacity	MW	420	
	Unit Size	MW	105	
	Service Life	Years	30	
	Heat Rate	Btu/kWh	8 350	
	Fuel Cost, Oil	¢/10^6 Btu	300	
	Annual Plant Factor	%	50	
			Financing	
			Pub.-nonfed. 1/	Federal
B.	Investment Cost	$/kW	360	355
C.	Annual Capacity Cost at Plant		$/kW-yr.	
	Fixed Charges		34.85	28.26
	Fuel Inventory		1.91	1.58
	Fixed O&M 2/		-	-
	Administrative and General		3.20	3.20
	Annual Capacity Cost at Generator Bus		39.96	33.04
D.	Energy Cost		mills/kWh	
	Fuel		25.05	25.05
	O&M		1.83	1.83
	Energy Costs at Generator Bus		26.88	26.88

TABLE IV (cont'd.)

Hydroelectric Plant Power Values At Market
Anchorage-Kenai Area
(Costs as of 7/1/78)

	Combined Cycle Generating Plant Financing		
	Pub.-nonfed.	Federal	
	- - - $/kW-yr. - - -		mills/kWh
E. Cost of Thermal Plant Output at Generator Bus	39.96	33.04	26.88
F. Plant to Market Thermal Plant Transmission Costs - 138 kV			
1. Step-up substation			
(a) Fixed charges	1.33	1.08	
(b) O&M and Adm. & Gen.	0.28	0.28	
2. Transmission Lines			
(a) Fixed charges	0.81	0.65	
(b) O&M and Adm. & Gen.	0.19	0.19	
3. Receiving Station			
(a) Fixed charges	0.19	0.16	
(b) O&M and Adm. & Gen.	0.04	0.04	
4. Losses			
(a) Capacity	2.30	1.89	
(b) Energy			1.02
G. Cost of Thermal Power Delivered at Market			
1. Capacity	45.10	37.33	
2. Energy			27.90
H. Hydro-thermal Capacity and Energy Value Adjustments			
1. Capacity	2.26	1.87	
2. Energy			- 3/
I. Value of Hydro Plant Output Delivered at Market			
1. Capacity	47.36	39.20	
2. Energy			27.90

1/ *REA, 75%; Municipal, 25%.*
2/ *Included in energy cost.*
3/ *Negligible.*

TABLE V

Hydroelectric Plant Power Values At Market
Fairbanks, Alaska
(Costs as of 7/1/78)

A. Plant Description		Coal-fired Generating Plant	
Capacity	MW	230	
Unit Size	MW	115	
Service Life	Years	30	
Heat Rate	Btu/kWh	10 500	
Fuel Cost	¢/10^6 Btu	80	
Annual Plant Factor	%	55	
		Financing	
		Pub.-nonfed.1/	Federal
B. Investment Cost	$/kW	1 475	1 510
C. Annual Capacity Cost at Plant		$/kW-yr.	
Fixed Charges		107.97	120.20
Fuel Inventory		0.48	0.57
Fixed O&M		16.29	16.29
Administrative and General		6.68	6.68
Annual Capacity Cost at Generator Bus		131.42	143.74
D. Energy Cost		mills/kWh	
Fuel		8.40	8.40
Variable O&M		1.82	1.82
Energy Costs at Generator Bus		10.22	10.22

TABLE V (cont'd.)

Hydroelectric Plant Power Values At Market
Fairbanks, Alaska
(Costs as of 7/1/78)

	Coal-fired Generating Plant — Financing: Pub.-nonfed. ($/kW-yr.)	Federal ($/kW-yr.)	mills/kWh
E. Cost of Thermal Plant Output at Generator Bus	131.42	143.74	10.22
F. Plant to Market Thermal Plant Transmission Costs - 230 kV			
1. Step-up substation			
(a) Fixed charges	3.18	3.47	
(b) O&M and Adm. & Gen.	0.89	0.90	
2. Transmission Lines			
(a) Fixed charges	11.19	12.66	
(b) O&M and Adm. & Gen.	3.61	3.65	
3. Receiving Station			
(a) Fixed charges	2.09	2.28	
(b) O&M and Adm. & Gen.	0.59	0.59	
4. Losses			
(a) Capacity	8.81	9.64	
(b) Energy			0.42
G. Cost of Thermal Power Delivered at Market			
1. Capacity	161.78	176.93	
2. Energy			10.64
H. Hydro-thermal Capacity and Energy Value Adjustments			
1. Capacity	16.18		
2. Energy			- 2/
I. Value of Hydro Plant Output Delivered at Market			
1. Capacity	177.96		
2. Energy			10.64

1/ Alaska Power Authority financing assumed.
2/ Negligible.

TABLE VI

Hydroelectric Plant Power Values At Market
Fairbanks, Alaska
(Costs as of 7/1/78)

A. Plant Description		Regen. Combustion Turbine Plant	
Capacity	MW	240	
Unit Size	MW	60	
Service Life	Years	30	
Heat Rate	Btu/kWh	10 000	
Fuel Cost, Oil	¢/10^6 Btu	210	
Annual Plant Factor	%	50	
		Financing	
		Pub.-nonfed.1/	Federal
B. Investment Cost	$/kW	265	270
C. Annual Capacity Cost at Plant		$/kW-yr.	
Fixed Charges		19.40	21.49
Fuel Inventory		1.09	1.30
Fixed O&M 2/		-	-
Administrative and General		2.08	2.08
Annual Capacity Cost at Generator Bus		22.57	24.87
D. Energy Cost		mills/kWh	
Fuel		21.00	21.00
O&M		1.19	1.19
Energy Costs at Generator Bus		22.19	22.19

TABLE VI (cont'd.)

Hydroelectric Plant Power Values At Market
Fairbanks, Alaska
(Costs as of 7/1/78)

	Regen. Combustion Turbine Plant Financing		
	Pub.-nonfed.	Federal	
	- - - $/kW-yr. - - -		mills/kWh
E. Cost of Thermal Plant Output at Generator Bus	22.57	24.87	22.19
F. Plant to Market Thermal Plant Transmission Costs - 138 kV			
1. Step-up substation			
(a) Fixed charges	1.60	1.75	
(b) O&M and Adm. & Gen.	0.44	0.45	
2. Transmission Lines			
(a) Fixed charges	1.88	2.14	
(b) O&M and Adm. & Gen.	0.62	0.62	
3. Receiving Station			
(a) Fixed charges	0.25	0.27	
(b) O&M and Adm. & Gen.	0.07	0.07	
4. Losses			
(a) Capacity	1.39	1.52	
(b) Energy			0.81
G. Cost of Thermal Power Delivered at Market			
1. Capacity	28.82	31.69	
2. Energy			23.00
H. Hydro-thermal Capacity and Energy Value Adjustments			
1. Capacity	1.44	1.58	
2. Energy			- 3/
I. Value of Hydro Plant Output Delivered at Market			
1. Capacity	30.26	33.27	
2. Energy			23.00

1/ *Alaska Power Authority financing assumed.*
2/ *Included in energy cost.*
3/ *Negligible.*

Department of Energy
Alaska Power Administration
P.O. Box 50
Juneau, Alaska 99802

November 9, 1978

MEMORANDUM FOR EUGENE NEBLETT, REGIONAL ENGINEER
FEDERAL ENERGY REGULATORY COMMISSION

FROM: ROBERT J. CROSS, ADMINISTRATOR

SUBJECT: ALTERNATIVE POWER SOURCES FOR THE RAILBELT AREA

Colonel Robertson's office sent us a copy of your October 31 memorandum explaining your assumptions on likely alternatives to Upper Susitna power for the Anchorage and Fairbanks areas.

I am not in tune with the suggestion that oil-fired plants may be a realistic alternative for the 1,500 MW Upper Susitna Project.

Many utilities in Alaska and other parts of the country will continue their push for more and more exemptions to allow continued use of oil and gas in both existing and new plants. How successful they will be and for how long is conjecture. NEP legislation this year does, as your letter points out, provide a range of exemptions.

We've looked at the same issues as a part of our report on marketability of Upper Susitna power. Our finding is that the exemptions don't seem all that permanent or pertinent in terms of a large new hydro project coming on line in 1992.

I just don't see the logic of the oil assumption in benefit determinations for 100-years of power from a major new hydro project.

cc: Colonel Robertson
Robert Volk, OPMC

ALASKA POWER AUTHORITY

333 WEST 4th AVENUE - SUITE 31 - ANCHORAGE, ALASKA 99501 Phone: (907) 277-7641
(907) 276-2715

November 17, 1978

Colonel George Robertson
U.S. Army Corps of Engineers
Alaska District
Post Office Box 7002
Anchorage, Alaska 99510

Dear Colonel Robertson:

I have reviewed the material provided by the Federal Energy Regulatory Commission (FERC), associated with the Upper Susitna study power values. I feel that oil-fired generation as an alternative to Susitna hydroelectric must be questioned. Oil-fired generation for new plants in Anchorage and Fairbanks will require exemptions from the Secretary of Energy from the provisions of the Powerplant and Industrial Fuel Use Act of 1978. The ability of Anchorage and Fairbanks to qualify for the exemptions to meet peak load requirements is doubtful. Due to limited refining capability in Alaska, distillate fuel oil requirements by 1990 would require a major expansion of refining capabilities in Alaska. Without expansion the utilities will import distillate fuel and pay associated high transportation costs. Therefore, oil-fired generation for the railbelt area may not be acceptable either for legal and regulatory reasons or from the standpoint of fuel availability.

The cost of fuel for oil-fired generation is an area that is not adequately addressed in the economic analysis of hydroelectric alternatives by the federal government. The provision of power values by FERC and the subsequent present worth analysis of alternative power generation is insensitive to National Energy Policy and the inelastic commodity demand of non-renewable resources such as distillate fuel. I feel that the economic analysis of the alternatives must be sensitive to these considerations by appraising the true costs of energy to the consumer over a fifty year time frame with the capital intensive nature of facilities, the economic life of facilities, and the projected cost of fuel taken into account. The Golden Valley Electric Cooperative in Fairbanks has recently studied the coal vs. oil-fired generation question for the next addition to GVEA's base load capacity. GVEA has determined that the coal fired generation alternative is preferable to oil.

Colonel George Robertson
Page Two
November 16, 1978

I hope these comments will assist the Corps of Engineers in the application of Upper Susitna power values in the supplemental feasibility studies currently in progress. Thank you for the opportunity to comment.

Sincerely,

Eric P. Yould
Executive Director

SECTION D

FOUNDATIONS AND MATERIALS

SECTION D

FOUNDATION AND MATERIALS

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

LIST OF CHARTS

LIST OF CHARTS (cont)

LIST OF PLATES

EXHIBITS

Number	Title
D-1	Location Maps and Seismic Refraction Velocity Profiles, Watana and Devil Canyon Damsites. By Shannon & Wilson, Inc. Geological Consultants; Contract No. DACW85-78-C-0027, November 1978
D-2	Report - Reconnaissance of the Recent Geology of the Proposed Devil's Canyon and Watana Damsites, Susitna River, Alaska. By Kachadoorian & Henry J. Moore, U.S. Geological Survey, November 1978
D-3	Report - Earthquake Assessment at the Susitna Project by E.L. Krinitzsky, U.S. Army Engineer Waterways Experimental Station, Vicksburg, Mississippi, 10 November 1978
D-4	Technical Note - Procedure for Estimating Borehole Spacing and Thaw Water Pumping Requirements for Artificially Thawing the Bedrock Permafrost at the Watana Damsite. By F.H. Sayles, U.S. Army Engineers Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, October 1978
D-5	Open File Report 78-558-A, U.S. Geological Survey - Reconnaissance geologic map and geochronology, Talkeetna Mountains Quadrangle, northern part of Anchorage Quadrangle, and southwestern portion of Healy Quadrangle, Alaska by Csejtey, et al 1978

SUMMARY OF CHANGES

CHANGES TO THE 1976 INTERIM FEASIBILITY REPORT

In 1978, The Alaska District, Corps of Engineers, performed additional field explorations and geologic studies to verify the feasibility of the Watana damsite. As a result of these studies, considerably more information is now available concerning the site and the regional geology of the area. Therefore, the entire sections on Regional Geology, pages D-1 through D-9; Watana Site, pages D-10 through D-12; and the paragraph on Seismology at Devil Canyon, page D-7, of Appendix D, Foundations and Materials, of the 1976 Interim Feasibility Report are deleted and replaced by this supplemental report. No changes to the Vee Canyon and Denali sites have been made. Plate D-3, Watana - Site Plan and Centerline Profile is deleted and replaced with revised drawings. Several new plates showing geologic sections, borrow areas, and exploration logs have been added. These are listed in the index.

CHANGES IN DESIGN

As a result of the additional field exploration and geologic studies, a more knowledgeable assessment of the proposed project can now be made. A summary of the items which reflect changes to the 1976 Interim Feasibility Report, or reinforce the basic concepts of that report follows.

1. Nothing was found during this phase of the study to cast doubt on the feasibility of a dam at the Watana damsite. All exploration and geologic studies reinforced the concept that a large earth and rockfill or a concrete gravity dam could be built in this general vicinity.

2. Detailed surveys were performed at the Watana site. It was found that the topography used for the 1976 report was in error by approximately 15 feet. Therefore, the elevations shown on the plates or sections in this supplement are 15 feet lower than those shown in the 1976 report. The detailed survey showed the valley section to be a little wider than previously assumed and therefore, the crest length of the dam and the total quantities within the dam are somewhat larger.

3. The explorations at the damsite indicate that the rock is as good or better than previously assumed. Foundation rock is considered adequate to support either an earth-rockfill structure or a concrete gravity dam. To support this conclusion, the regional and site geology as well as the rock structure are discussed in much greater detail in this supplemental report.

4. The 1976 report recognized that the Watana damsite is an area of marginal permafrost and, therefore, permanently frozen ground could be expected in the vicinity. In the 1978 exploration program, specific locations of permafrost were identified and a number of temperature measuring devices were installed. The earlier assumption that permafrost does exist over much of this area was confirmed; however, it was determined that this is a very "warm" permafrost, ranging from 0° C to -1° C. Premafrost was encountered in bedrock in the left abutment of the dam and its effects on the grouting in this area are discussed in this supplemental report. Permafrost was also encountered in the impervious borrow area; however, because of its marginal temperature, it tends to be soft and can be easily excavated. A more detailed discussion is contained in the body of this report.

5. The 1976 report envisioned rather large amounts of gravel available for construction of the shells of the dam and limited amounts of impervious core material. The recent explorations indicate that this is not the case since gravels in large quantities were not verified but large quantities of impervious core material were discovered near the damsite. Because of the apparent shortage of gravel and an excess of impervious material, the dam section has been completely revised. The gravel shells have been changed to rock shells. This change to rockfill has allowed the use of a somewhat steeper slope on the upstream face of the dam. A large portion of the rock will come from required excavation of the spillway. The remainder will come from excavation of underground facilities and access roads and from a large borrow source on the left abutment.

6. The foundation excavation has been increased to require the entire foundation of the dam to be stripped to bedrock. The 1976 report envisioned excavation to bedrock under the core and filters only. However, because the evidence of the limited drilling performed is inconclusive, it was considered adviseable to require removal of in situ gravels beneath the entire embankment. If additional drilling supports a less conservative approach, the change can be made under subsequent feature design.

7. The core has been widened somewhat from that shown in the 1976 report and a zone of semipervious material, approximately of the same width as the core, has been added. This was done because large amounts of semipervious material are available and estimates show that it can be placed within the dam at a considerably lower cost than the rock shell material. The total thickness of these impervious and semipervious zones was determined by considering their effect on total stability of the dam and the difficulties of placing materials which require careful moisture control in the arctic environment. Laboratory tests performed on these materials indicate that optimum moisture will be a rather critical factor in their compaction. Therefore, the use of such materials has been held to within reasonable limits.

8. The 1976 report showed a vertical access shaft to the low-level drain system which passed through the embankment of the dam. This has now been changed to a tunnel through the right abutment, thereby eliminating any structures in the dam embankment.

9. A grout gallery has been added to the lower portions of the dam to facilitate grouting and to accommodate the process of thawing the permafrost. Use of the gallery will allow embankment placement and curtain grouting to proceed simultaneously, resulting in a shortened construction schedule. The gallery will also provide for "read-out" stations for instrumentation in the foundation and lower levels of the embankment and for general access.

10. The spillway location as shown in the 1976 report has been shifted southwest to a location which insures rock cut for its entire length. The rock and overburden material from this large excavation will be utilized in the dam embankment.

11. The 1976 report discusses a potential problem of seepage along a relict channel in the right abutment. The 1978 explorations verified the existence of this channel; however, studies indicate that it is not a problem and, therefore, no remedial action is required.

12. The diverison tunnel portals have been shifted to ensure their location in reasonably sound rock.

13. Professional services of Ellis Krinitzsky of the Waterways Experiment Station and Reuben Kachadoorian and Henry J. Moore from the U.S. Geological Survey were obtained by contract to perform seismic studies and evaluate the earthquake risk at these sites. Their work was divided into two phases. Kachadoorian and Moore of USGS performed the field reconnaissance to look for active faults and other geologic hazards. Krinitzsky's work was aimed at assessing the potential earthquakes which could be associated with such faulting. The USGS report recognized that this is a highly seismic region; however, the geologic reconnaissance of the proposed Devil Canyon and Watana damsites and reservoirs did not uncover evidence of recent or active faulting along any of the known or inferred faults. In their work they did not uncover evidence of the Susitna Fault, which was previously thought to exist a short distance west of the Watana damsite. Krinitzsky's work assessed the possible occurrance of earthquakes at the damsite and the motions that are likely to be associated with earthqauke activity. His findings indicate that the design of the proposed dams to withstand such activity is within the state of the art of seismic design.

14. In the fall of 1978, the consulting firm of Shannon & Wilson was engaged to perform refraction seismograph work at both the Watana and Devil Canyon damsites. This work supplemented the drilling information. The location maps and seismic velocity profiles from the Shannon & Wilson report are included as Exhibit D-1 to this appendix.

REGIONAL GEOLOGY

PHYSIOGRAPHY

The area of study is located within the Coastal Trough Province of southcentral Alaska. The Susitna River is a glacially fed stream which heads on the southern slopes of the Alaska Range, and flows by way of a continuously widening valley to the tidewaters of Cook Inlet. Within the upper 200 river miles, the Susitna passes through a variety of land forms related to the lithology and geology of the region. From its proglacial channel in the Alaska Range, it passes through a broad, glaciated, intermontane valley characterized by knob and kettle topography and by braided river channels. Turning westward along the northern edge of the Copper River lowlands, the river enters a deep, V-shaped valley and traverses the Talkeetna Mountains, emerging into an outwash plain and broad valley which it follows to the sea.

Three regional topographic lows, still identifiable today, are the Susitna River-Chulitna River area downstream of the Devil Canyon site, the middle reach of the Susitna River from Prairie Creek to Watana Creek, and the Oshetna River area at the Susitna Big Bend. These may represent drainage base levels that existed during the glacial periods. Whether they were interconnected at one time is not known since glaciation has modified the original drainages. One possible interpretation is that the ancestral Susitna River may have followed the course of the present Watana Creek and continued southwest along an ancestral valley through the area now occupied by Stephan Lake, Prairie Creek, and the Talkeetna River.

The Susitna River, presently incised 500 feet into that broad, ancestral, U-shaped valley, makes two sharp right-angle turns downstream of Watana Creek in the Fog Creek area and leaves the ancestral valley to flow westward into the steep, V-shaped Devil Canyon area. Glaciation probably blocked its former southwest course forcing the river to find a new outlet in Devil Canyon. Once established in a westward course, the Susitna River downcut its channel rapidly and became entrenched in Devil Canyon.

INFERRED GEOLOGIC HISTORY

The upper Susitna River basin is a complex geologic area with a variety of sedimentary, igneous, and metamorphic rock types. These range from Pennsylvanian to Pleistocene in age and have undergone at least three major periods of tectonic deformation.

The oldest outcrops in the area are Pennsylvanian and Permian aged metavolcanic flows and tuffs, locally containing limestone interbeds that have subsequently been altered to marble. This transitional shelf environment continued throughout the Triassic and into early Jurassic times, with alternate deposition of basalt and thin sedimentary interbeds. Metavolcaniclastics include altered marine sandstones and shales. This deposition was contemporaneous with a massive outpouring of lavas in the eastern Alaska Range, resulting in regional subsidence.

The first major tectonic upheaval in the Susitna area occurred in mid to late Jurassic time and consisted of large plutonic intrusions accompanied by uplift and intense metamorphism. Erosional remnants of these intrusives include amphibolites, greenschists, diorites, and acidic granitic types in the upper Watana reservoir areas. This uplift, and subsequent erosional period, was followed by marine deposition of argillite and graywacke in late Cretaceous. These rocks are exposed in the northwestern half of the upper Susitna basin and include the phyllites of the Devil Canyon site.

The second major tectonic event occurred in middle to late Cretaceous. Most of the structural features in the Talkeetna Mountains, including thrust faulting, complex folding, and uplift, occurred at that time. As a result of the thrust faulting, Pennsylvanian and Permian volcanic flows and tuffs were thrust over the much younger late Cretaceous argillite and graywacke.

In early Tertiary, approximately 65 million years ago, the northwestern portion of the upper Susitna basin was intruded by plutons of igneous rock. The diorite pluton that underlies the Watana site is one of these intrusives. Deposition of undifferentiated volcanic flows, pyroclastics, and associated near-surface intrusives occurred concurrent with and following the intrusion of the plutons.

The third major tectonic event was a period of extensive uplift and erosion in middle Tertiary to Quaternary. Uplift of 3,000 feet has been measured in the southern Talkeetna Mountains. The widespread erosion that occurred during this period removed thick rock sequences from the Susitna basin area.

Glaciation has been the prime erosion agent during the past several million years. At least two, and probably more, periods of glaciation occurred within the upper Susitna basin area. The central and eastern portions of the area may have been partially covered by glacial lakes during the latter glaciations. Renewed uplift in late Pleistocene rejuvenated the erosion cycle until the streams, with their increased gradients, became incised within glaciated valleys. The area currently is undergoing continued stream erosion, and is covered in many areas with a veneer of glacial and alluvial clay, silt, sand, and gravel deposits.

REGIONAL TECTONICS

The arcuate structure of southcentral Alaska reflect both the magnitude and direction of regional tectonic forces caused by the collision of the North American and Pacific Plates. The Talkeetna Mountains and adjacent Susitna River basin are believed to have been thrust northwestward onto the North American Plate from their parent continental blocks. It was this thrusting action which caused most of the structural features now seen in the upper Susitna basin.

Two major tectonic features bracket the basin area. The Denali Fault, about 43 miles north of the damsites and active during the Holocene, is one of the better known Alaskan faults. A second fracture, the Castle Mountain Fault, is 75 miles south of the river basin. The Susitna basin is roughly subdivided by the northeast-southwest trending Talkeetna Thrust, which roughly parallels the location of the Susitna Fault, as referred to in the 1976 Interim Feasibility Report. The Talkeetna River is a surface expression of the southern portion of both structures; however, Kachadoorian and Moore were unable to locate evidence of faulting in the Tsusena Creek area and, therefore, expressed doubt that the Susitna Fault exists. They found evidence of movement in the Talkeetna River and Watana Creek valleys and postulated that the Talkeetna Thrust could be a projection of this feature. Such a projection passes about 4 miles to the south of Watana damsite. The major alpine orogeny which formed many of the basins' present northeast-southwest trending compressional structures occurred in conjunction with the Talkeetna Thrust in late Cretaceous. Another contemporary zone of intense shearing, roughly parallel to the Talkeetna Thrust, is located about 15 miles east of the Talkeetna Thrust.

Two poorly exposed normal faults of probable Cenozoic age have been projected from gravimetric data as occurring in the Chulitna River valley about 15 miles northwest of the proposed Devil Canyon damsite. These faults have the northeast-southwest trend typical of the major structures within the area. No faults with recent movement have been observed within the upper Susitna River basin.

SEISMICITY

A seismological assessment of the basin area was prepared by Dr. E.L. Krinitzsky of the U.S. Army Engineer Waterways Experiment Station in the summer of 1978, under contract with the Alaska District, Corps of Engineers. Field reconnaissance to look for active faults and other geological hazards was conducted by U.S. Geological Survey under the direction of Reuben Kachadoorian and Henry J. Moore. These reports are included as Exhibits D-3 and D-2 in this appendix. They recognize that the Devil Canyon and Watana damsites are in a region of high seismicity and major faults. However, the geologic reconnaissance of the proposed Devil Canyon and Watana damsites and reservoir areas by the USGS experts did not uncover evidence of recent or active faulting along any of the known or inferred faults. The tectonic framework of the region is not well understood because of the lack of local seismic monitoring stations. Present knowledge indicates that historical earthquakes in the area often have hypocenter depths in excess of 50 km. Such events are associated with movement along the Benioff zone and often are not directly associated with local surface faulting. The Denali Fault in the Alaska Range, approximately 43 miles to the north, is the dominant surface feature in this area. The Susitna Fault, previously thought to exist west of the Watana damsite, was not confirmed in recent geologic mapping by the USGS team, nor did they find any evidence of faulting in the river channel at either of the damsites. The results of the core drilling and geologic reconnaissance at the damsite are strong evidence that no major faulting exists under the Watana damsite. The lack of significant shearing in DH-21, the 600-foot cross river hole, reinforces this conclusion.

Krinitzsky's work assessed the possible occurrence of earthquake activity based on the USGS field work. He assumes an earthquake of magnitude 8 along the Denali Fault, however, these motions are not critical when attenuated to the damsites. To account for the possibility that a major active fault could exist near the damsites, Krinitzsky has assigned a "floating" earthquake of magnitude 7 which could occur in the near vicinity of the dam. This generates the most severe design motions. The rational for the "floating" earthquake and a table of associated motions is included in his report (Exhibit D-3). This criteria is within the state of the art for earthquake design for large dams, and therefore, should not preclude proceeding with detailed design of the projects.

ROCK AND SOIL UNITS

The proposed Watana damsite and reservoir area is underlain by a complex series of metamorphic, igneous, and sedimentary rock. Specific formation names have not been applied to most of these units and they are instead assigned lithologic descriptions for correlation and mapping purposes. The distribution of various rock units that underlie the proposed reservoir are shown on Plate 5. Following is a brief description of the various rock units, beginning at the upper end of the reservoir and proceeding downstream to the damsite. Additional information and descriptive details concerning the rock units are included in the U.S. Geological Survey's Open File Report 78-558-A, <u>Reconnaissance Geologic Map and Geochronology, Talkeetna Mountains Quadrangle,</u>

Northern Part of Anchorage Quadrangle, and Southwest Corner of Healy Quadrangle, Alaska, by Csejtey, et. al., 1978. This report is included at the back of this appendix as Exhibit 5.

The upper reaches of the reservoir are underlain by an amphibolite unit. These are metamorphic rocks including greenschists, diorites, and local marble interbeds. Directly downstream of this unit is a zone of granitic types that are exposed north of the river at elevations above the proposed reservoir level.

The oldest rocks exposed within the area are farther downstream within the middle reservoir reaches and include both volcanics and limestone units. The volcanics consist mostly of metamorphosed basalt and andesite flows and tuffs that outcrop in the vicinity of Jay Creek and downstream from Kosina Creek. The limestone unit consists of marble interbeds that occur locally within the volcanics. The volcanics are overlain farther downstream by a volcanic unit of younger age consisting of a series of metamorphosed basaltic flows with interbeds of chert, argillite, and marble. This unit is exposed both near the mouth of Watana Creek and on the higher slopes west of Watana Creek. A much younger series of interbedded conglomerates, sandstones, and claystones is exposed along the lower reaches of Watana Creek directly upstream from its mouth.

The downstream reaches of the reservoir area are underlain by a sequence of argillites and graywackes. Exposed within the immediate damsite area is a granitic body intruded into these metasediments. It consists primarily of diorite with upstream and downstream margins that include associated schist, gneiss, and composite igneous and metamorphic rock types. Andesite flows and dikes are associated with this diorite pluton.

Other granitic intrusives occur east of the reservoir area. Locally, these intrusives are overlain by a series of younger igneous flows and tuffs and related shallow intrusives.

Overburden units in the proposed reservoir area include deposits of glacial till and drift with associated outwash and lake sediments, colluvium including slopewash and talus, alluvium and local slide debris.

ROCK STRUCTURE

Rocks within the reservoir area have undergone a complex deformation sequence, including uplift, intrusion, thrust faulting, folding, shearing, and associated metamorphism. The most significant structural feature within the reservoir area is the Talkeetna Thrust which strikes northeastward across the lower reservoir area and is roughly parallel to the lower reaches of Watana Creek. The Talkeetna Thrust, within the Watana reservoir area, has displaced the volcanic unit over the much younger metasediments.

A northeast striking shear zone that dips steeply southeasterly, and is roughly parallel to the Talkeetna Thrust, crosses the reservoir area about 15 miles east of the Talkeetna Thrust near Kosina Creek. Whether this shear zone represents a significant feature is not known.

The most significant rock structure in the immediate dam area is the intrusive diorite pluton of Tertiary age. It is observable for 4 miles parallel to the river and 2 miles north and south and is probably of great depth. Upstream and downstream border zones developed with several different metamorphic and igneous rock varieties. Two distinct northwest trending shear zones have been mapped in the vicinity of the damsite. One is 3,400 feet upstream and the other 2,500 feet downstream from the proposed dam axis. Attitudes vary with strikes ranging from N 40° W to 60° W and dips from 70° to 90° either SW or NE. The two shears can be seen in the right valley wall, but not on the left valley wall. The left wall is obscured by a slide block at the upstream shear, and the left wall at the downstream shear has a rock face that parallels the shear direction making observations difficult. The upstream shear zone has been named "The Fins," and has an observable width in excess of 400 feet. It includes seven near vertical rock fins averaging 5 to 25 feet in width bounded on both sides by altered and crushed rock. The downstream shear zone, named "Finger Buster", is somewhat less distinct and is partially covered by slope debris. It has an estimated width of 300 feet. Another northwest trending shear zone, similar to the two shears mentioned above, occurs downstream from the damsite in the vicinity of Tsusena Creek.

Fracture patterns including both joints and local shears have been mapped within accessible areas in the vicinity of the damsite. Details of this mapping are shown on Plates D-3 and D-4. Fractures include both cooling type jointing and structural deformation jointing resulting from the regional tectonic forces of uplift and thrust faulting. Shear, tension, and relief joints resulting from unloading by erosion of overlying sediments and/or melting of glacial ice are all present within the damsite area. A joint diagram plotted on an equal area stereographic projection is shown in Figure D-6. The dominant fracture orientation is to the northwest, but fractures strike in several directions. The major joint sets are N 50° W and the minor joint sets are N 30° E as observed within the area.

SEISMIC REFRACTION SURVEY

During September 1978, seismic refraction surveys were undertaken at Watana and Devil Canyon damsites by Shannon and Wilson, geotechnical consultants. At Devil Canyon, the seismic survey consisted of three lines, each approximately 1,100 feet long. One of these lines was located near the proposed alinement of the saddle dam on the left abutment and the remaining two lines were located near an abandoned airstrip on the alluvial fan at the confluence of Cheechako Creek and the Susitna River (see Plate D-1). The seismic line near the centerline of the left abutment saddle dam was alined to expand information derived from drilling accomplished on this site by the U.S. Bureau of Reclamation (USBR) in 1957. The refraction profile correlated well with the top of rock from the drilling data (see Sheet No. 10, Exhibit D-1). A lower velocity zone of rock sandwiched between competent phyllite indicates the possibility of a shear zone at the low point of the saddle. This correlates with hole DH-6 which indicated shearing in the 20 feet of bedrock penetrated by the boring.

The seismic lines on the Cheechako Creek aggregate deposit were alined to establish the depth to bedrock beneath these deposits and thereby confirm the quantity of material available for borrow. The velocities for the material in the alluvium indicate that the area is composed of a layer of sands and gravels or glacial materials several hundred feet thick overlying bedrock. This confirms the existence of material well in excess of the requirements for the project.

The location map and seismic velocity profiles from the Shannon & Wilson report and included in Exhibit D-1 to this appendix.

MATERIAL REQUIREMENTS

Concrete Requirements

Material requirements for Devil Canyon dam are based on a concrete gravity dam. Under this proposal approximately 2.6 million cubic yards of concrete will be required, most of which will be mass concrete. The remainder will be structural concrete for the appurtenant structures to the dam, including the powerplant. With stockpile losses, this amount of concrete will require approximately 3 million cubic yards of processed aggregate.

The USBR located an extensive deposit of material which will yield concrete aggregate of adequate quality in an alluvial fan approximately 1,000 feet upstream of the proposed dam axis. The fan was formed at the confluence of Cheechako Creek and the Susitna River.

Thirteen test pits and trenches were dug in the fan area by Bureau of Reclamation personnel in 1957. About 1,300 pounds of minus 3-inch material was tested by the USBR for basic aggregate suitability studies. An additional 200 pounds of material was collected by Corps of Engineers personnel in 1975 from the existing Bureau test pits and the riverbank. This material was tested by the North Pacific Division Materials Laboratory in 1978 .

If the excavation of materials is confined to that part of the alluvium located above river level (elevation 910 to 920 feet) with conservative back slopes through the ridges and benches, approximately 6,000,000 cubic yards of material is available in this location with all the resulting excavation in the reservoir area. Seismic refraction surveys indicate that usable gravel exists to approximately elevation 870 feet, so additional material could be retrieved if needed by bailing from below the water surface. Placement of the coffer dam, sizing of the diversion tunnel, and the ability to control the flow in the river at Watana dam will ultimately affect the method of exploitation of this source.

The locations of the test pits are shown on Plate D-1 and the detailed logs can be found in the U.S. Bureau of Reclamation's Alaska Geologic Report #7, Devil Canyon Project, dated March 1960. Laboratory investigations of the aggregate samples were reported in USBR Report #C-932 by their Concrete Laboratory Branch, dated 21 December 1959.

Petrographic analyses of the fine (sand sized) particles and coarse (gravel size) particles indicate that the sands and gravels in the fan are composed of quartz diorites, diorites, granites, andesites, dacites, metavolcanic rocks, aplites, breccias, schists, phyllites, argillites, and amphibolites. The gravel particles are stream worn and generally rounded in shape. The sand grains vary from nearly rounded to sharply angular in shape, averaging subangular. The specific gravity (BSSD) of the material ranges from 2.68 to 2.80.

Results from both labs indicate that the material in the Cheechako Creek fan is of adequate quality for use as concrete aggregate.

Embankment Material Requirements

The saddle dam on the left abutment, associated with the concrete gravity dam, will require approximately 835,000 cubic yards of material. These materials will be obtained from the same sources as discussed in the Interim Feasibility Report.

SCOPE OF INVESTIGATIONS

Field Reconnaissance

Geologic reconnaissance and mapping of the reservoir area and damsite were conducted concurrently with subsurface investigations throughout the spring and early summer of 1978. The work of the geologic teams was made easier in the early spring as rock outcrops were not obscured by the leaves on the trees and the dense ground foliage. Through the months of March and April, geologic mapping of the lower canyon was done from the frozen surface of the river, which allowed access to areas otherwise inaccessible after the ice had melted and high summer flows on the river had begun. Within the damsite area the primary purpose was to find, identify, and trace the surface expressions of discontinuities and shear zones as an aid in directing the drilling program and to provide preliminary geologic mapping of the site. Within the reservoir area, the primary thrust of the reconnaissance was toward identification of slopes, which by reason of shape, structure or overburden mantle could develop minor slumps and slides as a result of permafrost degradation or seismic action.

Borings and Test Pits

During 1978, explorations were conducted in the dam foundation and relict channel area. Core borings in the valley walls and floor were used to explore the quality and structure of the foundation rock and to obtain representative samples for testing. Borings in the relict channel area were used to define the depth of overburden, the extent of permafrost, the location of the water table and to examine, by drilling and sampling, the nature and condition of the materials.

Shallow auger holes were also used to determine the extent of deposits in the borrow areas and to verify the existence of quantities necessary for embankment construction.

Locations of explorations are shown on Plate D-2. Logs are shown on Plates D-19 through D-37; and core photos are shown on Plates D-38 through D-45.

Test pits were dug in potential borrow areas utilizing tractor-mounted backhoes. Bulk sack samples were retrieved from each test pit for testing later at the North Pacific Divison Materials Laboratory in Troutdale, Oregon.

A total of 27 test pits were dug in four areas as follows:

1. The mouth of Tsusena Creek (Borrow Area 'E') - 6 test pits.

2. The glacial till borrow area (Borrow Area 'D') - 14 test pits.

3. Upper Tsusena Creek, north of Tsusena Butte, (Borrow Area 'C') - 1 test pit.

4. Middle Tsusena Creek - 6 test pits.

The locations of Test Pits 1 through 5 and 8 through 21 are shown on Plates D-12 and D-11. The remainder of the test pits are located in areas which are not presently considered as borrow areas; however, they may be located on Plate D-2. The logs of all the test pits are shown on the appropriate borrow area Plates D-19 through D-22.

Seismic Refraction Surveys

A seismic refraction exploration program consisting of 22,500 lineal feet of seismic refraction lines was completed by Dames and Moore, Consultants, in 1975. Results of those investigations were presented as Exhibit D-1, Section D, Foundation and Materials, in the 1976 Interim Feasibility Report. In the fall of 1978, an additional seismic refraction survey was completed by Shannon and Wilson, Consultants, which includes 47,665 feet of seismic refraction lines. Locations of these additional seismic explorations are shown on Plate D-2, and the location map and seismic velocity profiles are presented as Exhibit D-1. The survey confirmed the findings of the Dames and Moore study. It confirmed the existence of a buried channel in the relict channel area and in general supported conclusions relating to shear zones in the abutments as interpreted from the recent core borings and geologic reconnaissance. The Shannon and Wilson survey also confirmed the existence of large quantities of borrow materials on Tsusena Creek in the proposed borrow area.

Instrumentation

Instrumentation conducted under this phase of the project consisted of the installation and data reading of ground water measurement devices, temperature logging devices, and the recording of the ambient temperature.

Ground Water: All piezometers installed were of the open well point type and were filled with diesel oil where they extend through permafrost zones to prevent freezing. A total of 10 piezometers were installed at the following locations.

TABLE D-1

Location	Surface Elevation	Tip Elevation	Date Set	Size
DR-14	2,340	2,271.0	26 Apr	4"
	2,340	2,295.2	19 Aug	1-1/2"
DR-20	2,207	2,123.8	30 May	1-1/2"
DR-18	2,172	2,107.0	21 Jun	1-1/2"
DR-17	2,167	2,136.3	8 Jun	1-1/2"
DR-16	2,099	2,053.8	5 Jun	1-1/2"
AP-1	2,202	2,188.6	20 Jun	1-1/2"
AP-2	2,200	2,189.0	20 Jun	1-1/2"
DR-19	2,151	2,109.0	3 Jul	1-1/2"
DR-22	2,229	2,005.5	3 Aug	1-1/2"
DR-26	2,295	2,229.5	11 Aug	1-1/2"

All locations are shown on Plate D-2 and Plate D-11. Plotted data is shown on Plates D-16 through D-18.

Subsurface Temperature: The principal temperature logging device consisted of a 3/4-inch galvanized pipe, with the lower end capped and sealed. The pipe was filled with a mixture of ethylene glycol and water (50/50) or arctic grade diesel fuel. Readings were taken using a digital volt-ohm meter and a single thermister which was lowered into the pipe.

At location DR-26 both a 3/4-inch galvanized and a 1-1/2-inch PVC pipe were installed to determine if readings could be duplicated in a pipe of larger diameter. A total of 14 devices were installed at the locations shown in Table D-2.

TABLE D-2

Location	Date Installed	Length	Stick Up	Buried Depth	Fluid
AP-8	23 Jun	64'	4.2'	58.9'	Diesel
AP-9	23 Jun	21'	3.2'	17.8'	Diesel
DH-12	3 Jul	129'	1.8'	127.2'	Diesel
DH-23	17 Jul	76'	0.5'	75.5'	Antifreeze
DH-24	1 Aug	86'	1.2'	84.8'	Antifreeze
DR-18	21 Jun	251'	3.4'	247.6'	Diesel
DR-19	3 Jul	83'	3.9'	79.1'	Diesel
DR-22	3 Aug	492'	2.0'	490.0'	Antifreeze
DH-28	30 Aug	124'	1.0'	123.0'	Antifreeze
DR-26 (3/4" pipe)	11 Aug	68'	3.8'	64.2'	Antifreeze
DR-26 (1-1/2" pipe)	11 Aug	99'	3.4'	95.6'	Antifreeze
DR-14	19 Aug	65'	2.8'	62.2'	Antifreeze
DH-21	23 Aug	160'	2.0'	158.0'	Antifreeze
DH-25	15 Aug	80'	4.0'	76.0'	Antifreeze

All locations are shown on Plate D-2 and Plate D-11. The plotted temperature data can be found on Plates D-13 through D-15.

A second type of temperature logging device, installed at DR-22, consisted of a multipoint thermistor string. The purpose of this installation was to act as a check against the 3/4-inch fluid filled devices described above.

Ambient Temperature: The ambient temperature was obtained using a standard high-low Mercury thermometer placed in the shade on the right abutment riverbank approximately 4 feet above the ground. Prior to this phase of the project, there was no ambient temperature data available for this section of Alaska. Data obtained is shown on Table D-3.

TABLE D-3

Date	High °F	Low °F	Date	High °F	Low °F
23 Mar 78	22	0	23 May 78	60	39
24 Mar 78	24	13	24 May 78	60	32
25 Mar 78	28	19	25 May 78	61	40
27 Mar 78	32	10	26 May 78	41	36
28 Mar 78	26	13	27 May 78	64	--
29 Mar 78	40	6	28 May 78	--	36
30 Mar 78	35	6	29 May 78	58	33
31 Mar 78	36	5	30 May 78	63	36
1 Apr 78	31	5	31 May 78	66	40
2 Apr 78	28	-4	1 Jun 78	54	36
3 Apr 78	28	3	2 Jun 78	58	38
4 Apr 78	36	4	3 Jun 78	68	41
5 Apr 78	36	20	4 Jun 78	68	38
6 Apr 78	33	11	5 Jun 78	57	39
7-8 Apr 78	40	28	6 Jun 78	66	44
9 Apr 78	41	10	11 Jun 78	72	44
10 Apr 78	43	13	12 Jun 78	62	39
11 Apr 78	38	20	14 Jun 78	57	40
12 Apr 78	38	15	16 Jun 78	58	34
13 Apr 78	40	30	19 Jun 78	52	33
14 Apr 78	44	32	20 Jun 78	61	33
15 Apr 78	40	38	21 Jun 78	63	--
16 Apr 78	39	29	22 Jun 78	--	46
17 Apr 78	38	21	27 Jun 78	55	38
18 Apr 78	43	21	28 Jun 78	59	37
19 Apr 78	44	20	30 Jun 78	62	43
20 Apr 78	48	24	1 Jul 78	57	41
21 Apr 78	44	25	2 Jul 78	62	43
22 Apr 78	45	30	4 Jul 78	70	47
23-24 Apr 78	47	32	7 Jul 78	62	40
25-26 Apr 78	50	26	8 Jul 78	73	43
30 Apr 78	59	32	9 Jul 78	70	49
1 May 78	60	34	10 Jul 78	66	42
9 May 78	64	30	11 Jul 78	71	--
10 May 78	72	33	12 Jul 78	--	50
11 May 78	70	33	14 Jul 78	59	50
12 May 78	65	40	16 Jul 78	58	47
13 May 78	72	30	26 Jul 78	66	45
14 May 78	72	31	27 Jul 78	78	40
15 May 78	66	36	28 Jul 78	74	55
16 May 78	55	32	29 Jul 78	78	39
17 May 78	60	30	30 Jul 78	82	46
18 May 78	64	37	31 Jul 78	84	52
19 May 78	60	37	1 Aug 78	80	58
20 May 78	75	24	9 Aug 78	71	46
21 May 78	70	43	10 Aug 78	68	54
22 May 78	--	36	11 Aug 78	66	49

Accuracy of Subsurface Temperature Data: Resistance measurements were obtained using a Keithley volt-ohm meter, which allowed readings to the nearest ohm. With a span of 225 ohms per degree centigrade, 1 ohm represents 0.005° C. The temperature data in this report has been reported to 0.01° C and is reliable to that degree of accuracy. To verify the accuracy of each thermister, its resistance was measured in an ice bath. It was found that the thermistors are very stable and do not tend to drift from their original resistance at 0.00° C.

General Comments

The drilling in the permafrost was performed with core drills and rotary drills, which introduce a large amount of heat into the ground. Where the permafrost temperature is only slightly below the freezing point, this tends to melt the permafrost and makes identification very difficult. Therefore, the drilling operation may or may not reflect the existence of permafrost, and it is necessary to rely heavily on the instrumentation for a true evaluation of the location and depth, at which permafrost exists. By December of 1978, the temperature logging devices may not have stabilized due primarily to the fact that the drilling method used was rotary with drilling "mud" as the circulation medium, which tends to thaw the permafrost. Upon inspection of the plotted data for the locations in this area it can be seen that the temperatures are gradually approaching the 0° C point. Through a continual program of monitoring these points, a great deal can be learned about "freeze back."

At location DR-26, 3/4 inch and 1-1/2 inch pipes were installed to determine if convection currents in the pipe would affect the accuracy of the near surface readings. It can be seen from the temperature plots, shown on Plates D-13 through D-15, that there is a degree of convection in the upper zones, while with depth the two readings are very similar. At location DR-22, the string had 14 thermistors in a 150 foot length. The data obtained from this string has not been included in this report since its reliability is in question. This is due to damage received during installation as well as the fact that the thermistors are of a lower quality and adequate calibration could not be obtained prior to installation. At location DH-12 the 3/4-inch pipe temperature logging device was lost when it was decided that the bore-hole camera should be run in this boring. At location DH-25 no data is available because the 3/4-inch pipe froze up during installation.

SITE GEOLOGY

Introduction

The river valley at the site has a V-shaped lower or bottom canyon deeply incised into an upper, much broader, U-shaped river valley of considerable extent and width.

The lower river valley floor ranges from 300 to 600 feet wide and has side slopes of 35 to 60 degrees with locally scattered rock outcrops that rise in near vertical cliffs. The incised portion of the canyon extends from subriver level upward about 500 feet to approximate elevation 2,000 feet, where it ranges in width from 1,500 to 3,000 feet. Above elevation 2,000 feet, there is a distinct flattening of the valley slopes and the area broadens out into a very wide former river valley. Width of this former valley base level is from 8 to 10 miles in the lower reservoir area, narrows to about 1 mile in the midreservoir area upstream of Jay Creek and widens to more than 20 miles in the upper reaches of the reservoir.

Foundation Conditions

The site was mapped and explored with 17 core holes, 12 of which are on the dam axis shown in this report. Six of the holes are angle holes, five were drilled normal to the dominant structural trend, and one drilled across the river valley. The exploration plan with hole locations is presented on Plate D-2.

The river valley is filled with alluvium consisting of gravels, cobbles, and boulders in a matrix of sand or silty sand. Overburden depths in the valley bottom range from 40 to 80 feet and may exceed 100 feet in places. Overburden depths on the valley slopes range up to 10 feet deep on the left abutment and up to 20 feet on the right abutment. However, overburden upstream of the left abutment is more than 56 feet deep.

Overburden on the valley slopes is mostly glacial debris and talus consisting of various gravel and sand mixtures and some silts, with cobbles and small boulders. The underlying rock is diorite, granodiorite, and quartz diorite with local andesite porphyry dikes and more widely scattered minor felsite dikes. Most of the rock, although fractured, is relatively fresh and hard to very hard within 5 to 40 feet of top of rock. Overburden and rock stripping depths along the dam axis are shown in cross section on Plate D-7.

Fractures are closely to moderately spaced at the bedrock surface, generally becoming more widely spaced with depth. Fracture zones found at all depths tend to be tight or recemented with calcite or silica. The northwest trending joints and high angle shears mapped in the rock outcrops are found at different depths within most drill holes and range from single fractures to broken zones more than 20 feet thick. Broken rock within the shear zones is locally decomposed but consists mainly of moderately hard to very hard fragments. Many fractures have thin clay gouge seams and slicken sides. Pyrite and chlorite mineralization is found as coatings on many fracture surfaces. Shears are spaced from a few feet to more than 100 feet apart, and since the shears are mostly vertical, greater lengths of sheared material were recovered in vertical drill holes. In addition to the shears, primary and rehealed breccia zones occur in some areas adjacent to the andesite porphyry dikes. Most of these rehealed breccias are relatively competent rock, but a primary breccia zone downstream of the axis on the left abutment includes locally decomposed materials.

Valley Conditions

The river valley bottom was explored with six core drill holes. Three holes are on the axis and three are about 1,000 feet downstream of centerline in the toe area. River alluvium varied in depth from 44 to 78 feet. This alluvium consists of gravels, cobbles, and boulders imbedded in sands with local gravelly or silty sand lenses. The gravels and larger sizes are mostly subrounded to rounded with occasional large boulders. Most large sizes are of dioritic composition, but metamorphic and other rock types were also noted. Most of the gravels are fresh, but a few are coated with plastic fines. Alluvial materials in some areas were frozen to depths in excess of 50 feet and possibly all the way to bedrock at the time of drilling.

The bedrock is a diorite that in most holes is very closely fractured in the upper 10 to 20 feet. Fractures become more widely spaced with depth; however, local zones of closely spaced fractures occur throughout. Joints are both open and rehealed or cemented with calcite and silica. The rock below river level is mostly fresh and hard to very hard. Shear zones occur in several of the holes and include some thin clay gouge coatings and slickensides. Soft chloritic materials were also encountered in one shear zone, and iron staining with pyrite mineralization is common. It should be noted that DH-21 was drilled essentially across the river from the left to the right abutment. No major fault or significant change in materials was seen although six minor shear zones were encountered in the hole. Most of these zones are less than 3 feet thick, whereas, some of the vertical holes penetrated sheared material for distances of more than 10 feet. This confirms the near vertical nature of most shearing. Geologic mapping in rock exposures along the river-bank also indicates the near vertical nature of shearing. An andesite porphyry dike was penetrated at depth by DH-21. This dike has an apparent thickness of about 13 feet, and the contacts with the diorite are tight and contain no notable planes of weakness.

The left abutment was explored with five drill holes, three on the dam axis and one each upstream and downstream of the embankment. Over-burden depths in the downstream hole and the three axis holes are less than 10 feet. This overburden consists of small subangular to sub-rounded boulders in silt, sand, and gravel. Overburden in DH-28, located approximately 1,000 feet downstream of the axis at elevation 1,971 feet, consists of 6 feet of silty clay overlaying 2 feet of sand. DH-25, located about 750 feet upstream of the axis at elevation 2,045 feet, penetrated a vertical depth of 56 feet of glacial and alluvial deposits and had not yet encountered rock when it was abandoned. Overburden in DH-25 consists primarily of gravelly, silty sand with boulders to a depth of 15 feet, underlain by gravelly, clayey silt. Gravels are subrounded to rounded and the clayey silts are stiff and plastic.

Rock in the three axis holes is a hard quartz diorite, whereas in DH-28 downstream of the embankment, it is an andesite porphyry. The relationship between the quartz diorite as a plutontic rock and the andesite porphyry as a surface flow rock is not clearly understood. This contact area between the two type rocks is in the location of the underground powerhouse and will be closely explored during design investigations. It is assumed the underground powerhouse will be located in the dioritic rock. Weathering is primarily staining on fracture surfaces. Fracture spacings vary from very close to moderately spaced; spacing increases with depth.

Fractured zones, encountered in all holes, are from less than 1 to more than 20 feet thick and are separated by from 10 to more than 50 feet of relatively undisturbed rock. Many fractures include thin seams of clay gouge, slickensides, secondary pyrite, and breccia. DH-28, downstream of the embankment, appears to have been drilled in an andesite porphyry breccia contact zone adjacent to the diorite pluton. Much of the core is brecciated, moderately weathered to highly altered, and recovered in small fragments. Several zones of clay gouge were noted.

Right abutment conditions were explored with six core drill holes along the proposed dam axis. Three of these holes were angle holes drilled normal to the dominant structural trends. Overburden depths within the six holes range from 4 to 20 feet, with the greater depths in the holes farthest upslope. Overburden consists of gravelly sand with cobbles and small boulders.

Bedrock is moderately hard, but weathered, closely fractured and locally sheared in the upper 10 to 40 feet. The rock is diorite or quartz diorite with zones of quartz diorite breccia. The quartz diorite breccia is healed, probably formed during emplacement, and is not considered a zone of weakness.

Fractured zones encountered during drilling are similar to those noted on the left abutment. Shears range up to 22 feet thick and are separated from each other by about 10 to 100 feet of competent rock. Very thin films of clay gouge and slickensides occur on some fracture surfaces. Iron staining occurs on many fracture surfaces and fine disseminated pyrite mineralization occurs more widely.

Relict Channel Area

The relict channel is a suspected ancestoral Susitna River channel north of the right abutment under the broad terrace area between Deadman and Tsusena Creeks. Ground surfaces within the Relict Channel area are between elevation 2,100 and 2,300 feet along low elongated ridges and shallow depressions. This area was originally explored with two seismic lines and the results presented in the Feasibility Report, Appendix 1 as Exhibit D-1. Subsequent 1978 explorations include 1,814 linear feet of drilling, borrow explorations near Deadman Creek and 23,600 feet of seismic refraction lines. The 11 drill holes range from 21 to 494 feet in depth and were mostly noncore rotary holes supplemented with drive samples and some bedrock coring. The results of these 1978 explorations confirm the existence of the deeply buried bedrock surface depression discovered during the 1975 seismic investigations. The lowest bedrock elevation encountered in drilling was in DR-22 at 1,775 feet, MSL or 454 feet below ground surface.

Overburden consists of both glacial and alluvial materials occurring in varying sequences that are difficult to correlate with the limited drilling to date.

Outwash occurs over much of the area, consisting of gravelly, silty sands or silty, gravelly sands in varying proportions, with some local cobbles and boulders and more widely scattered clay lenses. These materials are mostly loose and the fines are predominantly non-plastic.

Glacial till is the most abundant overburden material found within the relict channel area. These tills occur in three separate sequences in the deepest drill holes, separated by lenses of alluvial materials. The near surface tills are normally consolidated while the tills from greater depths are highly over consolidated and dense. It is quite probable that this over consolidation was caused by glacial loading in the geologic past. All of the tills contain fines that are nonplastic or only moderately plastic. Smaller gravel sizes are rounded, while larger sizes are more subrounded to subangular. Materials are poorly sorted with little or no indication of bedding. The tills vary considerably in thickness from only a few feet to a maximum of 163 feet in DR-18.

Apparent river deposited alluvial lenses which represent inter-glacial periods, separate many of the till units. These deposits consist of sandy gravels with some silts. Sandy alluvial units have a tendency to cave during drilling and several appear to have relatively high permeabilities. Most of these river deposits were less than 50 feet in thickness but in DR-22, directly above bedrock, the alluvial unit was 159 feet thick.

At least two deposits of lake sediments were encountered during drilling. The larger of these was named "Lake Woller" and occurs in DR-13, DR-15, DR-26, and DR-27 in varying thicknesses. Maximum thickness is 60+ feet in DR-13. Lake Woller deposits appear to be confined between elevations 2,240 and 2,305 feet. Another apparent lake deposit was penetrated in DR-18 and DR-20. Maximum thickness of this deposit is 33 feet and appears to be confined between elevations 2,130 and 2,190 feet. Both lake deposits may represent either quiet lake deposition during an interglacial period, or possibly proglacial lakes formed during glacial retreats. The lake deposits consist primarily of highly to moderately plastic clays and silts with local gravel and sand lenses.

Spillway

The original location of the Saddle Spillway in the Interim Feasibility Report, Appendix I, Plate D-3, was found to lie directly upon two adverse structures. The overburden depths increased from 9 feet at DR-17 on the left side of the proposed alinement to 231 feet at DR-18 on the right or east side of the spillway. This depth of overburden prevailed throughout the length of the spillway, including the proposed gate structure area.

The glacial tills, clay, and intermittent sand lenses of the overburden would have required additional excavation and flatter sideslopes. Added expense would also have resulted from increased foundation requirements for the gate structure and from the full length lining which would have been required in the spillway channel. To avoid these disadvantages a change of the channel alinement was made.

The new proposed alinement lies approximately 800 feet laterally to the left (southwest) of the original design and will be in rock cut from inlet to final outlet at Tsusena Creek. This alinement will also avoid potential structural problems from the second adverse structure, the shear zone titled "The Fins" (Plate D-4) which will now parallel the spillway for its entire length. Rock quality is such that excavated rock will be used as dam shell rock.

As a result of the move, it is anticipated that sound bedrock will be encountered at a maximum depth of 25 feet at the gate structure and will continue down spillway for at least 2,500 feet. As the spillway dips down to Tsusena Creek, deeper glacial till is again encountered, so the final section of the outflow may not be totally founded on bedrock. The plunge pool at Tsusena Creek will be contained by existing rock cliffs.

Permafrost

The Watana damsite lies within the discontinuous permafrost zone of Alaska. For this reason it is to be expected that permafrost would be found during the exploratory effort, particularly on north facing slopes and areas where arctic vegetation has effectively insulated the ground surface. Depths of permafrost within the discontinuous zone are variable and often change drastically within short distances depending on exposure, ground cover, soil characteristics and other factors.

Permafrost conditions at Watana as indicated by the exploratory work done to date appear to be typical for the zone. The left abutment which faces north and is either continuously shaded or receives only low angle rays from the sun was explored with core drilling equipment. Five holes were drilled and pressure tested by pumping water into the drill holes at selected intervals using a double packer. Observation of drill water returns and pressure tests showed that permafrost exists for the entire depth of the holes. Holes drilled in the right abutment, where the sun's rays are most effective, did not indicate any permafrost. Within the relict channel areas, on the terrace north of the right abutment, indications of permafrost were observed as reflected by ground water conditions and water table measurements, drill action, and sampling. Drill hole DR-27 was sampled and ice lenses were retrieved from a depth of 30 through 36 feet. Permafrost was also encountered during test pit activities. However, in general, permafrost in the spillway and relict channel area, while encountered as near as 1 foot to the surface, is expected to be confined to a relatively shallow layer. This expectation has been reinforced by the fact that ground water has been encountered at various depths. In order to study the thermal regime of the permafrost and to more accurately define the lower limits of the frozen zone, temperature probes were installed at 13 locations. These locations are shown on Table 1 under the heading "Instrumentation" and the graphs of readings taken to date are shown on Plates D-13 through D-15. It is still too early to reach definite conclusions from the limited data obtained since installation due to the fact that heat was introduced into the regime by drilling and equilibrium may not yet be reestablished. However, it appears that the readings do support the conclusion that permafrost is not as widespread or as deep as was previous believed.

Of equal significance is the fact that the temperature probes indicate that the temperatures within the permafrost are generally within 1 degree of freezing. Construction in cold regious has shown that, within this range, materials can be excavated with considerably less dificulty than in areas where the permafrost temperatures are lower. Particularly in borrow areas, where a rather large area can be exposed, degradation is rapid and by alternating from side to side in the area, the material can be ripped, left exposed to the sun for a few hours and then handled in the normal fashion. The fragile nature of the permafrost regime as indicated by temperature studies will be of prime importance in the scheduling related to foundation grouting. Permafrost barely within the frozen range will be much easier to thaw and foundation grouting will be facilitated.

As explorations at the damsite continue, the installation of frost probes will be expanded to provide detailed knowledge of the extent of existing permaforst areas as well as their condition. A discussion of design type of probes installed and the degree of accuracy to be expected from data readings can be found under "Instrumentation."

Ground Water

Ground water conditions in the terrace area north of the spillway alinement were examined during exploratory drilling, but the use of drilling mud used for most of the rotary drilling made direct water table measurements difficult. Pervious zones were occasionally encountered where loss of drilling mud was noted. Examples are DR-22 where mud losses were experienced of approximately 50 gallons per foot of hole drilled between elevations 2,025 and 2,000 feet and losses of approximately 14 gallons per foot of hole drilled between elevation 1,940 and 1,855 feet. In a very few instances water tables could be measured at the time of drilling. A notable example of artesian head was measured while drilling DR-13 and DR-14. In both of these holes the ground water was under sufficient head to rise from elevation 2,240 and 2,270 feet, respectively, to elevation 2,300 $\pm$ feet when the overlying clay layer was penetrated by the drill.

A discussion of the overburden units encountered in the terrace area can be found under the heading "Relict Channel Area." It will be noted in that discussion that at least two deposits of lake sediments were encountered which appear to be rather extensive. As might be expected, perched water was encountered above the higher deposit, Lake Woller, in some holes because of the impermeability of the material. In the alluvial zones between the lake deposits water was usually encountered although, as previously noted, in only one instance was this water under artesian head. Below the lower lake deposit, approximate elevation 2,190 feet, the glacial tills were very compact and can be expected to be relatively impervious. The over consolidation of these materials as previously stated is probably due to being overloaded by the weight of ice in glacial times.

The significance of ground water conditions in this area lies in the fact that the deep deposits in the relict channel area will be under a head of approximately 400 feet from the proposed Watana reservoir. The decision as to whether or not an impervious cutoff across this channel is necessary depends on the pervious nature of the materials encountered. While a more detailed program of exploring, sampling, and testing will be undertaken to ensure that pervious layers will not present a seepage danger in this area, it is presently believed that no impervious barrier is required. A more detailed discussion of the rationale in support of this belief can be found under the heading "Seepage Control, Relict Channel."

Reservoir Geology

The Watana reservoir includes seven general zones of geology, as indicated by Plate D-5 (Watana Reservoir Surficial Geology). Glacial fill, outwash, and proglacial lake deposits predominate in the meandering reaches of the river upstream of the Oshetna River confluence. The next zone extends downstream along the incised channel to Jay Creek and Kosina Creek, and includes localized sedimentary and alluvial units with metamorphics such as the Vee Canyon schist. The predominating dioritic gneiss and amphibolite is laced with bands of mica schist, pyroxenite, and augen gneiss that are inferred to correspond with contact and shear zones trending northeast. The area around Jay and Kosina Creeks and downstream to Watana Creek includes two zones with outcrops of high grade schist and basalt flows at the river level. The surrounding hills are composed of volcanics with limestone interbeds on the south, and mixed volcanics and near surface intrusives to the north for a minimum of 10 miles. The Watana Creek area consists of basalt flows and semiconsolidated predominately clastic sediments overlain by thick glacial and outwash deposits. This area also contains the Talkeetna Thrust as identified by the U.S. Geological Survey. Downstream of Watana Creek lie the remaining two units, starting with moderately metamorphosed sediments (phyllite, argillite, graywacke) with two bands of schist. The final unit starts just upstream of Deadman Creek and includes all materials downstream to Fog Creek below the damsite. The predominate types are the diorites, granites, and migmatites of the damsite pluton.

The Watana reservoir includes many permafrost areas, especially on north facing slopes. Frozen overburden will tend to slough as the reservoir is filled and the permafrost degrades. Since most of the lower canyon elevations are covered with only shallow overburden deposits, sloughing will be minor and have minimal effects upon the reservoir. Deep overburden deposits, mostly of glacial origin, occur above approximate elevation 2,000 feet where the slopes flatten out into a broad river valley base level. Most of these glacial deposits will be stable due to the flat topography.

Some rock and overburden landslide deposits have occurred within the reservoir area. One such slide deposit, known as the "Slide Block," is located upstream of the axis on the south bank opposite "The Fins" shear. Several old and potential landslides are identified by Kachadoorian and Moore in their reconnaissance of the project area.

In general terms, the geology in the immediate damsite is controlled by the diorite intrusive believed to be the top of a stock which uplifted the surrounding sediments and volcanics and was later eroded by glaciers. Subsequent glacial and stream deposition has masked much of the flat upland areas and stream valleys.

DAM DESIGN

Dam Foundation Treatment

Main Dam: Foundation conditions are more than adequate for construction of an earth-rockfill dam. The underlying rock is a diorite or granodiorite which, in nonfractured fresh samples, had unconfined compressive strengths that ranged from 18,470 to 29,530 psi. Only the uppermost 20 to 40 feet of this rock is closely fractured and sufficiently weathered to require removal within the core area. Stripping depths along the centerline section are shown on Plate D-7. Stripping to sound foundation rock is required for the entire length and width of the impervious core. Foundation treatment within the rock excavation area will include removal of all loose and highly fractured rock and soft materials, cleanup, and dental treatment. If there are any zones where more than an 8 foot width of soft materials is removed, the dental concrete will be contact grouted to the adjoining rock. Stripping to rock will also be required under the remainder of the embankment area. However, in this area excavation will not include removal of the inplace rock. Only the loose and severly weathered surface rock will be removed. Steep or overhanging rock walls will be trimmed to a smooth shape for proper placement of embankment materials. Exploratory drilling in 1978 has shown the materials in the river channel to be a well graded mixture of gravels and cobbles as good, or better, than the materials that would be used to replace them. As the exploration program continues, these gravels will be more completely explored and it may be demonstrated at that time that there is no need for their removal beneath the shell zones. Should this prove to be the case, the change can be made during feature design.

Provision has been made for a 6- by 8-foot concrete grouting gallery with concrete lining to be constructed in foundation rock under the impervious core. This gallery will begin at elevation 1,900 feet on the left abutment and will terminate at elevation 1,800 feet on the right abutment. It will provide access for drilling and grouting which, in some areas may be delayed to allow thawing of permafrost. Access to the gallery will be provided from the powerhouse on the left abutment and, by adit, from the downstream toe of the right abutment. Grouting will be on a single line of holes utilizing split spacing, stage grouting techniques. Grout holes will be slanted upstream and may be included to intercept the dominant high angle northwest tending fracture system. Preliminary grout hole depths are estimated at two-thirds the height of the embankment to a maximum depth of 300 feet with primary spacing of 20 feet, secondary spacing of 10 feet, and tertiary spacing of 5 feet with additional holes as required.

Determination of final grout hole depths, spacing, inclination, grout mixtures, and grouting methods will be dependent on the results of future explorations, permeability studies, test grouting, and permafrost thawing investigations.

Rock permeability test results are shown on the drill logs presented on Plates D-28 through D-37. Coefficients of permeability (K) were computed in feet per minute times 10^{-4}. Permeability coefficients ranged from 0.0 to 23.1 and average 4.9 for those holes that were tested.

Drill holes in the left abutment area indicated very low permeability due to permafrost. River section hole DH-1 had variable permeability coefficients that range from 0.48 to 2.52 and averaged 1.98. Drill water returns in the river holes were quite variable throughout the entire hole depths and tended to drop off to low percentages at the greater depths in the axis area. Right abutment drill holes had permeability coefficients that ranged from 0.0 to 23.09 and averaged 5.47. DH-10 was the only hole tested that had relatively low permeability coefficients throughout. Drill water returns had similar patterns with variable percentage losses. DH-7 and DH-9 had 0 percent returns throughout and DH-8 and DH-11 maintained high percentages of drill water returns throughout.

The existence of permafrost in the left abutment and the possibility of minor amounts in the right abutment necessitates assessment of the problem of thawing a zone in the foundation bedrock sufficiently wide and deep to allow proper installation of the grout curtain. In anticipation of this need, the U.S. Army Cold Regions Research and Engineering Laboratory was asked to do a desk study on thawing the permanently frozen bedrock. The Technical Note which was submitted in response to the request is included as Exhibit D-4.

Embankment Design

Design of the dam embankment at Watana damsite has been based on the availability and proximity of construction materials in addition to their suitability as engineering materials. As a result of these considerations, the embankment contains a central section consisting of an impervious core buttressed on the downstream side by a semipervious zone.

This central section is supported, both upstream and downstream, by suitable fine and coarse filters and rockfill shells. A typical cross-section of the embankment is shown on Plate D-9.

The impervious core and semipervious zone will be constructed using the glacial till which is readily available in the area. The semi-pervious material will be obtained by selecting the coarser grained materials while the finer materials will be placed in the impervious zone. These materials, as discussed under "Embankment Materials," have been shown by exploration and test to be a well graded mixture, which, when compacted, has a very good shear strength and a high degree of impermeability. Tests have shown that this material is quite sensitive to moisture control; therefore, special attention must be paid to this aspect of the design and construction. The 14,000,000 cubic yards required are available within a very reasonable haul distance and will only require removal of oversize boulders prior to use.

The fine filter material can be obtained from the gravelly sand deposit at the mouth of Tsusena Creek. Chart D-3 shows an envelope of gradations from this source superimposed onto the envelope for the fine filter as established by engineering design criteria. This comparison indicates that the Tsusena Creek source can provide material within the ranges of sizes necessary to protect the core and semipervious zone against piping or migration of fines into the filter material.

Proven sources of gravel which can yield large quantities of material are scarce within short haul distances of the project. For this reason, the decision was made to use material from the rockfill source as a coarse filter. Chart D-5 is an envelope of the required gradation which will provide proper filtering action for the fine filter material. A curve has been superimposed on this envelope which represents the materials expected from the rockfill source. As indicated, the rockfill will provide the proper filter action. The maximum size material in the coarse filter and the lift thickness for placement will, of course, be limited to ensure design criteria are met.

The decision to utilize rockfill rather than gravel for the embankment shells was made when reconnaissance and exploration indicated that dependable deposits of gravels which would provide the necessary quantities could not be verified within reasonable haul distances of the damsite. On the other hand, rockfill can be readily obtained as discussed under "Embankment Materials." Riprap for wave protection can be obtained from the same source.

It is recognized that the 1 vertical on 2 to 2.25 horizontal side-slopes shown on the typical cross section for the dam are conservative for a rockfill dam, and, if rockfill is used, these slopes will be refined in accordance with sound engineering practice. Refraction seismic lines in the borrow areas show velocities which could represent large deposits of gravels or glacial materials but rather extensive explorations will be required to verify the true nature and quantity of the materials. Should these explorations reveal that suitable gravel deposits in the area are sufficiently extensive to provide the large quantities required for the dam shell sections, the gravel will be used in preference to borrowing quarried rock for rockfill.

Powerhouse and Underground Structures

An underground powerhouse is well suited to meet the restrictions of subarctic weather and other environmental factors. Topographically, the narrow Susitna Canyon is well situated for this type of underground construction. The diorite pluton that underlies the foundation area is expected to be competent for excavation and support of underground facilites, but the location and design of the various structures may have to be adjusted in some areas. "The Fins" and "Fingerbuster" Shear Zones shown on Plate D-3 and discussed in paragraph "Rock Structure" are the two most significant shears within the damsite area. Other northwest trending steep angled minor shears involving displacements of a fraction of an inch up to a few feet are common in the site area and were noted in many of the drill holes. These minor shears appear to represent mass adjustments to regional stress and compensation can be made for them in design and construction of the underground structures.

Prior to powerhouse excavation, exploratory adits located near the crown of the various chambers will be driven to confirm final design criteria. The chambers will be constructed with straight walls as required for maximum dimensions, and not notched or cut irregualarly for support of interior powerhouse facilities. Rock support will include pattern bolts consistent with wall and crown conditions. Use of steel channeling and remedial concrete is anticipated in local areas where fallout may occur or in fracture zones having a substantial width of crushed rock. Wire mesh will be utilized where necessary as a temporary facility prior to placing concrete. A thin layer of wire reinforced shotcrete may be placed on the main powerhouse chamber walls and crown as a protective measure against rock raveling. Additional shotcrete will be utilized, as required, to seal surfaces and retain rock strengths. Construction methods in the large chambers will include controlled blasting and rock removal in lifts from the top downward. Gutter and floor sloping for drainage will be provided in the interior structures between chambers.

Intake Structure

Consolidation grouting may be necessary for the intake structure foundation and the bridge pier footings. The higher bridge pier footings will also be recessed into sound rock. Tunnel portals will be designed so that there is a minimum of two tunnel diameters of sound rock above the heading where they go underground. Initial tunnel support will be by pattern bolts, with steel channeling and wire mesh where necessary in closely fractured areas. Major shear zones will require steel supports. Hydraulic and geologic considerations will necessitate final concrete linings for all but the access tunnels, and steel liners for the penstocks. Grout rings will be required in the penstock portal areas.

The two diversion tunnels are to be separated by a minimum of four tunnel diameters to provide greater structural stability. Downstream diversion tunnel portals will have to be located to avoid the "Finger Buster" shear zone to insure adequate portal construction conditions.

Spillway

The gated spillway has been relocated about 800 feet southeast of the alinement presented in the 1976 report so that it will be constructed in a through rock cut. The spillway will be unlined beyond the spillway gate structure and apron. The new spillway alinement extending from the Susitna north valley wall to Tsusena Creek and the spillway gradient are shown on Plates B-2 and B-5. It is anticipated that, with the exception of minor amounts of waste, all the excavated materials from the spillway will be used in the dam embankment. The major part of the excavation is in rock and this material will be used in the shell sections. The overburden materials are glacial till which, when separated from the boulders can be used in the impervious or semipervious zones.

Seepage Control - Relict Channel

The relict channel area is an overburden terrace underlain by a bedrock depression, and extends northward from the right abutment for about 6,000 feet. This terrace is composed of glacial till, some of which has been reworked by alluvial action. For this reason, consideration was given to the possibility of seepage through the area where rock contours are below the proposed reservoir elevation. However, preliminary seepage calculations indicate that even in the relict channel area, where the head differential approaches 350 feet, and using a very conservative 'k' value of 500 feet per day, the seepage would be less than 0.02 cubic feet per second per foot of width for a pervious layer assumed to be 80 feet thick. Assuming such a layer to be 200 feet wide, the seepage would be in the order of 4 cubic feet per second, which is a minor amount. The exit velocities associated with such seepage would be too low to cause serious piping or erosion. Investigations during the summer of 1978 support this conclusion. In holes DR-13 and DR-14, located in the vicinity of Borrow Area "D," ground water was encountered in alluvial layers between elevation 2,240 and 2,280 feet with an artesian head which exceeded the proposed reservoir level by 100 feet. In spite of this high head condition, no evidence was found indicating seepage out of this layer into either Deadman Creek or Tsusena Creek. Indeed, it is probable that the effect of this artesian water, which evidently has its access to the alluvial layer in the upper reaches of Tsusena or Deadman Creek, would be to resist flow from the reservoir into the aquifer. Because mud losses in DR-22, located at the center of the relict channel, indicated the possibility of permeable layers at approximate elevations 1,900 and 2,000 feet, a falling head permeability test was performed at this hole. The permeabilities calculated from this test are a further indication the seepage through the terrace would be minor or nonexistent. Consequently, it was unnecessary to include any cutoff through the saddle and relict channel area.

CONSTRUCTION MATERIALS

Material Requirements

Embankment: Approximately 57,792,000 cubic yards of embankment materials will be required to construct an earthfill dam at Watana site. The impervious core is estimated to require 7,373,000 cubic yards and the semipervious fill zone 6,077,000 cubic yards of material. The fine filters are estimated to require 5,621,000 cubic yards of material and the coarse filters 2,201,000 cubic yards. The pervious rock shells, which make up the largest portion of the dam, will require approximately 36,297,000 cubic yards. Slope protection on the upstream side of the dam is estimated to require 223,000 cubic yards of riprap.

Sources of Materials

General: Several sources of embankment materials were investigated in the damsite area. These sources included two quarry locations which could yield rock shell and coarse filter materials, a source of glacial till which could produce core material, and two areas containing relatively clean sands and gravels for the fine filter material. Additional embankment materials will be generated by required excavation for the dam foundation, underground facilities, and the spillway channel. All rock excavation from the spillway channel will be incorporated into the rock shell zone of the dam. The overburden encountered in the excavation for the spillway channel will be glacial till which can be processed by removal of oversize material for use as core material.

Rock Shell Materials: Rock shell materials may be obtained from two quarry locations shown on Plates D-10 and D-11.

Quarry sites were located on the left abutment of the dam (Quarry Source 'A') and in the northwest quadrant of the confluence of Deadman Creek and the Susitna River (Quarry Source'B'). The Quarry Source (A) on the left abutment is an outcrop of igneous rock ranging in elevation from approximately 2,300 to 2,630 feet. The total volume of the hill above the surrounding terrain is approximately 200 million cubic yards of rock. Development would consist of open faces on the north flank of the dome with the final quarry floor at an elevation of 2,300 feet. This type of development would maintain the visible profile of the hill essentially as it is now. The resulting quarry floor could provide an ideal site for parking areas, visitor facilities, and perhaps, the switchyard.

The material in the hill is a diorite on the western side and a rhyodacite porphory on the eastern half. The appearance of outcropings and exposed faces of each material indicates that the hill is composed of sound rock.

The product of this quarry will be used for the rockfill shell zones of the dam and in the coarse filter and riprap. This site (Quarry 'A') represents the nearest source of adequate quantities of rock materials for the dam. From the approximate center of the quarry to the approximate center of the dam is a distance of 4,000 feet and movement of material would be downhill. If properly developed, virtually all of the material removed from the quarry will be used in the dam and the oversize material, overburden and weathered waste material can be disposed of immediately adjacent to the quarry in the reservoir area upstream of the dam.

The quarry source at the confluence of Deadman Creek and the Susitna River (Source 'B') could be developed by excavating rock from the open faces visible on Deadman Creek and continuing the development of a face to the westward, maintaining the face between elevation 1,700 and 2,000 feet. Stripping and clearing would be minimized by developing a long, narrow quarry paralleling the river and using the quarry floor as a haul road for the length of development. If exploited in this way, the quarry could yield 17,000,000 cubic yards of material.

The rock exposed in this area is a moderately weathered diorite. The product of this quarry could be used on the rockfill shell sections of the dam. The distance from the center of the Quarry 'B' to the center of the dam is approximately 2 miles.

The only reason for utilizing this quarry source instead of the Quarry 'A' on the left abutment would be the lessened environmental impact since the quarry at Deadman Creek would be entirely in the reservoir area. However, since the haul distance is greater and the net environmental impact of the Quarry 'A' on the left abutment is small, this area is a less desirable source of embankment materials.

Core Material: Impervious and semipervious materials can be excavated from the glacial tills which are present at the damsite. The most logical source of glacial till appears to be in an area denoted as Borrow Area 'D' which lies between Deadman Creek and the saddle on the north side of the dam (see Plate D-11).

Exploration in this area was accomplished by drilling with a track-mounted, self-propelled auger and a Failing 1500 rotary drill, by test pitting with a backhoe, and by use of seismic refraction methods. Five holes were completed using the air rotary drill, 14 holes were completed using the auger, 14 pits were completed with the backhoe, and 4 seismic refraction lines were extended across the proposed limits of the borrow area. The material in the area is composed of a surface layer of natural ground cover of roots and moss, approximately 2 feet of boulders and organic silts underlain by the tills which are classified as gravelly silty sands. The tills range from 15 to 25 feet thick and usually overlie a clay, sandy gravelly clay and silty sandy gravel.

Sack samples from the test pits (in Borrow Area D) were tested at the North Pacific Division Materials Laboratory to determine gradations, compaction, consolidation characteristics, permeability, and triaxial shear strength.

Gradation tests were run on each sample from each test pit. An envelope of the gradation curves derived from the tests of samples from Test Pits 8 through 19 is shown on Chart D-2. Because the range of gradations of materials from the test pits centrally located in the area is limited, a composite sample was formed. Use of a composite sample was necessary to provide adequate material for a representative testing program since retrieval of large bulk samples from the site was not possible.

The coefficient of permeability (K_{20}) for the minus 1-inch fraction of the till material, compacted to 95 percent of maximum density with an optimum water content of 7.5 percent equals 10.90 X 10^{-6} cm/sec. This relatively low coefficient of permeability is coupled with an adequate shear strength at the optimum water content, acceptable consolidation values even when loaded to 32 tons/sq ft and a narrow band of gradation throughout the central portion of the outlined borrow area. The shape of the compaction curves indicates that moisture content is critical in obtaining maximum densities with a pronounced peak at the relatively low optimum moisture content of 7.5 percent. The results of the triaxial compression tests indicate that in the unsaturated and undrained condition the glacial tills will be sensitive to moisture contents higher than optimum but that if placed on the dry side of optimum they will maintain strength essentially equal to those obtained when placed at optimum.

The results of this testing program indicate that the glacial tills can be placed and compacted to provide a suitable material for both the impervious and semipervious zones. The specifications will need to provide for close controls of the moisture content and the quality assurance programs will have to be adequately staffed to provide for careful checks of moisture content in the pervious and semipervious fill. Detailed laboratory reports of the tests conducted are included as Charts D-6 through D-29.

The materials from Borrow Area D can be used with very little processing. The ground cover and organic silts and boulders will be stripped from the surface and disposed of as designated near the mouth of Deadman Creek in the reservoir area. The remainder of the material can be utilized in the core of the embankment if oversize (12 inch plus) material is removed by mechanically raking in the pit or on the embankment fill. Less than 10 percent of the material will be too large to use in the core. Since removal of only the silty, sandy gravel above the clays will result in the floor of Borrow Area 'D' being above reservoir elevation, it will be necessary to contour and seed the borrow area after the completion of removal of materials as a restoration measure. Approximately 630 acres will be restored.

Filter Material: The nearest source of clean sands and gravels for use in the fine filter of the embankment dam is an alluvial deposit formed by materials washed out of Tsusena Creek and deposited at the confluence of Tsusena Creek and the Susitna River on the right bank of the Susitna (Borrow Area 'E', see Plate D-12). Haul distance to the dam ranges from 3 to 5 miles. This area was explored by digging 5 test pits to a depth of 8 feet using a backhoe mounted on a small tractor.

The material in this area is composed of approximately 2 feet of organic, sandy silt overlaying 6 feet of clean, well graded sands and gravels having maximum size particles of up to 4 inches in diameter. The materials are sound, well rounded particles. The bottoms of the test pits indicate the possibility that the materials deeper than 8 feet below the ground surface contain up to 50 percent of boulders in excess of 8 inches in diameter and ranging up to 24 inches in diameter. The 6 feet of material which lies above the boulders may be used in the embankment with required processing limited to some blending and removal of material larger than 12 inches to produce fine filter material. An envelope of gradation curves derived from tests of samples from TP-1 through TP-5 is shown in Chart D-1. All of the samples are from the first 8 feet of material. All of this material lies above the water table and can be taken by front loaders. The quantity of material available in the first 8 feet is approximately 3.7 million cubic yards. After the boulders are encountered at a depth of 8 feet, the oversize material will have to be removed and material below the water table will have to be bailed from the area. A dike will be maintained to separate the borrow operations from the river so that all turbidity created by the excavation of materials will be filtered or settle prior to entering the Susitna River. In terms of grading, particle soundness and proximity, this area represents an excellent source of essential filter materials.

The second area in which clean sands and gravels were located is in the upper reaches of Tsusena Creek, north of Tsusena Butte (Borrow Area 'C'). The materials are sound, well rounded particles and are well graded with maximum sizes generally less than 4 inches. Considerable exploratory effort would be necessary to ensure quality and quantity of materials before this could be considered an acceptable source. Because of the haul distance of 12 miles, this source will not be considered unless further explorations and testing indicate that adequate materials may not be obtained from the sources closer to the damsite.

Exploration at Site 'C' was accomplished by digging one test pit, reconnaissance of the area on foot and from helicopter, and with a seismic survey.

Concrete Aggregates: Approximately 310,000 cubic yards of concrete will be required to construct the appurtenant structures for an embankment dam at Watana damsite. Most of this will be structural concrete placed in tunnel linings, the powerplant, gate structures, intake structures, and spillway channel lining. Maximum size aggregate will be 3 inches in all but the smaller structures or those with closely spaced reinforcing. The most readily available source of concrete aggregate is available at the confluence of Tususena Creek and the Susitna River (Borrow Area 'E'). The materials from the first 8 feet in the alluvium can be utilized with only limited screening. As oversize materials are encountered at greater depths, the larger particles will be crushed for use in the concrete aggregate, thereby achieving maximum utilization of gravels from the area and also to increase the tensile strain resistance of the concrete which will lessen problems with thermal cracking in the more massive sections. Since Borrow Area E represents the most economical source of concrete aggregate and the nearest acceptable source of essential filter material, maximum utilization of the material in this area is required.

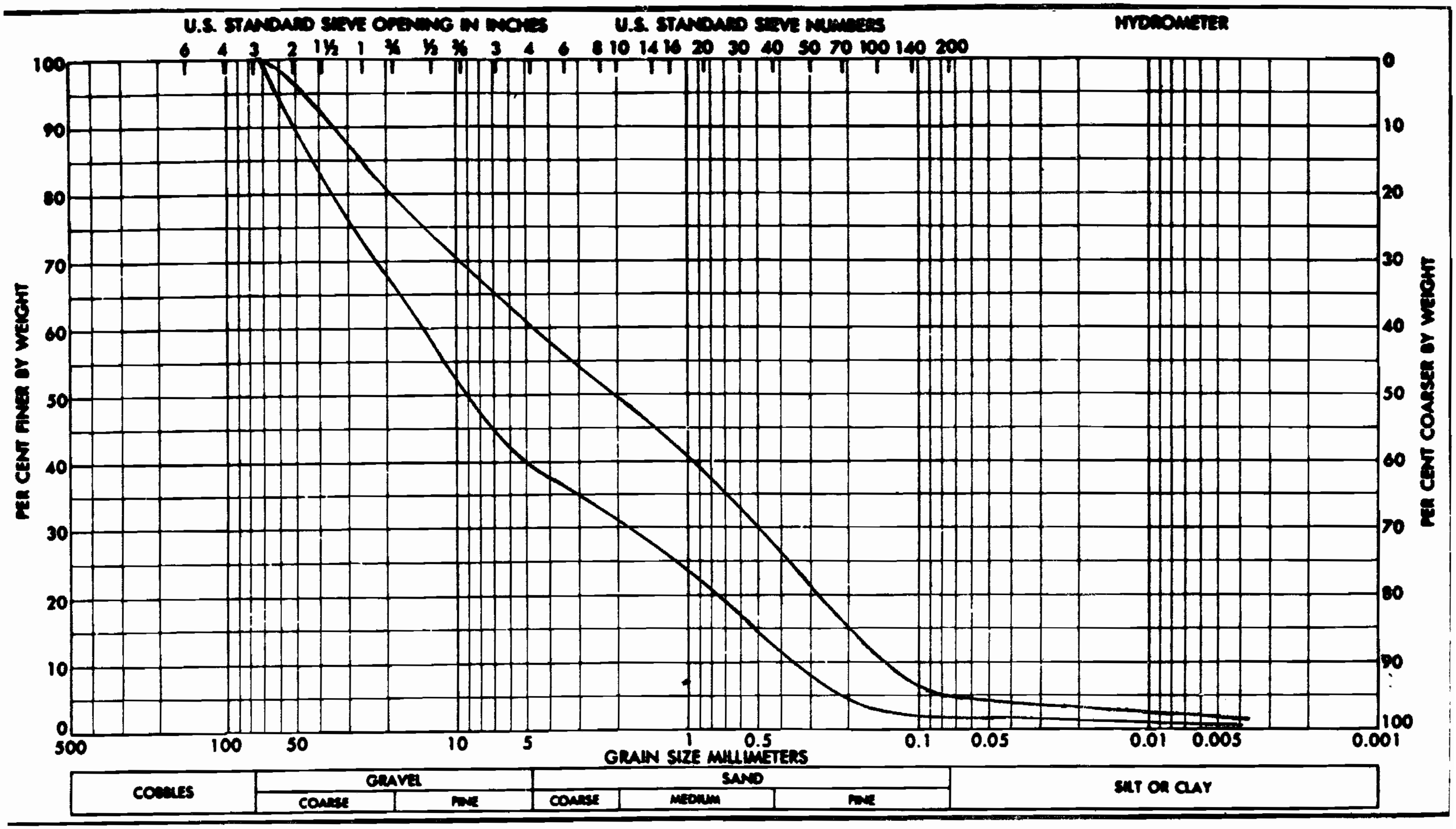
A petrographic analysis of sands and gravels from Borrow Area E was conducted by the Missouri River Division Laboratory at Omaha, Nebraska. The results show the material to be approximately 70 percent granitic rock with the remainder composed of basalt, andesite, and ryholite. Chert is present in such small quantities as to be nondeleterious.

The quarry site on the left abutment (Quarry Source 'A') is considered an alternate source of concrete aggregate. If material from the quarry were used in the embankment dam aggregate could be produced by placing a crushing and screening plant in the quarry and producing the concrete aggregate incidental to the production of embankment material. The concrete aggregates would be produced from the diorites in the quarry to avoid the potential of problems caused by the reaction of the alkalis in the concrete with the rhyodacite porphory in the eastern half of the hill.

The materials in upper Tsusena Creek (Borrow Source 'C') would produce excellent concrete aggregate; however, because of the haul distance involved (10 miles), it is not anticipated that this source would be exploited to produce concrete aggregate unless embankment materials are also taken from the same source.

It is anticipated that because of the relatively small quantities of required concrete aggregate compared to the large quantities of the various classes of embankment materials, that concrete aggregates will be produced incidental to the production of embankment material and stockpiled adjacent to the batch plants used.

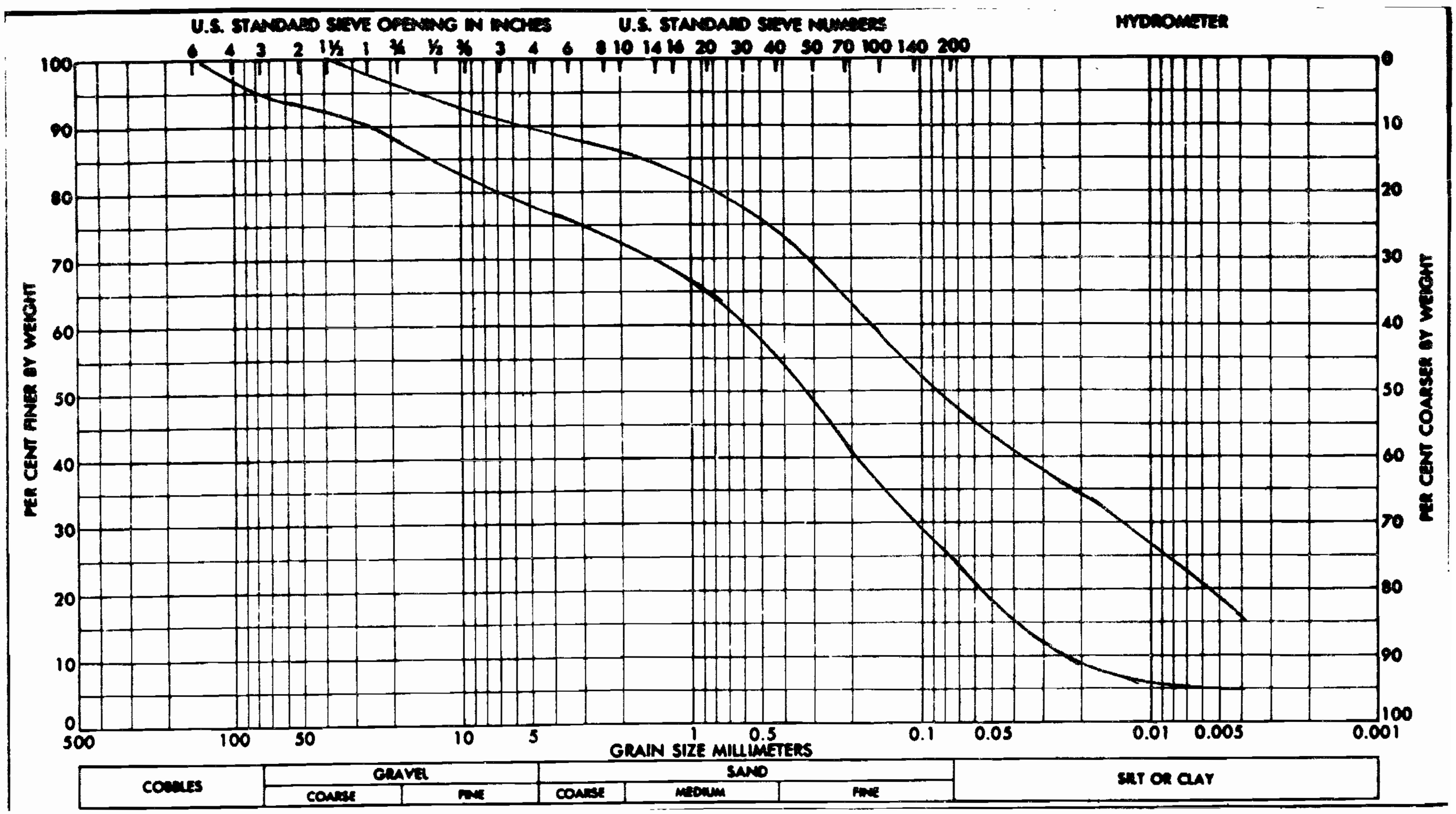
The first concrete required on the project will be that required to line the diversion tunnels and form gate and trashrack structures for river diversion. The aggregate for this work could be produced from Borrow Area E with a resulting haul distance of 2.3 miles.



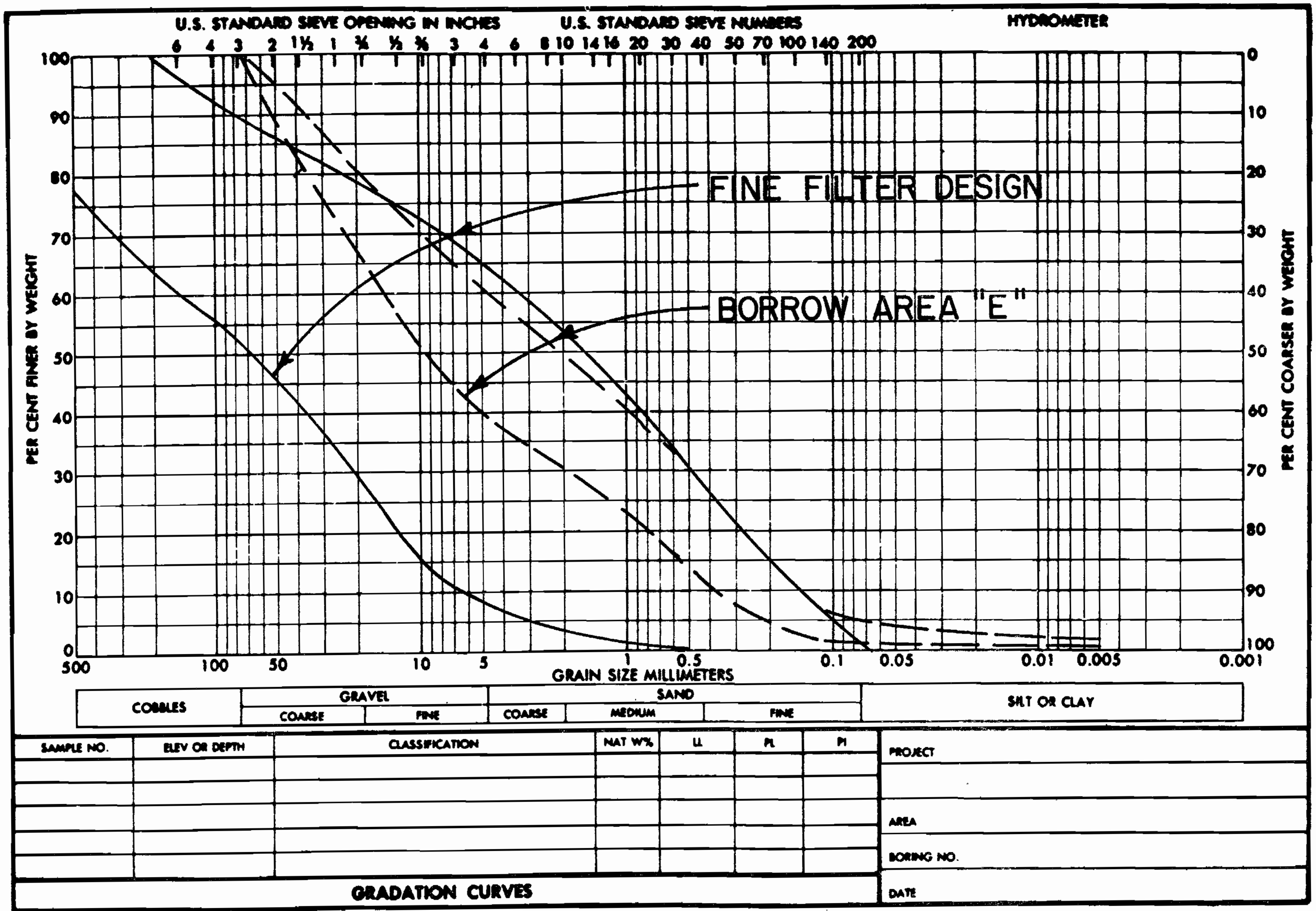
Envelope of gradation curves derived from tests of samples from test pits 1 thru 5, Borrow area E.

Chart D-1

Chart D-2

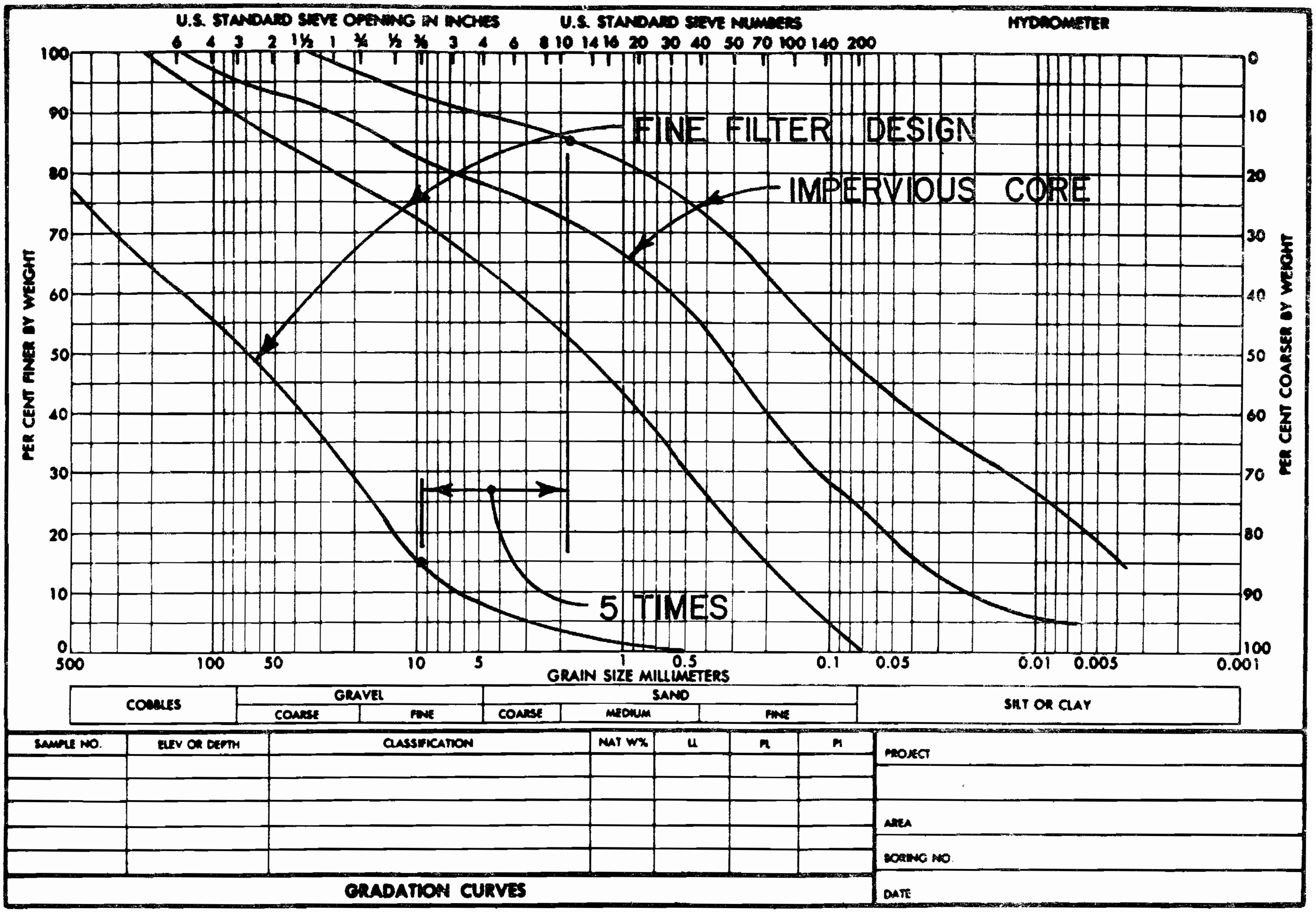


Envelope of gradation curves derived from tests of samples from test pits 8 thru 19, Borrow area D.

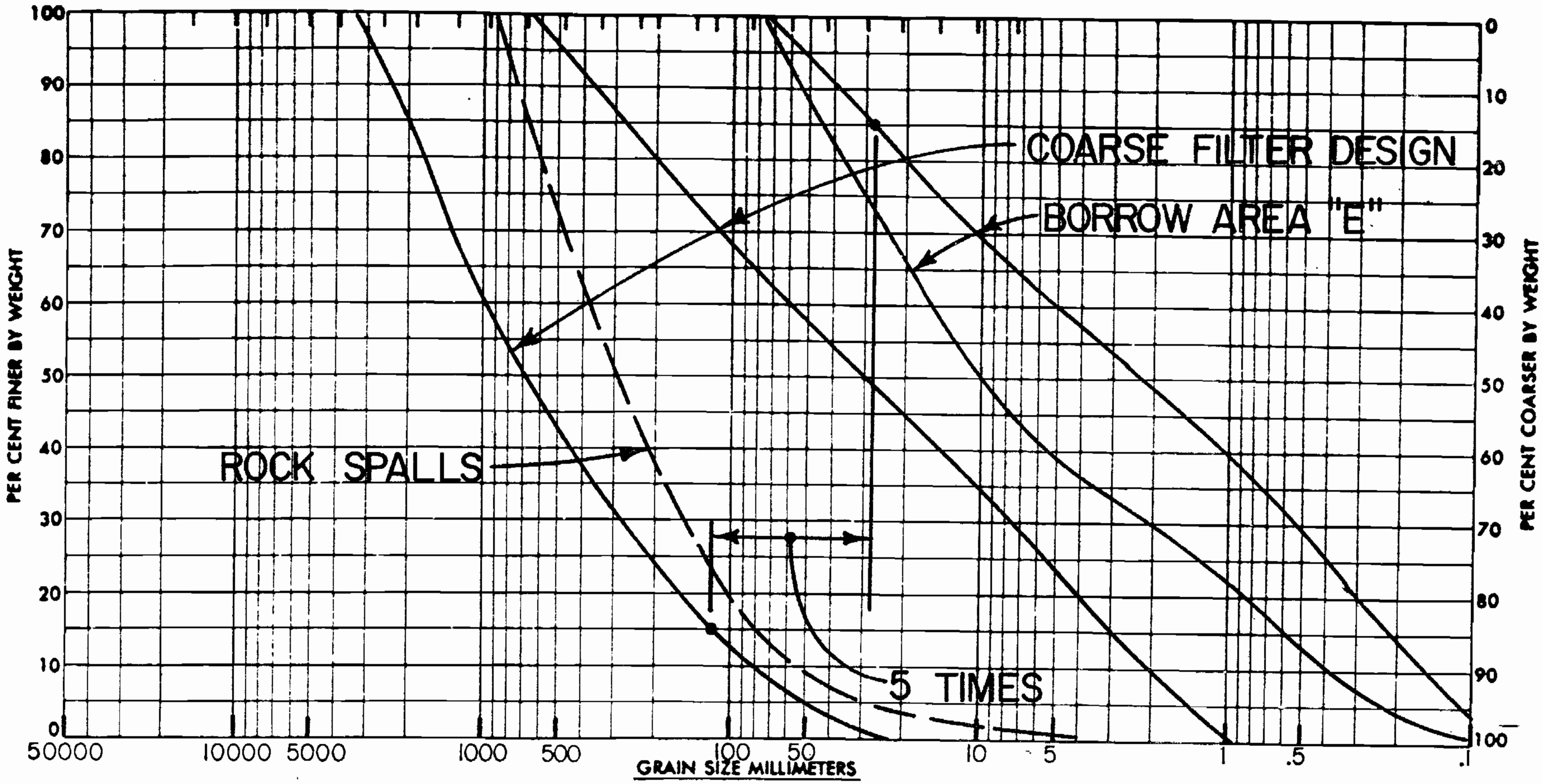


GRADATION ENVELOPES - BORROW AREA E SUPERIMPOSED ON FINE FILTER

Chart D-3



GRADATION ENVELOPES - FINE FILTERS AND IMPERVIOUS CORE



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT

AREA

BORING NO.

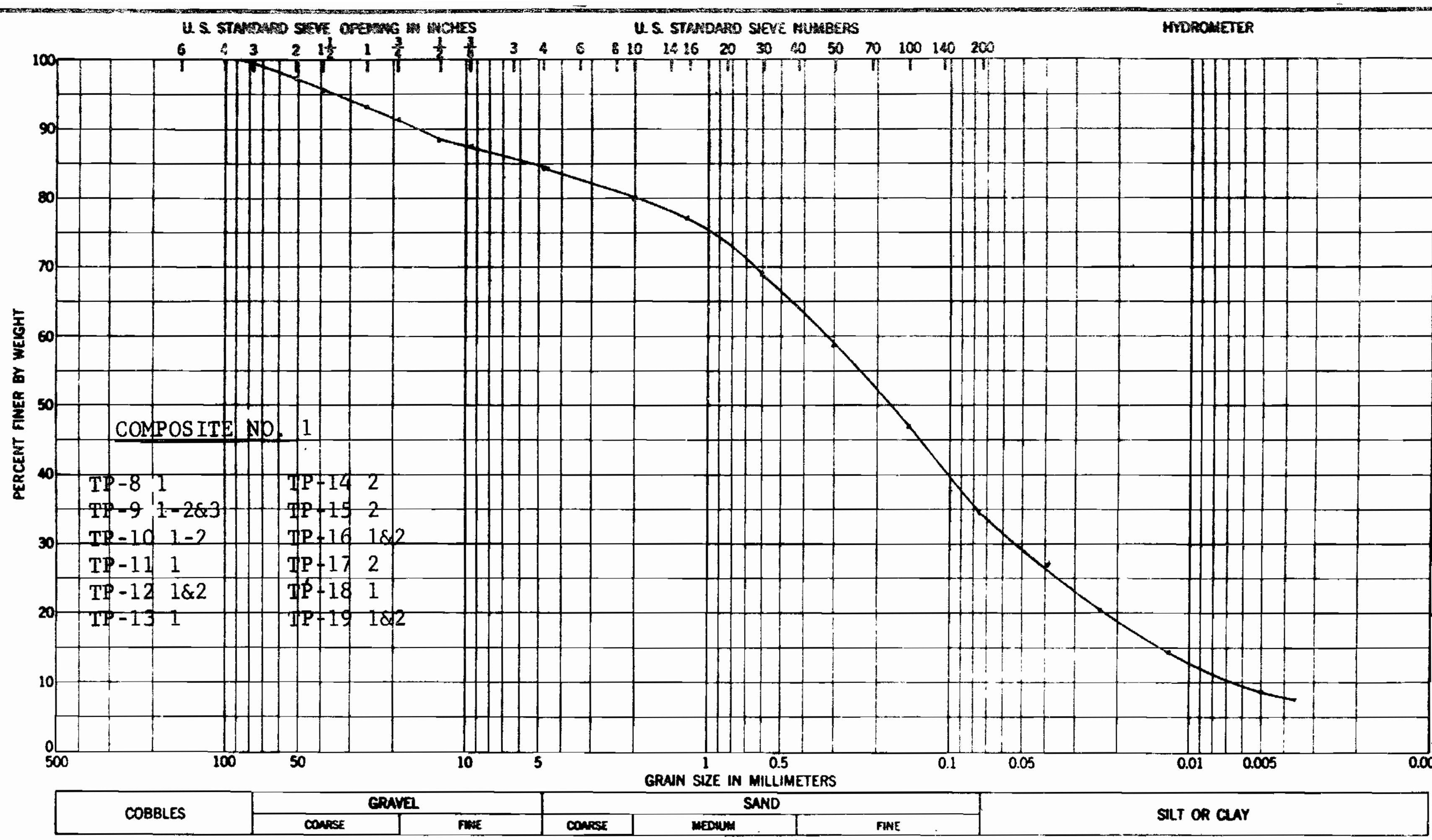
DATE

GRADATION CURVES

GRADATION ENVELOPES - COARSE FILTER AND BORROW AREA E.

Chart D-5

Chart D-6



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
Composite No.1		Gr. Si. SAND (SM)				

Project WATANA DAM

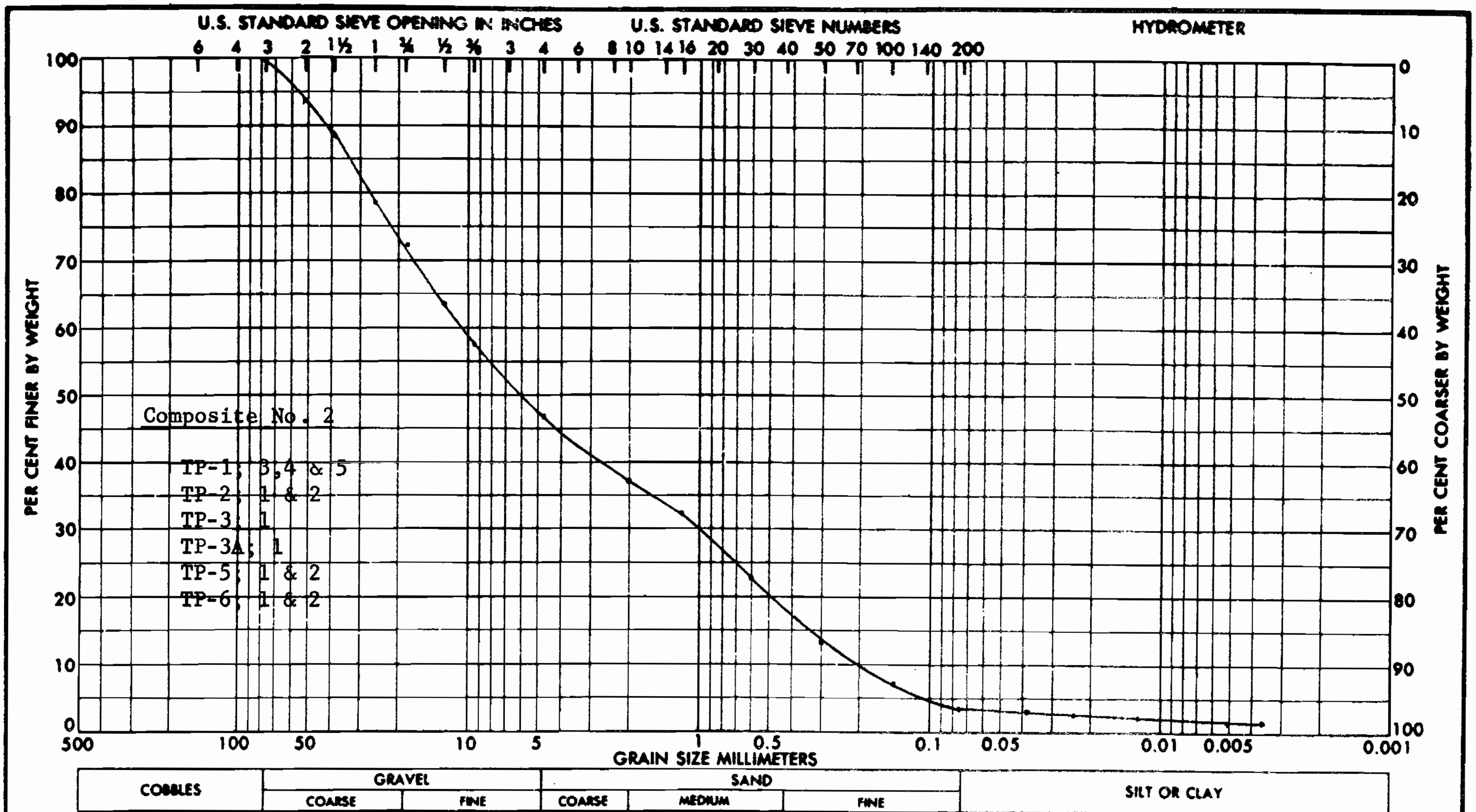
Area

Boring No. Composite No. 1

Date 14 NOV 1978 79-S-404

GRADATION CURVES NPD

ENG FORM 1 MAY 63 2087



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
Composite	No. 2	Sa. GRAVEL (GP)				

PROJECT WATANA DAM

AREA

BORING NO. Composite No. 2

DATE 20 NOV 1978 79-S-404

GRADATION CURVES NPD

ENG FORM 2087 1 MAY 63 — REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.

Chart D-7

14 NOV 1978

NPDEN-GS-L (79-S-404)

WATANA DAM

Composite No. 1

Report of Specific Gravity & Permeability Tests

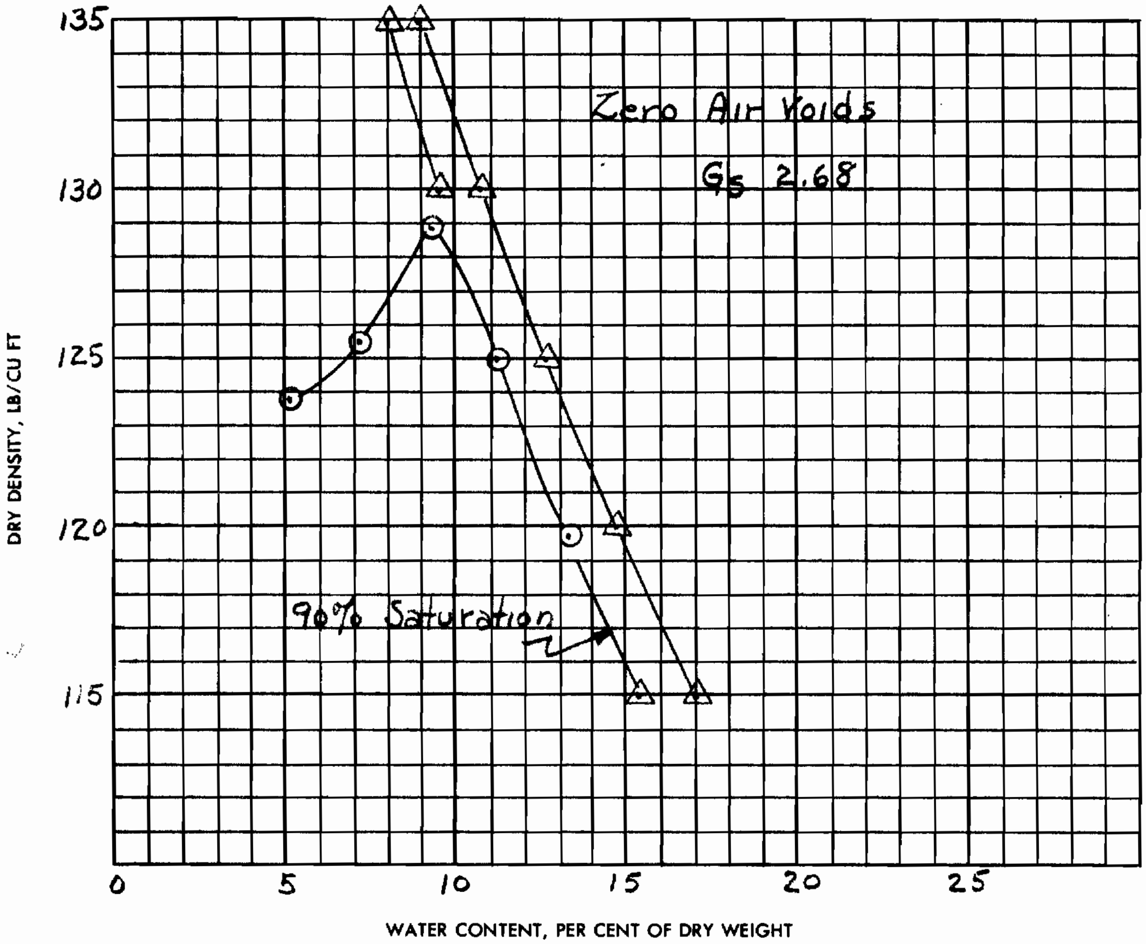
1. Specific Gravity & Absorption (ASTM C127 & C128)

	3/4 in. - No. 4	Minus No. 4
Bulk	2.633	
Bulk, SSD	2.671	
Apparent	2.737	2.683
% Absorption	1.44	

2. Coefficient of Permeability (Minus 1 inch material)

Remolded Density = 126.6 P.C.F.
Optimum Water Content = 7.5%
Permeability K_{20} = 10.90×10^{-6} cm/sec.

Chart D-8



Standard COMPACTION TEST

25 BLOWS PER EACH OF 3 LAYERS, WITH 5.5 LB RAMMER AND

12.0 INCH DROP. 4.0 INCH DIAMETER MOLD

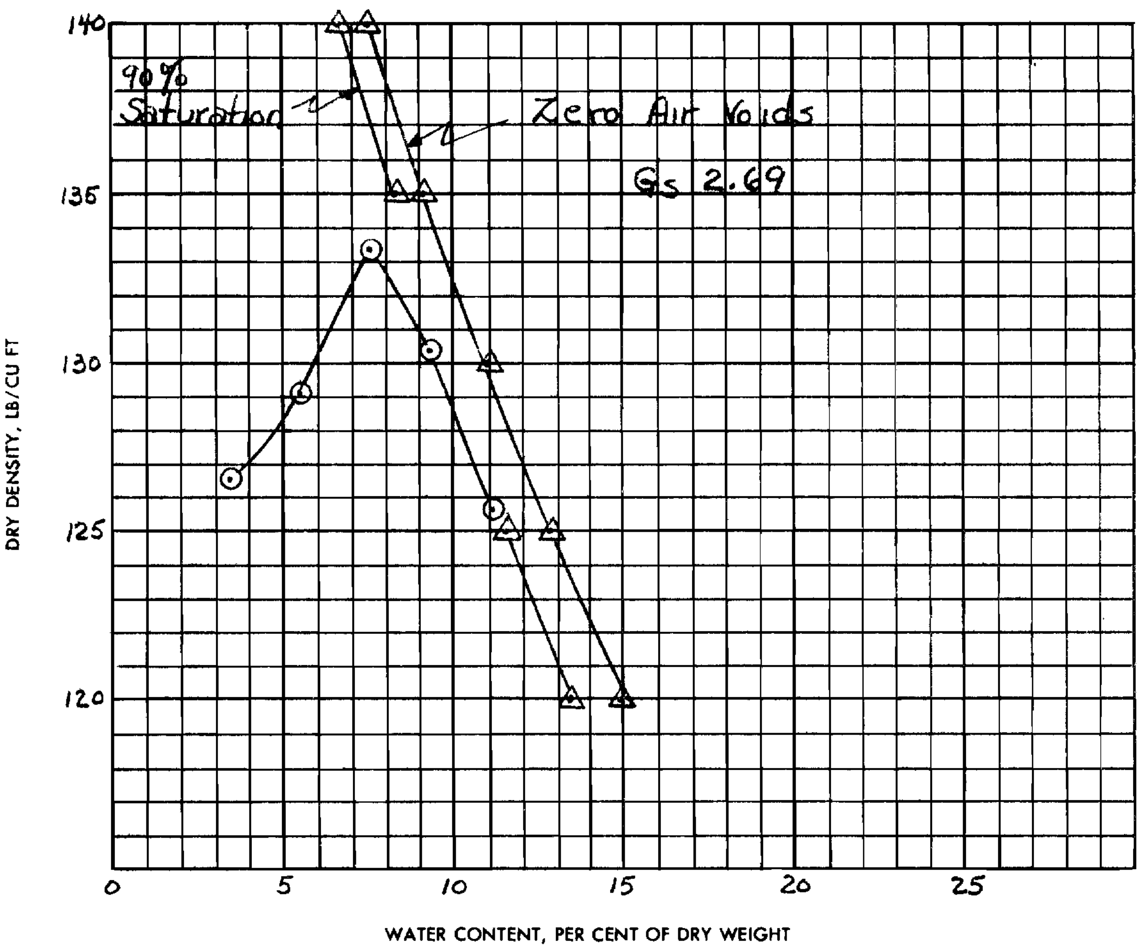
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	G	LL	PL	% > NO. 4	% > ¾ IN.
Composite No. 1		Si. SAND (SM)	2.68			—	—

SAMPLE NO.	Composite No. 1			
NATURAL WATER CONTENT IN PER CENT				
OPTIMUM WATER CONTENT IN PER CENT	9.3			
MAX DRY DENSITY IN LB/CU FT	128.9			

REMARKS	PROJECT WATANA DAM
AASHTO T-99	
Method A	AREA
	BORING NO. Composite No.1 — DATE 14 NOV 1978
	NPD **COMPACTION TEST REPORT**

ENG FORM 2091 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. *(TRANSLUCENT)* GPO : 1964 OF—715-178

Chart D-9



Standard COMPACTION TEST

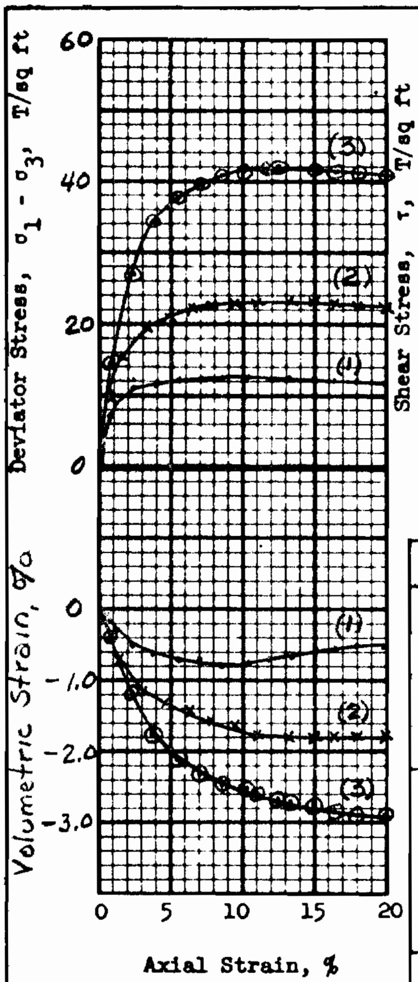
56 BLOWS PER EACH OF 3 LAYERS, WITH 5.5 LB RAMMER AND

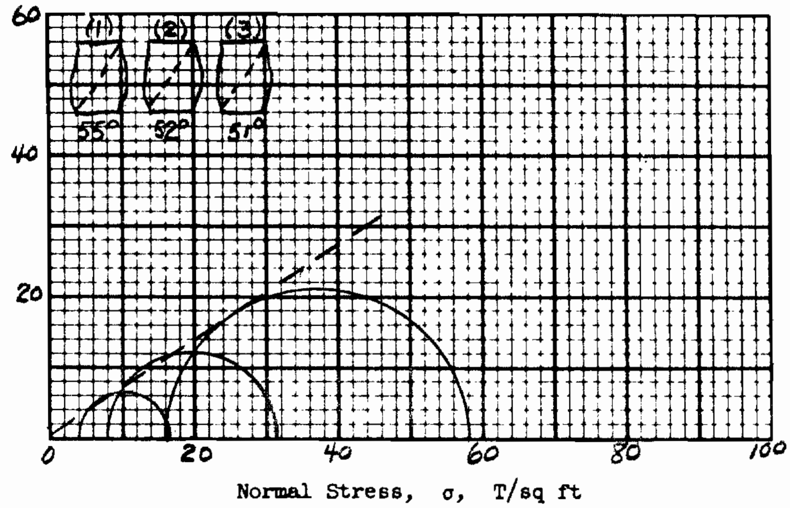
12.0 INCH DROP. 6.0 INCH DIAMETER MOLD

SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	G	LL	PL	% > NO. 4	% > ¾ IN.
Composite No.1		Gr.Si. SAND (SM)	2.69			13.1	-

SAMPLE NO.	Composite No.1			
NATURAL WATER CONTENT IN PER CENT				
OPTIMUM WATER CONTENT IN PER CENT	7.5			
MAX DRY DENSITY IN LB/CU FT	133.3			

REMARKS	PROJECT WATANA DAM
AASHTO T-99	
Method D	AREA
	BORING NO. Composite No.1 — DATE 14 NOV 1978
	NPD **COMPACTION TEST REPORT**





Shear Strength Parameters

ϕ = 33.5°

tan ϕ = 0.662

c = 0.66 T/sq ft

Method of saturation None

☐ Controlled stress

☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	7.7 %	7.6 %	7.5 %	%
	Void ratio	e_o	0.329	0.326	0.326	
	Saturation	S_o	63 %	62 %	62 %	%
	Dry density, lb/cu ft	γ_d	126.3	126.5	126.6	
Before Shear	Water content	$w_{\sigma_{III}}$	7.7 %	7.3 %	7.3 %	%
	Void ratio	$e_{\sigma_{III}}$	0.317	0.312	0.309	
	Saturation	$S_{\sigma_{III}}$	65 %	65 %	65 %	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	7.5 %	7.3 %	7.3 %	%
	Void ratio	e_f	0.307	0.289	0.274	
Minor principal stress, T/sq ft		σ_3	4.00	8.00	16.00	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	12.41	23.46	42.02	
Time to failure, min		t_f	26	35	32	
Rate of strain, percent/min			0.39	0.38	0.39	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	12.29	23.25	41.77	
Initial diameter, in.		D_o	5.87	5.87	5.87	
Initial height, in.		H_o	12.81	12.81	12.81	

Type of test Q | **Type of specimen** Remold

Classification Gr. Si. SAND (SM)

LL	PL	PI		G_s 2.69

Remarks Remolded at 95% Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content (7.5%)

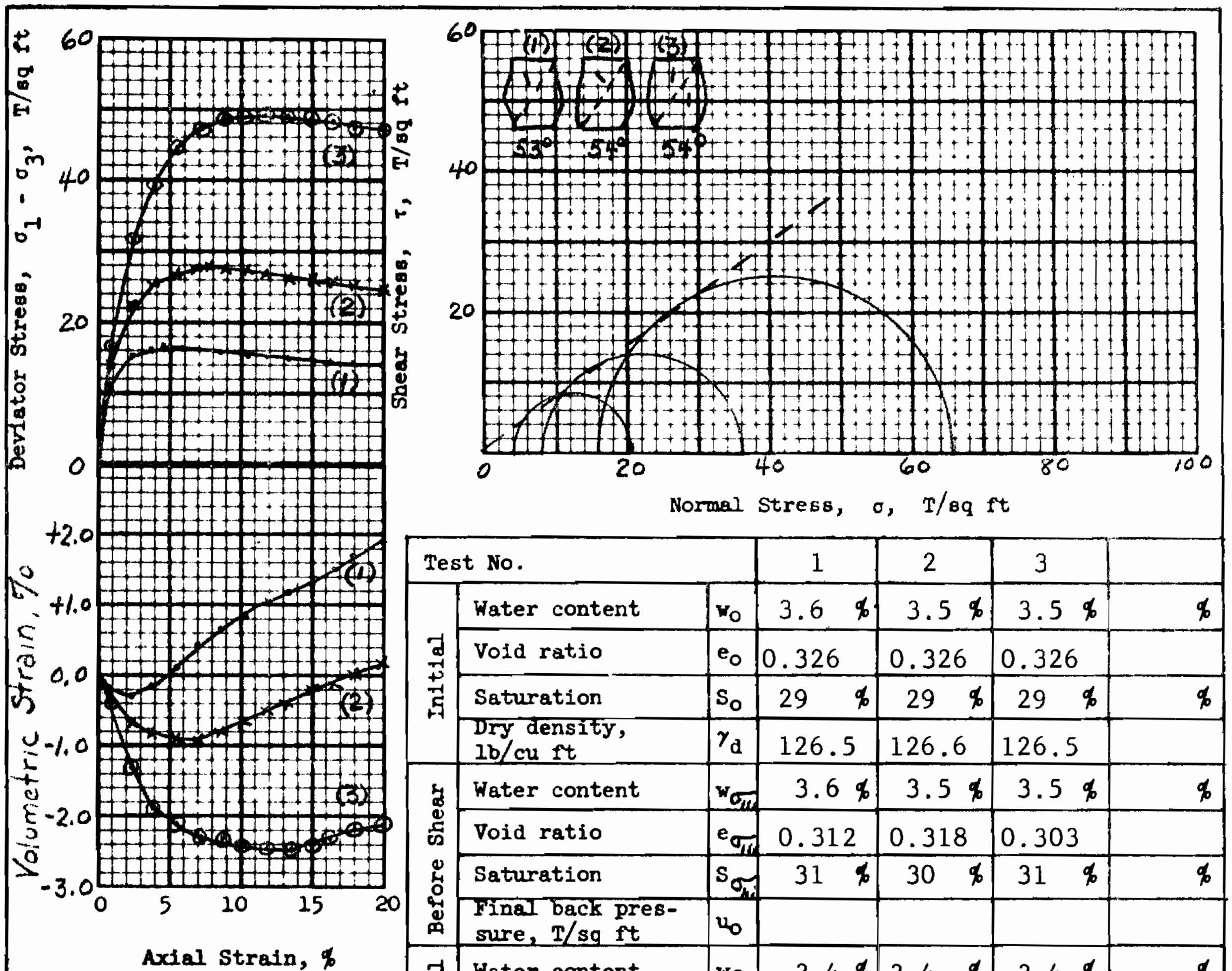
Project WATANA DAM

Area

Boring No. | **Sample No.** Composite No.1

Depth El | **Date** 14 NOV 1978

NPD TRIAXIAL COMPRESSION TEST REPORT



Test No.			1	2	3	
Initial	Water content	w_o	3.6 %	3.5 %	3.5 %	%
	Void ratio	e_o	0.326	0.326	0.326	
	Saturation	S_o	29 %	29 %	29 %	%
	Dry density, lb/cu ft	γ_d	126.5	126.6	126.5	
Before Shear	Water content	$w_{\overline{\sigma}_{1f}}$	3.6 %	3.5 %	3.5 %	%
	Void ratio	$e_{\overline{\sigma}_{1f}}$	0.312	0.318	0.303	
	Saturation	$S_{\overline{\sigma}_{1f}}$	31 %	30 %	31 %	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	3.4 %	3.4 %	3.4 %	%
	Void ratio	e_f	0.312	0.307	0.272	
Minor principal stress, T/sq ft		σ_3	4.00	8.00	16.00	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	16.49	28.10	49.64	
Time to failure, min		t_f	11	21	30	
Rate of strain, percent/min			0.43	0.37	0.39	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	14.95	26.25	48.72	
Initial diameter, in.		D_o	5.87	5.87	5.87	
Initial height, in.		H_o	12.81	12.81	12.81	

Shear Strength Parameters

ϕ = 35.5 °

tan ϕ = 0.712

c = 0.14 T/sq ft

Method of saturation None

☐ Controlled stress

☒ Controlled strain

Type of test Q	Type of specimen Remold			
Classification Gr. Si. SAND (SM)				
LL	PL	PI		G_s 2.69

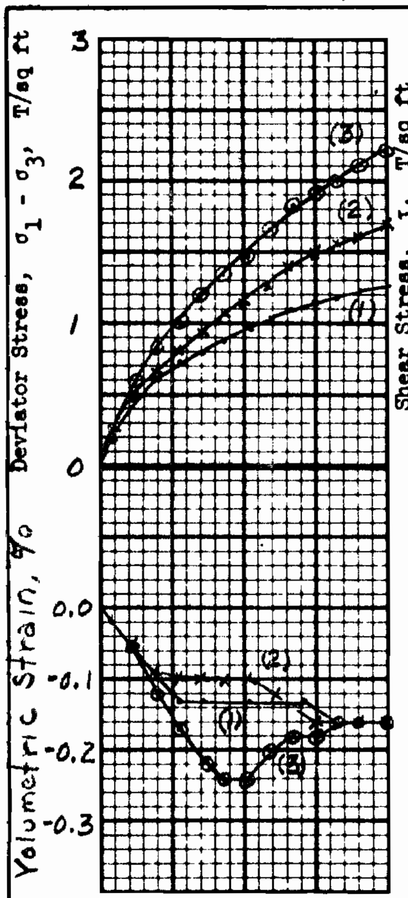
Remarks Remolded at 95% Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content minus 4% (3.5%)

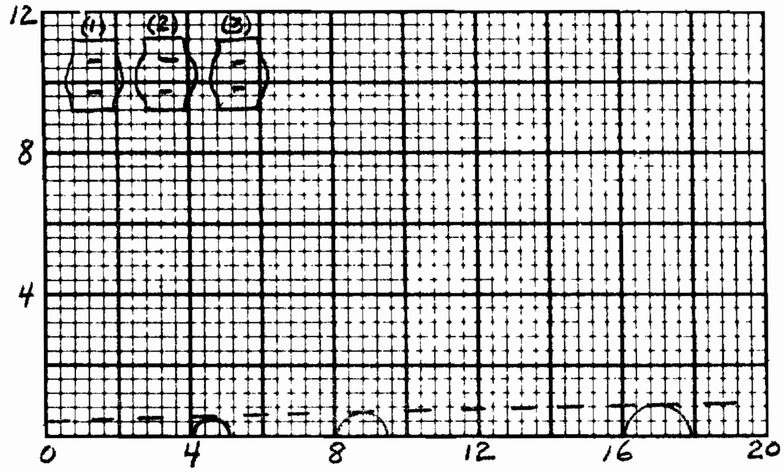
Project WATANA DAM	
Area	
Boring No.	Sample No. Composite No. 1
Depth El	Date 14 NOV 1978
NPD TRIAXIAL COMPRESSION TEST REPORT	

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE

Chart D-12

TRANSLUCENT





Test No.			1	2	3	
Initial	Water content	w_o	11.2 %	11.2 %	11.2 %	%
	Void ratio	e_o	0.326	0.328	0.326	
	Saturation	S_o	92 %	92 %	92 %	%
	Dry density, lb/cu ft	γ_d	126.1	126.4	126.6	
Before Shear	Water content	$w_{\bar{\sigma}_{iii}}$	11.2 %	11.2 %	11.2 %	%
	Void ratio	$e_{\bar{\sigma}_{iii}}$	0.302	0.304	0.303	
	Saturation	$S_{\bar{\sigma}_{iii}}$	100 %	99 %	99 %	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	11.2 %	11.2 %	11.2 %	%
	Void ratio	e_f	0.301	0.302	0.301	
Minor principal stress, T/sq ft		σ_3	4.00	8.00	16.00	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	1.15	1.50	1.91	
Time to failure, min		t_f	38	38	38	
Rate of strain, percent/min			0.39	0.39	0.39	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	1.15	1.50	1.91	
Initial diameter, in.		D_o	5.87	5.87	5.87	
Initial height, in.		H_o	12.81	12.81	12.81	

Shear Strength Parameters

ϕ = 1.75 °

tan ϕ = 0.0307

c = 0.44 T/sq ft

Method of saturation None

[ ] Controlled stress

[X] Controlled strain

Type of test Q **Type of specimen** Remold

Classification Gr. Si. SAND (SM)

LL **PL** **PI** G_s 2.69

Remarks Remolded at 95% Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content plus 4% (11.5%) Lost water during compaction

Project WATANA DAM

Area

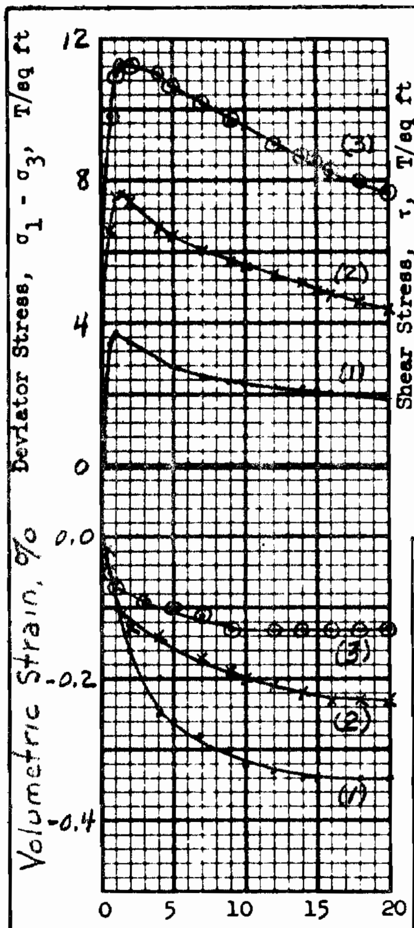
Boring No. **Sample No.** Composite No. 1

Depth El **Date** 14 NOV 1978

NPD **TRIAXIAL COMPRESSION TEST REPORT**

ENG FORM 1 JUN 65 2089 *(EM 1110-2-1902)* PREVIOUS EDITIONS ARE OBSOLETE *TRANSLUCENT*

Chart D-13



Shear Strength Parameters

ϕ = 12.3 °

tan ϕ = 0.218

c = 1.07 T/sq ft

Method of saturation Back Pressure

☐ **Controlled stress**

☒ **Controlled strain**

Test No.			1	2	3	
Initial	Water content	w_o	7.5 %	7.9 %	7.8 %	%
	Void ratio	e_o	0.326	0.331	0.331	
	Saturation	S_o	62 %	64 %	64 %	%
	Dry density, lb/cu ft	γ_d	126.6	126.1	126.2	
Before Shear	Water content	w_c	11.2 %	11.1 %	10.8 %	%
	Void ratio	e_c	0.303	0.300	0.291	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	5.04	7.20	5.04	
Final	Water content	w_f	11.2 %	11.1 %	10.8 %	%
	Void ratio	e_f	0.302	0.298	0.290	
Minor principal stress, T/sq ft		σ_3	4.00	8.00	16.00	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	3.84	7.59	11.28	
Time to failure, min		t_f	10	18	19	
Rate of strain, percent/min			0.10	0.08	0.08	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	2.13	4.92	8.49	
Initial diameter, in.		D_o	5.87	5.87	5.87	
Initial height, in.		H_o	12.81	12.81	12.81	

Type of test R **Type of specimen** Remold

Classification Gr. Si. SAND (SM)

LL **PL** **PI** G_s 2.69

Remarks Remolded at 95% Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content (7.5%).

Project WATANA DAM

Area

Boring No. **Sample No.** Composite No.1

Depth El **Date** 14 NOV 1978

NPD **TRIAXIAL COMPRESSION TEST REPORT**

ENG FORM 1 JUN 65 2089 *(EM 1110-2-1902)* PREVIOUS EDITIONS ARE OBSOLETE Chart D-14 A 2 ' ' 6 2

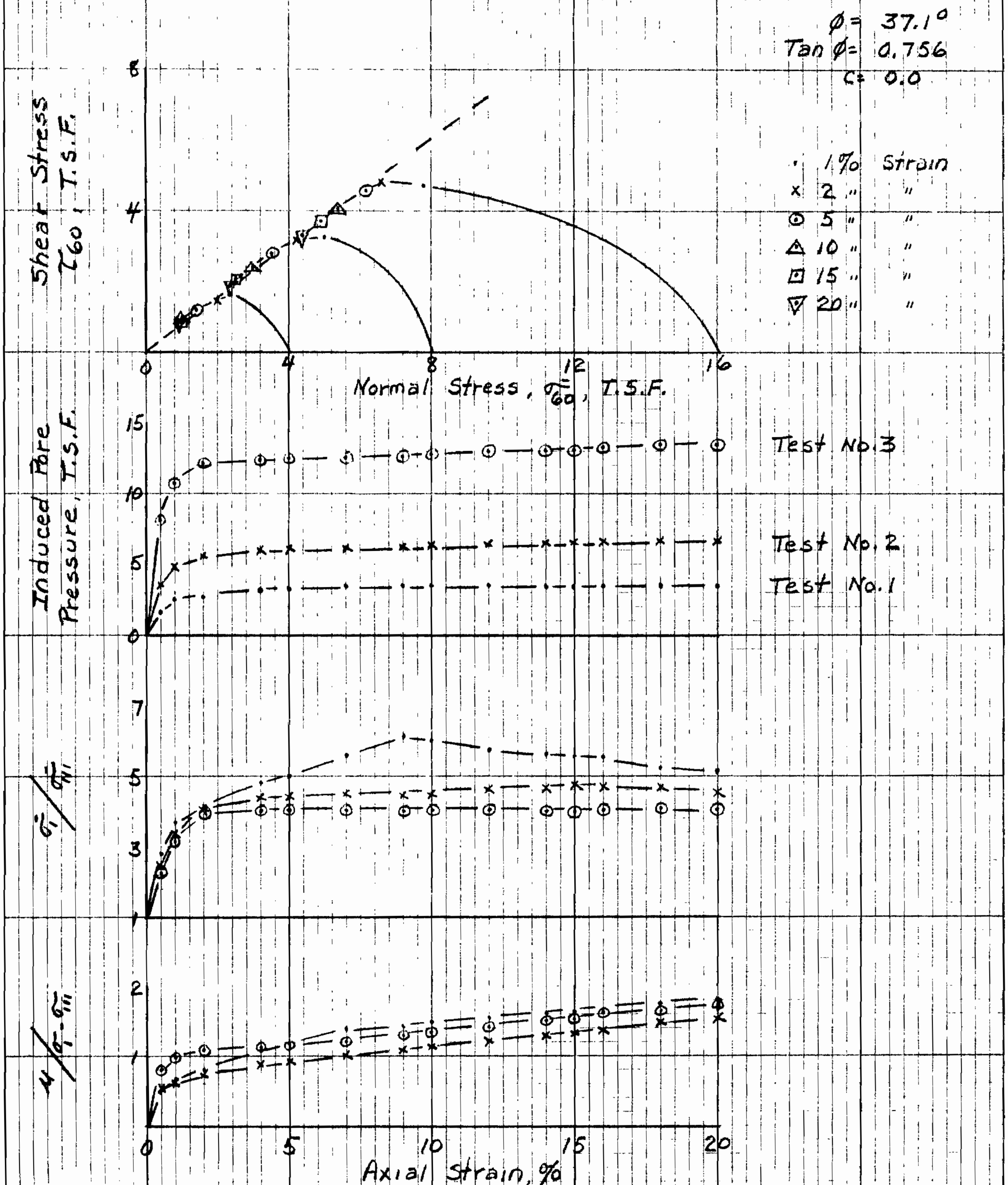
TRANSLUCENT

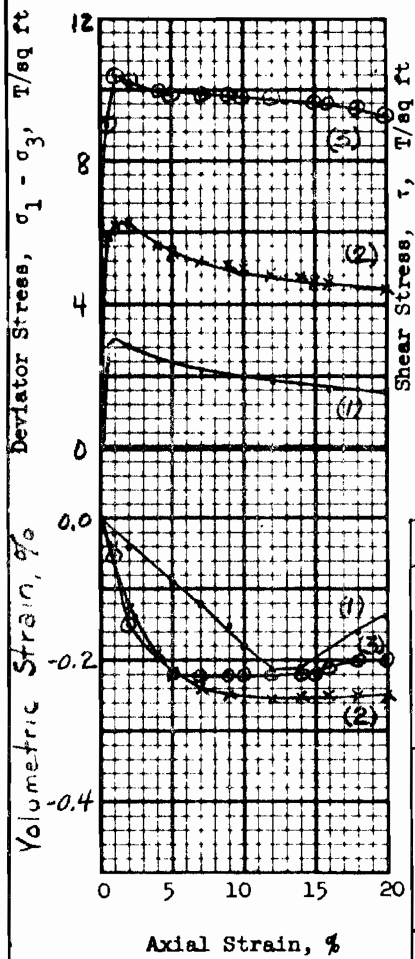
NPDEN-GS-L (79-S-404) WATANA DAM 14 NOV 1978

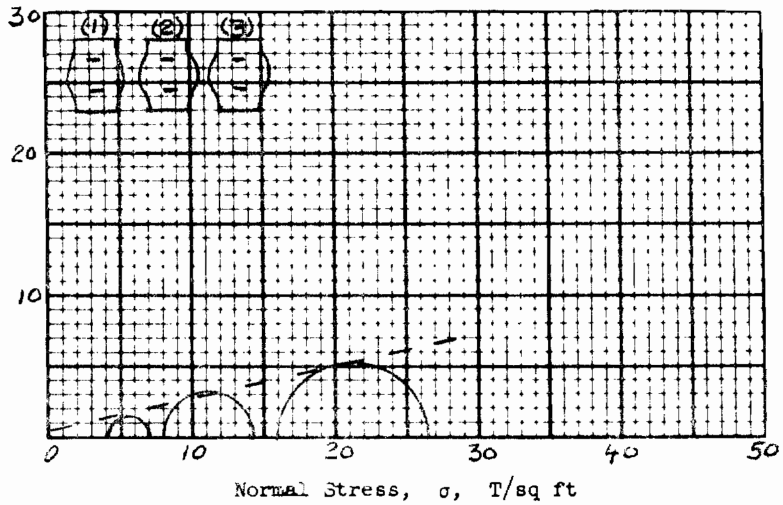
Composite No. 1

"R" Triaxial Back Pressure & Pore Pressure Test Data

Test Specimens Remolded at 95% Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content (7.5%).







Shear Strength Parameters

ϕ = 12.8 °

tan ϕ = 0.228

c = 0.52 T/sq ft

Method of saturation: Back Pressure

☐ Controlled stress

☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	3.9 %	3.9 %	3.9 %	%
	Void ratio	e_o	0.330	0.330	0.331	
	Saturation	S_o	31 %	31 %	32 %	%
	Dry density, lb/cu ft	γ_d	126.2	126.2	126.1	
Before Shear	Water content	w_c	11.7 %	11.0 %	10.5 %	%
	Void ratio	e_c	0.314	0.298	0.282	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	5.76	5.76	5.76	
Final	Water content	w_f	11.7 %	11.0 %	10.5 %	%
	Void ratio	e_f	0.313	0.297	0.282	
Minor principal stress, T/sq ft		σ_3	4.00	8.00	16.00	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	3.08	6.21	10.45	
Time to failure, min		t_f	12	19	12	
Rate of strain, percent/min			0.08	0.08	0.08	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	1.75	4.72	9.66	
Initial diameter, in.		D_o	5.87	5.87	5.87	
Initial height, in.		H_o	12.81	12.81	12.81	

Type of test R	Type of specimen Remold		
Classification Gr. Si. SAND (SM)			
LL	PL	PI	G_s 2.69

Remarks: Remolded at 95 % Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content minus 4 % (3.5 %).

Project WATANA DAM	
Area	
Boring No.	Sample No. Composite No.1
Depth El	Date 20 NOV 1978
NPD TRIAXIAL COMPRESSION TEST REPORT	

ENG FORM 1 JUN 65 2089 (EM 1110-2-1902) PREVIOUS EDITIONS ARE OBSOLETE TRANSLUCENT

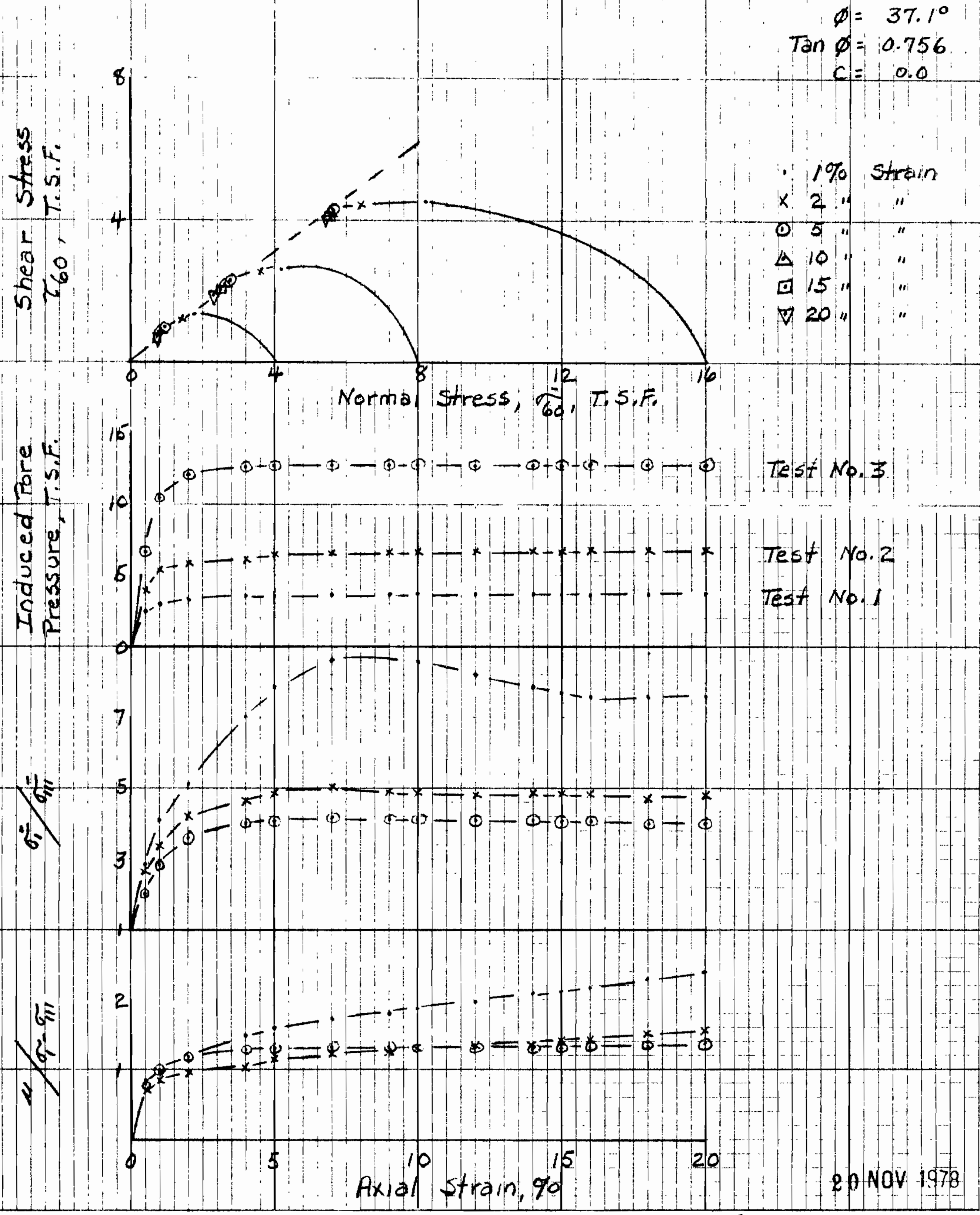
Chart D-16

NPDEN-GS-L (79-S-404)

WATANA DAM
Composite No. 1

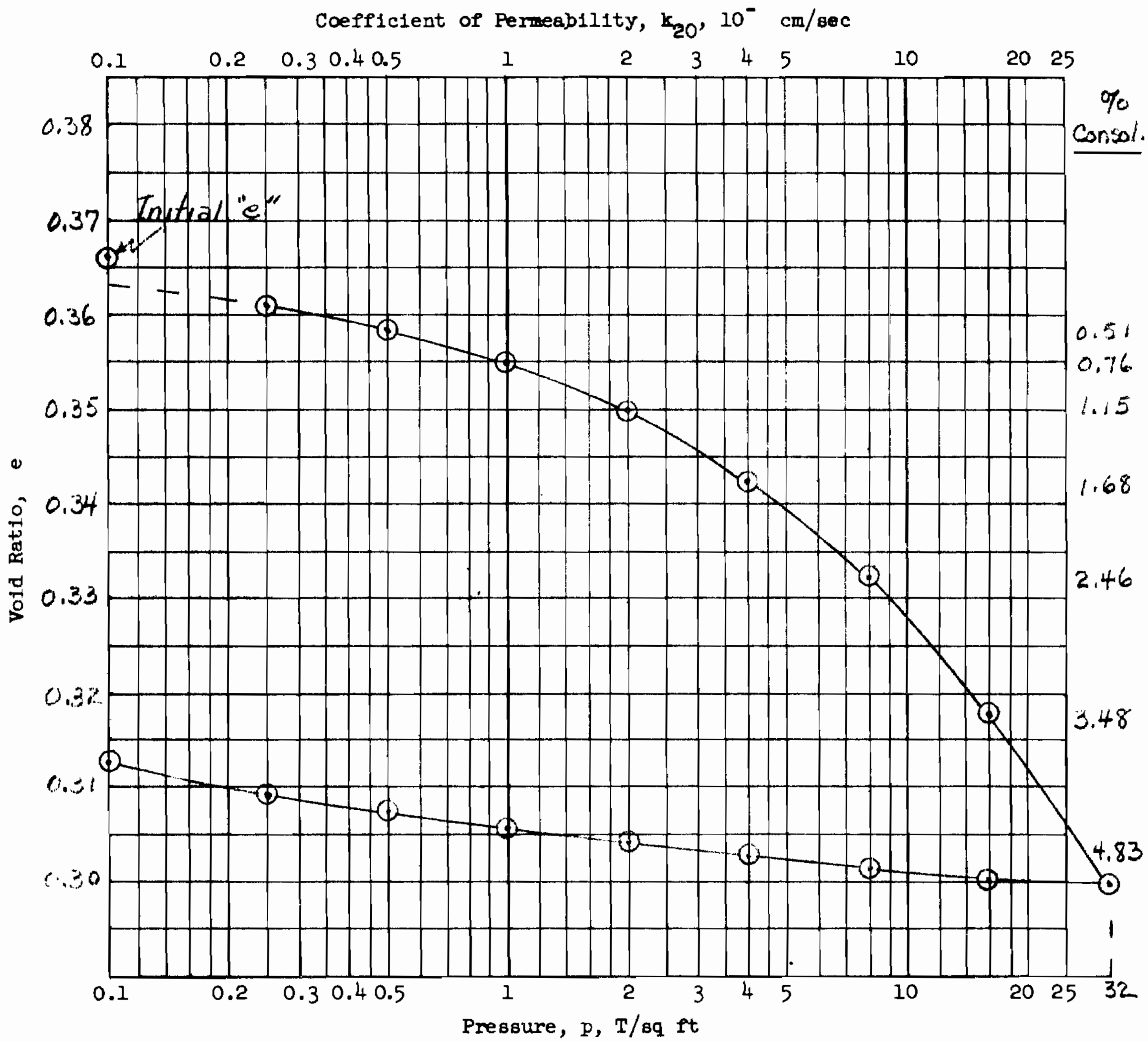
"R" Triaxial Back Pressure & Pore Pressure Test Data

Test Specimens Remolded at 95% Standard Compaction Density (126.6 P.C.F.) and Optimum Water Content minus 4% (3.5%)



20 NOV 1978

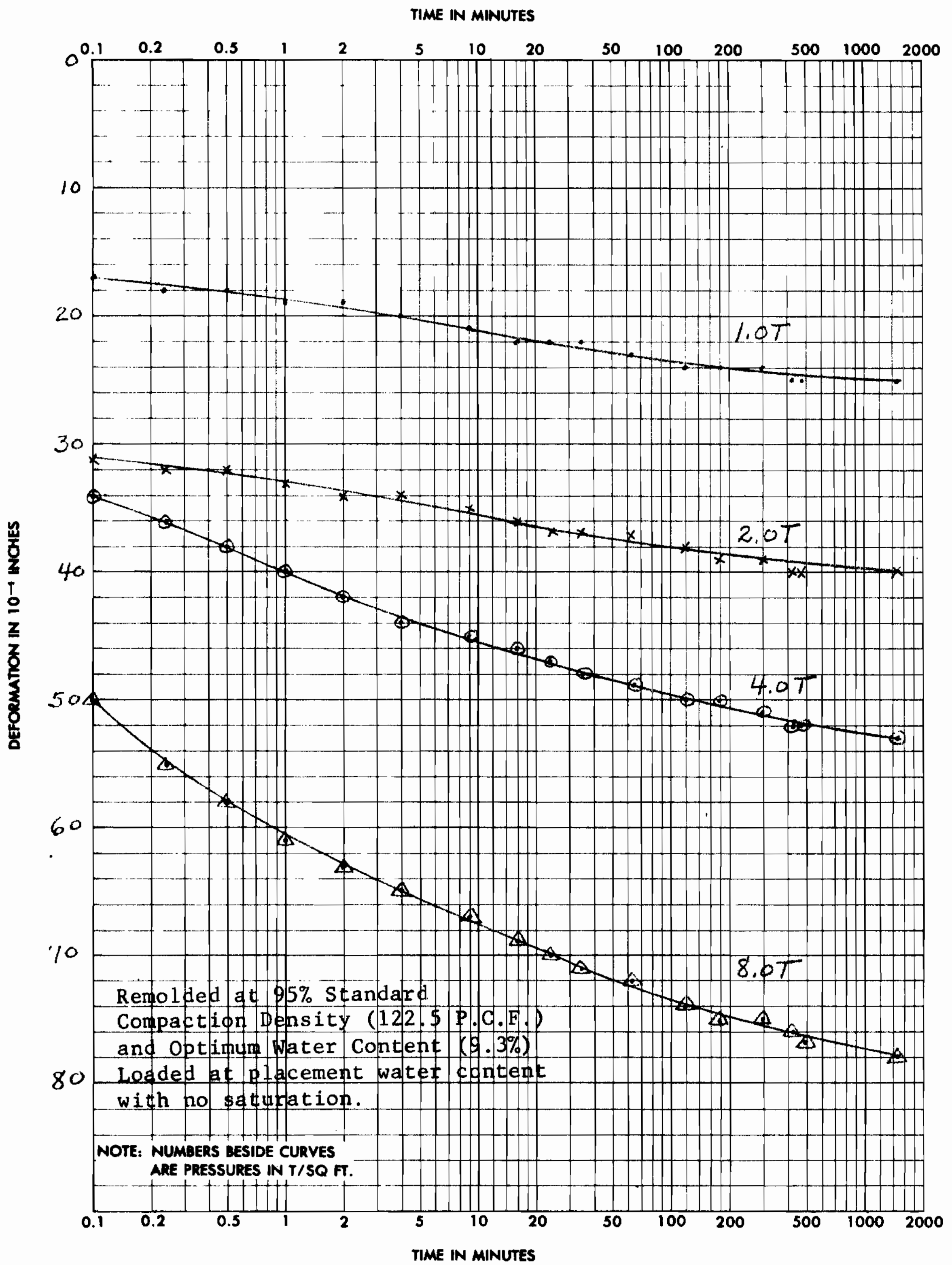
Chart D-17



Type of Specimen	Remold	Before Test		After Test	
Diam 4.445 in.	Ht 1.005 in.	Water Content, w_o	9.3 %	w_f	9.2 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	0.366	e_f	0.313
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	68 %	S_f	79 %
Compression Index, C_c 0.06		Dry Density, γ_d	122.5 lb/ft^3		127.4
Classification Si. SAND (SM)		k_{20} at e_o = × 10^{-} cm/sec			
LL	G_s 2.68	Project WATANA DAM			
PL	D_{10}				
Remarks Remolded at 95% Standard		Area			
Compaction Density (122.5 P.C.F.)		Boring No.		Sample No. Composite No.1	
and Optimum Water Content (9.3%)		Depth El		Date 14 NOV 1978	
Loaded at placement water content with no saturation		NPD **CONSOLIDATION TEST REPORT**			

ENG FORM 2090 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) 3424

Chart D-18

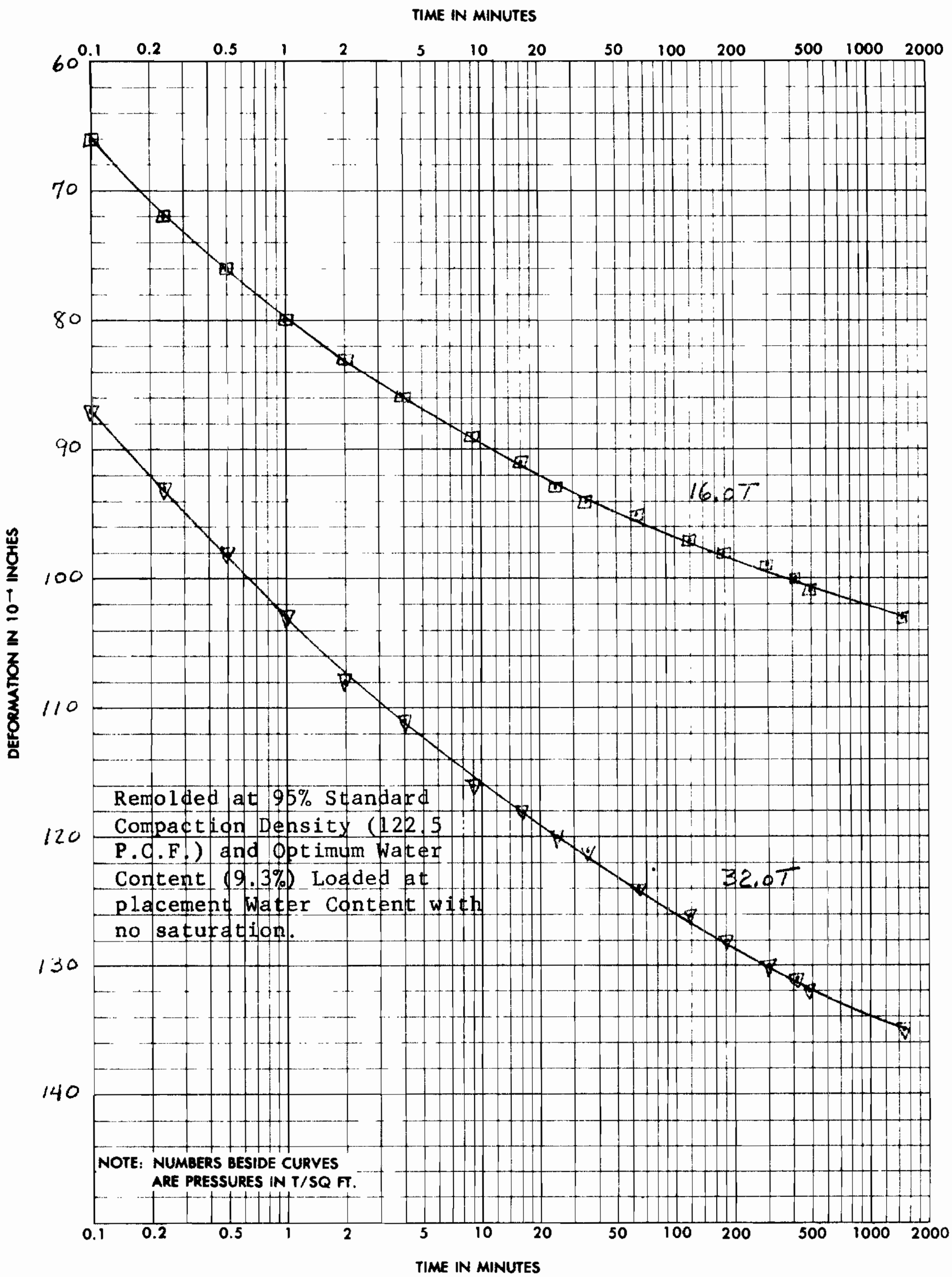


PROJECT WATANA DAM			
AREA			
BORING NO.	SAMPLE NO. Composite No.1	DEPTH EL	DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—715-965

Chart D-19



PROJECT WATANA DAM

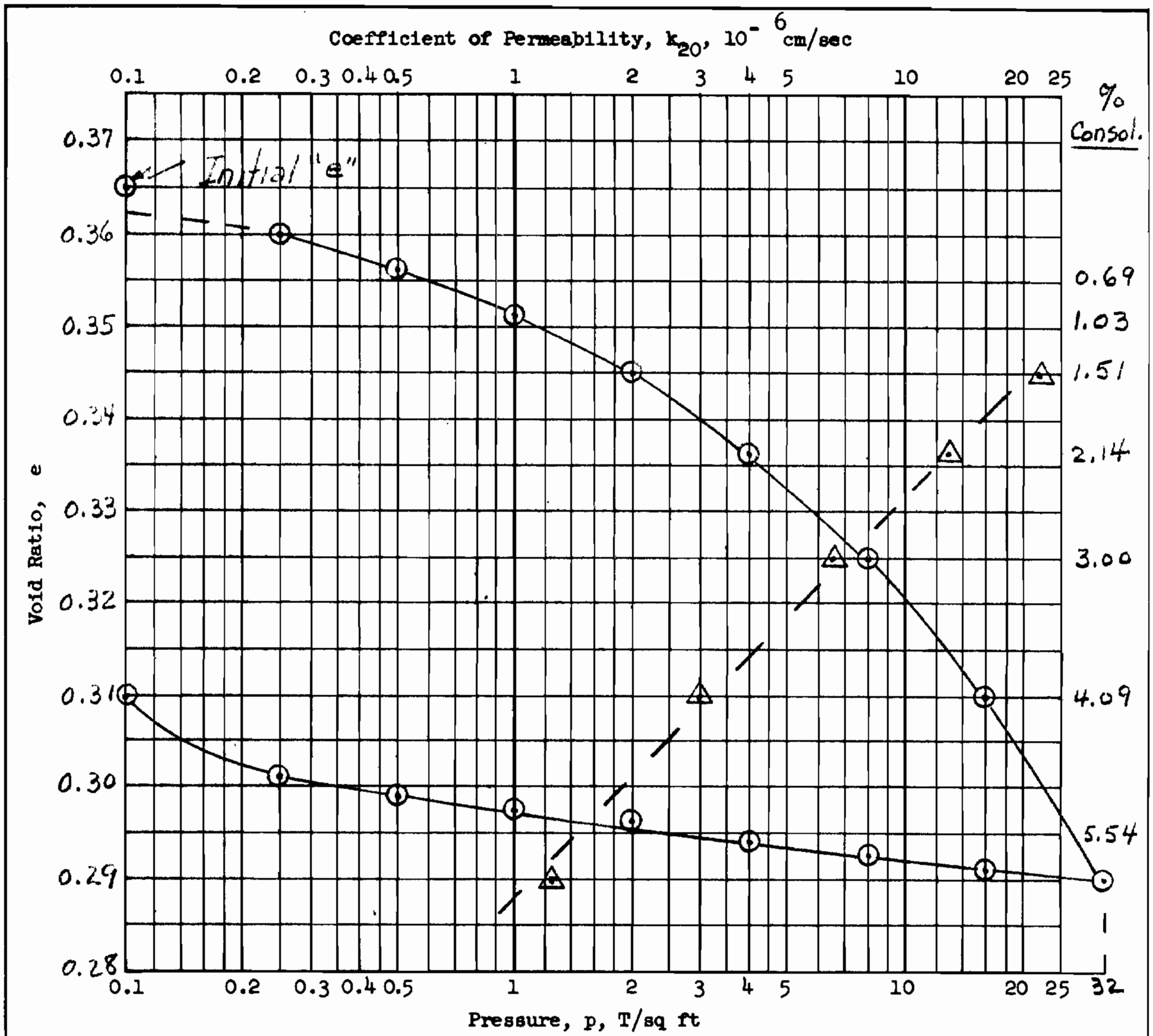
AREA

BORING NO. | SAMPLE NO. Composite No.1 | DEPTH EL | DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—715-965

Chart D-20

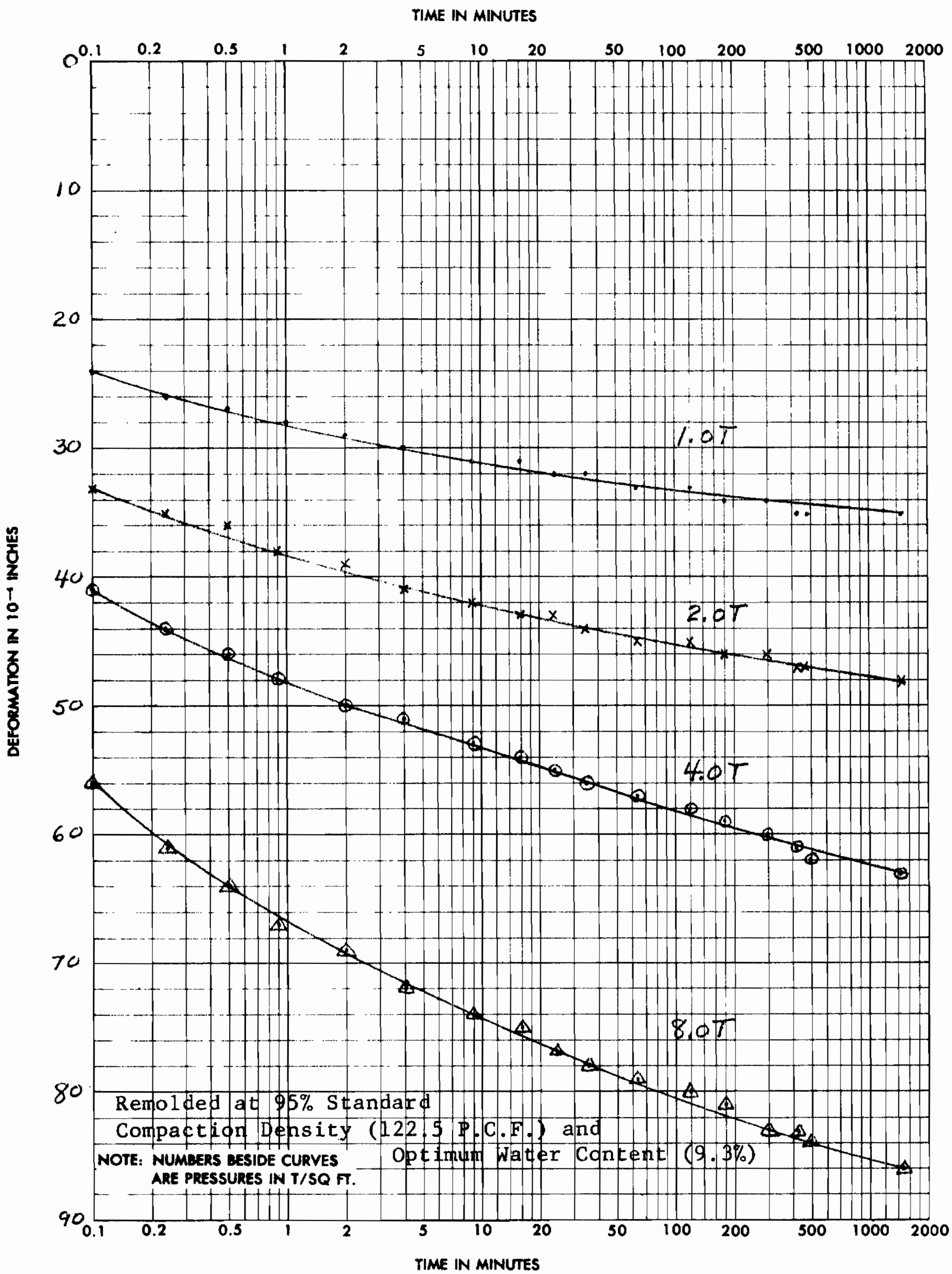


Type of Specimen Remold		Before Test			After Test	
Diam 4.444 in.	Ht 1.005 in.	Water Content, w_o	9.3 %		w_f	11.8 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	0.365		e_f	0.310
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	68 %		S_f	100 %
Compression Index, C_c 0.06		Dry Density, γ_d	122.5 lb/ft^3			127.6
Classification Si. SAND (SM)		k_{20} at e_o = × 10^{-} cm/sec				
LL	G_s 2.68	Project WATANA DAM				
PL	D_{10}					
Remarks Remolded at 95%		Area				
Standard Compaction Density		Boring No.		Sample No. Composite No.1		
(122.5 P.C.F.) and Optimum		Depth El		Date 14 NOV 1978		
Water Content (9.3%)		NPD **CONSOLIDATION TEST REPORT**				

ENG FORM 1 MAY 63 2090 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

Chart D-21

SHEET NO. 1

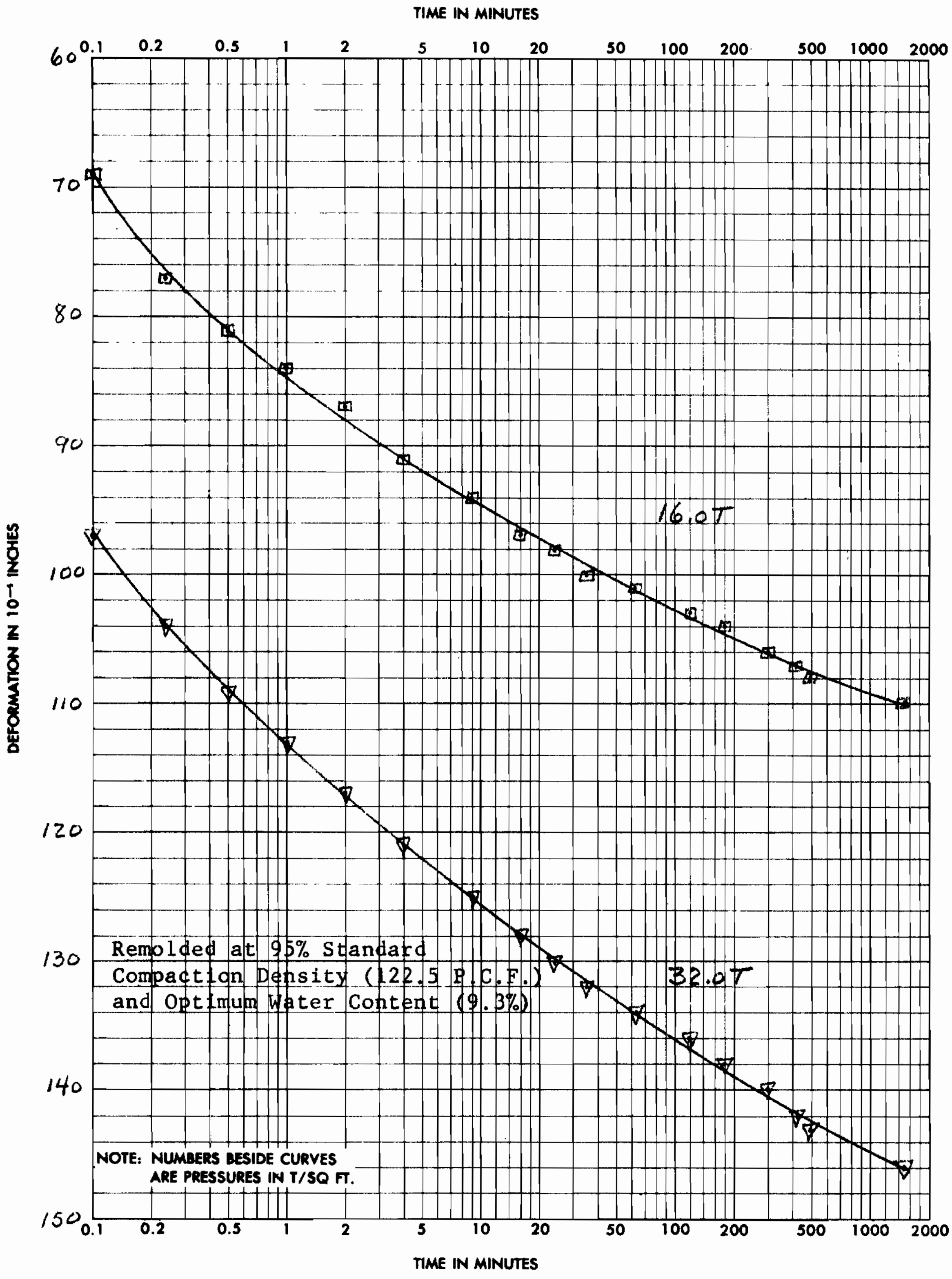


PROJECT WATANA DAM			
AREA			
BORING NO.	SAMPLE NO. Composite No.1	DEPTH EL	DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—715-965

Chart D-22



PROJECT WATANA DAM

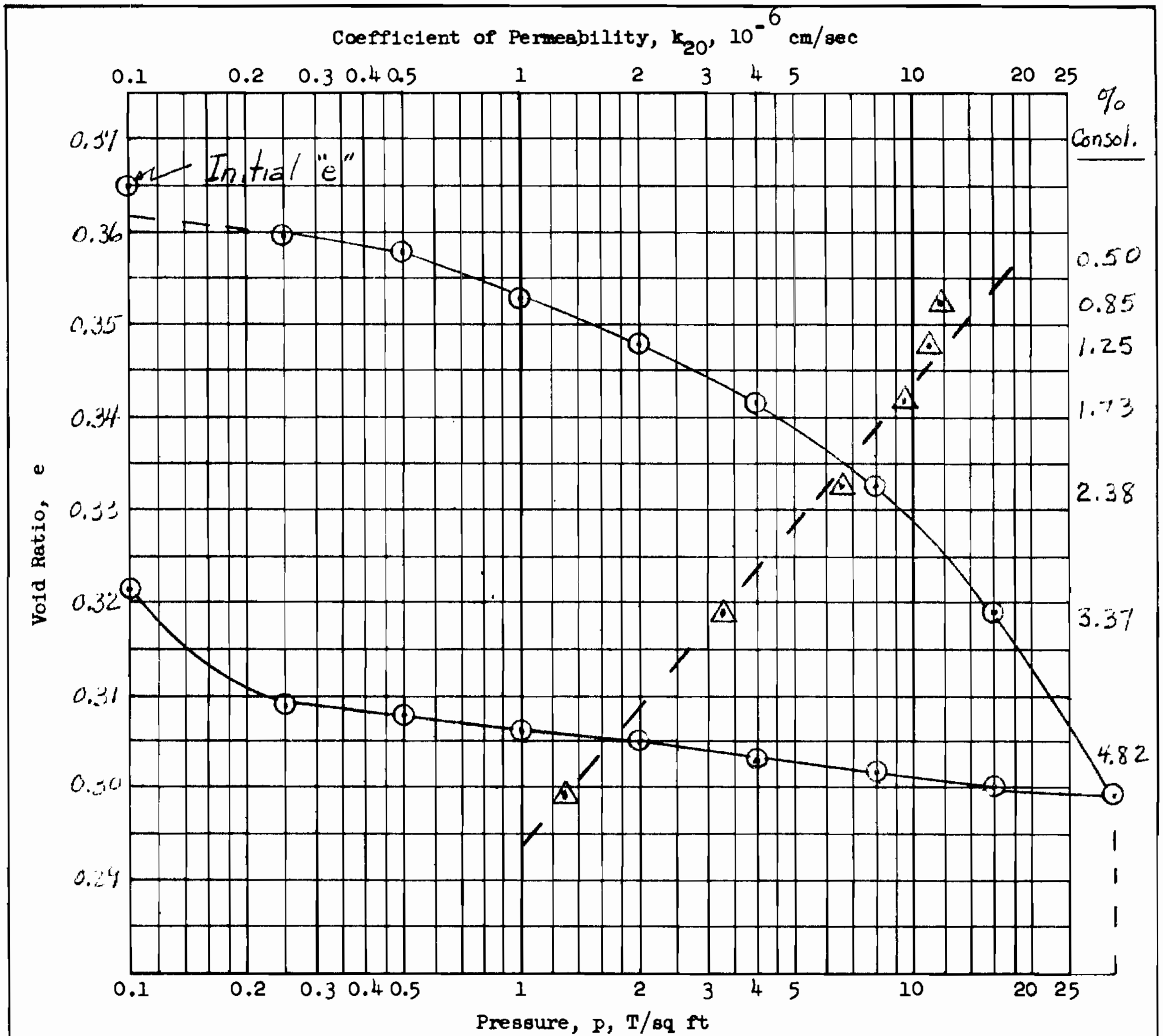
AREA

BORING NO. | SAMPLE NO. Composite No. 1 | DEPTH EL | DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

* GPO : 1964 OF—715-965

Chart D-23



Type of Specimen Remold		Before Test		After Test
Diam 4.445 in.	Ht 1.006 in.	Water Content, w_o	5.3 %	w_f 12.0 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	0.365	e_f 0.321
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	39 %	S_f 100 %
Compression Index, C_c 0.10		Dry Density, γ_d	122.5 lb/ft^3	126.6
Classification Si. SAND (SM)		k_{20} at e_o = × 10^- cm/sec		
LL	G_s 2.68	Project WATANA DAM		
PL	D_{10}			

Remarks Remolded at 95% Standard Compaction Density (122.5 P.C.F.) and Optimum Water Content minus 4% (5.3%)

Area

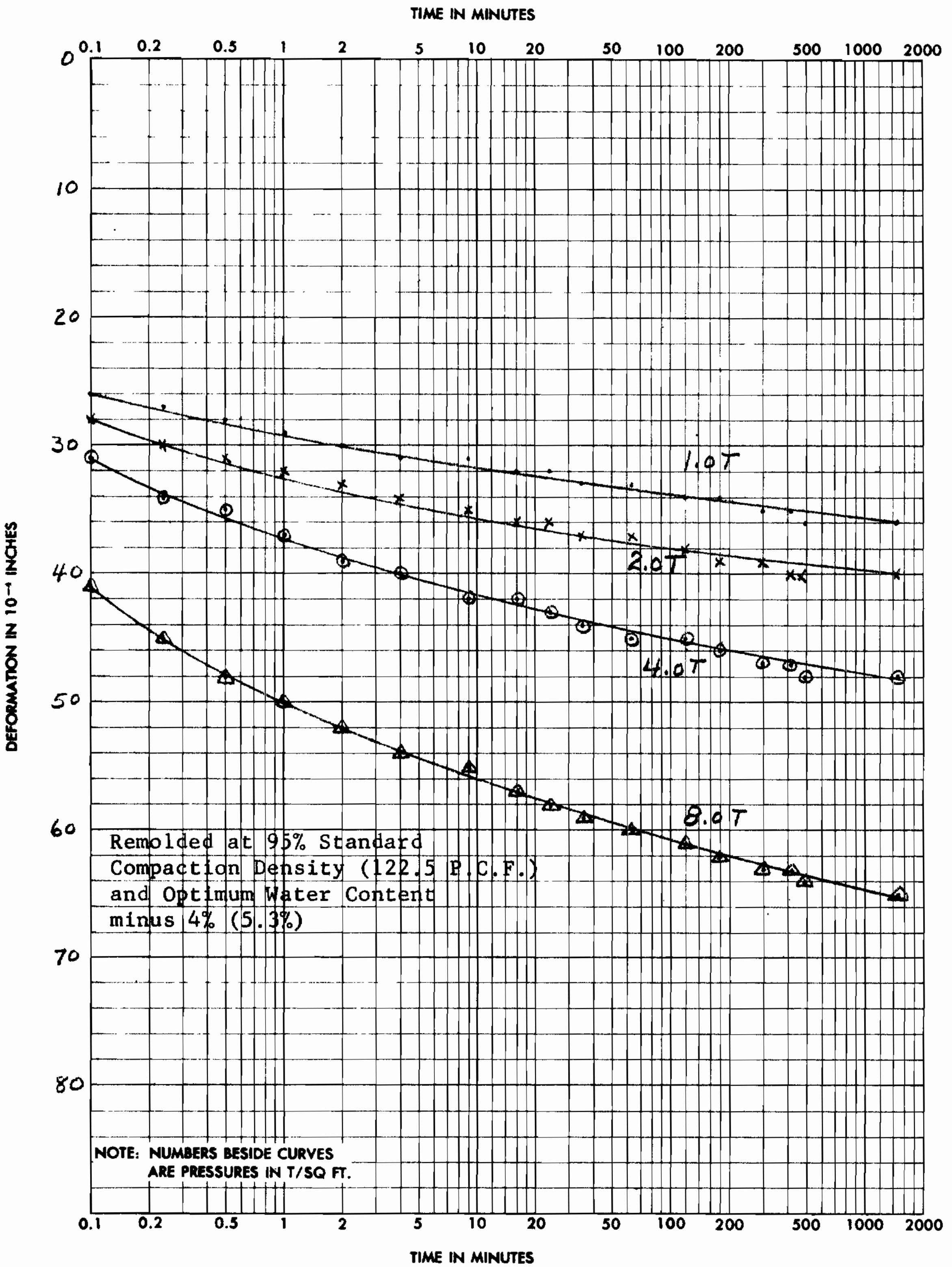
Boring No. — Sample No. Composite No.1

Depth El — Date 14 NOV 1978

NPI CONSOLIDATION TEST REPORT

ENG FORM 1 MAY 63 2090 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) n 3424

Chart D-24



PROJECT WATANA DAM

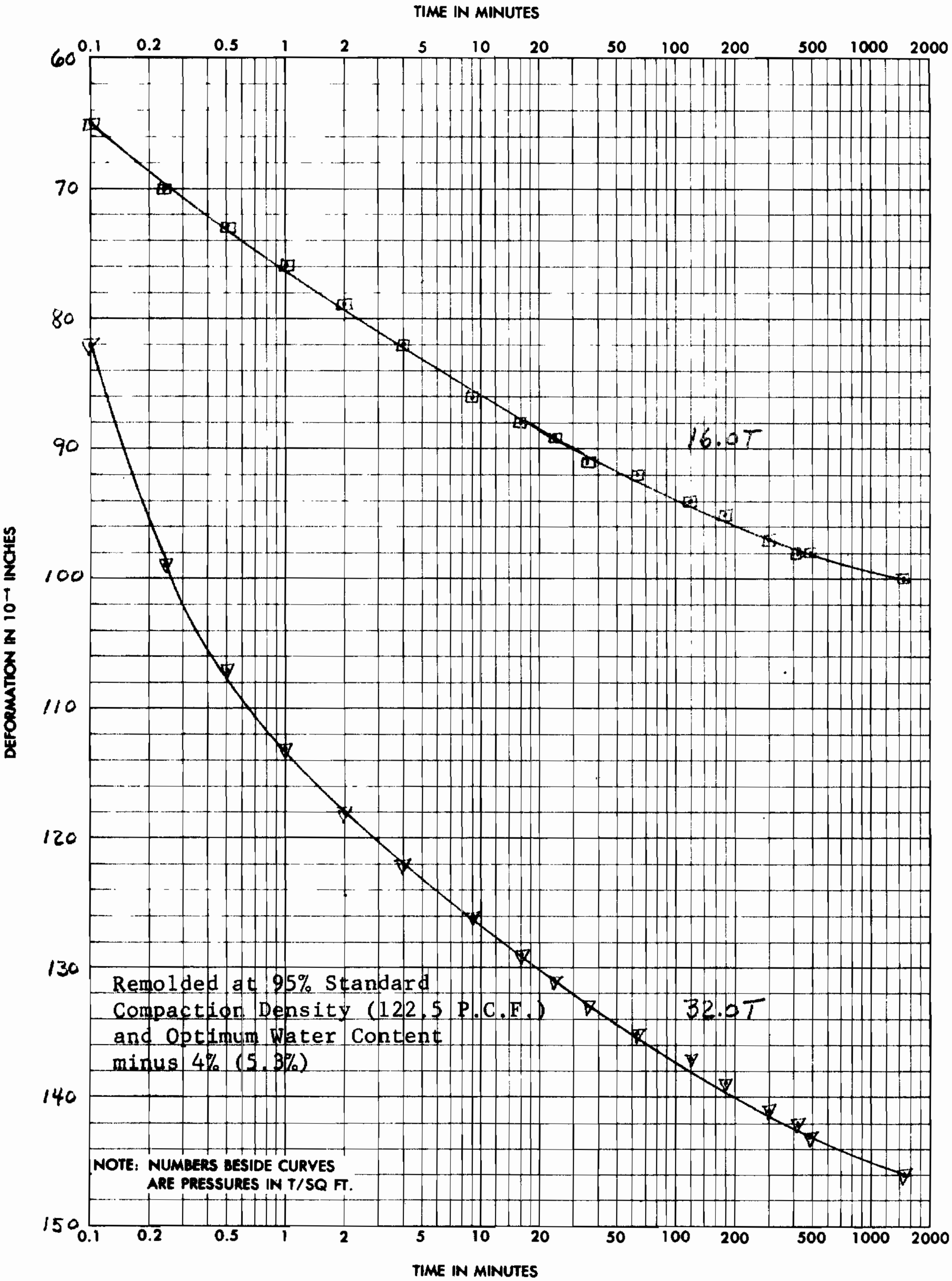
AREA

BORING NO. | SAMPLE NO. Composite No. 1 | DEPTH EL | DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—715-965

Chart D-25



PROJECT WATANA DAM

AREA

BORING NO.

SAMPLE NO. Composite No. 1

DEPTH

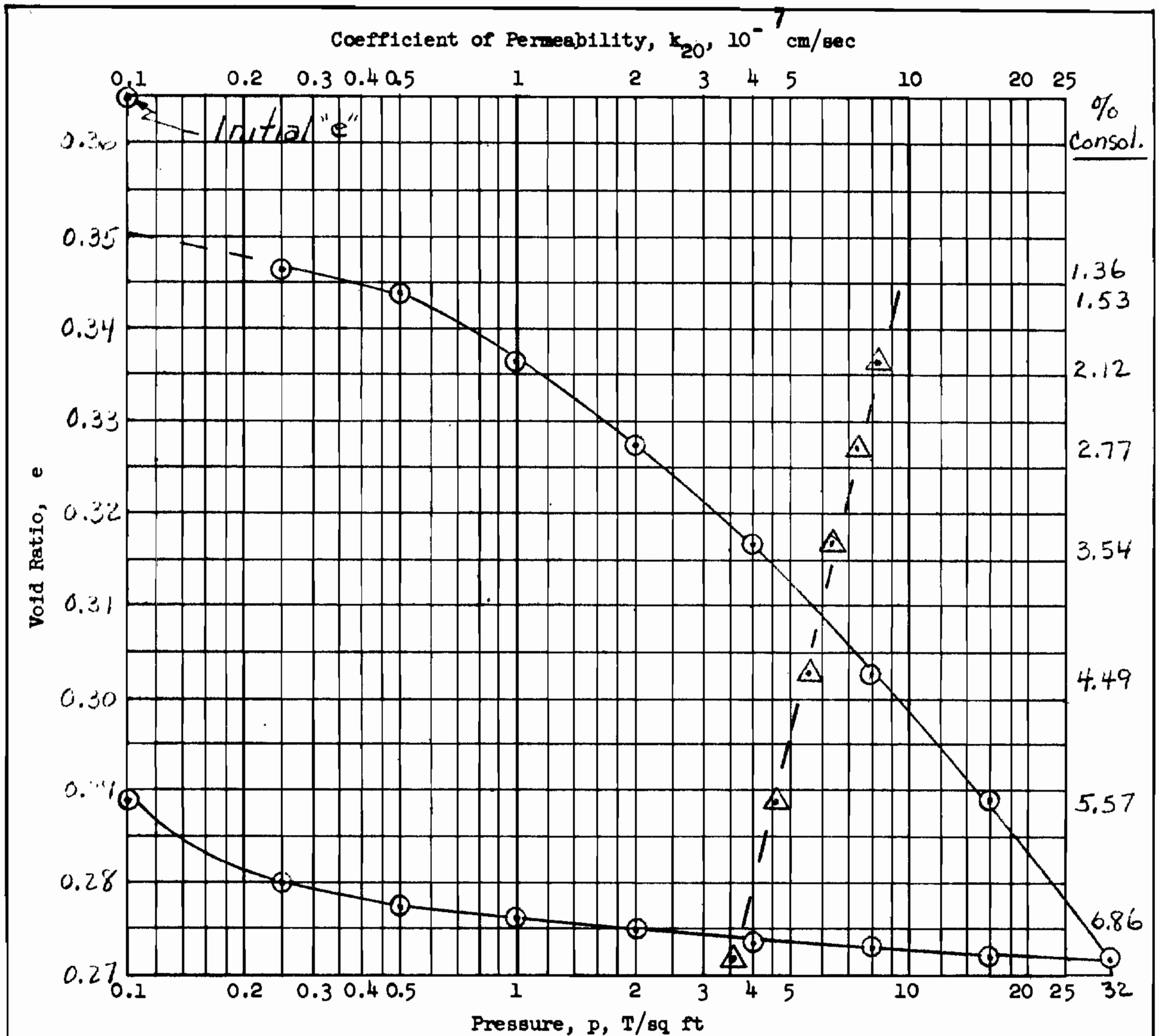
EL

DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—715-965

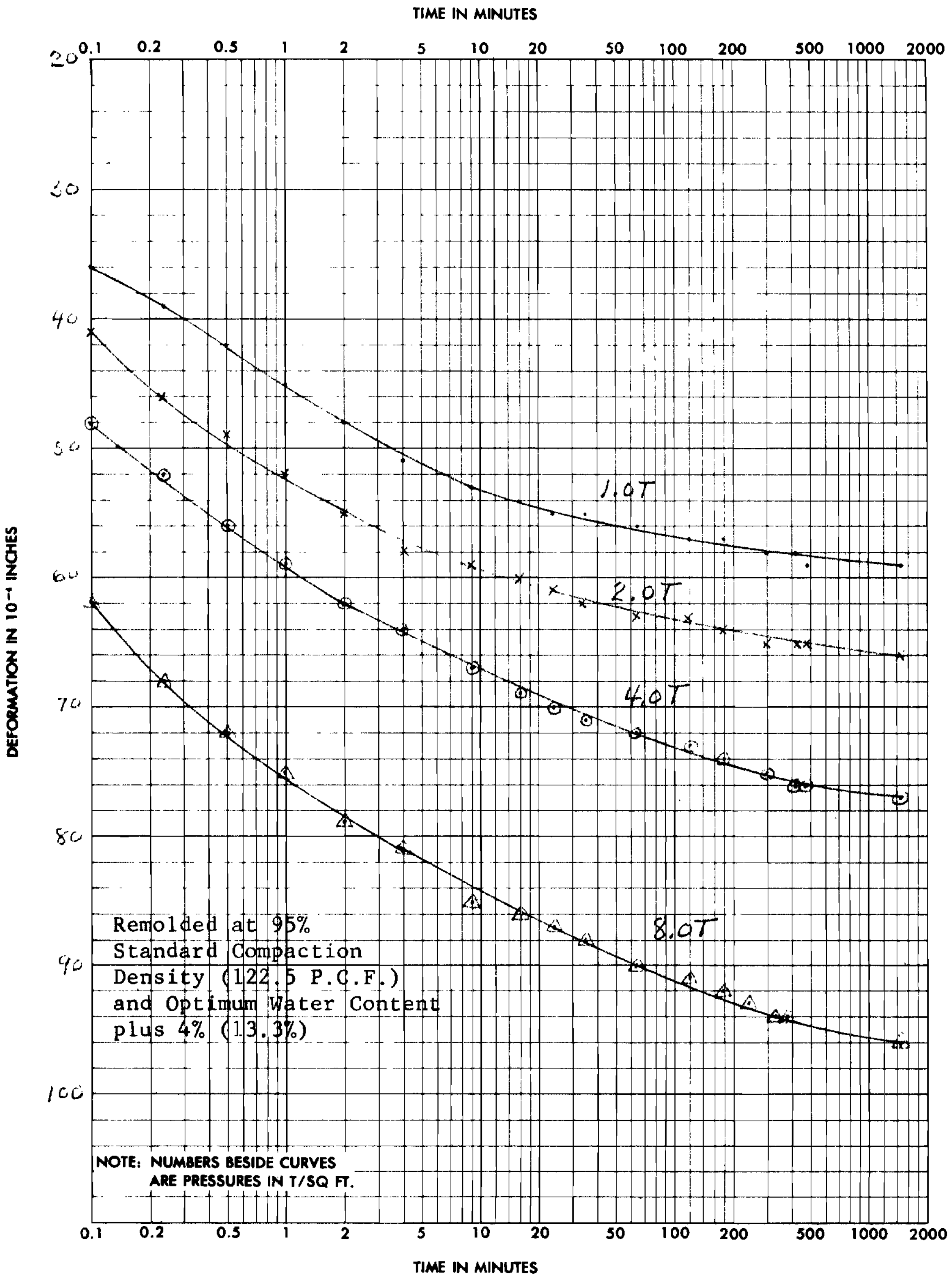
Chart D-26



Type of Specimen Remold		Before Test			After Test	
Diam 4.445 in.	Ht 1.006 in.	Water Content, w_o	13.3 %	w_f	10.9 %	
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	0.365	e_f	0.289	
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	98 %	S_f	100 %	
Compression Index, C_c 0.06		Dry Density, γ_d	122.5 lb/ft³		129.8	
Classification Si. SAND (SM)		k_{20} at e_o = × 10^{-} cm/sec				
LL	G_s 2.68	Project WATANA DAM				
PL	D_{10}					
Remarks Remolded at 95% Standard		Area				
Compaction Density (122.5 P.C.F.)		Boring No.		Sample No. Composite No.1		
and Optimum Water Content plus		Depth El		Date 14 NOV 1978		
4% (13.3%)		NPD CONSOLIDATION TEST REPORT				

ENG FORM 1 MAY 63 2090 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

G 3424
Chart D-27

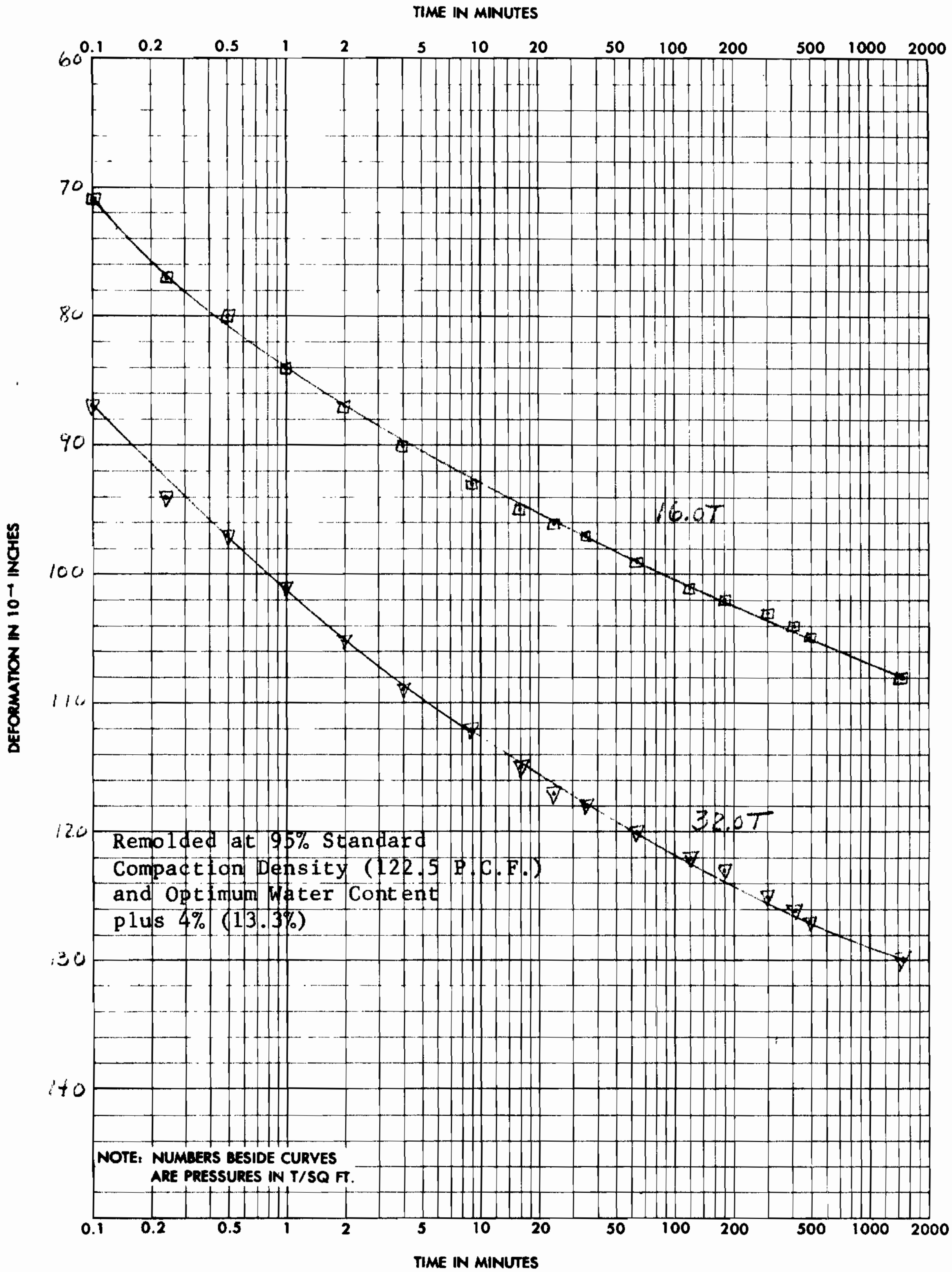


PROJECT WATANA DAM			
AREA			
BORING NO.	SAMPLE NO. Compsosite No.1	DEPTH EL	DATE 14 NOV 1978

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. NPD CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)

★ GPO : 1964 OF—715-965

Chart D-28



PROJECT WATANA DAM

AREA

BORING NO. | SAMPLE NO. Composite No.1 | DEPTH EL | DATE 14 NOV 1978

ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE. NPD **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—715-965

Chart D-29

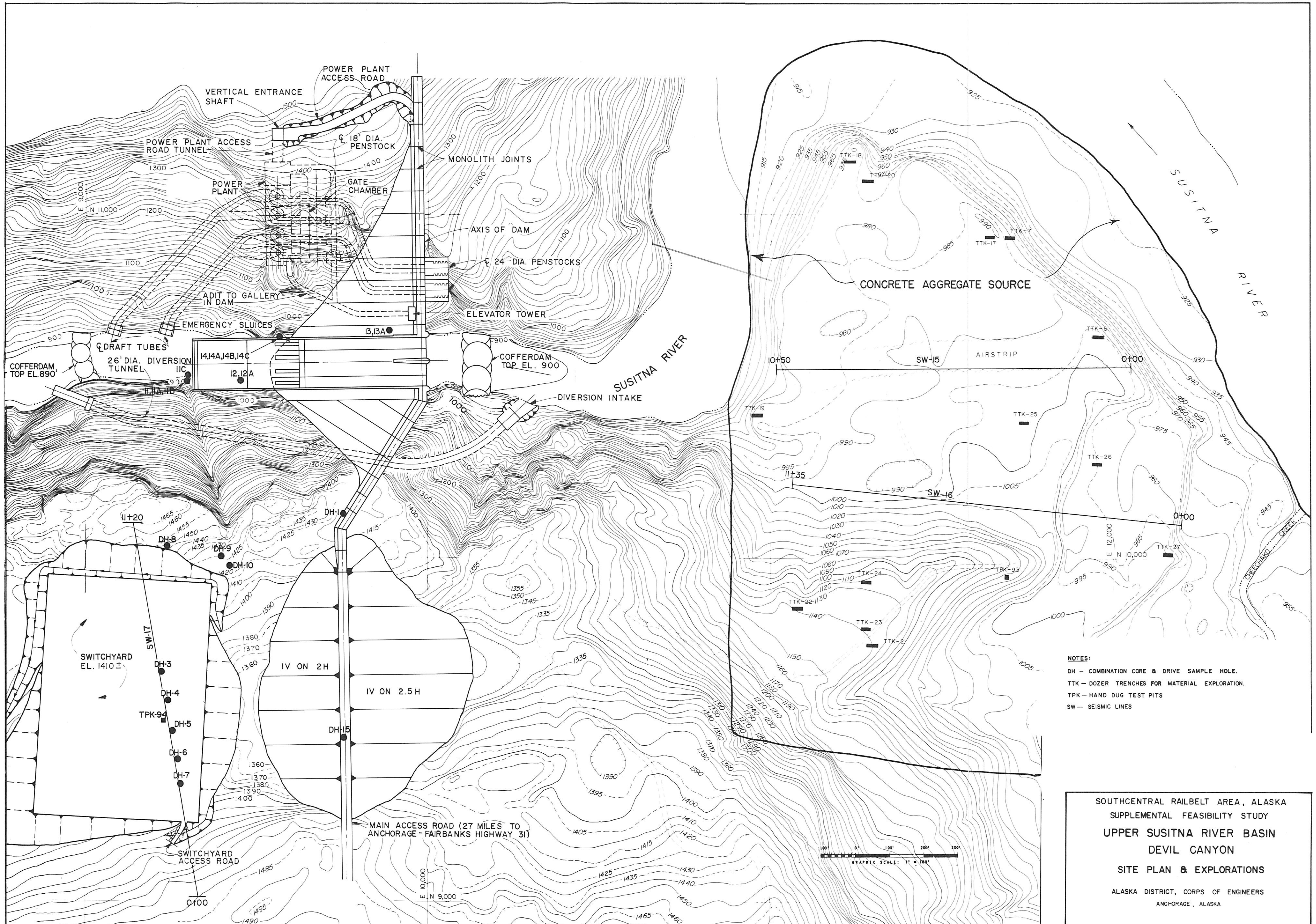
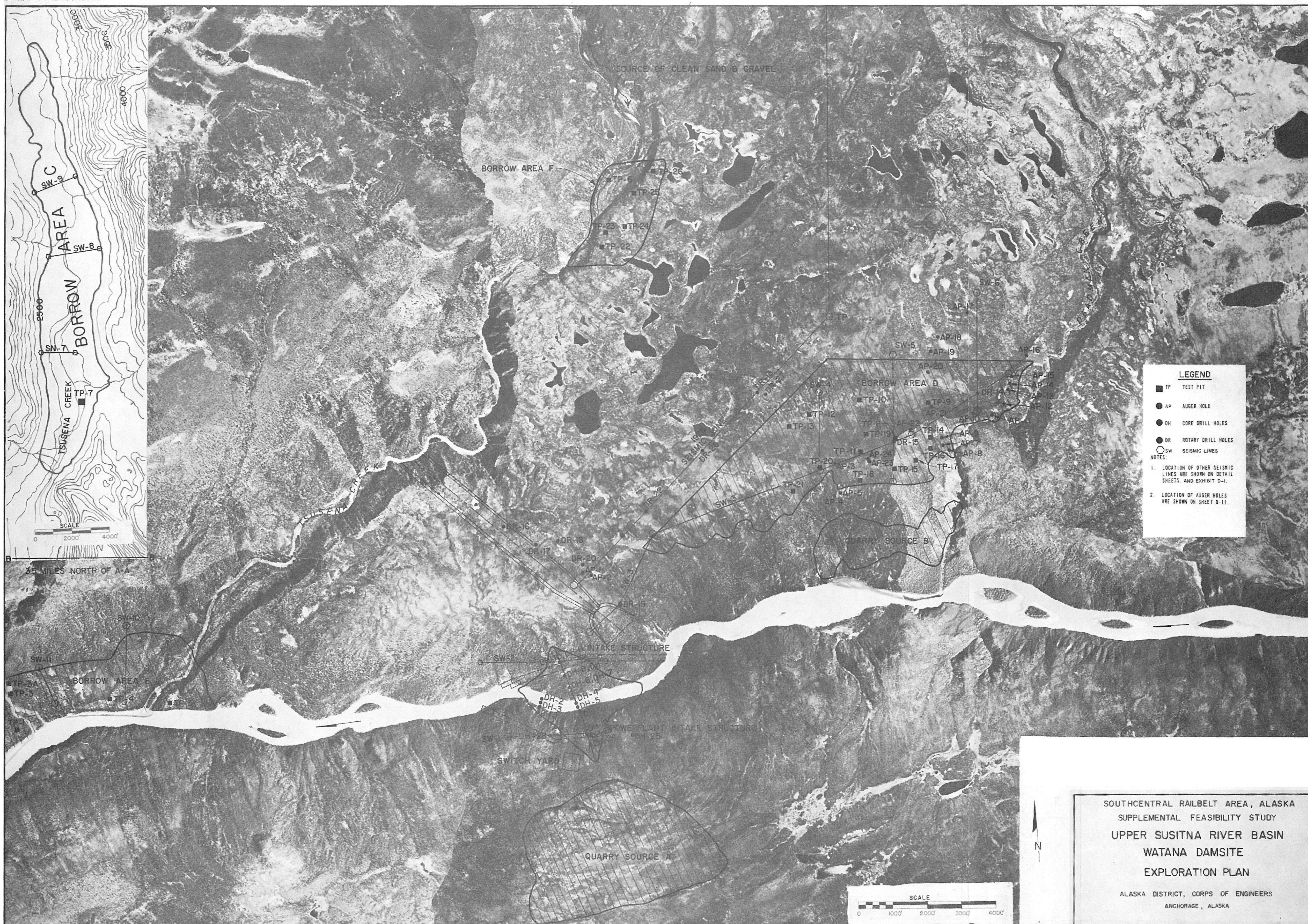
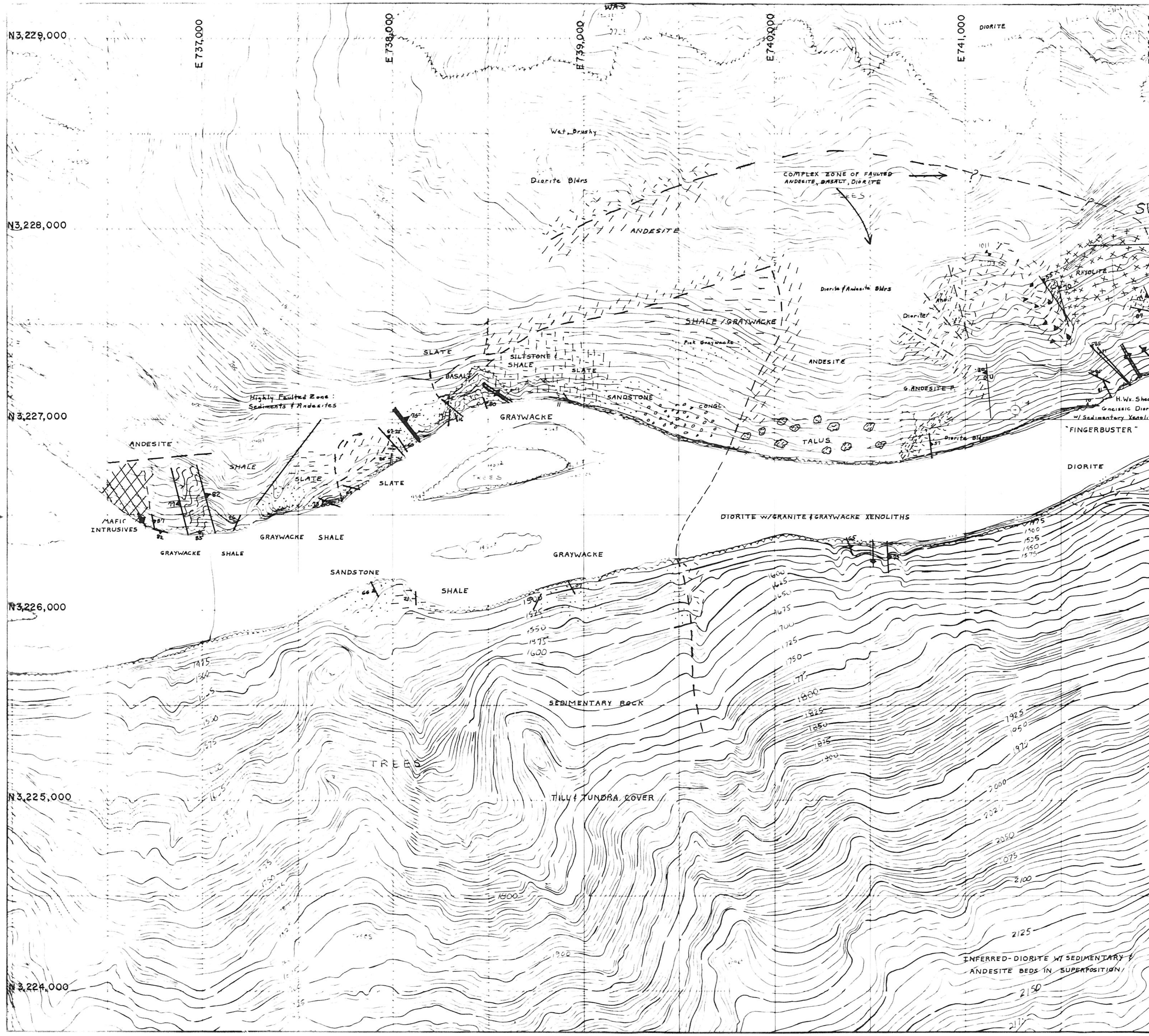

POWER PLANT ACCESS ROAD
VERTICAL ENTRANCE SHAFT
POWER PLANT ACCESS ROAD TUNNEL
℄ 18' DIA. PENSTOCK
MONOLITH JOINTS
POWER PLANT
GATE CHAMBER
AXIS OF DAM
℄ 24' DIA. PENSTOCKS
ADIT TO GALLERY IN DAM
ELEVATOR TOWER
EMERGENCY SLUICES
℄ DRAFT TUBES
26' DIA. DIVERSION TUNNEL
COFFERDAM TOP EL. 890'
COFFERDAM TOP EL. 900
DIVERSION INTAKE
SUSITNA RIVER
CONCRETE AGGREGATE SOURCE
AIRSTRIP
SW-15
SW-16
SW-17
SWITCHYARD EL. 1410±
SWITCHYARD ACCESS ROAD
IV ON 2H
IV ON 2.5 H
MAIN ACCESS ROAD (27 MILES TO ANCHORAGE - FAIRBANKS HIGHWAY 31)
CHEECHAKO CREEK
NOTES:
DH – COMBINATION CORE & DRIVE SAMPLE HOLE.
TTK – DOZER TRENCHES FOR MATERIAL EXPLORATION.
TPK – HAND DUG TEST PITS
SW – SEISMIC LINES
GRAPHIC SCALE: 1" = 100'
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
DEVIL CANYON
SITE PLAN & EXPLORATIONS
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

PLATE D-1


SOURCE OF CLEAN SAND & GRAVEL
BORROW AREA F
BORROW AREA D
BORROW AREA C
BORROW AREA E
TSUSENA CREEK
INTAKE STRUCTURE
SWITCH YARD
QUARRY SOURCE A
QUARRY SOURCE B
SCALE
0 2000' 4000'
SCALE
0 1000' 2000' 3000' 4000'
LEGEND
TP TEST PIT
AP AUGER HOLE
DH CORE DRILL HOLES
DR ROTARY DRILL HOLES
SW SEISMIC LINES
NOTES:
1. LOCATION OF OTHER SEISMIC LINES ARE SHOWN ON DETAIL SHEETS. AND EXHIBIT D-1.
2. LOCATION OF AUGER HOLES ARE SHOWN ON SHEET D-11.
N
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
EXPLORATION PLAN
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



LEGEND

- ACIDIC INTRUSIVES GRANITE, DIORITE
- ACIDIC EXTRUSIVES RHYOLITE, DACITE
- MAFIC INTRUSIVES GABBRO
- MAFIC EXTRUSIVES ANDESITE, BASALT
- PORPHORITIC ANDESITE, BASALT
- GRAVEL, CONGLOMERATE
- SAND, SANDSTONE
- SILT, SILTSTONE
- CLAY, SHALE
- BOULDERS (ROCK TYPE SHOWN)
- ROCK FRAGMENTS
- BRECCIA (USED W/ROCK TYPE)
- INTENSE SHEAR ZONE
- GEOLOGIC CONTACT. ON INFERRED - ?
- SIGNIFICANT WATER SEEPAGE
- EROSIONAL FEATURE INFERRED TO INDICATE A SHEAR ZONE
- BEDDING: WITH DIP (55), VERTICAL
- JOINT: WITH DIP (45), VERTICAL
- FAULT: WITH DIP (33), VERTICAL, INFERRED (17)
- DIKE: WITH DIP, ROCK TYPE PER SYMBOL (45)
- QUARTZ VEINS, WITH DIP (42)
- DH-25 DRILL HOLE
- 1401 SURVEY POINT
- WA-5 AIR PHOTO CONTROL POINT

ABBREVIATIONS

ALT	ALTERED	G	GREEN
B	BLACK	GR	GRANITE
BIO	BIOTITE	H	HIGHLY
BLDR	BOULDER	QTZ	QUARTZ
BR	BROWN	R	RED
CL	CLAY	S	SAND
DIOR	DIORITE	SS	SANDSTONE
FRAC	FRACTURED	WX	WEATHERED

NOTES:

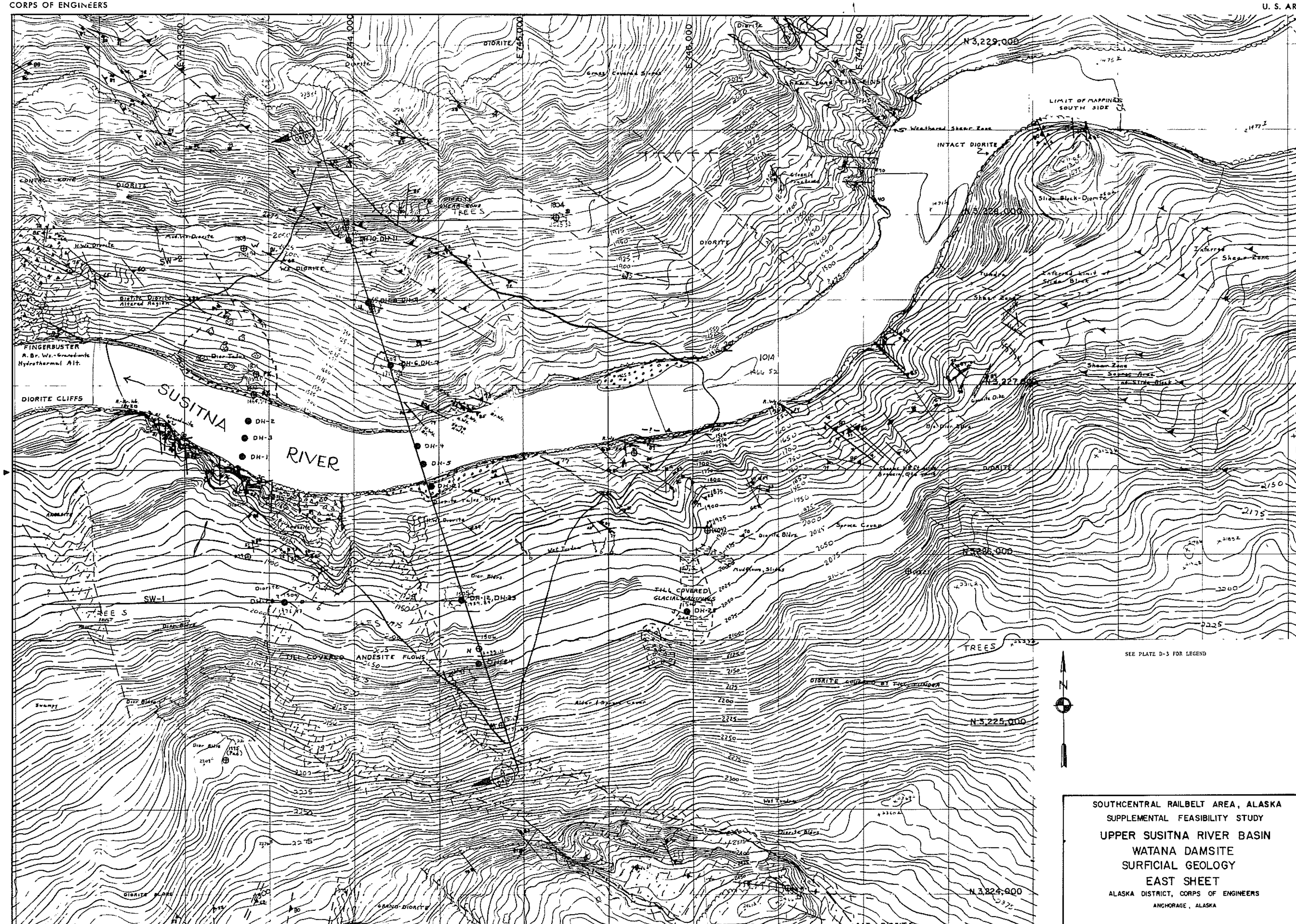
1. DIORITE HAS INTRUDED AND UPLIFTED SEDIMENTS AND ANDESITES. ANDESITES ARE INFERRED TO BE A PRE-PLUTONIC INTERCANYON FLOW UPLIFTED AND ALTERED BY DIORITE EMPLACEMENT.
2. GLACIAL CLAY AND ALLUVIUM APPEAR TO FILL PREEXISTING EROSIONAL CHANNELS IN UPPER CANYON WALLS.

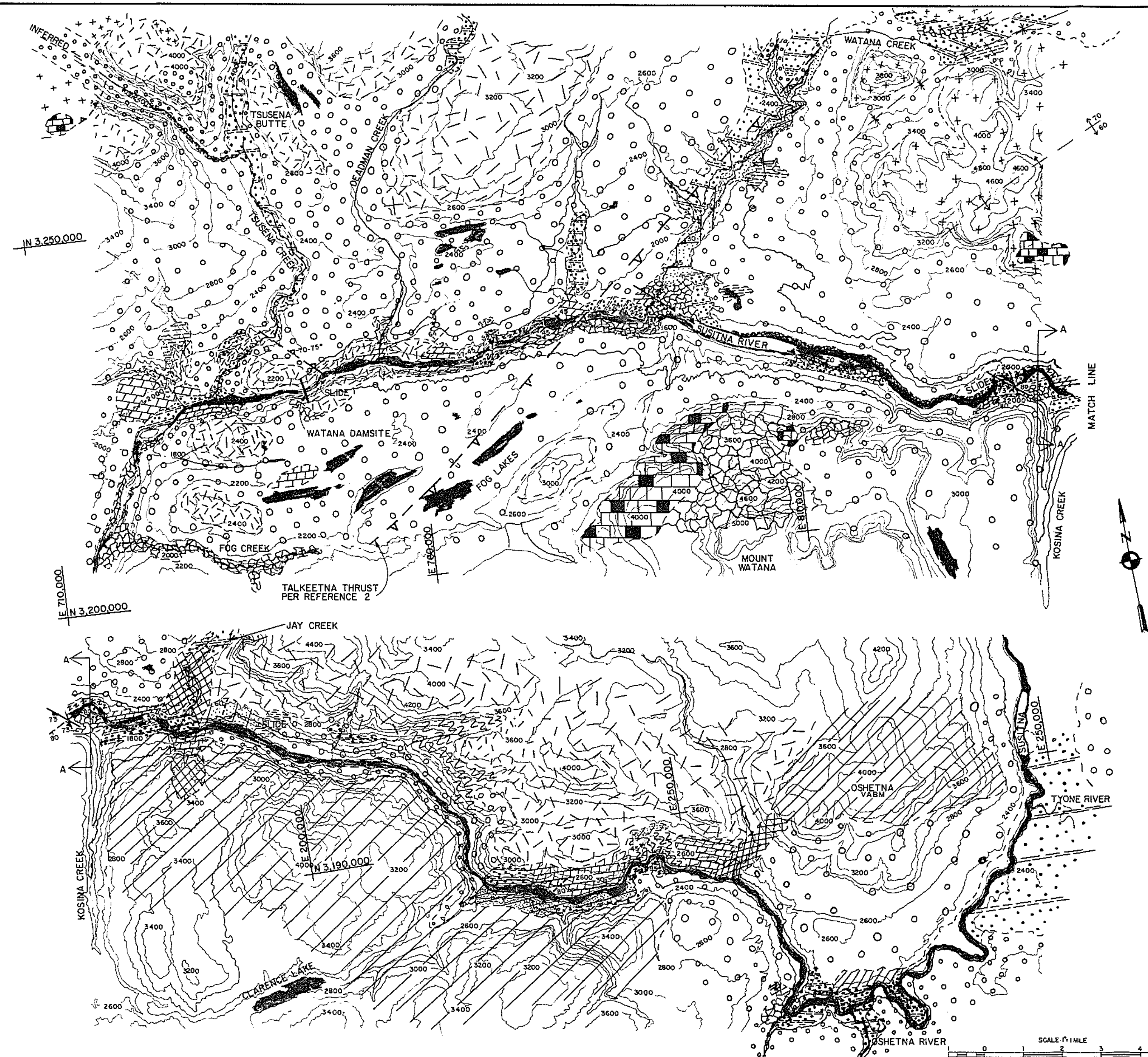
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
SURFICIAL GEOLOGY
WEST SHEET

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

PLATE D-3


SUSITNA RIVER
DIORITE
DIORITE CLIFFS
FINGERBUSTER
CONTACT ZONE
TILL COVERED ANDESITE FLOWS
TILL COVERED GLACIAL MARKINGS
LIMIT OF MAPPING SOUTH SIDE
INTACT DIORITE
Weathered Shear Zone
Inferred Shear Zone
Slide Block-Diorite
Grass Covered Slopes
Wet Tundra
Spruce Cover
Alder & Spruce Cover
DIORITE COVERED BY TILL, TUNDRA
Diorite Talus Slope
Mudflows, Slides
TREES
SWAMPY
ANDESITE
ALT. DIORITE
GRANO-DIORITE
DIORITE BLDRS
SW-1
SW-2
DH-1
DH-2
DH-3
DH-4
DH-5
DH-21
DH-23
DH-24
DH-25
E 743,000
E 744,000
E 745,000
E 746,000
E 747,000
N 3,229,000
N 3,228,000
N 3,227,000
N 3,226,000
N 3,225,000
N 3,224,000
SEE PLATE D-3 FOR LEGEND
N
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
SURFICIAL GEOLOGY
EAST SHEET
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



NOTES:

1. THIS SURFICIAL GEOLOGY MAP REPRESENTS GROSS LITHOLOGY AND STRUCTURE BASED ON LIMITED OUTCROP MAPPING. UNIT BOUNDARIES ARE APPROXIMATE.
2. LIMITS OF MAPPED UNITS CONFORMS WITH REFERENCE 2, EXCEPT AS MORE CLEARLY DEFINED BY CORPS OF ENGINEERS GEOLOGISTS. EXTENSIONS OF UNITS BEYOND 3 MILES FROM RESERVOIR BOUNDARY WERE BASICALLY DRAWN FROM REFERENCE 2.
3. BASE MAP (REFERENCE 1) IS NOT DUPLICATED IN FULL DETAIL. MAJOR BODIES OF WATER ARE SHOWN. ISLANDS, SMALL STREAMS AND MINOR TOPOGRAPHIC FEATURES HAVE BEEN DELETED.
4. 2200 FOOT CONTOUR HAS BEEN ACCENTED AS APPROXIMATE LIMIT OF RESERVOIR EFFECT.
5. NO PERMAFROST OR INTERMITTENT FROST ACTION AREAS ARE SHOWN.
6. SLIDES ARE AS INDICATED BY SURFACE EXPRESSIONS. MINOR AND INCIPIENT SLIDE AREAS AND AREAS SUSCEPTIBLE TO MASS MOVEMENT UNDER RESERVOIR INFLUENCE HAVE NOT BEEN SHOWN.
7. MANY AREAS SHOWN AS GLACIAL TILL COVERED HAVE MINOR OUTCROPS THAT WERE NOT DETECTED IN MAPPING. DETAILED MAPPING IS REQUIRED TO DEFINE CONTACTS, ZONES OF DISTURBANCE, AND TILL-COVERED AREAS.

TOPOGRAPHIC SYMBOLS

WATER - LAKE, STREAM OR RIVER

N 3,200,000 REFERENCE MARKS

2200 200' CONTOUR INTERVALS IN FEET ABOVE MEAN SEA LEVEL (REF. 1)

STRUCTURAL SYMBOLS

CONTACT SURFACE EXPRESSION

(1) 30 ; (2) SHEAR OR FAULT, WITH DIP (1); VERTICAL (2)

42 APPROXIMATE LOCATION OF FAULT OR SHEAR (ARROW DOWN DIP OF SHEAR PLANE)

31 (1) ; (2) BEDS - SEDIMENTARY OR FLOW STRUCTURE; WITH DIP (1); VERTICAL (2)

40 BEDS - APPROXIMATE DIP

SYNCLINE, SHOWING AXIS (APPROXIMATE LOCATION)

ANTICLINE, SHOWING CREST (APPROXIMATE LOCATION)

(1) 45 ; (2) FLOW FOLIATION, SCHISTOSITY: INCLINE (1); VERTICAL (2)

(1) 50 ; (2) JOINTS; INCLINED (1): VERTICAL DIPS (2)

LITHOLOGIC SYMBOLS

GLACIAL TILL

UNCONSOLIDATED CLASTIC ALLUVIAL DEPOSITS

UNCONSOLIDATED FINE ALLUVIAL DEPOSITS - CLAY, SILT, VARVED CLAYS

CONSOLIDATED BEDDED SEDIMENTARY DEPOSITS - ALL CLASTIC TYPES

LIMESTONE AND MARBLE

ALL TYPES ARGILLACEOUS ROCK INCLUDING METAMORPHIC FORMS THROUGH PHYLLITE

SCHIST INCLUDING LIT-PAR-LIT SCHIST, GREEN SCHIST AND CONTACT METAMORPHIC FORMS

AMPHIBOLITE, PYROXENITE, GABBROS, GNEISS, MAFIC INTRUSIVES AND HIGHGRADE METAMORPHICS

VOLCANIC FLOWS AND SILLS, ANDESITES AND BASALTS WITH INTERBEDS

HYPABYSSAL INTRUSIVES - DIABASE, DACITE, APLITE AND NEAR-SURFACE PORPHRY.

GRANITICS - GRANITES, MONZONITES, DIORITES.

ZONES OF VERY HIGH-GRADE ALTERATION AND METAMORPHISM TO INCLUDE SERITIZATION, SERPENTIZATION, SAUSSURITIZATION AND PRODUCTS OF CONTACT REMELTING.

REFERENCES

1. US GEOLOGICAL SURVEY 1:63,360 SERIES (TOPOGRAPHIC), TALKEETNA MOUNTAIN QUADRANGLE, SHEETS C1, C2, D3, D4.
2. "RECONNAISSANCE GEOLOGIC MAP AND GEOCHRONOLOGY, TALKEETNA MOUNTAINS QUADRANGLE, NORTHERN PART OF ANCHORAGE QUADRANGLE, AND SOUTHWEST CORNER OF HEALY QUADRANGLE, ALASKA." OPEN FILE REPORT 78-558A (PRELIMINARY), US GEOLOGICAL SURVEY, MENLO PARK, CALIFORNIA 1978. CSEJTEY, ET AL.

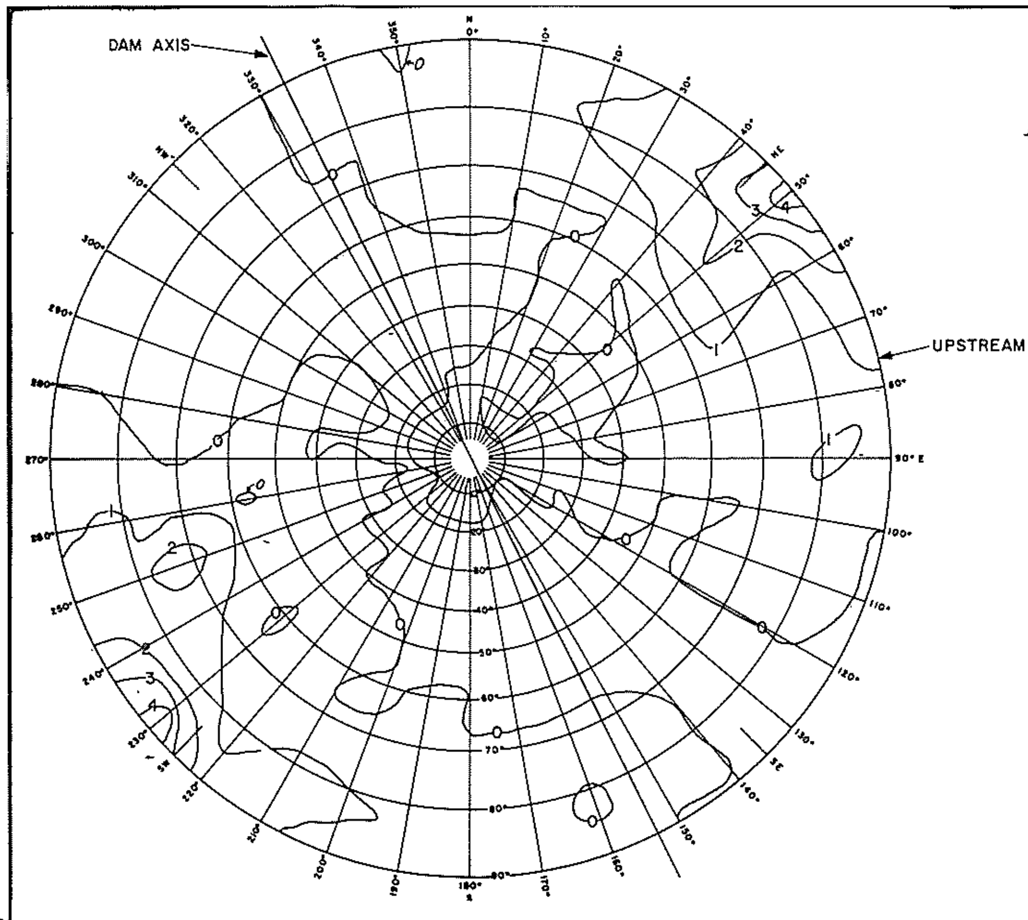
SOUTHCENTRAL RAILBELT AREA, ALASKA

SUPPLEMENTAL FEASIBILITY STUDY

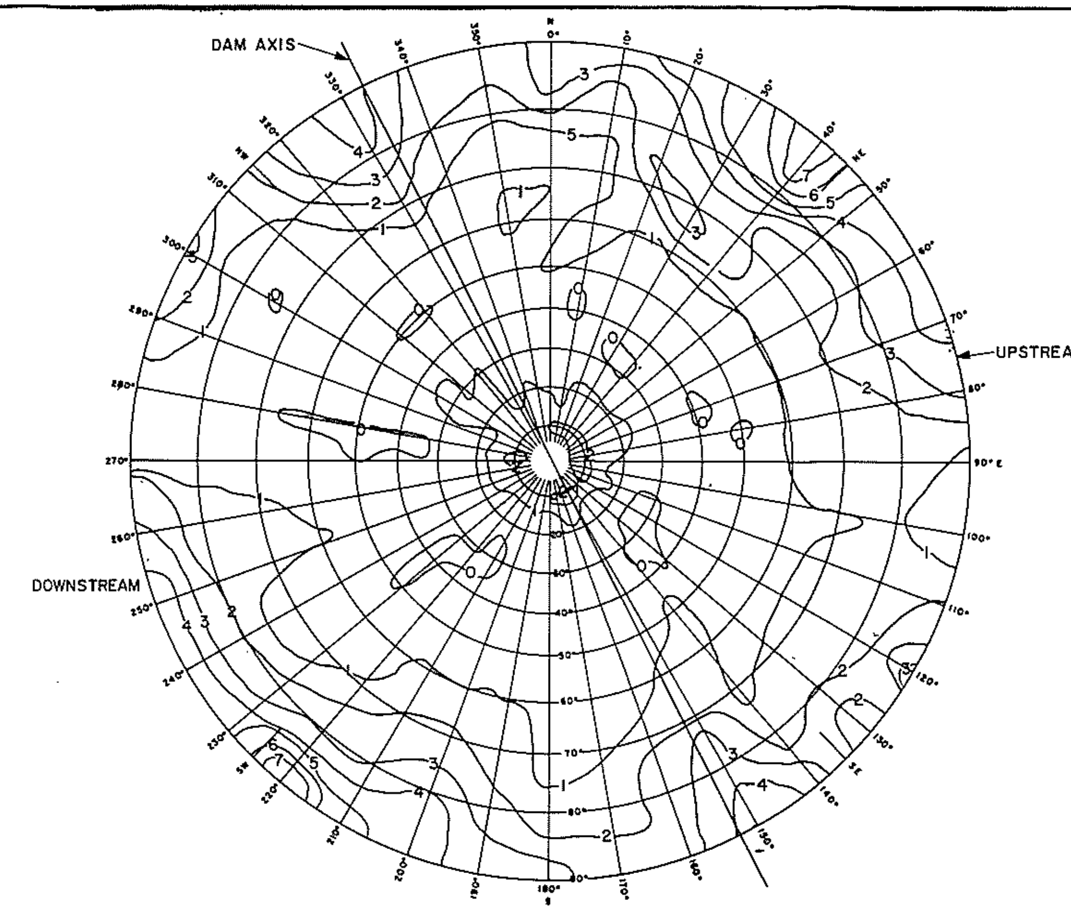
UPPER SUSITNA RIVER BASIN
WATANA RESERVOIR
SURFICIAL GEOLOGY

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

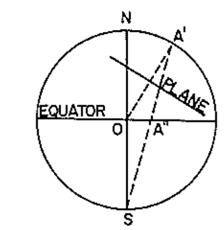


SHEARS
III POINTS



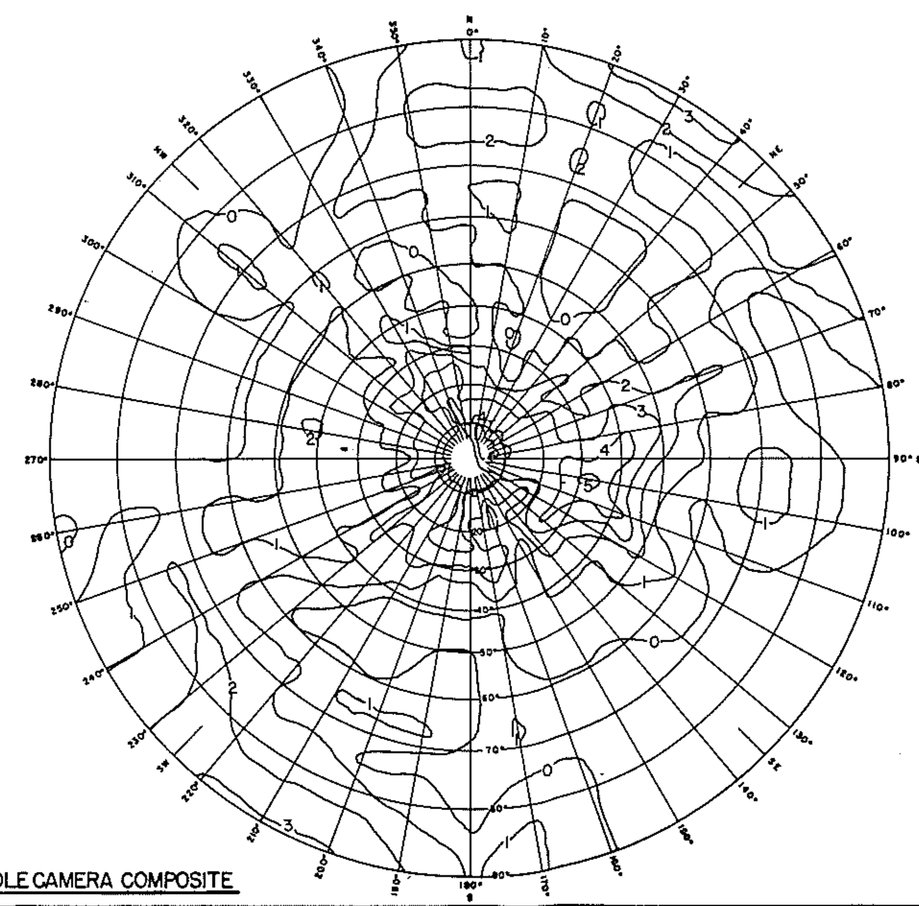
JOINTS
495 POINTS

MAJOR	N50W VERTICAL	(N40W-N65W, 80N-85S)
	N60E VERTICAL	(N45E-N70E, 75N-75S)
MINOR	N65W 70N	(N60W-N70W, 65N-75N)
	N30E VERTICAL	



NOTES

1. SINGLE POLE. UPPER HEMISPHERE PROJECTION OF JOINT AND SHEAR PLANES
2. PERCENTAGE OF POINTS CONTOURED.
3. UPPER DIAGRAMS REPRESENT RIVER MAPPING FROM 6000 FEET UPSTREAM OF AXIS DOWNSTREAM TO TSUSENA CREEK.
4. LOWER DIAGRAM IS A BORE HOLE CAMERA COMPOSITE OF THREE NX CORE HOLES REPRESENTING 518 POINTS IN 362.5 LINEAR FEET OF HOLE. NO SEPARATION OF JOINTS AND SHEARS MADE (DH-21, 23, 24).
5. STEREOGRAPHIC PROJECTIONS ARE USED TO DEFINE ANY PLANE. BY CONSTRUCTING A POLE PERPENDICULAR TO A PLANE AND PLOTTING THE POLE PROJECTION ON A HEMISPHERE (IN THIS CASE THE NORTHERN HEMISPHERE). THE ORIENTATION OF A PLANE CAN BE DEFINED AS A DISCREET POINT REGARDLESS OF SPACIAL COORDINATES. FOR EXAMPLE. A POLE CONSTRUCTED FROM A PLANE WITH A STRIKE OF N55°W AND A DIP OF N50°E WILL HAVE SPHERICAL COORDINATES OF 035°, 050°; A FLAT PLANE WILL PLOT AT THE NORTH POLE OF THE HEMISPHERE; A VERTICAL PLANE WILL PLOT AS TWO DISCREET POINTS ON THE EQUATOR, BOTH POINTS PERPENDICULAR TO STRIKE. POLE PROJECTIONS ARE THEN CONTOURED TO DEFINE DOMINANT AND SUBORDINANT PLANAR FEATURES.



BORE HOLE CAMERA COMPOSITE

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
STEREOGRAPHIC PROJECTIONS

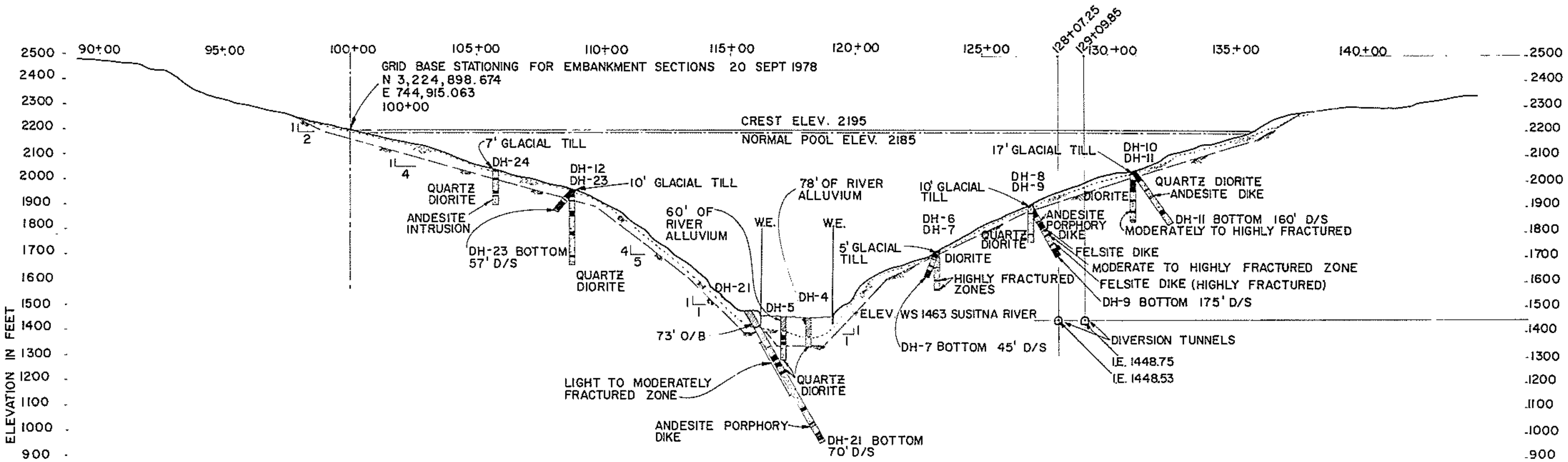
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

LEGEND

- SURFACE LINE
- TOP OF ROCK LINE
- FOUNDATION BEDROCK EXCAVATION LINE
- SHEAR ZONE
- D/S DOWNSTREAM
- U/S UPSTREAM
- O/B OVERBURDEN
- W.E. WATERS EDGE
- DH DRILL HOLE
- I.E INVERT ELEVATION
- TOP OF ROCK
- EXCAVATION LINE

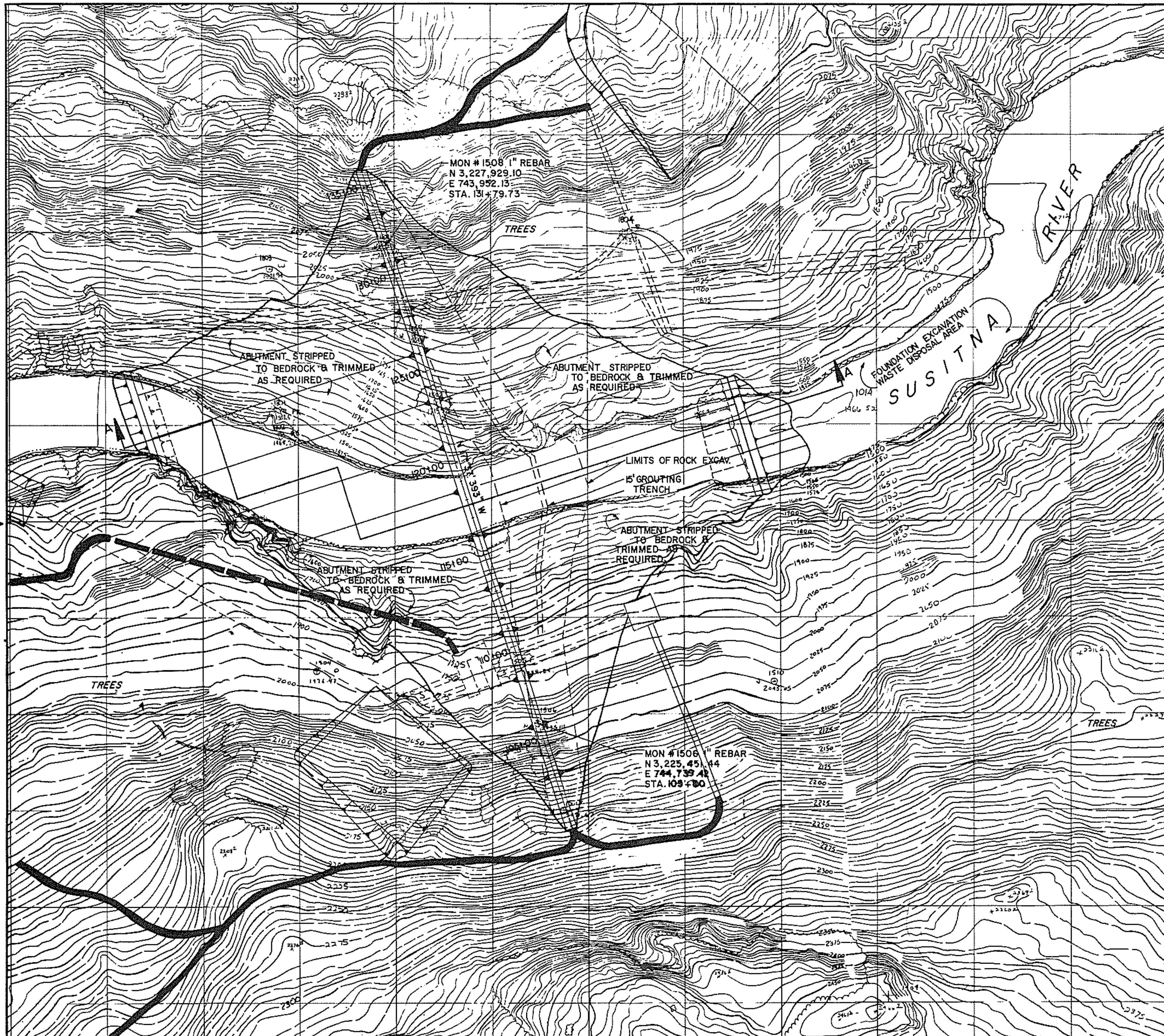
NOTE:
TOP OF ROCK LINE & EXCAVATION LINE SUBJECT TO CHANGE.

FOR LOCATION OF CROSS-SECTION SEE PLATE D-4



SECTION A-A

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
SECTION ALONG DAM AXIS
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



200' 0' 200' 400' 500'

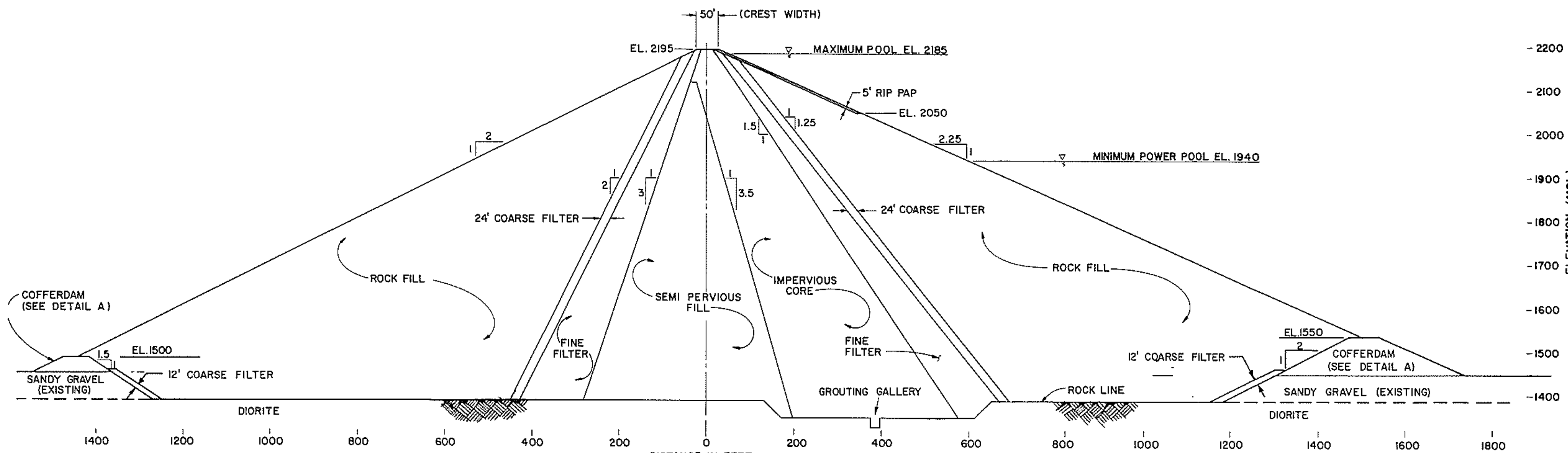
GRAPHIC SCALE: 1" = 200'

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA EMBANKMENT

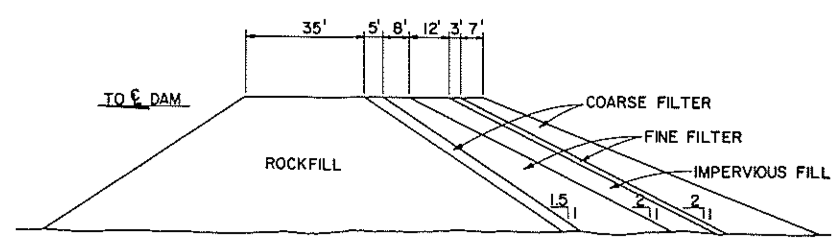
PLAN VIEW

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



SECTION A-A (FROM PLATE D-8)

100' 0' 100' 200'
GRAPHIC SCALE: 1" = 100'-0"



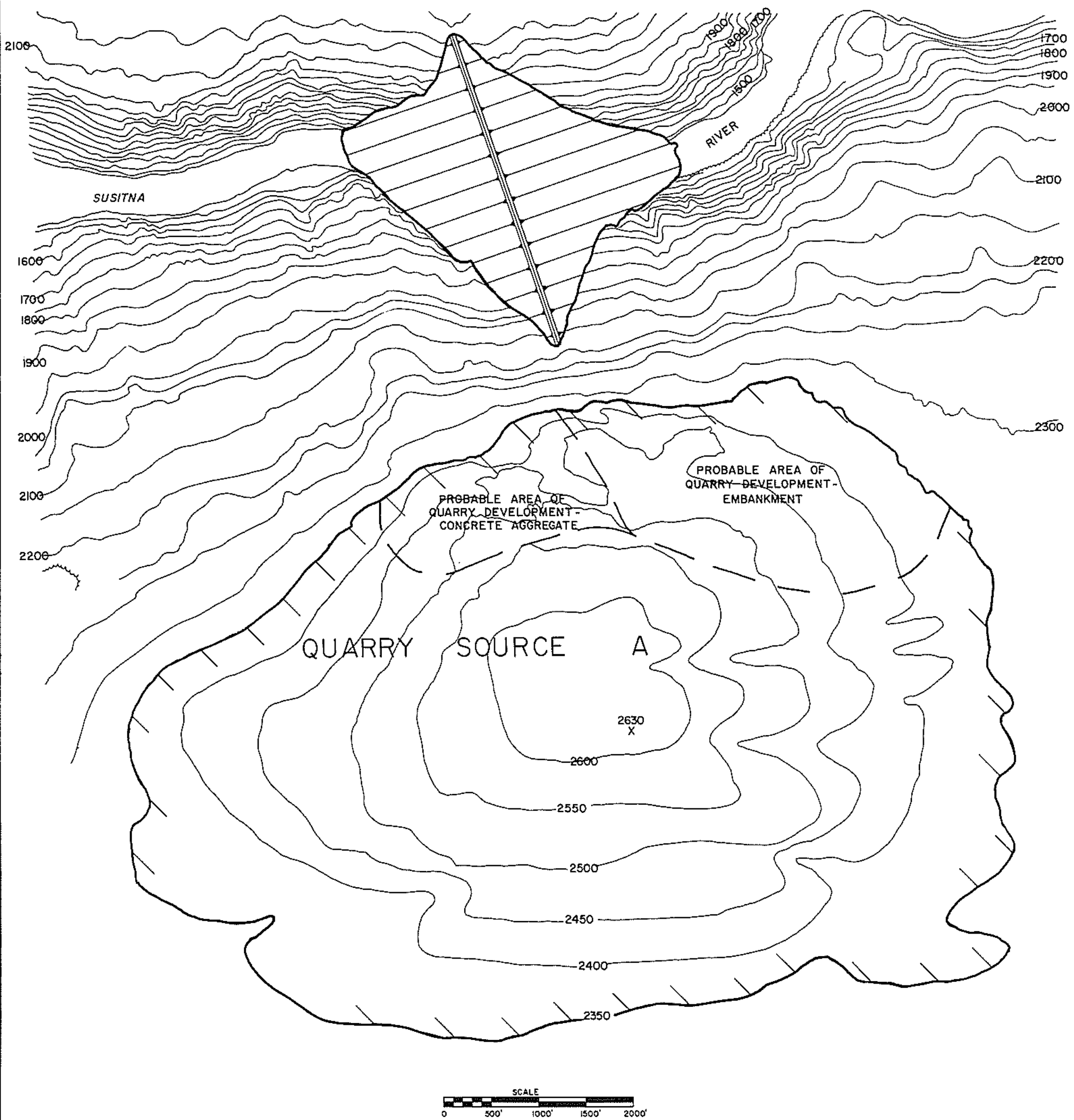
COFFERDAM - DETAIL A
TYP. EACH SIDE

20' 0' 20' 40'
GRAPHIC SCALE: 1" = 20'-0"

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA EMBANKMENT
SECTION A-A

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

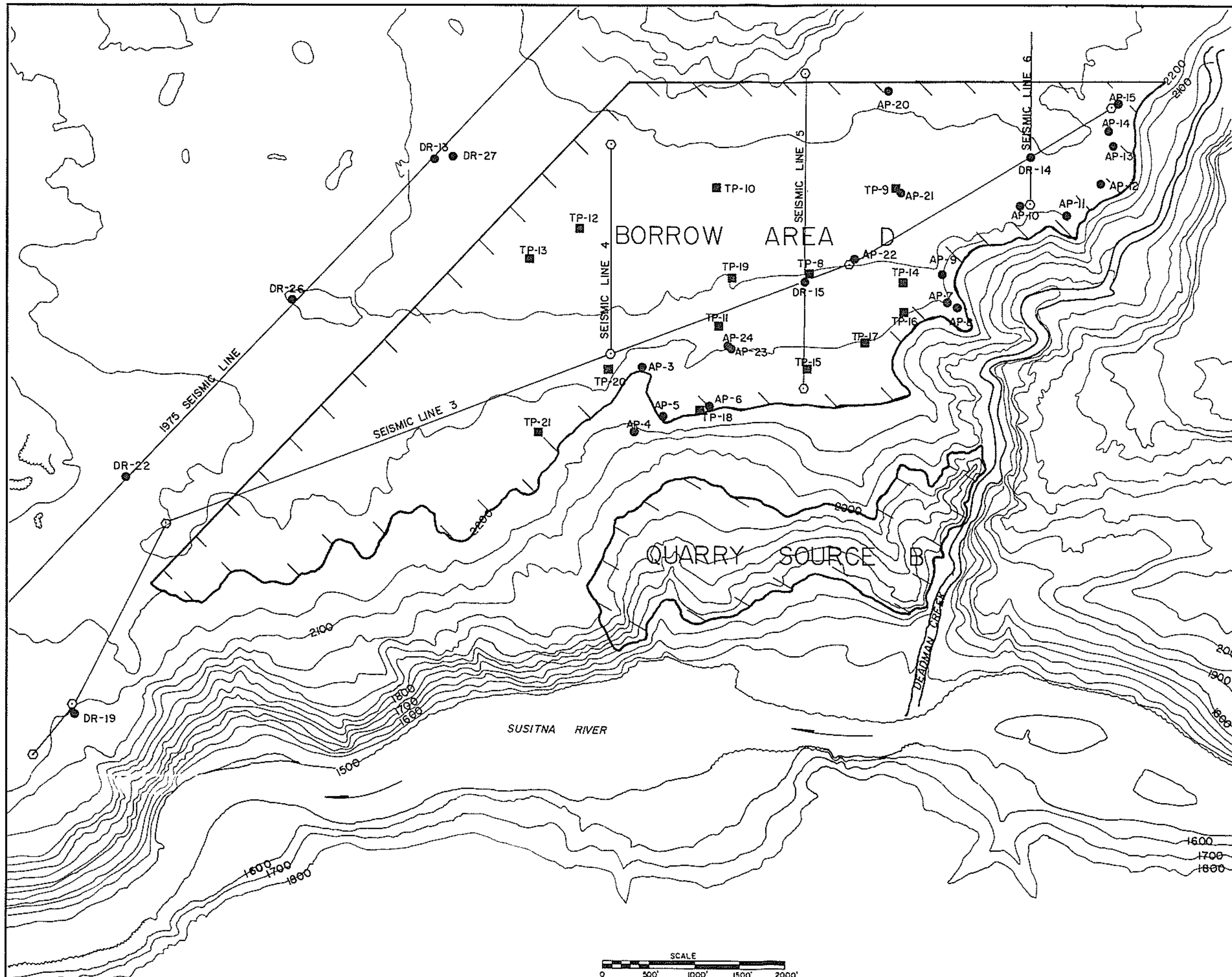


SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
QUARRY SOURCE A

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

PLATE D-10



N

LEGEND

- TP TEST PITS
- DR DRILL HOLE
- AP AUGER HOLE
- SW SEISMIC LINE

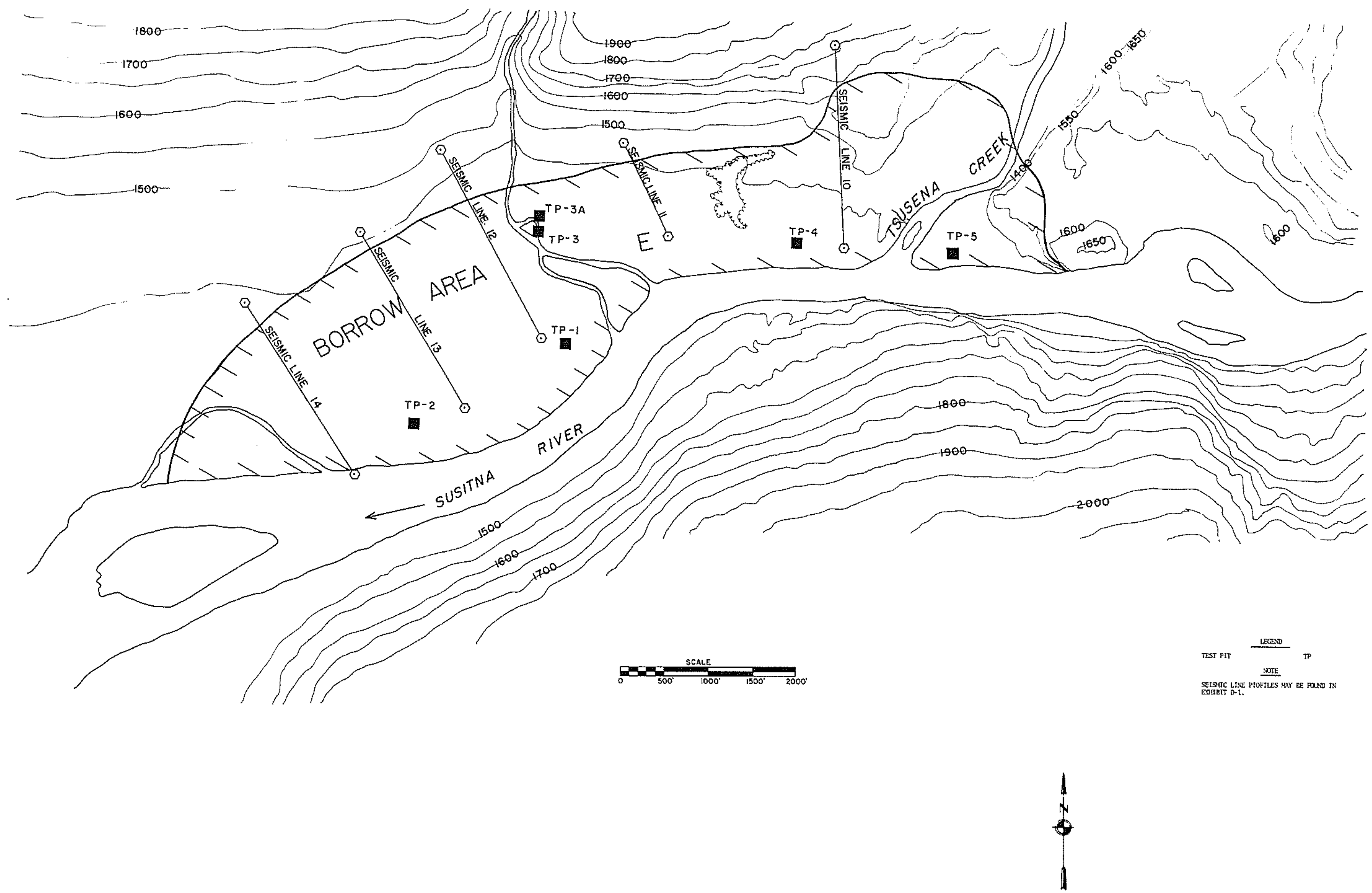
NOTES

1. SEISMIC LINE PROFILES MAY BE FOUND IN EXHIBIT D-1.
2. AUGER HOLES 16-19 LIE NORTH OF BORROW AREA D, ZERO TO ½ MILE NORTH OF AND BETWEEN AP-15 AND AP-20. SEE PLATE D-2.
3. AP-1 AND AP-2 ARE NEAR DR-20 IN SPILLWAY AREA. SEE PLATE D-2.
4. FOR LOCATION OF TP 6-7 AND TP 22-26, SEE PLATE D-2.

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
QUARRY SOURCE B & BORROW AREA D

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

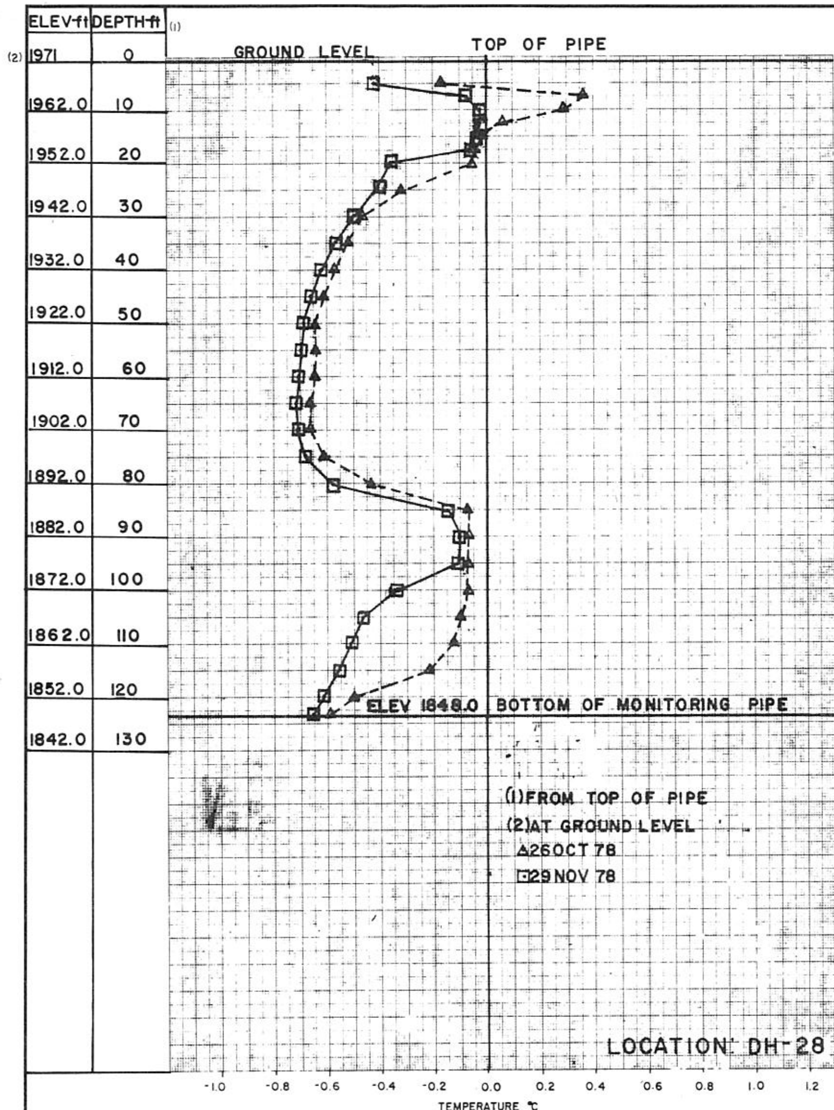


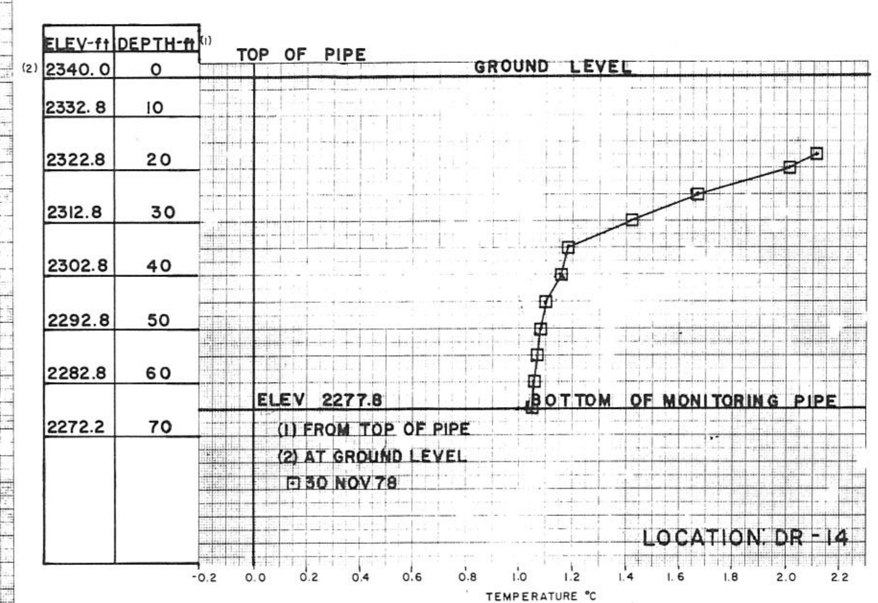
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

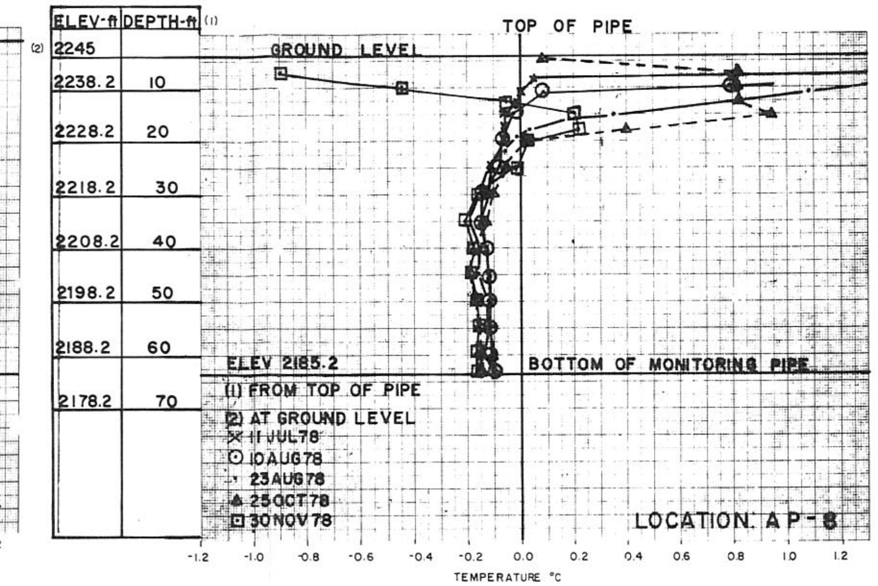
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA E

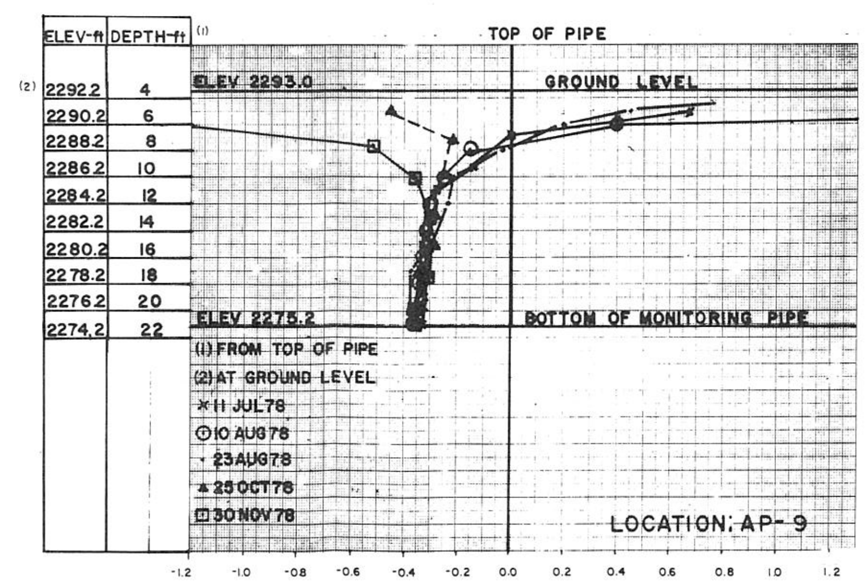
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE ALASKA

PLATE D-12









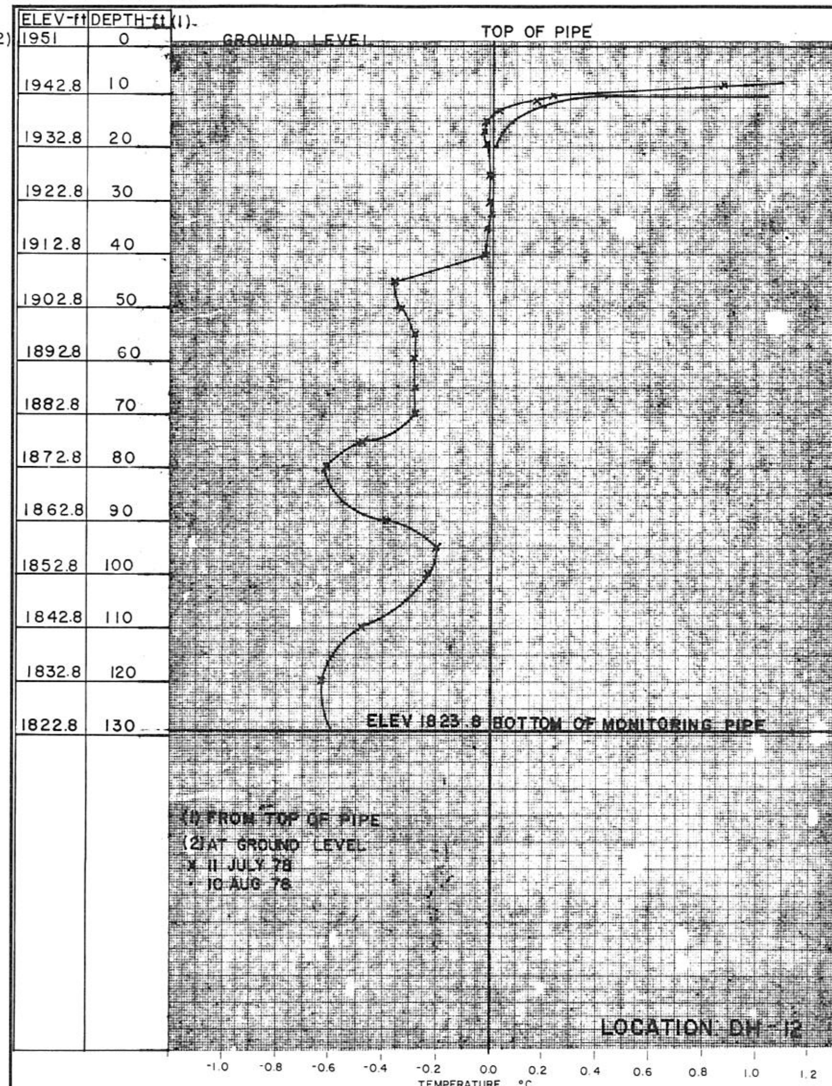
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

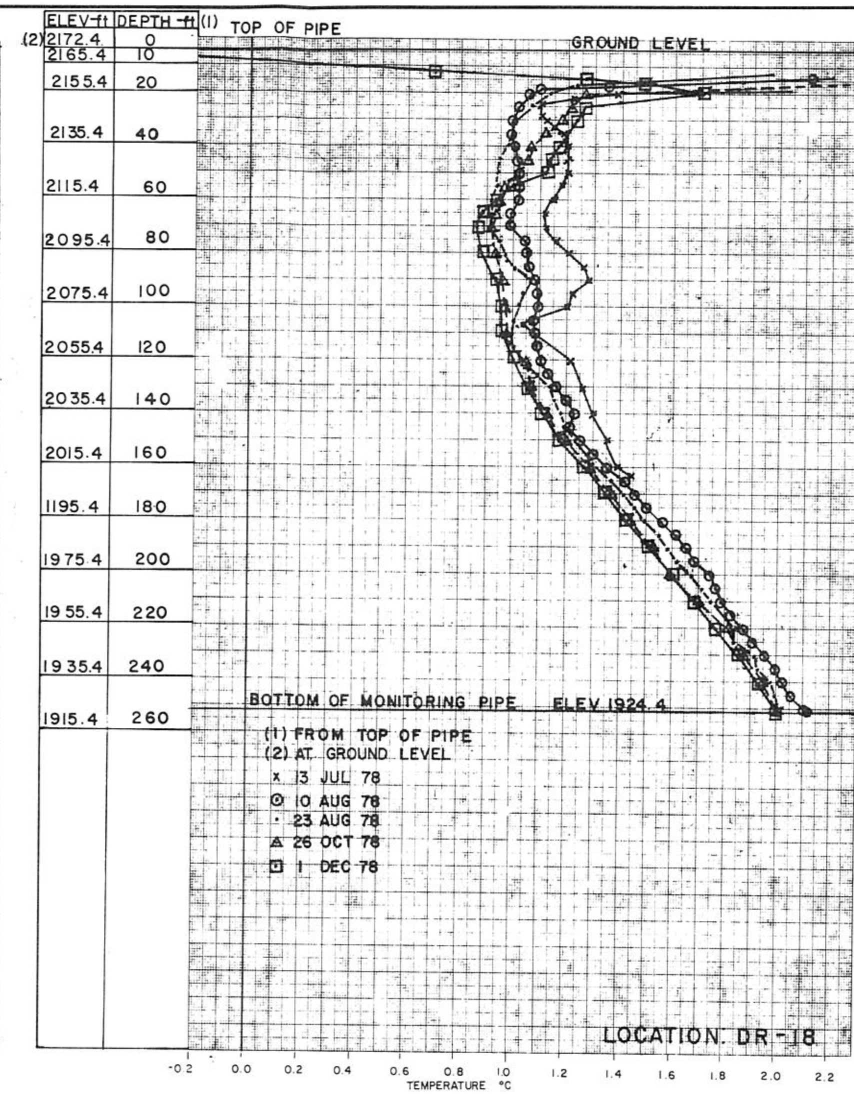
UPPER SUSITNA RIVER BASIN

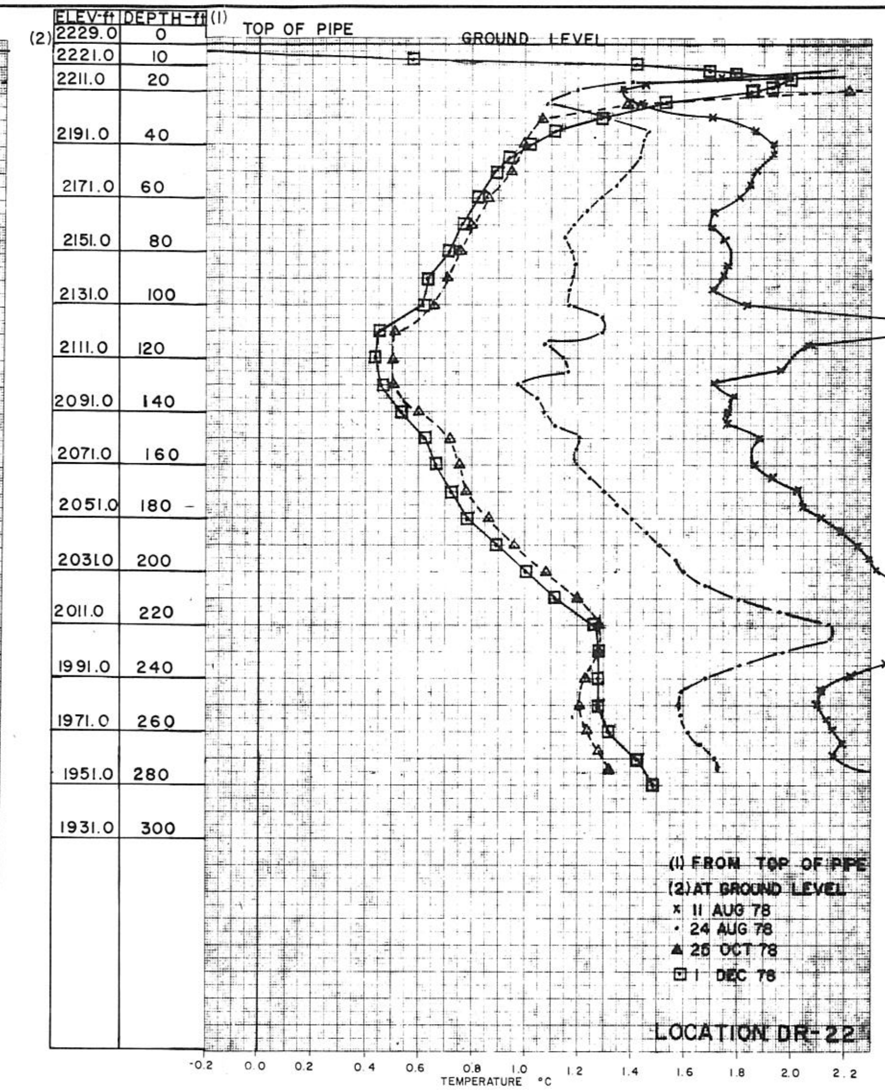
WATANA DAM SITE

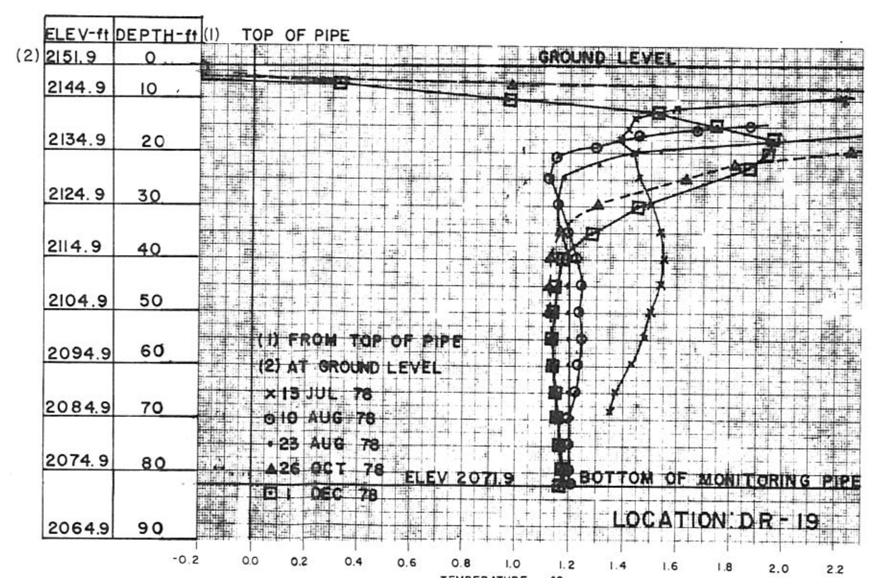
GROUND TEMPERATURE DATA I

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA









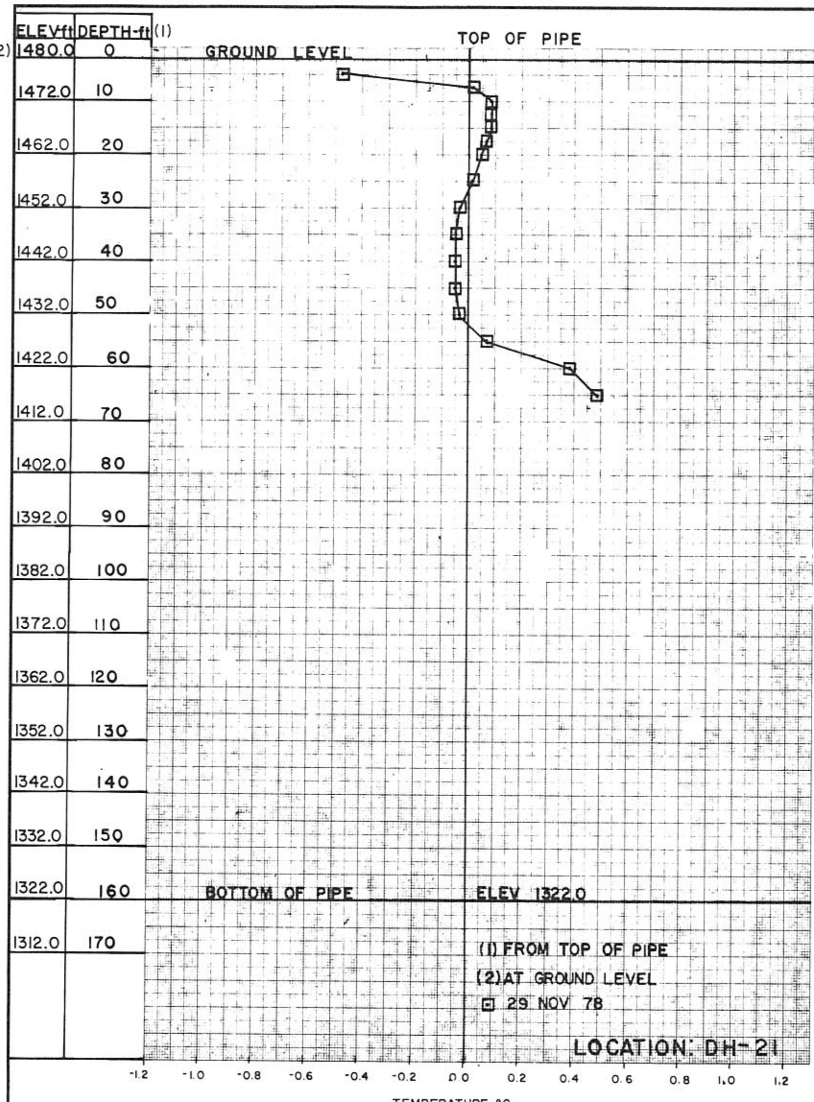
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

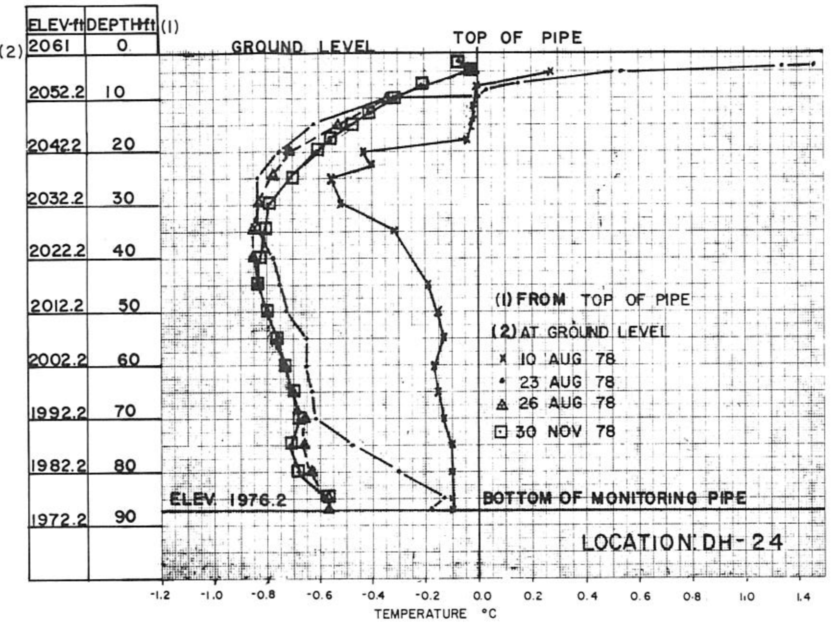
UPPER SUSITNA RIVER BASIN

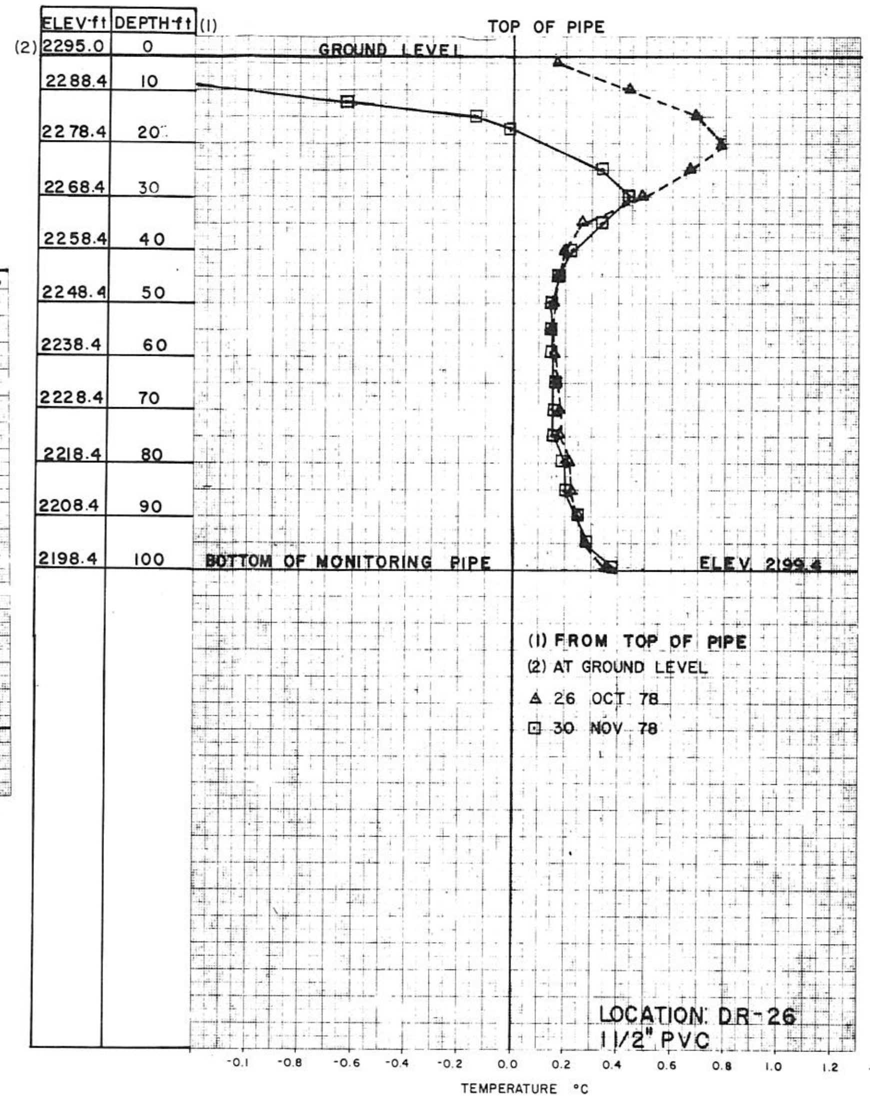
WATANA DAM SITE

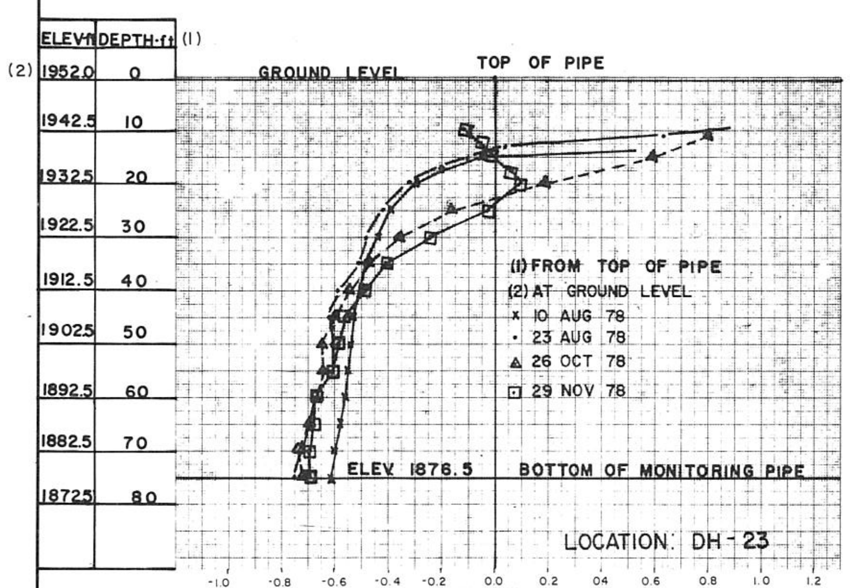
GROUND TEMPERATURE DATA II

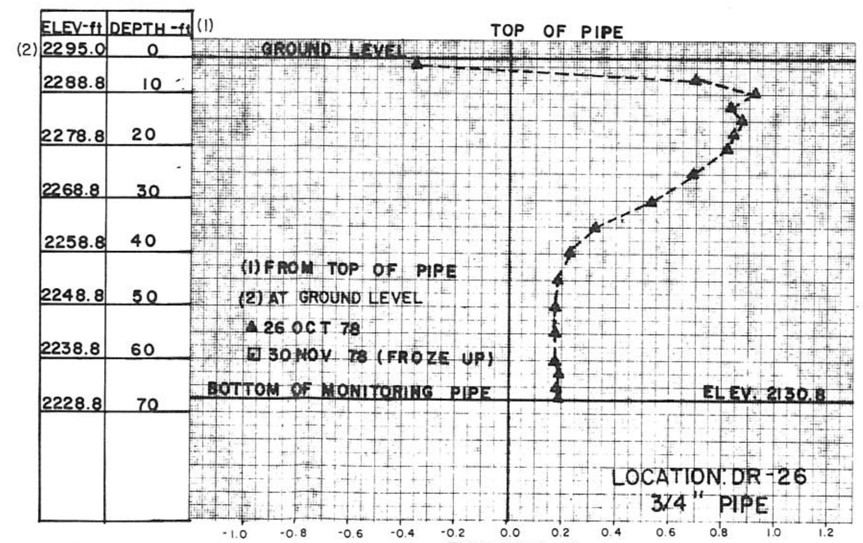
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA











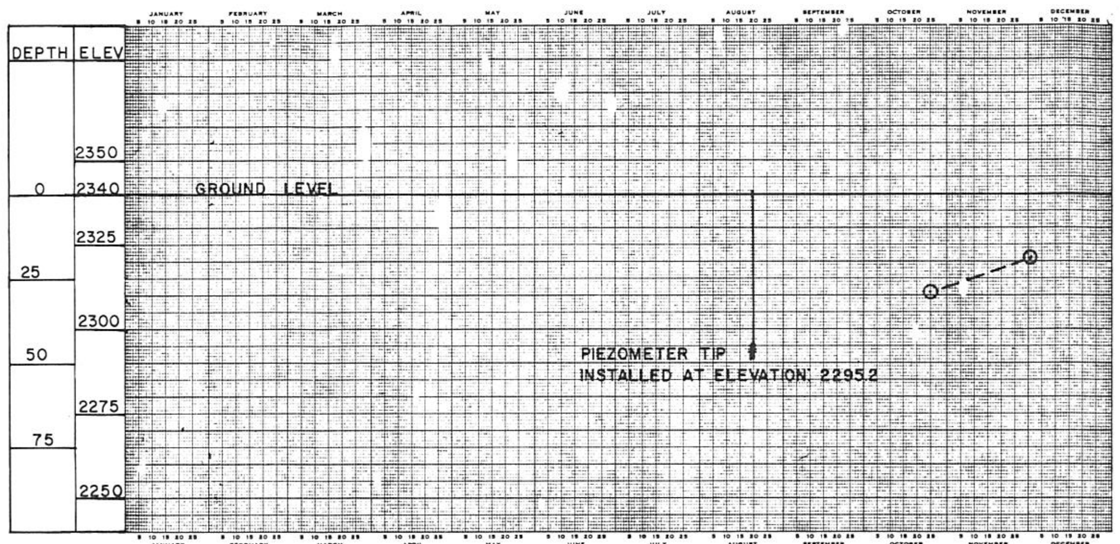
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

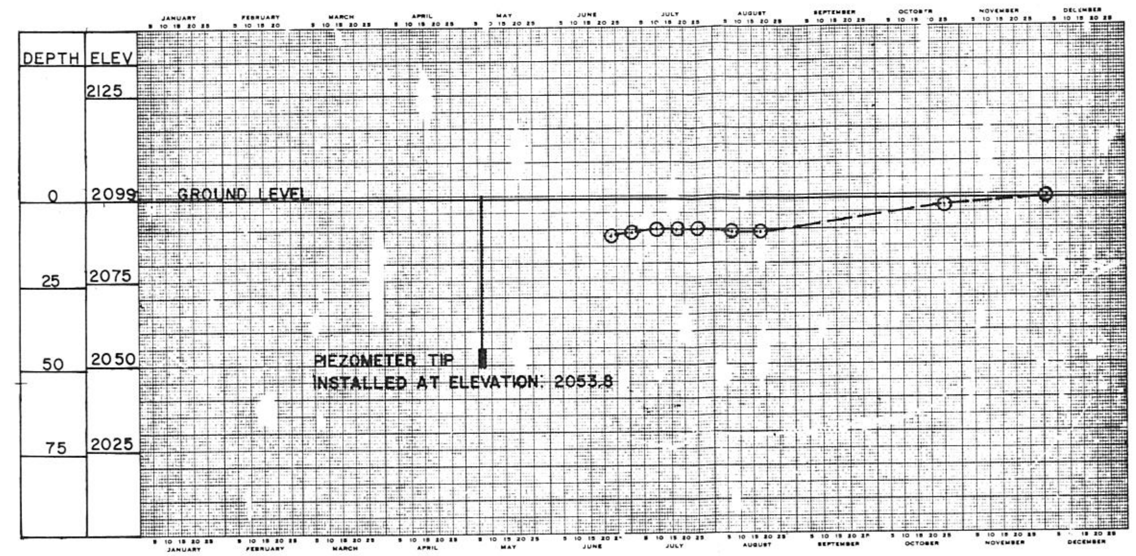
WATANA DAM SITE

GROUND TEMPERATURE DATA III

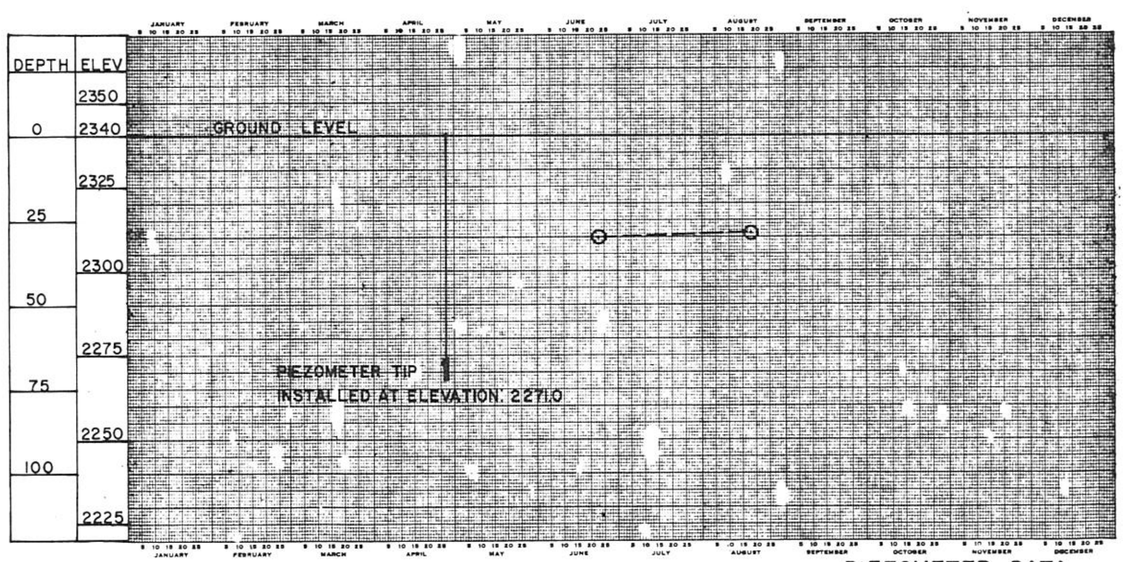
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



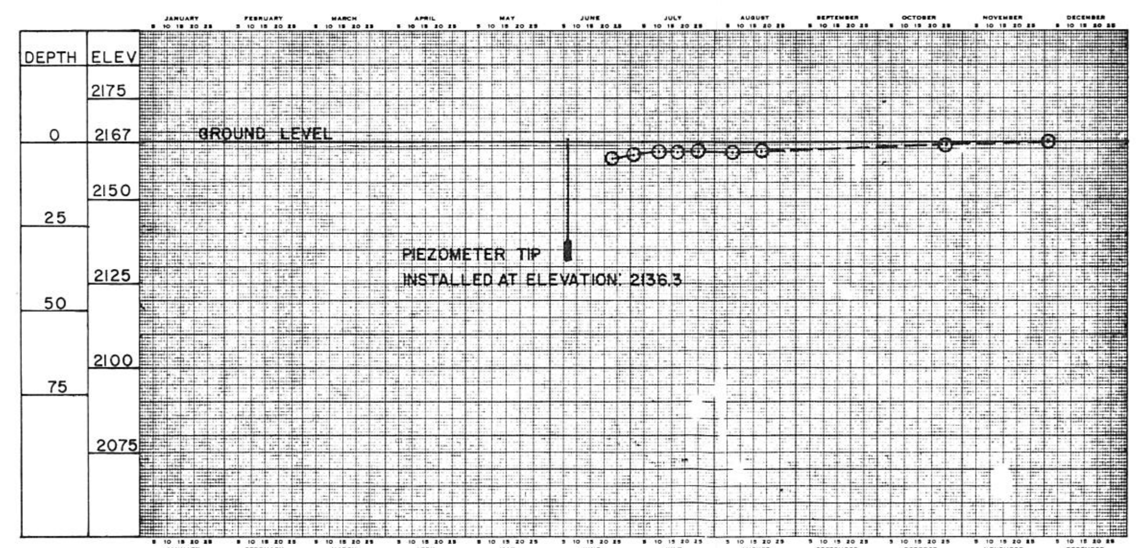
PIEZOMETER DATA
LOCATION: DR-14(1 1/2")



PIEZOMETER DATA
LOCATION: DR-16



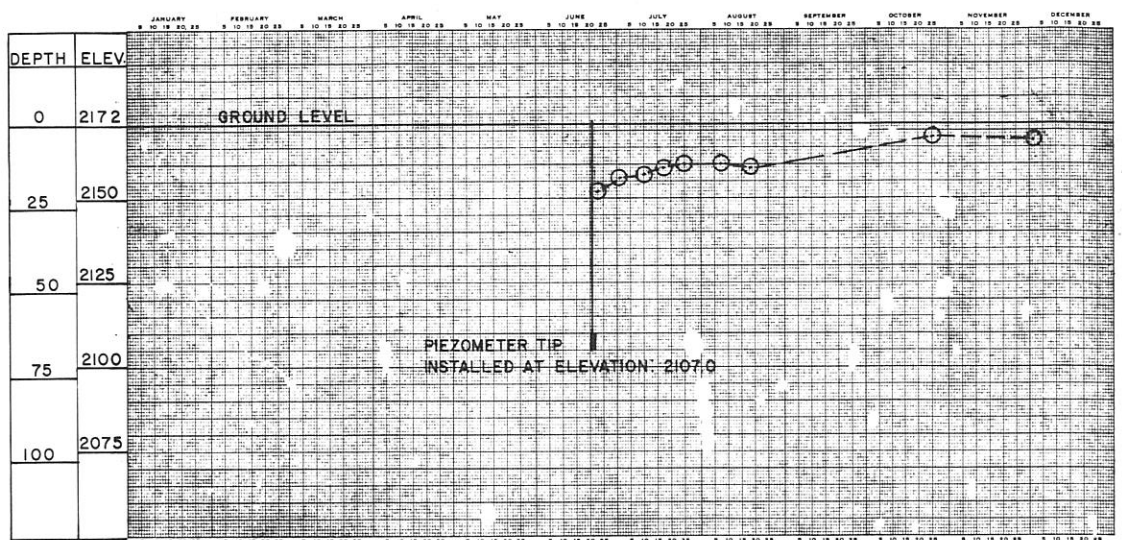
PIEZOMETER DATA
LOCATION: DR-14 (4")



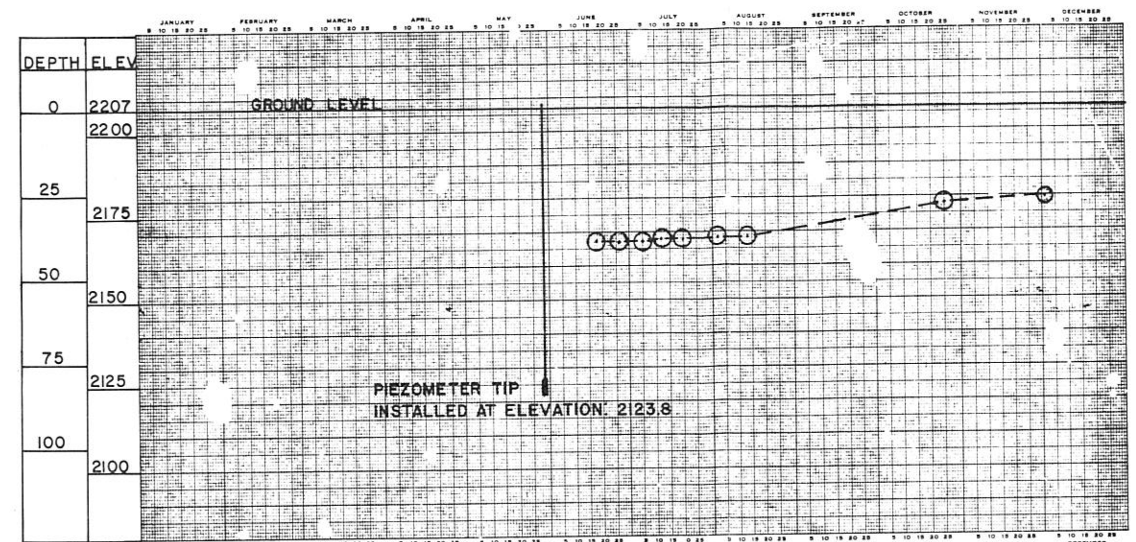
PIEZOMETER DATA
LOCATION: DR-17

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM SITE
PIEZOMETER DATA I

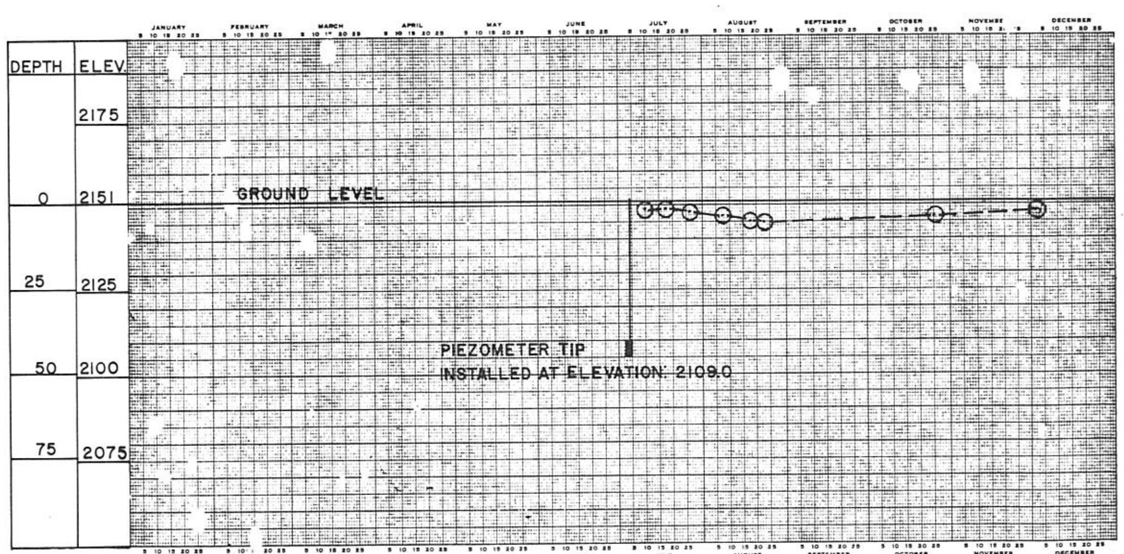
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



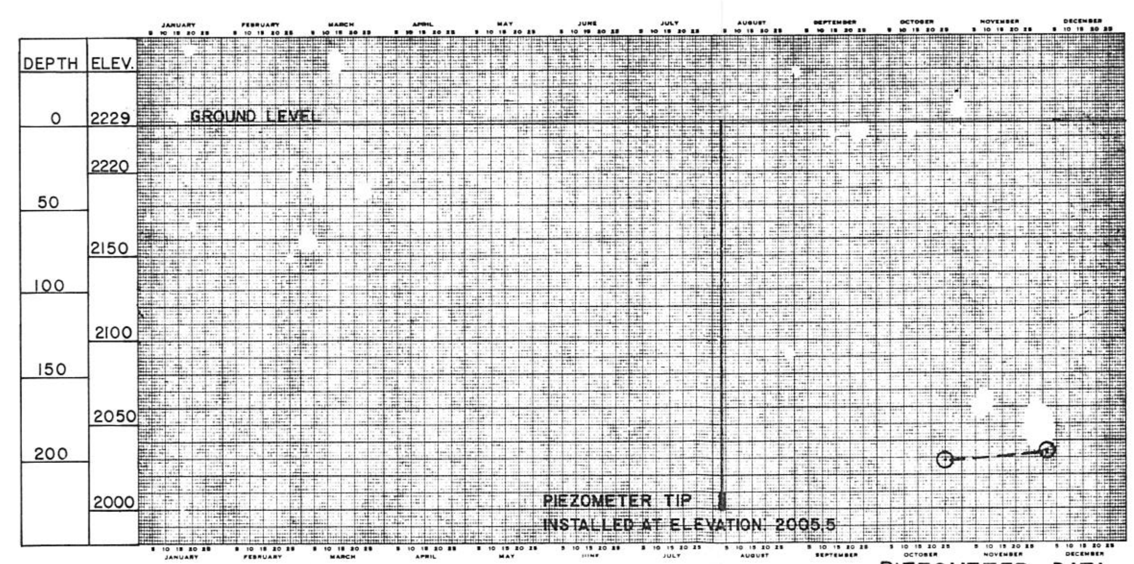
PIEZOMETER DATA
LOCATION: DR-18



PIEZOMETER DATA
LOCATION: DR-20



PIEZOMETER DATA
LOCATION: DR-19



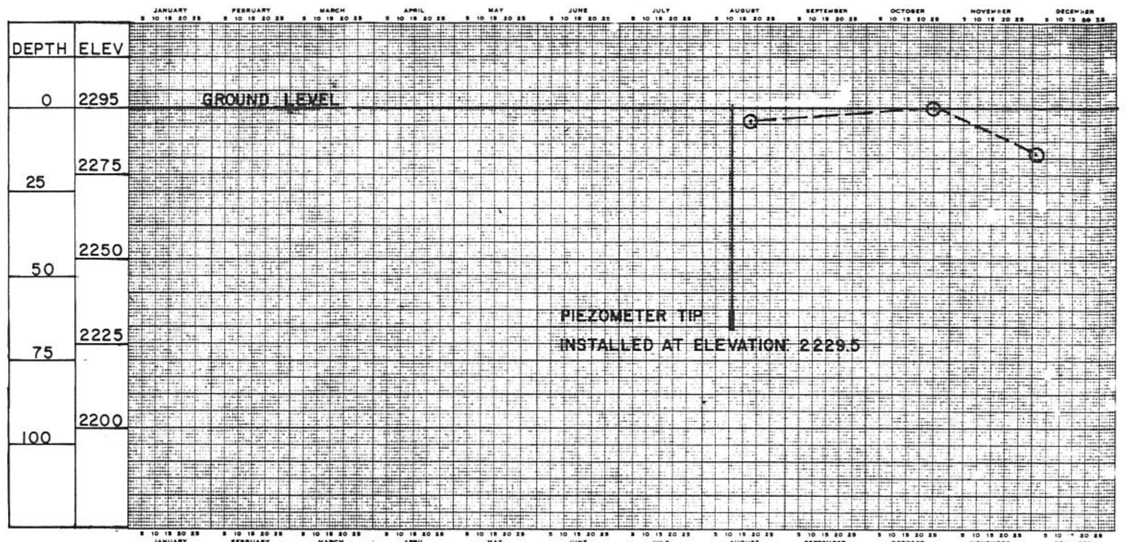
PIEZOMETER DATA
LOCATION: DR-22

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

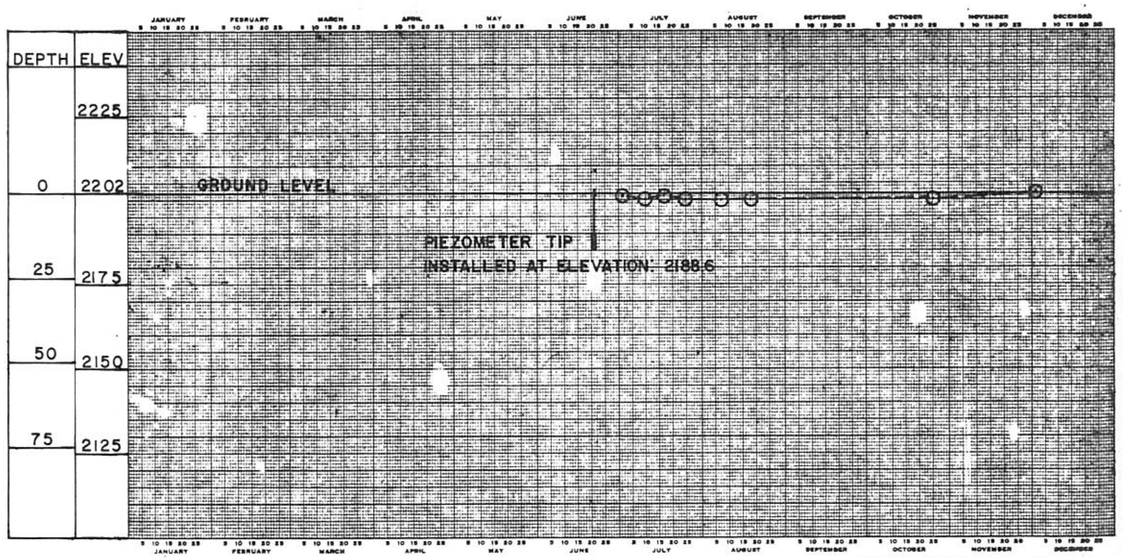
UPPER SUSITNA RIVER BASIN
WATANA DAM SITE

PIEZOMETER DATA II

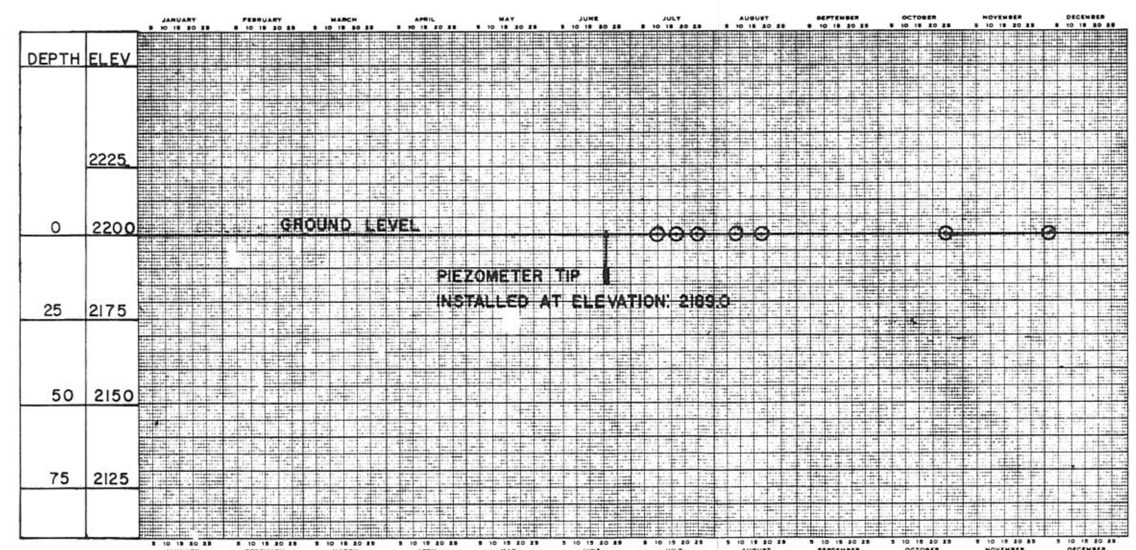
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



PIEZOMETER DATA
LOCATION: DR-26



PIEZOMETER DATA
LOCATION: AP-1



PIEZOMETER DATA
LOCATION: AP-2

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM SITE
PIEZOMETER DATA III
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EXPLORATION LOG — TP-1

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: Watana Dam — Sheet 1 of 1
Location (Coordinates or Station): N 3,225,990 E 728,700
Drilling agency: Corps of Engineers
Hole No.: Field TP-1, Permanent TP-1
Name of driller: D. Sullivan — Weather: P/C 60°
Type of hole: Test pit XXXX — Total depth of hole: 8.0'
Datum for elevation shown: MSL — Type of equipment: Melroe Bobcat and Backhoe
Total no. of samples: 5 — Type of samples: Grab
Date hole started: 6/21/78 — Completed: 6/21/78
El. top of hole: 1420 — Geologist: T. Sherman

Depth feet	% Water content	Sample no	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Sandy Silt		Vegetation Top 0.2' Some Organics, Fine
2			SP	Gravelly Sand	3"	Fine Clean; Traces of Clay
4		1&2	SP-SM	Silty Gravelly sand	14"	Boulders 30-40% Coarse Sand
6						Boulders 50-60%
8		3,4,&5		Plus No. 4-39% Minus No. 4-61%		
10						Bottom of Hole (Boulders) Note: Bobcat to 5' Backhoe to 8'

NPA FORM 19 (REV) DEC 1959
Project: Watana Dam — Permanent Hole No. TP-1

EXPLORATION LOG — TP-2

Project: Watana Dam — Sheet 1 of 1
Location: N 3,224,800 E 726,650
Drilling agency: Corps of Engineers
Hole No.: Field TP-2, Permanent TP-2
Name of driller: D. Sullivan — Weather: P/C 60°
Type of hole: Test pit XXXX — Total depth of hole: 9.2'
Datum for elevation shown: MSL — Type of equipment: Melroe Bobcat And Backhoe
Total no. of samples: 2 — Type of samples: Grab
Date hole started: 6/24/78 — Completed: 6/24/78
El. top of hole: 1415 — Geologist: T. Sherman

Depth feet	% Water content	Sample no	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Sandy Silt		Vegetation, Roots; Some Organics; Very Little Sand
4			SP	Silty sand	1/2"	Clean
			SM	Silty Sand		No Gravel
6–8		1&2	GP	Sandy Gravel; Plus No 4- 57% Minus No. 4-43%		
10						Bottom Of Hole (Boulders) Note: Bobcat to 4' Backhoe to 9.2'

NPA FORM 19 (REV) DEC 1959
Project: Watana Dam — Permanent Hole No. TP-2

EXPLORATION LOG — TP-3

Project: Watana Dam — Sheet 1 of 1
Location: N 3,226,680 E 728,600
Drilling agency: Corps of Engineers
Hole No.: Field TP-3, Permanent TP-3
Name of driller: D. Sullivan — Weather: P/C 60°
Type of hole: Test pit X-XX — Total depth of hole: 5.0'
Datum for elevation shown: MSL — Type of equipment: Melroe Bobcat and Backhoe
Total no. of samples: 1 — Type of samples: Grab
Date hole started: 9/25/78 — Completed: 9/25/78
El. top of hole: 1435 — Geologist: T. Sherman

Depth feet	% Water content	Sample no	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Sandy Silt		Vegetation, Roots
1–5		1	GP	Sandy Gravel; Plus No. 4-59% Minus No. 4-41%		20-30% Gravel
						Bottom Of Hole (Boulders) Note: Bobcate to 2.5' Backhoe to 5.0'

NPA FORM 19 (REV) DEC 1959
Project: Watana Dam — Permanent Hole No. TP-3

EXPLORATION LOG — TP-3A

Project: Watana Dam — Sheet 1 of 1
Location: N 3,226,820 E 728,750
Drilling agency: Corps of Engineers
Hole No.: Field TP-3A, Permanent TP-3A
Name of driller: D. Sullivan — Weather: P/C 60°
Type of hole: Test pit XXXX — Total depth of hole: 5.2'
Datum for elevation shown: MSL — Type of equipment: Melroe Bobcat and Backhoe
Total no. of samples: 1 — Type of samples: Grab
Date hole started: 7/25/78 — Completed: 7/25/78
El. top of hole: 1436 — Geologist: T. Sherman

Depth feet	% Water content	Sample no	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Sandy Silt		Vegetation, Roots
1–5		1	GP	Sandy Gravel; Plus No. 4-55% Minus No. 4-45%		Boulders 30% w/ lots of roots
						Bottom of hole (boulders) Note: Backhoe only

NPA FORM 19 (REV) DEC 1959
Project: Watana Dam — Permanent Hole No. TP-3A

EXPLORATION LOG — TP-4

Project: Watana Dam — Sheet 1 of 1
Location: N 3,226,690 E 731,300
Drilling agency: Corps of Engineers
Hole No.: Field TP-4, Permanent TP-4
Name of driller: D. Sullivan — Weather: P/C 60°
Type of hole: Test pit XXX — Total depth of hole: 9.2
Datum for elevation shown: MSL — Type of equipment: Melroe Bobcat and Backhoe
Total no. of samples: 2 — Type of samples: Grab
Date hole started: 7/26/78 — Completed: 7/26/78
El. top of hole: 1442 — Geologist: T. Sherman

Depth feet	% Water content	Sample no	Soil legend	Classification	Max size particle	Formation description & remarks
			SM	Sility Sand		Vegetation top 0.2' Some organic silts
2			SW	Sand		Clean
4			SM	Silty Sand		Traces of organics and Clay; Some gravels
6–8		1&2	GP-GM	Silty Sandy Gravel; Plus No. 4-53% Minus No. 4-47%	24"	25% Boulders
10						Bottom of Hole Water table @ 9.2' Note: Bobcat to 6' Backhoe to 9.2'

NPA FORM 19 (REV) DEC 1959
Project: Watana Dam — Permanent Hole No. TP-4

EXPLORATION LOG — TP-5

Project: Watana Dam — Sheet 1 of 1
Location: N 3,227,110 E 733,170
Drilling agency: Corps of Engineers
Hole No.: Field TP-5, Permanent TP-5
Name of driller: D. Sullivan — Weather: P/C 60°
Type of hole: Test pit XX — Total depth of hole: 8.2'
Datum for elevation shown: MSL — Type of equipment: Melroe Bobcat and Backhoe
Total no. of samples: 2 — Type of samples: Grab
Date hole started: 7/28/78 — Completed: 7/28/78
El. top of hole: 1455 — Geologist: T. Sherman

Depth feet	% Water content	Sample no	Soil legend	Classification	Max size particle	Formation description & remarks
			SM	Silty sand, gravelly		Vegetation top 0.2' Organic Silts
2			SP	Sand		Traces of organics; some gravel
4–8		1&2	GP	Sandy gravel; Plus No. 4-61% Minus No. 4-39%	24"	Sand, medium; 40% boulders; Sand, coarse
						Bottom of hole (boulders)

NPA FORM 19 (REV) DEC 1959
Project: Watana Dam — Permanent Hole No. TP-5

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA E
LOGS: TEST PITS 1 THRU 5

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

Exploration Log TP-7

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N. 3,276,190 E. 742,450
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-7, Permanent TP-7
- Name of Driller: D. SULLIVAN
- Weather: P/C 60°
- Type of Hole: Test Pit (X)
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: MELROE BOBCAT AND BACKHOE
- Total No. of Samples: 2
- Type of Samples: GRAB
- Date Hole: Started 23 JUN 78, Completed 24 JUN 78
- El. Top of Hole: 2390
- Geologist: P. GALBRAITH

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
1						
2				SANDY GRAVEL		
3						
4		1&2		60% GR. 40% SA		
						BOTTOM OF HOLE

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-7

Exploration Log TP-8

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N. 3,234,330 E. 754,280
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-8, Permanent TP-8
- Name of Driller: D. SULLIVAN
- Weather: CLOUDY
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 7'
- Size and Type of Bit: 1/4 YARD³ BUCKET
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: BACKHOE, JOHN DEERE "3"
- Total No. of Samples: 2
- Type of Samples: GRAB
- Date Hole: Started 16 AUG 78, Completed 16 AUG 78
- El. Top of Hole: 2292
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL/PT	PEAT		PEAT, VEG. SOME COBBLES, 18" DIA ROCK
2			SM	SILTY GRAVELLY SAND		GRAVELLY SILTY SAND, COBBLES
		1		30%SI, 17%GR, 53%SA		
4			SM	SILTY SAND GRAVEL		WATER SEEPING IN @ 4.5' GRAVELLY SILTY SAND WATER TABLE @ 7.0' APROX, HOLE CAVED IN.
6		2				
8				BOTTOM OF HOLE		
10						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-8

Exploration Log TP-9

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N. 3,235,360 E. 755,260
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-9, Permanent TP-9
- Name of Driller: D. SULLIVAN
- Weather: CLEAR
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 10'
- Size and Type of Bit: 1/4 YARD³ BUCKET
- Type of Equipment: BACKHOE, JOHN DEERE "3" 1/4 YD³
- Total No. of Samples: 4
- Type of Samples: GRAB
- Date Hole: Started 15 AUG 78, Completed 15 AUG 78
- El. Top of Hole: 2343
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		VEG. W/SILT, ROOTS, NOT FROZEN
			ML	SILT		DARK BROWN SILT W/ROCK 16" DIA.
2		A	ML	SANDY SILT		SILTY SAND W/GRAVEL TO 4", TAN GREY COLOR.
4		1	ML	SILTY GRAVELLY SAND 16% GR, 37%SI, 47%SA		MOIST, TAN GREY COLOR SOME GRAVEL TO 4" COBBLES WERE EXCAVATED FROM ALL LAYERS FROM 0' TO B.O.H. LARGEST ROCK TO COME OUT WAS 2.5' x 1.5' x 9" THICK FROM ABOUT 6.0', ONE 2'x3'x1' FROM 9' DOWN.
6		2		13%GR, 37%SI, 50%SA		
			SM	SILTY GRAVELLY SAND		TAN GREY COLOR
		3		41%SI, 15%GR, 45%SA		
			SM	SILTY, GRAVELLY SAND		WATER TABLE @ 9.8'
10				BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-9

Exploration Log TP-10

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N 3,234,870 E. 753,270
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-10, Permanent TP-10
- Name of Driller: D. SULLIVAN
- Weather: COOL & CLOUDY
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 10.6'
- Size and Type of Bit: 1/4" YD³ BUCKET
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: BACKHOE, JOHN DEERE "3"
- Total No. of Samples: 2
- Type of Samples: GRAB
- Date Hole: Started 21 AUG 78, Completed 21 AUG 78
- El. Top of Hole: 2326
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL/PT	SILT		ORGANIC SILT
2		1	SM	SILTY GRAVELLY SAND 17%GR 35%SI, 48%SA		SILTY GRAVELLY SAND W/COBBLES AND BOULDERS VARVED STRUCTURE I.E. W/SAND 1.5'~7.4'
4						
6						
8		2	SM	SILITY GRAVELLY SAND 37%SI, 12%GR, 51%SA		LAYERS OF COARSE SAND
			SM	SILTY GRAVELLY SAND		
10						
				BOTTOM OF HOLE		WATER SEEPING IN, HOLE CAVING
12						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-10

Exploration Log TP-11

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N 3,233,830 E. 753,210
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-11, Permanent TP-11
- Name of Driller: D. SULLIVAN
- Weather: CLEAR
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 8.2'
- Size and Type of Bit: 1/4 YD³ BUCKET
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: BACKHOE, JOHN DEERE "3"
- Total No. of Samples: 2
- Type of Samples: GRAB
- Date Hole: Started 18 AUG78, Completed 18AUG78
- El. Top of Hole: 2270
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL/PT	SILT		ORGANIC SILT, DARK BORWN W/ BOULDERS
2			SM	SILTY GRAVELLY SAND		9" COBBLES
4		1		26% SI, 17% GR, 57%SA		
			SM/SP	SILTY GRAVELLY SAND		STATIC WATER TABLE @ 4.2' MEASURED 19 AUG 78
6						
8		2				
				BOTTOM OF HOLE		HOLE CAVED IN, WATER OOZING IN FROM THE SIDES.
10						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-11

Exploration Log TP-12

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N 3,234,890 E. 751,690
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-12, Permanent TP-12
- Name of Driller: D. SULLIVAN
- Weather: COOL & CLOUDY
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 13.5'
- Size and Type of Bit: 1/4 YD³ BUCKET
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: BACKHOE JOHN DEERE "3"
- Total No. of Samples: 2
- Type of Samples: GRAB
- Date Hole: Started 21 AUG 78, Completed 21 AUG 78.
- El. Top of Hole: 2334
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		ORGANIC SILT W/LARGE BOULDERS
			ML	SILT		
2			SM	SILTY GRAVELLY SAND		BROWN
		1		44% SI, 13%GR, 43%SA		
4						
6						
8			SM	SILTY GRAVELLY SAND		LIGHT GREY COLOR, COBBLES TO 10"
10						
12		2		25% SI, 16%GR, 59% SA		
14				BOTTOM OF HOLE		WATER RUNNING INTO THE HOLE

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-12

Exploration Log TP-13

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N. 3,234,565 E. 756,135
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-13, Permanent TP-13
- Name of Driller: D. SULLIVAN
- Weather: CLEAR
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 10'
- Size and Type of Bit: 1/4 YD³ BUCKET
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: BACKHOE, JOHN DEERE, "3"
- Total No. of Samples: 1
- Type of Samples: GRAB
- Date Hole: Started 22 AUG 78, Completed 22 AUG78
- El. Top of Hole: 2330
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL/ML	SILT		SILT WITH LARGE BOULDERS
			SP/SM	SILTY GRAVELLY SAND		BROWN
2			SM	GRAVELLY SAND		W/SILT LENSES, DARK GREY COLOR, COBBLES
4						
6						
8		1		36%SI, 15% GR, 49%SA		
10				BOTTOM OF HOLE		HOLE SLOUGHED IN, WATER INFILTRATION FROM THE SIDES.
12						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-13

Exploration Log TP-14

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

- Project: WATANA DAM — Sheet 1 of 1
- Location (Coordinates or Station): N 3,234,330 E. 755,230
- Drilling Agency: Corps of Engineers (X)
- Hole No.: Field TP-14, Permanent TP-14
- Name of Driller: D. SULLIVAN
- Weather: CLOUDY
- Type of Hole: Test Pit (X)
- Total Depth of Hole: 3'
- Size and Type of Bit: 1/4 YARD³ BUCKET
- Datum for Elevation Shown: MSL (X)
- Type of Equipment: BACKHOE, JOHN DEERE "3"
- Total No. of Samples: 2
- Type of Samples: GRAB
- Date Hole: Started 17 AUG 78, Completed 17 AUG 78
- El. Top of Hole: 2286
- Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL/PT	PEAT, ORGANIC SILT		PEAT, SILT, LARGE BOULDER
2		1	SM	SILTY SAND 32% SI, 16% GR, 52%SA		FROZEN 1' TO 2', GREY SAND TAN GREY COLOR
		2		SILTY SAND		WATER SEEPING IN FROM THE SURFACE
				B.O.H.		
4						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. TP-14

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA C & D
LOGS: TEST PITS 7 THRU 14

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

Exploration Log — TP-15

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N. 3,233,390 E. 754,195
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-15 PERMANENT TP-15
NAME OF DRILLER	D. SULLIVAN
WEATHER	CLEAR
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	7'
SIZE AND TYPE OF BIT	1/4 YD³ BUCKET
TYPE OF EQUIPMENT	BACKHOE, JOHN DEERE "3"
TOTAL NO. OF SAMPLES	2
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	19 AUG 78
DATE HOLE COMPLETED	19 AUG 78
EL. TOP OF HOLE	2233
GEOLOGIST	D. JENSEN

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			OL/PT	PEAT		PEAT, ORGANIC SILT. 1 ROCK 5'x4'x18", W/COBBLES ON THE SURFACE
2		1	ML	SANDY GRAVELLY SILT		LIGHT GREY
4			SM	SILTY GRAVELLY SAND		
6		2		34% SI, 23%GR, 43%SA		WATER RUNNING IN FROM THE SIDES
				B.O.H.		HOLE CAVED IN CONTINUALLY
8						

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-15

Exploration Log — TP-16

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N. 3,234,010 E. 755,245
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-16 PERMANENT TP-16
NAME OF DRILLER	D. SULLIVAN
WEATHER	CLOUDY
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	10.5'
SIZE AND TYPE OF BIT	1/4 YARD³ BUCKET
DATUM FOR ELEVATION SHOWN	MSL
TYPE OF EQUIPMENT	BACKHOE, JOHN DEER "3"
TOTAL NO. OF SAMPLES	2
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	16 AUG 78
DATE HOLE COMPLETED	16 AUG 78
EL. TOP OF HOLE	2255
GEOLOGIST	D. JENSEN

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			OL/ML	SILT		DARK BROWN COLOR, 3' BOULDER FOUND.
2						WATER TABLE, MEASURED 17 AUG 78
4				SILTY GRAVELLY SAND		GREY COLOR
6		1		41% SI, 14%GR, 45%SA		
			SM	SILTY GRAVELLY SAND		W/COBBLES
8						
10		2		35% SI, 18%GR, 47%SA		
				B.O.H.		MOST OF THE BOULDERS ARE IN THE TOP 2' OF THE GROUND, FROM 2' TO 10.5' ENCOUNTERED COBBLES.
12						

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-16

Exploration Log — TP-17

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N 3,233,680 E. 754,810
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-17 PERMANENT TP-17
NAME OF DRILLER	D. SULLIVAN
WEATHER	CLOUDY
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	7'
SIZE AND TYPE OF BIT	1/4 YD³ BUCKET
DATUM FOR ELEVATION SHOWN	MSL
TYPE OF EQUIPMENT	BACKHOE, JOHN DEERE "3"
TOTAL NO. OF SAMPLES	2
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	18 AUG 78
DATE HOLE COMPLETED	18 AUG 78
EL. TOP OF HOLE	2247
GEOLOGIST	D. JENSEN

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			OL/PT	PEAT		PEAT, SILT W/VEG
			SM	GRAVELLY SILTY SAND		
2		1	SM	GRAVELLY SILTY SAND		FROZEN, NO VISIBLE ICE CRYSTALS.
4						
6		2		37%SI, 12%GR, 51%SA		
			SM			FROZEN
				B.O.H.		
8						

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-17

Exploration Log — TP-18

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N 3,233,300 E. 753,040
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-18 PERMANENT TP-18
NAME OF DRILLER	D. SULLIVAN
WEATHER	CLEAR
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	13.7'
SIZE AND TYPE OF BIT	1/4 YD³ BUCKET
DATUM FOR ELEVATION SHOWN	MSL
TYPE OF EQUIPMENT	BACKHOE, JOHN DEERE "3"
TOTAL NO. OF SAMPLES	4
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	19 AUG 78
DATE HOLE COMPLETED	19 AUG 78
EL. TOP OF HOLE	2211
GEOLOGIST	D. JENSEN

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			ML	SILT		SILT ML, PT
			SM	GRAVELLY SILTY SAND		FROM APPROX. 2.0' FROZEN DRY
2			SM	SILTY GRAVELLY SAND		DRY FROST. DIGS EASY AND SIDES DO NOT CAVE IN. NO VISIBLE ICE, LOW MC
6		1		48%SI, 11%GR, 41%SA		
8		2	SP	SAND		DRY FROST W/ SILT LENSES, & GRAVEL
10			ML	SILT		FROZEN, LOW MC
		3	SP	SAND W/ SILT LENSES		NO FROST
12		4	ML	SILT		UNFROZEN, DARK GREY COLOR, WATER SEEPING IN AT BOTTOM OF HOLE
14				B.O.H.		

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-18

Exploration Log — TP-19

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N. 3,234,365 E. 755,350
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-19 PERMANENT TP-19
NAME OF DRILLER	D. SULLIVAN
WEATHER	COOL & CLOUDY
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	13.7'
SIZE AND TYPE OF BIT	1/4 YD³ BUCKET
DATUM FOR ELEVATION SHOWN	MSL
TYPE OF EQUIPMENT	BACKHOE, JOHN DEERE "3"
TOTAL NO. OF SAMPLES	2
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	21 AUG 78
DATE HOLE COMPLETED	21 AUG 78
EL. TOP OF HOLE	2302
GEOLOGIST	D. JENSEN

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			OL/ML	SILT		VEG & SILTS
			ML	SILT		LIGHT BROWN W/COBBLES
2		1	SM	SILTY GRAVELLY SAND 35%SI, 15%GR, 50%SA		TAN GREY W/COBBLES
4						
6				SILTY GRAVELLY SAND		GREY COLOR
8						
10						
12		2		35%SI, 15%GR, 50%SA		VERY LITTLE WATER OOZING IN
14				B.O.H.		

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-19

Exploration Log — TP-20

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N. 3,233,370 E. 752,000
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-20 PERMANENT TP-20
NAME OF DRILLER	D. SULLIVAN
WEATHER	CLEAR
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	13.2
SIZE AND TYPE OF BIT	1/4 YD³ BUCKET
DATUM FOR ELEVATION SHOWN	MSL
TYPE OF EQUIPMENT	BACKHOE, JOHN DEERE "3"
TOTAL NO. OF SAMPLES	2
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	21 AUG 1978
DATE HOLE COMPLETED	21 AUG 78
EL. TOP OF HOLE	2265

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			ML	SILT		ORGANIC & SILT
			SM	SAND		ORGANIC STAINED SAND W/ SILT GRAVEL
			SM	SILTY GRAVELLY SAND		
2		1		17%SI, 8%GR, 75%SA		
4			SM	GRAVELLY SILTY SAND		W/COBBLES
6						
8						
10						
12		2				STATIC WATER TABLE MEASURED 22 AUG 78
				B.O.H.		STATIC WATER AT 11.8'
14						

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-20

Exploration Log — TP-21

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT	WATANA DAM
SHEET	1 OF 1
LOCATION (Coordinates or Station)	N. 3,232,670 E. 751,240
DRILLING AGENCY	CORPS OF ENGINEERS
HOLE NO.	FIELD TP-21 PERMANENT TP-21
NAME OF DRILLER	D. SULLIVAN
WEATHER	CLOUDY
TYPE OF HOLE	TEST PIT
TOTAL DEPTH OF HOLE	12'
SIZE AND TYPE OF BIT	1/4 YD³ BUCKET
DATUM FOR ELEVATION SHOWN	MSL
TYPE OF EQUIPMENT	BACKHOE, JOHN DEERE "3"
TOTAL NO. OF SAMPLES	4
TYPE OF SAMPLES	GRAB
DATE HOLE STARTED	23 AUG 78
DATE HOLE COMPLETED	23AUG78
EL. TOP OF HOLE	2229
GEOLOGIST	D. JENSEN

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			PT	ORGANICS		ORGANICS W/SILT & CLAY NO BOULDERS. ONLY COBBLES
2		1/A	CL	GRAVELLY CLAY. 60% FINER THAN NO. 200 LL=27, PL=15, PI=12		LEAN GRAVELLY CLAY NO SAND IN IT. SAMPLE TP-21-A @ 4' AT NATURAL MC. CAN BE ROLLED TO 1/16" NOT BLUE GREY IN COLOR BUT BROWN GREY
4		2	CL	GRAVELLY CLAY		GREY COLOR FROZEN FROM 3.8 4.9 BUT DIGS EASY BELOW 4.9 MAYBE BORDER LINE FROST
8						GREY COLOR
10		3	CL	GRAVELLY CLAY		
12		4		BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM PERMANENT HOLE NO. TP-21

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA D
LOGS: TEST PITS 15 THRU 21

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Project: Watana Dam Site — Sheet 1 of 1
Location: N 3,244,100 E 746,910
Drilling agency: Corps of Engineers
Hole No.: Field TP-6, Permanent TP-6
Weather: P/C 60°
Type of hole: Test pit
Total depth of hole: 5.7'
Datum for elevation shown: MSL
Type of equipment: Melroe Bobcat and Backhoe
Total no. of samples: 2 — **Type of samples:** Grab
Date hole: Started 6/29/78, Completed 6/29/78
El. top of hole: 2110 — **Geologist:** T. Sherman

Depth (ft)	% Water content	Sample No.	Soil legend	Classification	Max size particle	Formation description & remarks
			OL	Organic silts		Vegetation
1			GM	Silty Sandy Gravel		Some Organics
3			GP	Sandy Gravel W/Cobbles	3'	Sand, Medium; Boulders 20-30%
5		1&2		Plus No. 4-62% Minus No. 4-38%		Sand, Coarse
						Bottom of hole (boulders)

NPA Form 19 (Rev) Dec 1955

Project: Watana Dam Site — Permanent Hole No. TP-6

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Project: Watana Dam — Sheet 1 of 1
Location: N 3,240,115 E 745,850
Drilling agency: Corps of Engineers
Hole No.: Field TP-22, Permanent TP-22
Name of driller: D. Sullivan — **Weather:** Clear
Type of hole: Test pit
Total depth of hole: 13'
Size and type of bit: 1/4 yd³ Bucket
Datum for elevation shown: MSL
Type of equipment: Backhoe, John Deere "3"
Total no. of samples: 5 — **Type of samples:** Grab
Date hole: Started 24 Aug 78, Completed 24 Aug 78
El. top of hole: 2174 — **Geologist:** D. Jensen

Depth (ft)	% Water content	Sample No.	Soil legend	Classification	Max size particle	Formation description & remarks
			OL/PT	Peat		
			SM	Silty gravelly sand		1 boulder 4'x6'x2' many boulders in top 2'
2		1				
			SP/SM	Gravelly sand		Clean, some cobbles
4		2		7%Si, 40%Gr, 53%Sa		
6		3	ML	Grey silt		
			SP	Gravelly Sand		Brown Color clean
8		4				
			SM	Silty gravelly sand		Silt occurs as pockets
12		5		28%Si, 22%Gr, 50% Sa		
				B.O.H.		

NPA Form 19 (Rev) Dec 1955

Project: Watana Dam — Permanent Hole No. TP-22

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Project: Watana Dam — Sheet 1 of 1
Location: N 3,240,525 E 745,935
Drilling agency: Corps of Engineers
Hole No.: Field TP-23, Permanent TP-23
Name of driller: D. Sullivan — **Weather:** Clear
Type of hole: Test pit
Total depth of hole: 14'
Size and type of bit: 1/4 yd³ Bucket
Datum for elevation shown: MSL
Type of equipment: Backhoe, John Deere "3"
Total no. of samples: 3 — **Type of samples:** Grab
Date hole: Started 25 Aug 78, Completed 25 Aug 78
El. top of hole: 2160 — **Geologist:** D. Jensen

Depth (ft)	% Water content	Sample No.	Soil legend	Classification	Max size particle	Formation description & remarks
			OL/ML	Silt		Veg & Silt, large boulders
			SM	Silty sand w/gravel		Stained by organics, w/boulders to 3' dia.
2						W/12" Cobbles
4				Sandy gravel		
		1		55% Gr, 6%Si, 39%Sa		
6			SP/GP	Gravelly sand		Isolated silt pockets But few in number.
10			SP	Sand		Clean, uniform graded sand
12		2		4%Si, 2%Gr, 94% Sa		
14		3		Fine sandy silt B.O.H. @ 14'		No gravel

NPA Form 19 (Rev) Dec 1955

Project: Watana Dam — Permanent Hole No. TP-23

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Project: Watana Dam — Sheet 1 of 1
Location: N 3,240,660 E 746,500
Drilling agency: Corps of Engineers
Hole No.: Field TP-24, Permanent TP-24
Name of driller: D. Sullivan — **Weather:** Clear
Type of hole: Test pit
Total depth of hole: 6.6'
Size and type of bit: 1/4 yd³ Bucket
Datum for elevation shown: MSL
Type of equipment: Backhoe, John Deere "3"
Total no. of samples: 1 — **Type of samples:** Grab
Date hole: Started 25 Aug 78, Completed 25 Aug 78
El. top of hole: 2245 — **Geologist:** D. Jensen

Depth (ft)	% Water content	Sample No.	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Sandy Silt		ML vegetation, boulders
			GP/GM	Silty sandy gravel		Many rock fragments (broken) w/cobbles
4		1		52%Gr, 12%Si, 36%Sa		
6			SM	Silty gravelly sand		Angular rock fragments, cobbles, boulders
				Bottom of Hole		

NPA Form 19 (Rev) Dec 1955

Project: Watana Dam — Permanent Hole No. TP-24

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Project: Watana Dam — Sheet 1 of 1
Location: N 3,241,570 E 746,820
Drilling agency: Corps of Engineers
Hole No.: Field TP-25, Permanent TP-25
Name of driller: D. Sullivan — **Weather:** Clear
Type of hole: Test pit
Total depth of hole: 7.4'
Size and type of bit: 1/4 yd³ Bucket
Datum for elevation shown: MSL
Type of equipment: Backhoe, John Deere "3"
Total no. of samples: 2 — **Type of samples:** Grab
Date hole: Started 25 Aug 78, Completed 25 Aug 78
El. top of hole: 2190 — **Geologist:** D. Jensen

Depth (ft)	% Water content	Sample No.	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Silt		Silt, veg. boulders
2			SM	Very fine sand		Very fine sand w/silt and gravel and cobbles
		1				
4			GP/GM	Silty sandy gravel		W/boulders
6		2		8%Si, 53%Gr, 39%Sa		
			SP	Gravelly sand		W/boulders
8				Bottom of Hole		

NPA Form 19 (Rev) Dec 1955

Project: Watana Dam — Permanent Hole No. TP-25

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Project: Watana Dam — Sheet 1 of 1
Location: N 3,242,210 E 747,470
Drilling agency: Corps of Engineers
Hole No.: Field TP-26, Permanent TP-26
Name of driller: D. Sullivan — **Weather:** Clear
Type of hole: Test pit
Total depth of hole: 13.5'
Size and type of bit: 1/4 yd³ Bucket
Datum for elevation shown: MSL
Date hole: Started 25 Aug 78, Completed 25 Aug 78
El. top of hole: 2232

Depth (ft)	% Water content	Sample No.	Soil legend	Classification	Max size particle	Formation description & remarks
			ML	Silt		Veg. boulders, cobblers
2		1	SM	Silty gravelly sand 48% Gr. 15% Sa, 37%Sa		W/Cobbles
			SM	Silty gravelly sand		W/Cobbles
8		2		20%Si, 23%Gr, 57%Sa		
14				Bottom of Hole		

NPA Form 19 (Rev) Dec 1955

Project: Watana Dam — Permanent Hole No. TP-26

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA F
LOGS: TEST PITS 6 AND 22 THRU 26

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location: N 3,230,477 E 745,110 — Drilling agency: Corps of Engineers
Hole No.: Field AH-1, Permanent AP-1 — Name of driller: K. MITCHELL — Weather: LIGHT RAIN
Type of hole: Auger hole — Total depth of hole: 15'
Size and type of bit: 4" FLIGHT AUGER — Datum for elevation shown: MSL — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: DRIVE — Started: 15 JUN 78
El. top of hole: 2202 — Geologist: A. MACLEOD

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
1–2				FROST AT 1-2 FT.
4	1			SAMPLE #1 AT 3.5 - 5' BROWN, WET PERCHED WATERTABLE 3-4" COBBLES
8		SM SP	GRAVELLY SAND	SUB-ANGULAR GRAVELS, BROWN, WET
10	2			SAMPLE #2 AT 8.5-10 BROWN, DAMP
10–15 (5')	3			SAMPLE # 3 AT 13.5-15' BROWN WET, SOME GRAVELS
15			BOTTOM OF HOLE	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-1

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location: N 3,230,326 E 745,402 — Drilling agency: Corps of Engineers
Hole No.: Field AH-2, Permanent AP-2 — Name of driller: K. MITCHELL
Type of hole: Auger hole — Total depth of hole: 11.0 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 1 — Type of samples: GRAB — Started: 20 JUN 78
El. top of hole: 2200 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
0		OL/ML	ORGANICS	
4		SM	SILTY GRAVELLY SAND	GREY COLOR, BOULDERS, VERY HARD DRILLING, SATURATED
6	1		17%GR, 31%SI, 52%SA	SAMPLE #1 FROM 5' TO 6.5', SATURATED, CAME OUT AS A SLURRY, VERY COLD
10		GM	SANDY SILTY GRAVEL	BOULDERS, HARD DRILLING, GREY COLOR, SET PIEZOMETER AT BOTTOM OF HOLE
11			BOTTOM OF HOLE	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-2

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 2
Location: N 3,233,699 E 752,434 — Drilling agency: Corps of Engineers
Hole No.: Field AH-3, Permanent AP-3 — Name of driller: K. MITCHELL
Type of hole: Auger hole — Total depth of hole: 18.0 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Started: 20-21 JUN 78
El. top of hole: 2279 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
0		OL ML	SURFACE SILT	WITH ORGANICS
2–4		SM	SILTY SAND	COBBLES, GRAVEL, MOIST BUT NOT SATURATED, GREY
4	1		7%GR, 46%SI, 47%SA	SAMPLE #1 AT 4'
6		SM	SILTY SAND	COBBLES, GRAVEL, GREY
10		SM	SILTY SAND	COBBLES, SOME GREAVEL, GREY
13	2		11%GR, 37%SI, 52%SA	SAMPLE #2 AT 13'
14		SM	SILTY SAND	HUNG UP ON COBBLES

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-3

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 2
Hole No.: Field AH-3, Permanent AP-3 — Name of driller: K. MITCHELL
Total depth of hole: 18.0 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Started: 20-21 JUN 78
El. top of hole: 2279 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
14–16	3	CL	SILTY SANDY CLAY 5%GR, 40%SA, MINUS NO. 200-55% LL 25.6, PI 9.7	DARK GREY SAMPLE #3 AT 16' AT BOTTOM OF HOLE, ON TOP OF ROCK
18			BOTTOM OF HOLE	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-3

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location: N 3,232,742 E 752,451 — Drilling agency: Corps of Engineers
Hole No.: Field AH-4, Permanent AP-4 — Name of driller: K. MITCHELL
Type of hole: Auger hole — Total depth of hole: 3.5 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: NONE — Type of samples: GRAB — Started: 21 JUN 78
El. top of hole: 2140 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
0		ML	SILT	WITH ORGANICS AND ROOTS
2		GM	SILTY GRAVEL	BOULDERS, EXTREMELY DIFFICULT TO DRILL. REFULAL AT 3.5'
3.5			BOTTOM OF HOLE	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-4

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 2
Location: N 3,282,820 E 752,591 — Drilling agency: Corps of Engineers
Hole No.: Field AH-5, Permanent AP-5 — Name of driller: K. MITCHELL
Type of hole: Auger hole — Total depth of hole: 27.5 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Started: 21 JUN 78
El. top of hole: 2205 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
0		SM	SAND	ORGANIC, STAINED
2		SM	SILTY GRAVELLY SAND	GREY, TAN
3.5	1		11%GR, 41%SI, 48%SA	SAMPLE #1 AT 3.5' BOULDERS ENCOUNTERED AT 4'
6		GM SM	SANDY SILTY GRAVEL	AUGER DOES NOT GIVE A GOOD GRAVEL SAMPLE
10–12		SM	SILTY GRAVELLY SAND	DARKER GREY COLOR, MOIST
14		SM	SILTY GRAVELLY SAND	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-5

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 2
Hole No.: Field AH-5, Permanent AP-5 — Name of driller: K. MITCHELL
Type of hole: Auger hole — Total depth of hole: 27.5 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Started: 21 JUN 78
El. top of hole: 2205 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
14–16	2	CL	SANDY CLAY 29%SA MINUS NO. 200 71% LL 25.8, PI 7.9	DARK GREY, ALMOST PLASTIC SAMPLE #2 AT 15'
18		ML	SANDY SILT	WITH GRAVEL, MOIST, BROWN
20–22		SM	SILTY GRAVELLY SAND	BROWN-GREY, VERY COMPACT WITH MORE GRAVEL. HIT LARGE BOULDER/COBBLE AT 19.5'
24		SM	SILTY GRAVELLY SAND	MOIST
26	3	SM	SILTY GRAVELLY SAND 11%GR, 41%SI, 48%SA LL 19.2, PI 0.9	MOIST, HARD TO DRILL, TIGHT AND COMPACT SAMPLE #3 AT 26'
28			BOTTOM OF HOLE	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-5

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 2
Location: N 3,233,022 E 753,170 — Drilling agency: Corps of Engineers
Hole No.: Field AH-6, Permanent AP-6 — Name of driller: K. MITCHELL
Type of hole: Auger hole — Total depth of hole: 27.0 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 6 — Type of samples: GRAB — Started: 21 JUN 78
El. top of hole: 2219 — Geologist: D. JENSEN

Depth (feet)	Sample No.	Soil Legend	Classification	Formation Description & Remarks
0		OL	VEGETATION	
2		SM	SILTY SAND	WITH GRAVEL, LIGHT TAN
3	1		49%SI, 51%SA	SAMPLE #1 AT 3'
4		SM	SILTY SAND	LIGHT TAN
6–8		ML	GRAVELLY SANDY SILT	GREY BROWN, MOIST
10–12		ML	SANDY SILT	DARK GREY, MOIST, FEW ROCKS, DRILLS GOOD
13	2	ML	3%GR, 44%SA, 53%SI SANDY SILT	WITH FEW ROCKS, MORE MOIST THAN ABOVE. SAMPLE #2 AT 13' MOIST, ALMOST PLASTIC, DRILLS WELL, DARK GREY
14		ML	SANDY SILT	

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-6

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA D
LOGS: AUGER HOLES 1 THRU 6 (CONT.)
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 2
Location (Coordinates or Station): N — E —
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-6, Permanent AP-6
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 27.0 FT
Size and Type of Bit: 4' AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 6
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 21 JUN 78; Completed: —
El. Top of Hole: 2219
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
14			ML	SANDY SILT		SLURRY, COMPLETELY SATURATED
		3		25%SA, MINUS No. 200 75% LL 23.4, PI 9.0		SAMPLE #3 AT 15' MC = 20.3%
16			CL	SILTY CLAY		DENSE, DARK GREY
18		4	CL	35%SA, MINUS No. 200 65% LL 34.5, PI 13.7 SILTY CLAY		SAMPLE #4 AT 18.5' DENSE, NO ROCKS, BLUE-GREY
20–22		5	CL	SILTY CLAY 13%SA, MINUS No. 200 87% LL 30.0, PI 13.7		ALMOST PLASTIC, WITH GRAVEL, BLUE-GREY SAMPLE #5 AT 22'
24–26		6	CL	SANDY SILTY CLAY 7%GR, 40%SA MINUS NO. 200 53% LL 23.5, PI 11.0		BLUE GREY, MOIST, SOME GRAVEL SAMPLE #6 AT 27'
28				BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-6

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location (Coordinates or Station): N 3,234,241 E 755,625
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-7, Permanent AP-7
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 7.0 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: NONE
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 21 JUN 78; Completed: —
El. Top of Hole: 2255
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
0			OLML	SILT-VEGETATION		
2			SM	SILTY GRAVELLY SAND		EXTREMELY HARD TO DRILL, GREY, FROZEN
4–6			SM	SILTY SAND		WITH COBBLES, FROZEN, DRY FROST. HIT BOUDER AT 7.0'
7				BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-7

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 5
Location (Coordinates or Station): N 3,234,092 E 755,790
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-8, Permanent AP-8
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 58.3 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 8
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 23 JUNE 1978; Completed: —
El. Top of Hole: 2245
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
0			DLML	VEGETATION		
2		1	SM	SILTY SAND 9%GR, 39%SI, 52%SA		GREY SAMPLE #1 AT 3'
4			SM	SILTY SAND		WITH GRAVEL, GREY
6		2	CL	SANDY SILTY CLAY 5%GR, 35%SA MINUS No. 200 60% LL 28.6 PI 11.9		GREY + BLUE SAMPLE #2 AT 7'
8		3		9%GR, 30%SA MINUS No. 200 61% LL 29.3, PI 15.0		SAMPLE #3 AT 9'
10–12			CL	SANDY SILTY CLAY		BLUE-GREY, FEELS PLASTIC NOT FROZEN
14		4				SAMPLE #4 AT 14'

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-8

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 5
Location (Coordinates or Station): N — E —
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-8, Permanent AP-8
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 58.3 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 8
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 23 JUNE 1978; Completed: —
El. Top of Hole: 2245
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
14–18		4	CL	25%GR, 22%SA MINUS No. 200 53% GRAVELLY SANDY CLAY SILTY CLAY		SAMPLE #4 AT 14' WITH GRAVEL, FROZEN WITH ICE CRYSTALS TO 1/2" SATURATED
19			CL	SANDY SILTY CLAY		WITH GRAVEL, FROZEN
20–22		5		5%GR, 24%SA MINUS No. 200 71% LL 28.6, PI 13.2		SAMPLE #5 AT 20' MC = 23%
24–26		6	CL-ML	SILTY CLAY 25%SA, MINUS No. 200 75% LL 27.8, PI 7.6		FROZEN, ICE CRYSTALS 1/4" TO 1/2" MAX SAMPLE # 6 AT 25' MC = 40%
28						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-8

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 3 of 5
Location (Coordinates or Station): N — E —
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-8, Permanent AP-8
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 58.3 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 8
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 23 JUNE 1978; Completed: —
El. Top of Hole: 2245
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
28			CL-ML	SILTY CLAY		FROZEN, ICE CRYSTALS TO 1/2" MAX
30–32		7	CL-ML	23%SA, MINUS No. 200 77% LL 26.2, PI 9.1, SILTY CLAY		SAMPLE #7 AT 30' MC = 31.3% BLUE GREY, MIGHT BE SILT ONLY. VERY SATURATED WITH ICE. DILLER REPORTS ICE LENSES IN DRILLING
34–36			CL-ML	SILTY CLAY		BLUE GREY, FROZEN ICE CRYSTALS
38–42			CL ML	SILTY CLAY		FROZEN, BLUE GREY, SATURATED WHEN THAWED

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-8

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 4 of 5
Location (Coordinates or Station): N — E —
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-8, Permanent AP-8
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 58.3 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 8
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 23 JUNE 1978; Completed: —
El. Top of Hole: 2245
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
42–52			CL-ML	SILTY CLAY		FROZEN, BLUE GREY, SATURATED WHEN THAWED
54–56			ML-CL	SILTY CLAY		FROZEN, SATURATED

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-8

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 5 of 5
Location (Coordinates or Station): N — E —
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-8, Permanent AP-8
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 58.3 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 8
Type of Samples: GRABE
Depth to Ground-Water: —
Date Hole Started: 23 JUNE 1978; Completed: —
El. Top of Hole: 2245
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
56–58		8	CL	SILTY CLAY MINUS No. 200 99% LL 35.4, PI 13.9		FROZEN, SATURATED SAMPLE #8 AT 58' MC = 28%
58.3				BOTTOM OF HOLE		SET A 3/4" PIPE IN THE HOLE FOR FROST MEASUREMENTS 4.7' STICK UP, CAPS ON BOTH ENDS
60						

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-8

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 2
Location (Coordinates or Station): N 3,234,460 E 755,514
Drilling Agency: CORPS OF ENGINEERS [X]; OTHER [ ]
Hole No.: Field AH-9, Permanent AP-9
Name of Driller: K. MITCHELL
Weather: —
Type of Hole: Test Pit [ ]; Auger Hole [X]; Churn Drill [ ]
Depth to: —; Depth Drilled Into: —; Total Depth of Hole: 18.0 FT
Size and Type of Bit: 4" AUGER
Datum for Elevation Shown: TBM [ ]; MSL [ ]
Type of Equipment: B-36
Total No. of Samples: 3
Type of Samples: GRAB
Depth to Ground-Water: —
Date Hole Started: 23 JUNE 1978; Completed: —
El. Top of Hole: 2293
Geologist: D. JENSEN
Chief, Geology Section: —
Chief, Foundations & Materials Branch: —; Date: —

Depth Feet	% Water Content	Sample No	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
0			OLML	SILT-VEGETATION		FROZEN
2		1	SM	SILTY GRAVELLY SAND 7%GR, 37%SI, 56%SA		LIGHT BROWN, FROZEN, SOME COBBLES SAMPLE #1 AT 3.5'
4–8			SM	SILTY GRAVELLY SAND		
10–14		2	SM	SILTY GRAVELLY SAND		DRILLER SAYS FROZEN SAMPLE #2 AT 14' DOESN'T APPEAR SATURATED. VERY COLD DRILLED UP IN LITTLE BALLS. BROWISH TAN

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO AP-9

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA D
LOGS: AUGER HOLES 6 (CONT.) THRU 9 (CONT)

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EXPLORATION LOG — AP-9 (Sheet 2 of 2)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 2
Location (Coordinates or Station): N — E —
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-9, Permanent AP-9
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [XXX] Churn Drill [ ]
Depth to: — Depth drilled into: — Total depth of hole: 18.0 FT
Size and type of bit: 4" AUGER — Datum for elevation shown: [ ] TBM [ ] MSL — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Depth to ground-water: — Date hole started: 23 JUNE 1978, completed:
El. top of hole: 2293 — Geologist: D. JENSEN — Chief, Geology Section: — Chief, Foundations & Materials Branch: — Date:

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
14		2		15%GR, 33%SI, 52%SA; LL 18.9, PI 4.0		
16			SM-SC	SILTY GRAVELLY SAND		FROZEN
		3		5%GR, 43%SI, 52%SA; LL 11.8, PI 5.2		SAMPLE #3 AT 17'
18				BOTTOM OF HOLE		SET 3/4" GALV. PIPE IN HOLE CAPS BOTH ENDS. 3' STICK UP

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-9

EXPLORATION LOG — AP-10 (Sheet 1 of 1)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location: N 3,235,158 E 756,514
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-10, Permanent AP-10
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [XXXX] Churn Drill [ ]
Total depth of hole: 15.0 FT
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Date hole started: 23 JUNE 1978
El. top of hole: 2319 — Geologist: D. JENSEN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	ORGANIC SILT		BROWN WITH VEGETATION
2			SM	SILTY GRAVELLY SAND		LIGHT TAN
4		1		7%GR, 31%SI, 62%SA		SAMPLE #1 AT 3.5'
6			SM	SILTY GRAVELLY SAND		LITTLE SILT, MOIST, TAN GREY
8		2		17%GR, 17%SI, 66%SA		SAMPLE #2 AT 8'
10			SM	SILTY GRAVELLY SAND		CLEAN MOIST
5 FT		3		25%GR, 18%SI, 57%SA		SAMPLE #3 AT 13'
15						HIT BOULDER AT 15'

BOTTOM OF HOLE
NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-10

EXPLORATION LOG — AP-11 (Sheet 1 of 2)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 2
Location: N 3,235,094. E. 757,045.
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-11, Permanent AP-11
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [X] Churn Drill [ ]
Total depth of hole: 25'
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 4 — Type of samples: GRAB — Depth to ground-water: NE — Date hole started: 28 JUN 78
El. top of hole: 2309 — Geologist: W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		WITH ORGANICS, VEGETATION
2–6			SP SM	SILTY GRAVELLY SAND		BROWN, GRAVELS ROUNDED MOIST
8		1				SAMPLE # 1 AT 8.1 FT.
10			SM	SILTY SAND		MOIST, WET, BROWN
12		2	ML	SANDY SILT		SAMPLE #2 AT 13.0 FT FROZEN, ICE LENSES AT 12' LENSES OF ORGANIC CLAY
14						

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-11

EXPLORATION LOG — AP-11 (Sheet 2 of 2)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 2
Location: N 3,235,094. E 757,045.
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-11, Permanent AP-11
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [X] Churn Drill [ ]
Total depth of hole: 25'
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 4 — Type of samples: GRAB — Depth to ground-water: NE — Date hole started: 28 JUN 78
El. top of hole: 2309 — Geologist: W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
16			ML	SANDY CLAYEY SILT		FROZEN, MARGINALLY PLASTIC WET, SATURATED WHEN THAWED. OCCASIONAL GRAVELS.
18		3				SAMPLE #3 AT 18.1'
20			GM	GRAVELLY, SANDY CLAYEY SILT		FROZEN, BROWN, WET
22–24		4				SAMPLE # 4 AT 23 - 25'
26				BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-11

EXPLORATION LOG — AP-12 (Sheet 1 of 1)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location: N 3,235,414. E. 757,404.
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-12, Permanent AP-12
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [X] Churn Drill [ ]
Total depth of hole: 14.1'
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 3 — Type of samples: GRAB — Depth to ground-water: NE — Date hole started: 28 JUN 78
El. top of hole: 2303 — Geologist: W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		W/ ROOTS, ORGANICS, BROWN
2			ML OL	CLAYEY SILT		W/ ORGANICS, BROWN FROZEN AT 2'
4		1	SM	GRAVELLY SILTY SAND		FROZEN, BROWN SAMPLE # 1 AT 3.5'
6			SM	SILTY SAND		FROZEN, BROWN, SOME ORGANIC ZONES
8		2				SAMPLE # 2 AT 7.5'
10			SM	GRAVELLY, SILTY, SAND		FROZEN, BROWN, TAN, HIT BOULDER AT 14.1'
14		3				SAMPLE # 3 AT 13.5' - 14.1'

BOTTOM OF HOLE
NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-12

EXPLORATION LOG — AP-13 (Sheet 2 of 2)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 2 of 2
Location: N. 3,235,885. E. 757,509.
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-13, Permanent AP-13
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [X] Churn Drill [ ]
Total depth of hole: 22'
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 4 — Type of samples: GRAB — Depth to ground-water: NE — Date hole started: 28 JUN 78
El. top of hole: 2306 — Geologist: W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
16			SP	SAND		FROZEN, ISOLATED PEBBLES CLEAN
18		3				SAMPLE # 3 AT 18.2 - 19'
20			SP	SAND		FROZEN WITH ISOLATED COBBLES, CLEAN
22		4				SAMPLE #4 AT 21 - 22'
				BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-13

EXPLORATION LOG — AP-13 (Sheet 1 of 2)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 2
Location: N. 3,235,885. E. 757,509.
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-13, Permanent AP-13
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [X] Churn Drill [ ]
Total depth of hole: 22'
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 4 — Type of samples: GRAB — Depth to ground-water: NE — Date hole started: 28 JUN 78
El. top of hole: 2306 — Geologist: W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		W/ ORGANICS
			OL ML			W/ ORGANICS, WET, BROWN
2–4			SM	GRAVELLY SILTY SAND		FROZEN AT 3', BROWN, TAN
6			ML	SANDY, CLAYEY SILT		FROZEN, ISOLATED PEBBLES TAN, PLASTIC, HARD DRILLING
8		1				SAMPLE # 1 AT 7.5' - 8.2'
14		2	SP	SAND		FROZEN, CLEAN, ISOLATED PEBBLES/ SAMPLE #2 AT 13-14'

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-13

EXPLORATION LOG — AP-14 (Sheet 1 of 1)

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

Project: WATANA DAM — Sheet 1 of 1
Location: N 3,236,005. E 757,565.
Drilling Agency: [X] Corps of Engineers [ ] Other
Hole No.: Field AH-14, Permanent AP-14
Name of Driller: K. MITCHELL — Weather:
Type of Hole: Test Pit [ ] Auger Hole [X] Churn Drill [ ]
Total depth of hole: 11'
Size and type of bit: 4" AUGER — Type of equipment: B-36
Total no. of samples: 2 — Type of samples: GRAB — Depth to ground-water: NE — Date hole started: 28 JUN 78
El. top of hole: 2307 — Geologist: W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		W/ ORGANICS, VEGETATION
			OL ML	SILT		W/ ORGANICS, DARK BROWN WET
2			ML	CLAYEY SILT		W/ ORGANICS, BROWN
6			SM	GRAVELLY, SILTY SAND		BROWN, TAN, DAMP
8		1				SAMPLE # 1 AT 8 - 8.5'
10		2	SP	GRAVELLY SAND		CLEAN, MOIST, BROWN, TAN SAMPLE # 2 AT 10 - 10.5'
				B.O.H.		

NPA FORM 19 (REV) DEC 1959
PROJECT WATANA DAM — PERMANENT HOLE NO. AP-14

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA D
LOGS: AUGER HOLES 9 (CONT.) THRU 14

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

DEPARTMENT OF THE ARMY — NORTH PACIFIC DIVISION — U.S. ARMY ENGINEER DISTRICT, ALASKA — EXPLORATION LOG

Hole AH-15 / AP-15

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,236,240. E 757,639.
Drilling agency	[X] CORPS OF ENGINEERS
Hole no.	Field AH-15, Permanent AP-15
Name of driller	K. MITCHELL
Type of hole	AUGER HOLE [X]
Total depth of hole	9.5'
Size and type of bit	4" AUGER
Type of equipment	B-36
Total no. of samples	1
Type of samples	GRAB
Depth to ground-water	NE
Date hole started	28 JUN 78
El. top of hole	2308
Geologist	W. FRYE

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	SILT		W/ ORGANICS AND ROOTS
			ML	SILT		W/ SOME GRAVEL, BROWN FROZEN AT 1.5'
		1	SM	GRAVELLY SILTY SAND		TAN, GREY, FROZEN; SAMPLE # 1 AT 7-8'
				BOTTOM OF HOLE		

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-15

Hole AH-16 / AP-16

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,236,881 E 758,027
Drilling agency	[X] CORPS OF ENGINEERS
Hole no.	Field AH-16, Permanent AP-16
Name of driller	D. SULLIVAN
Weather	P/C 60° F
Type of hole	AUGER HOLE [XXX]
Total depth of hole	3.5'
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Type of samples	GRAB
Date hole started	6/13/78
Date hole completed	6/13/78
El. top of hole	2311
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
				VEGETATION		TUNDRA
			ML	SANDY SILT W/ ORGANICS		FINE, BROWN
						BOTTOM OF HOLE (HIT BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-16

Hole AH-17 / AP-17

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,238,045 E 756,318
Drilling agency	[XX] CORPS OF ENGINEERS
Hole no.	Field AH-17, Permanent AP-17
Name of driller	D. SULLIVAN
Weather	P/C 60°F
Type of hole	AUGER HOLE [XX]
Total depth of hole	12.5
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Date hole started	6/13/78
Date hole completed	6/13/78
El. top of hole	2405
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
				VEGETATION		
			ML	SILT		GREYISH BROWN
			GM	SILTY, SANDY GRAVELS		-3/4" ROUNDED GRAVEL NOTE: PROBABLY FROZEN @ 9'
						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-17

Hole AH-18 / AP-18

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,237,346 E 755,487
Drilling agency	[XX] CORPS OF ENGINEERS
Hole no.	Field AH-18, Permanent AP-18
Name of driller	D. SULLIVAN
Weather	P/C 60°F
Type of hole	AUGER HOLE [XXX]
Total depth of hole	16.0'
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Date hole started	6/13/78
Date hole completed	6/13/78
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	ORGANIC SILT		VEGETATION TOP 0.3'
			GM	SILTY, SANDY GRAVELS		MEDIUM GRAY ROCK @ 5'
			GM	SILTY, SANDY GRAVELS		FINE; WATER TABLE @ 14'
						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-18

Hole AH-19 / AP-19

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,236,950 E 755,254
Drilling agency	[XX] CORPS OF ENGINEERS
Hole no.	Field AH-19, Permanent AP-19
Name of driller	D. SULLIVAN
Weather	P/C 60°F
Type of hole	AUGER HOLE [XX]
Total depth of hole	19.3
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Date hole started	6/13/78
Date hole completed	6/13/78
El. top of hole	2375
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	ORGANIC SILT		VEGETATION TOP 0.3'
			GM	SILTY SANDY GRAVEL		FINE, GRAY; ROCKY @ 4'
			ML	SANDY SILT		FINE, SATURATED
			SM	SILTY SAND		FINE, LIGHT BROWN, DAMP BUT NOT SATURATED
			GM	SILTY SANDY GRAVEL		GRAY
						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-19

Hole AH-20 / AP-20

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,236,325 E 755,158
Drilling agency	[XX] CORPS OF ENGINEERS
Hole no.	Field AH-20, Permanent AP-20
Name of driller	D. SULLIVAN
Weather	P/C 60°
Type of hole	AUGER HOLE [XXX]
Total depth of hole	17
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Date hole started	6/15/78
Date hole completed	6/15/78
El. top of hole	2355
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	ORGANIC SILT		0.5' VEGETATION TOP 0.2'
			GM	SILTY, SANDY GRAVEL		GRAY
						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-20

Hole AH-21 / AP-21

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,235,352 E 755,176
Drilling agency	CORPS OF ENGINEERS
Hole no.	Field AH-21, Permanent AP-21
Name of driller	D. SULLIVAN
Weather	P/C 60°F
Type of hole	AUGER HOLE [XX]
Total depth of hole	19.3
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Date hole started	6/15/78
Date hole completed	6/15/78
El. top of hole	2344
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			SM	SILTY SAND		VEGETATION TOP 0.1'
			SP	SILTY, GRAVELLY, SAND		GREY, VERY LITTLE SILT SATURATED @ 13'
			SM	SILTY SAND		W/ SOME GRAVEL
			CH	CLAY		DARK GRAY FROZEN @ 15'
			SM	SILTY SAND		W/ SOME GRAVEL
						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AH-21

Hole AH-22 / AP-22

Field	Entry
Project	WATANA DAM
Sheet	1 of 1
Location	N 3,234,632 - E 754,641
Drilling agency	CORPS OF ENGINEERS
Hole no.	Field AH-22, Permanent AP-22
Name of driller	D. SULLIVAN
Weather	P/C 60°F
Type of hole	AUGER HOLE [XX]
Total depth of hole	13.4
Size and type of bit	4" FLITE AUGER
Datum for elevation shown	[XX] MSL
Type of equipment	B-36 MOBILE
Total no. of samples	NONE
Date hole started	6/13/78
Date hole completed	6/13/78
El. top of hole	2323
Geologist	T. SHERMAN

Depth Feet	% Water Content	Sample No.	Soil Legend	Classification	Max Size Particle	Formation Description & Remarks
			OL	ORGANIC SILT		BROWN VEGETATION TOP 0.3'
			GM	SILTY SANDY GRAVEL		BROWN ROCKY @ 5'; SATURATED @ 10'
						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959 — PROJECT WATANA DAM — PERMANENT HOLE NO. AP-22

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA D
LOGS: AUGER HOLES 15 THRU 22

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT: WATANA DAM — SHEET 1 OF 1
LOCATION (Coordinates or Station): N 3,233,766 E 753,415
DRILLING AGENCY: [X] CORPS OF ENGINEERS [ ] OTHER
HOLE NO.: FIELD AH-23 PERMANENT AP-23
NAME OF DRILLER: D. SULLIVAN
WEATHER: P/C 60°F
TYPE OF HOLE: TEST PIT [ ] AUGER HOLE [X] CHURN DRILL [ ]
DEPTH TO: — DEPTH DRILLED INTO: — TOTAL DEPTH OF HOLE: 9.5'
SIZE AND TYPE OF BIT: 4" FLITE AUGER
DATUM FOR ELEVATION SHOWN: [ ] TBM [ ] MSL
TYPE OF EQUIPMENT: B-36 MOBILE
TOTAL NO. OF SAMPLES: NONE
TYPE OF SAMPLES:
DEPTH TO GROUND-WATER:
DATE HOLE STARTED: 6/15/78 COMPLETED: 6/15/78
EL. TOP OF HOLE: 2273
Geologist: T. SHERMAN
Chief, Geology Section:
Chief, Foundations & Materials Branch: Date:

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
						VEGETATION TOP 0.2'
2			SM	SILTY SAND		SOME ORGANICS
4						
6			SM	SILTY SAND, GRAVELLY		CLEAN W/ SOME ANGULAR GRAVEL
8						ORGANICS @ 8' -2" ROUNDED GRAVEL @ 9.5'
10						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959

PROJECT: WATANA DAM PERMANENT HOLE NO: AP-23

DEPARTMENT OF THE ARMY
NORTH PACIFIC DIVISION
U.S. ARMY ENGINEER DISTRICT, ALASKA
EXPLORATION LOG

PROJECT: WATANA DAM — SHEET 1 OF 1
LOCATION (Coordinates or Station): N 3,233,770 E 753,409
DRILLING AGENCY: [X] CORPS OF ENGINEERS [ ] OTHER
HOLE NO.: FIELD AH-24 PERMANENT AP-24
NAME OF DRILLER: D. SULLIVAN
WEATHER: P/C 60°F
TYPE OF HOLE: TEST PIT [ ] AUGER HOLE [X] CHURN DRILL [ ]
DEPTH TO: — DEPTH DRILLED INTO: — TOTAL DEPTH OF HOLE: 15.0'
SIZE AND TYPE OF BIT: 4" FLITE AUGER
DATUM FOR ELEVATION SHOWN: [ ] TBM [X] MSL
TYPE OF EQUIPMENT: B-36 MOBILE
TOTAL NO. OF SAMPLES: NONE
TYPE OF SAMPLES:
DEPTH TO GROUND-WATER:
DATE HOLE STARTED: 6/15/78 COMPLETED: 6/15/78
EL. TOP OF HOLE: 2255
Geologist: T. SHERMAN
Chief, Geology Section:
Chief, Foundations & Materials Branch: Date:

DEPTH FEET	% WATER CONTENT	SAMPLE NO.	SOIL LEGEND	CLASSIFICATION	MAX SIZE PARTICLE	FORMATION DESCRIPTION & REMARKS
			SM	SILTY SAND		SOME ORGANICS
4						
8			SM	SILTY SAND, GRAVELLY		SOME GRAVELS FROZEN @ 11.5'
12						
16						BOTTOM OF HOLE (BOULDERS)

NPA FORM 19 (REV) DEC 1959

PROJECT: WATANA DAM PERMANENT HOLE NO: AP-24

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
BORROW AREA D
LOGS: AUGER HOLES 23 THRU 24

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

SUMMARY LOG — HOLE NO. DH-1 (SHEET 1 OF 2)

SUMMARY LOG HOLE NO. DH-1	N 3226585 / E 744341	SHEET 1 OF 2	SURFACE ELEV. 1459
PROJECT Watana Dam	DRILL DATES: START 28 Mar 78	COMP. 2 Apr 78	
DEPTH OF HOLE 122.8'	DEPTH OF OVERBURDEN 43.8'	DIAM. OF HOLE NCQ	
ROCK DRILLED 79.0'	CORE RECOVERED 79.0'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -----	COMPILED BY, DATE: Sat 10 Oct 78	
DISTANCES: VERTICAL, 122.8'; HORIZONTAL, -----			

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	0	Overburden: Gravels Cobbles and Boulders in Sand Matrix.		Tricone Bit 0.0' To 11.5' Core Drilled 11.5' To Bottom
	10	Boulders To 3' In Diameter 11' To 17'		4 Inch CSG To 13.6'
	20	Cobbles To 0.7' With Minor Clay On Surfaces, 21' To 24' Diorite Boulder 24.2' - 27.9'		
	30			
1415	40	Top Of Rock		43.8'
	50	Quartz Diorite, Soft To Hard, Medium Grained, Moderately Weathered (Highly Weathered In Shears), Highly Fractured, Light Gray. Clay Gouge And Slickensides Common.		NW Casing To 47.5' Fracture Spacing 44'-60' <0.1' To 0.8' 1 58.6'
1400	60			
	70	Diorite, Hard, Medium Grained, Lightly Weathered (Moderately Weathered On Fractures), Moderately To Lightly Fractured, Light Gray. Iron Stain In Fractures Common.		K=0.48 Fracture Spacing 60'-80' 0.1' To 1.6' 1.6 2 1
	80	Fine, Disseminated Pyrite Present Throughout.		K=2.52
	90			Fracture Spacing 80'-100' <0.1' To 0.9' 2 3
	100	Shear Zone 96.1' To 105.1'		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-1

SUMMARY LOG — HOLE NO. DH-1 (SHEET 2 OF 2)

SUMMARY LOG HOLE NO. DH-1	N 3226585 / E 744341	SHEET 2 OF 2	SURFACE ELEV. 1459
PROJECT Watana Dam	DRILL DATES: START 28 Mar 78	COMP. 2 Apr 78	
DEPTH OF HOLE 122.8'	DEPTH OF OVERBURDEN 43.8'	DIAM. OF HOLE NCQ	
ROCK DRILLED 79.0'	CORE RECOVERED 79.0'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -----	COMPILED BY, DATE: Sat 10 Oct 78	
DISTANCES: VERTICAL, 122.8'; HORIZONTAL, ------			

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Shear Zone 96.1' To 105.1' Rock Grades Between Diorite And Granodiorite 117.1' To Bottom.		Fracture Spacing 100'-110' 0.1' To 0.5'
	110	Gouge 111.6' Porphoritic Andesite Inclusion 116.8' To 117.1'		K=1.98 Fracture Spacing 110'-122.8' 0.1' To 2.5'
1336	120			122.8' 3
	130	Bottom Of Hole Depth of Hole 122.8' Thickness of Over-Burden 43.8' Rock Cored 79.0' Core Recovered 79.0' % Core Recovered 100		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-1

SUMMARY LOG — HOLE NO. DH-2 (SHEET 1 OF 1)

SUMMARY LOG HOLE NO. DH-2	N 3226585 / E 744341	SHEET 1 OF 1	SURFACE ELEV. 1463
PROJECT Watana Dam	DRILL DATES: START 23 Mar 78	COMP. 12 Apr 78	
DEPTH OF HOLE 29.0'	DEPTH OF OVERBURDEN 29.0'	DIAM. OF HOLE NCQ	
ROCK DRILLED 0.0'	CORE RECOVERED 0.0'	% RECOVERY N/A	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -----	COMPILED BY, DATE: Sat 10 Oct 78	
DISTANCES: VERTICAL, 29.0'; HORIZONTAL, ------			

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	0	Overburden: Boulders, Cobbles And Gravel With Minor Sand.		Hole Attempted Four Times; Maximum Advance Was 29.0'
	10			
	20			
1434	30	Bottom Of Hole Depth Of Hole 29.0' Thickness of Overburden 29.0' Rock Cored 0.0' Core Recovered N/A		29.0'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-2

SUMMARY LOG — HOLE NO. DH-3 (SHEET 1 OF 2)

SUMMARY LOG HOLE NO. DH-3	N 3226688 / E 743355	SHEET 1 OF 2	SURFACE ELEV. 1459
PROJECT Watana Dam	DRILL DATES: START 3 Apr 78	COMP. 18 Apr 78	
DEPTH OF HOLE 174.5'	DEPTH OF OVERBURDEN 77.6'	DIAM. OF HOLE NCQ/BX	
ROCK DRILLED 96.9'	CORE RECOVERED 81.3'	% RECOVERY 83.3	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ----	COMPILED BY, DATE: Sat 10 Oct 78	
DISTANCES: VERTICAL, 174.5'; HORIZONTAL, ----			

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	0	Overburden; Gravel, Cobbles And Boulders In Sand Matrix		River Hole
	10			4 Inch Csg To 15.6'
1433	20			26'
	30	Gravelly Sand		
1418	40			41'
	50	Gravel, Cobbles And Boulders In Sand Matrix		NX CSG To 52.2'
	60			
	70	Boulders To 3.5' Below 65' Top Of Rock		BX Csg To 74.5' 77.6'
1381	80	Diorite, Hard, Medium Grained Moderate To Highly Fractured, Gray; Rock Irregularly Grades To Quartz Diorite And Granodiorite.		BX Core Core Loss Due to Mechanical Problems
	90	Clay Coating on Fractures Common.		Fractures Spacing 77.6'-100' 0.1' To 0.8'
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-3

SUMMARY LOG — HOLE NO. DH-3 (SHEET 2 OF 2)

SUMMARY LOG HOLE NO. DH-3	N 3226688 / E 743355	SHEET 2 OF 2	SURFACE ELEV. 1459
PROJECT Watana Dam	DRILL DATES: START 3 Apr 78	COMP. 18 Apr 78	
DEPTH OF HOLE 174.5'	DEPTH OF OVERBURDEN 77.6'	DIAM. OF HOLE NCQ/BX	
ROCK DRILLED 96.9'	CORE RECOVERED 81.3'	% RECOVERY 83.3'	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -----	COMPILED BY, DATE: Sat 10 Oct 78	
DISTANCES: VERTICAL, 174.5'; HORIZONTAL, -----			

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Diorite; Ibid Light To Moderate Fracture 100' To 130'		No Dwr
	110			Fracture Spacing 100'-130' 0.1' To 2.4'
	120			
	130			
	140	Moderately To Highly Fractured 130' To 150'		Fracture Spacing 130'-150' <0.1' To 0.9'
	150			
	160	Lightly Fractured 150' To Bottom.		Core Loss Due to Mechanical Problems Fracture Spacing 150'-Bottom <0.1' To 1.5'
1285	170			174.5'
	180	Bottom Of Hole Depth Of Hole 174.5' Thickness of Over-Burden 77.6' Rock Cored 96.9' Core Recovered 81.3' % Core Recovered 83.3%		Hole Not Pressure Tested; Hole Caved
	190			
	200			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-3

SUMMARY LOG — HOLE NO. DH-4 (SHEET 1 OF 2)

SUMMARY LOG HOLE NO. DH-4	N 3226640 / E 744376	SHEET 1 OF 2	SURFACE ELEV. 1460
PROJECT Watana Dam	DRILL DATES: START 17 Apr 78	COMP. 23 Apr 78	
DEPTH OF HOLE 122.9'	DEPTH OF OVERBURDEN 77.7'	DIAM. OF HOLE NQ	
ROCK DRILLED 45.2'	CORE RECOVERED 40.9'	% RECOVERY 90.5	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE: Sat 10 Oct 78	
DISTANCES: VERTICAL, 122.9'; HORIZONTAL, —			

ELEV	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1460	0	Overburden: Gravels, Cobbles And Boulders With Sand.		5" Csg To 7.9'
	10			
	20			
	30			
	40			
	50			
	60			
1382	70	Top Of Rock		77.7'
	80	Quartz Diorite, Very Hard, Medium Grained, Lightly Weathered, Lightly Fractured, Gray.		NX Csg To 78.1' Fracture Spacing 78' To 100' <0.1'-4.0'
	90			
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-4

LEGEND

- ACIDIC INTRUSIVES INCLUDING DIORITE, QUARTZ DIORITE AND GRANODIORITE
- ANDESITE
- BRECCIA (USED WITH ROCK TYPE)
- PORPHORITIC ANDESITE
- SHEAR
- ROCK FRAGMENTS
- BOULDER
- GRAVEL
- SAND
- SILT
- CLAY
- CORE RECOVERY — RECOVERED — LOST

NOTES:

1. DH: DIAMOND DRILL HOLE (CORE)
   DR: LARGE DIAMETER MUD AND AIR ROTARY; CORING IN BEDROCK.
2. HOLES DH-1 THROUGH DH-5 DRILLED FROM RIVER ICE; OVERBURDEN THICKNESS WILL VARY.
3. FOR CORE LOSS SHOWN ON DR HOLES, SEE REMARKS COLUMN.
4. LIGHTLY FRACTURED - CORE LENGTHS GENERALLY GREATER THAN 0.8 FEET.
   MODERATELY FRACTURED - CORE LENGTHS GENERALLY BETWEEN 0.4 FEET AND 0.8 FEET.
   HIGHLY FRACTURED - CORE LENGTHS GENERALLY LESS THAN 0.4 FEET.
5. LIGHTLY WEATHERED - ESSENTIALLY FRESH, HARD ROCK.
   MODERATELY WEATHERED - MEDIUM HARD ROCK, STAINED; INDIVIDUAL GRAINS CAN BE FREED WITH SOME DIFFICULTY.
   HIGHLY WEATHERED - RELATIVELY SOFT ROCK, GENERALLY STAINED; INDIVIDUAL GRAINS CAN BE FREED WITH LITTLE DIFFICULTY.
6. PRESSURE TESTS PERFORMED WITH AIR PACKERS.
7. DRIVE SAMPLES - 300 POUND HAMMER/30 INCH DROP AND 3 INCH DRIVE SPOON, UNLESS NOTED.
8. FOLLOWING PLATES HAVE PHOTOS OF ALL CORE SAMPLES.

ABBREVIATIONS:

- CSG- CASING
- DWR- DRILL WATER RETURN
- IBID- AS DESCRIBED ABOVE, EXCEPT AS NOTED.
- K- TRANSMISSIBILITY CONSTANT; MEASURED IN FEET PER MINUTE PER SQUARE FOOT $\times 10^{-4}$
- SWL. STATIC WATER LEVEL

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 1
DH-1 THRU DH-4

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

SUMMARY LOG — HOLE NO. DH-4 (Sheet 2 of 2)

PROJECT: Watana Dam	N 3226640 / E 744376	SURFACE ELEV. 1460
DRILL DATES: START 17 Apr 78	COMP. 23 Apr 78	
DEPTH OF HOLE 122.9'	DEPTH OF OVERBURDEN 77.7'	DIAM. OF HOLE NQ
ROCK DRILLED 45.2'	CORE RECOVERED 40.9'	% RECOVERY 90.5
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 122.9'; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz Diorite: Ibid		Fracture Spacing 100' To 122.9 0.1' To 3.8'
	110			Core Loss Due To Mechanical Problems
1337	120			122.9'
	130	Bottom Of Hole Depth of Hole 122.9' Thickness of Over-Burden 77.7' Rock Drilled 45.2' Core Recovered 40.9' Percent Core Recovery 90.5		Hole Not Pressure Tested Due To Caving

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-4

SUMMARY LOG — HOLE NO. DH-5 (Sheet 1 of 2)

PROJECT: Watana Dam	N 3226539 / E 744410	SURFACE ELEV. 1460
DRILL DATES: START 18 Apr 78	COMP. 3 May 78	
DEPTH OF HOLE 176.9'	DEPTH OF OVERBURDEN 59.6'	DIAM. OF HOLE NQ
ROCK DRILLED 117.3'	CORE RECOVERED 114.0'	% RECOVERY 97%
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ------	COMPILED BY, DATE: ASM 22 June 1978
DISTANCES: VERTICAL, 176.9'; HORIZONTAL, ------		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1460	0	Overburden: Gravels, Cobbles And Boulders With Some Sand		
	10–50			
1400	60	Top Of Bedrock		NX Csg Reamed To 59.2' 59.6'
	60	Quartz Diorite: Very Hard, Medium To Coarse Grained, Lightly Weathered, Moderately To Lightly Fractured Light Gray.		Fracture Spacing 60' To 70'; 0.1' To 0.3' Core Loss Due To Mechanical Problems
	70			Fracture Spacing 70' To 80' 0.01' To 1.4' 100% Dwr; 59.6' To 88.6'
	80	Shear Zone 73.0' To 100.0' Highly Fractured With Slicks And Gouge. Hole Following Near Vertical (35°) Shear		25% Dwr; 88.6' To 92.8'
	90			Fracture Spacing 80' To 100'; 0.1' 0.6'
	100			No Dwr 92.8' To Bottom

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-5

SUMMARY LOG — HOLE NO. DH-5 (Sheet 2 of 2)

PROJECT: Watana Dam	N 3226539 / E 744410	SURFACE ELEV. 1460
DRILL DATES: START 18 Apr 78	COMP. 3 May 78	
DEPTH OF HOLE 176.9'	DEPTH OF OVERBURDEN 59.6'	DIAM. OF HOLE NQ
ROCK DRILLED 117.3'	CORE RECOVERED 114.0'	% RECOVERY 97%
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: AGM 22 June 1978
DISTANCES: VERTICAL, 176.9; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz Diorite: Ibid Healed Fractures Common To 111.3'		
	120	Slicks At 123.1'		
	140			Fracture Spacing 100' To 176.9'; 0.1' To 1.7'
1283	170			Left 0.2' In Hole 176.9'
	180	Bottom Of Hole Depth Of Hole 176.9 Thickness Of Over-Burden 59.6 Rock Drilled 117.3 Core Recovered 114.0 Percent Core Recovery 97%		Hole Not Pressure Tested-River Ice Deteriorated Rapidly
	190–200			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-5

SUMMARY LOG — HOLE NO. DH-6 (Sheet 1 of 2)

PROJECT: Watana Dam	N 3227119 / E 744219	SURFACE ELEV. 1716
DRILL DATES: START 28 Apr 78	COMP. 2 May 78	
DEPTH OF HOLE 149.5'	DEPTH OF OVERBURDEN 3.5'	DIAM. OF HOLE NCQ
ROCK DRILLED 146.0'	CORE RECOVERED 143.9'	% RECOVERY 98.6
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ------	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 149.5'; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1716 / 1712	0	Overburden, Organic Silt With Rock Fragments		3.5'
	10	Diroite, Medium Hard, Medium Grained, Moderately to Highly Weathered, Moderately To Highly Fractured, Light Gray Iron Staining Common On Fractures. Occassional Shears With Slickensides And Gauge Moderately Weathered From 10.0' To 40.0'		Fracture Spacing 3.5'-10' 0.1' To 0.5' NX Casing To 8.4' 1 No Dwr 0.0 To 31.0' K= 0.0 2 1 Fracture Spacing 10'-60' 0.1' To 2.0' Dwr 50% 31.0' To 48.0'
	40	Diorite, Ibid, Very Hard, Lightly Weathered, Lightly To Moderately Fractured With Occassional Highly Fractured And Shear Zones		No Dwr 48.0' To Bottom. 3 2
	60	Shear 59.0' To 59.2' (60°)		K = 0.0 Fracture Spacing 60'-70' 0.1' To 0.8' 4 3
	70–80			K = 2.13 Fracture Spacing 70'-90' <0.1' To 1.2' 5 4
	100			K 0.34

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-6

SUMMARY LOG — HOLE NO. DH-6 (Sheet 2 of 2)

PROJECT: Watana Dam	N 3227119 / E 744219	SURFACE ELEV. 1716
DRILL DATES: START 28 Apr 78	COMP. 2 May 78	
DEPTH OF HOLE 149.5'	DEPTH OF OVERBURDEN 3.5'	DIAM. OF HOLE NCQ
ROCK DRILLED 146.0'	CORE RECOVERED 143.9	% RECOVERY 98.6
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 149.5'; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Diorite, Ibid		Fracture Spacing 90'-110' <0.1' To 0.8' 6 5
	110–120	Highly Fractured 112.1' To 122.4'		Fracture Spacing 110'-120' <0.1' To 1.1' K = 0.5 Fracture Spacing 120'-130' <0.1' To 0.9' 6 7
	130			SWL 132.0' 2 May 78 Fracture Spacing 130'-140' 0.1' To 1.1' K= 0.36
1611	140	Moderately Fractured 142.2' To Bottom		Fracture Spacing 140'-149.5' <0.1' To 0.7' 149.5' 7
	150	Bottom Of Hole Depth of Hole 149.5' Thickness of Overburden 3.5' Rock Cored 146.0' Core Recovered 143.9' % Core Recovered 98.6'		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-6

SUMMARY LOG — HOLE NO. DH-7 (Sheet 1 of 2)

PROJECT: Watana Dam	N 3227117 / E 744219	SURFACE ELEV. 1716
DRILL DATES: START 6 May 1978	COMP. 17 May 1978	
DEPTH OF HOLE 122.2'	DEPTH OF OVERBURDEN 8.5'	DIAM. OF HOLE NCQ
ROCK DRILLED 113.7'	CORE RECOVERED 108.3'	% RECOVERY 95
ANGLE FROM VERT. 31°	AZIMUTH FROM NORTH 210°	COMPILED BY, DATE: ASM 22 June 1978
DISTANCES: VERTICAL, 104.8'; HORIZONTAL, 63.0'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1716	0	Overburden: Sand With Rock Fragments Top Of Rock		No Dwr Full Depth 8.5'
1709	10	Diorite: Hard, Medium Grained, Highly Fractured To Medium Fractured, Grey Highly Weathered Zone 8.5 To 16.0		NX Csg to 19.6'
	20–30	Shear Zone 24.0 To 29.0' Iron Staning On Fractures Common.		Fracture Spacing 8.5'-30' <0.1' To 0.5'
	40–50	Shear Zone 44.0' To 47.0'		Fracture Spacing 40' to 70' <0.1' To 1.6
	60	Quartz Rich, Veins 60.5'-61.9'		
	70–90	Shear Zone 70' To 90'		Fracture Spacing 70'-90' <0.1' To 0.6' Fracture Spacing 90' To 100' <0.1' To 1.7'
	100			

NPA Form 7(Test) APR. 66 — PROJECT WATANA DAM — HOLE NO. DH-7

SUMMARY LOG — HOLE NO. DH-7 (Sheet 2 of 2)

PROJECT: Watana Dam	N 3227117 / E 744219	SURFACE ELEV. 1716
DRILL DATES: START 6 May 1978	COMP. 17 May 78	
DEPTH OF HOLE 122.2'	DEPTH OF OVERBURDEN 8.5'	DIAM. OF HOLE NQ
ROCK DRILLED 113.7'	CORE RECOVERED 108.3'	% RECOVERY 95
ANGLE FROM VERT. 31°	AZIMUTH FROM NORTH 210°	COMPILED BY, DATE: AGM 22 June 1978
DISTANCES: VERTICAL, 104.8'; HORIZONTAL, 63.0'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Diorite: Ibid		Fracture Spacing 100' To 110' <0.1' To 1.0'
	110	Shear Zone W/Slicks And Gouge 111.0' - 113.9'		Fracture Spacing 100' -122.2' 0.1' To 1.7'
1610	120			122.2'
		Bottom of Hole Depth of Hole 122.2' Thickness of Overburden 8.5' Rock Cored 113.7' Core Recovered 108.3' % Core Recovered 95		Hole Not Pressure Tested Due to Caving

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-7

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

DRILL HOLE LOGS NO. 2

DH-4 (CONT.) THRU DH-7

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SUMMARY LOG — HOLE NO. DH-8 (SHEET 1 OF 2)

SUMMARY LOG HOLE NO. DH-8	N 3227485 / E 744090	SHEET 1 OF 2 — SURFACE ELEV. 1910
PROJECT Watana Dam	DRILL DATES: START 21 May 78	COMP. 29 May 78
DEPTH OF HOLE 150.0'	DEPTH OF OVERBURDEN 16.2'	DIAM. OF HOLE NCQ
ROCK DRILLED 133.8'	CORE RECOVERED 133.8'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ------	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 150.0'; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	0	Overburden: Boulders, 2' To 4' In Diameter, In Sand Matrix.		No Dwr 0.0'-32.2'
1894		Top Of Rock		16.2'
	20	Quartz Diorite, Hard Medium Grained, Moderately to Highly Weathered, Lightly To Moderately Fractured, Light Gray. Occassional Shears and Highly Fractured Zones. Iron Stain Common On Joints		NX CSG To 19.0' Fracture Spacing 20'-30' 0.1' To 0.8'
	30	Shears at 25.9'-28.3' And 38.3'-44.1'		Dwr 32.2'-45.3' 100% K=27
	40	Lightly To Moderately Weathered 20.3'-33.0' Lightly Weathered Below 33.0'		
	50	Slickensides 48.0'		Fractures Spacing 30'-90'; 0.1' To 3.6' K=17
	60	Chloritization Below 65.0'		
	70			Dwr 45.3'-98.4' 40% K=5.5
	90	Fractures Become Serpentized At 95.0'		Fracture Spacing 90'-100' 0.2' To 0.8' K=11
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-8

SUMMARY LOG — HOLE NO. DH-8 (SHEET 2 OF 2)

SUMMARY LOG HOLE NO. DH-8	N 3227485 / E 744090	SHEET 2 OF 2 — SURFACE ELEV. 1910
PROJECT Watana Dam	DRILL DATES: START 21 May 78	COMP. 29 May 78
DEPTH OF HOLE 150.0'	DEPTH OF OVERBURDEN 16.2'	DIAM. OF HOLE NCQ
ROCK DRILLED 133.8'	CORE RECOVERED 133.8'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 150.0'; HORIZONTAL, ---------		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz Diorite, Ibid		Fracture Spacing 100'-140' 0.1' To 1.7'
	110	Shear 112.5'-114.0'		Dwr 98.4'-110.4' 30% Dwr 110.4'-120.4' 20%
	120			K=9.5
	130			Dwr 120.4'-Bottom 0%
	140			K=8.0 Fracture Spacing 140'-150'; 0.1' To 0.6'
1760	150	Bottom of Hole Depth of Hole 150.0' Thickness of Overburden 16.2' Rock Cored 133.8' Core Recovered 133.8' % Core Recovered 100		150.0'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-8

SUMMARY LOG — HOLE NO. DH-9 (SHEET 1 OF 3)

SUMMARY LOG HOLE NO. DH-9	N 3227487 / E 744092	SHEET 1 OF 3 — SURFACE ELEV. 1913
PROJECT Watana Dam	DRILL DATES: START 30 May 78	COMP. 29 Jun 78
DEPTH OF HOLE 283.8'	DEPTH OF OVERBURDEN 5.6'	DIAM. OF HOLE NCQ
ROCK DRILLED 278.2'	CORE RECOVERED 276.7	% RECOVERY 99.5
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 043°	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 200.6; HORIZONTAL, 200.6		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1913	0	Overburden, Diorite And Quartz Diorite Boulders In Sand Matrix		
1910		Top Of Rock		5.6
	10	Quartz Diorite Breccia (Emplacement Breccia), Hard, Medium Grained, Moderately Fractured, Light Gray. Iron Stains Common Fractures. Healed Fractures Common.		18.9'
1902	20	Quartz Diorite, Hard, Medium Grained, Lightly Weathered, Lightly to Moderately Fractured, Light Gray. Minor Iron Stains On Joints; Decreasing With Depth. Healed Fractures Common.		Fracture Spacing 6' To 50'; <0.1' To 3.3'
	40	Quartz Diorite Breccia, Ibid Lightly Weathered.		37.1'
1887		Quartz Diorite, Ibid. Lightly Weathered With Occasional Shear Zones And Healed Emplacement Breccia Zones		43.6'
	50	Healed Emplacement Breccia 50.1' To 51.6' Shear Zone, 51.6' To 63.4' Highly Fractured With Thin Red-Brown Gouge Common. Shear Is Moderately Weathered		NX CSG To 54.0' Fracture Spacing 50' To 60'; <0.1' To 0.8' K=23.09
	70			K=20.52 Fracture Spacing 60' To 90'; 0.1' To 1.0' K=19.61
	90	Shear Zone, 87.0 To 99.4' Moderately Weathered 87.0' To 100.3'. Minor Hydrothermal Alteration 94.2' To 94.5' With Gouge. Moderately To Highly Fractured.		Fracture Spacing 90' To 100' <0.1' To 0.9' K=17.69
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-9

SUMMARY LOG — HOLE NO. DH-9 (SHEET 2 OF 3)

SUMMARY LOG HOLE NO. DH-9	N 3227487 / E 744092	SHEET 2 OF 3 — SURFACE ELEV. 1913
PROJECT Watana Dam	DRILL DATES: START 30 May 78	COMP. 29 Jun 78
DEPTH OF HOLE 283.8'	DEPTH OF OVERBURDEN 5.6'	DIAM. OF HOLE NCQ
ROCK DRILLED 278.2'	CORE RECOVERED 276.7'	% RECOVERY 99.5'
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 043°	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 200.6'; HORIZONTAL, 200.6'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1851	100	Porphoritic Andesite Dike Moderately Hard, Fine Grained Lightly Weathered, Moderately Fractured, Gray.		100.3' 103.8' K=17.22
	110	Quartz Diorite, Ibid. Iron Stains On Joints Below Andesite Dike; Decreasing With Depth.		K=16.95
	120			Fracture Spacing 100' To 140'; 0.1' To 1.8' K=15.19
	130	Quartz Diorite Breccia (Healed) 131.9' To 133.4'		K=14.64 138.8'
1830	140	Felsite Dike, Hard, Medium Grained, Moderately To Lightly Weathered, Moderately Fractured, White. High Quartz Content. Iron Stains Common.		Fracture Spacing 140' To 150' 0.1' To 0.9' K=13.54 150.1'
1823	150	Quartz Diorite. Ibid Occasional Iron Staining On Joints. Occasional Gouge.		K=13.08
	160	Gouge 160.6'		Fracture Spacing 150' To 200' 0.1' To 1.7' K=10.87
	170			No Pressure Test 170' To 180'
	180	Moderately To Highly Fractured 181.0' To 192.5'		K=8.15
	190	Moderately Fractured 192.5' To 214.6'		K=7.22
	200			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-9

SUMMARY LOG — HOLE NO. DH-9 (SHEET 3 OF 3)

SUMMARY LOG HOLE NO. DH-9	N 3227487 / E 744092	SHEET 3 OF 3 — SURFACE ELEV. 1913
PROJECT Watana Dam	DRILL DATES: START 30 May 78	COMP. 29 Jun 78
DEPTH OF HOLE 283.8'	DEPTH OF OVERBURDEN 5.6'	DIAM. OF HOLE NCQ
ROCK DRILLED 278.2'	CORE RECOVERED 276.7'	% RECOVERY 99.5
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 043°	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 200.6'; HORIZONTAL, 200.6'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	200	Quartz Diorite, Ibid. Moderately Fractures.		Fracture Spacing 200 To 210 <0.1' To 1.1' K=7.68
	210	Moderately To Highly Fractured 214.6 To 230.6 Iron Staining Common.		Fracture Spacing 210' To 230' <0.1' To 0.7' K=7.33
	220			K=7.22
1775	230	Felsite Dike, Highly Fractured.		231.3' 232.4' K=6.63
	240	Quartz Diorite, Ibid.		Fracture Spacing 230' To 240' <0.1' To 1.3' K=6.32
	250	Shear Zone, 244.4' To 266.5' Very Highly Fractured With Slicks And Gouge. Altered 256.3' To 257.2'		Fracture Spacing 240' To 270 <0.1' To 0.7 K=4.50 K=6.49
	270			Fracture Spacing 270' To Bottom <0.1' To 0.9' K=6.57
1743	280	Bottom Of Hole		283.8'
	290	Depth of Hole 283.3' Thickness Of Overburden 5.6' Rock Cored 278.2' Core Recovered 276.7' % Core Recovered 99.5'		
	300			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-9

SUMMARY LOG — HOLE NO. DH-10 (SHEET 1 OF 3)

SUMMARY LOG HOLE NO. DH-10	N 3227858 / E 743973	SHEET 1 OF 3 — SURFACE ELEV. 2033
PROJECT Watana Dam	DRILL DATES: START 8 May 1978	COMP. 19 May 78
DEPTH OF HOLE 203.5'	DEPTH OF OVERBURDEN 19.6'	DIAM. OF HOLE NX
ROCK DRILLED 183.9'	CORE RECOVERED 153.7'	% RECOVERY 83.6
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -----	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 203.5'; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2033	0	Overburden, gravelly sand with cobbles and small boulders.		
2013.4	20	Top Of rock		19.6'
	20	Diorite, hard, medium grained moderately weathered, moderately fractured, light gray. Highly weathered and highly fractured in shear zones. Iron staining common.		DWR 100% at 20' (light gray) Series "X" Barrel used 13.6' to 136.3'
	40	Shear zone, 36.0'-65.8' highly weathered diorite, highly fractured. Sand and clay sizes recovered from 42' to 49'		DWR 80% at 45' (brown) NX CSG to 52.3' DWR 100% at 50' (gray) K=0.69 65.8'
	70	Diorite, ibid, lightly weathered. Moderately to lightly fractured.		K=0.4
	80	Shear, 78.3'-80.6' diorite, soft, highly altered, highly fractured.		DWR 90% at 85' (light gray) K=0.1
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-10

SUMMARY LOG — HOLE NO. DH-10 (SHEET 2 OF 3)

SUMMARY LOG HOLE NO. DH-10	N 3227858 / E 743973	SHEET 2 OF 3 — SURFACE ELEV. 2033
PROJECT Watana Dam	DRILL DATES: START 8 May 1978	COMP. 19 May 78
DEPTH OF HOLE 203.5'	DEPTH OF OVERBURDEN 19.6'	DIAM. OF HOLE NX
ROCK DRILLED 183.9'	CORE RECOVERED 153.7'	% RECOVERY 83.6
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -----	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 203.5'; HORIZONTAL, -----		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Diorite, ibid Shear zone 107.8 to 110.4 highly weathered, altered		K=0.1 DWR 80%, pinkish gray at 110.0' 110.4'
1923	110	Diorite breccia: ibid. Emplacement breccia, completely healed.		K=0.24
	130	Shear zone, 126.6' to 136.6', soft, altered. Alteration effects continue to 153.6'		DWR 80% at 130' (white) "N" series barrel used 136.3' to bottom.
	140			K=0.0
1870	160			DWR 80% at 159' (light gray) 163.2'
	170	Diorite, ibid Moderately to highly fractured 163.2' to 174.0'		K=0.06
	180	Slickensides 185.5'		
	190			K=0.15
	200			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-10

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 3
DH-8 THRU DH-10
ALASKA DISTRICT CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

SUMMARY LOG — HOLE NO. DH-10 (Sheet 3 of 3)

N 3227858 · E 743973 · SURFACE ELEV. 2033

PROJECT: Watana Dam · DRILL DATES: START 8 May 1978 COMP. 19 May 78

DEPTH OF HOLE 203.5' · DEPTH OF OVERBURDEN 19.6' · DIAM. OF HOLE NX

ROCK DRILLED 183.9' · CORE RECOVERED 153.7' · % RECOVERY 83.6

ANGLE FROM VERT. 0° · AZIMUTH FROM NORTH ----- · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 203.5'; HORIZONTAL, -----

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1829.5	200	Diorite, Ibid.		203.5
	210	Bottom of Hole Depth of hole 203.5' Thickness of overburden 19.6' Rock cored 183.9' Core recovered 153.7' % Core recovered 83.6'		Hole drilled in near vertical shear zone.

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-10

SUMMARY LOG — HOLE NO. DH 11 (Sheet 1 of 3)

N 3227856 · E 743970 · SURFACE ELEV. 2034

PROJECT: Watana Dam · DRILL DATES: START 22 May 1978 COMP. 5 Jun 78

DEPTH OF HOLE 300.0' · DEPTH OF OVERBURDEN 22.7' · DIAM. OF HOLE NX

ROCK DRILLED 277.3' · CORE RECOVERED 276.1' · % RECOVERY 99.6

ANGLE FROM VERT. 45° · AZIMUTH FROM NORTH 032° · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 212.1'; HORIZONTAL, 212.1'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2034	0	Overburden, Gravelly Sand Boulders		Tricone Bit 0.0 To 10.8' Started Coring At 10.8'
	20	Boulder 20.6' To 22.7'		
2016		Top Of Rock		22.7'
	30	Quartz Diorite, Moderately Hard To Hard, Medium Grained, Moderately Weathered, Highly Fractured, Gray; Highly Weathered In Shears. Iron Staining Common On Joints, Slickensides Common.		NX Casing To 22.7'
	40			Lost All Dwr At 42.0'
	50	Shear Zone 47.2' To 52.4' Lightly Weathered Below 52.4' Moderately Fractured Below 52.4'		Fracture Spacing 50' To 80' 0.1' To 1.5' Dwr 50% To 100% 42' To 86'
	60			1
	70			K= 0.11
	80			Swl 80' (7 Jun 78) 1/2 Fracture Spacing 80' To 90'; 0.1' To 0.9'
	90			Lost All Dwr 86.0' To 215.0' K= 13.05 Fracture Spacing 90' To 100'; 0.1' To 1.5' 2
	100			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH 11

SUMMARY LOG — HOLE NO. DH-11 (Sheet 2 of 3)

N 3227856 · E 743970 · SURFACE ELEV. 2034

PROJECT: Watana Dam · DRILL DATES: START 22 May 1978 COMP. 5 Jun 78

DEPTH OF HOLE 300.0' · DEPTH OF OVERBURDEN 22.7' · DIAM. OF HOLE NX

ROCK DRILLED 277.3' · CORE RECOVERED 276.1' · % RECOVERY 99.6'

ANGLE FROM VERT. 45° · AZIMUTH FROM NORTH 032° · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 212.1'; HORIZONTAL, 212.1'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz Diorite; Ibid; Lightly Weathered, Moderately To Lightly Fractured.		Fracture Spacing 100' To 110'; 0.1' To 1.9'
	110			K= 0.58
	120	Shear Zone 114.0' To 120.0' Highly Fractured With Gouge		Fracture Spacing 110' To 120'; 0.1' To 0.7' 3/4
1929	130			K= 4.15
	140	Quartz Diorite Breccia; Ibid; Emplacement Breccia, Completely Healed.		4/5
1915	150	Andesite Dike, Hard, Fine Grained Lightly Fractured, Dark Gray, Porphoritic.		149.4' K= 4.1 152.2'
	160	Quartz Diorite Breccia, Ibid. Thin Clay Gouge At 161.8'		5/6 Fracture Spacing 120' To 190'; 0.1' To 2.1'
	170			K= 0.82
	180			6/7
	190	Shear 191.6' To 195.5' Very Highly Weathered, Very Highly Fractured.		K= 5.47 Fracture Spacing 190' To 200'; 0.1' To 0.4' 7
	200			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH 11

SUMMARY LOG — HOLE NO. DH-11 (Sheet 3 of 3)

N 3227856 · E 743970 · SURFACE ELEV. 2034

PROJECT: Watana Dam · DRILL DATES: START 22 May 1978 COMP. 5 Jun 78

DEPTH OF HOLE 300.0' · DEPTH OF OVERBURDEN 22.7' · DIAM. OF HOLE NX

ROCK DRILLED 277.3' · CORE RECOVERED 276.1' · % RECOVERY 99.6'

ANGLE FROM VERT. 45° · AZIMUTH FROM NORTH 032° · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 212.1'; HORIZONTAL, 212.1'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	200	Quartz Diorite Breccia; Ibid. Moderately To Highly Fractured 201.0 To 205.4		8 Fracture Spacing 200' To 300'; 0.1' To 2.6'
	210	Moderately To Lightly Fractured 205.4 To Bottom. Breccia Grades To Quartz Diorite Between 205' And 210'		K= 2.98 Dwr 10% 215' To 245'
	220			8/9
	230			K= 7.07
	240			9/10
	250			Dwr Lost 245' To Bottom. K= 3.24
	260			10/11
	270			K= 5.04
1796	280	Bottom of Hole Depth of Hole 300.0' Thickness Of Overburden 22.7' Rock Cored 277.3' Core Recovered 276.1' % Core Recovered 99.6		11/12
	290			K= 0.16
	300			0.3' Left In Hole 300.0' 12

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH 11

SUMMARY LOG — HOLE NO. DH-12 (Sheet 1 of 4)

N 3225738 · E 744620 · SURFACE ELEV. 1951

PROJECT: Watana Dam · DRILL DATES: START 11 Jun 78 COMP. 3 Jul 78

DEPTH OF HOLE 301.1' · DEPTH OF OVERBURDEN 9.5' · DIAM. OF HOLE NX

ROCK DRILLED 291.6' · CORE RECOVERED 285.3' · % RECOVERY 98%

ANGLE FROM VERT. 0° · AZIMUTH FROM NORTH ------- · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 301.1'; HORIZONTAL, -------

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1951	0	Overburden: Talus, 0.3' To 0.7' Diorite Cobbles, Subangular To Subrounded.		100% Dwr, Full Depth Swl 0.0' To 1.4' (21 Jun-3 Jul 78)
1942	10	Top Of Rock Quartz Diorite, Hard Medium Grained, Moderately Weathered Moderately Fractured, Gray. Iron Staining Common On Fractures. Occasional Hydrothermal Alteration, Healed Emplacement Breccia And Shear Zones.		9.5' Started Coring At 10.8' Top Of Permafrost 14' (11 Jul 78) NX Csg To 19.4'
	20	Shear 26.5' To 27.7'		Fracture Spacing 10' To 30'; 0.1' To 0.7' 27.7
	30	Quartz Diroite, Ibid, Lightly Weathered.		
	40			Fractured Spacing 30'-50'; 0.1' To 2.5'
	50	Hydrothermal Alteration 46.6' To 61.0' Healed Breccia 53.0' - 55.6'		Series X Core Barrel Used 10.8' To 97.2'
	60	Pyrite Common On Fractures.		Hole Pressure Tested 21.9' To 102.9' K 0.0 Permafrost.
	70			Fracture Spacing 50'-100'; 0.1' To 1.0'
	80	Shear 84.1' To 85.5' Minor Hyrdrothermal Alteration 84.1' To 102.9'		
	90	Shear 91.2' To 97.9'		
	100			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-12

SUMMARY LOG — HOLE NO. DH-12 (Sheet 2 of 4)

N 3225738 · E 744620 · SURFACE ELEV. 1951

PROJECT: Watana Dam · DRILL DATES: START 11 Jun 78 COMP. 3 Jul 78

DEPTH OF HOLE 301.1' · DEPTH OF OVERBURDEN 9.5' · DIAM. OF HOLE NX

ROCK DRILLED 291.6' · CORE RECOVERED 285.3' · % RECOVERY 98%

ANGLE FROM VERT. 0° · AZIMUTH FROM NORTH ----- · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 301.1'; HORIZONTAL, -------

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Shear, 100.5' To 109.0' Highly Fractured; Decomposed 101.0' To 102.9' Quartz Diorite, Ibid, Light To Moderately Fractured Except In Shears		Series M Core Barrel Used 97.2' To Bottom. No Pressure Tests Below 102.9'; Permafrost
	130	Healed Breccia 135.6' To 137.2'		Fracture Spacing 100'-200'; 0.1' To 1.8'
	180	Shear 175.0' To 184.2' Moderately To Highly Fractured; Decomposed With Gray Gouge 180.7' To 183.3'		
	190	Healed Shear 192.7' To 193.7'		
	200			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-12

SUMMARY LOG — HOLE NO. DH-12 (Sheet 3 of 4)

N 3225738 · E 744620 · SURFACE ELEV. 1951

PROJECT: Watana Dam · DRILL DATES: START 11 Jun 78 COMP. 3 Jul 78

DEPTH OF HOLE 301.1' · DEPTH OF OVERBURDEN 9.5' · DIAM. OF HOLE NX

ROCK DRILLED 291.6' · CORE RECOVERED 285.3' · % RECOVERY 98%

ANGLE FROM VERT. 0° · AZIMUTH FROM NORTH ------ · COMPILED BY, DATE: [signature] 10 Oct 78

DISTANCES: VERTICAL, 301.1'; HORIZONTAL, ------

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	200	Quartz Diorite, Ibid		
	250	Healed Shear 249.5' To 250.9'		Fracture Spacing 200' To 300' 0.1' To 4.2'
	270	Healed Shear 269.5' To 279.0'		
	290	Quartz Diorite Emplacement Breccia 291.5' To 296.5'		
	300			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-12

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 4
DH-10 (CONT.) THRU DH-12

ALASKA DISTRICT CORPS OF ENGINEERS
ANCHORAGE ALASKA

SUMMARY LOG — HOLE NO. DH-12

N 3225738	E 744620	SHEET 4 OF 4	SURFACE ELEV. 1951
PROJECT Watana Dam	DRILL DATES: START 11 Jun 78	COMP. 3 Jul 78	
DEPTH OF HOLE 301.1'	DEPTH OF OVERBURDEN 9.5'	DIAM. OF HOLE NX	
ROCK DRILLED 291.6'	CORE RECOVERED 285.3'	% RECOVERY 98%	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -------	COMPILED BY, DATE Pat 10 Oct 78	
DISTANCES: VERTICAL, 301.1'; HORIZONTAL, --------			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1650	300	Quartz diorite ibid		
		Bottom Of Hole Depth Of Hole 301.1' Thickness Of Over-Burden 9.5' Rock Cored 291.6' Core Recovered 285.3' Percent Core Recovered 98%		301.1' 3/4 Inch Galvanized Pipe Installed As Temperature Probe, Readable To 127.8' (11 Jul 78)
	310			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-12

SUMMARY LOG — HOLE NO. DR-13

N 3235654	E 750106	SHEET 1 OF 1	SURFACE ELEV. 2321
PROJECT Watana Dam	DRILL DATES: START 17 Apr 1978	COMP. 24 Apr 1978	
DEPTH OF HOLE 84'	DEPTH OF OVERBURDEN 84'	DIAM. OF HOLE See Remarks	
ROCK DRILLED 0'	CORE RECOVERED N/A	% RECOVERY N/A	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ---	COMPILED BY, DATE Pat 10 Oct 78	
DISTANCES: VERTICAL, 84'; HORIZONTAL,			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2321	0–15	ML, Gravelly, sandy silt, brown, non-plastic. Rounded minus 3/4 inch gravels. [Glacial Outwash]	1	8 inch roller bit and air 0'-19' Sample 1, 0'-17' cuttings 15'
2306	15–78	Silty clay, blue-gray, moist (15'-20') to damp (20'-78'), plastic (45'-65') non-plastic (15'-45' & 65'-78') varved. CL 15'-45' Minor rounded gravel above 45' [Lake Deposit] CH 45'-65' CL 65'78'	2, 3, 4, 5, 6, 7, 8	SWL 15.6' (22 Apr '78) Sample 2, 17'-26' cuttings 6 inch roller bit and air 19'-60' 8 inch CSG to 20' 6 inch CSG to 21' Sample 3, 26'-35' cuttings Sample 4, 35'-45' cuttings Sample 5, 45'-55' cuttings Sample 6, 60.0'-60.5' Sample 7, 60.5'-61.0' Drive Samples Sample 8, 65'-75' cuttings 5 inch CSG to 81' 78'
2237	78–84	Sandy gravel, brown, wet, loose, non-plastic. Artesian head to 15.6'		NX Core 81'-84' No recovery 84'
		Bottom of Hole Depth of Hole 84'		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-13

SUMMARY LOG — HOLE NO. DR-14

N 3235725	E 756634	SHEET 1 OF 1	SURFACE ELEV. 2340
PROJECT Watana Dam	DRILL DATES: START 25 Apr 1978	COMP. 26 Apr 78	
DEPTH OF HOLE 75'	DEPTH OF OVERBURDEN 75'	DIAM. OF HOLE See Remarks	
ROCK DRILLED 0'	CORE RECOVERED N/A	% RECOVERY N/A	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ---	COMPILED BY, DATE Pat 10 Oct 78	
DISTANCES: VERTICAL, 75'; HORIZONTAL, ---			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2340	0–20	SM, Gravelly, silty sand, brown, damp. Gravels small and rounded. Sands angular with occasional mica. (Glacial Till/Outwash)	1	6 inch button bit and air 0'-20' 5 1/2 inch button bit and air 20'-61' 3 3/8 inch button bit and air 61'-75' 20' 6 inch Csg to 20'
2320	20–34	SM, Gravelly, silty sand, gray, damp, dense.	2	Perched water table at 20' SWL 28.6' (18 Aug 78) SWL 30.5' (23 Jun 78) 34'
	34–41	SM-SC, silty, gravelly sand gray, damp, dense.	3	SWL 37.8' (26 Apr 78) 41'
	41–53	GM, silty, sandy gravel, gray, damp, dense.	4	Sample 4, 41'-51' 53'
	53–70	SW-SM, silty, gravelly sand, gray, wet, permeable. Artesian head to 37.8'.	5, 6	Sample 5, 51'-61' Sample 6, 61'-63' 70'
2265	70–75	SM, gravelly, silty sand, gray, wet. (Alluvial Deposit)	7	4 inch CSG to 71' 75'
		Bottom of Hole Depth of hole 75'		All samples from cuttings.

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-14

SUMMARY LOG — HOLE NO. DR-15 (Sheet 1)

N 3234335	E 754173	SHEET 1 OF 4	SURFACE ELEV. 2294
PROJECT Watana Dam	DRILL DATES: START 27 Apr 1978	COMP. 16 May 1978	
DEPTH OF HOLE 316.5'	DEPTH OF OVERBURDEN 286'	DIAM. OF HOLE See Remarks	
ROCK DRILLED 30.5'	CORE RECOVERED 21.3'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Pat 18 Oct 78	
DISTANCES: VERTICAL, 316.5'; HORIZONTAL,			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2294	0–15	SM, Silty, gravelly sand, brown, damp, non-plastic. Gravel sub-rounded to 2 inch diameter. (Outwash)	1	8 inch button bit and air, 0' to 18'. Sample 1, 0'-15' cuttings 15'
2279	15–22	GM-GC, silty, sandy gravel, gray, damp to wet, non-plastic. Occasional rock fragments.	2	Sample 2, 15'-22', cuttings 22' 8 inch Csg to 18.5'
2272	22–36	CL, sandy silt, gray, damp, non-plastic. Occasional sand and gravel. (Lake Deposit)	3, 4	Sample 3, 25.0'-26.3' Drive sample Sample 4, 26.3'-36' cuttings 36'
2258	36–65	GP-GM, silty, sandy gravel to SP-SC, gravelly, silty sand, gray, wet, marginally plastic. Gravel rounded to 2 inch diameter. (Outwash)	5, 6	Sample 5, 41.0'-42.0' Drive sample 6 inch button bit and air, 18'-51' 65'
2229	65–100	Gravelly clay with boulders and cobbles, gray, damp, dense, plastic. Random layers of sand and silt. (Till)	7	Sample 7, 67.0'-67.5' Drive sample

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-15

SUMMARY LOG — HOLE NO. DR-15 (Sheet 2)

N 3234335	E 754173	SHEET 2 OF 4	SURFACE ELEV. 2294
PROJECT Watana Dam	DRILL DATES: START 27 Apr 1978	COMP. 16 May 1978	
DEPTH OF HOLE 316.5'	DEPTH OF OVERBURDEN 286'	DIAM. OF HOLE See Remarks	
ROCK DRILLED 30.5'	CORE RECOVERED 21.3'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Pat 18 Oct 78	
DISTANCES: VERTICAL, 316.5'; HORIZONTAL,			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	100–200	Gravelly clay, sandy, ibid. (Till)	8	Sample 8, 107.0'-108.0' 2-3/4 x 3-7/8 core. 5-5/8 inch tricone bit and mud, 51'-295.2'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-15

SUMMARY LOG — HOLE NO. DR-15 (Sheet 3)

N 3234335	E 754173	SHEET 3 OF 4	SURFACE ELEV. 2294
PROJECT Watana Dam	DRILL DATES: START 27 Apr 1978	COMP. 16 May 1978	
DEPTH OF HOLE 316.5'	DEPTH OF OVERBURDEN 286'	DIAM. OF HOLE See Remarks	
ROCK DRILLED 30.5'	CORE RECOVERED 21.3'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Pat 18 Oct 78	
DISTANCES: VERTICAL, 316.5'; HORIZONTAL,			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	200–286	Gravelly clay, ibid. (Till)		5-5/8 inch tricone bit and mud, 51'-295.2'
2008	286–300	Top of Rock Quartz diorite, hard, medium grained, lightly weathered, moderately fractured, light gray. Fractures at 45° and 75° dominant.		286' 2-3/4 x 3-7/8 core 295.2'-316.1' 4 inch Csg to 296.0'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-15

SUMMARY LOG — HOLE NO. DR-15 (Sheet 4)

N 3234335	E 754173	SHEET 4 OF 4	SURFACE ELEV. 2294
PROJECT Watana Dam	DRILL DATES: START 27 Apr 1978	COMP. 16 May 78	
DEPTH OF HOLE 316.5'	DEPTH OF OVERBURDEN 286'	DIAM. OF HOLE See Remarks	
ROCK DRILLED 30.5'	CORE RECOVERED 21.3'	% RECOVERY 100	
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Pat 18 Oct 78	
DISTANCES: VERTICAL, 316.5'; HORIZONTAL,			

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	300	Quartz diorite, ibid.		NXC-3 Core 305.1'-316.5'
1978	316.5	Bottom of Hole Depth of Hole 316.5' Thickness of Overburden 286' Rock drilled 30.5' Rock cored 21.3' Core recovered 21.3' % Core recovered 100		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-15

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 5
DH-12 (CONT.) THRU DR-15
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

PLATE D-32

SUMMARY LOG — HOLE NO. DR-16

HOLE NO. DR-16	N 3231733 / E 742644	SHEET 1 OF 1; SURFACE ELEV. 2099
PROJECT Watana Dam	DRILL DATES: START 31 May 1978	COMP. 4 Jun 78
DEPTH OF HOLE 91.5'	DEPTH OF OVERBURDEN 67'	DIAM. OF HOLE See Remarks
ROCK DRILLED 24.5'	CORE RECOVERED 9.2'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH	COMPILED BY, DATE Pat 18 Oct 78
DISTANCES: VERTICAL, 91.5'; HORIZONTAL,		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2099	0	SM, Silty sand, gravelly with boulders, brown, moist, loose, non-plastic. Boulders to 1 foot diameter. (Outwash)	1	5-5/8 inch tricone bit and mud, 0.0'-78.5'. SWL 8.8'-11.0' (23 Jun-18 Aug 1978). Sample 1, 13.2'-14.2' Drive sample, 50 Blows. 6 inch Csg to 20'. 23'
2076	20	Gravelly, silty sand, dark gray, moist, loose to dense, non-plastic. (Outwash)		31'
2068	30	CL-ML, sandy silt, dark gray, moist to wet, dense, non-plastic. Occasional clay layers and scattered grounded gravel to 1-1/2 inch diameter. (Lake Deposit)	2A, 2B	Sample 2A, 32.2'-32.8' shelby tube. Sample 2B, 32.8'-33.5' Pitcher barrel. 47'
2052	50	Gravelly, silty sand with boulders, dark gray, dense, moist, non-plastic. Quartz diorite boulder 57'-64'. Top of Rock		Description from cuttings. 67'
2032	70	Diorite, moderately hard, medium grained, hydrothermally altered, highly fractured, light gray to white. Clay common on fractures.		Piezometer installed to 71.5'. 2-3/4 x 3-7/8 core 78.5'-81.0' and 83.8'-91.5'. 5-5/8 inch tricone bit 81.0'-83.8'. 91.5'
2008	90	Bottom of Hole		Casing left in hole.
	100			

Depth of Hole	91.5'
Thickness of Overburden	67'
Rock drilled	24.5'
Rock cored	9.2'
Core Recovered	9.2'
% Core Recovered	100

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-16

SUMMARY LOG — HOLE NO. DR-17

HOLE NO. DR-17	N 3231232 / E 743625	SHEET 1 OF 1; SURFACE ELEV. 2167
PROJECT Watana Dam	DRILL DATES: START 6 Jun 1978	COMP. 8 Jun 78
DEPTH OF HOLE 35.7'	DEPTH OF OVERBURDEN 9.0'	DIAM. OF HOLE See Remarks
ROCK DRILLED 26.7'	CORE RECOVERED 21.2'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ----	COMPILED BY, DATE Pat 10 Oct 78
DISTANCES: VERTICAL, 35.7'; HORIZONTAL, ----		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2167	0	SM, Silty sand, dark brown, wet, loose, non-plastic. [TILL]	1	Sample 1, 5.0'-6.0' cuttings. 6.0'
		GP, Silty sand with cobbles and gravel, brown, wet, loose, non-plastic.		9.0'
2158	10	Top of Rock. Diorite, hard, medium grained, lightly weathered, moderately to lightly fractured, light gray. Fractures high angle to vertical with occasional iron staining.		5-5/8 inch tricone bit and mud 0.0' to 14.5'. 2-3/4 x 3-7/8 inch core 14.5' to 35.7'; 100% recovery. SWL 5.6'-23 Jun 1978; 3.9'-1 Jul 1978; 2.8'-10 Jul 1978; 2.6'-17 Jul 1978; 2.5'-18 Aug 1978
2131		Bottom of Hole		35.7'. Piezometer installed to 35'
	40			
	50			

Depth of hole	35.7'
Thickness of Overburden	9.0'
Rock drilled	26.7'
Rock cored	21.2'
Core Recovered	21.2'
% Core recovered	100

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-17

SUMMARY LOG — HOLE NO. DR-18 (Sheet 1 of 3)

HOLE NO. DR-18	N 3231373 / E 744284	SHEET 1 OF 3; SURFACE ELEV. 2172
PROJECT Watana Dam	DRILL DATES: START 9 Jun 1978	COMP. 21 Jun 1978
DEPTH OF HOLE 248.3'	DEPTH OF OVERBURDEN 231'	DIAM. OF HOLE See Remarks
ROCK DRILLED 17.3'	CORE RECOVERED 5.5'	% RECOVERY 60
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE Pat 18 Oct 78
DISTANCES: VERTICAL, 248.3'; HORIZONTAL, —		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2172	0	ML, Sandy Silt, with boulders and and cobbles, brown, damp, non-plastic. (Outwash)	A, 1	Sample A, 0.5'-1.0' Grab sample. 12'
2160	10	ML, Sandy silt, gray-brown, damp, non-plastic. Occasional gravel and clay layers.		Sample 1, 12.0'-13.0' Drive sample, 100 Blows. 20'
2152	20	CL-ML to ML, Sandy silt, gray, wet, dense, non-plastic. Frozen. Natural moisture content 42.5%. Liquid Limit 20.7%	2, 3	6 inch Csg to 20'. Sample 2, 28.1'-29.6' Drive sample, 69 Blows. Sample 3, 38.5'-40.0' Drive Sample, 50 blows. No recovery. 48'
2124	50	SM, silty sand, gray, wet, dense, non-plastic. Frozen	4	Piezometer installed to 65'. Sample 4, 63'-65.0' Drive sample, 105 blows (2 inch spoon). 68'
2104	70	CM-ML, Sandy silt, gray, damp, dense, non-plastic. Minor sub-rounded coarse sand. Occasional sub-rounded small gravel below 90'	5, 6	Sample 5, 72.7'-74.5' Drive sample, 68 blows. 5-5/8 inch tricone bit and mud, 0'-239.2'. Sample 6, 97.6'-98.6' Drive Sample, 81 blows
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-18

SUMMARY LOG — HOLE NO. DR-18 (Sheet 2 of 3)

HOLE NO. DR-18	N 3231373 / E 744284	SHEET 2 OF 3; SURFACE ELEV. 2172
PROJECT Watana Dam	DRILL DATES: START 9 Jun 78	COMP. 21 Jun 78
DEPTH OF HOLE 248.3'	DEPTH OF OVERBURDEN 231'	DIAM. OF HOLE See Remarks
ROCK DRILLED 17.3'	CORE RECOVERED 5.5'	% RECOVERY 60
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE Pat 18 Oct 78
DISTANCES: VERTICAL, 248.3'; HORIZONTAL, —		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	100	CL-ML, Sandy silt, IBID.		110'
2062	110	GM, Sandy, Silty gravel with cobbles and boulders, gray-brown, damp, dense non-plastic. Gravel rounded to sub-rounded; boulders to 1.5 feet in diameter. Occasional weathered zones with iron staining. (Till)	7, 8	Sample 7, 118.5'-122.7' NXC-3 core. 5-5/8 inch tricone bit and mud, 0'-239.2'. Sample 8, 158.3'-159.6' Drive Sample, 7 blows. 170'
2002	170	Sandy silt with minor gravel, gray-brown, damp, dense to very dense, non-plastic. Boulders and cobbles absent. (Till)		190'
1982	190	MH Sandy silt interlayered with silty clay.		Sample 9, 199.1'-200.2' Drive sample, 100 blows.
	200			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-18

SUMMARY LOG — HOLE NO. DR-18 (Sheet 3 of 3)

HOLE NO. DR-18	N 3231373 / E 744284	SHEET 3 OF 3; SURFACE ELEV. 2172
PROJECT Watana Dam	DRILL DATES: START 9 Jun 1978	COMP. 21 Jun 78
DEPTH OF HOLE 248.3'	DEPTH OF OVERBURDEN 231'	DIAM. OF HOLE See Remarks
ROCK DRILLED 17.3'	CORE RECOVERED 5.5'	% RECOVERY 60
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE Pat 18 Oct 78
DISTANCES: VERTICAL, 248.3'; HORIZONTAL, —		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	200	MH, sandy silt, gray-brown, damp, very dense, plastic, interlayered, with silty clay, blue-gray, damp, very dense, plastic. Occasional random scattered gravel and cobbles. (Till)	9	5-5/8 inch tricone bit and mud, 0'-239.2'
1941	230	Top of Rock		231'
		Dioroite, moderately hard, medium grained, altered, highly fractured, gray. Disseminated sulfides throughout.		4 inch Csg to 240'. 2-3/4 x 3-7/8 inch core 239.2'-248.3'. 248.3'
1924	250	Bottom of Hole		3/4 inch galvanized pipe installed to bottom; temperature measurement. 6 inch Csg left in Hole. SWL rising: 19.9' - 23 Jun 1978; 15.6' - 1 Jul 1978; 13.8' - 10 Jul 1978; 12.8' - 17 Jul 1978; 12.3' - 25 Jul 1978; 12.1' - 7 Aug 1978; 12.6' - 18 Aug 1978; 12.1' - 23 Aug 1978

Depth of Hole	248.3'
Thickness of overburden	231'
Rock drilled	17.3'
Rock cored	9.1'
Core recovered	5.5'
% Core recovered	60

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-18

SUMMARY LOG — HOLE NO. DR-19

HOLE NO. DR-19	N 3229568 / E 746163	SHEET 1 OF 1; SURFACE ELEV. 2151
PROJECT Watana Dam	DRILL DATES: START 29 Jun 78	COMP. 3 Jul 78
DEPTH OF HOLE 78.3'	DEPTH OF OVERBURDEN 55'	DIAM. OF HOLE
ROCK DRILLED 23.3'	CORE RECOVERED 11.8'	% RECOVERY 96%
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE Pat 10 Oct 78
DISTANCES: VERTICAL, 78.3'; HORIZONTAL, ---		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2151	0	Gravelly silty sand with boulders, brown, moist to wet, dense, non-plastic. Red-brown iron stain common. Gravel rounded, 1-2 inches in diameter.	1, 2	7 7/8 inch tricone bit and mud, 0.0'-21.0'. Sample 1, 8.5'-9.4' cuttings. Sample 2, 21.0'-22.3' drive sample, 100 blows. 5 5/8 inch tricone bit and mud 21.0'-66.2'. 36'
2115		Silty, sandy gravel with boulders, brown, moist to wet, dense, non-plastic. Red-brown iron stain common. Gravels and cobbles rounded. Top of Rock	3	Sample 3, 36.2'-36.9' Drive sample, 150 blows. Low recovery. Piezometer installed to 42.0'. 55'
2096		Diorite, moderately hard, medium grained, moderately weathered, moderately fractured, gray. Iron stain common on fractures.		2 3/4 x 3 7/8 core 66.2'-78.3'. 78.3'
2073	80	Bottom of Hole		3/4 inch galvanized pipe to bottom; temperature measurement. SWL: 2.2' 10 Jul 78; 2.6' 17 Jul 78; 2.9' 25 Jul 78; 4.1' 7 Aug 78; 5.6' 18 Aug 78; 5.2' 23 Aug 78
	100			

Depth of hole	78.3'
Thickness of overburden	55'
Rock drilled	23.3'
Rock cored	12.1'
Core recovered	11.8'
% Core recovered	

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-19

SUMMARY LOG — HOLE NO. DR-20 (Sheet 1 of 3)

HOLE NO. DR-20	N 3230729 / E 745062	SHEET 1 OF 3; SURFACE ELEV. 2207
PROJECT Watana Dam	DRILL DATES: START 17 May 1978	COMP. 29 May 78
DEPTH OF HOLE 252.6'	DEPTH OF OVERBURDEN 210'	DIAM. OF HOLE See Remarks
ROCK DRILLED 42.6'	CORE RECOVERED 17.5	% RECOVERY See Remarks
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ----	COMPILED BY, DATE Pat 10 Oct 78
DISTANCES: VERTICAL, 252.6'; HORIZONTAL, ----		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2207	0	SM, silty sand with occasional boulders, gravel and clay, brown, damp, loose, non-plastic. Gravels are rounded. [Glacial Outwash]	1	7 7/8 inch tricone bit with mud 0.0'-40.0'. Sample 1; 9.0'-11.0' cuttings. 20.5'
2187	20	Clayey, sandy silt, dark gray, moist, compact.	2A, 2B	Sample 2; 24.0'-25.5' Drive sample/25 blows. 30'
	30	CL, silty clay, dark gray, moist, compact to dense.	3	SWL 40.1'-38.7' (23 Jun-18 Aug 1978). Sample 3; 37.0'-38.5' Drive Sample/100 blows. 40'
	40	SM, sandy silt to CL, silty clay, dark gray, moist, compact. [Lake Deposit]	4A, 4B	Sample 4; 50.0'-51.5' Drive Sample/100 blows. 53'
2154	50	Sandy gravel, brown, wet, loose. Gravels are rounded. [Alluvial Deposit]	5	Sample 5; 58.3'-58.6' Drive sample/125 blows. Cuttings; 58.6'-63.0'. 5 5/8 inch tricone bit with mud 40.0'-237.6'. Samples 5, 6 & 7 lost. Descriptions from cuttings. Piezometer installed to 82.5'. 90'
2117	90	Silty, sandy gravel with rock fragments and occasional boulders, gray to dark gray, moist, compact to dense.		
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-20

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

DRILL HOLE LOGS NO. 6

DR-16 THRU DR-20

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

PLATE D-33

SUMMARY LOG — HOLE NO. DR-20 — SHEET 2 OF 3

N 3230729 · E 745062 · SURFACE ELEV. 2207
PROJECT: Watana Dam · DRILL DATES: START 17 May 1978 · COMP. 28 May 78
DEPTH OF HOLE 252.6' · DEPTH OF OVERBURDEN 210' · DIAM. OF HOLE See Remarks
ROCK DRILLED 42.6' · CORE RECOVERED 17.2' · % RECOVERY See Remarks
ANGLE FROM VERT. 0° · AZIMUTH FROM NORTH ---- · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 252.6'; HORIZONTAL, ----

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	100	Silty, sandy gravel, IBID.		
			6	
	110–128	Sandy silt; 106'-128'		
	130–150	[Glacial Till]		
2040	160	Quartzdiorite boulder; 158'-167'	7	167'
	170	Clayey, silty sand with minor gravel and occasional boulders, light brown, moist, compact to dense. Occasional sand and clay layers.		
	180		8	Sample 8; 179'-185'. cuttings
	190	[Glacial Till]	9	Sample 9; 189.5'-195.1' 2-3/4 x 3-7/8 inch core.
	200			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DR-20

SUMMARY LOG — HOLE NO. DR-20 — SHEET 3 OF 3

N 3230729 · E 745062 · SURFACE ELEV. 2207
PROJECT: Watana Dam · DRILL DATES: START 17 May 1978 · COMP. 29 May 78
DEPTH OF HOLE 252.6' · DEPTH OF OVERBURDEN 210' · DIAM. OF HOLE See Remarks
ROCK DRILLED 42.6' · CORE RECOVERED 17.2' · % RECOVERY See Remarks
ANGLE FROM VERT. 0° · AZIMUTH FROM NORTH ---- · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 252.6'; HORIZONTAL, ----

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	200	IBID [Glacial Till]	10	Sample 10; 200'-202' cuttings.
1997	210	Top of Rock		210'
		Diorite, soft, medium grained, highly fractured to decomposed, blue-gray. Clay gouge common. Shear zone.	11A 11B	Sample 11; 218.0'-222.7' 2-3/4 x 3-7/8 inch core. (Sample not boxed; shipped to laboratory)
	230–240		0 100	Rock cored 237.6' to bottom.
1954	250			
		Bottom of Hole Depth of Hole 252.6' Thickness of Overburden 210.0' Rock drilled 42.6' Rock cored 19.7' Core recovered 17.2' % Core recovered 82%		
	260–300			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DR-20

SUMMARY LOG — HOLE NO. DH-21 — SHEET 1 OF 7

N 3226405 · E 744457 · SURFACE ELEV. 1480
PROJECT: Watana Dam · DRILL DATES: START 3 Jul 78 · COMP. 16 Aug 78
DEPTH OF HOLE 603.7' · DEPTH OF OVERBURDEN 84.5' · DIAM. OF HOLE NCQ
ROCK DRILLED 519.2' · CORE RECOVERED 519.2' · % RECOVERY 100
ANGLE FROM VERT. 32.4°* · AZIMUTH FROM NORTH 03.90°* · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 509.7'; HORIZONTAL, 323.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	0	Overburden: Boulder 0.0 to 2.7' Organic Silt 2.7 to 6.8' Cobbles and Rock Fragments 6.8' To 11.2' (Colluvium)		Tundra Frozen At 0.9'
1469	10			11.2'
	20	River Sands & Gravels. Fine Sand 11.2' To 15.4' Sub-Angular to Sub-Rounded; Occasionally Angular Boulder 16.0' To 17.0' Fine Silty Sand 15.4' To 24.7' Occasional Organic Material Gravelly Sand 24.7' To 26.5' Rock Fragments 26.5' To 30.0'		100% Dwr 0.0' To 26.5' (Permafrost) 30.0'
1450	30	Cobbles In Sand Matrix.		4" CSG To 33.4' 0%-20% Dwr 26.5 To 43.4' (Thawed)
	40			100% Dwr 43.4' To 49.5' (Permafrost) 45.0'
1435	50	Sandy Gravel, Gravel Sub-Rounded, Occasional Boulders, Grading to Boulders in Sand Matrix From 50' to 84.5' (Alluvium)		0% Dwr 49.5' To 50.0' (Thawed) 100% Dwr 50.0' To 69.5' (Permafrost)
	60–80			Samples of Cobbles And Boulders Recovered 0% Dwr 69.5' To 84.5' (Thawed)
1396		Top Of Rock		84.5' NXCSG To 84.7'
	90–100	Quartz Diorite, Hard, Medium Grained, Lightly Weathered, Moderately Fractured, Gray. Light to Moderate Fracture Below 90.4' Locally Grades To Granodiorite		Fracture Spacing 84.5' To 100'; Fragments to 2.1' 100% Dwr 84.5' To 100.0'

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-21

SUMMARY LOG — HOLE NO. DH-21 — SHEET 2 OF 7

N 3226405 · E 744457 · SURFACE ELEV. 1480
PROJECT: Watana Dam · DRILL DATES: START 3 Jul 78 · COMP. 16 Aug 78
DEPTH OF HOLE 603.7' · DEPTH OF OVERBURDEN 84.5' · DIAM. OF HOLE NCQ
ROCK DRILLED 519.2' · CORE RECOVERED 519.2' · % RECOVERY 100
ANGLE FROM VERT. 32.4°* · AZIMUTH FROM NORTH 03.9°* · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 509.7'; HORIZONTAL, 323.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz Diorite, Ibid		
	120	Lightly Fractured 119.1' To 133.7' Healed Fractures Common Below 120'		
	130–140	Lightly To Moderately Fractured 133.7'-328.5'. Zone Is Predominantely Lightly Fractured With Short Highly Fractured Sections.		100% Dwr 129.4'-209.0'
	160	Shear With Gouge, 162.6' To 163.8' Partially Healed. 45° To Core.		Fracture Spacing 100'-200'; 0.1' To 2.1'
	180–200	Healed Shear 187.0', 45° To Core		

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-21

SUMMARY LOG — HOLE NO. DH-21 — SHEET 3 OF 7

N 3226405 · E 744457 · SURFACE ELEV. 1480
PROJECT: Watana Dam · DRILL DATES: START 2 Jul 78 · COMP. 16 Aug 78
DEPTH OF HOLE 603.7' · DEPTH OF OVERBURDEN 84.5' · DIAM. OF HOLE NCQ
ROCK DRILLED 519.2' · CORE RECOVERED 519.2' · % RECOVERY 100
ANGLE FROM VERT 32.4 · AZIMUTH FROM NORTH 03.9°* · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 509.7'; HORIZONTAL, 323.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	200	Quartz Diorite, Ibid Healed Shear 201.0-202.5. Moderately Soft		
	210	Healed Fractures More Common Below 200'		
	220	Highly Fractured 215.5' To 223.1 Healed Shear 218.3'-218.6'		Pink Feldspars Common (Local Granodiorite)
	230			100% Dwr 200'-300' Fracture Spacing 200' To 300' 0.1' To 1.6'
	240–250	Shear 243.9' To 244.6' With Light Gray Gouge. Healed Shear 247.5' To 248.4'		
	260	Minor Alteration In Healed Shear 259.0'-259.8' Highly Fractured 260.0'-262.0'		
	280	Shear, 278.1'-280.0' Moderately Weathered To Partly Decomposed, Gouge Present. Highly Fractured 284.2'-286.7'		
	290–300			

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-21

SUMMARY LOG — HOLE NO. DH-21 — SHEET 4 OF 7

N 3226405 · E 744457 · SURFACE ELEV. 1480
PROJECT: Watana Dam · DRILL DATES: START 3 Jul 78 · COMP. 16 Aug 78
DEPTH OF HOLE 603.7' · DEPTH OF OVERBURDEN 84.5' · DIAM. OF HOLE NCQ
ROCK DRILLED 519.2' · CORE RECOVERED 519.2' · % RECOVERY 100
ANGLE FROM VERT. 32.4°* · AZIMUTH FROM NORTH 03.9°* · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 509.7'; HORIZONTAL, 323.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	300	Quartz Diorite Ibid.		
	310	Highly Fractured 302.3'-305.0' Healed Fractures 303.6'-304.2' 305.2'-305.7' Pyrite Common On Fractures Below 315.7'		Fracture Spacing 300'-330' 0.1' To 1.7'
	320			100% Dwr 309' To 345'
	330	Lightly Fractured 328.5'-391.2'		Fracture Spacing 330'-390' 0.1' To 3.7'
	340			0% Dwr 345'- 354
	350			100% Dwr 354'-364.2'
	360			0% Dwr 364.2'-381.3'
	380			100% Dwr 381.3'-390'
	390–400	Moderately Fractured 391.2'-395.5' Highly Fractured 395.5'-397.1'		0% Dwr 390'-394' 50% Dwr 394'-400' Fracture Spacing 390'-400' 0.1' To 1.1'

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-21

SUMMARY LOG — HOLE NO. DH-21 — SHEET 5 OF 7

N 3226405 · E 744457 · SURFACE ELEV. 1480
PROJECT: Watana Dam · DRILL DATES: START 3 Jul 78 · COMP. 16 Aug 78
DEPTH OF HOLE 603.7' · DEPTH OF OVERBURDEN 84.5' · DIAM. OF HOLE NCQ
ROCK DRILLED 519.2' · CORE RECOVERED 519.2' · % RECOVERY 100
ANGLE FROM VERT. 32.4°* · AZIMUTH FROM NORTH 03.9°* · COMPILED BY, DATE: Sat 10 Oct 78
DISTANCES: VERTICAL, 509.7'; HORIZONTAL, 323.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	400	Quartz Diorite Ibid Highly Fractured 402.5'-403.4' Moderately Fractured 417.3'-468.7'		50% Dwr 400'-414.2' 25% Dwr 414.2'-440'
	410–440			Fracture Spacing 400'-440 0.1' To 2.2'
	450	Shear 449.8'-452.0' Gouge 450.0' Slicks Show Movement Perpendicular To Core. Shear Partially Healed.		Fracture Spacing 440'-470' 0.1' To 1.9'
	460	Shear, 457.5'-463.0; Moderately To Highly Weathered, Partially Decomposed, Altered. Healed Fractures Common. Gouge 468.2'		0% Dwr 440'-500'
	470–490	Lightly Fractured 463.7'-499.1		Fracture Spacing 470'-499' 0.1' To 3.8'
	500	Highly Fractured 499.1'-500.5'		

NPA Form 7(Test) APR. 66 · PROJECT Watana Dam · HOLE NO. DH-21

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 7
DR-20 (CONT.) AND DH-21
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SUMMARY LOG — HOLE NO. DH-21 (Sheet 6 of 7)

N 3226405 / E 744457	SHEET 6 OF 7	SURFACE ELEV. 1480
PROJECT Watana Dam	DRILL DATES: START 3 Jul 78	COMP. 16 Aug 78
DEPTH OF HOLE 603.7'	DEPTH OF OVERBURDEN 84.5'	DIAM. OF HOLE NCQ
ROCK DRILLED 519.2'	CORE RECOVERED 519.2'	% RECOVERY 100
ANGLE FROM VERT. 32.4°*	AZIMUTH FROM NORTH 03.9°*	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 509.7'	HORIZONTAL, 323.5'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	500	Quartz Diorite; Ibid. Minor Clay On Fractures 499.1'-500.5		50% Dwr 500'-522.5'. Fracture Spacing 500'-511.2' <0.1' To 1.4'
968	510	Moderately Fractured 509.5' To 511.2'		512.5'
955	520	Andesite Porphory, Hard, Lightly, Weathered Fine Grained, Lightly Fractured, Dark Gray. Contact 512.5-513.7' & 524.1-525.1', Green Chill Zone. Disseminated Pyrite Common Healed Fractures (Dike)		525.1'
	530–540	Minor Alteration 525.1'-526.9' (Thermal). Quartz Diorite Ibid. Healed Breccia 535.0'-538.2'. Minor Alteration		Fracture Spacing 511.2'-570' <0.1' To 5.0'
	550–560	Healed Fractures Rare Below 550'. Lightly Fractured 511.2'-568.0'		0° Dwr 522.5'-603.7'
	570–580	Shear 568.6'-580.4', Highly Fractured; Yellow-Brown Gouge Common. Decomposed 570.3'-570.9'. Lightly Fractured 580.4' 603.7'		Fracture Spacing 570'-580' 0-1' To 0.4'. Core Breaks Common On Healed Fractures
	590–600	Shear, 589.6', White Clay Gouge		Fracture Spacing 560'-603.7' <0.1'-1.6'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-21

SUMMARY LOG — HOLE NO. DH-21 (Sheet 7 of 7)

N 3226405 / E 744457	SHEET 7 OF 7	SURFACE ELEV. 1480
PROJECT Watana Dam	DRILL DATES: START 3 Jul 78	COMP. 16 Aug 78
DEPTH OF HOLE 603.7'	DEPTH OF OVERBURDEN 84.5'	DIAM. OF HOLE NCQ
ROCK DRILLED 519.2'	CORE RECOVERED 519.2'	% RECOVERY 100
ANGLE FROM VERT. 32.4°*	AZIMUTH FROM NORTH 03.9°*	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 509.7'	HORIZONTAL, 323.5'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
876	600	Quartz Diorite; Ibid		603.7'
	610	Bottom Of Hole. Depth Of Hole 603.7'; Thickness of Overburden 84.5'; Rock Cored 519.2'; Core Recovered 519.2'; % Core Recovered 100		Hole Not Pressure Tested Due To Mechanical Problems. Hole Caped For Later Testing.

* Hole Survey

Depth	Bearing	Angle From Vert
598.7'	----	33°
548.7'	03°	32°
498.7'	03.5°	32°
448.7'	03°	32°
398.7'	04°	32°
348.7'	03°	32°
298.7'	06°	33°
248.7'	04.5°	33°
198.7'	04°	33°
148.7'	03°	32°
98.7'	05°	32°

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-21

SUMMARY LOG — HOLE NO. DR-22 (Sheet 1 of 6)

N 3232202 / E 746805	SHEET 1 OF 6	SURFACE ELEV. 2229
PROJECT Watana Dam	DRILL DATES: START 5 Jul 1978	COMP. 3 Aug 1978
DEPTH OF HOLE 493.6'	DEPTH OF OVERBURDEN 454'	DIAM. OF HOLE See Remarks
ROCK DRILLED 39.6'	CORE RECOVERED 17.6'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE: Pat 17 Oct 78
DISTANCES: VERTICAL, 493.6'	HORIZONTAL, —	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2229	0–50	SM, Silty Sand, Gravelly With Boulders, Brown, Wet, Dense; Rounded Gravels. Boulders 2'-3' In Diameter Common; Occassional Clay Layers. (Outwash)	1, 2	Sample A; 0.5'-1.0' Grab Sample. 7-7/8 inch Tricone Bit And Mud, 0.0'-17.5'. Sample 1; 17.5'-19.0' Drive Sample/77 Blows. 5-5/8 inch Tricone Bit and Mud, 17.5'-417.0'. Sample 2; 37.9'-39.8' Drive Sample/25 Blows. 6 inch Csg to 53'. 56'
2173	60–70	SM-SC, Gravelly, Silty Sand Clayey with Boulders, Gray, Moist, Dense. Moisture Content Avg. 8.1% (Till)	3	Sample 3; 58.0'-59.5' Drive Samples/100 Blows. 72'
2157	70–80	CL-ML, Gravelly, Sandy Silt, Dark Gray, Damp, very Dense, Non-plastic. Frozen Sub-rounded Gravel; Occasional Cobbles. (Till)	4	Sample 4; 77.4'-78.9' Drive Samples/144 Blows. 90'
2139	90–100	SM, Gravelly, Silty Sand Brown, Wet, Non-plastic; Occasional Layers of Gray Silt. (Alluvium)	5	Sample 5; 97.0'-98.5' Drive Sample/200 Blows

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-22

SUMMARY LOG — HOLE NO. DR-22 (Sheet 2 of 6)

N 3232202 / E 746805	SHEET 2 OF 6	SURFACE ELEV. 2229
PROJECT Watana Dam	DRILL DATES: START 5 Jul 1978	COMP. 3 Aug 1978
DEPTH OF HOLE 493.6'	DEPTH OF OVERBURDEN 454'	DIAM. OF HOLE See Remarks
ROCK DRILLED 39.6'	CORE RECOVERED 17.6'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE: Pat 19 Oct 78
DISTANCES: VERTICAL, 493.6'	HORIZONTAL, —	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	100–130	SM, Gravelly, Silty Sand, IBID. Frozen 90'-110'. Coarse to Medium Grained Becoming Finer With Depth. (Alluvium)	6	5-5/8 inch Tricone Bit And Mud; 17.5'-417.8'. Thermistor to 105'. Sample 6; 117.2'-118.5' Drive Sample/180 Blows. 131'
2098	130–180	SC, Silty, Gravelly Sand With Clay Layers and Boulders. Sand, Coarse, Sub rounded to Subangular, Brown, Non-plastic. Gravel, Rounded to 1 Inch. Clay, Gray, Plastic, Wet, Dense. Boulders Common, 2'-3' in Diameter. LL 65.7, PL 21.4, PI 44.3 (Till)	7, 8	Sample 7; 139.5'-140.0' No recovery. Sample 8; 157.9'-158.4' Drive Sample/150 Blows. 183'
2046	180–200	SM, Sand With Interbedded Silt Layers. Silt, Gray, Non-plastic, Moist, Varved. 1 inch Silt Layer in Sample 9.	9	Sample 9; 198.3'-199.5' Drive Sample/500 Blows

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-22

SUMMARY LOG — HOLE NO. DR-22 (Sheet 3 of 6)

N 3232202 / E 746805	SHEET 3 OF 6	SURFACE ELEV. 2229
PROJECT Watana Dam	DRILL DATES: START 5 Jul 1978	COMP. 3 Aug 1978
DEPTH OF HOLE 493.6'	DEPTH OF OVERBURDEN 454'	DIAM. OF HOLE See Remarks
ROCK DRILLED 39.6'	CORE RECOVERED 17.6'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE: Pat 17 Oct 78
DISTANCES: VERTICAL, 493.6'	HORIZONTAL, —	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	200	SM, Sand With Interbedded Silt Layers; IBID. (Alluvium)		5-5/8 inch Tricone Bit and Mud; 17.5'-417.8'. 208'
2021	210–230	GP, Sandy Gravel With Occassional Sand Layers. (Alluvium)	10	Sample 10; 212'-217' Cuttings. Mud Loss 208'-231' 50+ Gal./Ft. Piezometer to 222.9'. 231'
1998	230–290	SM-SC, Gravelly, Silty Sand With Boulders, Brown, Damp, Non-plastic, very dense. Boulder 242'-248'. Boulders normally 1'-2' in Diameter. Occasional Sand and Silt Layers. Silt and Sand Common Around Boulders. (Till). Boulder 281'-291'	11	Sample 11; 238.4'-238.8' Drive Sample/500 blows. 293'
1936	290–300	Sandy Gravel With Boulders.		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-22

SUMMARY LOG — HOLE NO. DR-22 (Sheet 4 of 6)

N 3232202 / E 746805	SHEET 4 OF 6	SURFACE ELEV. 2229
PROJECT Watana Dam	DRILL DATES: START 5 Jul 1978	COMP. 3 Aug 78
DEPTH OF HOLE 493.6'	DEPTH OF OVERBURDEN 454'	DIAM. OF HOLE See Remarks
ROCK DRILLED 39.6'	CORE RECOVERED 17.6'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH —	COMPILED BY, DATE: Pat 17 Oct 78
DISTANCES: VERTICAL, 493.6'	HORIZONTAL, —	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	300–375	Sandy Gravel With Boulders. Layered Sands And Gravels. Boulder Common, 2'-5' in Diameter. (Alluvium). Boulder 354'-366'		Mud Loss 293'-375' 14+ Gal/Ft. Description From Cuttings. 5-5/8 inch Tricone Bit and Mud; 17.5'-417.8'. 375'
1854	375–400	Gravel and Boulders, Sand and Silt Lenses Common. Boulder 393'-401'		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-22

SUMMARY LOG — HOLE NO. DR-22 (Sheet 5 of 6)

N 3232202 / E 746805	SHEET 5 OF 6	SURFACE ELEV. 2229
PROJECT Watana Dam	DRILL DATES: START 5 Jul 78	COMP. 3 Aug 78
DEPTH OF HOLE 493.6'	DEPTH OF OVERBURDEN 454'	DIAM. OF HOLE See Remarks
ROCK DRILLED 39.6'	CORE RECOVERED 17.6'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -------	COMPILED BY, DATE: Pat 17 Oct 78
DISTANCES: VERTICAL, 493.6'	HORIZONTAL, -------	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
	400–454	Boulders; Ibid. Gravels Rounded; Silts Laminated. Boulder 412'-422. Silt. Boulder 422'+-432.7'. (Alluvium). Top of Rock	12	5-5/8 Inch Tricone Bit And Mud; 17.5'-417.8'. 4 Inch Csg to 417.8'. Sample 12; 422'-422'+ Grab between Boulders. Cored With 2 3/4 X 3-7/8 Inch Barrel; 417.8'-432.7'. 3-3/8 Inch Tricone Bit And Mud; 432.7'-476.0'. 454'
1775	454–493.6	Quartz Diorite, Soft To Hard Medium Grained, Lightly Weathered with Minor Alteration of Mafics, Moderately Fractured (45° And 85° Preferred), White To Light Gray.		Cored With 2-3/4 X 3-7/8 Inch Barrel 476.0- 493.6'. 493.6'
1735	500	Bottom Of Hole		3/4 Inch Pipe (Temperature Probe) To 492.4'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-22

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 8
DH-21 (CONT.) AND DR-22

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE ALASKA

SUMMARY LOG — HOLE NO. DR-22

N 3232202 / E 746805	SHEET 6 OF 6	SURFACE ELEV. 2229
PROJECT: Watana Dam	DRILL DATES: START 5 Jul 78	COMP. 3 Aug 78
DEPTH OF HOLE 493.6'	DEPTH OF OVERBURDEN 454'	DIAM. OF HOLE See Remarks
ROCK DRILLED 39.6'	CORE RECOVERED 17.6'	% RECOVERY 100
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH --------	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 493.6'	HORIZONTAL, ---------	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
		Depth of Hole 493.6' Thickness of Overburden 454' Rock Drilled 39.6' Rock Cored 17.6' Core Recovered 17.6' % Core Recovered 100		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-22

SUMMARY LOG — HOLE NO. DH-23

N 3225734 / E 744618	SHEET 1 OF 2	SURFACE ELEV. 1952
PROJECT: Watana Dam	DRILL DATES: START 7 Jul 1978	COMP. 17 Jul 1978
DEPTH OF HOLE 119.2'	DEPTH OF OVERBURDEN 7.0'	DIAM. OF HOLE NX
ROCK DRILLED 112.2'	CORE RECOVERED 111.4'	% RECOVERY 99.4
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 220° 18'	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 84.3'	HORIZONTAL, 84.3'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1952	0	Overburden; Talus in silt & sand.		
1951		Top of Rock.		7.0'
	10	Quartz diorite, lightly weathered, moderately to highly fractured, medium grained, hard, gray.		Top of permafrost 14' (23 Aug 1978)
		Shear 16.3' to 18.2'; shear contains healed breccia from prior movement.		NX CSG to 19.4'
	20			Fracture spacing 7.0' to 30.0' <0.1' to 0.8'
	30	Shear 31.1' to 31.8'		
		Moderately to lightly fractured 30' to 40'.		K=0.0
	40			Fracture spacings 30.0' to 40.0' <0.1' to 1.3'
		Shear 45.5' to 47.9'; healed fractures and red-brown gouge common.		
	50	Moderately fractured 40' to 90'.		
	60	Shear 61.5' to 64.0'		Fracture spacing 40.0' to 90.0' <0.1' to 0.7'
	70	Fragments with slicks 74.4' to 75.6'		Healed fracture spacing 7.0' to 119.0' <0.1' to 2.0'
		Hydro thermal alteration 76.7' to 81.0'		
	80			K=0.0
		Shear zone 74.4' to 99.4' zones of fresh, hard, lightly weathered quartz diorite between shears.		
	90	Highly fractured & altered 86.7' to 94.6'		Fracture spacing 90.0' to 100.0' <0.1' to 0.4'
	100	0.2' clay gouge 99.2' to 99.4'		

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-23

SUMMARY LOG — HOLE NO. DH-23

N 3225734 / E 744618	SHEET 2 OF 2	SURFACE ELEV. 1952
PROJECT: Watana Dam	DRILL DATES: START 7 Jul 1978	COMP. 17 Jul 78
DEPTH OF HOLE 119.2'	DEPTH OF OVERBURDEN 7.0'	DIAM. OF HOLE NX
ROCK DRILLED 112.2'	CORE RECOVERED 111.4'	% RECOVERY 99.4
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 220°18'	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 84.3'	HORIZONTAL, 84.3'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz diorite, IBID, lightly fractured.		Fracture spacing 100.0' to 119.2' 0.1' to 2.0'
	110			Left 0.3' in hole
1861	120			119.2'
		Bottom of Hole Depth of hole 119.2' Thickness of overburden 7.0' Rock cored 112.2' Core recovered 111.4' % Core recovered 99.4		Hole left open and filled with antifreeze.

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-23

SUMMARY LOG — HOLE NO. DH-24

N 3225362 / E 744727	SHEET 1 OF 2	SURFACE ELEV. 2061
PROJECT: Watana Dam	DRILL DATES: START 25 Jul 1978	COMP. 31 Jul 78
DEPTH OF HOLE 139.9'	DEPTH OF OVERBURDEN 6.9'	DIAM. OF HOLE NCQ
ROCK DRILLED 133.0'	CORE RECOVERED 129.9'	% RECOVERY 97.7
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ----	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 139.9'	HORIZONTAL, ----	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2061	0	Overburden: Talus in silt, sand and gravel.		Annual frost at 0.8' (25 Jul 1978)
2054		Top of Rock.		6.9'
	10	Quartz diorite, hard, medium grained, lightly to moderately fractured, highly fractured in shear zones, gray.		Top of permafrost 8' NX CSG to 8.6'
				Fracture spacing 10'-20' <0.1' to 2.7'
	20	Minor hydro thermal alteration below 21'.		
		Healed fractures common. Iron staining on joints common.		
	30			K (12.8'-139.9')0.0
	40	Shear 39.4'-40.5', highly fractured with light gray gouge.		
		Healed breccia 45.6'-46.7'		
	50			Fracture spacing 20'-80' <0.1' to 1.5'
	60			
	70			
	80	Shear Zone, 81.81'-86.8; Stained, Partially Decomposed, Highly Fractured.		
	90			Fracture spacing 80'-100' <0.1' to 0.8'
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-24

SUMMARY LOG — HOLE NO. DH-24

N 3225362 / E 744727	SHEET 2 OF 2	SURFACE ELEV. 2061
PROJECT: Watana Dam	DRILL DATES: START 24 Jul 1978	COMP. 31 Jul 78
DEPTH OF HOLE 139.9'	DEPTH OF OVERBURDEN 6.9'	DIAM. OF HOLE NCQ
ROCK DRILLED 133.0'	CORE RECOVERED 129.9'	% RECOVERY 97.7
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ----	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 139.9'	HORIZONTAL, ----	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Quartz diorite, IBID.		100.5'
		Small shear 102.2'-102.6' Healed quartz diorite breccia, hard, medium grained, light to moderately fractured, gray. Lightly fractured below 128.1'.		Fracture spacing 100'-120' <0.1' to 1.5'
	110			
	120	Cored edge of porphoritic andesite intrusion, 113.0'-139.9'. Brecciated (healed), hard, fine grained, lightly to moderately fractured, dark gray. Pyrite common.		
	130			Fracture spacing 120'-139.9' 0.1' to 4.4'
1921	140			139.9'
		Bottom of Hole Depth of hole 139.9' Thickness of overburden 6.9' Rock cored 133.0' Core recovered 129.9' % Core recovered 97.7		
	150			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-24

SUMMARY LOG — HOLE NO. DH-25

N 3225661 / E 745950	SHEET 1 OF 1	SURFACE ELEV. 2045
PROJECT: Watana Dam	DRILL DATES: START 8 Aug 78	COMP. 13 Aug 78
DEPTH OF HOLE 79.9'	DEPTH OF OVERBURDEN 79.9'	DIAM. OF HOLE NX
ROCK DRILLED 0.0'	CORE RECOVERED SEE REMARKS	% RECOVERY N/A
ANGLE FROM VERT. 46°	AZIMUTH FROM NORTH 047°	COMPILED BY, DATE: Pat 16 Oct 78
DISTANCES: VERTICAL, 57.5'	HORIZONTAL, 55.5'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2045	0	Gravelly silty sand.		Permafrost below 1.5'
2039				9.0'
	10	Gravelly, silty sand with boulders. 70% silty sand 30% gravel and boulders.		
	20	Silty sand 60% sand, fine grained, blue-gray, wet, dense. 40% silt, plastic, blue-gray, wet, soft when thawed (Lake deposit)		Methane gas at 24.1' (Peat layer)
2023	30			32.0'
		Gravelly, clayey silt, blue-gray, wet, stiff; clayey silt is plastic. 70% Clayey silt 30% Gravel; 0.1'-0.3'; well rounded to sub-rounded.		Samples obtained by dry blocking NX barrel
	40			
		60% Clayey silt 40% Gravel } 43.4'-49.5'	1	Sample 1 48.0'-48.7'
	50		2	Sample 2 56.0'-56.8'
	60	Occasional rock fragments below 60'		
		Density increases with depth. Occasional sand layers below 70.' (Lake deposit)	3	Sample 3 66.5'-68.3'
	70			NX Csg to 77.0'
1991	80			79.9'
		Bottom of Hole Depth of Hole 79.9'		Hole abandoned due to hill creep. 3/4 inch galvanized pipe installed as temperature probe
	90			
	100			

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-25

SUMMARY LOG — HOLE NO. DR-26

N 3234115 / E 748380	SHEET 1 OF 1	SURFACE ELEV. 2295
PROJECT: Watana Dam	DRILL DATES: START 9 Aug 78	COMP. 11 Aug 78
DEPTH OF HOLE 94.8'	DEPTH OF OVERBURDEN 94.8'	DIAM. OF HOLE SEE REMARKS
ROCK DRILLED 0.0'	CORE RECOVERED N/A	% RECOVERY N/A
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ------	COMPILED BY, DATE: Pat 10 Oct 78
DISTANCES: VERTICAL, 94.8'	HORIZONTAL, ------	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2295	0	Gravelly, silty sand with boulders; brown, wet, loose. Boulders 1'-2'	A	Sample A 0.5'-7.0' grab sample SWL 4.2' (18 Aug 1978)
	10	(Till)		
				19'
2276	20	Gravelly silt with occ. cobbles; gray-brown, damp, compact, frozen. Rounded gravels, occ. angular.		7-7/8 inch tricone bit and revert mud-0'-21'
			1	Sample 1; 27.3'-28.6' Drive sample, 200 blows
	30	Random zones of gray (unweathered) material. (Outwash)		
			2	Sample 2; 37.5'-38.2' Drive sample, 200 blows
	40			45'
2250		Clayey silt, dark gray, damp, dense; occ. gravel. Frozen (Lake deposit)	3	Sample 3; 48'-50' cuttings
	50			55'
2240		Sandy gravel with interbedded silt layers. Coarse sand and rounded to sub-rounded gravel. (Alluvium)	4	Sample 4; 57.5'-58.0' drive sample 260 blows Piezometer to 65.5'
	60			67'
2228		Boulders, gravel and silty sand, dark gray, wet, compact. Occ. sand layers and silty clay zones. Gravels sub-rounded to sub-angular		5-5/8 inch tricone bit and revert mud, 21'-94.8'
	70			
	80	Samples taken in wet silty sand.	5	Sample 5; 77.5'-78.7' drive sample 200 blows.
		Boulder to 1 foot diameter.		
	90	(Till)	6	Sample 6; 94.1'-94.8' drive sample 206 blows 94.8'
2200	100	Bottom of Hole Depth of Hole 94.8'		3/4 inch PVC temperature probe to 94.8'

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-26

SEE PLATE D-26 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
DRILL HOLE LOGS NO. 9
DR-22 (CONT.) THRU DR-26

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

SUMMARY LOG — HOLE NO. DR-27

SUMMARY LOG HOLE NO. DR-27	N 3235676 / E 750345	SHEET 1 OF 1 — SURFACE ELEV. 2322
PROJECT Watana Dam	DRILL DATES: START 13 Aug 78	COMP. 19 Aug 78
DEPTH OF HOLE 44.0'	DEPTH OF OVERBURDEN 44.0'	DIAM. OF HOLE SEE REMARKS
ROCK DRILLED N/A	CORE RECOVERED N/A	% RECOVERY N/A
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH --------	COMPILED BY, DATE
DISTANCES: VERTICAL, 44.0' ; HORIZONTAL, --------		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	SAMPLE	REMARKS
2322	0	Organic silt, tundra		1.0'
		Boulders		4.8'
		Cobbles with sand lenses. Sand lenses at 4.8'-5.1, 5.6'-6.0', 3.3'-8.8', 10.2'-10.7', 11.7'-11.9', 17.5'-17.6'		Permafrost at 1.0'. SWL 8', 18 Aug 1978. 7-7/8 inch tricone bit, water and mud 0.0'-20.0'. 6 inch Csg to 24.3'
2301	20	Occ. gravel in sand lenses.		21'
		Clayey, sandy silt, blue-gray, plastic, frozen. Ice lenses to 3 inches thick common. Occ. rounded to subrounded gravel; 1 inch to 3-1/2 inches in diameter.	1, 2, 3, 4, 5, 6, 7, 8, 9	Sample 1; 22.1'-23.1' Drive sample. 6 inch air hammer 20.0' to 44.0'. Sample 2; 28.3'-29.5' 4 x 4 1/2 inch core. Sample 3; 30.6'-32.1' drive sample /26 blows. Sample 4; 33.1'-34.6' drive sample /35 blows. Sample 5; 34.5'-36.0' drive sample. Samples 4 and 5 waxed. Sample 6; 37.0'-38.5' Drive sample, 23 blows. Sample 7; 38.5'-40.0' Drive sample, Sample 8, 40.0'-41.5' Drive sample, 24 blows. Sample 9,42.5'-44.0'
2282		Bottom of Hole Depth of Hole 44.0'		Hole caved; abandoned

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DR-27

SUMMARY LOG — HOLE NO. DH-28 (Sheet 1 of 2)

SUMMARY LOG HOLE NO. DH-28	N 3225723 / E 743581	SHEET 1 OF 2 — SURFACE ELEV. 1971
PROJECT Watana Dam	DRILL DATES: START 17 Aug 78	COMP. 30 Aug 78
DEPTH OF HOLE 125.2'	DEPTH OF OVERBURDEN 9.2'	DIAM. OF HOLE NCO
ROCK DRILLED 116.0'	CORE RECOVERED 99.3'	% RECOVERY 89
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH -------	COMPILED BY, DATE Sat 18 Oct 78
DISTANCES: VERTICAL, 125.2'; HORIZONTAL, -------		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1971	0	Overburden		SWL 7.6' (19 Aug 78)
		Top of Rock		9.2'
1962	10	Porphoritic andesite breccia, soft, fine grained, moderately weathered, highly fractured to fragments, gray. Iron stains and thin red-brown gouge common. Phenocrysts to 10 mm.		NX Csg bit to 13.1' Dwr 100% except 20%; 13.1'-14.2'
	30	Hole in permafrost.		Core lengths generally less than 0.5'
	50	Disseminated sulfide mineralization 49.0'-53.1'		
		Baked Zone 56.1'-58.3'		58.3'
1913	60	Porphoritic andesite, moderately hard, fine grained, lightly weathered, highly fractured to fragments, light gray.		
		Brecciated 58.3'-68.1'		
		Phenocrysts generally less than 5mm. and widely scattered		
	80	Stiff lightgray clay gouge 78.9'-79.5'		
	90	Brecciated 80.4' to bottom. High angle (70°-80°) shear planes dominant. Fat clay gouge very common.		

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-28

SUMMARY LOG — HOLE NO. DH-28 (Sheet 2 of 2)

SUMMARY LOG HOLE NO. DH-28	N 3225723 / E 743581	SHEET 2 OF 2 — SURFACE ELEV. 1971
PROJECT Watana Dam	DRILL DATES: START 17 Aug 78	COMP. 30 Aug 78
DEPTH OF HOLE 125.2'	DEPTH OF OVERBURDEN 9.2'	DIAM. OF HOLE NCO
ROCK DRILLED 116.0'	CORE RECOVERED 99.3'	% RECOVERY 89
ANGLE FROM VERT. 0°	AZIMUTH FROM NORTH ------	COMPILED BY, DATE Sat 18 Oct 78
DISTANCES: VERTICAL, 125.2'; HORIZONTAL, -------		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	Porphoritic andesite, Ibid. Soft, highly weathered and very highly fractured in Shear		Hole follows near vertical shear zone.
	110	Brecciated porphoritic andesite.		
	120	Clay gouge, fat, lightgray 115.5'-115.9', 118.2'-118.4' 118.6'-118.8' 119.2'-119.3' and 124.9'-125.2'		
1846		Bottom Of Hole Depth of hole 125.2' Thickness of Overburden 9.2' Rock Drilled 116.0' Rock Cored 112.1' Core Recovered 99.3' % Core Recovered		125.2'

Depth scale: 100, 110, 120, 130, 140, 150

NPA Form 7(Test) APR. 66 — PROJECT Watana Dam — HOLE NO. DH-28

SEE PLATE D-28 FOR LEGEND

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

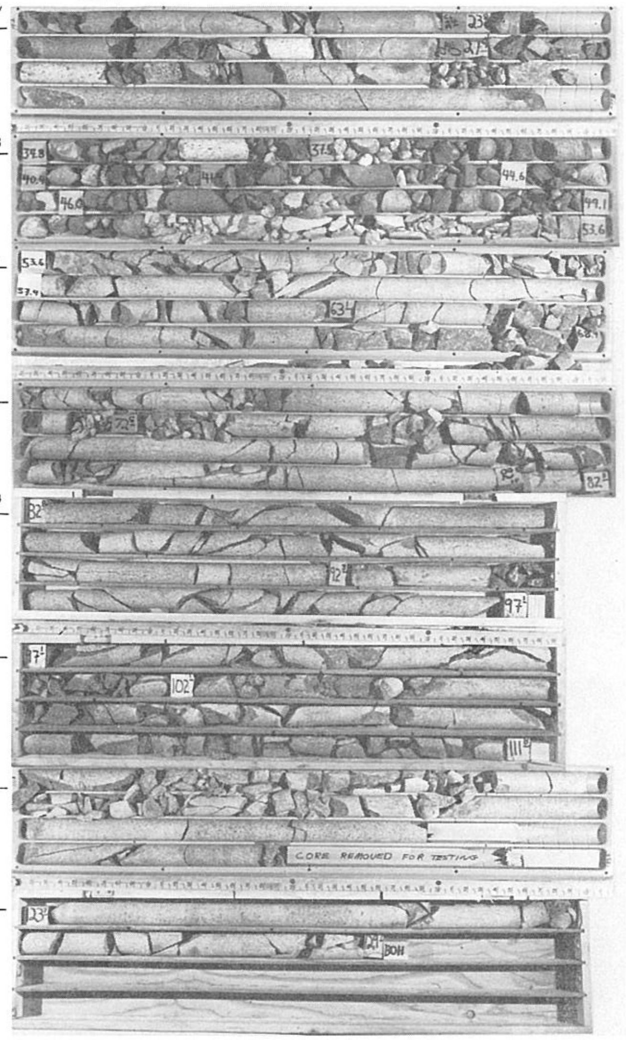
UPPER SUSITNA RIVER BASIN

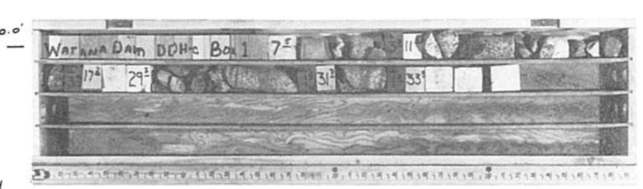
DRILL HOLE LOGS NO. 10

DR-27 AND DH-28

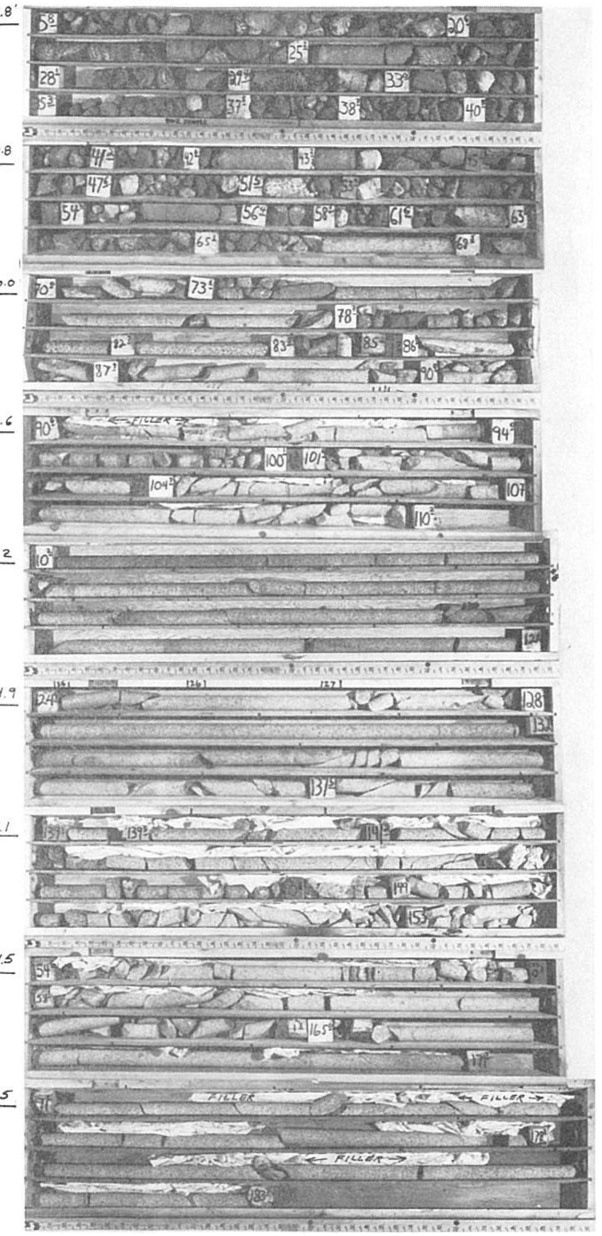
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE ALASKA

DH-1 8 BOXES WATANA DAMSITE 28 MAR-2 APR 1973 DEPTH: 122.8'

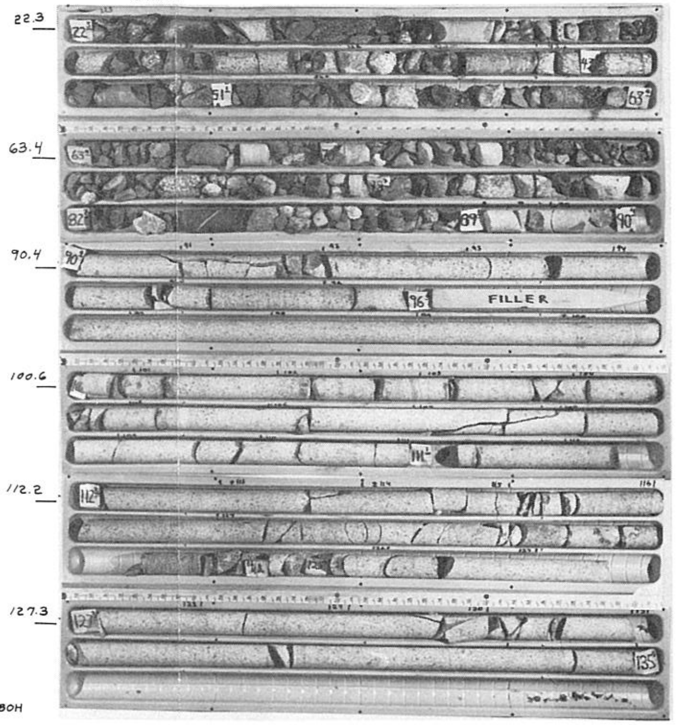




DH-3 9 BOXES WATANA DAMSITE 3 APR-13 APR 1978 DEPTH: 174.5'



DH-4 6 BOXES WATANA DAMSITE 17 APR-23 APR 1973 DEPTH: 122.9'



NOTES;

1. DEPTHS SHOWN ON DH-1 THRU DH-5 ARE FROM TOP OF RIVER ICE.

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
CORE PHOTOS NO. 1
DH-1 THRU DH-4

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

DH-5

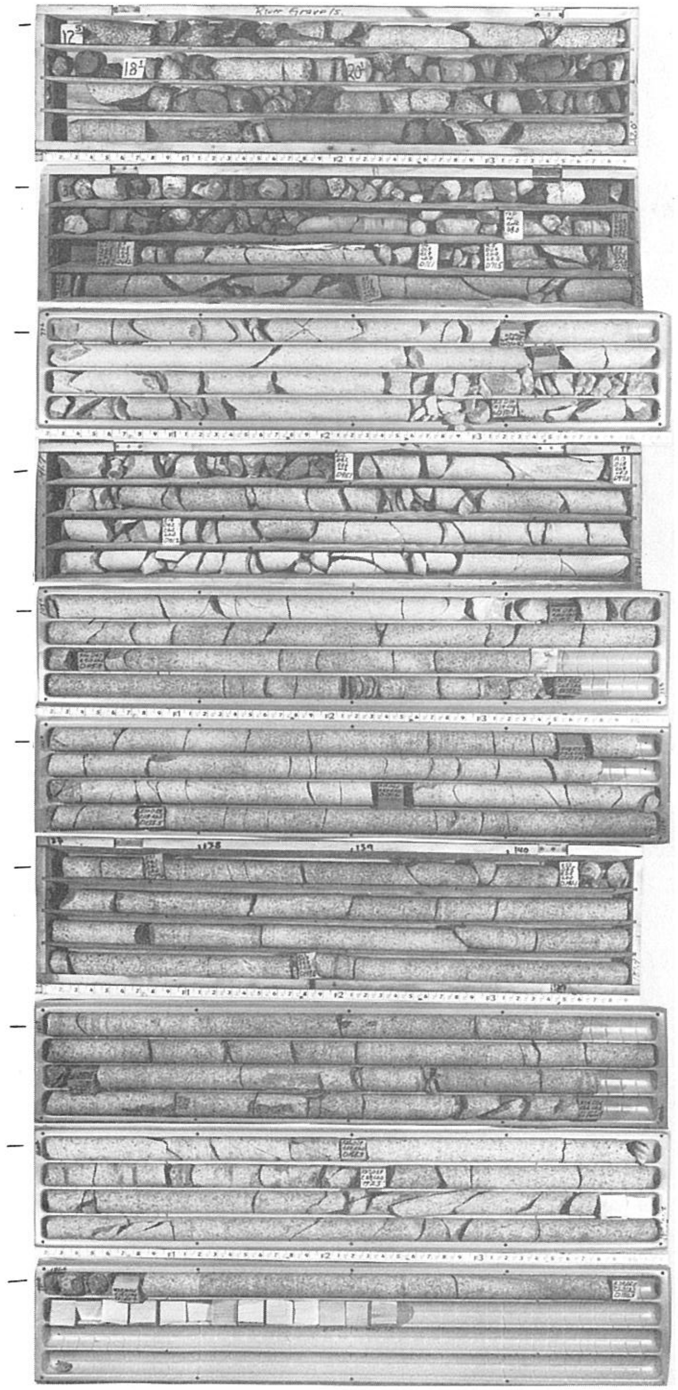
10 BOXES

WATANA DAMSITE

18 APR-3 MAY 1978

DEPTH: 176.9'

12.5
32.0
77.1
91.7
108.0
122.2
137.0
151.9
166.4
182.2
BOH



DH-6

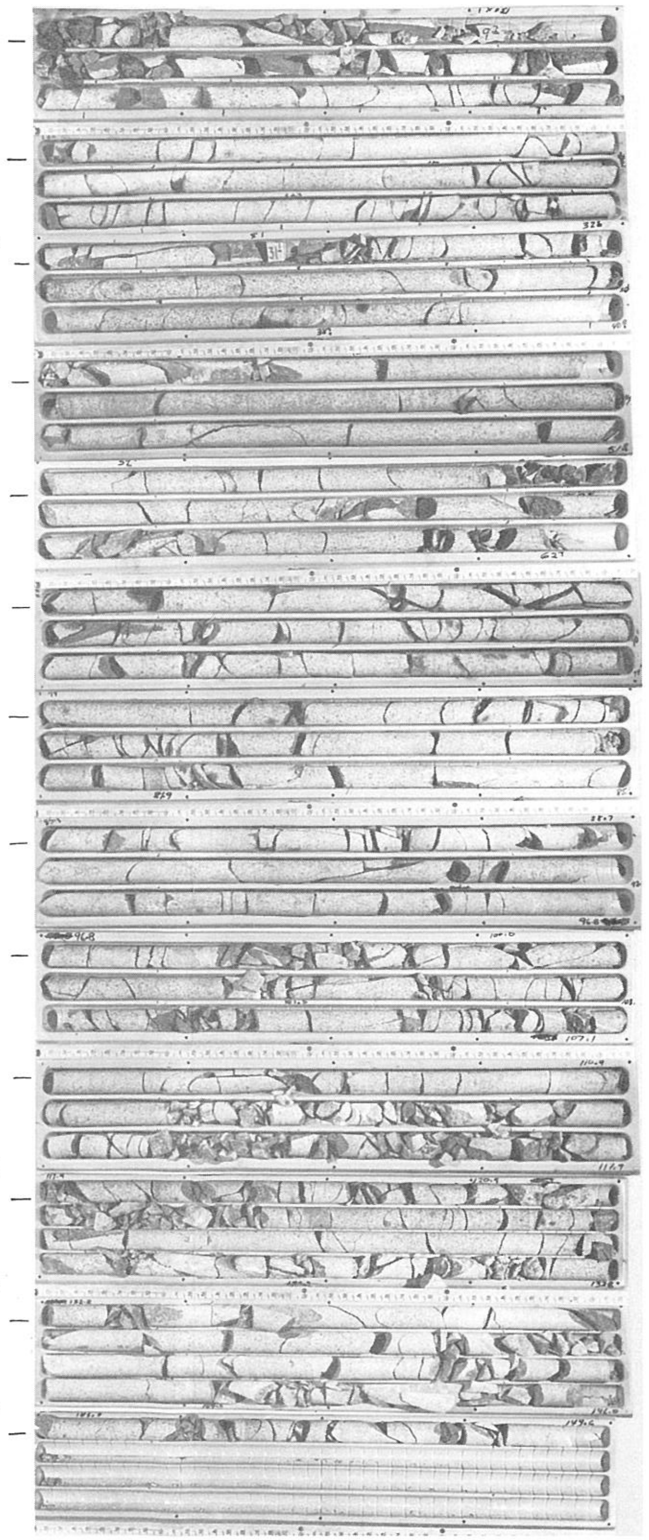
13 BOXES

WATANA DAMSITE

23 APR-2 MAY 1978

DEPTH: 149.5'

0.0
17.3
29.3
40.8
51.8
62.3
74.0
85.1
96.8
107.1
117.9
132.8
146.0
BOH



SOUTHCENTRAL RAILBELT AREA, ALASKA

SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

WATANA DAMSITE

CORE PHOTOS NO. 2

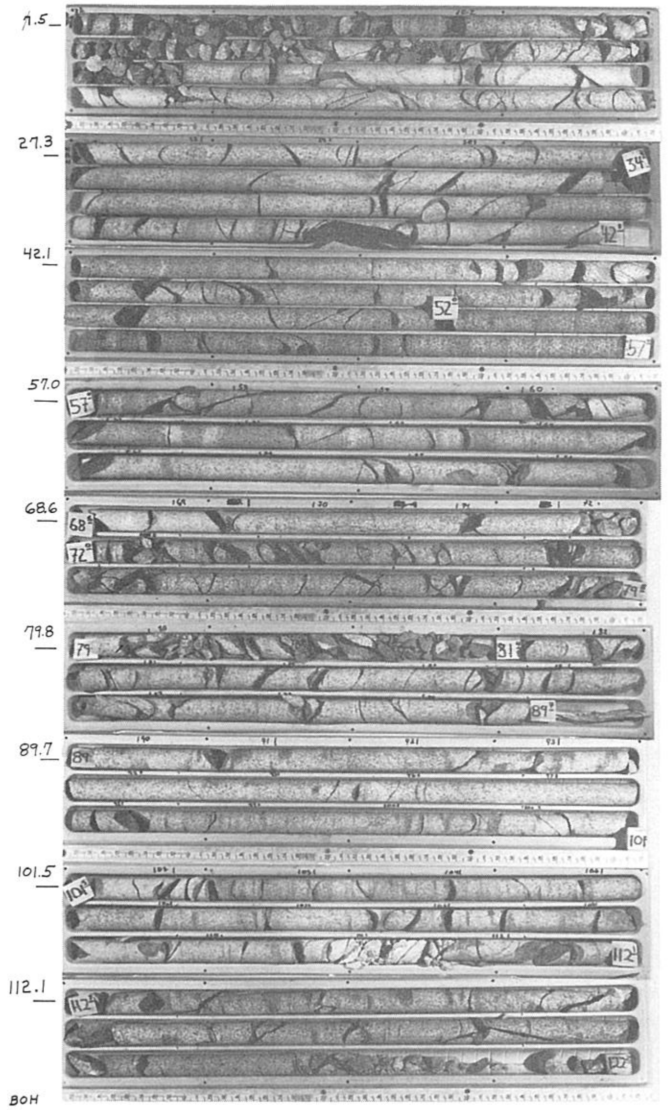
DH-5 THRU DH-6

ALASKA DISTRICT, CORPS OF ENGINEERS

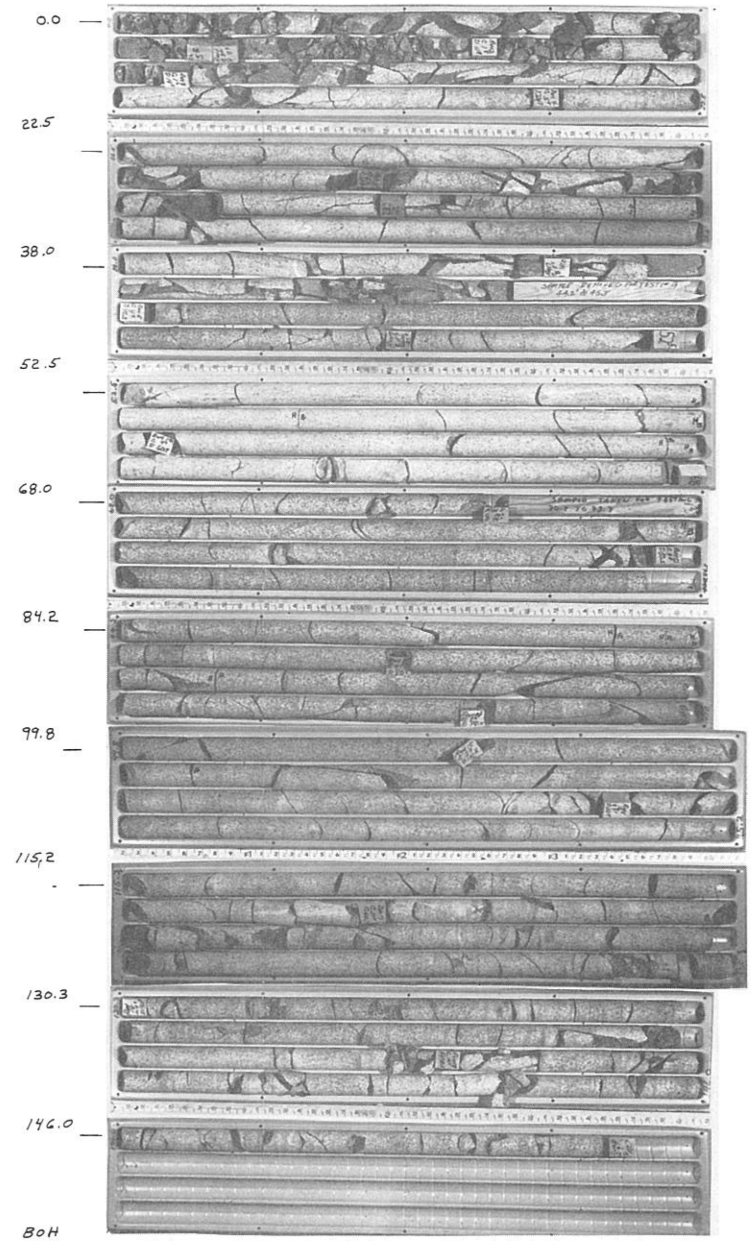
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

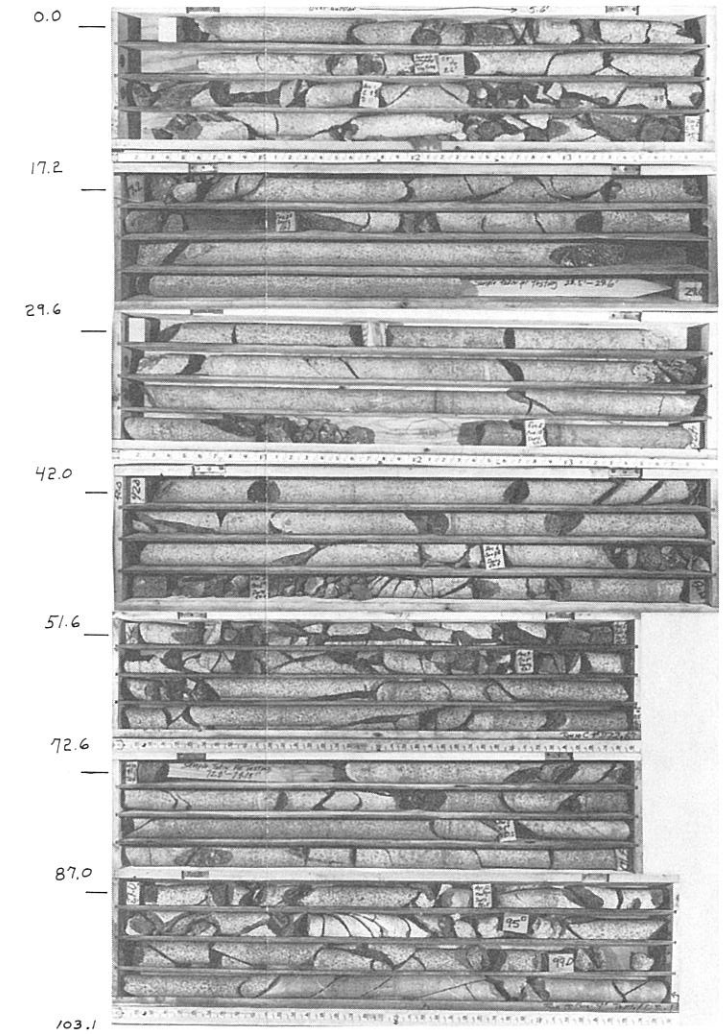
DH-7
9 BOXES
WATANA DAMSITE
6 MAY-17 MAY 1978
DEPTH: 122.3'



DH-8
10 BOXES
WATANA DAMSITE
21 MAY-29 MAY 1978
DEPTH: 150.0'



DH-9
20 BOXES
WATANA DAMSITE
30 MAY-29 JUN 1973
DEPTH: 283.8'



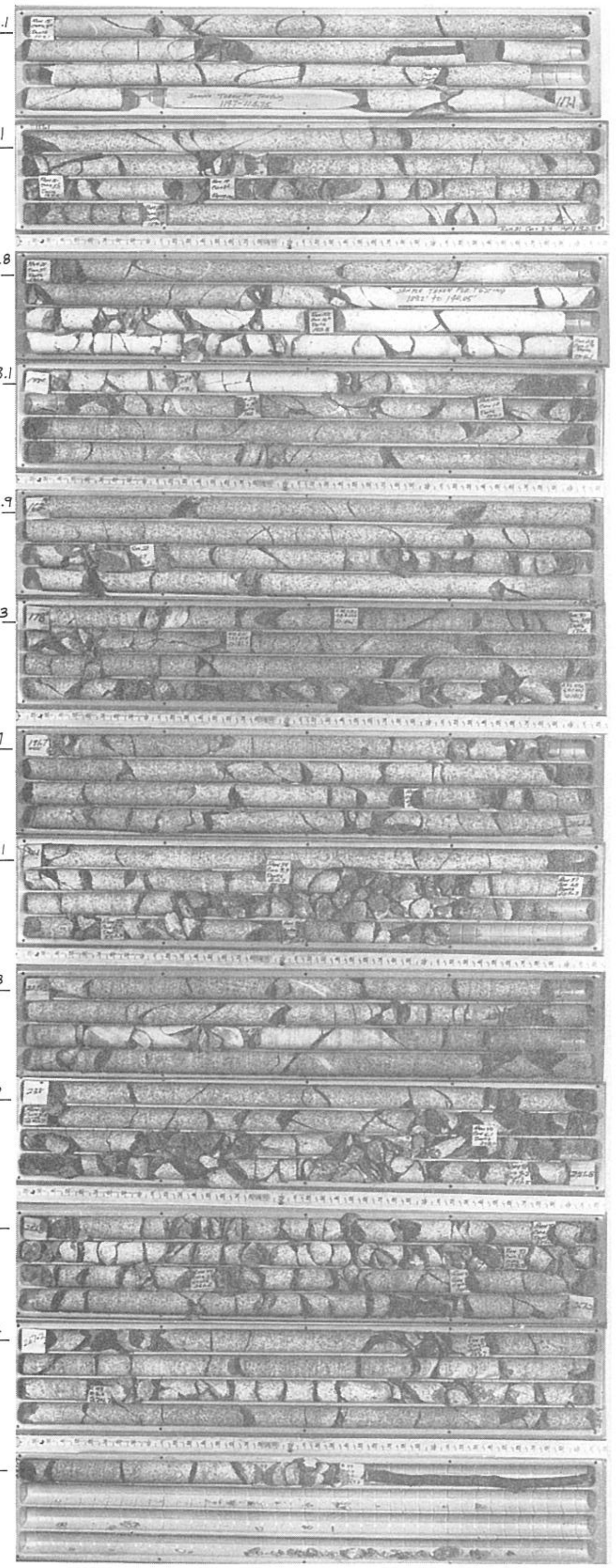
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
CORE PHOTOS NO. 3
DH-7 THRU DH-9
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

DH-9

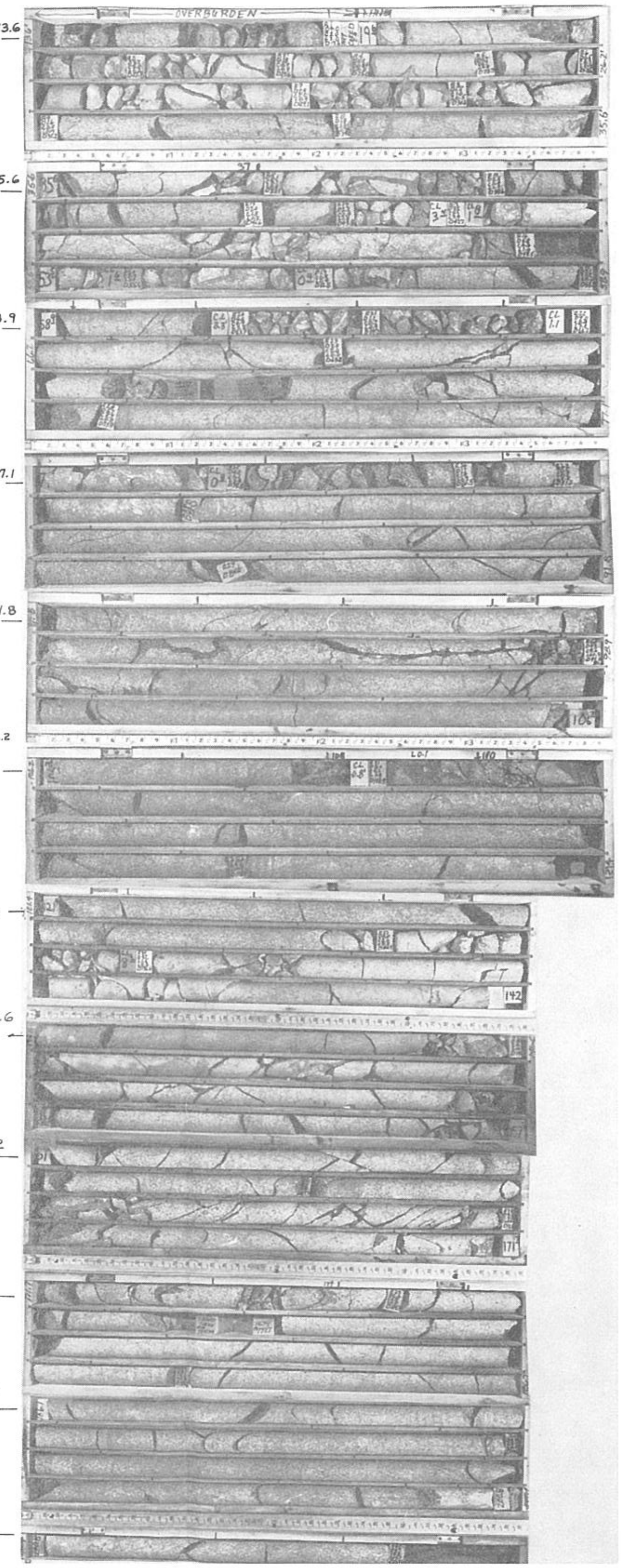
CONT'D

103.1
117.1
132.8
148.1
162.9
178.3
191.7
206.1
223.3
238.0
251.8
267.2
281.9
BOH



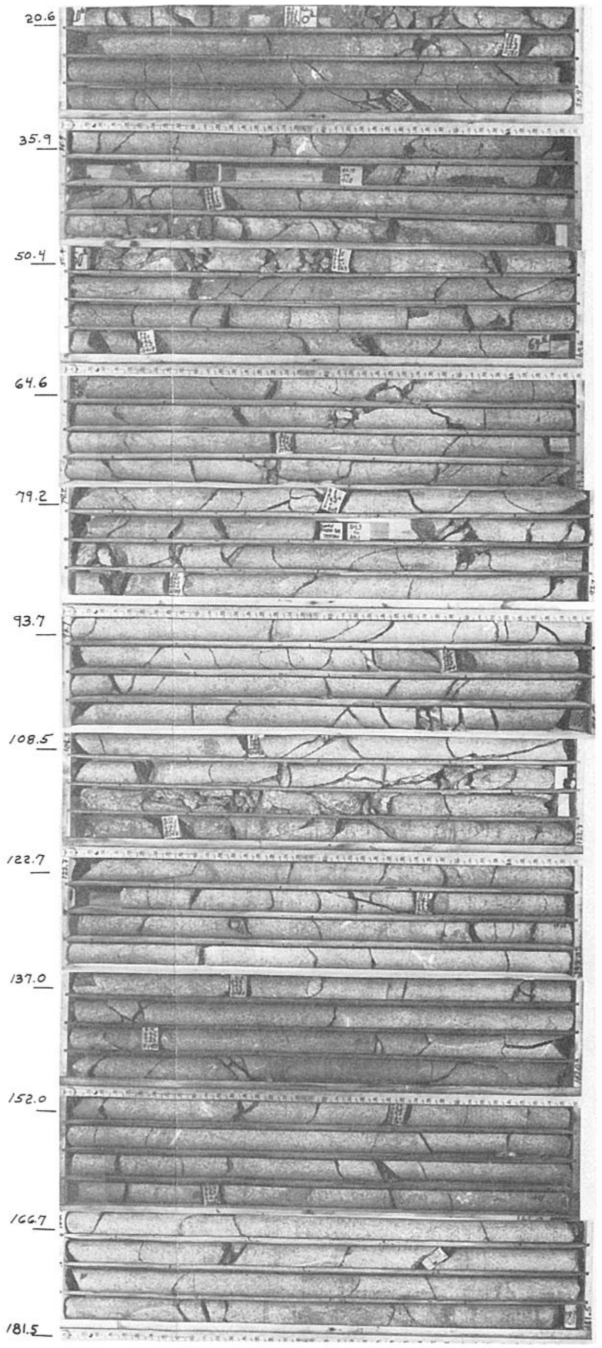
DH-10 12 BOXES WATANA DAMSITE 8 MAY-19 MAY 1973 DEPTH: 203.5'

13.6
35.6
58.9
77.1
91.8
106.2
121.4
142.6
157.2
171.7
186.7
200.8
BOH



DH-11 22 BOXES WATANA DAMSITE 22 MAY-5 JUN 1978 DEPTH: 300.0'

20.6
35.9
50.4
64.6
79.2
93.7
108.5
122.7
137.0
152.0
166.7
181.5



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

WATANA DAMSITE

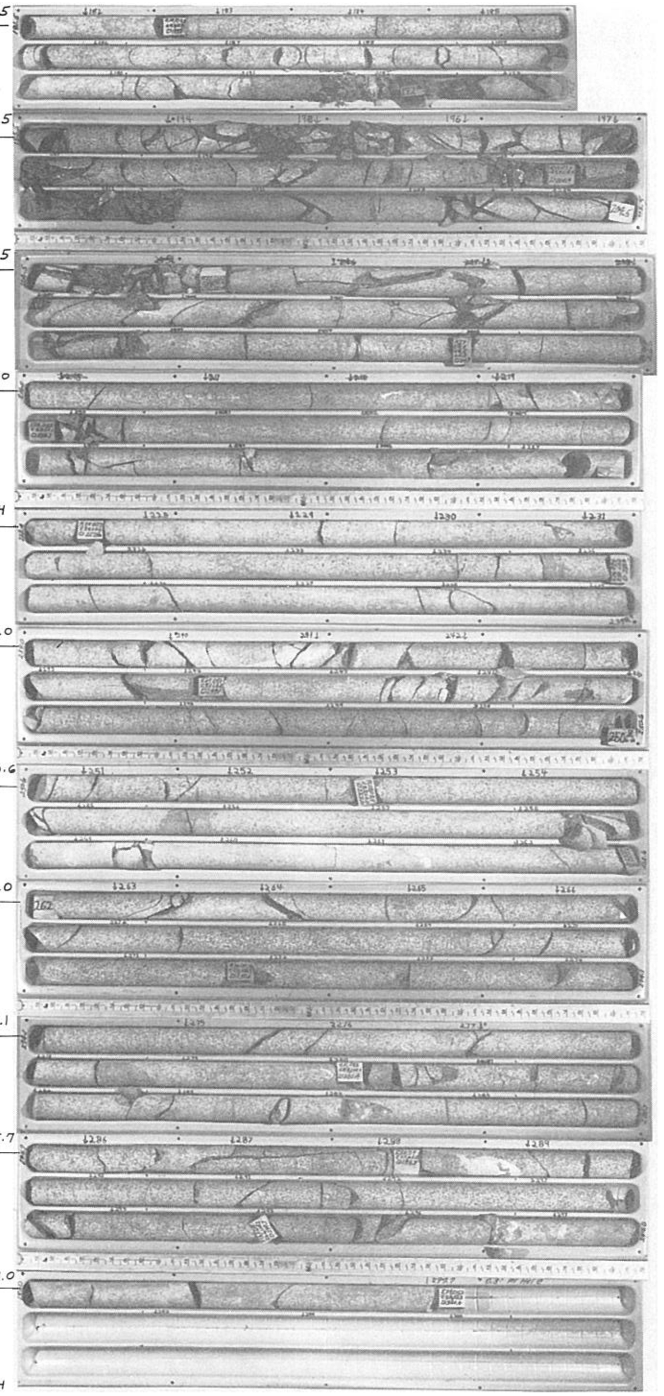
CORE PHOTOS NO. 4

DH-9 (cont) THRU DH-11

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DH-11

CONT'D



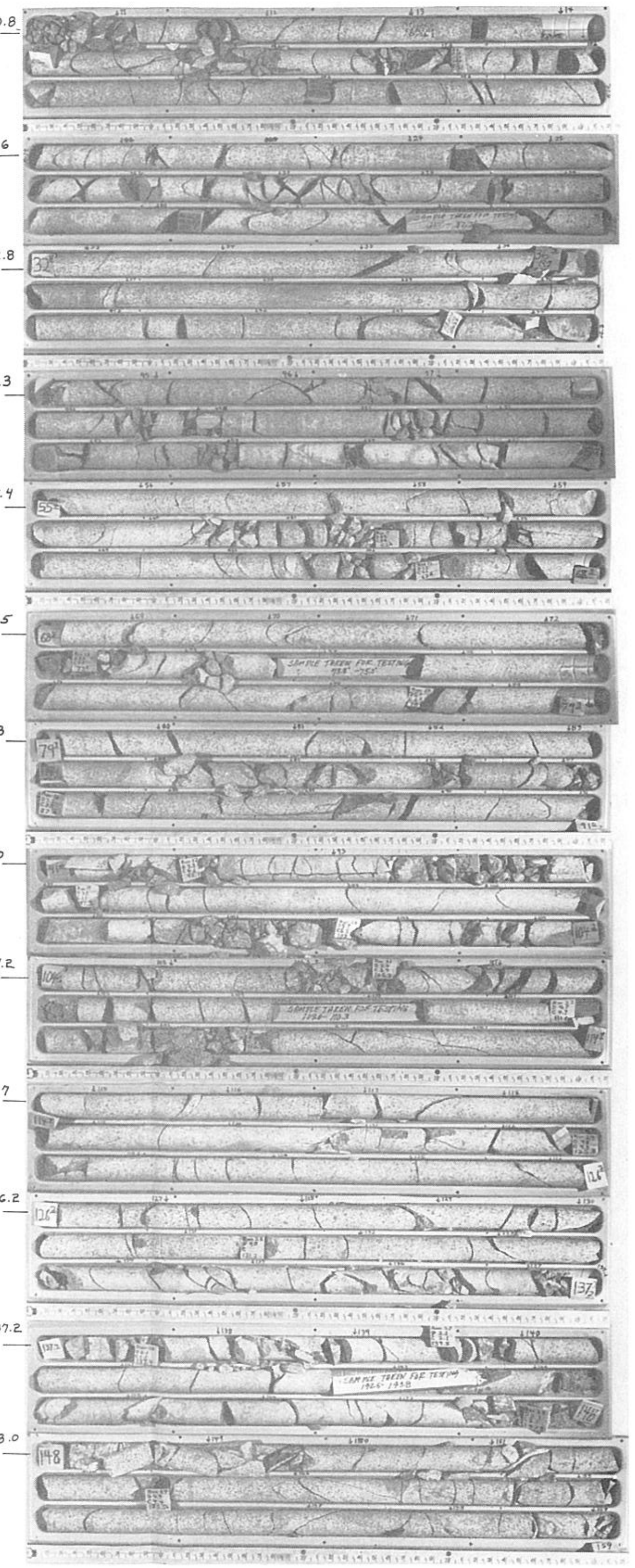
DH-12

24 BOXES

WATANA DAMSITE

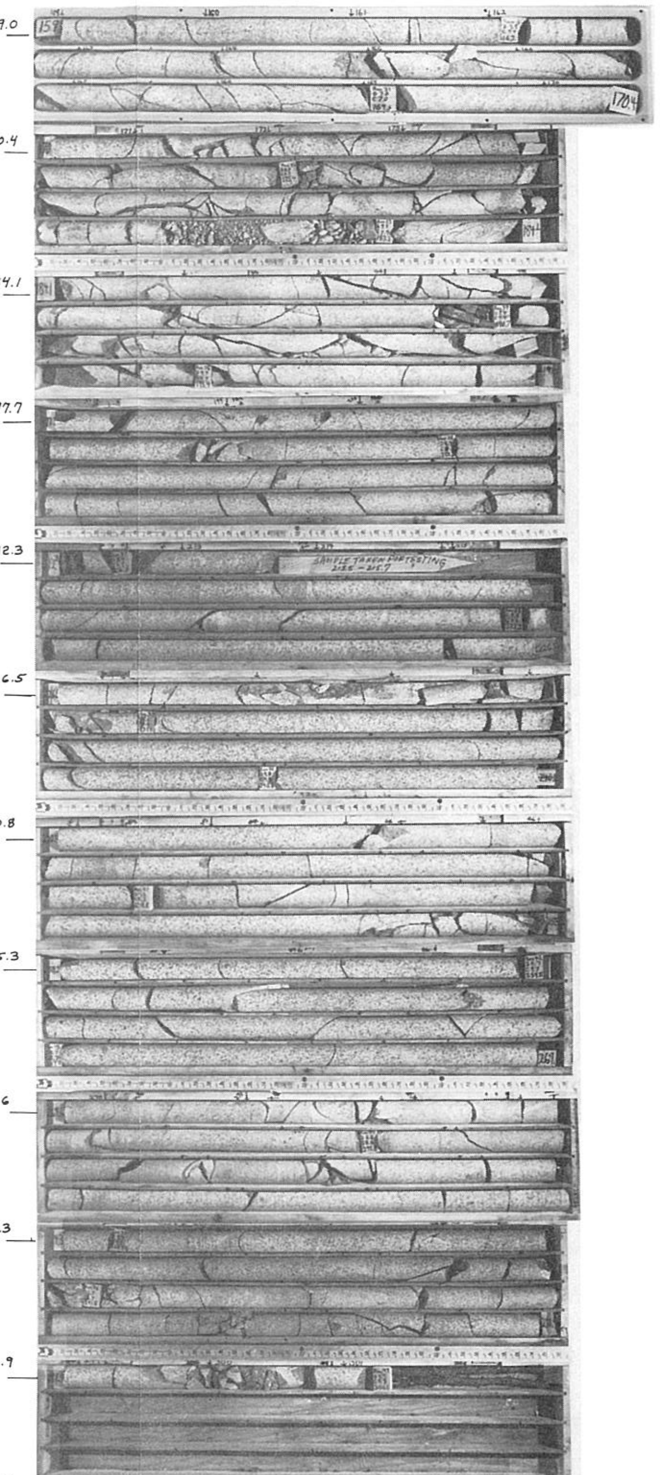
11 JUN-3 JUL 1973

DEPTH: 301.1'



DH-12

CONT'D



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

WATANA DAMSITE

CORE PHOTOS NO. 5

DH-11 (cont.) THRU DH-12

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

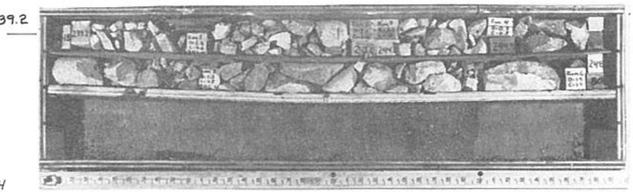
EUGENE DIETZGEN COMPANY

DR-15
2 BOXES
WATANA DAMSITE
27 APR-16 MAY 1978
DEPTH: 316.5'

296.0
305.1
BOH

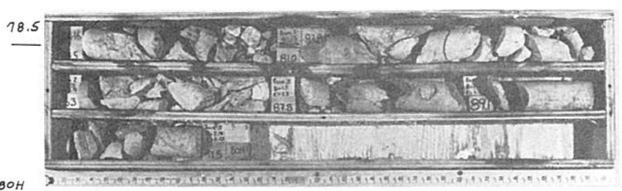
DR-18
1 BOX
WATANA DAMSITE
9 JUN-21 JUN 1973
DEPTH: 248.3'

239.2
BOH



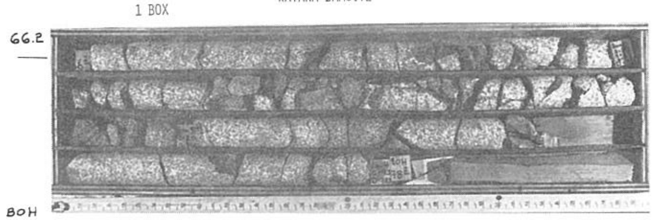
DR-16
1 BOX
WATANA DAMSITE
31 MAY-4 JUN 1978
DEPTH: 91.5'

78.5
BOH



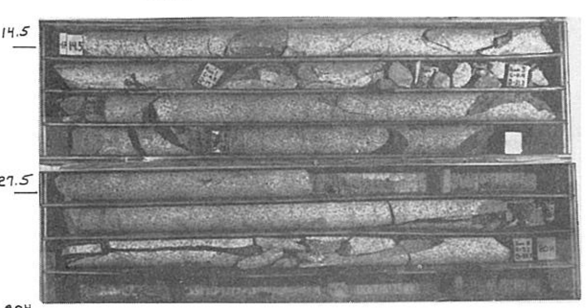
DR-19
1 BOX
WATANA DAMSITE
29 JUN-3 JUL 1973
DEPTH: 78.3'

66.2
BOH



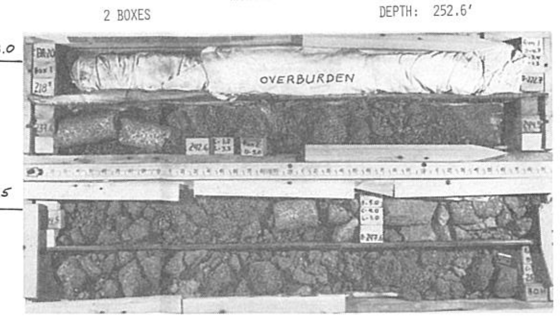
DR-17
2 BOXES
WATANA DAMSITE
6 JUN-J JUN 1978
DEPTH: 35.7'

14.5
27.5
BOH

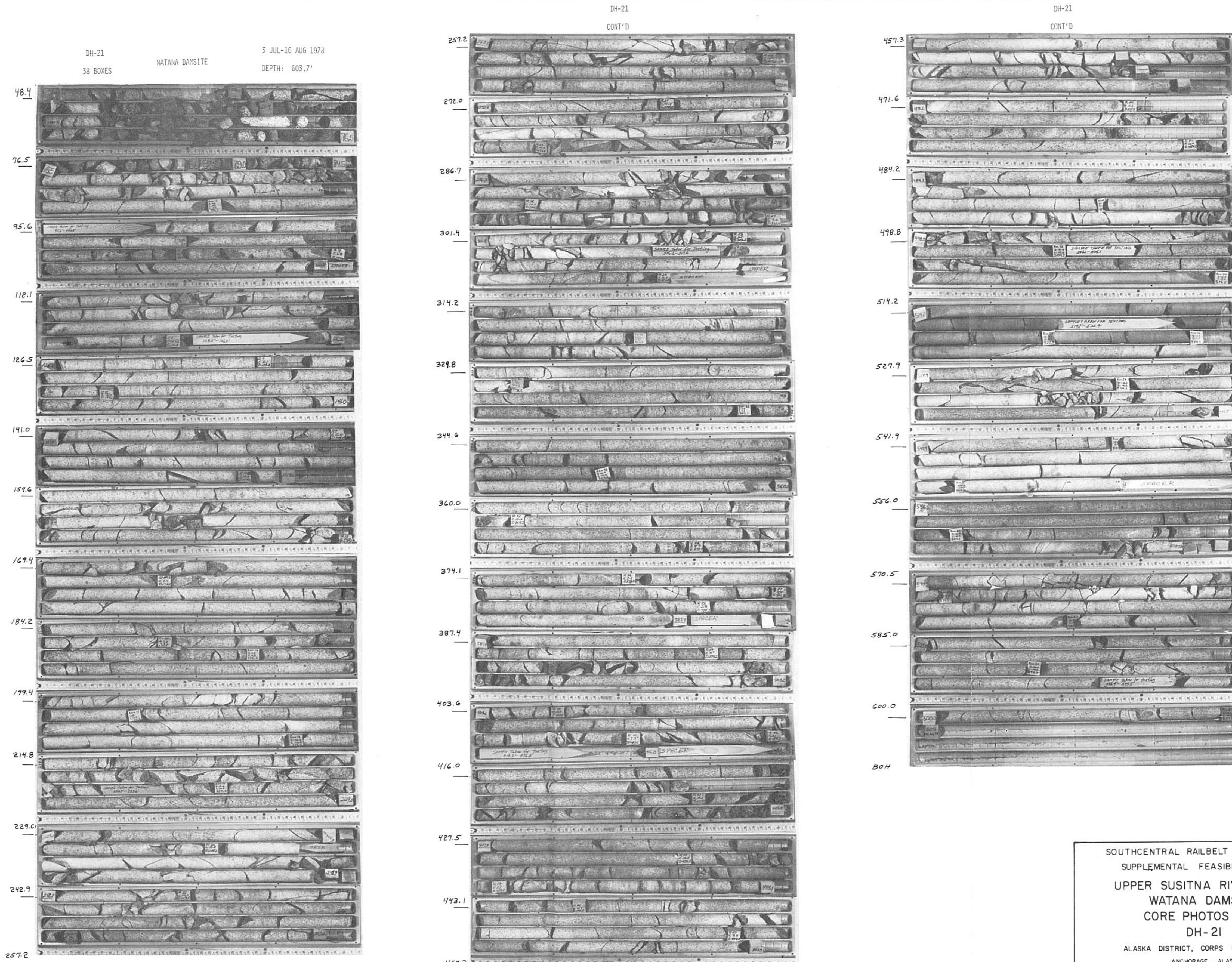


DR-20
2 BOXES
WATANA DAMSITE
17 MAY-29 MAY 1973
DEPTH: 252.6'

218.0
244.5
BOH



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
CORE PHOTOS NO. 6
DR-15 THRU DR-20
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
CORE PHOTOS NO. 7
DH-21

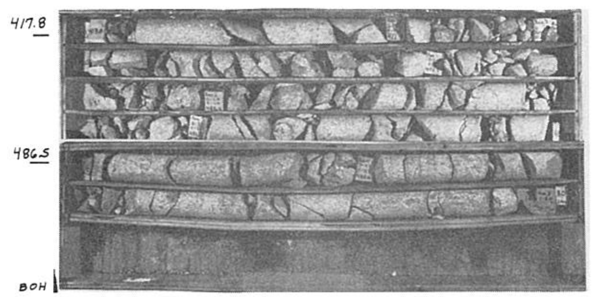
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

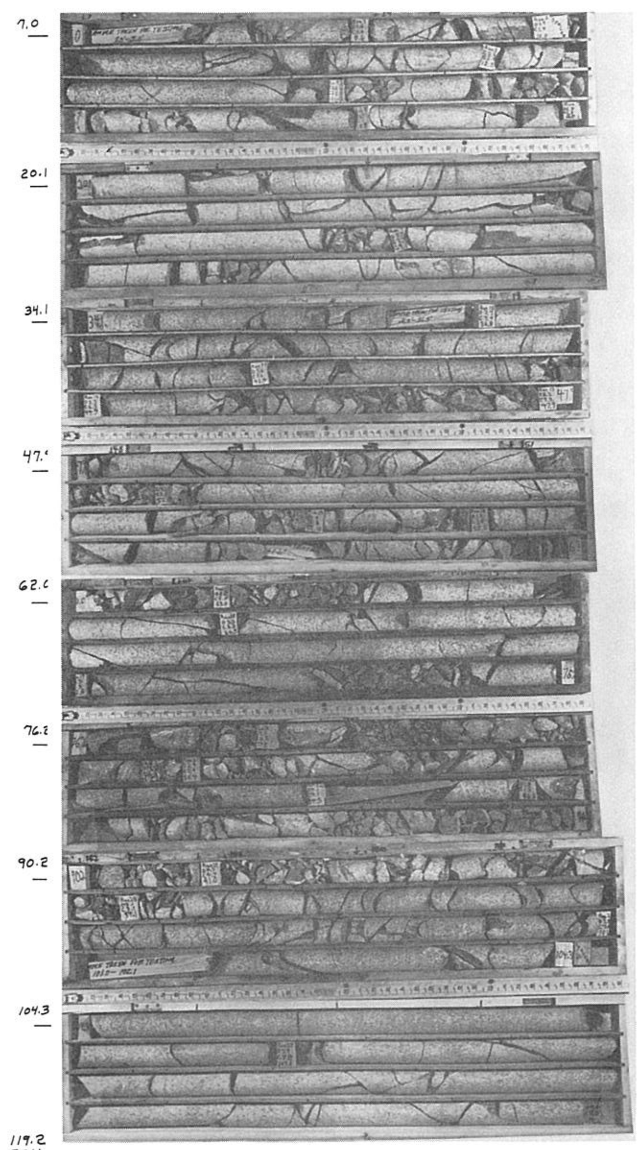
EUGENE DIETZGEN COMPANY

PLATE D-44

DR-22 5 JUL-3 AUG 1978

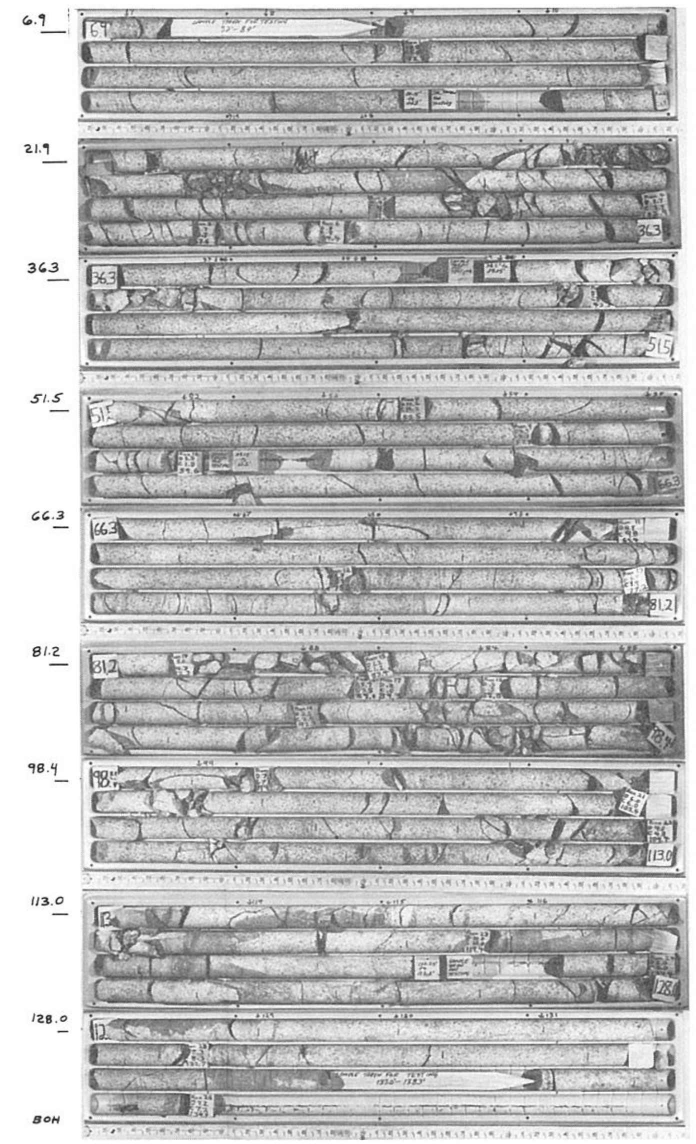
2 BOXES WATANA DAMSITE DEPTH: 493.6'





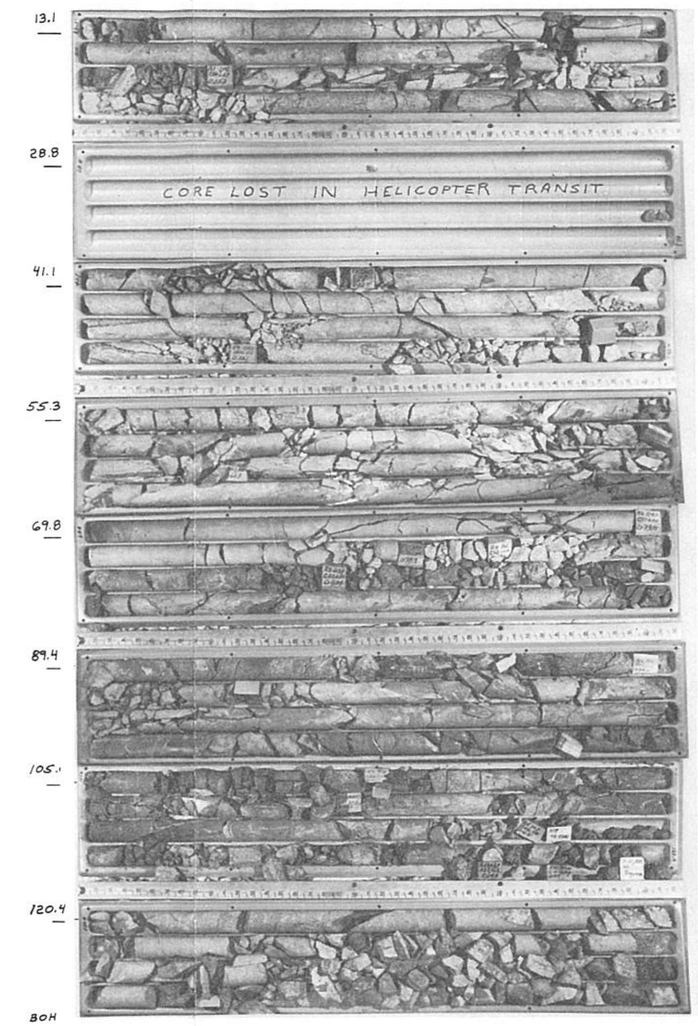
DR-24 25 JUL-31 JUL 1978

9 BOXES WATANA DAMSITE DEPTH: 139.9'



DH-28 17 AUG-30 AUG 1978

8 BOXES WATANA DAMSITE DEPTH: 125.2'



SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

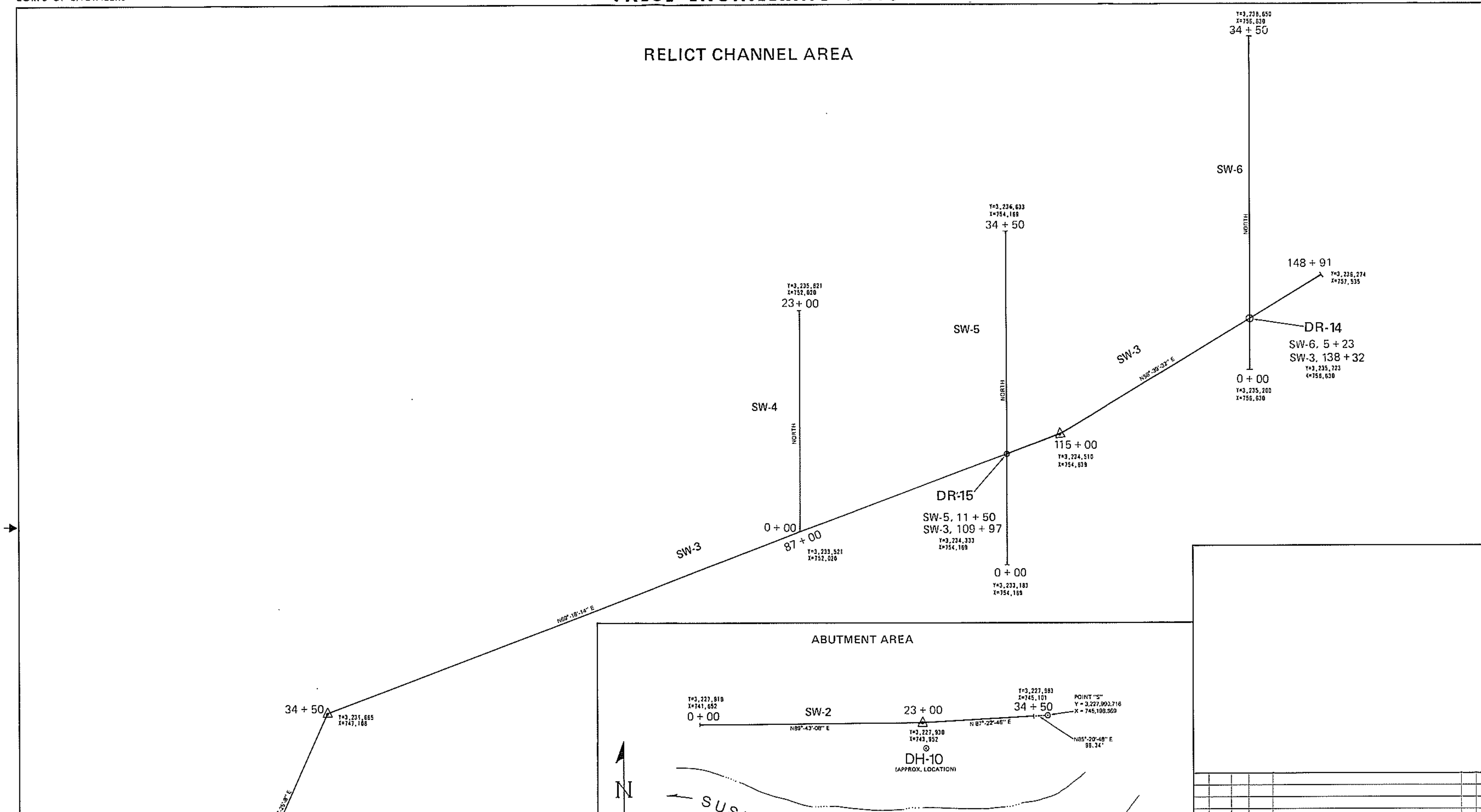
UPPER SUSITNA RIVER BASIN
WATANA DAMSITE
CORE PHOTOS NO. 8
DR-22 THRU DH-28

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA

EUGENE DIETZGEN COMPANY

EXHIBIT D-1

Location Maps and Seismic Refraction Velocity Profiles, Watana and Devil Canyon Damsites.



REV.	DATE	C.O.	ACTION	DESCRIPTION	BY	APPD.

CONTRACT NO. ______
CONTRACTOR ______
CITY ______ STATE ______

RECOMMENDED: D. B. PRIME CONTRACTOR | APPROVED: RESIDENT ENGINEER | DATE:

SHANNON & WILSON, INC.
GEOTECHNICAL CONSULTANTS
FAIRBANKS

ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

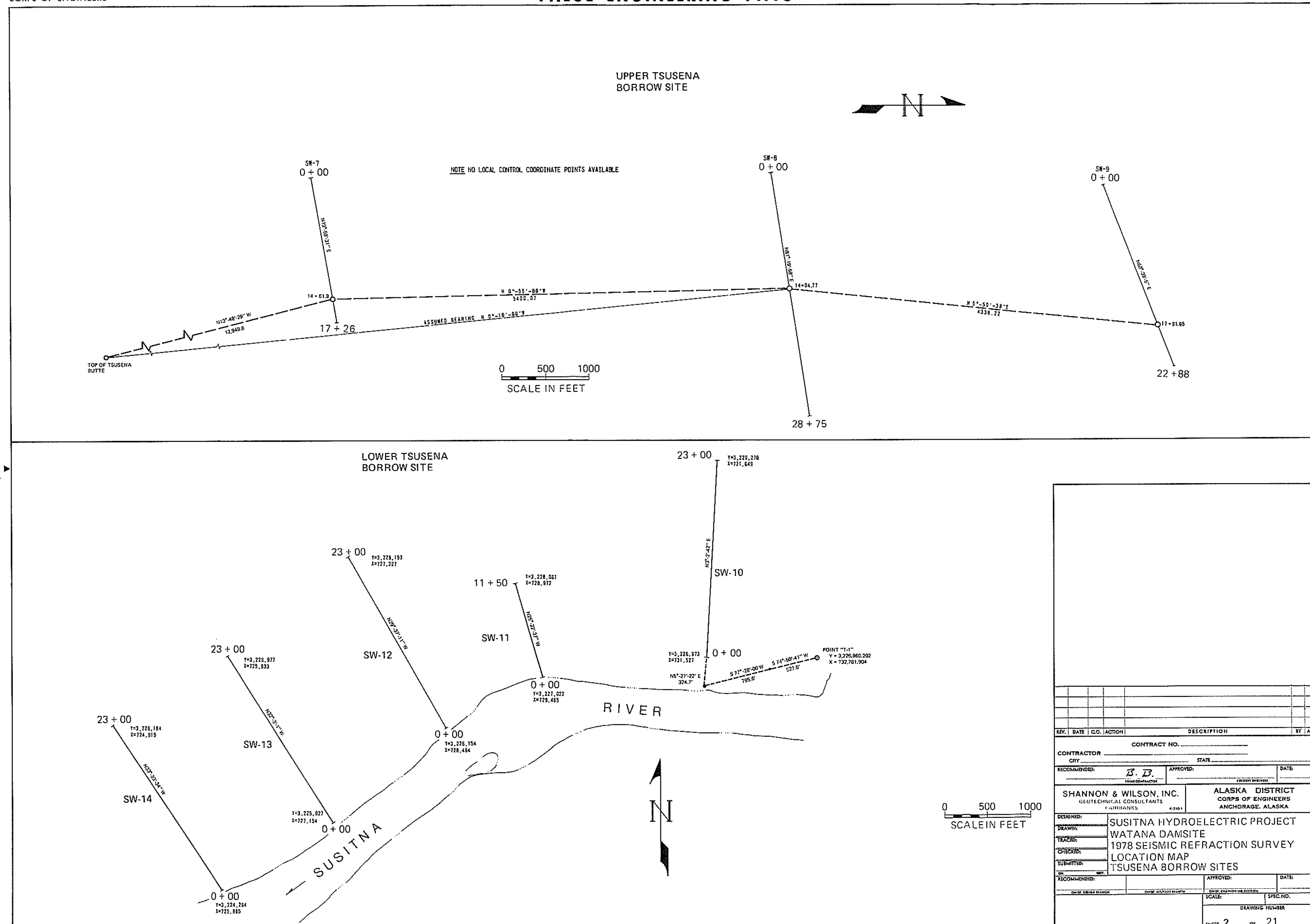
DESIGNED:
DRAWN:
TRACED:
CHECKED:
SUBMITTED:

SUSITNA HYDROELECTRIC PROJECT
WATANA DAMSITE
1978 SEISMIC REFRACTION SURVEY
LOCATION MAP

RECOMMENDED: CHIEF, DESIGN BRANCH | CHIEF, MILITARY BRANCH | APPROVED: CHIEF, ENGINEERING DIVISION | DATE:

SCALE: | SPEC. NO.

DRAWING NUMBER
SHEET 1 OF 21


UPPER TSUSENA
BORROW SITE
N
NOTE NO LOCAL CONTROL COORDINATE POINTS AVAILABLE
SW-7
0 + 00
17 + 26
SW-8
0 + 00
28 + 75
SW-9
0 + 00
22 + 88
TOP OF TSUSENA BUTTE
0 500 1000
SCALE IN FEET
LOWER TSUSENA
BORROW SITE
SW-10
23 + 00
0 + 00
SW-11
11 + 50
0 + 00
SW-12
23 + 00
0 + 00
SW-13
23 + 00
0 + 00
SW-14
23 + 00
0 + 00
RIVER
SUSITNA
N
0 500 1000
SCALE IN FEET
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CONTRACT NO.
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APPROVED:
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SHANNON & WILSON, INC.
GEOTECHNICAL CONSULTANTS
FAIRBANKS
ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DESIGNED:
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WATANA DAMSITE
1978 SEISMIC REFRACTION SURVEY
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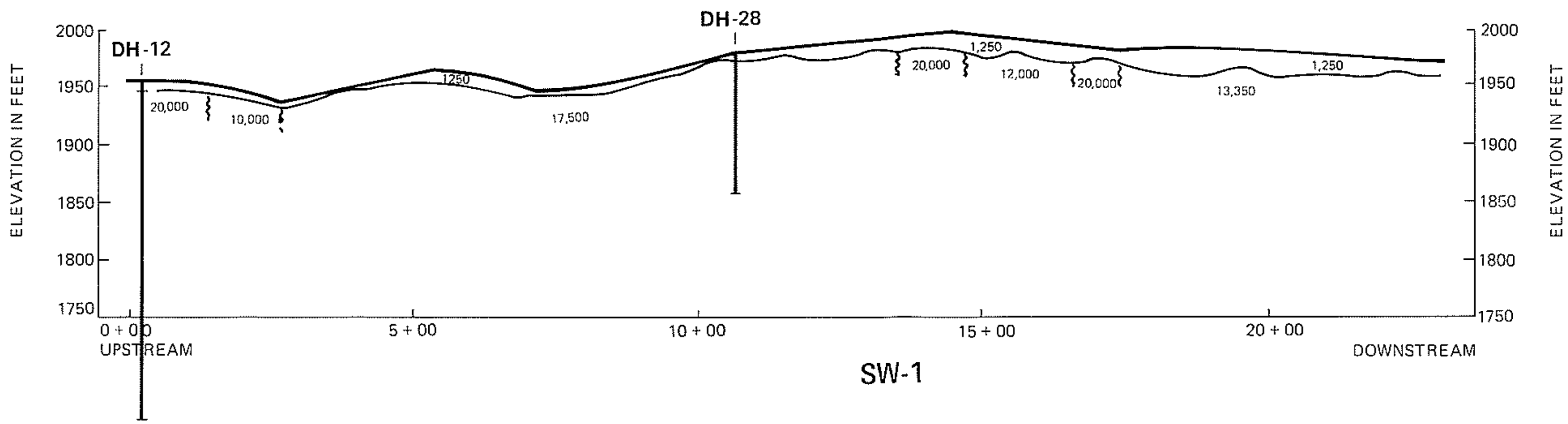
SHEET 2 OF 21



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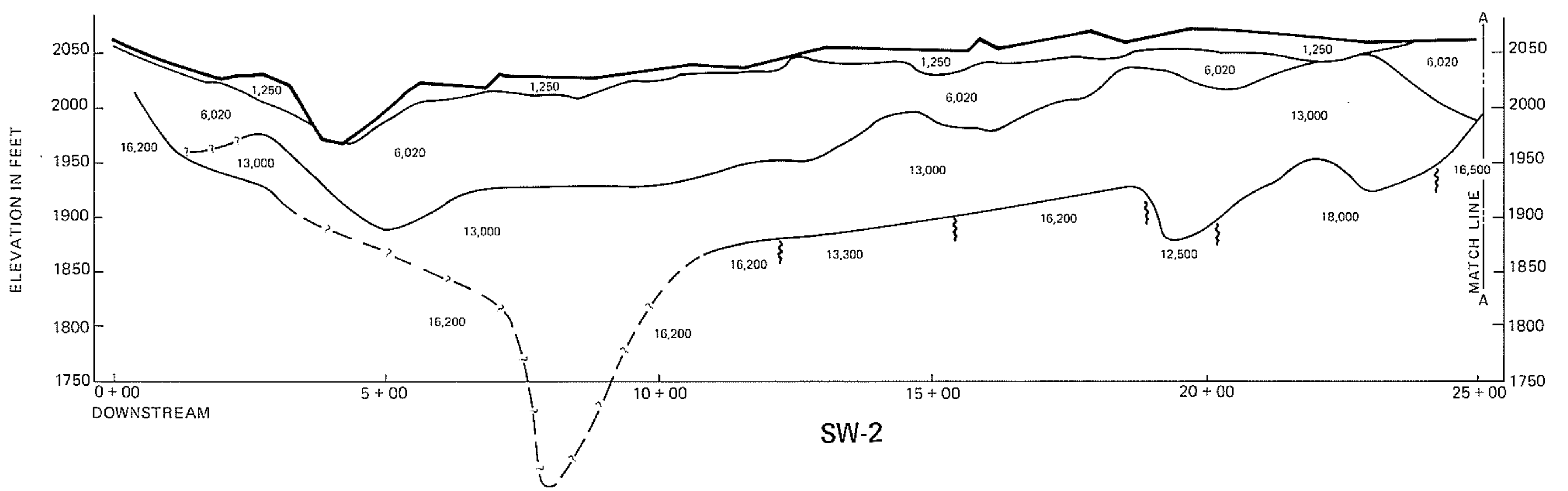

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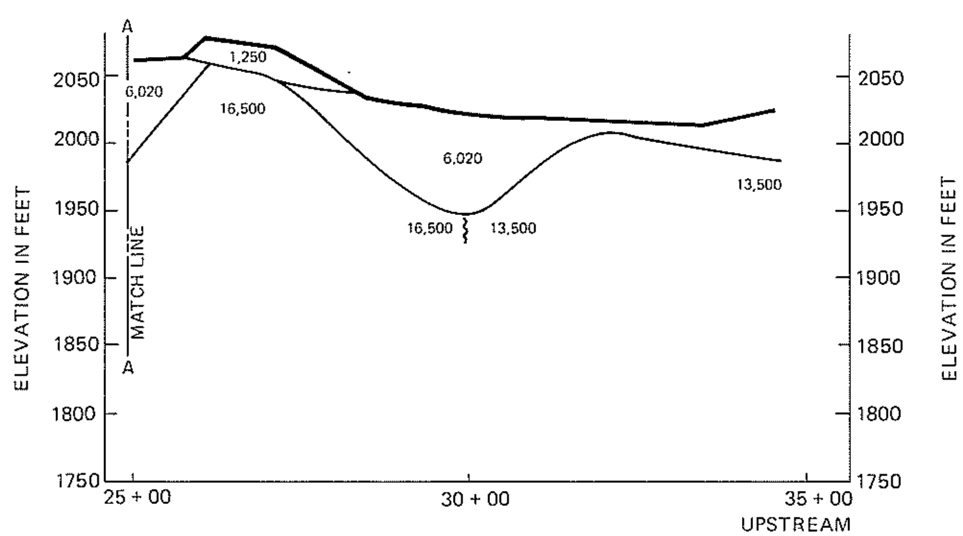

SW-2

LEGEND

POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

DH-12 BORING DESIGNATION

APPROXIMATE LOCATION OF CHANGE IN MATERIAL

0 50 100 150
VERTICAL SCALE IN FEET

0 100 200 300
HORIZONTAL SCALE IN FEET

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SUSITNA HYDROELECTRIC PROJECT
WATANA DAMSITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-1 SW-2

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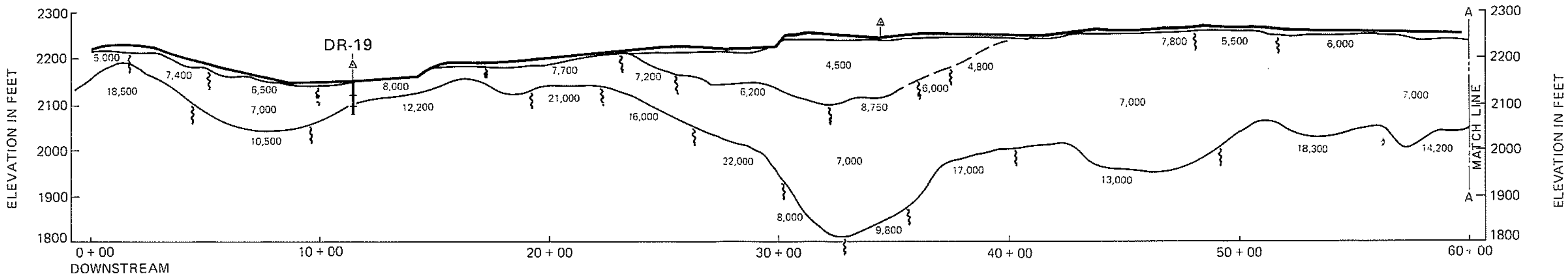
INV. NO. DACW85-78-C-0027



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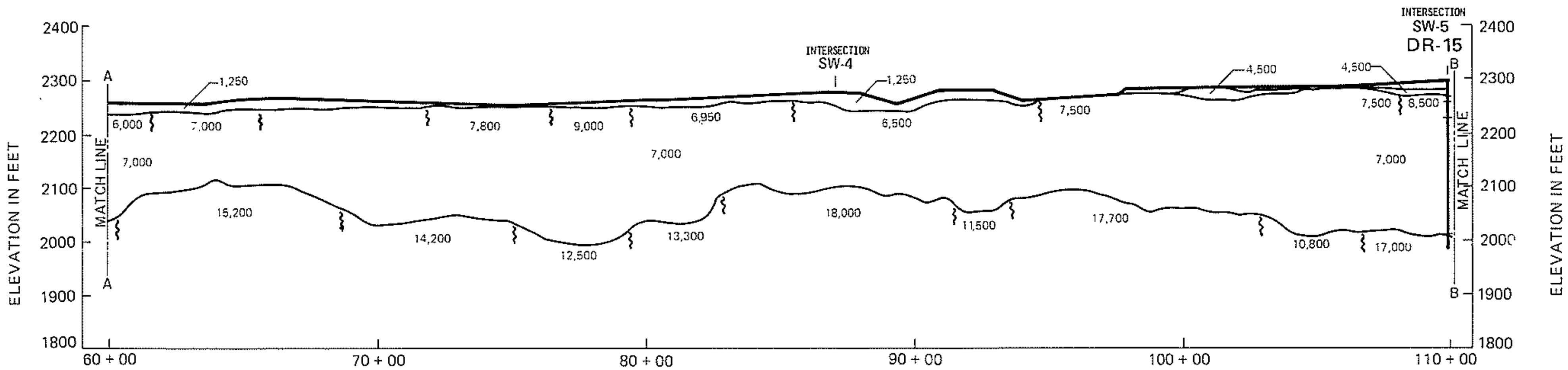
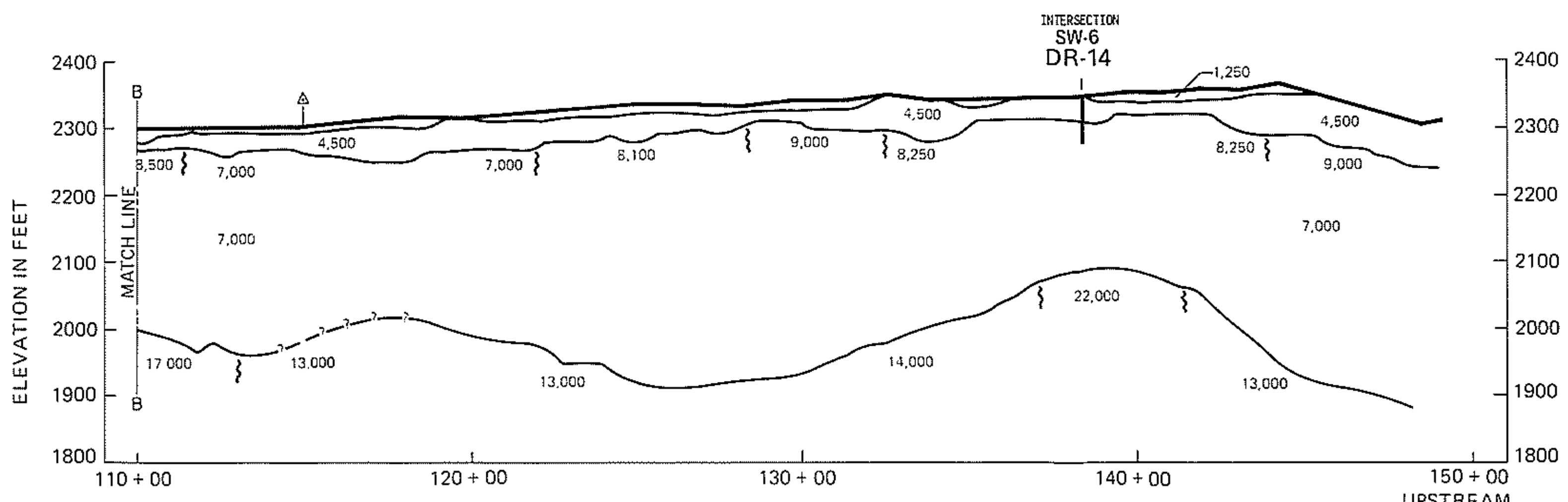


SW - 3

0 100 200 300
VERTICAL SCALE IN FEET

0 200 400 600
HORIZONTAL SCALE IN FEET



SW - 3

LEGEND

{ POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

DR-15 BORING DESIGNATION

APPROXIMATE LOCATION OF CHANGE IN MATERIAL

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SUSITNA HYDROELECTRIC PROJECT
WATANA DAMSITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-3

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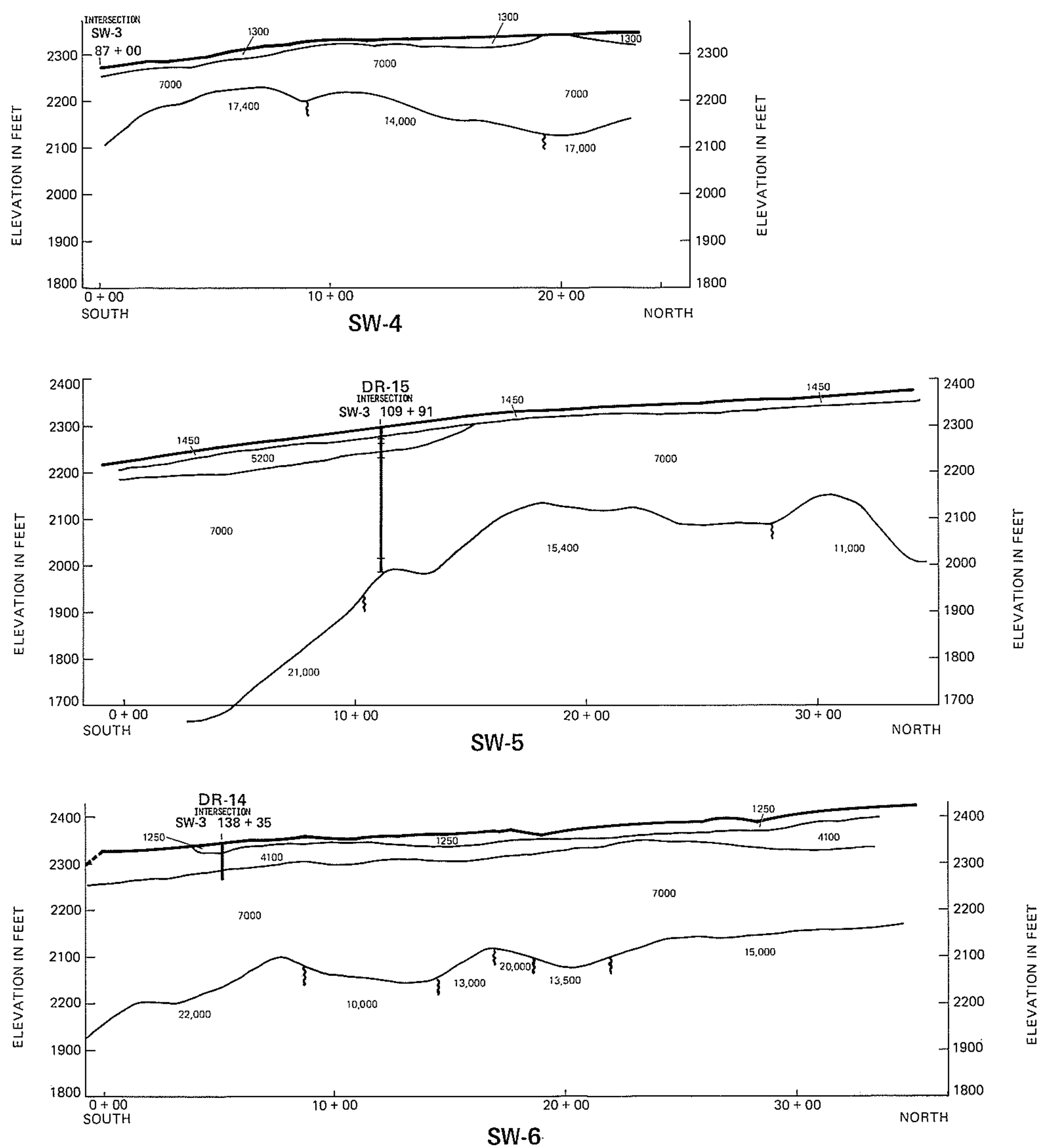
DRAWING NUMBER
SHEET 4 OF 21

INV. NO. DACW85-78-C-0027



LEGEND

⌇ POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

DR-15 BORING DESIGNATION

← APPROXIMATE LOCATION OF CHANGE IN MATERIAL

0 100 200 300

VERTICAL SCALE IN FEET

0 200 400 600

HORIZONTAL SCALE IN FEET

REV.	DATE	C.O.	ACTION	DESCRIPTION	BY	APPD.

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SUSITNA HYDROELECTRIC PROJECT
WATANA DAMSITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-4 SW-5 SW-6

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SCALE: SPEC. NO.

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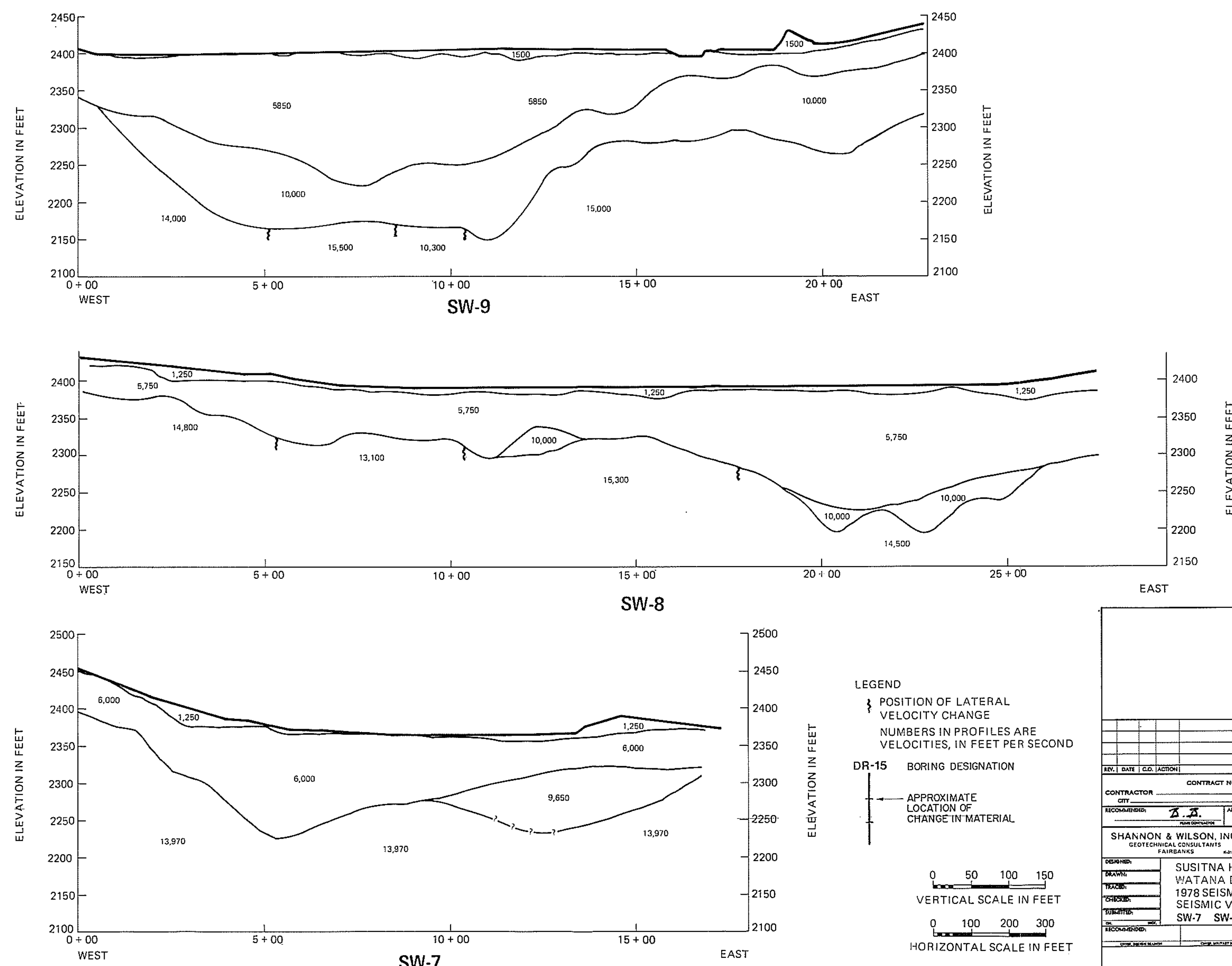
SHEET 5 OF 21

INV. NO. DACW85-78-C-0027

UPPER TSUSENA BORROW SITE



LEGEND

⌇ POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

DR-15 BORING DESIGNATION

APPROXIMATE LOCATION OF CHANGE IN MATERIAL

0 50 100 150
VERTICAL SCALE IN FEET

0 100 200 300
HORIZONTAL SCALE IN FEET

REV. | DATE | C.O. | ACTION | DESCRIPTION | BY | APPD.

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ANCHORAGE, ALASKA

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SUSITNA HYDROELECTRIC PROJECT
WATANA DAM SITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-7 SW-8 SW-9

APPROVED: DATE:
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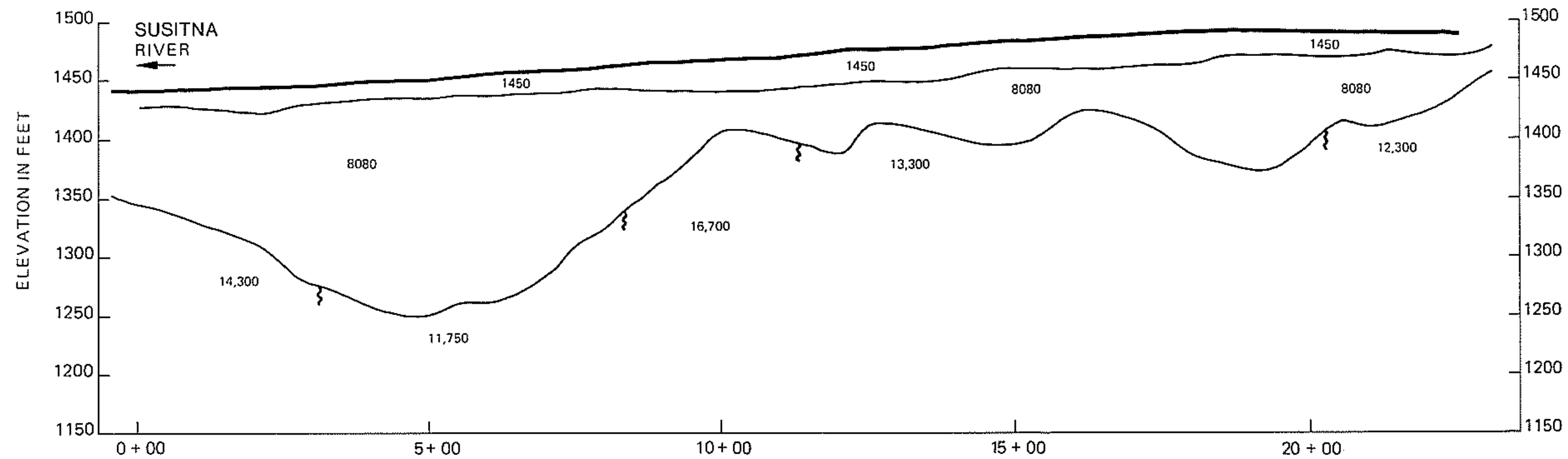
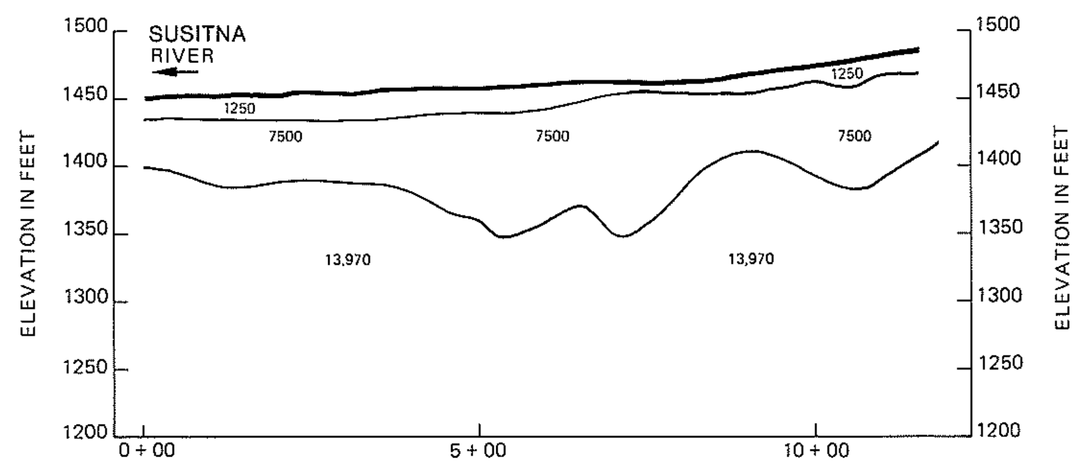
DRAWING NUMBER
SHEET 6 OF 21

INV. NO. DACW85-78-C-0027

LOWER TSUSENA BORROW SITE



SW-12



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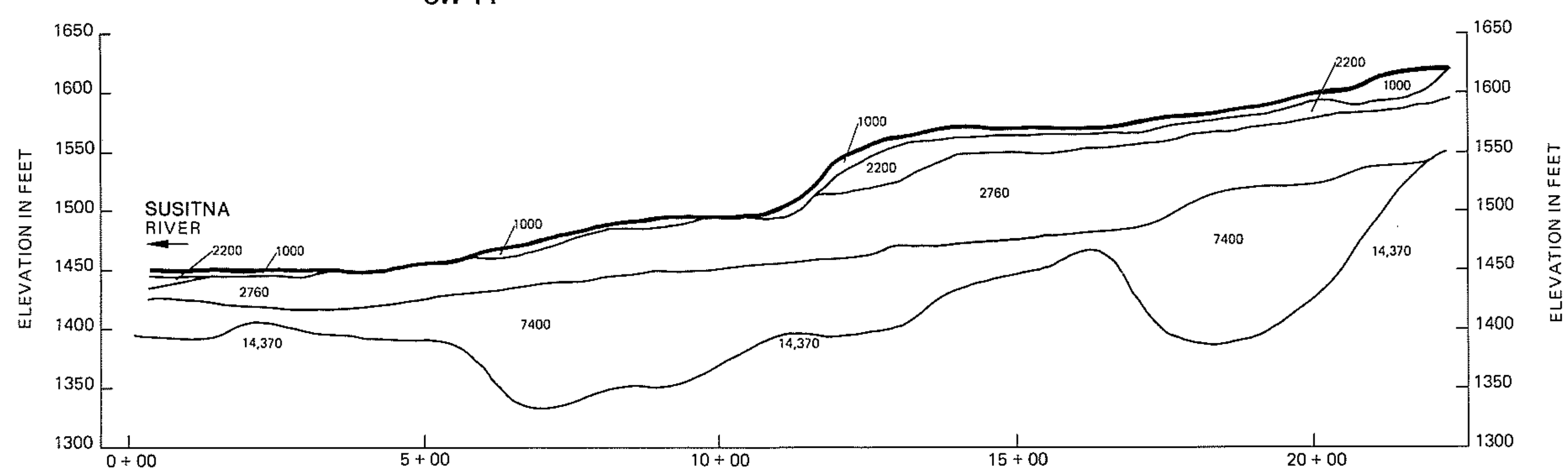

SW-10

LEGEND

POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

DR-15 BORING DESIGNATION

APPROXIMATE LOCATION OF CHANGE IN MATERIAL

0 50 100 150
VERTICAL SCALE IN FEET

0 100 200 300
HORIZONTAL SCALE IN FEET

REV.	DATE	C.O.	ACTION	DESCRIPTION	BY	APP'D.

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RECOMMENDED: B.B. APPROVED: DATE:

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ANCHORAGE, ALASKA

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SUSITNA HYDROELECTRIC PROJECT
WATANA DAMSITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-10 SW-11 SW-12

RECOMMENDED: APPROVED: DATE:

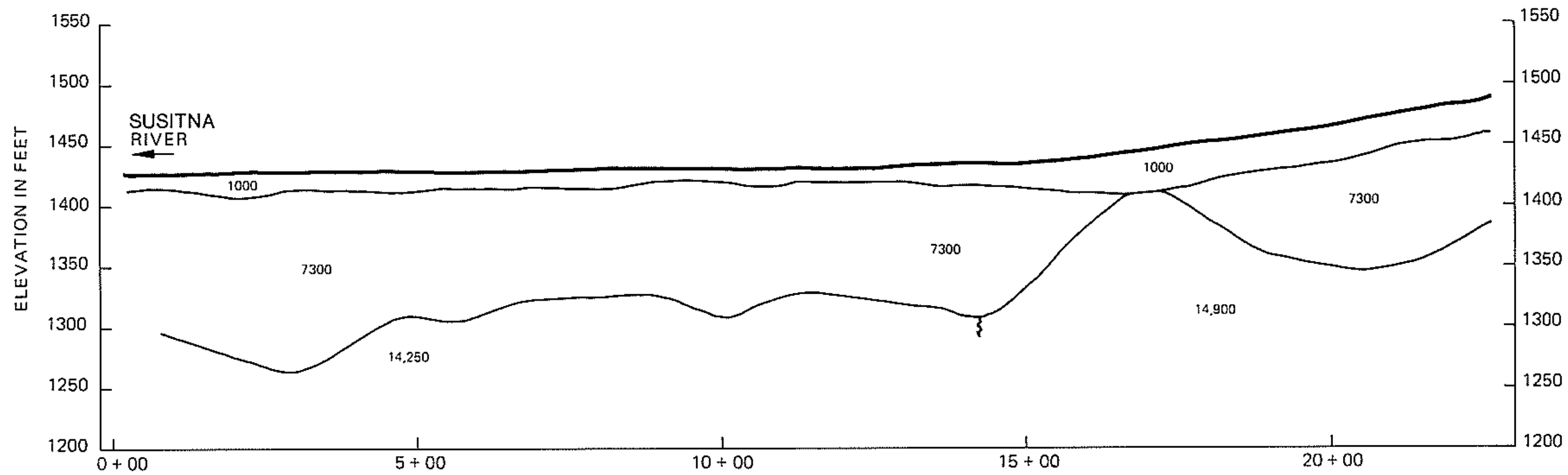
SCALE: SPEC. NO.

DRAWING NUMBER

SHEET 7 OF 21

INV. NO. DACW85-78-C-0027

LOWER TSUSENA BORROW SITE



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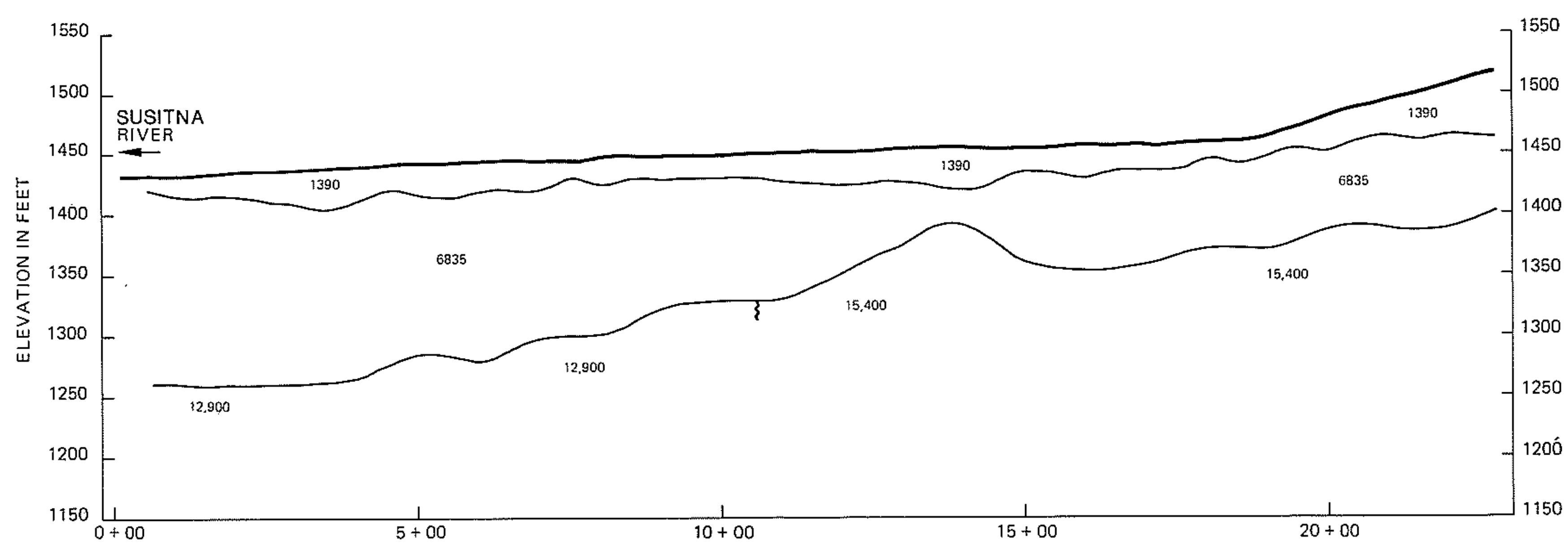


SW-13

LEGEND

⌇ POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

0 50 100 150
VERTICAL SCALE IN FEET

0 100 200 300
HORIZONTAL SCALE IN FEET

REV.	DATE	C.O.	ACTION	DESCRIPTION	BY	APPD.

CONTRACT NO.
CONTRACTOR
CITY STATE
RECOMMENDED: B. B. APPROVED: DATE:

SHANNON & WILSON, INC.
GEOTECHNICAL CONSULTANTS
FAIRBANKS

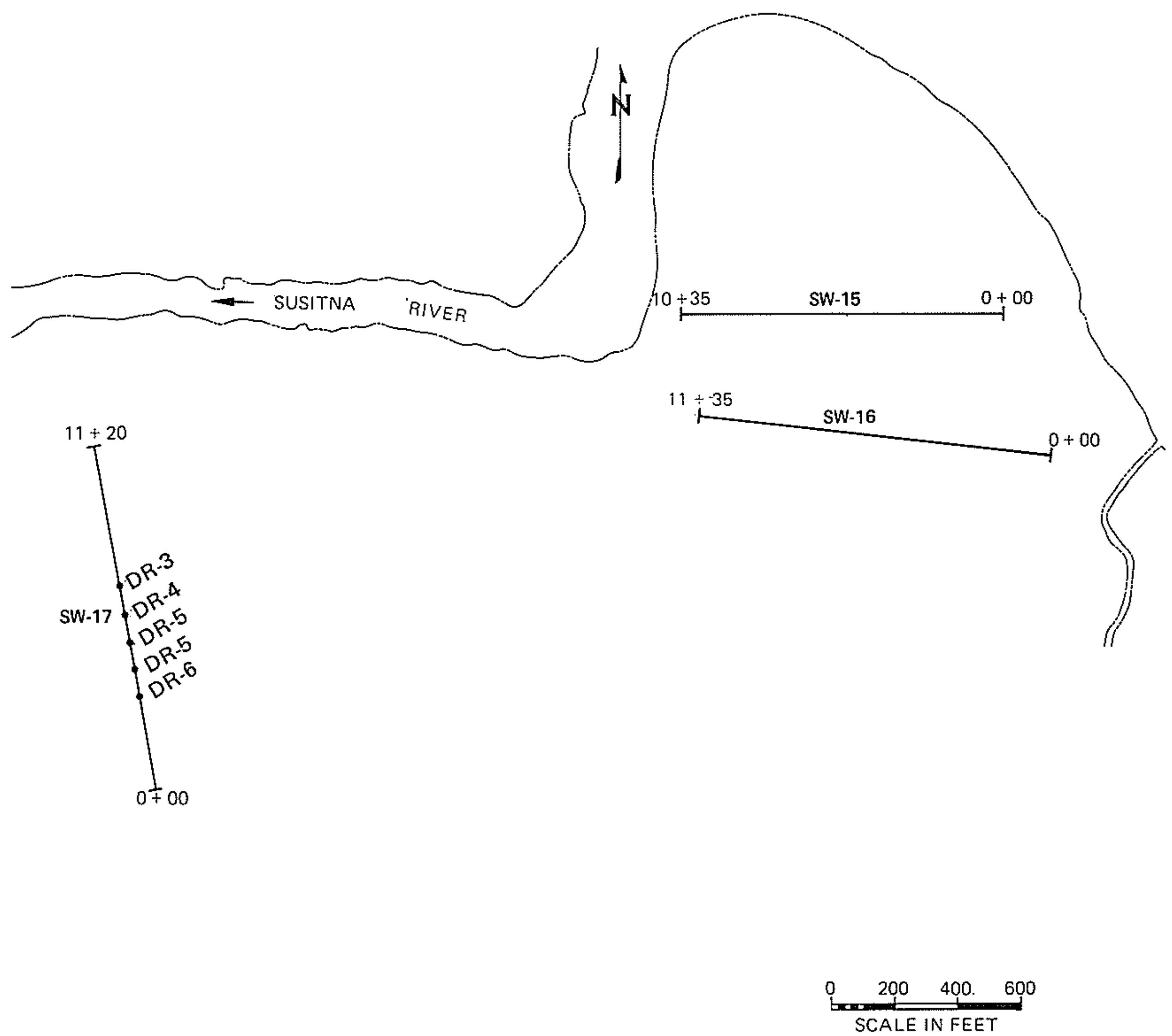
ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

DESIGNED:
DRAWN:
TRACED:
CHECKED:
SUBMITTED:

SUSITNA HYDROELECTRIC PROJECT
LOWER TSUSENA BORROW SITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-13 SW-14

RECOMMENDED: APPROVED: DATE:
SCALE: SPEC. NO.
DRAWING NUMBER
SHEET 8 OF 21

INV. NO. DACW85-78-C-0027



REV.	DATE	C.O.	ACTION	DESCRIPTION	BY	APPD.

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CONTRACTOR ______
CITY ______ STATE ______

RECOMMENDED: B. B. PRIME CONTRACTOR — APPROVED: ______ RESIDENT ENGINEER — DATE: ______

SHANNON & WILSON, INC.
GEOTECHNICAL CONSULTANTS
FAIRBANKS K-0101

ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

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SUSITNA HYDROELECTRIC PROJECT
DEVIL'S CANYON DAMSITE
1978 SEISMIC REFRACTION SURVEY
LOCATION MAP
SW-15 SW-16 SW-17

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DRAWING NUMBER
SHEET 9 OF 21

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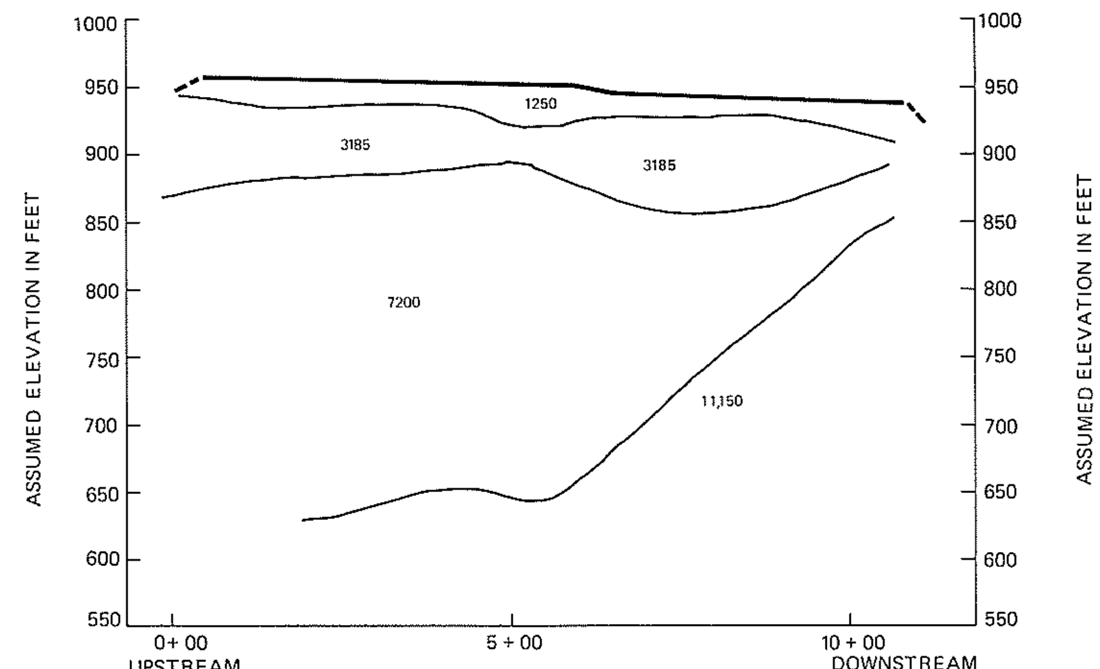

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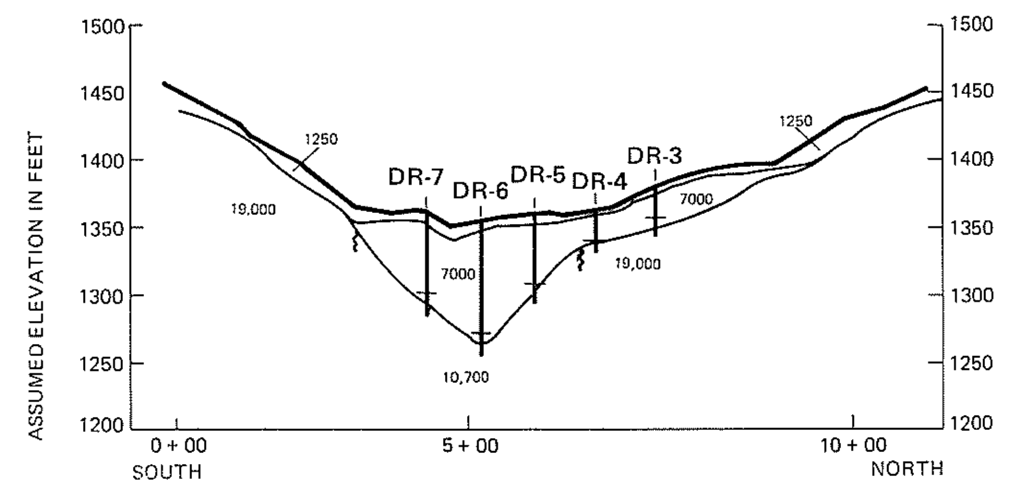

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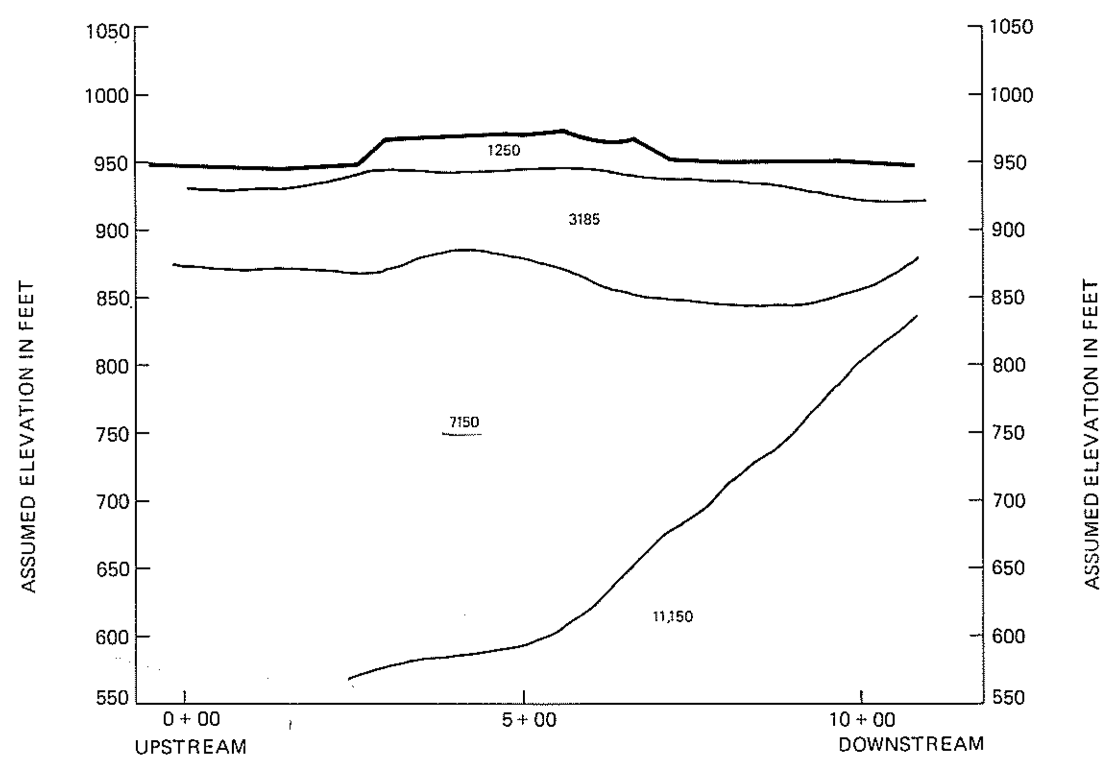

SW-16

LEGEND

⌇ POSITION OF LATERAL VELOCITY CHANGE

NUMBERS IN PROFILES ARE VELOCITIES, IN FEET PER SECOND

DR-15 BORING DESIGNATION

APPROXIMATE LOCATION OF CHANGE IN MATERIAL

0 50 100 150
VERTICAL SCALE IN FEET

0 100 200 300
HORIZONTAL SCALE IN FEET

REV.	DATE	C.O.	ACTION	DESCRIPTION	BY	APP'D.

CONTRACT NO.
CONTRACTOR
CITY STATE
RECOMMENDED: APPROVED: DATE:

SHANNON & WILSON, INC.
GEOTECHNICAL CONSULTANTS
FAIRBANKS

ALASKA DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

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SUSITNA HYDROELECTRIC PROJECT
DEVIL'S CANYON DAMSITE
1978 SEISMIC REFRACTION SURVEY
SEISMIC VELOCITY PROFILES
SW-15 SW-16 SW-17

RECOMMENDED: APPROVED: DATE:
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SHEET 10 OF 21

EXHIBIT D-2

Reconnaissance of the Recent Geology of the Proposed Devil's Canyon and Watana Damsites, Susitna River, Alaska.

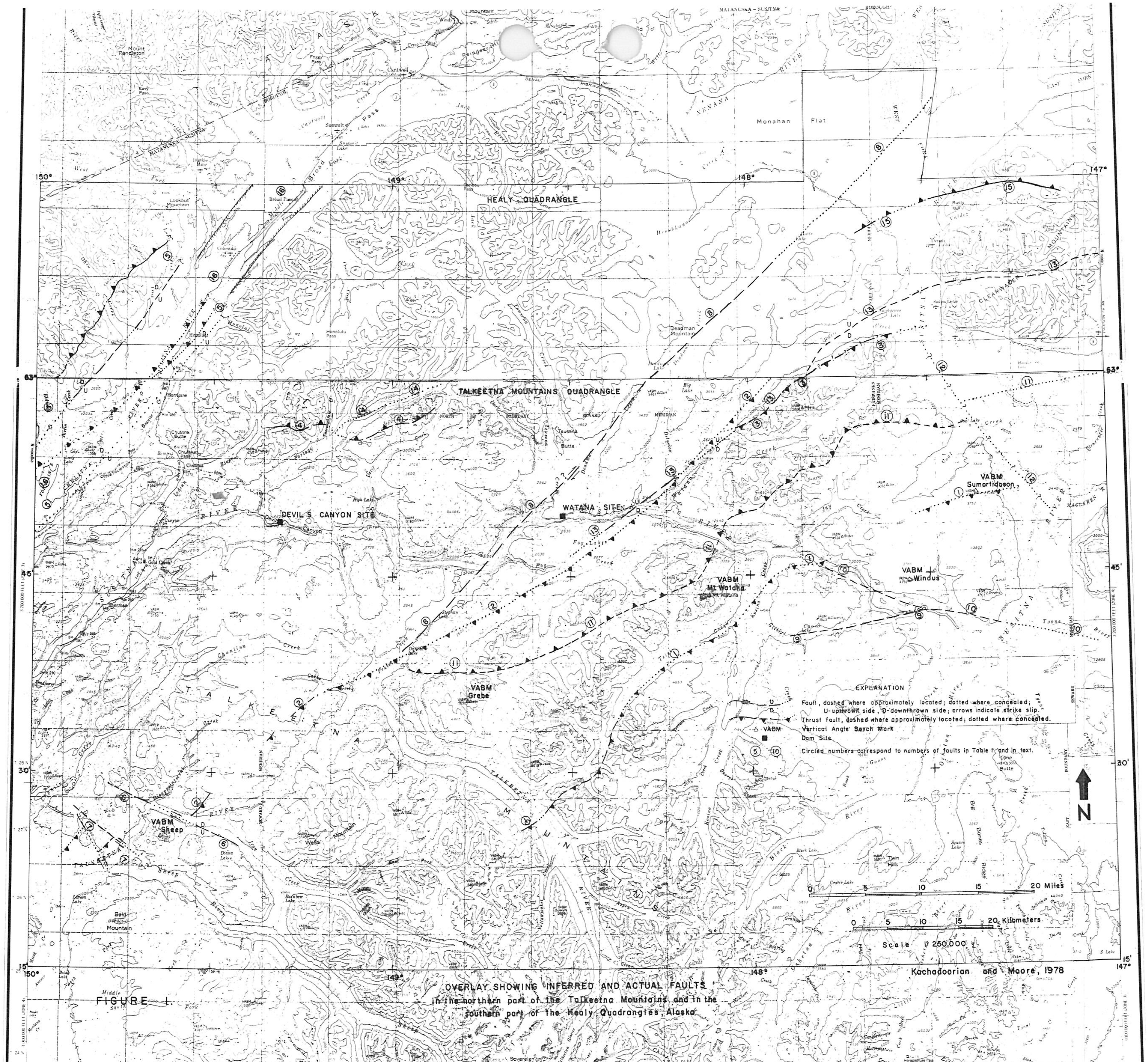

FIGURE 1.

OVERLAY SHOWING INFERRED AND ACTUAL FAULTS in the northern part of the Talkeetna Mountains and in the southern part of the Healy Quadrangles, Alaska.

RECONNAISSANCE OF THE RECENT GEOLOGY OF THE PROPOSED DEVILS CANYON AND WATANA DAMSITES, SUSITNA RIVER, ALASKA

by

Reuben Kachadoorian

and

Henry J. Moore

CONTENTS

Illustrations

Figures

Tables

Appendices

PRELIMINARY REPORT OF THE RECENT GEOLOGY OF THE PROPOSED DEVILS CANYON AND WATANA DAMSITES, SUSITNA RIVER, ALASKA

by

Reuben Kachadoorian and Henry J. Moore

ABSTRACT

At the request of the Corps of Engineers, the U.S. Geological Survey conducted a reconnaissance of the recent geology of the proposed Devils Canyon and Watana damsite areas, Susitna River, Alaska. The purposes of the reconnaissance were to look for active faults and other geologic hazards. Field work by the Geological Survey was conducted between July 25, 1978 and August 7, 1978 using a helicopter which was shared jointly and in cooperation with personnel of the Corps of Engineers.

The geologic reconnaissance of the proposed Devils Canyon and Watana damsite and reservoir areas did not uncover any evidence for recent or active faulting along any of the known or inferred faults. Recent movement of surficial deposits has occurred as the result of mass wasting processes and, possibly, by seismic shaking and minor displacements of bedrock along joints.

Landsliding has occurred in the past and future landsliding appears probable. The occurrence of unconsolidated glacial debris, alluvium, and Tertiary sediments at elevations below the proposed reservoir water levels may slump and slide into the reservoirs when they are inundated. Some of these sediments may be permanently frozen and, locally, may be

ice-rich which increases the probability of slumping and sliding when the sediments are thawed by the water impounded behind the dams.

The tectonic framework of the Devils Canyon and Watana damsite areas is not well understood. The present knowledge of the area indicates that the seismicity of the region ranges in depth from less than 10 km to greater than 175 km.

Additional detailed geologic and seismic studies are necessary in order to reliably evaluate the potential geologic hazards in the region of the proposed dam and reservoir sites.

INTRODUCTION

The feasibility of two dams on the Susitna River, Alaska, is currently under evaluation by the U.S. Army Corps of Engineers. The Corps of Engineers has proposed two dams for the purpose of developing the hydroelectric power potential of the Susitna River: one at Devils Canyon and the other at the Watana site. The proposed Devils Canyon site is located about 29 km (18 miles) upstream from Gold Creek Station on The Alaska Railroad. This dam would be 194 m (635 ft) high and the reservoir formed would have a water altitude of 442 m (1,450 ft) above sea level and would extend about 45 km (28 miles) upstream to the proposed Watana site. The height of the proposed Watana dam would be 247 m (810 ft) and its reservoir would have a maximum water altitude of 671 m (2,200 ft) and extend upstream 87 km (54 miles). The total power produced by both structures would be about 600 megawatts (MW); approximately 270 MW at Devils Canyon and the remaining 330 (MW) at Watana. The current proposed locations for the damsites are shown in Figure 1.

The study of active faults, seismic activity, potential and recent landslides, and other potential geologic hazards are of particular concern in the preliminary evaluation of the proposed Devils Canyon and Watana damsites and their reservoirs. The U.S. Army Corps of Engineers requested the U.S. Geological Survey to make such a study. Authorization for the Geological Survey to make the study is embodied in a letter from F. R. Brown, Technical Director, Corps of Engineers Waterways Experiment Station to Dr. Dallas Peck, Chief Geologist, Geological Survey (Appendix A) and a proposal letter to Dr. Ellis

Krinitzsky, Corps of Engineers, by Reuben Kachadoorian (Appendix B). In practice, the scope of this reconnaissance was modified to include a much larger area than that stated in Appendix B.

This report is based essentially on reconnaissance geologic observations, both on the surface and from overflights, between July 25, 1978 and August 7, 1978. Field work was conducted using a helicopter which was shared jointly and in cooperation with Corps of Engineers personnel who were conducting detailed studies at the proposed Watana damsite. Unfortunately, adverse weather significantly curtailed the number of surface observations during the limited amount of time that the helicopter was available to us.

Details of the bedrock geology are beyond the scope of this report but the geologic map and report of Csejtey and others (1978) is included in this report as Appendix C for the sake of completeness and because we refer to some of the geologic map units. The geologic map in the report was important to our reconnaissance and wherever we field checked it, we found it to be correct and commensurate with its scale. It should be realized that mapping at a larger scale would permit finer subdivision of the map units and portrayal in more detail. Additionally, the definitions of the map units are not directed toward engineering problems, but rather geologic ones; and, therefore, this fact must be considered when using the enclosed geologic map. The map should be used only to determine the gross geologic setting of the proposed Devils Canyon and Watana damsites and their reservoirs. The map includes all of the Talkeetna Mountains, Alaska, Quadrangle, and small segments of the Healy, Alaska, Quadrangle, in the northwest part of the map and the Anchorage, Alaska, Quadrangle in the south.

Figure 1 is intended to clarify the discussions and data presented in this report. It has three parts: (1) a 1:250,000 scale topographic map of the Healy, Alaska, Quadrangle, (2) a 1:250,000 scale topographic map of the Talkeetna Mountains, Alaska, Quadrangle, and (3) a transparent overlay depicting the inferred and actual faults in the reconnaissance area. The overlay includes the northern three-fourths of the Talkeetna Mountains Quadrangle and the southern one-fourth of the Healy Quadrangle. The transparent overlay may be superposed on the topographic maps to locate the inferred and actual faults and other items in the text. Additionally, certain features discussed in the text can be located on the topographic maps by Townships, Ranges, and Sections. The geologic map in Appendix C also has the same scale as the topographic maps and transparent overlay.

We must emphasize that the data and conclusions presented in this report are based on a reconnaissance study of the proposed Devils Canyon and Watana dam and reservoir sites. To evaluate thoroughly the proposed damsites and their reservoirs additional studies must be made. We specify some of these studies later in this report.

GEOLOGIC BACKGROUND

The geology of the Susitna River area (Csejtey and others, 1978; Appendix C) is rather complex. Bedrock consists chiefly of tightly folded, metamorphosed, and faulted volcanic and sedimentary sequences that range in age from late Paleozoic to late Cretaceous and of late Cretaceous to Early Tertiary granodiorite (55 to 75 m.y. old). These rocks are overlain by Tertiary volcanic and sedimentary rocks (about 50 to 58 m.y. old). Tertiary sediments of possibly late Oligocene age (about 25 m.y. old) (Wolfe, written communication, 1977) are exposed in Watana Creek about 7 km (4.5 miles) upstream of its confluence with the Susitna River. The Tertiary sediments are gently tilted and possibly faulted.

Unconsolidated sediments of late Wisconsin glaciation (8,000-12,000-years ago; Péwé, 1975) cover much of the study area. These late Wisconsin glacial sediments consist of unconsolidated tills, moraines, sand and gravel deposits and eskers. Glacial scour features caused by this glaciation are also present. The glacial sediments, in turn, have been and are being eroded, cut, and modified by the Susitna River drainage system and by mass wasting. These recent geologic events are represented by V-shaped valleys, river sands and gravels, terrace sediments, solifluction, slumps, landslides, talus, lakes, stream channels, and other features due to mass wasting processes.

The late Wisconsin glaciation (8,000 to 12,000 y. old) covered the Devils Canyon, Watana dam, and reservoir sites. Kachadoorian (1974) reported field evidence from Devils Canyon indicating that the Susitna River occupies the same channel at the present as it did prior to the

Late Wisconsin glacial period. Recent discovery of glacial debris on the floor of the Susitna River Canyon upstream from the Watana damsite confirms Kachadoorian's previous observation at Devils Canyon.

Of particular interest here are the faults that have been inferred to exist by various investigators in the area. These faults are shown in Figure 1 and are listed in Table 1. Table 1 also includes the designation, type, and the reference from which we obtained the information about these faults.

Table 1. Inferred faults in the general area of the Devils Canyon and Watana damsites, Susitna River, Alaska[1]

Number	Designation	Reference	Type	Remarks
1.	Zone of intense shearing	Csejtey and others, 1978	Thrust	Evidence is stratigraphic and petrographic.
2.	Talkeetna Thrust	Csejtey and others, 1978	Thrust	Evidence is stratigraphic.
3.	Near Watana Creek	Csejtey and others, 1978	Thrust	Evidence is stratigraphic.
4.	Near Portage Creek	Csejtey and others, 1978	Thrust	Evidence is stratigraphic.
5.	Chulitna River	Csejtey and others, 1978	Thrust & Vertical	Evidence is stratigraphic.
6.	North of VABM Sheep	Csejtey and others, 1978	Strike Slip	Right lateral with some vertical displacement.
7.	West of VABM Sheep	Csejtey and others, 1978	Strike Slip	Two faults; left lateral and right lateral.
8.	Susitna Fault	Anon., 1974a, Turner and others, 1974; Gedney and Shapiro, 1975; Turner and Smith, 1974	Strike Slip	Evidence is topographic lineament; inferred to be right lateral from seismic data.
9.	Near Clarence Lake	Beikman, 1974; Smith and others, 1975; Turner and Smith, 1974	High Angle	Displacement apparently vertical.
10.	Near VABM Windus	Beikman, 1974; Smith and others, 1975, Turner and Smith, 1974	High Angle	Displacement apparently vertical.
11.	North of VABMs Grebe-Mt. Watana	Anon., 1974a; Beikman, Smith and others, 1975, Turner and Smith, 1974	Thrust	Evidence is apparently stratigraphic.
12.	East of VABM Sumartidason	Anon., 1974a	Strike Slip	Existence is questioned by the authors.
13.	Watana Creek	Anon., 1974a; Turner and Smith, 1974, Smith and others, 1975	Normal	Evidence is stratigraphic.
14.	Along Portage Creek	Csejtey, personal comm., 1975; Lahr and Kachadoorian, 1975	Thrust	Alternate trace for number 4
15.	North of Denali	Anon., 1974a; Beikman, 1974; Turner and Smith, 1974	Thrust	Evidence is apparently stratigraphic.
16.	Cretaceous to recent shearing	Csejtey, personal commun., 1975; Lahr and Kachadoorian, 1975	Complex	Evidence partly stratigraphic.

[1] Traces of these inferred faults are shown in Figure 1 and indicated by corresponding number.

PROCEDURES

Four kinds of information have been gathered in this preliminary reconnaissance· (1) ground and aerial observations on the traces of known and inferred faults, (2) visual observations of surficial deposits and landforms made during helicopter overflights and locally supplemented by ground observations, (3) a comparison of first order leveling elevations conducted in 1922 and 1965, and (4) the location of epicenters and hypocenters of seismic events in the general area. Additionally, relevant reports in the literature have been consulted for certain areas where our observations were incomplete due to inclement weather and lack of time.

Ground and aerial observations from a helicopter were intended to seek or confirm stratigraphic evidence for faults in the general area and to seek topograpic and geomorphic evidence for recent faulting along the mapped and inferred traces. These fault traces were obtained from the available literature and unpublished reports (Csejtey and others, 1978 and Appendix C; Anon., 1974a; Gedney and Shapiro, 1975; Turner and others, 1974; Beikman, 1974; Turner and Smith, 1974; Smith and others, 1975; Lahr and Kachadoorian, 1975).

Visual observations during helicopter overflights involved searching for scarps, topographic lineations, and offsets of landforms that might be the result of faulting--particularly active faulting. The criteria required to establish active faulting and recent movements were: (1) offsets of glacial landforms, (2) offsets of other landforms such as stream courses, (3) fresh scarps that were devoid of vegetation, and (4) superposition of landforms over preexisting ones. A partial list of the kinds of scarps and landforms that one might expect to observe are listed in Table 2.

First order leveling elevation data were obtained from literature supplied by Thomas Taylor, Topographic Division, U.S. Geological Survey, Anchorage, Alaska.

The section on Seismic Activity was written by John Lahr and Christopher Stephens, Center for Earthquake Studies, U.S. Geological Survey, Menlo Park, California. John Lahr made his unpublished data available to us.

Our criteria for designating a fault as active were constrained by the local geology. Much of the area around the Devils Canyon and Watana dam sites is mantled by late Wisconsin (8,000 to 12,000 y. ago) glacial sediments. In such cases our definition of an active fault necessarily is one that has moved within the last 8,000 to 12,000 years. In areas underlain by bedrock, a fault would be considered active if there were fresh scarps. Most inferred fault traces were locally mantled by late Wisconsin and younger surficial deposits.

Table 2. Partial list of scarps and landforms that may be found in a search for active faults.

Primary

- Volcanoes, flow fronts

Rock structures

- Joint scarps (mass wasting, rock terraces, shear zones, folds, foliations, etc.

Glacial features

- Moraines (lateral, end, ground), eskers, kames, kettles.
- Ice contact features (scours, channels, U-shaped valleys, rock terraces, roches mountonnée, etc.)

River

- Bars, terraces, meander scars, valleys

Lake

- Wave cut cliffs, bars, deltas, thaw scarps

Other unconsolidated deposits

- Soil creep scarps, solifluction lobes, gravity slumps

Rock flow

- Landslides, avalanches, rock glaciers

Tectonic

- Fault scarps, sag features, offset drainage, etc.

Wind

- Sand dunes

Ground and aerial observations along traces of known and inferred faults

During this part of our reconnaissance we found no evidence for active faulting that could be unequivocally related to the inferred or actual faults in the general area. Each of the faults is discussed below by their corresponding number in Table 1.

1. Zone of intense shearing. The zone of intense shearing was examined on the ground near the Talkeetna River (T28N, R5E, S34, NW 1/4). At this locality, cataclastically deformed Jurassic granodiorite was observed to be in contact with late Paleozoic metavolcanics rocks (unit Pzv, Appendix C) along an intense zone of shearing. The contact or faulted zone between these two units was oxidized. Thus, we concur with the existence of this shear zone as mapped by Csejtey and others (1978).

No evidence for active faulting was observed on the ground. Near the Talkeetna River, the flat top of the mountain was not vertically offset where it was intersected by the shear zone. In addition, observations during an overflight of the shear zone a few miles to the southwest across the Talkeetna River and to the northwest along Tsisi Creek to Kosina Creek and then to VABM Sumartidason yielded no evidence of fresh scarps and drainage offsets. Stratigraphic evidence indicates no movement has occurred since early Tertiary (Csejtey and others, 1978; Appendix C).

2. Talkeetna Thrust. This thrust fault is inferred to be concealed throughout almost all of its length. It is exposed along its

southwest trace (T27N, R1W, S6) where late Paleozoic metavolcanic rocks (unit Pzv, Appendix C) form the hanging wall and phyllites and schists (unit Kag, Appendix C) form the footwall. Unfaulted Tertiary volcanics overlie the thrust (T28N, R1W). The fault and Tertiary volcanics as mapped by Csejtey and others (1978) appear to be correct.

No evidence for scarps or active faulting along the inferred trace from Prairie Creek, by Fog Lakes, and along Watana Creek were found by us. Tertiary (Oligocene?) sediments in Watana Creek are gently tilted and possibly faulted, but not recently.

3. Near Watana Creek. This thrust is well exposed (T33N, T22S, R2W) and, where we examined it, Triassic metavolcanic rocks (unit TRv, Appendix C) make up the hanging wall and Jurassic sediments (unit Js, Appendix C) constitute the footwall. Near the fault trace, slickensided Jurassic sediments are abundant. We agree with both the existence and location of this fault as mapped by Csejtey and others (1978). Aerial reconnaissance suggests the fault continues into the Healy Quadrangle as indicated in Figure 1.

We found no evidence for active faulting at the locality examined or along the fault trace to the northeast in the Healy Quadrangle.

4. Near Portage Creek. This thrust is well exposed along its mapped length (T33N, R9W, R8W) and Triassic metabasalts and slates (unit TRvs, Appendix C) are found to the north of the fault trace while Cretaceous phyllites (unit Kag, Appendix C) are found to the south of the trace. Unfaulted Tertiary volcanics and sediments overlie the thrust to the east (T22S, R7W, R6W) and the thrust is terminated by intrusion of Tertiary granodiorite to the west (T33N, R1E, S18).

We found no evidence of active faulting along this trace and agree that movement occurred before the early Tertiary (Csejtey and others, 1978).

5. Chulitna River. Time and inclement weather did not permit adequate reconnaissance of this area but stratigraphic evidence shows a variety of faults are present (Csejtey and others, 1978). Existing maps indicate there is no active to recent faulting (Csejtey and others, 1978), Appendix C; Reed and Nelson, 1977). First order leveling elevations were measured across the Chulitna River; the results of these measurements are discussed later in this report.

6. North of VABM Sheep. Ground observations were not made by us. Evidence for strike slip and vertical movement is represented by offset of contacts between Tertiary granodiorites and older Cretaceous and Paleozoic rocks (Csejtey and others, 1978).

During overflights along the trace of the fault, no evidence for active faulting was found either over the wooded areas or along the Talkeetna River.

7. West of VABM Sheep. Ground observations were not made by us. Evidence for these faults is similar to that in 6 above. During overflights along the traces of these faults, no evidence for active faulting was found.

8. Susitna fault. The trace of this inferred fault passes from the vicinity of Stephan Lake, along Deadman Creek to Butte Lake in the Healy Quadrangle, and then across the west fork of the Susitna River (Anon., 1974a). Evidence for this fault is primarily geomorphic, and comprises a prominent linear on LANDSAT imagery (Gedney and Shapiro,

1975). Right lateral displacement has been postulated on the basis of seismic evidence (Gedney and Shapiro, 1975). In contrast to Gedney and Shapiro (1975), we find no compelling evidence for this fault in the seismic data reported by them or available to us (see Appendix D). This position is based on two factors. First, plots of our data and their data do not show a striking correlation, if any, of epicenters with the inferred trace of the fault. Second, the data are not complete enough or precise enough to be used in this way because the coverage of the seismic net is inadequate for precise determination of epicenter and hypocenter locations in the Susitna fault area. Additional seismic stations could resolve the problem.

Stratigraphic evidence for this fault is weak to non-existent. The geologic map of Turner and Smith (1974) indicates stratigraphic evidence which is contradicted by Csejtey and others (1978). Tertiary granodiorites and their border phases (unit Tsmg or migmatized rocks, Appendix C) lie along the trace of the fault. Tertiary volcanic rocks (unit Tv, Appendix C) occur at relatively low altitudes in Fog Creek (T31N, R4E, R5E) and may be down-faulted. Lack of time prevented us from making detailed studies of the volcanic rocks in Fog Creek.

Overflights along the inferred trace of this inferred fault indicate that active faulting has not occurred along the trace. Evidence for scarps and horizontal offsets are absent from Stephan Lake northeast to a point across the Susitna River. Numerous fresh scarps occur along lower Tsusena Creek and upper Deadman Creek to Butte Lake. Fresh scarps and horizontal offsets are absent northeast of Butte Lake where late Wisconsin re-advance (8,000 y. ago) glacial ground moraines are present. The fresh scarps observed are believed to be due to landsliding, slumping, solifluction, and stream erosion. Orientation of the scarps and the localized hummocky topography at the edge of Tsusena Creek near Watana the damsite (T32N, R5E, S21, 28, 29) are consistent with a landslide. In upper Deadman Creek, fresh scarps have a variety of orientations but they tend to face in southerly or in a downslope direction. The traces of the scarps are commonly arcuate and a kilometer (about 0.6 of a mile) or less in length. For these reasons, we believe these scarps are the result of recent slumping, solifluction and soil creep. It is noteworthy that fresh scarps are absent in the moraines northeast of Butte Lake. If these scarps were interpreted to result from faulting, it would follow that the faulting was pre-moraine (older than about 8,000 yrs and younger than 12,000 yrs). Other fresh scarps on Deadman Creek are clearly meander scars.

In summary, we find no conclusive evidence for a fault or active faulting along the inferred trace of the Susitna fault but rather landsliding, slumping, solifluction, and soil creep. The production of the fresh scarps may be partly related to general seismic activity in the area, however.

9. Near Clarence Lake. The evidence for this inferred fault is apparently stratigraphic (Turner and Smith, 1974), but no such stratigraphic evidence was found by Csejtey and others, (1978; Appendix C). Jurassic amphibolites (unit Jam, Appendix C) occur on both sides of the inferred fault trace but there is a change in metamorphic grade in zones parallel to it (Csejtey, personal comm., 1978). A few scarps occur along the hillsides near the trace but these are best

attributed to solifluction and slumping.

10. Near VABM Windus. This fault runs parallel to the Susitna River and passes to the south of VABM Windus. Here again, Turner and Smith (1974) report stratigraphic evidence for it whereas Csejtey and others (1978) do not report evidence for the fault. Jurassic amphibolites (unit Jam, Appendix C) occur on both sides of the inferred trace over nearly its entire length.

We found no evidence for active faults along the trace of this inferred fault. The eastern part of the trace transects glacial ground moraines and eskers. No vertical or horizontal offsets of the associated landforms were observed. Fresh scarps with 3 to 4.6 m (10 to 15 ft) of relief are particularly abundant near the trace in the vicinity of VABM Windus. Traces of these fresh scarps parallel the local elevation contours and a few occur on the northeast slopes of the Windus hill. This, combined with large amounts of surface and spring water runoff observed during the overflight, suggest that the scarps are due to slumping, solifluction, and soil creep. Tilted trees south of the scarp suggest movement of surface materials occurred within the last 40 to 50 years.

11. North of VABMs Grebe and Mt. Watana. This inferred fault transects Paleozoic rocks (unit Pzv, Appendix C) north of VABMs Grebe and Mt. Watana, crosses the Susitna River, and then more or less parallels the contact between the Paleozoic rocks (unit Pzv) and Triassic metavolcanics (TRv, Appendix C). Stratigraphic evidence for this fault is generally lacking, although the contact between the Paleozoic rocks and Triassic metavolcanics might be inferred to be a

fault. Csejtey and others (1978) do not report a fault along the inferred trace. When we checked this fault on the ground, we found no stratigraphic or geomorphic evidence for it.

During the overflight along the trace of the inferred fault, fresh scarps and horizontal offsets of glacial features (moraines, eskers, etc.) and other surficial deposits were not observed. Thus, active faulting has not occurred along the inferred trace after the glacial features were formed.

12. East of VABM Sumartidason. The existence of this fault is questioned by the authors (Anon., 1974a). The trace was not examined during an overflight because it was unknown to us prior to the reconnaissance.

13. Watana Creek. The trace of this fault generally coincides with the inferred traces of the Talkeetna thrust (see 2 above) and the "Near Watana Creek" (see 3 above) faults and has been inferred to have vertical displacement (north-side up) (Anon., 1974a; Turner and Smith, 1974). Stratigraphic evidence in support of this fault includes Jurassic sediments (unit Js, Appendix C) in fault contact with Triassic volcanics (unit TRv, Appendix C) and the occurrence of tilted Tertiary sediments (unit Tsu, Appendix C; T32N, R7E) at low altitudes.

We found no evidence for active faulting along the trace of this fault.

14. Along Portage Creek. This fault trace was an alternate trace to the eastern part of the thrust fault in 4 above (Csejtey, personal comm., 1975). We found no evidence for active faulting along Portage Creek.

15. North of Denali. Evidence for this fault is apparently stratigraphic and its trace is truncated by intrusives (Cretaceous in age?) (Anon., 1974a; Turner and Smith, 1974). Both the mapping and overflights in the general area indicate this fault is inactive.

16. Cretaceous to recent shearing. Time and inclement weather did not permit adequate reconnaissance of this area which is the same area as number 5 above. The reasons for inferring recent faulting are two poorly exposed normal faults in the Chulitna River valley (Csejtey and others, 1978). Csejtey (personal comm., 1978) states that apparently middle Tertiary or younger sediments have been displaced by the faults. However, existing maps indicate there is no active to recent faulting (Csejtey and others, 1978; Appendix C; Reed and Nelson, 1977).

As stated earlier, lack of time and inclement weather did not permit us to investigate these faults thoroughly. Therefore, it is unknown to us whether any active faulting has occurred along these faults in the Chulitna valley. We attempt, however, to evaluate this fault zone by studying first order leveling data. The results of first order leveling surveys across the fault zone are discussed later.

Visual observations during helicopter flights

Within the study area, a number of geologic phenomena were observed from the air which are relevant to the geologic problems related to dam construction. The most important are: 1) very steeply dipping joint sets and shear zones are common, 2) there are a significant number of short fresh scarps, 3) landslides have occurred in the past and new ones may occur in the future, 4) permafrost is present, at least locally, and 5) locally tills, alluvium, and Tertiary sediments with very low cohesions occur at altitudes near and below the expected water level of the Devils Canyon and Watana dam reservoirs.

1. Very steeply dipping joint sets and shear zones are common (see for example Kachadoorian, 1974). Although these joint sets and shear zones do not necessarily pose dam construction problems, their implications to active tectonic movements and landsliding are important. In regard to active tectonic movements, it seems conceivable that minor vertical and horizontal adjustments during tectonic activity could occur along them without producing long continuous faults but rather short scarps with small displacement (4.6 m, 15 ft). Thus, uplift and deformation could be accomplished by small vertical and horizontal movements along a myriad of joints. In some places, joint sets are so numerous that the Tertiary granodiorites superficially resemble columnar basalt (such as in T31N, R3E, S17). In many places both fresh scarps and graben-like structures appear to be controlled by these joints while in other places, fresh scarps parallel the shear zones.

In addition to providing planes of weakness for minor tectonic movements, the joint sets will also partly control landsliding and rock falls.

2. Fresh scarps are conspicuously abundant in the general area. None of these can be unequivocally ascribed to active faulting but local minor vertical adjustments of the order of 1.5 to 3 m (5 to 10 ft) cannot be excluded for some of them. Others are best attributed to slumping, solifluction, soil creep, and landslip.

a. Solifluction and slump scarps. Fresh scarps near VABM Windus are a good example of scarps produced by slumping and solifluction. They are fresh and unvegetated with reliefs to about 4.6 m (15 ft). They appear to be the result of recent movement by solifluction because segmented traces of scarps to the south of VABM Windus trend parallel to the topographic contours, a few of them occur on the northeast side of the Windus hill, and trees downslope have a variety of orientations. Judging from the tilted trees, movement has occurred within the last 40 to 50 years. Numerous springs were observed during the overflight and polygons are present 2.5 km (1.5 miles) west of VABM Windus.

Additional places where the fresh scarps can be attributed to solifluction and slumping are listed in Table 3.

b. Other scarps. A variety of other types of scarps are present (Table 4) and some of these need special discussion. In general, fresh appearing scarps face in southerly directions. A group of such scarps near the Watana damsite deserve special comment because detailed geologic studies and aerial observations reveal nearly vertical shear zones that trend northwest (Glen Greely, Corps of Engineers, personal commun., 1978) and the traces of nearby fresh scarps also trend in northwesterly directions. These scarps appear to be of two types which are unrelated to the shear zones. The first type (item 2, Table 4) is

Table 3. Location of selected examples of scarps in the Taleetna Mountains Quadrangle.

Number			Township	Range	Section
1.		C-1	T 30 N	R 11 E	1, 2, 11, 13, 14
2.	VABM Windus	C-2	T 31 N	R 10 E	26 through 30 33 through 36
3.		C-2	T 30 N	R 10 E	22
4.		C-2	T 30 N	R 9 E	15, 16
5.		C-2	T 30 N	R 8 E	3, 9, 15, 14
6.		C-2	T 29 N	R 1 E	19, 20, 21, 28, 29
7.		D-2	T 33 N	R 10 E	22
8.		D-3	T 22 S	R 4 W	21, 28, 29, 31, 33
9.		D-3	T 33 N	R 5 E	19, 20, 25, 26, 27, 34
10.	Watana Site	D-4	T 32 N	R 5 E	21
11.		D-4	T 33 N	R 4 E	28, 29, 31
12.		D-4	T 33 N	R 3 E	27, 28, 34, 36
13.		D-4	T 32 N	R 4 E	29, 32

Table 4. Selected examples of landforms with steep scarp-like surfaces.

Feature	Location[1]	Contents
Fresh appearing		
1. Meander scars/cut banks	(D-3) T33N R6E S19	In Deadman Creek
2. Meander scars/thaw lake shores	(D-3) T32N R5E S14	Near Watana damsite
3. Thaw lake shores	(C-2) T30N R9E S7,8	
4. Altiplanation scarps	(C-5) T29N R1E S21	
5. Landslide	(D-4) T32N R5E S29,S28	Near Watana damsite
6. Eskers	(C-1) T30N R11E, R12E, S24,25	
	(C-1) T30N R12E S9,16,17	
	(C-3) T30N R5E S24	
	(C-3) T30N R7E S19	
	(C-4) T30N R5E S30	
	(D-2) T31N R8E S9,16,17	Close to Susitna River
7. Moraines	(C-4) T30N R5E S5,8,17	Lateral
	(D-3) T22S R5W S36	End
	(D-3) T22S R4W S30	Lateral
8. Kames and Kettles	(C-3) T30N R8E S5,6,7,8	
	Healy Quad. T20S R1W S4,5,6	
Old appearing		
9. Glacial Scour	(C-4) T30N R2E S24	
	(C-1) T30N R11E S23	
	(D-4) T31N R3E S7,8,17	
10. Old River channels	(C-2) T31N R9E S25,36	
	(C-2) T30N R10E S11	
	(D-5) T32N R2E S33	

[1]Letter designations refer to 1:63,360 scale topographic maps of the Talkeetna Mountains.

believed to be due to the combined effects of ancient streams and thaw lakes. Excavation of the materials in one of the scarps revealed it is underlain by bedded, pebbly to cobbly fine- to medium-grained sands deposited by streams. The complex array of the scarps suggest that they are former meander scars. Additionally, many of the scarps partly surround thaw lakes and bouldery beds of former thaw lakes. Although fresh scarps in the area tend to face southwest, some vegetated ones that face in north to northeast directions are present. Thus, we attribute this type of scarp to the combined action of ancient lakes and streams and to recent thawing and freezing.

The second type (item 5, Table 4) is classified as a landslide because the hummocky surface of southwest facing scarps and benches are confined to a small area and are consistent with soil movement toward the southwest. The landslide is not related to the shear zones because sediments comprise the material of the slide and no bedrock occurs in it. Freezing and thawing may have been the major cause of movments producing these scarps and benches but we have classed them as landslides because of the relatively large amount of movement.

The origin of some fresh scarps is unclear and the relatively large abundance of scarps might be partly the result of mild tectonic activity and seismic shaking. Many scarps, both fresh and old, are aligned parallel to local joint directions (C-5, T31N, R1E, S34, 35; and C-5, T31N, R2E, S33) and could represent the results of local tectonic adjustments. The fresh scarps associated with joint sets and slumping are clearly recent as shown by their lack of vegetation and tilted trees. Seismic waves may be partly responsible for these recent movements.

2. Older Scarps. Older vegetated and lichen covered scarps are similar to the fresh scarps, but here, two additional types have been observed: graben-like structures in bedrock and old river channels. The graben-like structures (item 10, Table 4) are generally short in length (a fraction of a km) and shallow. Their lengths trend westerly which is the general direction of glacial movement in the area. Because of the short length, orientation, and graben-like form, we attribute them to glacial plucking and scouring. Old river channels also occur (item 9, Table 4). These old channels are arcuate graben-like landforms subparallel to the present course of the Susitna River.

3. Landslides. Although not particularly abundant throughout the Devils Canyon and Watana area, landslides have occurred in the past and new ones may occur in the future. We noted several large landslides along the Susitna River in the proposed Devils Canyon and Watana reservoir sites. The evidence for old landslides is straightforward. Those composed chiefly of rock occur as isolated blocks (or hills) downslope of arcuate scars with about the same aerial dimensions as the

block. Two such slides were observed and are listed in Table 5 (items 1 and 2). Landslides in unconsolidated sediments, such as alluvium and glacial till, form hummocky surfaces of scarps, terraces, and ridges (item 3, Table 5).

Identification of potential landslides using geomorphic evidence from overflights is problematical and the number of potential landslides listed in Table 5 could either be an overestimate or an underestimate of the potential landslides in the Devils Canyon and Watana reservoir areas. We have, however, listed them to indicate the potential for future landsliding in the area. Also, those listed do not include possible landsliding of bedrock and unconsolidated sediments once they become saturated with water during reservoir filling.

It was not within our charter to map in detail the abutments of the proposed Watana damsite as Kachadoorian (1974) did at the proposed Devils Canyon damsite. Therefore, the abutments of the Watana site should be thoroughly examined for possible potential landslides.

4. Permafrost. Permanently frozen ground or permafrost is present in the proposed dam and reservoir areas. During our overflights numerous ice wedge polygons were noted, some of which are listed in Table 6. We also noted slumping of surficial debris on permafrost in the Susitna River canyon at about altitude 580 m (1,900 ft) (T31N, R4E, S21), about 11 km (7 miles) downstream of the proposed Watana damsite. Permafrost was also reported in the surficial deposits during drilling at the proposed Vee Canyon damsite (Anon., 1962) about 65 km (40 miles) upstream of the Watana site and in unconsolidated sediments and bedrock of the left abutment of the proposed Watana damsite (Corps of Engineers, personal commun., 1978).

Table 5. Locations of old landslides and potential landslides.

Location[1]	Comments
Old Landslides	
1. (D-3) T32N R6E S-28 (SE 1/4)	Block of rocks is several hundred feet across.
2. (D-4) T32N R4E S-33 (NE 1/2) & S34 (NW 1/4)	Block of rocks is several hundred feet across.
3. (D-4) T32N R5E S-28 (NW 1/4) & S-29 (NE 1/4)	North of Watana damsite, slide material is alluvium and fill.
Potential Landslides	
4. (D-3) T32N R6E S-32 (N 1/2)	Weakly developed scarp at 549 m (1800 ft).
5. (D-4) T31N R2E S-12 (E 1/2)	Weakly developed scarp at 366 m (1200 ft).
6. (C-2) T31N R9E S-26 (S 1/2)	Top of mass at 610 m (2000 ft).

[1]Letter designations refer to 1:63,360 scale topographic maps of the Talkeetna Mountains Quadrangle.

Table 6. Locations where patterned ground was observed.

Location[1]
(D-4) T32N R5E S28
(C-2) T31N R10E S28,33
(C-2) T30N R9E S10,15
(C-4) T30N R5E S7,8
(C-4) T29N R4E S2
(C-5) T30N R1W S3
(C-5) T30N R1E S19

[1] Letter designations refer to 1:63,360 scale topographic maps of the Talkeetna Mountains Quadrangle.

In order to evaluate the permafrost-related geotechnical problems in the proposed Devils Canyon and Watana dam and reservoir sites, a detailed study of the nature, character, and distribution of permafrost should be made. Of particular importance is the permafrost that underlies the left abutment of the proposed Watana damsite.

5. Till, alluvium, and Tertiary sediments. Locally, poorly consolidated tills, alluvium, and Tertiary sediments occur at water levels that are lower than the planned altitudes of the filled reservoirs of the two dams (Devils Canyon: 442 m (1,450 ft); Watana 666 m (2,185 ft)). Wetting of the materials and thawing of ice in them will cause weakening of the materials and may cause subsequent slumping, mud slides, and other mass movements. This problem is more probable for the Watana reservoir than it is for the Devils Canyon reservoir. For the Devils Canyon reservoir, the frequency of outcrops of rock below altitudes of 442 m (1,450 ft) is striking along the entire length of the Susitna River valley that would be occupied by the reservoir. Tills appear to occur above about 610 m (2,000 ft) but some alluvial fans would be innundated.

For the Watana reservoir, the occurrence of till and sediments begins within 3 km (about 2 miles) upstream of the proposed damsite. Here, tills and sediments overlie bedrock and the contact between them is near 579 to 610 m (1,900 to 2,000 ft). The amount of bedrock exposed along the Susitna River upstream of the planned damsite is impressive but at altitudes near 610 m (2,000 ft) and higher, tills and other sediments are conspicuous. Eskers occur upstream at an altitude of 549 m (1,800 ft). Alluvium and talus are also common below 671 m (2,200 ft) along the river.

Both tills and Tertiary fluviatile sediments that would be inundated by the reservoir occur in Watana Creek. Some of the fluviatile Tertiary sediments are clays which, when wetted, become very weak and may even disaggregate.

First Order Leveling Observations

The results of first order leveling are included here because (1) the traverse passes across the zone of Cretaceous to recent shearing and faulting in the Chulitna River valley (Table 1, number 16) and across the Denali fault (Lahr and Kachadoorian, 1975), and (2) because the leveling was accomplished before and after the Alaskan earthquake of 1964. Comparisons of the first order altitudes, measured in the summers of 1922 and 1965 along The Alaska Railway from Sunshine to McKinley Park (Rappleye, 1930; Anon., 1973) reveal that differences in altitudes of bench marks measured in the two surveys cannot be attributed to faults with large displacements. These altitudes, which are tabulated in Table 7, are everywhere within 0.21 m (0.7 ft) of one another. According to Thomas Taylor of the Topographic Division of the Geological Survey in Anchorage, Alaska, differences in excess of 0.30 m (1 ft) would probably exceed the uncertainties in altitude changes of some benchmarks due to frost heaving. A tentative analysis of the data indicate, however, that there may be a systematic change in altitudes between the two surveys. The data indicate that there appears to be some tilting, of the order of a foot (0.3 m) with the south side down between Sunshine on the south to Yanert to the north. Because we do not know which of the benchmarks are in unconsolidated sediment and subject to frost heaving and which are not, we do not believe an analysis of the data can permit us to state that there has been any active faulting between 1922 and 1965.

Because of the differences in altitudes detected during the first-order leveling, we believe the Vertical Angle Bench Marks should be remeasured in order to detect possible displacements with the Devils Canyon and Watana damsite areas subsequent to the initial surveys.

Table 7. First-Order leveling from the vicinity of Sunshine to McKinley Park.

		Altitude (in feet)[1]		
Station	Designation	1922	1965	Difference
J-2	Sunshine	285.895	285.219	-0.676
M-2	Talkeetna	346.259	345.675	-0.584
0-2	Chase	411.239	410.718	-0.521
U-2	Curry	543.358	543.004	-0.354
V-2	Sherman	587.200	586.908	-0.292
X-2	Gold Creek	691.764	691.610	-0.154
Z-2	Canyon	856.173	856.015	-0.158
A-3	Canyon	1044.555	1044.417	-0.138
E-3	Hurricane Gulch	1629.974	1629.951	-0.023
F-3	Honolulu	1495.322	1495.381	+0.059
K-3	Colorado	2063.090	2063.247	+0.157
L-3	Broadpass	2059.569	2059.720	+0.151
P-3	Cantwell	2246.373	2246.547	+0.174
S-3	Windy	2076.036	2076.285	+0.249
T-3	Windy	1996.873	1996.974	+0.101
U-3	Carlo	1956.367	1956.627	+0.260
V-3	Yanert	1950.357	1950.678	+0.321
W-3	Yanert	1950.574	1950.905	+0.331
Y-3	McKinley Park	1717.201	1717.382	+0.181

[1] Altitude reported in feet because First-Orderleveling recorded in feet.
The conversion factor is 0.3048 meters/foot.

- indicates decrease in altitude from 1922 to 1965.

+ indicates increase in altitude from 1922 to 1965.

Additional Observations

Although it may not be within our charter, we would like to comment about the sediment load in the glacially fed Susitna River. Of particular interest here is the rate at which the Watana reservoir might be filled by the suspended load and the bed load of the river. Our estimates of the time to fill the reservoir using nominal values of the rates and suspended load (Anon., 1974b), are near one or two thousand years. However, suspended and bed loads of glacially fed streams are highly variable. Thus, we feel that there may be insufficient detailed data to provide an adequate estimate of the lifetime of the dam and that such data should be gathered and analyzed to insure that there is an adequate lifetime for the Watana dam.

During our aerial and ground observations, we found no evidence for recent volcanism. Scoriaceous rocks do occur in the Tertiary sediments of Watana Creek but these are the result of heating by subsurface burning of the lignite beds in the distant past.

Henry Moore noted evidence for icing on or near the left abutment of the proposed Watana damsite. Such icing was verified by Glen Greely, Corps of Engineers (personal comm., 1978). We do not know the source of water for this icing. Therefore, we recommend that the left abutment be thoroughly investigated to determine the source and location of the water relative to the proposed dam.

We detected some lineaments in the active outwash plain of the West Fork Glacier. These lineaments occur about 5 km (3 miles) south of the present terminus of the glacier and are about 97 km (60 miles) northeast of the proposed Watana damsite. The lineaments are interpreted to be sand dikes that developed during seismic shaking from an earthquake. The age of the sand dikes is unknown but they are considered to be relatively young because they are well preserved and occur in the active outwash plain of the West Fork Glacier. Lack of time did not permit us to make an extensive investigation of the area to adequately determine the extent and distribution of the sand dikes.

Seismic Activity

The Devils Canyon and Watana damsite area lies within a region characterized by a high rate of seismic activity that is the result of tectonic interaction between the Pacific and North American lithospheric plates. The Pacific plate is being thrust to the northwest beneath the North American plate (Lahr and Kachadoorian, 1975). The earthquakes affecting this region are generally of three types: (1) shallow (depth less than about 50 km) earthquakes (such as the 1964 Alaska earthquake) which occur on the surface of contact between the Pacific and North American plates to accommodate their relative motion; (2) shallow earthquakes which occur within the North American plate (including Alaska) in response to the stresses produced by interaction with the Pacific plate; and (3) deeper earthquakes (depths from 50 to 200 km) that occur within the portion of the Pacific plate that has been thrust beneath Alaska. These latter earthquakes define a region called the Benioff zone. Earthquakes which are occurring in the region of the proposed damsites are of the types described in the last two categories, although earthquakes of all three types are capable of producing strong ground shaking at the proposed sites.

Lahr and Kachadoorian (1975) reviewed the seismic data available from the U.S.G.S. (formerly N.O.A.A.) Earthquake Data File for the period 1900 to February 1975. Using only the more reliable earthquake locations, they showed that the depth of earthquakes in the region of the proposed reservoirs range from less than 10 km to greater than 175 km. The depth to the Benioff zone directly beneath the proposed damsites is about 50 km to 80 km. Distribution of epicenters of shallow earthquakes, according to presently available data, is too scattered to reliably associate them with individual faults.

For design purposes there are two questions of major importance. First, are there potential active faults or other zones of weakness beneath the proposed structures which could cause direct structural damage during an earthquake? Second, what are the spatial, temporal, and magnitude distributions of earthquakes in the region and as a result, what accelerations will the proposed structures probably experience during their lifetime?

The process of identifying active faults on the basis of earthquake locations is limited by the accuracy to which the locations can be determined, as well as by the smallest magnitude earthquake that can be recorded. These two parameters are highly dependent upon the number and distribution of seismograph stations used in determining a location. A regional seismograph network did not exist in southern Alaska before 1967. Prior to that time, the accuracy of epicentral coordinates was 50 km or more, errors in depth were on the order of 100 km or more, and the smallest magnitude events that had been detected were about 4 1/2 on the Richter scale. Since 1967, routine locations for earthquakes as small in magnitude as about 3 have been determined with accuracies of 10-15 km in epicenter and about 25 km in depth. Since 1971 the U.S.G.S. has operated a network of seismic stations in southern Alaska. The distribution of earthquake hypocenters and magnitudes detemined using this network generally confirms the conclusions reached by Lahr and Kachadoorian (1975). Recent U.S.G.S. data allow more precise resolution of the depth to the top of the Benioff zone and of the extent of shallow crustal activity. The distribution of the epicenters of the shallow

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The tectonics of the region are too poorly known at this time to make a reliable prediction for the distribution of events that may strongly shake the damsites. Certainly the Benioff zone activity will continue as will the shallow regional activity. In addition, the Denali fault, which lies less than 80 km north of the proposed damsites, is a major strike-slip fault with geologic evidence for a 3 cm/yr average Holocene slip. This fault could sustain a magnitude 8.0 event.

In addition to the naturally occurring earthquake activity in the region, there is also the hazard that filling of a reservoir may trigger potentially damaging earthquakes (as large as magnitude 6 or greater) in the immediate vicinity of the damsites (Lahr and Kachadoorian, 1975). Continuous monitoring by a local network of seismic stations in the region beginning well in advance of filling the reservoirs would allow the level of natural ambient seismicity to be determined. Unless the natural level is well established, an important opportunity to study this phenomena will be lost, and possibly unwarranted conclusions concerning induced seismicity may be made in the future.

SUMMARY

Our geologic reconnaissance of the proposed Devils Canyon and Watana damsites and reservoir areas, Susitna River, Alaska, did not uncover evidence for recent or active faulting along any of the known and inferred faults. Recent movement of surficial deposits has occurred as the result of mass wasting processes that have produced scarps and downslope movement of surficial debris. It is possible that some fresh scarps may have been triggered or produced by seismic shaking and minor displacements of bedrock along joints.

Landsliding into the Susitna River has occurred in the past and future landsliding appears probable. Additionally, the occurrance of poorly consolidated glacial debris, alluvium, and Tertiary sediments at altitudes below the proposed reservoir water levels, especially at the Watana Dam reservoir, may slump and slide into the reservoirs. Some of these sediments contain permafrost and may be ice-rich which increases the probability of slumping and sliding when they are thawed by the water impounded behind the dams.

The proposed Devils Canyon and Watana dams are located in a region of high seismicity. The tectonic framework of the region is not well understood because of the lack of local seismic monitoring stations. Our present knowledge of the region indicates that hypocenters of earthquakes in the region of the proposed dams ranges in depth from less than 10 km to greater than 175 km. We are unable at this time to reliably predict the location and magnitude of future crustal earthquakes that could effect the proposed structures.

RECOMMENDATIONS

The conclusions presented in this report are based on a reconnaissance study of the proposed Devils Canyon and Watana dam and reservoir sites, and, therefore, should be considered to be preliminary. A thorough evaluation of the geotechnical problems of the proposed dam and reservoir sites will require more data. It will be necessary to (1) map the Healy, Alaska, Quadrangle, at a scale of 1:250,000, from the Talkteena Mountains Quadrangle to the Denali Fault, about 80 km (48 miles) north of the damsites, (2) map the proposed Devils Canyon and Watana damsites at an appropriate scale to determine the bedrock structure and distribution of unconsolidated sediments overlying the bedrock, (3) map the reservoir sites at a scale of 1:63,360 in order to (a) establish the type and distribution of unconsolidated sediments and bedrock, (b) locate additional potential landslide areas, and (c) determine the nature and distribution of permafrost, (4) initiate a seismic monitoring program of the dam and reservoir areas, (5) continue the active fault study, (6) redetermine the altitudes of the Vertical Angle Benchmarks, and (7) collect detailed data on the suspended loads and bed loads of the Susitna River in order to determine if the reservoir filling rates are acceptable.

REFERENCES CITED

Anon., 1962, Engineering Geology of the Vee Canyon Damsite: Bureau of Reclamation unpublished report 37, p.4, Appendices.

Anon., 1973a, Vertical Control Data: National Geodetic Survey, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey.

Anon., 1974a, Annual Report 1973: Division of Geologic and Geophysical Survey, Department of National Reserve, State of Alaska, 59 p.

Anon., 1974b, Water Resources Data for Alaska, Part 1, Surface Water Records, Part 2, Water Quality Records: U.S. Geological Survey, 299 p.

Beikman, Helen M., 1974, Preliminary Geologic Map of the Southeast Quadrant of Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 612, 2 sheets.

Csejtey, Béla, Jr., Nelson, W. H., Jones, D. L., Siberling, N. J., Dean, R. M., Morris, M. S., Lamphere, M. A., Smith, J. G., and Silberman, M. L., 1978, Reconnaissance Geologic Map and Geochronology, Talkeetna Mountains Quadrangle, northern part of Anchorage Quadrangle, and southwest corner of Healy Quadrangle, Alaska: U.S. Geological Survey Open-file Report 78-558-A.

Gedney, Larry and Shapiro, Lewis, 1975, Structural Lineaments, Seismicity, and Geology of the Talkeetna Mountains Area, Alaska: Geophysical Institute, University of Alaska, Fairbanks, Alaska; 18 p., 5 plates. Report prepared for the U.S. Army Corps of Engineers (N.A.S.A. Contract NAS 5-20803, NASA Grant NGL 02-001-092 and U.S.G.S. Contract 14-08-0001-14857).

Kachadoorian, Reuben, 1974, Geology of the Devils Canyon damsite, Alaska, U.S. Geological Survey Open-file Report 74-40, 17 p.

Lahr, John C. and Kachadoorian, Reuben, 1975, Preliminary geologic and seismic evaluation of the proposed Devils Canyon and Watana Reservoir areas, Susitna River, Alaska: Informal report to the U.S. Army Corps of Engineers, 24 p.

Péwé, Troy L., 1974, Quaternary geology of Alaska: U.S. Geological Survey Professional Paper 835, 145 p., 3 plates.

Rappleye, Howard S., 1930, First-order leveling in Alaska: U.S. Department of Commerce, Coast and Geodetic Survey Special Publication 169, _____ p.

Smith, Thomas E., Bundtzan, Thomas K., and Trible, Thomas C., 1975, Stratabound copper-gold occurrence, Northern Talkeetna Mountains, Alaska: Alaska Division of Geologic and Geophysical Surveys, Miscellaneous Paper 3, 7 p.

Reed, B. L. and Nelson, S. W., 1977, Geologic map of the Talkeetna Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-870-A.

Turner, D. L. and Smith, T. E., 1974, Geochronology and generalized geology of the Central Alaska Range, Clearwater Mountain, and Northern Talkeetna Mountains: Alaska Division of Geological and Geophysical Surveys, Open-file Report 72, 11 p., 1 map.

Turner, D. L., Smith, T. E., and Forbes, R. B., 1974, Geochronology and offset along the Denali Fault Syst (abs.), in Abstracts with programs 70th Annual Meeting, Cordillerian Section, Geological Society of America, v. 6, no. 3, p. 268-269.

EXHIBIT D-3

Earthquake Assessment of the Susitna Project

EARTHQUAKE ASSESSMENT AT THE
SUSITNA PROJECT, ALASKA

by

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10 November 1978

CONTENTS

PART I: INTRODUCTION

1. The following sections of this report will assess the possible occurrence of earthquakes at the dam sites and the motions that are likely to be associated with earthquake activity.

2. The assessments are preliminary since the investigations on which they are based were done on a reconnaissance level and are necessarily incomplete.

PART II: PROCEDURES FOR ASSIGNING EARTHQUAKE MOTIONS

3. Earthquakes are associated with faults. Tectonism causes gradual differential movements in the earth's crust. The rock is subjected to strain and the buildup of stresses. Relief then may come abruptly as slippage along a fault. When slip occurs, the adjacent rocks may rebound elastically with vibratory motions. The resulting shaking constitutes the earthquake.

4. Earthquakes may be assumed to result from movement along existing faults rather than from rock rupture that produces new faults. While new faults cannot be eliminated entirely, information extending through geological time and the ubiquitous occurrence of faults suggests that for practical purposes earthquakes can be considered to be associated with slippage along existing faults.

5. Since faults are found everywhere, the engineering geologist is faced with the problem of determining which faults are active, or subject to movement, and which are inactive. Of faults that are active, movement can be occurring steadily and slowly by creep and without earthquakes. The engineering geologist must determine which are the "capable" faults, capable meaning that they can generate earthquakes.

6. Corps of Engineers criteria for a capable fault (see ER 1110-2-1806 of 30 April 1977) are as follows:

a. Movement at or near the ground surface at least once within the past 35,000 years.

b. Macro-seismicity (3.5 magnitude or greater) instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.

c. A structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other.

7. The geological investigation of faults uses all of the techniques that are available: aerial and satellite imagery, inspection from

overflights, low sun angle photography, reviews of regional and local geology, geophysical surveys, details of geomorphology and relevant information from the seismic history.

8. For a careful investigation of a construction site, the field evidence may be checked further by borings, geophysical profiles, trenches, and stripping.

9. Monitoring programs for corroborative evidence may include strain gages, leveling points, geodimeter readings, and microearthquake monitoring.

10. Often, it is desirable to make a critical restudy of historic earthquake events using the original documentation in newspapers, diaries, etc. Relocation of epicenters may result and they may accord better with geologic information and possibly with specific faults. The maximum intensities of events may be subject to revision also.

11. The direction of future movement on an active fault is predictable since the past is a very good guide to the future. However, secondary and tertiary faults may have motions that are different from that of a major fault. Where such data are available, one can readily guard against the effects of fault movement under a structure simply by moving the structure.

12. Once a fault is identified as capable of generating earthquakes, and its dimensions are ascertained, the next factor to determine is the worst earthquake that the fault will produce. Toward this end, there are a number of relationships and assumptions that involve the size of faulting, or dimension of maximum movement, with the maximum earthquake that might reasonably be expected. The data are best for major strike-slip faults. The dispersion of data is much greater for normal and thrust faults. However, the variants in field conditions can be enveloped with a reasonable degree of dependability. Relationships between fault length and earthquake magnitude have been summarized for Corps use in a report by Slemmons (1977).

13. Though major active faults and major centers of earthquakes can be accounted for, small faults may be missed in any investigation so that often a floating earthquake of appropriate size may be provided in order to account for them.

14. The earthquakes that are thus determined can be expressed in terms of magnitude* but they need also to be expressed in Modified Mercalli (MM) intensity in order to relate to historic earthquake effects. The MM scale is shown in Table 1.

Table 1

MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

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* Magnitude (Richter scale) is calculated from a standard earthquake, one which provides a maximum trace amplitude of one micrometer on a Wood-Anderson torsion seismograph at a distance of 100 km. Magnitude is the $\log_{10}$ of the ratio of the amplitude of any earthquake at the standard distance to that of the standard earthquake. Though the scale is open-ended, the largest earthquake may be at a limit of magnitude 8.7. Each full numeral step in the scale (2 to 3, for example) represents an energy increase of about 32 times.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

15. Thus, a fault can be judged for its capacity to generate earthquakes and the maximum event it might produce expressed both in magnitude and intensity. The intensity can be attenuated from a source to a site.

16. Predicting the time of the maximum earthquake is of interest for other purposes but is of no interest for the design of a major

structure such as a dam. A dam has to be designed on the basis of the maximum earthquake without regard for its time of occurrence or its interval of recurrence, since a maximum earthquake may come at any time. Cost-risk benefits can be sought for appurtenant structures which, if failed, pose no hazard to life. For these lesser structures, probabilities may be used in order to select smaller events that will then serve as operational basis earthquakes. Arbitrarily lower numbers, such as a fraction of the motions for the maximum earthquake, can be equally suitable.

17. The foregoing considerations bring us to the point where motions must be selected to define the effects of earthquakes on a dam. These motions should be conservative so that the designs developed for a dam are safe for any eventuality. The motions are in the following categories:

a. Those that cause relative displacement in the foundation and consequently displacements in the dam, and

b. Those that induce unacceptable strains in a dam or liquefaction if it is an earth structure.

18. The examination of a major dam for the effects of earthquake shaking requires a dynamic analysis. If there are potentials for strain beneath the structure, earth fill may be specified as the construction material. For an earth dam it is essential to provide appropriate time histories of earthquake motion. The time histories are needed because the material is nonlinearly elastic. Each cycle of shaking may impart an effect on the material and the effects are cumulative. Thus, the time histories must be as realistic as possible in simulating the maximum earthquake.

19. In order to generate time histories, a synthesis may be made of motions recorded during earthquakes in order to develop peak motions (acceleration, velocity, displacement, duration and predominant period). In Corps of Engineers practice, the time histories are developed first and response spectra are made from the time histories.

20. Any large collection of strong motion records has a tremendous spread in the values for earthquake motions. There are many causes:

differences in fault mechanism and fault shape, rock types and configuration, refraction and reflection of waves, superposition and buildup of waves, or diminution, etc. Such factors contribute to an infinity of differences in the resulting motions. The accelerations for Modified Mercalli Intensity V range from 0.01 g to 0.61 g, a spread of 60 times. Mean values, in such circumstances, have no real significance.

21. The solution is to work with a large body of strong motion records and to provide envelopes that encompass the spread in the data.

22. Specific parameters, such as a given fault type plus some specified distance from epicenter, tend to restrict the number of records available to only a very few. They may have less spread. However, if there were more records, even for those limited conditions, there is every reason to believe there would be more spread. It is best not to be restrictive but to envelope a wide variety of conditions.

23. An extensive statistical analysis of strong motion data from the western United States in terms of intensity was made by Trifunac and Brady (1975). Their analyses included acceleration, velocity and displacement, and they distinguished vertical and horizontal components of motion. They showed the mean value for each intensity level and the mean with one standard deviation. The latter provides a measure of the dispersion. A problem arises with the sparseness of data for the higher intensities beginning with MM VIII. There are no data for MM IX, and one record for MM X. The latter is the Pacoima record with its peak horizontal acceleration of 1.25 g.

24. The same western United States data uniformly processed at the California Institute of Technology were used in studies made at the Waterways Experiment Station (see Krinitzsky and Chang, 1977) to find means for assigning motions for dynamic analyses of dams. The values were expressed in MM intensity.

25. The CIT data were separated by Krinitzsky and Chang (1977) into "near field" and "far field."

26. In the near field, complicated reflection and refraction of waves occur in the subsurface with resonance effects and a large range

in the scale of ground motions. Intense ground motions and high-frequency components of motion are present. In the far field the wave patterns are orderly; the oscillations in wave forms are more muted and more predictable; and frequencies are lower.

27. The distance from epicenter to the limits of the near field, and beginning of the far field, vary with the magnitude of the earthquake, consequently with the maximum epicentral intensity, and with the region in which the earthquake occurs. Usually, the intensity in the near field attenuates linearly and rapidly; in the far field, the rate of attenuation for intensity becomes smaller.

28. Limits of the near field are as follows:

Richter Magnitude M	MM Maximum Intensity I_o	Radius of Near Field KM
5.0	VI	5
5.5	VII	15
6.0	VIII	25
6.5	IX	35
7.0	X	40
7.5	XI	45

29. Figures 1 and 2 show the relation between MM intensity and acceleration for near field and far field, respectively. Figures 3 and 4 show intensity versus velocity, near and far field, and Figures 5 and 6 for displacement, near and far field. The motions are horizontal. Vertical components of motion are taken to be two-thirds the horizontal. The spread of data were divided into equal 10 percent increments between 50 percent, taken at the median line, and 100 percent, taken along a line which approximates the limit of observed data. The curves for these increments are suitable for obtaining peak motions at levels selected either at the maximum or at lesser levels determined by decisions on the seismic risk that is acceptable.

30. Figures 1 to 6 also show the mean-plus-one standard deviation for the respective intensity levels. Figure 1 shows that mean plus σ drops as the intensity increases from MM VII to VIII. The drop-off is

not from lesser motions but simply from a decrease in the quantity of data. The projection of the 10 percent lines attempts to compensate for this lack of data.

31. No distinction was made between data from soil and rock since the values overlap too greatly to provide useful comparison. The Figures 1 to 6 are intended to provide peak components of ground motion on bedrock at the surface.

32. The mean-plus-σ values show that the data points are concentrated far below the 100-percent line. In effect, the 70- to 80-percent band brackets an upper boundary for the great body of data. Peak motions at this level are conservative for nearly all designs. However, if at a site there was a capable fault seen at the ground surface, then the 100-percent motion, or even a higher value, might be appropriate.

33. The next element in developing a time history of motion is the duration. Duration was taken as the bracketed time interval in which the acceleration is greater than 0.05 g.

34. Some examinations of the data are appropriate. Figure 7 shows near field durations in terms of earthquake magnitude. There is a large dispersion with distinctly higher peak values for soil as compared to rock. Peak durations increase steeply with increase of earthquake magnitude. The same data are shown in Figure 8 by local MM intensity. Again, soil shows greater peak durations than rock. However, the slope of the peak duration for rock does not increase as steeply with greater intensity as it does for magnitude. The discrepancy results from incompleteness of data and the inexactness that is inherent in intensity and a difference in the comparability of the scales. Figure 8 provides conservative upper limits for duration to be used with MM intensities in the near field. Far field durations are shown in Figure 9.

35. The earthquake records selected for use or for rescaling may be either actual strong motion records or synthetic ones designed for specified geological settings. They should be for field conditions that are analogous to those for the site under study. They should be for comparable types of faults, comparable geology (whether crystalline rocks,

sedimentary basin, etc.), and similar distances from causative faults. Records should be selected also with predominant periods that may correspond to periods of engineering works that are being evaluated.

36. The time histories developed from rescaling earthquake records are preferable for such structures as earth dams since the structures are nonlinearly elastic and actual earthquake records are both more realistic and have fewer motions than the synthetic ones. For concrete portions of a structure, the necessary response spectra can be made from the time history or it can be obtained independently following the guidelines of the Nuclear Regulatory Commission.

37. The scaling for large motions (in the region of 1 g) presents a problem because there is only one record (Pacoima, San Fernando earthquake of 1971) and the rescaling of lesser records to this level may produce unrealistic motions. Instead of straight scaling, high-frequency motions may be added to lower earthquakes in combination with a process of scaling. Multiple records should be examined. Strong motion records should be selected that require as little rescaling as possible. Chang (1978) provided a first step toward cataloging earthquakes in a manner that will facilitate their selection for scaling. If a record has to be scaled as much as 4X, the record should be discarded.

38. The spectral composition and predominant period of a record is site dependent (whether soil or rock) and is dependent also on distance from source. Here again judgments must be made not on a few records but by envelopes of extensive collections of data. Some guidance is provided in compilations by Chang and Krinitzsky (1977).

PART III: EARTHQUAKE EVALUATION

39. A geological reconnaissance of the general area in which the Devils Canyon and Watana damsites are located was performed for this study by Drs. Reuben Kachadoorian and Henry J. Moore of the U.S. Geological Survey. Their study entitled "Preliminary Report of the Recent Geology of the Proposed Devils Canyon and Watana Damsites, Susitna River, Alaska," is included in the present overall report.

40. Drs. Kachadoorian and Moore were charged primarily with the task of investigating the area for the presence of absence of active faults. In addition, observations were made on the seismicity of the area and on the possibilities of landslides into the potential lakes.

41. Prior to the work done by Drs. Kachadoorian and Moore, a study has been made for the Corps of Engineers by Gedney and Shapiro (1975) of lineations interpretable for this area from Landsat and Slar imagery. The lineations were presented along with the seismic history and the general geology.

42. Gedney and Shapiro show a large number of lineations including ones that trend along the Susitna Valley and pass through the Devils Canyon and Watana damsites. Lineations may be caused by faults but they may be caused also by processes that have no relation to tectonism. In no case can a lineation be accepted as a fault unless confirmation is found on the ground by a process that is called "ground truthing." Thus the work by Kachadoorian and Moore was an important step in validating the earlier work. The judgments concerning faults should be those of the latter work.

43. Kachadoorian and Moore report a group of 16 faults. For the most part, these faults are identified by stratigraphic evidence. There

was no surface evidence of recent movement along any of these faults; consequently, the faults were tentatively judged to be inactive. However, confirmation of this judgment will require more detailed field work. The nearest known active fualt is the Denali fault, 80 km away, with the capacity to produce magnitufe 8.0 earthquakes.

44. Gedney and Shapiro generally found no relation between seismic events in the region and faults. However, for the Susitna fault (Fault No. 8 of Kachadoorian and Moore), Gedney and Shapiro associated two earthquakes of 1 October 1972 and 5 February 1974 (magnitudes 4.7 and 5.0 respectively). Gedney and Shapiro reported no associated breakage along the Susitna fault but these events gave suitable fault plane solutions indicating right-lateral offset. Kachadoorian and Moore question the reliability of associating these earthquakes with the mapped fault. Kachadoorian and Moore found no relation between seismicity and mapped faults, however they point out that a closer grid of seismometers may uncover such relationships.

45. In summary:

a. No faults of important regional extent were found to be present at the damsites.

b. Major faults in the region were reconnoitered and no evidence was found of recent movement.

c. The region is one of relatively high seismicity, however, no association was established between seismic events and specific faults.

d. The nearest positive capability for an earthquake is along the Denali faault, approximately 80 km distant, where a maximum magnitude of 8.0 can be expected.

e. Except for the conclusions concerning the Denali fault, the work done so far is preliminary. More work is needed.

PART IV: INTERPRETED PEAK MOTIONS

46. On the basis of the present incomplete geological and seismological information, earthquake motions at the damsites must be postulated by making certain conservative assumptions.

47. Potential earthquakes are as follows:

a. An earthquake originating at the Denali fault. The maximum magnitude is 8.0 in accordance with assumptions made by the U.S. Geological Survey in their Trans-Alaska Pipeline Study (see Page, et at, 1972). The earthquake is attenuated 80 km to the Devils Canyon and Watana damsites. Using the Krinitzsky-Chang (1977) attenuation for western United States, the event will produce a MM intensity of IX at these sites. The motions are far field. It is conservative to base the motions on the 70 percent spread level of the charts of Figures 2, 4, and 6 since that level encompasses over 95 percent of the data in the velocities (see Figure 4). The duration is taken for rock from Figure 9. The corresponding peak motions are acceleration, velocity, displacement, and duration are tabulated in Table 2.

TABLE 2
PEAK EARTHQUAKE MOTIONS AT DEVILS CANYON AND WATANA DAMSITES

				Peak Motions (hor.*) on Bedrock at Surface			
Earthquake Source	Magnitude	Field	Site Intensity MM	Accel. g	Vel. cm/sec	Displ. cm	Duration sec
Denali fault	8.0	Far	IX	0.28	40	22	10
Local floating event	7.0	Near	X	0.68	68	30	12

* Vertical motion may be taken as two-thirds of horizontal.

b. A local floating earthquake with fault breakage that does not occur at the damsites. The inconclusive nature of the geologic-seismologic studies requires that a floating earthquake be assigned. The earthquake may occur anywhere in the general vicinities of the damsites but not immediately under the dams themselves. The elimination of an earthquake beneath the dams is based ont hework of Kachadoorian and Moore for this study in which they identify no appropriate faults. The magnitude of the floating earthquake is 7.0. This magnitude is in accordance with the earthquake used for this area in the Trans-Alaska Pipeline Study of Page, et al (1972). The magnitude accords satisfactorily with the possible fault lengths presented by Kachadoorian and Moore, which are on the order of a hundred or more km. Such faults correspond to magnitude 7 earthquakes according to available worldwide data presented by Slemmons (1977) in his Figure 27. Since the near field for an earthquake of this size extends 40 km from the source, and Kachadoorian and Moore have located major fault trends within 3 to 15 km of the dams, the motions at the dams must be taken as near field. It is conservative to use the 70-percent spread lines of the moitons in Figures 1, 3, and 5 since that level envelopes all but a few extreme values. The duration for bedrock at the surface is taken from Figure 8. The peak motions are tabulated in Table 2.

c. An earthquake at the damsites. On the basis of present information, an earthquake from a major fault rupture at the damsite is not expected to occur. However, it is understood that present information may be subject to revision when further studies are made.

48. The motions in Table 2 of this report were developed somewhat differently from those of the USGS Trans-Alaska Pipeline Study (Page, et al, 1972). The floating earthquake for the near field but not at the site has no equivalent in the USGS analysis. The USGS values are for earthquakes that occur at a site. Also, the USGS peaks were reduced from what they might be by a filtering that they applied to the Pacoima record of the 1971 San Fernando earthquake. Their objective was to provide motions for a quasi-static analysis of the pipeline in which the input was restricted to a range of 2 to 8 Hz. Their resulting magnitude 7 at a site has values that are higher than ours (1.05 vs 0.68g) in acceleration, higher in velocity (120 vs 68 cm/sec) and higher in displacement (55 vs 45 cm). The durations also are greatly different. The USGS duration is 25 sec against 12 sec for ours. The difference is that their duration includes soils whereas ours is for bedrock alone.

49. Predominant period and records for rescaling are not recommended at this point since specification of types of faulting and distance from faulting are yet to be made.

50. The operating basis earthquake, which is lesser earthquake than that taken for the design of the dam, may be tested with peak motions that begin at half those of the maximum earthquakes.

51. Reservoir loading has in some cases induced significant earthquakes and earthquakes have triggered landslides and caused water waves or seiches. Also, in regions of tectonism there may be problems during excavation from overstressed conditions in rock.

Induced seismicity from reservoir loading

52. A few large reservoirs in the world have induced appreciable earthquakes. Simpson (1976) has provided a summary and critical review. The reservoir is a triggering agent. It does not cause earthquakes greater than the ones that may be expected from the normal tectonism. The maximum earthquakes will be the ones used in design. An induced earthquake, if such should occur, would not be greater though it may occur at a different time. Further, the worldwide experience, according to Simpson (1976), suggests that induced effects may be highest in regions of low to moderate natural seismicity. In areas of high levels of natural seismicity, as in Alaska, the stress changes induced by the reservoir are small compared to natural variations. Thus, induced seismicity should not add any input to design. Nonetheless, observations relating to induced seismicity made before and after reservoir filling are appropriate and will be valuable on a research level.

Water waves from earthquake shaking

53. Water waves produced by earthquake shaking, under certain circumstances, may be a factor though hardly comparable to the effects of large landslides and ordinarily not more severe than wind effects. The effects are dependent on the spectral composition of the horizontal ground motions, the shape and size of the reservoir, and the duration of shaking. If a resonance is developed there may be significant resulting wave amplitudes. Lee and Hwang (1977), in assessing this problem, suggest that wave heights of half the amplitude of horizontal ground motions are possible but they do not assess resonance. In practice, protection against the effects of landslides will probably more than adequately provide protection against water waves as well.

Earthquake-induced landslides

54. Landslides are a pronounced feature at the sites of major earthquakes. Kachadoorian and Moore have noted appreciable landslides in the Susitna Valley. These, and others that may be judged to be present as potential hazards, should be evaluated. The worst known potential slides can be monitored and remedial measures can be specified, including the removal of the potential slide material.

55. The problem when dealing with a major earthquake is that one cannot be sure that slides that might be generated have been anticipated. Given sufficient topographic relief and large masses of loose or fractured material, one should take into account major slides for which no prevention can be specified. Developments along the borders of the reservoir, the freeboard of the dam, etc., should be planned so that possible disasters are avoided.

56. Studies of the effects of landslides into reservoirs may be either theoretical, using a numerical model (see Raney and Butler, 1975), or they may be empirical. The latter is perhaps the most practical approach. They involve using undistorted hydraulic models (cf Davidson and Whalin, 1974). For both methods, the slide geometry, volume, velocity and reservoir configuration are essentials. Field investigations where actual landslides have occurred may aid in developing estimates of velocities (see Banks and Strohm, 1974). The procedures will produce assessments of wave heights and wave runups.

Tectonic strain and overstressed conditions in rock

57. A totally unknown set of conditions are those that relate to tectonic strain and resulting possible overstressing in the rock. Residual stresses from the movements of active faults can affect the making of excavations and the stability of the structure. At present there are no data. It is anticipated that field measurements relating to stresses and the buildup of strain will be made as part of any continuing investigations.

PART VI: CONCLUSIONS

58. The geological-seismological investigations to date were made on reconnaissance levels. The Devils Canyon and Watana damsites are in a region of high seismicity and major faults. However, no movements were found on the faults that might be indicative of earthquakes. Also, no seismic activity was identified as associated with these faults, though the data suffers from inexactness in the accuracy of locations. No active faults were found at the damsites. Active faults of appreciable length are required if large earthquakes are to be generated in close proximity of the proposed structures.

59. The area was provided with a floating earthquake of magnitude 7 placed at a short distance from the damsites. The magnitude 7 is in conformity with general fault lengths in this area and with worldwide experiences between such faults and resulting earthquakes. However, further field studies will be made to determine conclusively whether or not there are faults closer to the sites with possible more severe motions. An earthquake of magnitude 8 from the Denali fault at a distance of 80 km was evaluated by attenuating the event to the damsites.

60. Peak motions were assigned for the earthquakes following the practices of the Corps of Engineers. The magnitude 7 earthquake near the damsites has motions that are: acceleration 0.68 g, velocity 68 cm/sec, displacement 30 cm, and duration 12 sec. An earthquake at the Denali fault attenuated to the sites provides motions of 0.28 g, 40 cm/sec, 22 cm, and 10 sec.

61. A closer specification of which sets of peak motions to apply and the appropriate time histories will await further field studies.

62. Possible induced seismicity from reservoir loading is not a factor needing additional design but is accounted for in the existing motions. However, water waves from possible earthquake-triggered landslides and possible overstressed conditions in rock pose problems for which at present there is a paucity of data and a need for further evaluation.

PART VII; REFERENCES

1. Banks, Don C. and William E, Strohm (1974), Calculations of Rock-slide Velocities. Advances in Rock Mechanics, National Academy of Sciences, Washington, D. C., pp 839-847.

2. California Institute of Technology, Earthquake Engineering Research Laboratory (1971-1975), Strong Motion Earthquake Accelerograms; Corrected Accelerograms and Integrated Ground Velocities and Displacements, Vol 2, Parts A-N, Pasadena, California.

3. Chang, Frank K. (1978), Catalogue of Strong Motion Earthquake Records, Vol 1, Western United States, 1933-1971, State-of-the-Art for Assessing Earthquake Hazards in the United States, MP S-73-1, Report 9, Waterways Experiment Station, Vicksburg, Mississippi, 28 pp and 2 appen.

4. Chang, Frank K. and E. L. Krinitzsky (1977), Duration, Spectral Content and Predominant Period of Strong Motion Earthquake Records from Western United States, State-of-the-Art for Assessing Earthquake Hazards in the United States, MP S-73-1, Report 8, Waterways Experiment Station, Vicksburg, Mississippi, 58 pp and 2 appen.

5. Davidson, D. Donald and Robert W. Whalin (1974), Potential Landslide-Generated Water Waves, Libby Dam and Lake Koocanusa, Montana. TR H-74-15, Waterways Experiment Station, Vicksburg, Mississippi, 33 pp.

6. Gedney, Larry and Lewis Shapiro (1975), Structural Lineaments, Seismicity, and Geology of the Talkeetna Mountains Area, Alaska, Geophysical Institute, University of Alaska, Fairbanks, Alaska, 18 pp and 5 plates.

7. Krinitzsky, E. L. and Frank K. Chang (1977), Specifying Peak Motions for Design Earthquakes, State-of-the-Art for Assessing Earthquake Hazards in the United States, MP S-73-1, Report 7, Waterways Experiment Station, Vicksburg, Mississippi, 34 pp.

8. Lee, Y. Keen and Li-San Hwang (1977), Waves Generated by Horizontal Oscillations in Bays. Journ. Waterways, Port, Coastal and Ocean Div., ASCE, Vol 103, No. WW4, pp 411-422.

9. Page, Robert A., David M. Boore, William B. Joyner, and Henry W. Coulter (1972), Ground Motion Values for Use in the Seismic Design of the Trans-Alaska Pipeline System, U. S. Geological Survey, Circular 672, 23 pp.

10. Raney, Donald C. and H. Lee Butler (1975), A Numerical Model for Predicting the Effects of Landslide-Generated Water Waves. TR H-75-1, Waterways Experiment Station, Vicksburg, Mississippi, 22 pp.

11. Simpson, David W. (1976), Seismicity Changes Associated with Reservoir Loading, Elsevier, Engineering Geology, 10:123-150.

12. Slemmons, David B. (1977), Faults and Earthquake Magnitude, State-of-the-Art for Assessing Earthquake Hazards in the United States, Report 6, Waterways Experiment Station, Vicksburg, Mississippi, 129 pp plus Appendix, 37 pp.

13. Trifunac, M. D. and A. G. Brady (1975), On the Correlation of Seismic Intensity Scales with the Peaks of Recorded Strong Ground Motion, B. Seism. Soc. Am., Vol 65, No. 1, pp 139-162.

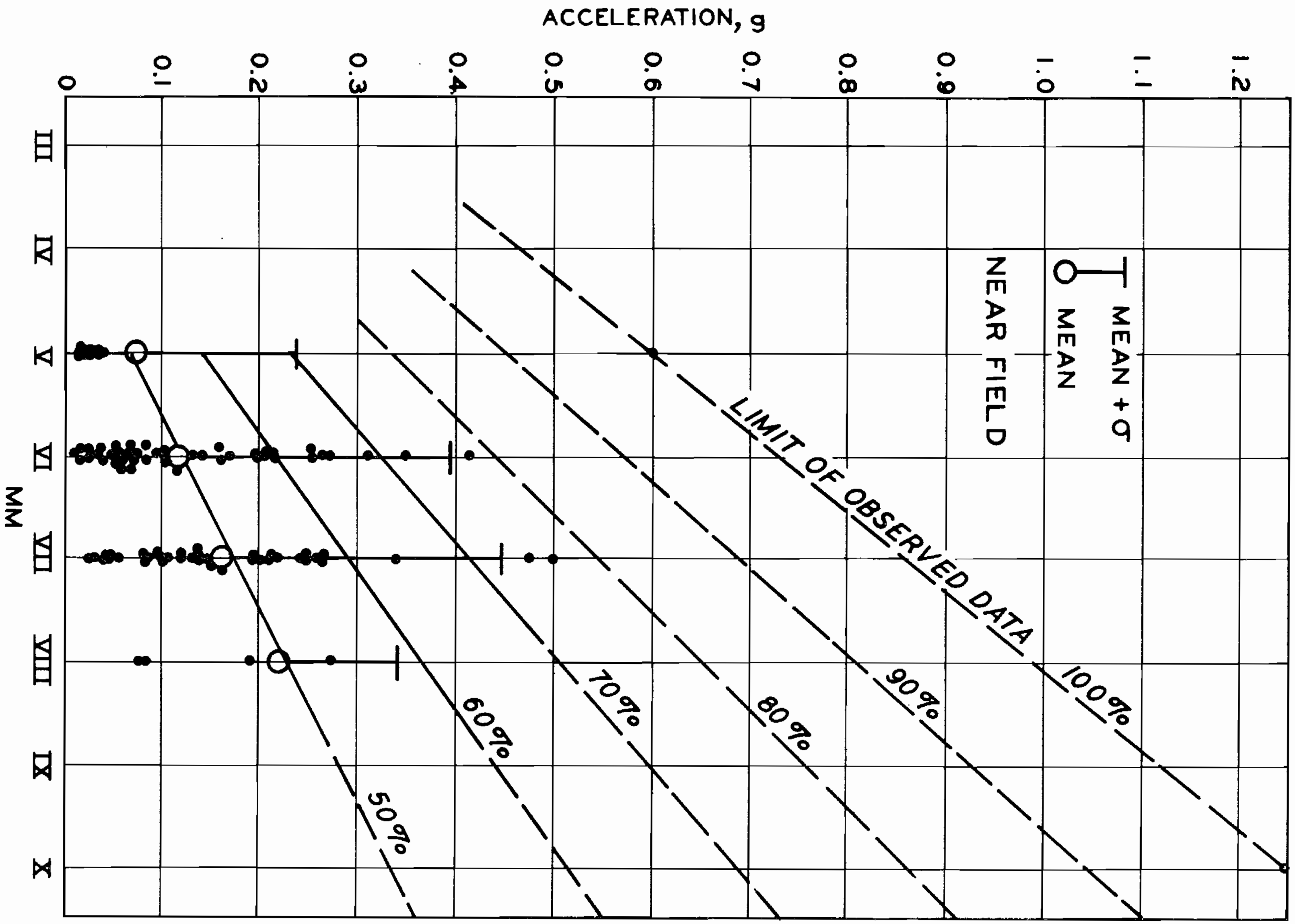

Figure 1. Acceleration versus MM Intensity in the Near Field. Percentages are ten percent increments in the spread between the mean (50%) and the limit of observed data (100%).

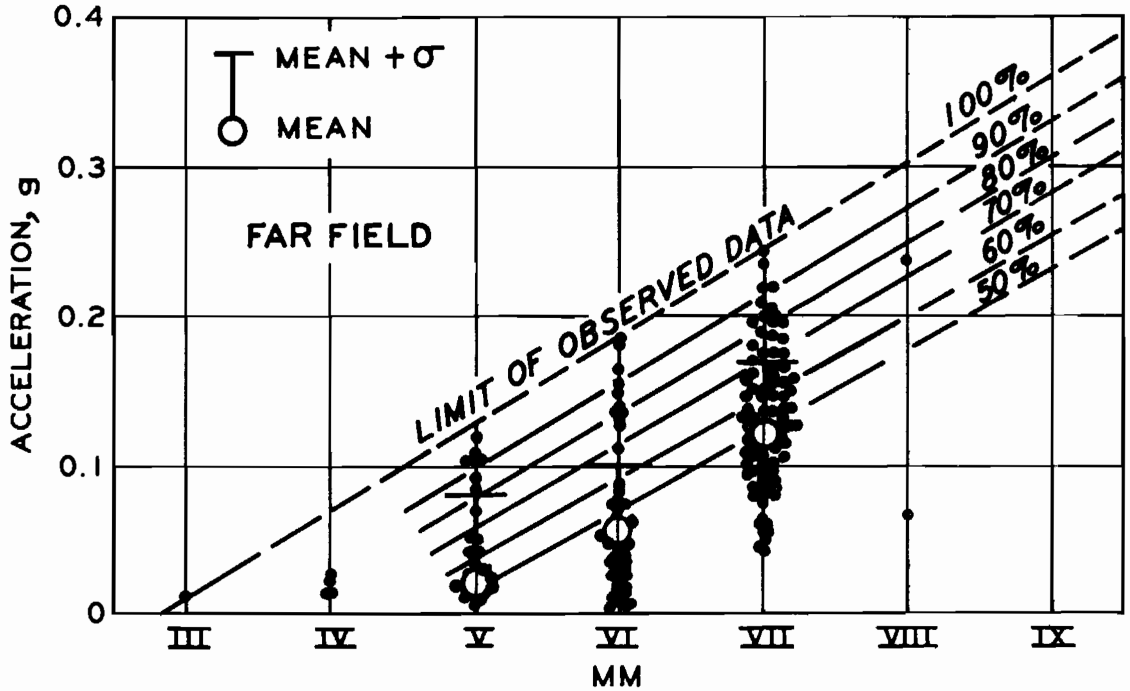

Figure 2. Acceleration versus MM Intensity in the Far Field. Percentages are ten percent increments in the spread between the mean (50%) and the limit of observed data (100%).

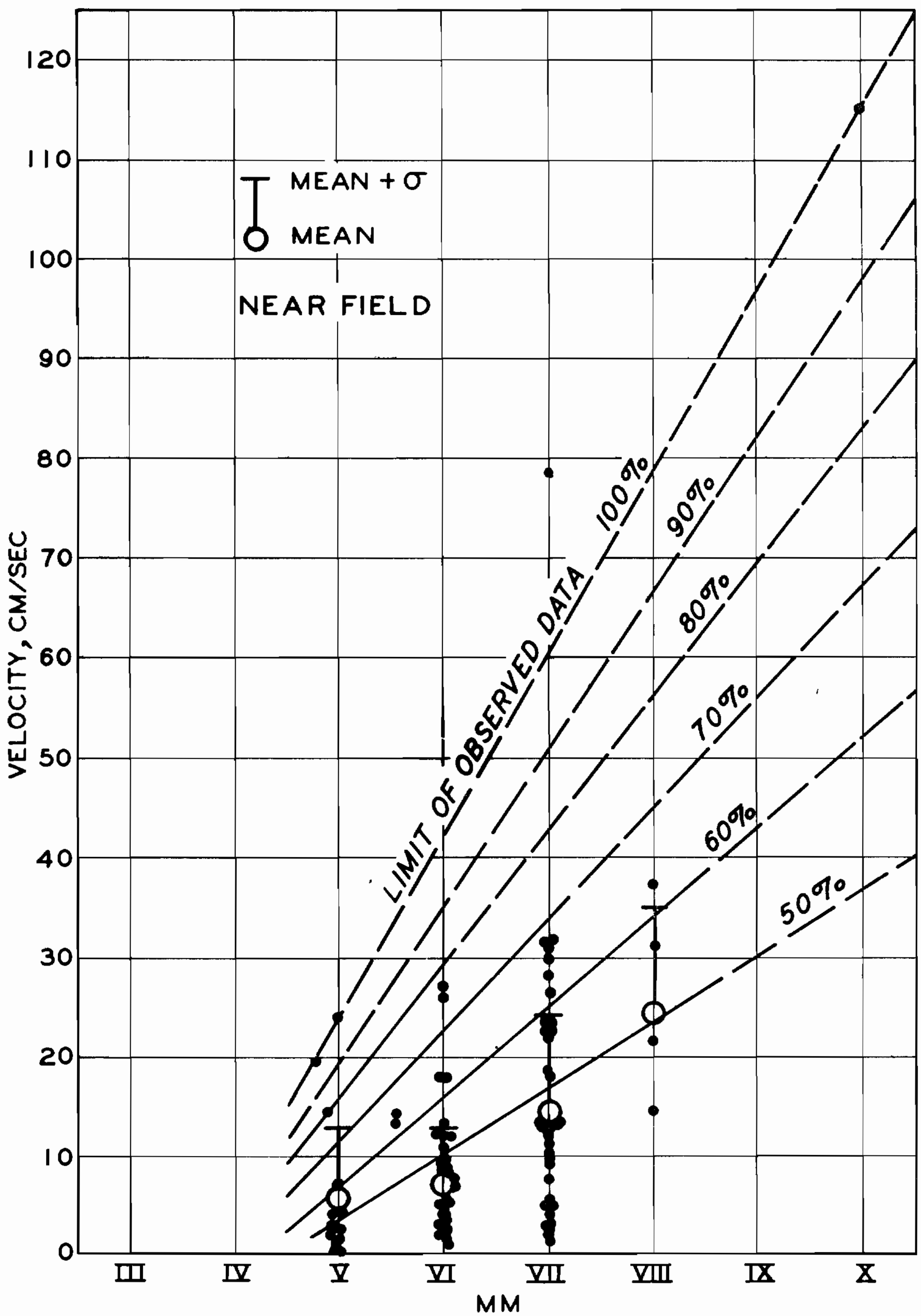

Figure 3. Velocity versus MM Intensity in the Near Field. Percentages are ten percent increments in the spread between the mean (50%) and the limit of observed data (100%).

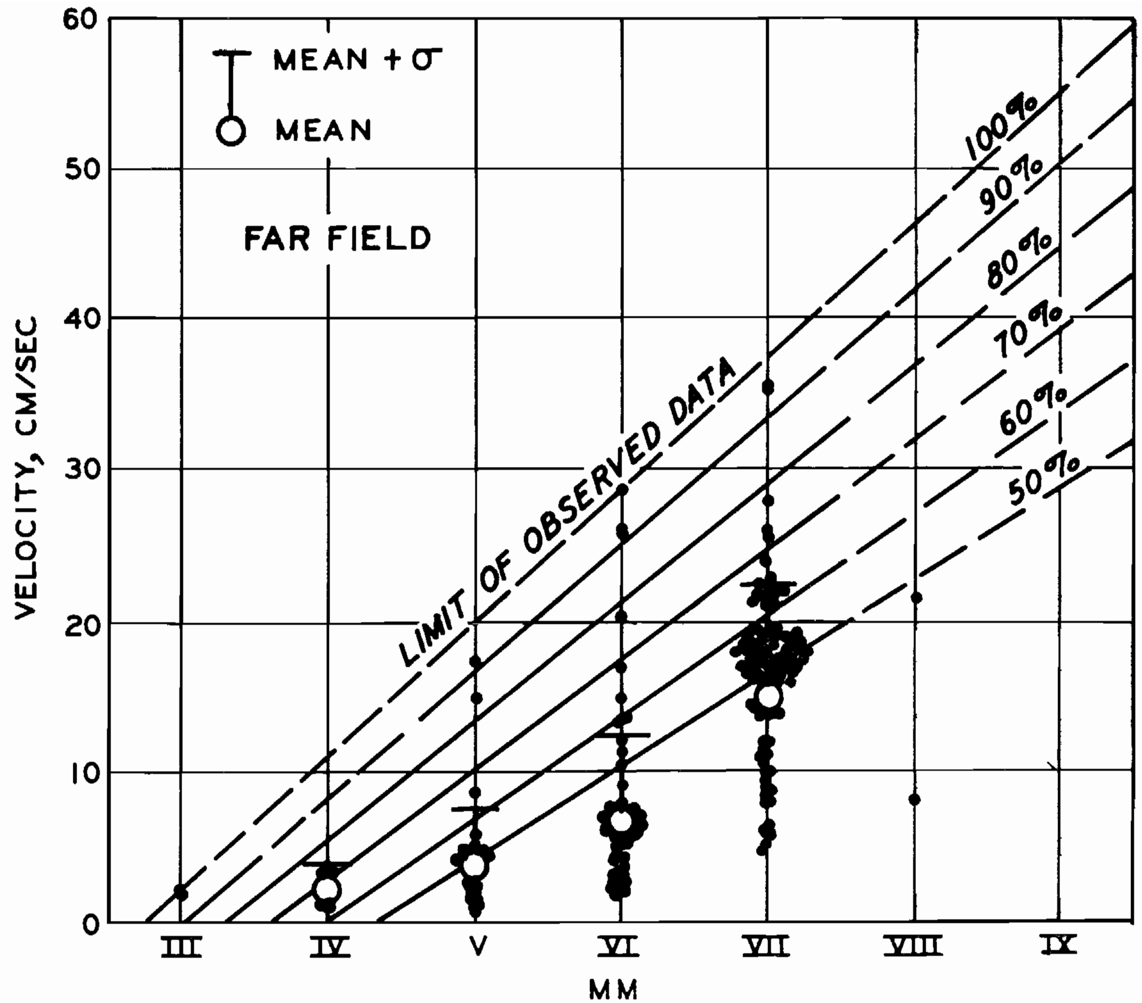

Figure 4. Velocity versus MM Intensity in the Far Field. Percentages are ten percent increments in the spread between the mean (50%) and the limit of observed data (100%).

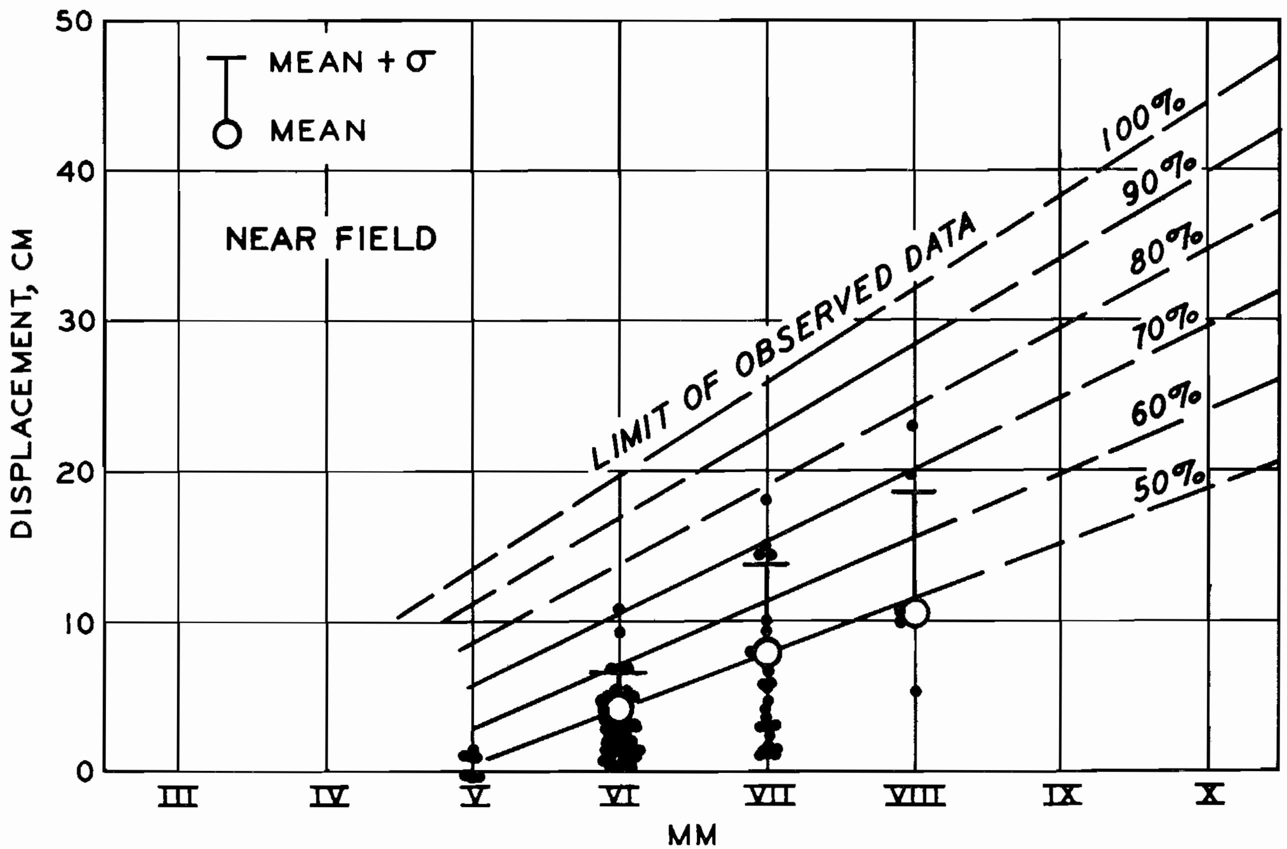

Figure 5. Displacement versus MM Intensity in the Near Field. Percentages are ten percent increments in the spread between the mean (50%) and the limit of observed data (100%).

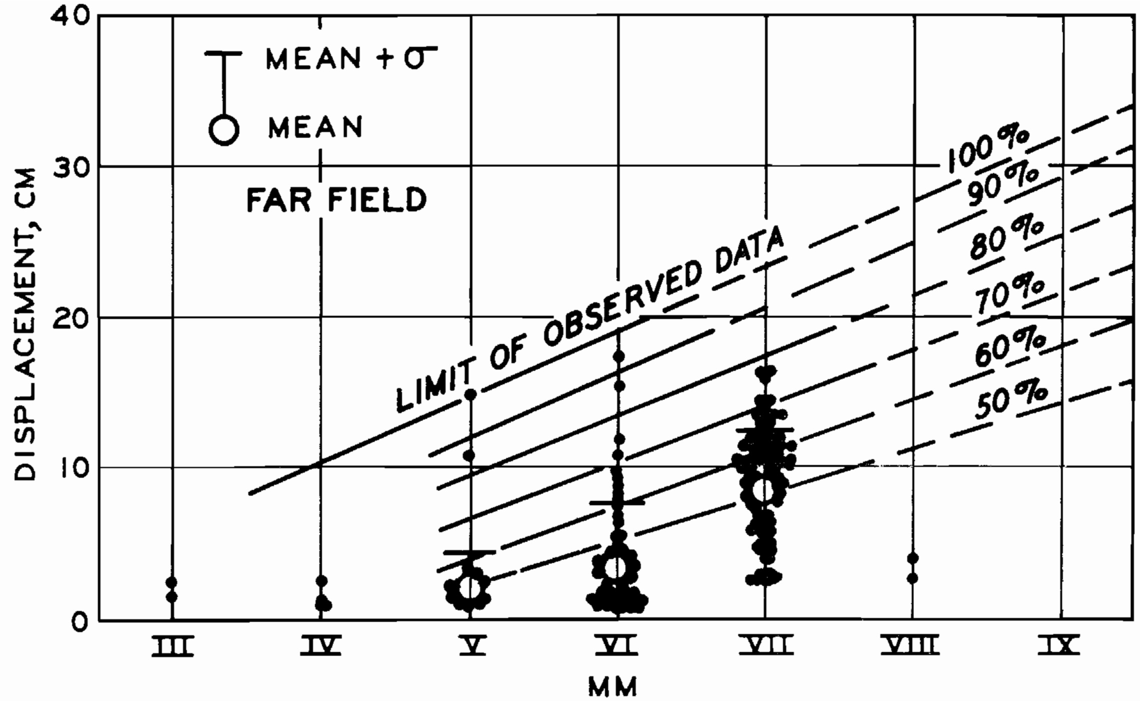

Figure 6. Displacement versus MM Intensity in the Far Field. Percentages are ten percent increments in the spread between the mean (50%) and the limit of observed data (100%).

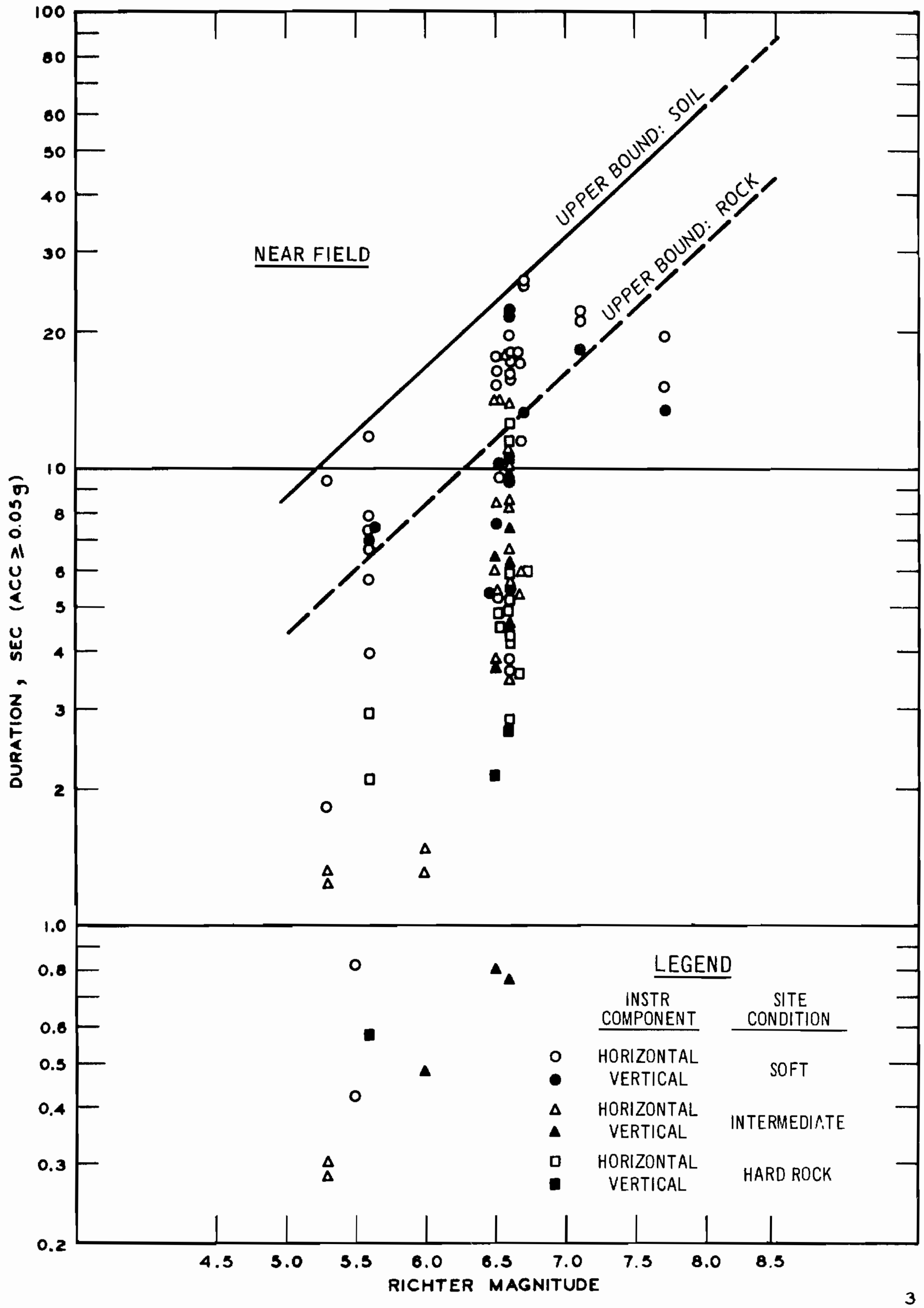

Figure 7. Duration versus Richter Magnitude in the Near Field.

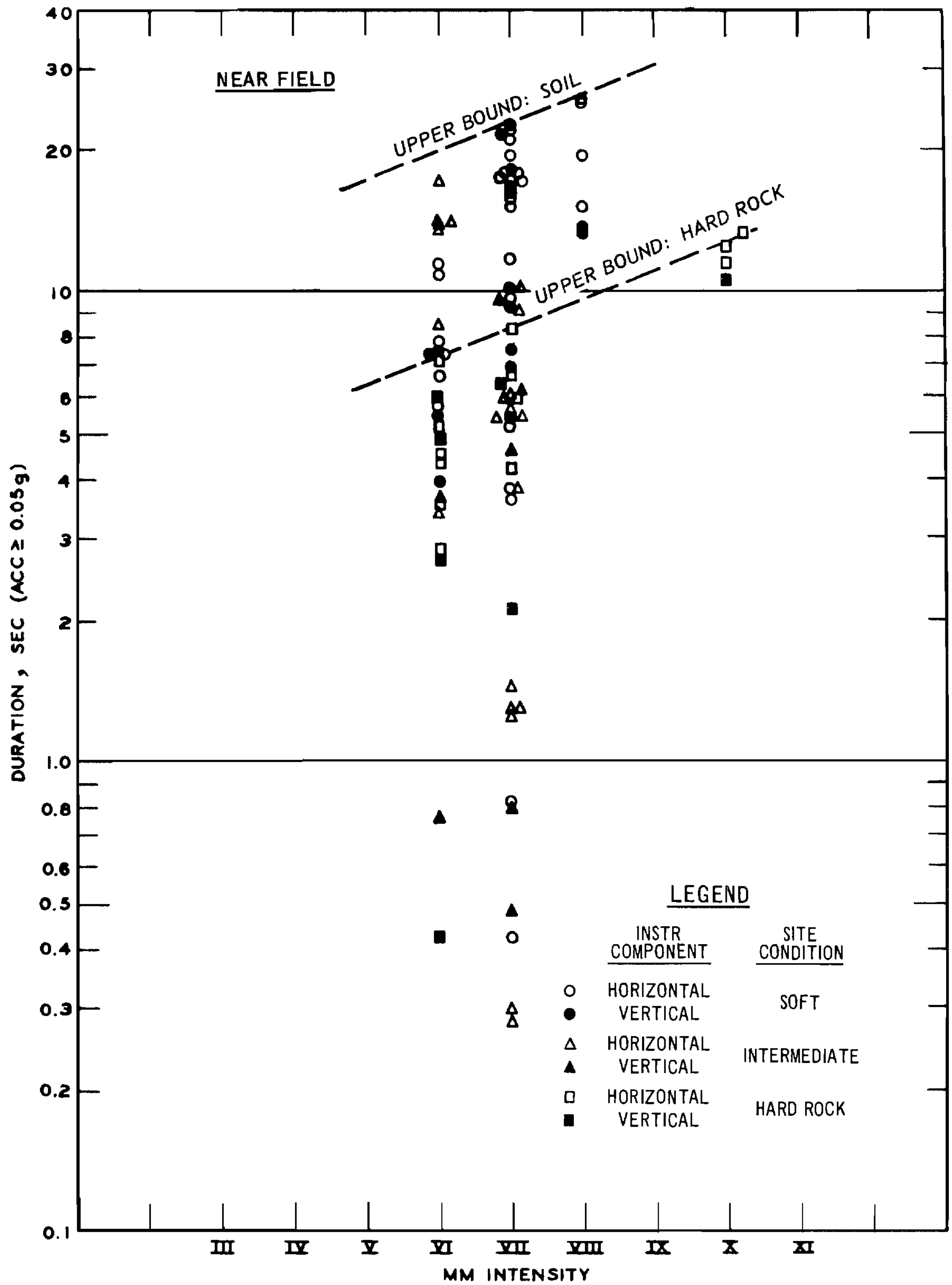

Figure 8. Duration versus MM Intensity in the Near Field.

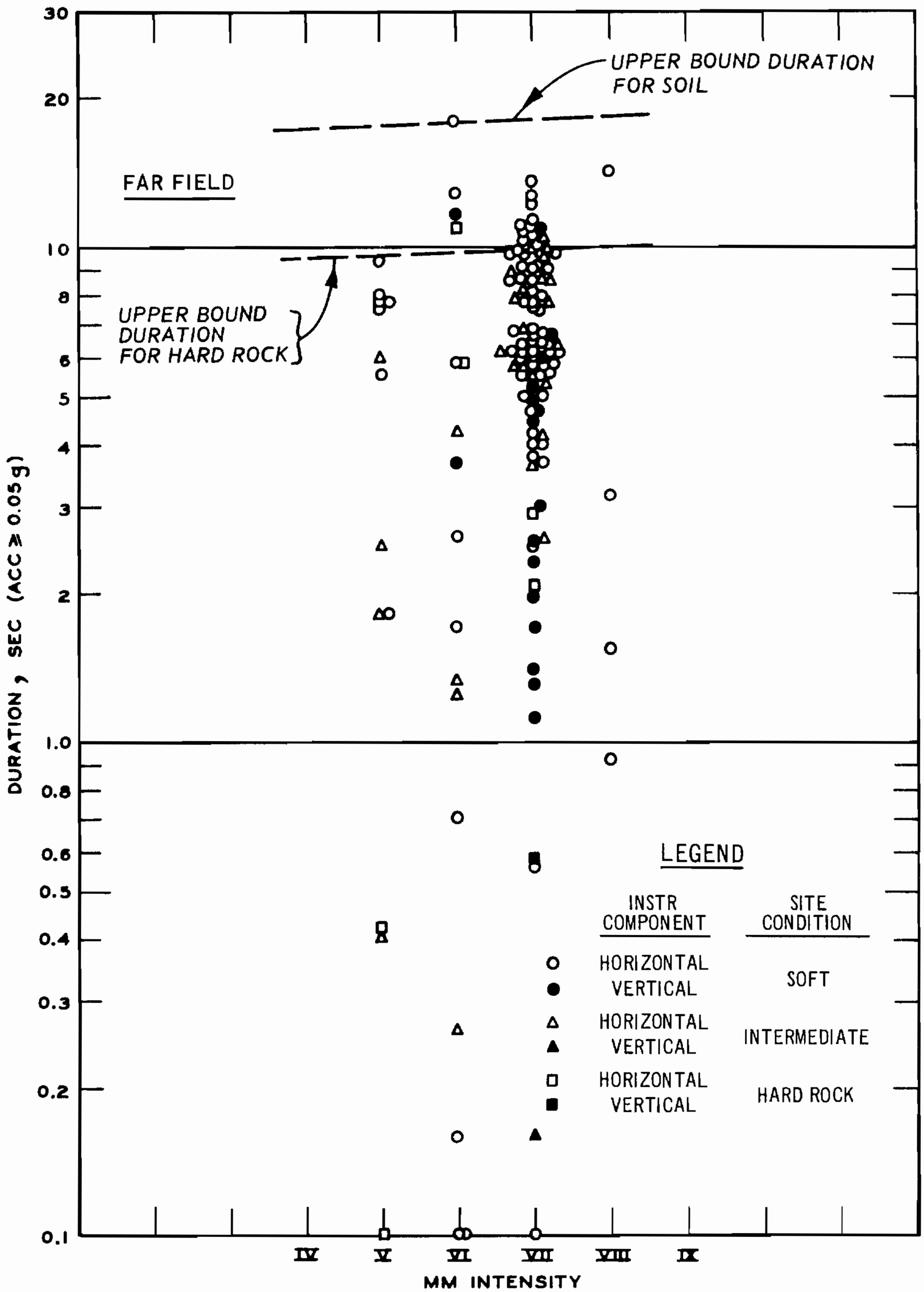

Figure 9. Duration versus MM Intensity in the Far Field.

EXHIBIT D-4

Procedure for Estimating Borehole Spacing and Thaw Water Pumping Requirements for Artificially Thawing the Bedrock Permafrost at the Watana Damsite.

Technical Note

PROCEDURE FOR ESTIMATING BOREHOLE SPACING AND THAW-WATER PUMPING REQUIREMENTS FOR ARTIFICIALLY THAWING THE BEDROCK PERMAFROST AT THE WATANA DAM SITE

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Introduction

The procedure outlined in this note for estimating the time to artificially thaw permafrost bedrock assumes that water will be pumped into a pattern of boreholes drilled to the bottom of the permafrost zone. The water would flow down a feed pipe to the bottom of the borehole and back up the annulus between the outside of the feed pipe and the wall of the borehole. During the upward flow, heat from the water would flow radially through the borehole wall to melt the existing ice and raise the temperature of the surrounding rock. During the first stage of this thawing process a series of essentially vertical parallel thawed cylinders would be formed, the diameter of which would grow with time until the surface of adjacent cylinders touched. Upon touching a fluted wall would exist which then will thicken as additional heat is supplied by the thaw-water in the boreholes until either the desired wall thickness is attained or a thermal equilibrium is established. Once the desired wall thickness is reached, the rate of thaw-water flow (i.e., pumping) can be reduced to establish thermal equilibrium. To avoid freezing back the bedrock it may be necessary to continue pumping water until grouting is initiated or until it is unnecessary to maintain the wall in a thawed condition. If the permafrost is at $32^{O}F$ at the Watana dam site, it probably would not be necessary to use maintenance pumping since freeze-back would be quite slow.

The purpose of this note is to furnish procedures for establishing a drilling pattern; estimating the time to thaw a 20 ft. wide zone of rock permafrost along the alignment of the Watana Dam; and estimating the thaw-water pumping requirements for the thawing operation.

Assumptions

The graphs used in this procedure were developed using the thermal computational methods outlined in the paper, "Thermal and Rheological Computations for Artificially Frozen Ground Construction," which is attached as Appendix B. The assumed rock properties and thermal conditions are listed in Appendix A. Graphs in figures 1 and 2 were developed for 1½ inch diameter boreholes. Use of larger diameter boreholes would reduce the thawing time (e.g., a 3 inch diameter borehole will reduce the thaw time by less than 10%).

It should be emphasized that this procedure assumes a uniform distribution of ice in the bedrock with an overall ice saturated porosity of 1½% and that it is quite probable that some of the rock will contain much larger volumes of ice. At locations where large volumes of ice do exist, the thawing would be much slower than predicted by Figure 1. More accurate predictions of the thawing times can be made when details of the amount and location of the ice-filled cracks are determined. The temperature of the permafrost bedrock at the dam site has not been established precisely. In this note, bedrock temperature is assumed to be 32°F with all water frozen.

To control the thawing process during construction, it is essential to monitor the bedrock temperature at several locations both horizontally and vertically. Good temperature and pumping records will assist in improving the thawing operations as the work progresses and will provide data for refining the procedure for predicting subsequent thawing times and pumping requirements.

Procedure

(1) From the curves on Figure 1 choose a borehole arrangement (i.e., single row or two rows of boreholes) and spacing. The choice would be based on the time available for thawing, the temperature of the available thaw-water and the economic trade-offs between additional holes vs heating the water and pumping water.

(2) After selecting the borehole spacing, enter the graph on Figure 2 using the borehole spacing and thaw-water temperature chosen in (1) to obtain a time at which the thawing cylinders will just touch each other. This time (t_I) is given in days on the abscissa.

(3) Using (t_I) from (2), enter the abscissa of the graph on Figure 3 and obtain an estimate of the number of gallons per minute (GPM) that must be supplied to each borehole for the thaw-water temperature selected. Note that this is the thaw-water flow required when the thawed cylinders just touch. This is more than that required to continue thawing until the wall obtains its full width but it is a conservative average value to use in estimating. The maximum flow rate is required at the start of pumping. Theoretically it is infinite but in practice it is close to the values shown at time zero on Figure 3. Therefore, after the first few days of pumping, the pumping capacity can be reduced, e.g., one or more of the pumps can be used somewhere else. The curves on this graph are based on the temperature gradient or temperature loss shown on the graph. If sufficient

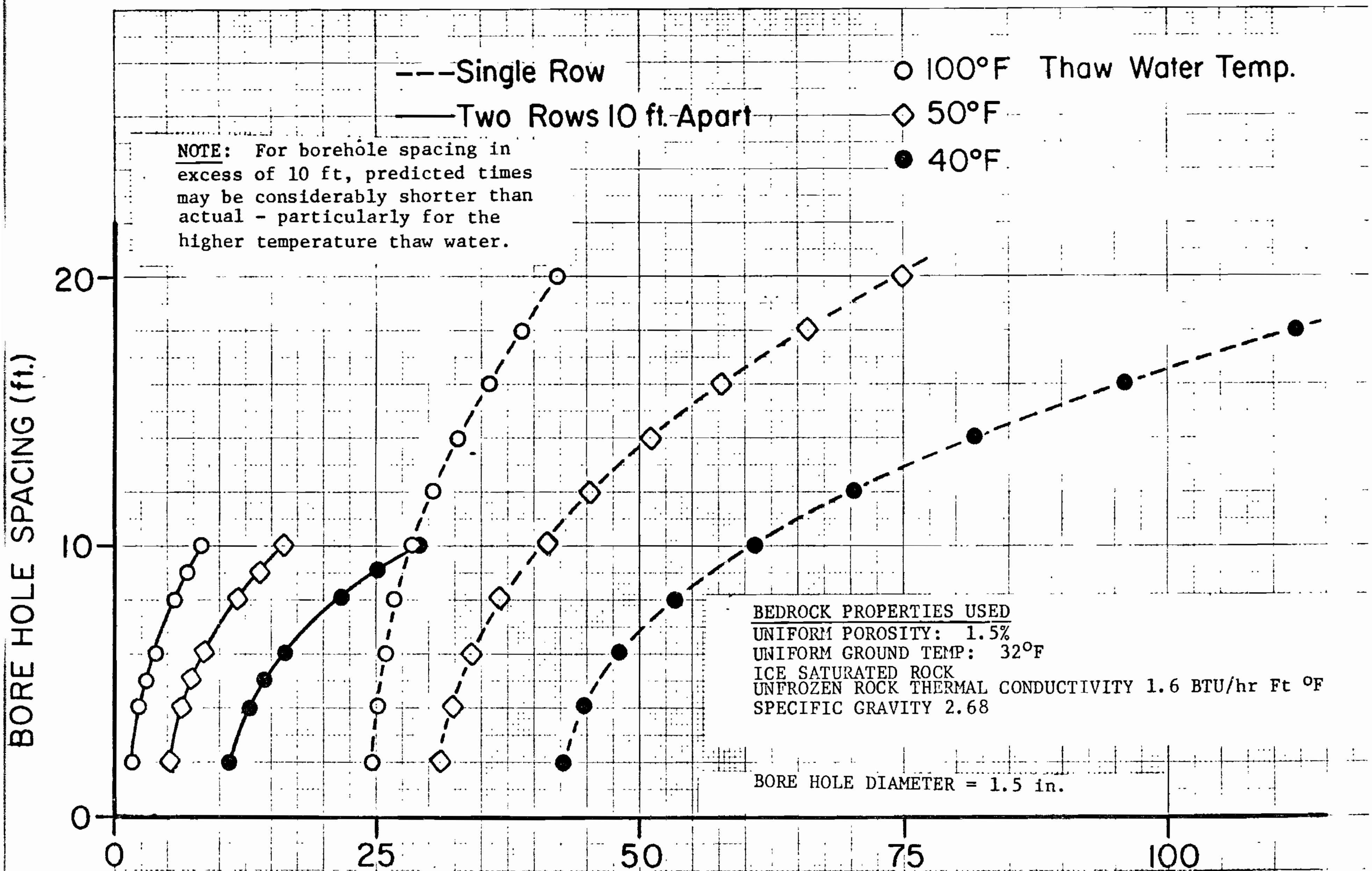
flow is not supplied to the boreholes, the temperature gradient will rise and the time required to thaw will increase.

(4) After the rate of flow for each borehole is estimated, the velocity of the thaw-water flow in the feed pipes and the annulus between the outside of the feed pipe and the borehole wall should be computed to determine if either the velocity or pressure drop is excessive.

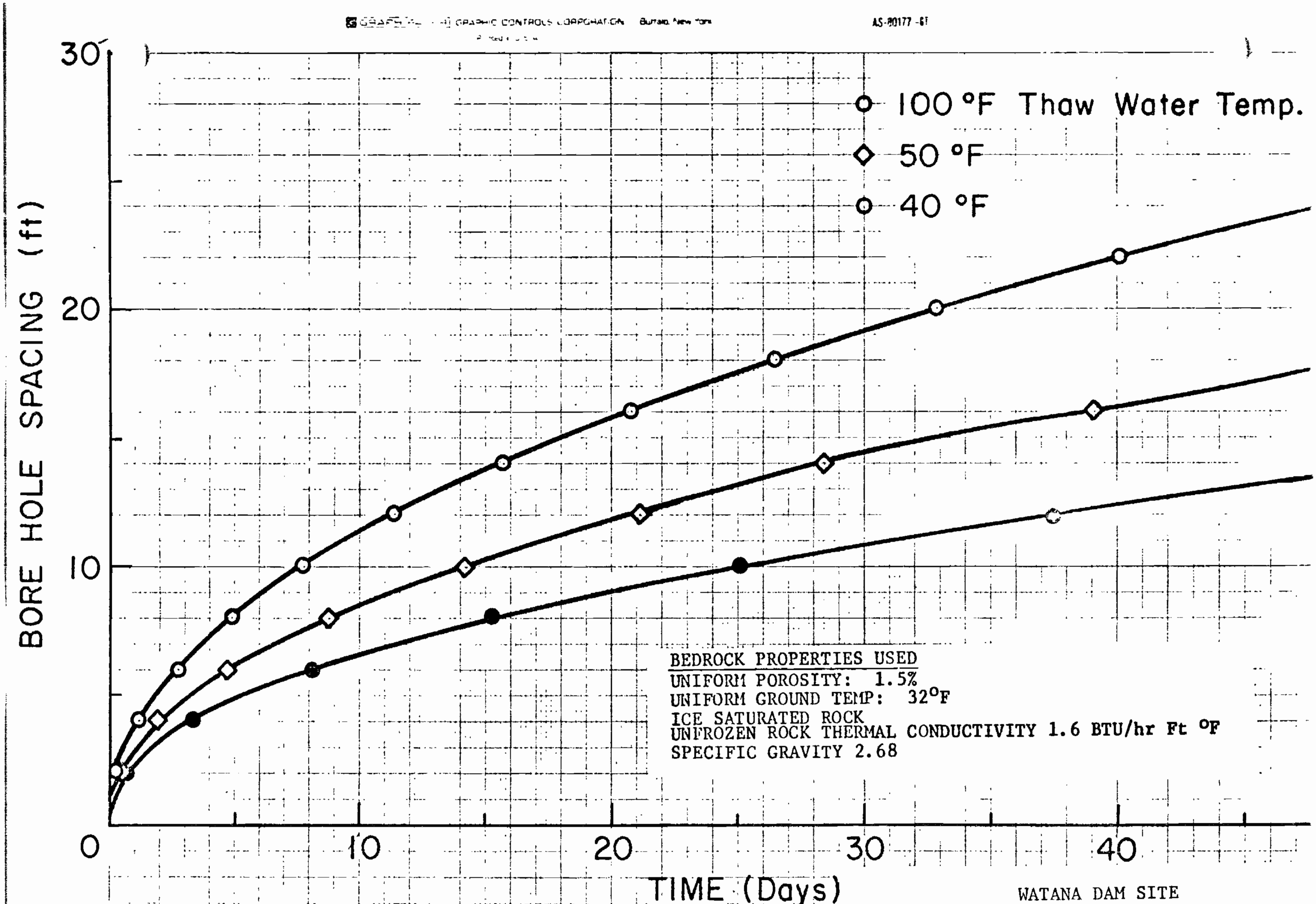
(5) The total rate of flow for determining the size and number of pumps is determined by summing up the number of boreholes that are used for thawing at one time.

It might be noted that if water is artificially heated, there will be a large energy loss if the overflow from the borehole is not captured and reused.

Ponding of water in a location where the sun can warm it is one way to get higher thaw-water temperatures than would be obtained by taking water directly from the river.

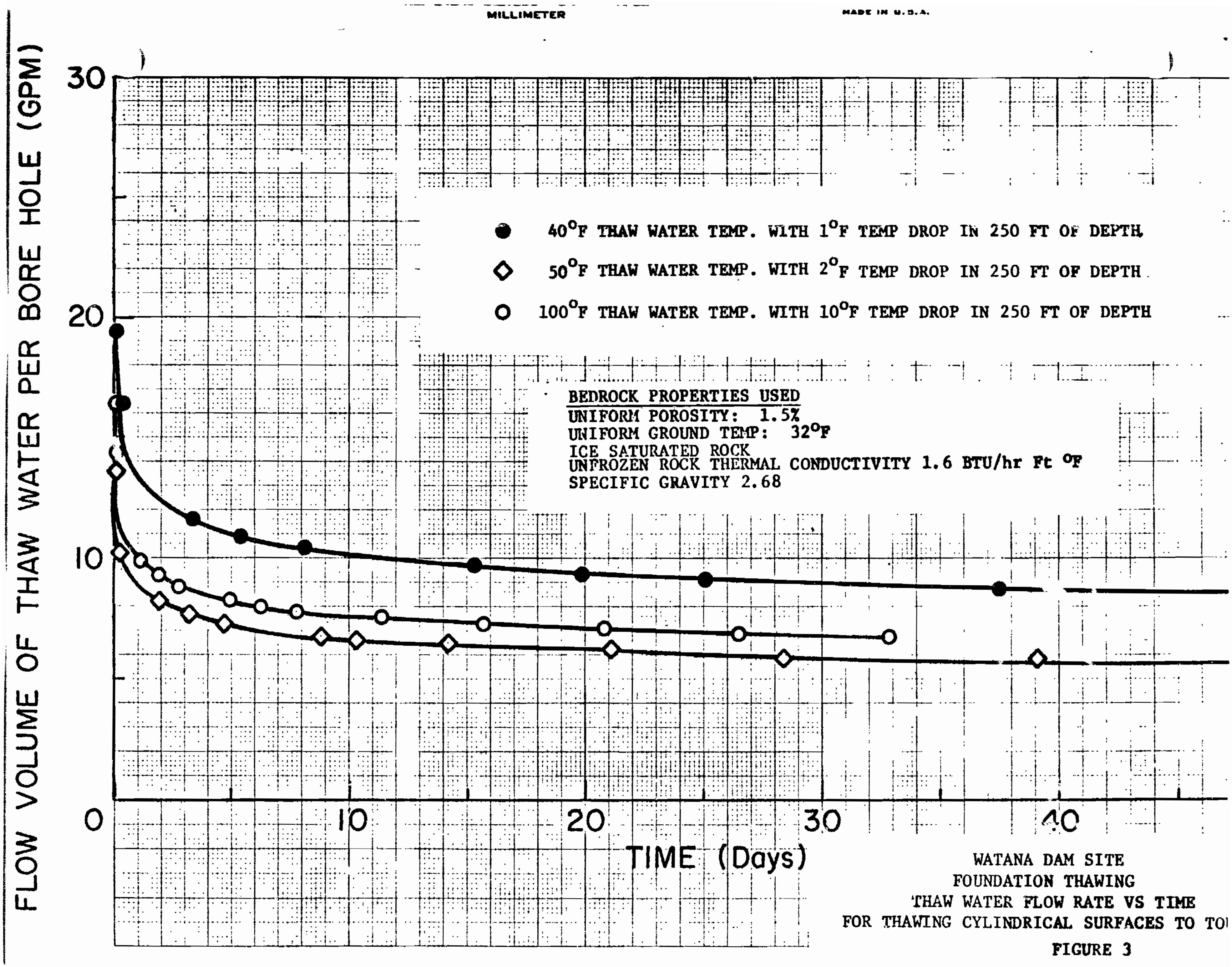


WATANA DAM SITE
FOUNDATION THAWING
BOREHOLE SPACING VS MINIMUM TIME
TO THAW A 20 FOOT WIDTH OF FROZEN ROCK FIGURE 1



WATANA DAM SITE
FOUNDATION THAWING
BOREHOLE SPACING VS TIME
FOR RADIAL THAWING FROM A SINGLE BOREHOL

FIGURE 2



WATANA DAM SITE
FOUNDATION THAWING
THAW WATER FLOW RATE VS TIME
FOR THAWING CYLINDRICAL SURFACES TO TO

FIGURE 3

APPENDIX A

ASSUMED ROCK PROPERTIES AND THERMAL VALUES

ROCK PROPERTIES

Uniform porosity	1.5%
Specific Gravity	2.68
Dry Unit Weight	165 lb/ft^3
Ice Saturate	

THERMAL VALUES

Volumetric Specific Heat

Unfrozen Rock	33.9 BTU/ft^3
Frozen Rock	33.4 BTU/ft^3

Conductivity for Unfrozen Rock	1.6 BTU/hr. ft. ^{o}F
Latent Heat of Ice Saturated Rock	124 BTU/ft^3

EXHIBIT D-5

U.S. Geologicaly Survey Reconnaissance Geologic Map and Geochronology, Talkeetna Mountains Quadrangle, Northern Part of Anchorage Quadrangle, and Southwestern Portion of Healy Quadrangle, Alaska.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RECONNAISSANCE GEOLOGIC MAP AND GEOCHRONOLOGY, TALKEETNA MOUNTAINS QUADRANGLE, NORTHERN PART OF ANCHORAGE QUADRANGLE, AND SOUTHWEST CORNER OF HEALY QUADRANGLE, ALASKA

OPEN-FILE REPORT 78-558-A

Menlo Park, California
1978

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

RECONNAISSANCE GEOLOGIC MAP AND GEOCHRONOLOGY, TALKEETNA MOUNTAINS QUADRANGLE, NORTHERN PART OF ANCHORAGE QUADRANGLE, AND SOUTHWEST CORNER OF HEALY QUADRANGLE, ALASKA

By

Bėla Csejtey, Jr., W. H. Nelson, D. L. Jones, N. J. Silberling, R. M. Dean, M. S. Morris, M. A. Lanphere, J. G. Smith, and M. L. Silberman

Description of map units, Structure, Tectonics, Reference list, and tables to accompany Open-file Report

DESCRIPTION OF MAP UNITS

SEDIMENTARY AND VOLCANIC ROCKS

Qs SURFICIAL DEPOSITS, UNDIFFERENTIATED (Quaternary)--Glacial and alluvial deposits, chiefly unconsolidated gravel, sand, and clay.

Tv VOLCANIC ROCKS, UNDIFFERENTIATED (Paleocene to Miocene, uppermost part may be as young as Pleistocene)--Over 1,500-m-thick sequence of felsic to mafic subaerial volcanic rocks and related shallow intrusives. Lower part of sequence consists of small stocks, irregular dikes, lenticular flows, and thick layers of pyroclastic rocks; made up dominantly of medium- to fine-grained, generally medium-gray quartz latite, rhyolite, and latite. A few dikes and intercalated flows of brown andesite are also present. Rocks of the lower part of the sequence, occurring mostly in the upper Talkeetna River area, are interpreted to be vent facies deposits and near vent deposits of stratovolcanos. The upper part of the sequence consists of gently dipping brown andesite and basalt flows interlayered with minor amounts of tuffs. A few lenses of fluviatile conglomerate are also present. Locally, at Yellowjacket Creek for instance, the feeder dikes of the mafic flows make up more than half the volume of the underlying country rocks. According to E. M. MacKevett, Jr. (oral commun., 1975), the andesite and basalt flows are lithologically identical to the basal andesites of the Wrangell Lava in eastern Alaska.

Contact between the dominantly felsic lower part and mafic upper part of the sequence is gradational through intertonguing of the two rock types. The three samples for potassium-argon age determinations (map numbers 7, 8, 13 in table 1), indicating Paleocene and Eocene ages, were obtained from andesite flows near the middle of this sequence.

Tim HYPABYSSAL MAFIC INTRUSIVES (Paleocene to Miocene, youngest rocks may be Pleistocene)--Small stocks and irregular dikes of diorite porphyry, diabase, and basalt. They probably are the subvolcanic equivalents of the andesite and basalt flows of unit Tv.

Tif HYPABYSSAL FELSIC INTRUSIVES (Paleocene to Miocene, some rocks may be as young as Pleistocene)--Small stocks and irregular dikes of rhyolite, quartz latite, and latite. Lithologically, they are identical to, and thus probably correlative with the felsic subvolcanic rocks of unit Tv.

Ttw TSADAKA (Miocene) AND WISHBONE (Paleocene and Eocene) FORMATIONS, UNDIVIDED--Tsadaka Formation, occurring only at Wishbone Hill, consists of cobble-boulder conglomerate with thin interbeds of sandstone, siltstone, and shale; about 200 m thick. The Wishbone Formation, which unconformably underlies the Tsadaka, comprises well-indurated fluviatile conglomerate with thick interbeds of sandstone, siltstone, and claystone; about 600 to 900 m thick (Detterman and others, 1976; Barnes, 1962). The present map unit also includes over 150 m of fluviatile conglomerate and coaly sandstone (unit Tf of Grantz, 1960a, b) in the eastern Talkeetna Mountains.

Tc CHICKALOON FORMATION (Paleocene)--Well-indurated, continental, dominantly fluviatile sequence of massive feldspathic sandstone, siltstone, claystone, and conglomerate, containing numerous beds of bituminous coal; over 1,500 m thick (Barnes, 1962).

Tsu SEDIMENTARY ROCKS, UNDIFFERENTIATED (Tertiary)--Fluviatile conglomerate, sandstone, and claystone with a few thin interbeds of lignitic coal. Lithologically, these rocks look similar to the Tertiary sedimentary rocks of the southern Talkeetna Mountains, but lack of fossil evidence does not permit more definitive correlation. The largest exposure of these rocks is along Watana Creek, and, according to Smith (1974a), the sequence is over 160 m thick. Lithologically, it resembles the Paleocene Chickaloon Formation of the Matanuska Valley.

PLUTONIC AND METAMORPHIC ROCKS

Tgd TERTIARY GRANODIORITE (Eocene)--Contains hornblende and biotite. This granodiorite is part of a small pluton along the northern edge of the map area. Turner and Smith (1974) report an Eocene age for this pluton, determined by the potassium-argon method on biotite (48.8 ± 1.5 m.y.) and on hornblende (44.8 ± 1.3 m.y.) from a sample just north of the present map area.

Thgd BIOTITE-HORNBLENDE GRANODIORITE (Paleocene, in part may be Eocene)--Rocks of this unit occur in one large and several smaller, poorly exposed plutons in the western and northern Talkeetna Mountains. All of the plutons were forcibly intruded in the epizone of Buddington (1959). Granodiorite is the dominant rock, but locally it grades into adamellite (= granite with plagioclase and alkali feldspar in approximately equal proportions), tonalite, and quartz diorite. All these rocks are medium to dark gray, medium grained, generally structureless, and have granitic to seriate textures. In all of them, hornblende is the chief mafic mineral. Biotite- and hornblende-rich xenoliths of reconstituted country rock are common in every pluton. The lithologic compositions and available age determinations (see table 1) indicate that these granitic rocks are the plutonic equivalents of some of the felsic rocks in the lower portion of unit Tv.

Tbgd BIOTITE GRANODIORITE (Paleocene, in part may be Eocene)--Biotite granodiorite and adamellite in approximately equal proportions. Biotite is the chief mafic mineral, hornblende is occasionally present. Color is light to medium gray, grain size is from medium to coarse, texture is granitic to seriate. Very faint flow structures have developed only locally. These rocks occur in shallow, forcibly emplaced epizonal plutons in the northwestern Talkeetna Mountains. Aplitic and pegmatitic dikes are common in all the plutons. Just north of the map area, these plutonic rocks grade into felsic volcanic rocks. Potassium-argon age determinations (see table 1) indicate that the biotite granodiorite and adamellite of the present unit are essentially of the same age as the biotite-hornblende granodiorite (unit Thgd). Thus, the rocks of these two units, in view of their spatial proximity, probably are the products of differentiation of the same parent magma, either in situ or at some deeper levels in the Earth's crust. The biotite granodiorite intrusives are also considered to be the plutonic equivalents of some of the felsic volcanic rocks in the lower portion of unit Tv.

Tsmg SCHIST, MIGMATITE, AND GRANITE (Paleocene intrusive and metamorphic ages)--Undifferentiated terrane of andalusite and (or) sillimanite-bearing pelitic schist, lit-par-lit type migmatite, and small granitic bodies with moderately to well-developed flow foliation. These rocks occur in approximately equal proportions, and the contacts between them are generally gradational, as is the contact between the schist and its unmetamorphosed pelitic rock equivalents (unit Kag) outside the present map unit.

The pelitic schist is medium to dark gray, medium grained, has well-developed but wavy foliation, and contains lit-par-lit type granitic injections in greatly varying amounts. Rock-forming minerals of the schist include biotite (pleochroism Nz = dark reddish brown, Nx = pale brown), quartz, plagioclase, minor K-feldspar, muscovite, garnet, and sillimanite which locally coexists with andalusite.

The lit-par-lit type granitic injections within the schist are medium gray, medium grained, and consist of feldspar, quartz, and biotite.

The rocks of the small, granitic bodies range in composition from biotite adamellite to biotite-hornblende granodiorite. They are medium gray and medium grained, generally have granitic textures, and, in addition to the flow foliation, locally display flow banding of felsic and mafic minerals. These granitic bodies appear to be the source of the lit-par-lit intrusions.

The proximity of the schist to the small granitic bodies, the occurrence of the lit-par-lit injections, and the presence of andalusite in the schist indicate that the schist is the result of contact metamorphism. Perhaps this metamorphism took place in the roof zone of a large pluton, the cupolas of which may be the small granitic bodies.

TKt TONALITE (Upper Cretaceous and Lower Paleocene)--Dominantly biotite-hornblende tonalite, locally grades into quartz diorite. The tonalite is medium gray, coarse to medium grained, has a granitic texture and a fairly well-developed primary foliation. It occurs in a large, possibly composite, batholith, approximately 75 to 61 m.y. old (see table 1), which was emplaced in the epizone and mesozone of Buddington (1959). The tonalite is described in more detail in Csejtey (1974).

TKa ADAMELLITE (Upper Cretaceous and Lower Paleocene)--Occurs in a large epizonal pluton in the southwestern part of the map area. The dominant rock type is adamellite but locally includes granodiorite. Biotite is the chief mafic mineral, muscovite occurs in subordinate amounts. The typical adamellite is medium to light gray, medium to coarse grained, its texture ranges from granitic to seriate. The adamellite appears to be intrusive into the tonalite (unit TKt), but concordant potassium-argon ages on one sample (map no. 24, table 1) indicate the adamellite to be essentially the same age as the tonalite. These rocks apparently are comagmatic.

TKgr GRANITIC ROCKS, UNDIVIDED (Cretaceous and (or) Tertiary)--These rocks of uncertain age occur in four smaller epizonal plutons of granodiorite and tonalite. Their color is medium to dark gray, grain size is medium, texture is granitic. Mafic minerals are hornblende and (or) biotite. The largest of these plutons, in the northeast corner of the map area, is reported by Smith and others (1975) to be of Cretaceous age.

TKlg LEUCOGABBRO (Cretaceous and (or) Tertiary)--Small, poorly exposed intrusive of uncertain age in west-central part of map area, essentially consisting of plagioclase (around An70 and about 80 percent of volume), and pale-green hornblende. The leucogabbro is medium to light gray, coarse to medium grained, with a granitic to seriate texture.

Sedimentary and volcanic rocks

Kar ARKOSE RIDGE FORMATION (Cretaceous)--Arkosic sandstone, conglomerate, graywacke, siltstone, and shale (Detterman and others, 1976; Grantz and Wolfe, 1961). Clastic components consist chiefly of granitic and metamorphic rock fragments, quartz, feldspar, and biotite, indicating a dominantly plutonic and, to a lesser extent, metamorphic provenance (G. R. Winkler, oral commun., 1977). Numerous plant fragments suggest a dominantly terrestrial origin. Recent field and petrographic studies (Csejtey and others, 1977) indicate that this formation is of Cretaceous age. A pre-Tertiary age is also indicated by a potassium-argon age determination on biotite (map no. 37, table 1). The biotite was separated from a sample of graywacke with secondary biotite, obtained from near the tonalite pluton (unit TKt). The formation rests unconformably on Jurassic granitic and metamorphic rocks and is as much as 700 m thick. In this report the Arkose Ridge is considered to be a dominantly nonmarine facies of the Cretaceous Matanuska Formation.

Km MATANUSKA FORMATION (Lower and Upper Cretaceous)--Well-indurated shale, siltstone, sandstone, graywacke, with subordinate conglomerate interbeds; occurs along the southern edge of the map area, mostly in the Matanuska Valley. These rocks, having a total thickness in excess of 1,200 m, are generally dark gray and thinly bedded, and for the most part were deposited in a marine environment of moderate to shallow depths. Some of the sandstone beds contain fragmentary plant remains. Age of the formation ranges from Maestrichtian at the top to Albian at the base (Grantz, 1964). The formation rests with a pronounced angular unconformity on Lower Cretaceous and older strata. In part, the Matanuska Formation correlates with the Kennicott, the Shulze, the Chititna, and the MacCall Ridge Formations of the southern Wrangell Mountains (Jones, 1967).

Ksu SEDIMENTARY ROCKS, UNDIVIDED (Lower Cretaceous)--A shallow water marine sequence of thinly bedded calcareous sandstone, siltstone, claystone, minor conglomerate, and thick-bedded to massive clastic limestone; interpreted as a continental shelf-type deposit; over 100 m thick. These strata occur in the southeastern Talkeetna Mountains, and they have been previously mapped and dated by Grantz (1960a, b). The present undivided unit includes Grantz' units Ks, Kc, and the Nelchina Limestone. The contact between these strata and the underlying Jurassic Naknek Formation (unit Jn) is a slightly angular unconformity. The Nelchina Limestone correlates with the Berg Creek Formation of the southern Wrangell Mountains (E. M. MacKevett, Jr., oral commun., 1977).

Jn NAKNEK FORMATION (Upper Jurassic)--Shallow water marine, thin to thick bedded, intercalated strata of fossiliferous gray siltstone, shale, sandstone, and conglomerate; over 1,400 m thick. Previously mapped and dated by Grantz (1960a, b). The Naknek Formation is restricted to the southeastern Talkeetna Mountains, lacks any contemporaneous volcanic material, and appears to have been deposited in a continental shelf environment. Its contact with the underlying Chinitna Formation is a very slightly angular unconformity. The Naknek correlates with the Root Glacier Formation of the southern Wrangell Mountains (E. M. MacKevett, Jr., oral commun., 1977).

Jct CHINITNA FORMATION (Upper Jurassic) AND TUXEDNI GROUP (Middle Jurassic), UNDIVIDED--The Chinitna Formation consists of a shallow marine, intercalated sequence of dark-gray shale, siltstone, and subordinate graywacke; contains numerous large limestone concretions; it is as much as 600 m thick. The Tuxedni Group unconformably underlies the Chinitna, and consists of shallow marine, well-indurated, thinly to thickly bedded graywacke, sandstone, and massive conglomerate in its lower part, and thinly to thickly bedded dark siltstone and shale in its upper part. The Tuxedni is about 300 to 400 m thick. Both the Chinitna and Tuxedni have been previously mapped and dated by Grantz (1960a, b; 1961a, b), by Grantz and others (1963), and by Detterman and others (1976). Both formations occur in the southeastern part of the map area, are devoid of coeval volcanic material, and are interpreted to have been deposited in a continental shelf environment. The contact between the Tuxedni Group and the underlying Talkeetna Formation (unit Jtk) is a major angular unconformity. The Chinitna and Tuxedni are partly correlative with the Nizina Mountain Formation of the southern Wrangell Mountains (E. M. MacKevett, Jr., oral commun., 1977).

Jtk TALKEETNA FORMATION (Lower Jurassic)--Andesitic flows, flow breccia, tuff, and agglomerate; subordinate interbeds of sandstone, siltstone, and limestone (mapped separately as unit Jls), especially in upper part of the formation. A dominantly shallow marine sequence, about 1,000 to 2,000 m thick (Grantz, 1960a, b; 1961a, b; Grantz and others, 1963; Detterman and others, 1976). This formation occurs only in the southeastern half of the mapped area and its base is nowhere exposed. The occurrence of marble (units Jmb and Jmbr) within the plutonic and metamorphic rocks just northwest of the Talkeetna Formation outcrop area suggests that the formation is underlain by volcanogenic rocks of Triassic (unit TRv) and of Paleozoic age (unit Pzv).

Jls LIMESTONE (Lower Jurassic)--Light- to dark-gray, fine- to medium-grained unfossiliferous limestone; near granitic rocks recrystallized to medium- to coarse-grained marble. Forms discontinuous lenticular bodies, as much as 30 m thick, within Talkeetna Formation.

Plutonic and metamorphic rocks

Kum SERPENTINIZED ULTRAMAFIC ROCKS (Lower and (or) Upper Cretaceous)--These rocks occur in small, tectonically emplaced, discordant bodies (protrusions) within the probably Lower to Middle Jurassic pelitic schist (unit Jps) near Willow Creek. They are medium greenish gray to black in color, and are composed of aphanitic masses of serpentine, talc, minor amounts of actinolite-tremolite, chlorite, and opaque minerals. Relict textures were nowhere observed, and all these bodies are strongly sheared. Semiquantitative spectrographic analyses indicate chromium contents to be between 1,000 and 5,000 ppm and nickel between 1,000 and 2,000 ppm (analyses by D. F. Siems and J. M. Motooka, 1973). Fire assay analyses of ten samples show both platinum and palladium contents to range from 0.0 ppm to 0.030 ppm (analyses by R. R. Carlson, 1973). However, the average platinum to palladium ratio is only about three to one. Potassium-argon age determinations on actinolite-tremolite from two samples yielded early Late Cretaceous minimum ages (map nos. 32, 36, table 1). These minimum ages coincide in time with a middle to Late Cretaceous period of intense, alpine-type orogenic deformation (see Structure and Tectonics sections) of the Talkeetna Mountains region. Thus, the serpentinite bodies, whose original age is unknown, are assumed to have been emplaced during this orogeny.

Jtr TRONDHJEMITE (Upper Jurassic)--Forms a discordant, northeast-trending, elongate, epizonal pluton of fairly uniform lithology in the central Talkeetna Mountains. Large portions of the pluton have been sheared and saussuritized. Typically, the trondhjemite is light gray, medium to coarse grained with a granitic texture. A faint flow foliation is locally developed. Major rock forming minerals are plagioclase (oligoclase to sodic andesine), quartz, K-feldspar (between 0 to 10 percent of volume), and biotite, with subordinate amounts of muscovite, and opaque minerals. Color index ranges from 3 to 9. Average oxide percentages, by weight, of seven trondhjemite analyses are: SiO_2 - 70.30, Al_2O_3 - 16.74, K_2O - 1.27, Na_2O - 5.07, CaO - 3.33. Potassium-argon age determinations (map nos. 21, 22, 26, 31, table 1) from the southern part of the pluton show considerable variation in age, which is attributed to resetting. However, three age determinations from the northern half of the pluton (map nos. 10, 11, 14, table 1), including concordant ages on a mineral pair of muscovite and biotite, yielded very similar numbers indicating the emplacement of the trondhjemite pluton between 145 to 150 m.y. ago. The trondhjemite is the youngest member of a group of Jurassic plutonic and metamorphic rocks in the Talkeetna Mountains.

Jgd GRANODIORITE (Middle to Upper Jurassic)--Dominantly granodiorite but includes minor amounts of tonalite and quartz diorite.

These epizonal plutonic rocks, underlying considerable areas in the central and eastern Talkeetna Mountains, were probably emplaced as multiple intrusion of consanguineous magmas. They are medium to dark gray, medium grained, and in undeformed rocks the texture is granitic. Mafic minerals are hornblende and biotite in various proportions. Along the northwestern border of its exposure area, the granodiorite and related rocks have been cataclastically deformed, resulting in a pronounced northeast-trending secondary foliation and, to a lesser degree, lineation. The width of the deformed zone varies from about 2 km to 25 km. Isotopic age determinations (map numbers 15-17, 27, tables 1, 2) from four separate localities indicate that emplacement, probably multiple intrusions, took place approximately 150 and 175 m.y. ago. While the Upper Jurassic trondhjemite intrudes the granodiorite, the granodiorite itself intrudes the Talkeetna Formation of Lower Jurassic age (Grantz and others, 1963).

Jgdm MIGMATITIC BORDER ZONE OF GRANODIORITE (Middle to Upper Jurassic)--Forms a terrane of poorly exposed, intricately intermixed contact schist, amphibolite, and small dikes and veinlets of granodiorite; all of these rock types occur in approximately equal proportions.

The contact schist is dark to medium gray, medium grained; rock-forming minerals are quartz, biotite, and subordinate plagioclase.

The amphibolite is dark gray, medium grained, and consists of hornblende and plagioclase; megascopic schistosity is seldom conspicuous.

The granodiorite is the same as that of unit Jgd; most of the veinlets have been intruded along foliation planes.

The metamorphic rocks of this unit were probably derived from either the Talkeetna Formation (unit Jtk) or from the upper Paleozoic volcanogenic sequence (unit Pzv), or possibly in part from the Upper Triassic basaltic sequence (unit ꞦRv).

Jmrb MARBLE (Middle to Upper Jurassic metamorphic age)--Contact metamorphosed marble bed more than 40 m thick within migmatitic border zone (unit Jgdm). The marble is poorly exposed and occurs only along John Creek, a tributary of upper Kosina Creek. The rock is white, coarse to medium grained, and contains numerous porphyroblastic crystals of andradite garnet and diopside. The marble was derived from a limestone bed, probably within the upper Paleozoic volcanogenic sequence (unit Pzv) or possibly within the Upper Triassic basaltic sequence (unit ꞦRv).

Jqd QUARTZ DIORITE (Lower to Middle Jurassic)--Epizonal intrusive in the southern Talkeetna Mountains. Dominantly quartz diorite but also includes diorite and tonalite. Large portions of this rock have been sheared and intensively altered. The fresh quartz diorite is medium to dark greenish gray, medium to coarse grained, and has a granitic texture. Rock-forming minerals are plagioclase (andesine), quartz, hornblende, subordinate biotite and K-feldspar. Where altered, the quartz diorite consists of mineral aggregates of epidote, chlorite, and sericite, as well as some remnants of the primary minerals. The age of the quartz diorite is probably late Early Jurassic or early Middle Jurassic because it intrudes the Talkeetna Formation and is intruded by the Middle to Upper Jurassic granodiorite of unit Jgd.

Jam AMPHIBOLITE (Lower to Middle Jurassic metamorphic age)--Forms a metamorphic terrane consisting dominantly of amphibolite but includes subordinate amounts of greenschist and foliated diorite. This metamorphic terrane also includes several interbeds of coarsely crystalline marble which are mapped and described separately (unit Jmb).

The amphibolite is generally dark greenish gray, medium to coarse grained, but fine-grained varieties also occur. Foliation and lineation are generally poorly developed, and segregation layering is rare. Major rock-forming minerals are, in approximately equal proportions, anhedral to euhedral hornblende (Z = dark green to brownish green, occasionally bluish green) and anhedral, generally twinned plagioclase ranging from labradorite to calcic andesine. Accessory minerals are quartz, garnet, sphene, apatite, opaques, occasional epidote, and, in some of the rocks, shreds of biotite.

The greenschist is dark greenish gray, fine to medium grained, with a moderately well-developed schistosity. Major minerals are actinolite, untwinned plagioclase (probably albite), epidote, chlorite, quartz, and opaques. Some of the actinolite-like amphibole may actually be aluminous hornblende, thus some of these rocks may be transitional to amphibolite.

The foliated diorite is very similar to the amphibolite in appearance. It is dark greenish gray, medium to coarse grained, with a generally well-developed shear foliation. A remnant granitic texture is always discernible in thin section. Rock-forming minerals are hornblende, twinned and occasionally zoned plagioclase (andesine to sodic labradorite), with subordinate amounts of chlorite and epidote, minor quartz and biotite, and opaques.

All of the above rocks, as well as the quartz diorite of unit Jqd, apparently are the earliest products of a Jurassic plutonic and metamorphic event which appears to have started in the Talkeetna Mountains in late Early Jurassic time after the deposition of the Talkeetna Formation (unit Jtk). A potassium-argon age determination on hornblende of a diorite or amphibolite sample (map no. 5, table 1) from the northeast part of the map area yielded an age of 176.6 m.y. (Turner and Smith, 1974), suggesting an Early to Middle Jurassic age for the amphibolite and associated rocks. The quartz diorite of unit Jqd in the southern Talkeetna Mountains is probably correlative with the sheared diorite of the amphibolite terrane.

The metamorphic rocks of the amphibolite terrane probably were derived from any or all of the following dominantly basic volcanic formations: Talkeetna Formation (unit Jtk), upper Paleozoic volcanogenic sequence (unit Pzv), or the Upper Triassic basaltic sequence (unit ℞v). The pods of greenschist, intercalated with the amphibolite, suggest that the metamorphism in the amphibolite terrane was not of uniform intensity.

Jmb MARBLE (Lower to Middle Jurassic metamorphic age)--White, medium- to coarse-grained marble. It occurs in massive interbeds, as much as 30 m thick, within the amphibolite terrane of unit Jam. The marble contains subordinate amounts of garnet and diopside. Its parent rock was a limestone bed, probably within the Talkeetna Formation (unit Jtk) or within the upper Paleozoic volcanogenic sequence (unit Pzv), or, least likely, within the Upper Triassic basaltic sequence (unit ℞v).

Jmi AMPHIBOLITE AND QUARTZ DIORITE (Lower to Middle Jurassic metamorphic and plutonic ages)--Forms a terrane of intricately intermixed amphibolite and quartz diorite in about equal amounts in the southern Talkeetna Mountains.

The amphibolite is very similar to the amphibolite of unit Jam, thus the two amphibolites are considered to be correlative, and no description is given here. One difference is that segregation layering of mafic and felsic components is more prevalent in the amphibolite of unit Jmi. A thin wedge of biotite-quartz-feldspar gneiss, probably derived from a nonvolcanic clastic interbed, is intercalated with the amphibolite along lower Granite Creek (Detterman and others, 1976; Travis Hudson, oral commun., 1978).

The quartz diorite is petrographically identical to the quartz diorite in adjacent unit Jqd (see rock description there), and the two rocks are considered to be correlative. The quartz diorite of the present unit is generally more altered than that of unit Jqd.

Jgs GREENSTONE (Probably Lower to Middle Jurassic metamorphic age)--The basic metavolcanic rocks of this unit form small, isolated hills along the eastern edge of the map area near the Susitna River. The typical greenstone is a dark greenish gray, fine grained, generally structureless rock. Original rock-forming minerals were pyroxene, amphibole, and plagioclase (andesine to labradorite) which more or less altered to chlorite, epidote, serpentine, calcite, and minor sericite and quartz. The proximity of the amphibolite terrane (unit Jam) strongly suggests that the metavolcanic greenstones of the present unit represent a low-grade facies of the same metamorphism which produced the amphibolite. The relative position of the greenstone within the northeasterly structural trend of the Talkeetna Mountains suggests that the greenstone was probably derived from the Talkeetna Formation (unit Jtk) or, possibly, from either the upper Paleozoic volcanogenic sequence (unit Pzv) or the Upper Triassic basaltic sequence (unit ╥Rv).

Jps PELITIC MICA SCHIST (Probably Lower to Middle Jurassic metamorphic age)--This rock occurs only in the southwestern corner of the map area near the headwaters of Willow Creek. The schist is medium to dark gray, medium grained, with uniform lithology throughout its exposure area. Its ubiquitous mineral constituents are quartz, muscovite, albite, chlorite, chloritized crystals of garnet and subordinate biotite. Very thin laminae of carbonaceous material occur sparsely. Small open folds and crenulations form an incipient slip cleavage at a large angle to the primary schistosity. Numerous thin veins and stringers of hydrothermal quartz occur throughout the schist. Detailed petrographic descriptions of the mica schist are given in Ray (1954).

The present mineralogy of the schist is indicative of the greenschist metamorphic facies of Turner (1968). However, it is probably retrograde from higher metamorphism, possibly the amphibolite facies. Evidence for this is the chloritized garnet and biotite crystals and the sparse mineral outlines consisting of chlorite which probably are pseudomorphs after hornblende.

The age of the schist is imperfectly known, but, based on regional geologic interpretations, the primary metamorphism is considered to be Early to Middle Jurassic in age. Thus, the schist and the amphibolite of unit Jam are interpreted to be the products of the same metamorphism. The retrograde metamorphism is assumed to be of middle to Late Cretaceous in age and related to an alpine-type orogeny in the Talkeetna Mountains at that time. However, the Late Cretaceous Arkose Ridge Formation, which lies unconformably on the schist, has not been affected by this retrograde metamorphism. The three potassium-argon age determinations, measured on muscovite from the schist (map nos. 33-35, table 1), yielded obviously reset Paleocene ages.

The parent rock of the schist is unknown because no pelitic rocks of comparable thickness (the schist is at least several hundred meters thick) are known to occur in the pre-Middle Jurassic rocks of the Talkeetna Mountains.

Jpmu PLUTONIC AND METAMORPHIC ROCKS, UNDIFFERENTIATED (Lower to Upper Jurassic plutonic and metamorphic ages)--This unit consists of an intricately intermixed mosaic of most of the previously discussed Jurassic metamorphic and plutonic rocks (units Jtr, Jgd, Jgdm, Jqd, Jam, Jgs, and Jps). Within the terrane of the present unit, the exposure area of an individual rock type is not more than a few square kilometers. Two rock types, amphybolite and sheared quartz diorite, comprise approximately 60 percent of the terrane. Next in importance are sheared granodiorite and associated migmatites. Subordinate amounts of pelitic mica schist and greenstone also occur. Numerous apophyses of trondhjemite, as much as several meters thick, occur along the eastern edge of the terrane adjacent to the large trondhjemite pluton (unit Jtr). All of these rocks are lithologically very similar to their correlative map units, and they will not be described here. At two localities, the sheared granodiorite (unit Jgd) was mapped separately to show the proximity of sheared Jurassic granitic rocks to the Late Cretaceous and early Paleocene unsheared tonalite (unit TKt).

NORTHWESTERN TALKEETNA MOUNTAINS AND UPPER CHULITNA RIVER AREA

Sedimentary and volcanic rocks; rocks of each column occur in separate fault blocks.

Central and northern Talkeetna Mountains

ŦRv BASALTIC METAVOLCANIC ROCKS (Upper Triassic)--This shallow water marine unit consists of amygdaloidal metabasalt flows with very subordinate amounts of thin interbeds of metachert, argillite, metavolcaniclastic rocks, and marble (Smith and others, 1975). Rocks of this unit have been mapped only in the northeast portion of the map area. However, small blocks of the basaltic rocks may occur within the complexly deformed late Paleozoic volcanogenic sequence (unit Pzv) toward the southwest. The basaltic rocks rest with angular unconformity on the late Paleozoic volcanics (unit Pzv); the top of the basalts is unexposed. The minimal thickness of the basaltic metavolcanic rocks is 800 m.

The individual metabasalt flows are as much as 10 m thick and, according to Smith and others (1975), display columnar jointing and locally pillow structures. The typical metabasalt is dark greenish gray, fine grained, and generally contains numerous amygdules. Thin sections show the metabasalts to consist of labrodorite, augite, and opaques in an intergranular or subophitic texture. Secondary minerals are chlorite, epidote, clinozoisite, very subordinate allanite, sericite, and possibly some kaolin. The amygdules consist of chlorite, silica, and zeolites. The present mineralogy is probably the result of deuteric alteration and low-grade regional metamorphism which apparently did not reach the intensity of the greenschist facies of Turner (1968).

From a marble interbed in upper Watana Creek (locality 1, table 3), T. E. Smith (unpub. data, 1974) collected fossil specimens which were identified and interpreted by K. M. Nichols and N. J. Silberling to be *Halobia* cf. *H. symmetrica* Smith, indicating a latest Karnian or early Norian age. Previously, Smith (1974a) and Smith and others (1975) have correlated the basaltic metavolcanic rocks of the present unit with the Amphitheater Group of the central Alaska Range. Accordingly, the fossils collected by T. E. Smith suggest that the Amphitheater Group is younger than, and thus not correlative with the lithologically very similar Nikolai Greenstone of pre-late Karnian age in eastern Alaska (Jones and others, 1977).

Pzv BASALTIC TO ANDESITIC METAVOLCANOGENIC ROCKS (Pennsylvanian(?) and Early Permian)--Rocks of this unit occur in a northeast-trending belt across the center of the Talkeetna Mountains, and they form an interlayered heterogeneous, dominantly marine sequence over 5,000 m thick. The base of the sequence is nowhere exposed, and the contact with the overlying Triassic metabasalts is an angular unconformity. The metavolcanogenic sequence consists dominantly of metamorphosed flows and tuffs of basaltic to andesitic composition, and of coarse- to fine-grained metavolcaniclastic rocks with clasts composed chiefly of mafic volcanic rocks. Mudstone, bioclastic marble (mapped and described separately as unit Pls), and dark-gray to black phyllite are subordinate. The various rock types of the sequence form conformable but lenticular units of limited areal extent. The crudely layered and poorly sorted metavolcaniclastic units have thicknesses in excess of 1,000 m, and the thickness of the phyllites ranges from a few meters to several hundred meters. The whole sequence has been tightly folded and complexly faulted, and the rocks have been regionally metamorphosed into mineral assemblages mostly of the greenschist and the prehnite-pumpellyite facies, but locally along Tsisi Creek of the amphibolite facies of Turner (1968). Detailed petrographic descriptions of these rocks were given by Csejtey (1974).

The age of the metamorphism is uncertain. The most intensive metamorphism in the mapped area probably took place in Early to Middle Jurassic time, contemporaneously with the development of the amphibolite terrane (unit Jam). Subsequent but less severe metamorphism, primarily shearing, occurred probably in middle to Late Cretaceous time during the alpine-type orogenic deformation of the Talkeetna Mountains (see discussions in Structure and Tectonics sections).

The composition and lithologic character of the metavolcanogenic sequence strongly suggest that this sequence is a remnant of a complex volcanic arc system (Csejtey, 1974, 1976). Fossil evidence (see description of unit Pls) from a marble interbed near the top of the sequence indicates an Early Permian age. However, because of the considerable thickness of the sequence, its lowermost portion may be as old as Late Pennsylvanian.

Pls MARBLE (Pennsylvanian(?) and Early Permian)--Forms lenticular interbeds, as much as a few tens of meters thick, within the basaltic to andesitic late Paleozoic metavolcanogenic sequence (unit Pzv). Most of the rock is light gray to white, medium to coarse grained, thick-bedded to massive marble, but some less metamorphosed varieties also occur. Still discernible organic remains and bedding features indicate that the marble interbeds were derived from bioclastic limestone which probably was deposited by high energy currents on shallow banks of limited areal extent. A number of the marble interbeds contain poorly preserved and generically unidentifiable crinoid columnals, brachiopods, bryozoans, and rarely corals (see table 3) of late Paleozoic or probable late Paleozoic ages. However, one of the marble interbeds near the top of the sequence (locality 8, table 3) yielded well-preserved brachiopods and crinoid columnals which were identified and interpreted by J. T. Dutro, Jr. (Csejtey, 1976) to be late Early Permian, that is, late Leonardian to early Guadalupian in age. The regional correlation of these rocks and that of the late Paleozoic metavolcanogenic sequence (unit Pzv) has been previously discussed by Csejtey (1976).

Northern Watana Creek area

Js SEDIMENTARY AND VOLCANIC ROCKS, UNDIVIDED (Upper Jurassic)--These rocks only occur in a small, apparently tectonic sliver along the northern edge of the map area. They comprise a section of intercalated argillite and graywacke, pebble conglomerate, and flows and dikes of andesitic to latitic feldspar porphyry. Some of these rocks are sheared but some, mostly the pebble conglomerates, are not sheared.

The argillite and fine-grained graywacke are thinly to moderately thickly bedded and generally are dark gray. However, dark-greenish-gray varieties also occur, suggesting the presence of volcanic ash or fine-grained tuffaceous material. The conglomerates are massive, and the well-rounded to subrounded pebbles consist chiefly of unmetamorphosed andesite, latite, and subordinate amounts of dacite. A minority of the pebbles are composed of dark-gray argillite and white quartz. The feldspar porphyry is dark gray, with flow alined phenocrysts of zoned andesine and oligoclase as much as 1 cm long, and some hornblende and biotite, in an aphanitic matrix.

An argillite bed at the top of the 5,053-ft hill in the Healy A-2 quadrangle, just north of the present map area, yielded well-preserved fossils of *Buchia rugosa* (Fischer), indicating a Late Jurassic age for these rocks (D. L. Jones, oral commun., 1977). On the basis of lithology and age, the rocks of the present unit are considered to be the westernmost occurrence of the Gravina-Nutzotin terrane of Berg and others (1972).

Northwest Talkeetna Mountains

Kag ARGILLITE AND LITHIC GRAYWACKE (Lower Cretaceous)--These rocks occur in a monotonous, intensely deformed flyschlike turbidite sequence, probably several thousand meters thick, in the northwest part of the mapped area, north of the Talkeetna thrust fault. The whole sequence has been compressed into tight and isoclinal folds and probably has been complexly faulted as well. The rocks are highly indurated, and many are sheared and pervasively cleaved as a result of low-grade dynamometamorphism, the intensity of which is only locally as high as the lowermost portion of the greenschist metamorphic facies of Turner (1968).

Most of the cleavage is probably axial plane cleavage. Neither the base nor the top of the sequence is exposed and, because of the intense deformation, even its minimal thickness is only an estimate.

The argillite is dark gray or black. Commonly it contains small grains of detrital mica as much as 1 mm in diameter. Because of the dynamometamorphism, in large areas the argillite is actually a slate or fine-grained phyllite. Thin sections show that some of the argillites are derived from very fine grained siltstone and that they contain considerable carbonaceous material.

The typical lithic graywacke is dark to medium gray, fine to medium grained, and occurs intercalated with the argillite in graded beds ranging in thickness from laminae to about 1.5 m. The individual graywacke beds are not uniformly distributed throughout the whole sequence, of which they comprise about 30 to 40 percent by volume, but tend to be clustered in zones 1 to 5 m thick. Thin sections of graywacke samples show them to be composed of angular or subrounded detrital grains of lithic fragments, quartz, moderately fresh plagioclase, and some, generally altered, mica in a very fine grained matrix; euhedral opaque grains, probably authigenic pyrite, are present in most thin sections. The lithic fragments consist in various proportions of little altered, fine-grained to aphanitic volcanic rocks of mafic to intermediate composition; fine-grained, weakly foliated low-grade metamorphic rocks; chert; and some fine-grained unmetamorphosed sedimentary rocks possibly of intraformational origin. No carbonate grains were seen. The matrix constitutes about 20 to 30 percent of the rock by volume, generally contains some secondary sericite and chlorite, and, in the more metamorphosed rocks, biotite and possibly some amphibole.

Analyses of paleocurrent features, such as small-scale cross-stratification, found in several exposures near the western edge of the mapped area, suggest that depositional currents came from the east or northeast (A. T. Ovenshine, oral commun., 1974).

Because fossils are extremely sparse, the exact age of the argillite and lithic graywacke sequence is imperfectly known. A poor specimen of *Inoceramus* sp. of Cretaceous age was found just west of the map area between the Chulitna and Susitna Rivers, and a block of *Buchia*-bearing limestone of Valanginian age was found in float near Caribou Pass in the Healy quadrangle north of the mapped area (D. L. Jones, oral commun., 1978).

Northwestern Talkeetna Mountains

TRvs METABASALT AND SLATE (Upper Triassic)--Shallow water marine, interbedded sequence of amygdaloidal metabasalt flows and slate, found only in two allochthonous klippen near the northwest corner of the mapped area. The sequence is tightly folded, along with the underlying Cretaceous rocks (unit Kag), and is slightly metamorphosed and unevenly sheared. The basalt and slate are intercalated in approximately equal proportions in individual units as much as 15 m thick.

The metabasalt is dark greenish gray, aphanitic, with numerous amygdules. In thin sections the primary minerals are twinned labradorite, augite, and opaques which probably are, for the most part, ilmenite. Secondary minerals are chlorite (much of it after glass), epidote, clinozoisite, minor zoisite, calcite, leucoxene, very minor sericite, very fine grained felty amphibole (probably uralite after augite), and possibly some very subordinate albite. The original texture was intersertal and subophitic. The amygdules consist of chlorite, zeolites (primarily prehnite), quartz, and some feldspar.

The slate is dark gray to black. Thin sections show that some of the rock is fine-grained metasiltstone. All of the rocks contain considerable carbonaceous material and some amounts of fine-grained, secondary sericite. Secondary biotite is present in some of the slates.

The secondary mineral assemblages suggest that, in addition to deuteric alteration, the metabasalt and slate sequence underwent very low grade regional metamorphism.

The metabasalt and slate sequence has been dated in the Healy quadrangle, north of the present map area, near the East Fork of the Chulitna River where D. L. Jones and N. J. Silberling (oral commun., 1977) found upper Norian fossils of *Monotis subcircularis* and *Heterostridium* sp. in slightly metamorphosed argillaceous beds. Thus, the age of the present sequence is similar to, and the lithology of its basalt is identical to, that of the Upper Triassic metabasaltic sequence (unit ℞v) in the northeast Talkeetna Mountains. These two rock sequences may represent different facies, brought closer by thrusting, of the same geologic terrane.

Upper Chulitna River area

DSga GRAYWACKE, ARGILLITE, AND SHALE (Silurian(?) to Middle Devonian) --These rocks occur in an apparently allochthonous tectonic block along the western side of the Chulitna Valley and comprise a poorly and inaccessibly exposed, complexly deformed and sheared sequence. As a result, the sequence is poorly known; it was briefly examined in outcrop only along Long Creek. There the component rocks are medium to dark gray, sheared and tightly folded with vertical dips, and occur intercalated in beds as much as 1 m thick. The graywackes are fine grained and appear to contain some volcanogenic detritus. Reconnaissance field checking by D. L. Jones (oral commun., 1977) further to the north indicates that the sequence also includes some chert, cherty tuff, and phyllite.

In Long Creek, two fossiliferous limestone beds (mapped and described separately as unit DSls) were found; they probably are in depositional contact with, and thus date, the enveloping unfossiliferous clastic rocks. It is possible, however, that some of the limestone contacts are tectonic and that some of the enveloping rocks are of a different age.

DSls LIMESTONE (Silurian(?) to Middle Devonian)--Massive to thick-bedded, medium-gray, fine-grained, moderately sheared bioclastic limestone, probably formed in patch reefs. It occurs at three separate localities, in apparent depositional interbeds as much as 20 m thick, within fine-grained clastic rocks (unit DSga). Of the two limestone beds in Long Creek, one yielded fossils of Devonian, probably Middle Devonian, age, the other of Silurian or Devonian age (map nos. 12, 13, respectively, table 3). The fossils also indicate shallow marine deposition. The types of fossils and the characteristics of the host limestones and the enveloping clastic rocks suggest deposition along an ancient continental margin. These continental margin-type deposits crop out only about 6 km to the southeast of Upper Devonian ophiolitic rocks (unit Dbs) that are indicative of ocean floor deposition. The proximity of these rocks that are close in age but different in depositional environment is additional evidence for large-scale Alpine-type orogenic deformation in south-central Alaska (Csejtey and others, 1977; Jones and others, 1978).

Upper Chulitna River area

Jta CRYSTAL TUFF, ARGILLITE, CHERT, GRAYWACKE, AND LIMESTONE (Lower to Upper Jurassic)--Shallow to moderately deep marine sequence, tightly folded and internally faulted, at least several thousand meters thick. These rocks are interpreted to occur in a thrust block along the western slope of the upper Chulitna Valley. Four-fifths of the sequence is comprised of the massive, cliff-forming crystal tuff, while the remaining rocks form only a narrow outcrop belt along the western margin of the map unit. The contact between these two groups of rocks may be tectonic.

The crystal tuff is light to dark gray, locally with a greenish tint, and weathers to various shades of brown. It is massive with obscure rhythmic laminations and thin bedding. The tuff is composed of abundant small feldspar crystals (albite?) set in a very fine grained matrix of devitrified volcanic glass in which some shards can be recognized. Sparse but unidentifiable fragments of radiolaria were also found. A thin interbed of volcaniclastic sandstone yielded the following fossils: *Arctoasteroceras jeletskyi* Frebold, *Paltechioceras (Orthechioceras?)* sp., and *Weyla* sp. (Jones and others, 1978; fossil locality in Silberling and others, 1978). According to R. W. Imlay (written commun. to D. L. Jones, 1976), these fossils indicate a late Sinemurian age.

The argillite, chert, graywacke, and limestone occur interbedded in various proportions in individual units as much as several tens of meters thick. The argillite and chert are dark gray to black; the graywacke is medium to dark gray, very fine to medium grained, locally with graded bedding. The limestone is medium gray, generally phosphatic, in part sandy, locally is associated with limy siltstone and conglomerate; forms blocks and lenticular beds as much as several kilometers in extent. Some of the chert beds yielded radiolaria of late Kimmeridgian or early Tithonian age (Late Jurassic), and at five different localities, the limy rocks yielded Early Jurassic ammonite faunas of early Sinemurian age (Jones and others, 1978; fossil localities in Silberling and others, 1978). Probably these Lower and Upper Jurassic rocks originally formed a coherent stratigraphic sequence which subsequently was disrupted by folding and faulting.

Ohio Creek area

Dsb SERPENTINITE, BASALT, CHERT, AND GABBRO (Upper Devonian)--Tectonically intermixed assemblage that forms a northeast-trending belt of apparent thrust slivers in the northwest corner of the mapped area. Sheared serpentinite is the most abundant rock type; the remaining component rocks occur in various proportions in lenticular and podiform tectonic blocks as much as several hundred meters in extent. Many chert lenses occur intercalated with basalt flows which locally show poorly preserved pillow structures. Rocks of this map unit have been previously described and interpreted as a dismembered ophiolite assemblage by Clark and others (1972) and by Jones and others (1978).

The serpentinite is dark gray to dark greenish gray, always sheared, and consists almost entirely of clinochrysotile and lizardite with subordinate brucite, talc, and chromite. Sparse relict olivine crystals and a bastite texture suggest that the serpentinite originally was a pyroxene-olivine ultramafic rock.

Basalt is dark gray, aphanitic to fine grained with a few phenocrysts, as much as 4 mm in maximum dimension, of altered plagioclase, pyroxene, and olivine. The rock is locally vesicular or amygdaloidal and generally is fragmental; many of the fragments are palagonite. Some of the vesicles and amygdules are concentrated along spherical surfaces which may be parts of pillow structures. Depositionally intercalated marine chert beds further indicate that the basalts were formed as submarine flows.

The chert is generally red, but reddish-brown and greenish-gray varieties also occur. It is commonly in beds a few millimeters to a few centimeters in thickness, and contains abundant radiolaria.

The gabbro is medium to dark greenish gray, fine to coarse grained, and is composed of altered plagioclase, pyroxene, olivine, and opaques. Compositional layering, interpreted to be cumulate textures, is common, and the layers range in thickness from a few millimeters to a few centimeters. The best exposed gabbro occurs in a lens about 100 m thick and about 1 km long on the ridge north of the unnamed northern branch of Shotgun Creek.

Age determinations of radiolaria and conodonts in chert samples from eight separate localities reliably indicate a Late Devonian (Famennian) age for the ophiolitic rocks (Jones and others, 1978; Silberling and others, 1978).

Long Creek area

TRr RED BEDS (probably Upper Triassic)--Red sandstone, siltstone, argillite, and conglomerate similar to the red beds of unit JTRrs. Clasts of gabbro, serpentinite, and fossiliferous Permian(?) limestone are present in these rocks but have not been identified in rocks of unit JTRs. Also, a thin conglomerate bed containing angular clasts of rhyolite is locally present at the base. These rocks lie with depositional unconformity on late Paleozoic, possibly Triassic, and older strata in the map area. Just north of the map area, the red beds rest on Lower Triassic limestone (Jones and others, 1978). The red beds lack fossils and, therefore, have not been dated, but they are assumed to be equivalent in age to the Upper Triassic red beds of unit JTRrs (Jones and others, 1978).

Pzsv VOLCANOGENIC AND SEDIMENTARY ROCKS, UNDIVIDED (Upper Devonian to Lower Permian)--Heterogeneous intercalated sequence of greenish-gray to black tuffaceous chert, lesser amounts of maroon volcanic mudstone, breccia composed largely of basaltic detritus, laminated flyschlike graywacke and shale, and large lenses of light-gray, thick-bedded limestone. Fossils from the thick-bedded limestone are Early Permian in age; brachiopods from the conglomerate are also of Early Permian age; and fossils from the chert are Devonian and Carboniferous, but some poorly preserved fossils may possibly, though not likely, be as young as Triassic (Jones and others, 1978). The stratigraphic and structural relations between these diverse rocks are obscured by abundant folds and poor exposures. A detailed discussion of these rocks is given by Jones and others (1978), and fossil localities are shown in Silberling and others (1978).

Ohio Creek area

JTRs RED AND BROWN SEDIMENTARY ROCKS AND BASALT, UNDIVIDED (Upper Triassic and Lower Jurassic)--The basal part of this unit consists of a red-colored sequence of sandstone, siltstone, argillite, and conglomerate, with a few thin interbeds of brown fossiliferous sandstone, pink to light-gray dense limestone, and intercalated massive basalt flows. This red bed sequence grades upward into highly fossiliferous brown sandstone, which in turn grades upward into brownish-gray siltstone with yellowish-brown limy concretions.

Clasts in the red beds are dominantly basalt grains and pebbles which probably were derived from basalt flows of unit TRlb that lies unconformably below the red beds and from massive basalt flows within the red bed sequence. Subordinate amounts of the clasts consist of white, in part foliated, metaquartzite pebbles; flakes of white mica which, along with the metaquartzite, must have been derived from an unidentified siliceous metamorphic terrane; and red radiolarian chert pebbles and grains, which probably were derived from the ophiolitic rocks of unit Dsb. No other clasts that can be identified as coming from the ophiolitic rocks have been recognized.

Fossils from the limestone and the overlying brown sandstone are of Upper Triassic age, and those from the yellowish-brown limy concretions are of Upper Triassic and Lower Jurassic age.

Detailed discussions of both the red and brown beds are given by Jones and others (1978), and fossil localities are shown in Silberling and others (1978).

TRlb LIMESTONE AND BASALT (Upper Triassic)--Interlayered sequence of limestone, partly recrystallized to marble, and flows of altered amygdaloidal basalt. Individual units are as much as several tens of meters thick. These rocks occur in a complexly faulted zone in the northwest corner of the mapped area.

The limestone is medium gray, massive to thick bedded, but locally it has altered to fine- to medium-grained marble.

It contains sparse fragments of poorly preserved corals and thick-shelled *Megalodontid*(?) bivalves up to 20 cm in length. A single specimen of *Spondylospira* sp., in conjunction with the *Megalodontid* bivalves, suggests a Norian age for the sequence (Jones and others, 1978; fossil localities shown in Silberling and others, 1978).

The amygdaloidal basalt is dark gray to greenish gray, aphanitic, with numerous amygdules. Locally, it displays well-developed pillow structures. Primary rock-forming minerals are fine-grained labradorite, titanium-rich augite, and opaques in an originally intersertal or subophitic texture. The original mineral assemblage has been more or less altered to an aggregate of chlorite (much of it after glass), epidote, calcite, sericite, and some zeolite, probably prehnite. The amygdules consist of chlorite, calcite, prehnite, and minor quartz. Most of the secondary minerals are probably the result of deuteric alteration, but some might be the product of very low-grade regional metamorphism. Fifteen chemical analyses of least altered basalt samples indicate that the basalts are somewhat low in silica (normalized SiO_2 contents average 46.7 percent by weight, ranging from 43.7 to 48.7 percent), high in alkalis (normalized Na_2O contents average 3.06 percent by weight, ranging from 1.3 to 5.2 percent; and normalized K_2O contents average 0.47 weight percent, ranging from 0.07 to 1.5 percent), and are high in titanium (normalized TiO_2 contents average 3.8 weight percent, ranging from 2.5 to 5.0 percent). The chemistry and mineralogy suggest that these basalts had alkali affinities prior to alteration.

The fossils and the lithologies of the limestones and the basalts indicate shallow water marine deposition. The probable alkali affinity of the basalts further suggests that they either were part of an ocean island shield volcano, perhaps associated with a barrier reef, or that they were formed on a continental margin.

Upper Copeland Creek area

KJs ARGILLITE, CHERT, SANDSTONE, AND LIMESTONE (Upper Jurassic and Lower Cretaceous)--This unit consists of dark-gray argillite, dark-gray to greenish-gray bedded chert, thick-bedded sandstone, thin-bedded gray sandstone, and rare thin beds of shelly limestone. Both Upper Jurassic and Lower Cretaceous radiolarias were obtained from the chert. The thick-bedded sandstone contains abundant fragments of *Inoceramus* sp. of Hauterivian to Barremian age, and some of the limestone beds contain *Buchia sublaevis* of Valanginian age. Some of the thin-bedded sandstone contains abundant detrital white mica and may be as young as Albian (mid-Cretaceous). Thicknesses and the stratigraphic relations within these rocks and with adjacent rocks are unknown because of complex folding and faulting and poor exposures. A more detailed discussion of these rocks is given by Jones and others (1978), and fossil localities are shown in Silberling and others (1978).

Structure

The rocks of the Talkeetna Mountains region have undergone complex and intense thrusting, folding, faulting, shearing, and differential uplifting with associated regional metamorphism and plutonism. At least three major periods of deformation are recognized: a period of intense metamorphism, plutonism, and uplifting in the late Early to Middle Jurassic, the plutonic phase of which persisted into Late Jurassic; a middle to Late Cretaceous alpine-type orogeny, the most intense and important of the three; and a period of normal and high-angle reverse faulting and minor folding in the middle Tertiary, possibly extending into the Quaternary.

Most of the structural features in the Talkeetna Mountains region are the result of the Cretaceous orogeny which produced a pronounced northeast-southwest-trending structural grain of the region. The vergence of this structural grain is steeply to moderately toward the northwest, but across the Chulitna Valley in the northwest part of the map area, it abruptly reverses toward the southeast with steep attitudes. This Cretaceous deformation is most intense in the central and northwestern part of the map area, and it rapidly decreases toward the southeast. The complex fault pattern along and near the southern edge of the Talkeetna Mountains is part of the late Cenozoic Castle Mountain-Caribou fault systems, consisting chiefly of high-angle reverse and normal faults of probably local significance.

Evidence for the Jurassic deformation is provided by the post-Talkeetna Formation major unconformity and the apparently coeval regional metamorphism, up to the amphibolite grade, and associated plutonic rocks (all the Lower to Middle Jurassic metamorphic and plutonic units). The higher crustal level manifestation of this Jurassic tectonic event was regional uplift and consequent rapid denudation of the intruded epizonal plutons.

Complex folding produced by the Cretaceous orogeny is especially pronounced in the areas northwest of the belt of Jurassic metamorphic and plutonic rocks. The folds are chiefly tight or isoclinal, with amplitudes of several hundred to several thousand meters. The limbs are generally sheared out or faulted out. As a result, no individual beds can be traced in the field for more than a few kilometers. Many of the large folds, especially in the Cretaceous argillites and graywackes (unit Kag), have a well-developed axial plane slaty cleavage. Fine-grained sericite and biotite are commonly developed along these cleavages. The folding must have taken place in several episodes during the orogeny because thrust faults not only truncate folds within both the upper and lower plates but are themselves folded. The folded thrusts are especially evident in the Chulitna area where, in contrast to the regional northwest vergence, the axial planes of the folds steeply dip toward the northwest.

Most prominent of the Cretaceous faults is the Talkeetna thrust which has placed Paleozoic, Triassic, and, locally, Jurassic rocks over Cretaceous sedimentary rocks across the whole map area. The thrust is generally poorly exposed except near the Lower Talkeetna River. There it dips steeply toward the southeast. Another thrust, the one delineating the klippe of rocks of unit TRvs, has been sharply folded. The thrusts in the northwest corner of the map area are very complex, also have been intensely folded, and are more numerous than could be shown on the present map. A number of them are not fully understood, and thus their subsurface configuration is speculative. It is certain, however, that these thrusts stack and bring together on top of the Kag unit a wide variety of rock sequences of different ages and depositional environment. The root zone of all the thrusts in the northwest half of the map area is herein interpreted to be the Talkeetna thrust (see cross section).

Another Cretaceous feature is an intense shear zone, locally as much as 25 km wide, trending across the Talkeetna Mountains, parallel to, but southeast of the Talkeetna thrust. Although not supported by any evidence, it is possible that the shear zone marks a thrust zone of significant displacement. (The center of this shear zone is shown as a postulated thrust on the map.) The dips in the zone are generally southeasterly. The shearing is penetrative, and its most spectacular result is that portions of all the Jurassic plutonic rocks, including the Upper Jurassic trondhjemite, have been transformed to cataclastic gneiss. The 75 to 61 m.y. old Upper Cretaceous and lower Paleocene tonalite pluton (unit TKt) truncates this shear zone and is not affected by it.

The age of the Cretaceous orogeny, or at least its major phase, is rather well bracketed by stratigraphic evidence. The youngest rocks involved are the Cretaceous argillites and graywackes (unit Kag) which are as young as Valanginian or possibly even younger in age. A maximum upper age bracket is provided by the late Paleocene granitic plutons, which are structurally unaffected, and intrude the already folded and faulted country rocks in the northwest half of the map area. Two of the Cretaceous thrusts, including the Talkeetna thrust, are actually intruded by these plutons. A slightly older upper age bracket is provided by the previously discussed 61 to 75 m.y. old tonalite pluton (unit TKt) that cuts and is unaffected by the prominent shear zone in the central Talkeetnas. Thus, the most important orogenic deformation in the Talkeetna Mountains region must have taken place during middle to Late Cretaceous time. Such an age assignment for the orogeny is further supported by potassium-argon age determinations of 88 and 91 m.y. for the serpentinite protrusions in the southwest corner of the map area (unit Kum).

The dominant features of the middle Tertiary to Quaternary deformation are the already mentioned Castle Mountain-Caribou fault systems, along which the southern Talkeetna Mountains have been uplifted locally as much as 2,800 m (Detterman and others, 1976). The only other features of this Cenozoic deformation recognized within the map area are the two poorly exposed normal faults in the Chulitna River valley (see map and cross section). In addition to field observations, the existence of these faults is also supported by gravity data (R. L. Morin, oral commun., 1977; N. B. Harris, oral commun., 1977). No other Cenozoic faults, or any other faults with obvious Recent movement, were observed within the map area.

Tectonics

The Talkeetna Mountains and adjacent areas are part of the dominantly allochthonous terrane of southern Alaska. Previously, this terrane has been interpreted to have developed by accretion of allochthonous continental blocks to the ancient North American plate (Richter and Jones, 1973; Csejtey, 1974) in late Mesozoic time (Csejtey, 1976; Jones and others, 1978). Although the exact number or even the extent of these allochthonous blocks is still imperfectly known, they appear to have moved northward considerable distances prior to their collision with the North American plate. For one of the blocks in eastern Alaska (Wrangellia of Jones and others, 1977), a probable northward movement of several thousand kilometers has been shown by Hillhouse (1977). The results of the present investigations and those of Jones and others (1978) not only lend credence to the accretionary concept of southern Alaska but also provide additional evidence for the time, method, and direction of emplacement.

One of the keys to the tectonic history of the Talkeetna Mountains region, and to southern Alaska as well, is the occurrence of the tectonically emplaced diverse rock packages in the Chulitna area in the northwest part of the map area. Most of the Triassic and Jurassic rocks there, especially the Triassic red beds, do not occur anywhere else in Alaska, and the fossil faunas and lithologic characteristics of these Mesozoic rocks strongly suggest deposition in warm water at low paleolatitudes (Jones and others, 1978). Furthermore, the pre-middle Cretaceous rocks above the Talkeetna thrust, above the root zone of the Chulitna faults, are either structurally part of the allochthonous Wrangellia terrane of Jones and others (1977) or belong to a different terrane lying south (that is outboard) of Wrangellia. Thus, all available evidence strongly indicates that, with the exception of unit Kag, all pre-middle Cretaceous rocks of the Talkeetna Mountains region are allochthonous, and, after the collision of their parent continental blocks with the middle Cretaceous North American continent, they were thrust upon, that is obducted onto the margin of the continent. In turn, the middle Cretaceous Alaskan margin of the continental North American plate itself probably developed by still earlier accretions (D. L. Jones, oral commun., 1977). The distance the allochthonous rocks of the Talkeetna Mountains region were thrusted beyond the edge of the continent is not known with certainty, but it must be at least several hundred kilometers. In accordance with the present obduction concept, all the tectonic and depositional rock assemblages normally associated with the continental upper plate of a subducting system, especially trench deposits and volcanic arc rocks, are now hidden by the overthrust rock masses. Possibly the small tectonic sliver of Upper Jurassic sedimentary and volcanic rocks (unit Js) along the Talkeetna thrust is the only exposed remnant of these hidden assemblages. As shown on the cross section, the main thrust along which most movement presumably occurred is the Talkeetna thrust, and all other thrusts northwest of it are interpreted to be slivers below it.

The northeast-southwest-trending compressional structural features, that is the folding and thrusting, indicate a general northwestward tectonic transport. This is further supported by the sharp character of the suture zone in eastern Alaska, along which the allochthonous rocks of southern Alaska, especially the Wrangellia terrane, are in contact with the pre-middle Cretaceous North American continent. This suture zone in eastern Alaska trends northwesterly and is devoid of the structural complexities of the Chulitna area. This part of the suture, the part southeast of Paxson, which also coincides with the middle Tertiary to Holocene Denali fault, is thus interpreted to have been a transform or a wrench fault. In contrast, the great variety of tectonically juxtaposed rock packages in the Chulitna area may be the result of "bulldozing" by a large continental block drifting toward the northwest.

The age of this orogenic period of continental collision and subsequent obduction is indicated by the age of its structural features, which are discussed in the Structure section, to be middle to Late Cretaceous.

In summary, southern Alaska is interpreted to have developed geologically by the accretion of an indeterminate number of northwestward drifting continental blocks to the North American continent. After collision, at least parts of these blocks were thrust several hundred kilometers onto the North American continent in middle to Late Cretaceous time. The resulting structural features are truly alpine in character and compare favorably with the classic structures of the Alps in their grandeur and complexity.

A corollary of the present tectonic interpretation of southern Alaska is that the present Denali fault, a middle Tertiary and younger feature (Richter and Jones, 1973), has not played a significant role in the tectonic development of southern Alaska. The eastern, that is strike-slip portion of the Denali fault (Csejtey, 1976), may not have more than a few tens of kilometers of total movement.

An interesting, but still unresolved, tectonic problem in the Talkeetna Mountains region is the shallow depth of the present Benioff zone (Lahr, 1975). The 50-km contour (below sea level) for the upper surface of the Benioff zone strikes northeasterly and is approximately below the Jurassic trondhjemite batholith (unit Jtr). The 100-km contour, also striking northeasterly, is located approximately under the northwest corner of the map area. According to plate tectonic concepts, in conjunction with a subducting system, the top of the undergoing slab should descend at least 100 km below sea level for magma generation. It appears that in the Talkeetna Mountains region there is not enough thickness of upper plate for magma to form. For the Jurassic and older igneous rocks the problem can be explained that these rocks are allochthonous and have been tectonically cut off and transported away from their roots. However, for the Upper Cretaceous and younger igneous rocks, this mechanism cannot be invoked. Two explanations are possible. First, that the present shallow position of the Benioff zone is a relatively recent phenomenon achieved by shearing and cutting away of the base of the upper plate by the downgoing slab. Perhaps the development of the present Denali fault and other middle Tertiary and younger faults of southern Alaska could be related to this process. The other possibility is that all the Upper Cretaceous and younger igneous rocks of the Talkeetna Mountains region were formed in a thin upper plate by exceptionally high heat flow of unknown origin and mechanism (atectonic anatexis by Reed and Lanphere, 1974).

References cited

Anderson, R. E.,,1969, Geology and geochemistry of the Diana Lakes area, western Talkeetna Mountains, Alaska: Alaska Div. Mines and Geology Geol. Rept. 34, 27 p.

Barnes, F. F., 1962, Geologic map of lower Matanuska Valley, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-359.

Berg, H. C., Jones, D. L., and Richter, D. H., 1972, Gravina-Nutzotin belt--Tectonic significance of an upper Mesozoic sedimentary and volcanic sequence in southern and southeastern Alaska, _in_ Geological Survey research 1972: U.S. Geol. Survey Prof. Paper 800-D, p. D1-D24.

Buddington, A. F., 1959, Granite emplacement with special reference to North America: Geol. Soc. America Bull., v. 70, p. 671-747.

Clark, A. L., Clark, S. H. B., and Hawley, C. C., 1972, Significance of upper Paleozoic oceanic crust in the Upper Chulitna district, west-central Alaska Range, _in_ Geological Survey research 1972: U.S. Geol. Survey Prof. Paper 800-C, p. C95-C101.

Csejtey, Béla, Jr., 1974, Reconnaissance geologic investigations in the Talkeetna Mountains, Alaska: U.S. Geol. Survey Open-file Rept. 74-147, 48 p.

_____1976, Tectonic implications of a late Paleozoic volcanic arc in the Talkeetna Mountains, south-central Alaska: Geology, v. 4, p. 49-52.

Csejtey, Béla, Jr., Nelson, W. H., Eberlein, G. D., Lanphere, M. A., and Smith, J. G., 1977, New data concerning age of the Arkose Ridge Formation, south-central Alaska, in Blean, K. M., ed., The United States Geological Survey in Alaska: Accomplishments during 1976: U.S. Geol. Survey Circ. 751-B, p. B62-B64.

Detterman, R. L., Plafker, George, Tysdal, R. G., Hudson, Travis, 1976, Geology and surface features along part of the Talkeetna segment of the Castle Mountains-Caribou fault system, Alaska: U.S. Geol. Survey Map MF-738.

Detterman, R. L., Reed, B. L., and Lanphere, M. A., 1965, Jurassic plutonism in the Cook Inlet region, Alaska, in Geological Survey research, 1965: U.S. Geol. Survey Prof. Paper 525-D, p. D16-D21.

Evernden, J. F., Curtis, G. H., Obradovich, J. D., and Kistler, R. W., 1961, On the evaluation of glauconite and illite for dating sedimentary rocks by the potassium-argon method: Geochim. et Cosmochim. Acta, v. 23, p. 78-99.

Grantz, Arthur, 1960a, Geologic map of the Talkeetna Mountains A-1 quadrangle and the south third of the Talkeetna Mountains B-1 quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-314, scale 1:48,000.

______1960b, Geologic map of the Talkeetna Mountains A-2 quadrangle, Alaska and the contiguous area to the north and northwest: U.S. Geol. Survey Misc. Geol. Inv. Map I-313, scale 1:48,000.

Grantz, Arthur, 1961a, Geologic map of the north two-thirds of Anchorage D-1 quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-343, scale 1:48,000.

_____1961b, Geologic map and cross sections of the Anchorage D-2 quadrangle and northernmost part of the Anchorage D-3 quadrangle, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-342, scale 1:48,000.

_____1964, Stratigraphic reconnaissance of the Matanuska Formation in the Matanuska Valley, Alaska: U.S. Geol. Survey Bull. 1181-I, 33 p.

Grantz, Arthur, Thomas, Herman, Stern, T. W., and Sheffey, N. B., 1963, Potassium-argon and lead-alpha ages for stratigraphically bracketed plutonic rocks in the Talkeetna Mountains, Alaska, in U.S. Geological Survey Research 1963: U.S. Geol. Survey Prof. Paper 475-B, p. B56-B59.

Grantz, Arthur, and Wolfe, J. A., 1961, Age of Arkose Ridge Formation, south-central Alaska: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 1762-1765.

Hillhouse, J. W., 1977, Paleomagnetism of the Triassic Nikolai Greenstone, McCarthy quadrangle, Alaska: Canadian Jour. Earth Sci., v. 14, p. 2578-2592.

Jones, D. L., 1967, Cretaceous ammonites from the lower part of the Matanuska Formation, southern Alaska: U.S. Geol. Survey Prof. Paper 547, 49 p.

Jones, D. L., Silberling, N. J., Csejtey, Béla, Jr., Nelson, W. H., and Blome, C. D., 1978, Age and structural significance of the Chulitna ophiolite and adjoining rocks, south-central Alaska: U.S. Geol. Survey Prof. Paper. (in press).

Jones, D. L., Silberling, N. J., and Hillhouse, John, 1977, Wrangellia --A displaced terrane in northwestern North America: Canadian Jour. Earth Sci., v. 14, p. 2565-2577.

Lahr, J. C., 1975, Detailed seismic investigation of Pacific-North American plate interaction in southern Alaska: New York City, Columbia Univ., Ph.D. thesis, 141 p.

Ray, R. G., 1954, Geology and ore deposits of the Willow Creek mining district, Alaska: U.S. Geol. Survey Bull. 1004, 86 p.

Reed, B. L., and Lanphere, M. A., 1974, Chemical variations across the Alaska-Aleutian Range batholith: U.S. Geol. Survey Jour. Research, v. 2, p. 343-352.

Richter, D. H., and Jones, D. L., 1973, Structure and stratigraphy of eastern Alaska Range, Alaska: Am. Assoc. Petroleum Geologists Mem. 19, p. 408-420.

Rose, A. W., 1967, Geology of an area on the upper Talkeetna River, Talkeetna Mountains quadrangle, Alaska: Alaska Div. Mines and Minerals Geol. Rept. 32, 7 p.

Silberling, N. J., Jones, D. L., Csejtey, Béla, Jr., and Nelson, W. H., 1978, Interpretive bedrock geologic map of part of the Upper Chulitna district (Healy A-6 quadrangle), Alaska Range, Alaska: U.S. Geol. Survey Open-file Rept.

Smith, T. E., 1974a, Newly discovered Tertiary sedimentary basin near Denali: Alaska Div. Geol. and Geophys. Surveys Ann. Rept., 1973, p. 19.

_____1974b, Regional geology of the Susitna-MacLaren River area: Alaska Div. Geol. and Geophys. Surveys Ann. Rept., 1973, p. 3-6.

Smith, T. E., Bundtzen, T. K., and Trible, T. C., 1975, Stratabound copper-gold occurrence, northern Talkeetna Mountains, Alaska: Alaska Div. Geol. and Geophys. Surveys Misc. Paper 3, 7 p.

Turner, D. L., and Smith, T. E., 1974, Geochronology and generalized geology of the central Alaska Range, Clearwater Mountains, and northern Talkeetna Mountains: Alaska Div. Geol. and Geophys. Surveys Open-file Rept. 72, 11 p.

Turner, F. J., 1968, Metamorphic petrology, mineralogical and field aspects: New York, McGraw-Hill, 403 p.

Table 1.--Potassium-argon age determinations from the

Talkeetna Mountains quadrangle and the northern part of

the Anchorage quadrangle, Alaska

Map no.	Location Lat. (N)	Long. (W)	Field No.	Rock type	Mineral dated	K_2O* (weight percent)	$^{40}Ar_{rad}$ $\left(10^{-10}\ \frac{moles}{gram}\right)$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Calculated age*** (millions of years)	Reference
1.	62°59'50"	149°23'48"	75ACy92	Granite (adamellite)	Biotite	7.54(2)	6.218	0.49	57.8±1.7	This report
2.	62°57'25"	148°48'18"	75ACy146	Granodiorite	Biotite	9.08(2)	7.583	0.89	58.6±1.8	This report
3.	62°58'28"	148°25'50"	TT-1-72	Grandiorite	Biotite	--	--	--	58.7±1.7	Turner and Smith (1974)
4.	62°45'46"	149°56'20"	75ACy2	Granite (adamellite)	Biotite	8.68(2)	6.970	0.78	56.3±1.7	This report
5.	62°45'36"	147°18'30"	72ASt290	Diorite or amphibolite	Hornblende	--	--	--	176.6±5.1	Turner and Smith (1974)
6.	62°37'30"	149°24'34"	75ACy7	Granite (adamellite)	Biotite	5.35 (2)	4.468	0.60	58.6±1.8	This report
7.	62°28'38"	149°29'30"	75ASj520	Andesite	Hornblende	0.555(2)	0.4077	0.56	50.4±2.0	This report
8.	62°35'24"	148°53'40"	75ASj521B	Andesite	Whole rock	2.348±0.045(4)	1.757	0.34	51.3±2.5	This report
9.	62°27'28"	148°18'34"	73ACy109	Quartz diorite	Biotite	8.68(2)	18.79	0.92	144±4.3	This report
					Hornblende	0.590(2)	1.365	0.63	154±4.6	This report
10.	62°30'43"	147°52'35"	73ASt275	Trondhjemite	Biotite	--	--	--	148.5±4.3	Turner and Smith (1974)
11.	62°34'55"	147°41'55"	73ASt256	Trondhjemite	Biotite	--	--	--	146.5±4.3	Turner and Smith (1974)
12.	62°18'42"	149°46'32"	73ACy101	Tonalite	Biotite	8.48(2)	6.783	0.83	54.8±1.6	This report
13.	62°16'51"	148°43'26"	75ASj526	Andesite	Whole Rock	0.843(2)	0.6942	0.31	56.3±2.5	This report
14.	62°19'03"	148°10'09"	62AE4	Trondhjemite	Biotite	6.21(2)	13.33	0.91	143±4.3	This report
					Muscovite	9.77(2)	21.49	0.92	146±4.4	This report
15.	62°21'22"	147°49'18"	59AGzM58	Granodiorite	Biotite	--	--	--	174	Grantz and others (1963)
					Hornblende	--	--	--	167±6.0	Detterman and others (1965)

See footnotes at end of table

Table 1.--Continued

Map no.	Location Lat. (N)	Long. (W)	Field No.	Rock type	Mineral dated	K_2O* (weight percent)	$^{40}Ar_{rad}$ $\left(10^{-10} \frac{moles}{gram}\right)$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Calculated age*** (millions of years)	Reference
17.	62°12'50"	148°06'35"	59AGzM26	Quartz diorite	Biotite	--	—	—	173	Evernden and others (1961)
					Biotite	--	—	—	170±6	Detterman and others (1965)
					Biotite	--	--	--	161	Grantz and others (1963)
					Hornblende	--	--	--	163±6	Detterman and others (1965)
18.	62°09'00"	149°13'30"	72ACy117	Quartz diorite	Biotite	9.33	9.207	0.79	67.3±2	Csejtey, 1974
					Hornblende	1.042(2)	9.869	0.77	64.6±2	Csejtey, 1974
19.	62°08'46"	149°18'30"	72ACy127	Tonalite	Biotite	9.30	9.055	0.87	66.4±2	Csejtey, 1974
					Hornblende	0.782(2)	0.7371	0.78	64.3±2	Csejtey, 1974
20.	62°06'27"	148°59'44"	73ACy95	Granodiorite	Biotite	9.64(2)	8.705	0.94	61.7±1.9	This report
					Hornblende	1.024(2)	1.071	0.88	71.3±2.1	This report
21.	62°04'51"	148°45'58"	73ACy114	Trondhjemite	Biotite	9.70(2)	9.643	0.88	67.8±2.0	This report
22.	62°04'49"	148°30'29"	73ACy115	Trondhjemite	Muscovite	9.91(2)	19.98	0.93	135±4.0	This report
					Biotite	9.62(2)	14.16	0.97	99.4±3.0	This report
23.	62°04'38"	149°11'14"	73ACy94	Tonalite	Biotite	9.46(2)	8.593	0.81	61.7±1.9	This report
					Hornblende	0.970(2)	0.8669	0.71	61.0±1.8	This report
24.	61°59'18"	149°25'00"	75ACy135	Granodiorite	Muscovite	10.64(2)	10.21	0.72	67.2±2.0	This report
					Biotite	9.68(2)	9.025	0.67	65.0±2.0	This report
25.	61°56'31"	148°59'38"	73ACy97	Quartz diorite	Biotite	8.70(2)	8.594	0.83	67.4±2.0	This report
					Hornblende	0.918(2)	0.9669	0.72	71.8±2.2	This report
26.	61°56'47"	148°41'04"	74ACy146	Trondhjemite	Muscovite	3.46(2)	6.680	0.69	129±3.9	This report
27.	61°59'33"	148°26'15"	74ACy149	Granodiorite	Biotite	8.06(2)	20.44	0.89	168±5.0	This report
28.	61°49'36"	149°14'30"	60AGz40	Tonalite	Hornblende	0.759(2)	0.8153	0.74	73.1±2.2	This report

See footnotes at end of table

Table 1.--Continued

Map no.	Location Lat.(N)	Long.(W)	Field no.	Rock type	Mineral dated	K_2O* (weight percent)	$^{40}Ar_{rad}$ $\left(10^{-10}\frac{moles}{gram}\right)$	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Calculated ages*** (millions of years)	Reference
29.	61°48'48"	149°12'48"	66AGzW2	Tonalite	Biotite	8.61(2)	8.711	0.89	69.0±2.1	This report
					Hornblende	0.880(2)	0.9475	0.86	73.3±F2.2	This report
30.	61°47'12"	149°13'06"	66AGzW4	Tonalite	Biotite	7.22(2)	7.624	0.91	72.0±2.2	This report
					Hornblende	0.492±0.003(3)	0.5374	0.41	74.4±2.2	This report
31.	61°49'38"	148°53'50"	74ACy151	Trondhjemite	Muscovite	10.58(2)	21.23	0.95	134±4.0	This report
32	61°45'03"	149°25'08"	73ACy17	Serpentinite	Actinolite	0.032**	0.04194	0.064	88.9±4.4	This report
33.	61°43'00"	149°32'30"	73ACy85	Muscovite schist	Muscovite	8.34(2)	7.189	0.85	59.0±1.8	This report
34.	61°43'50"	149°26'05"	73ACy27	Muscovite schist	Muscovite	8.86(2)	8.554	0.89	65.9±3.0	This report
35.	61°44'32"	149°25'28"	73ACy11a	Muscovite schist	Muscovite	9.10(2)	7.928	0.84	59.6±1.8	This report
36.	61°44'03"	149°23'37"	74ASj100e	Serpentinite	Actinolite	0.029**	0.03897	0.10	91.0±4.6	This report
37.	61°46'20"	149°10'20"	76ACy19	Metamorphosed graywacke	Biotite	1.078(2)	1.067	0.45	67.5±2.4	This report

*Mean and, where more than two measurements were made, standard deviation. Number of measurements is in parentheses.

**Potassium determined by isotope dilution. Potassium determined by flame photometry for other samples.

***λ_e = 0.572X10^{-10}yr^{-1}, λ'_e = 8.78X10^{-13}yr^{-1}, $\lambda\beta$ = 4.963X10^{-10}yr^{-1}. $^{40}K/K$ = 1.167X10^{-4}mol/mol. The ± figures are estimates of analytical precision at the 68 percent level of confidence. All previously published ages were recalculated using these decay constants. For this report, potassium analyses were done by L. B. Schlocker, G. E. Ambats, J. G. Smith, H. C. Whitehead, S. T. Neil, and H. L. Silberman; and argon measurements were done by M. A. Lanphere, J. C. von Essen, A. L. Berry, B. M. Myers, S. E. Sims, J. G. Smith, and M. L. Silberman.

Table 2.--*Lead-alpha age determinations on zircon from southeastern part of Talkeetna Mountains quadrangle, Alaska*

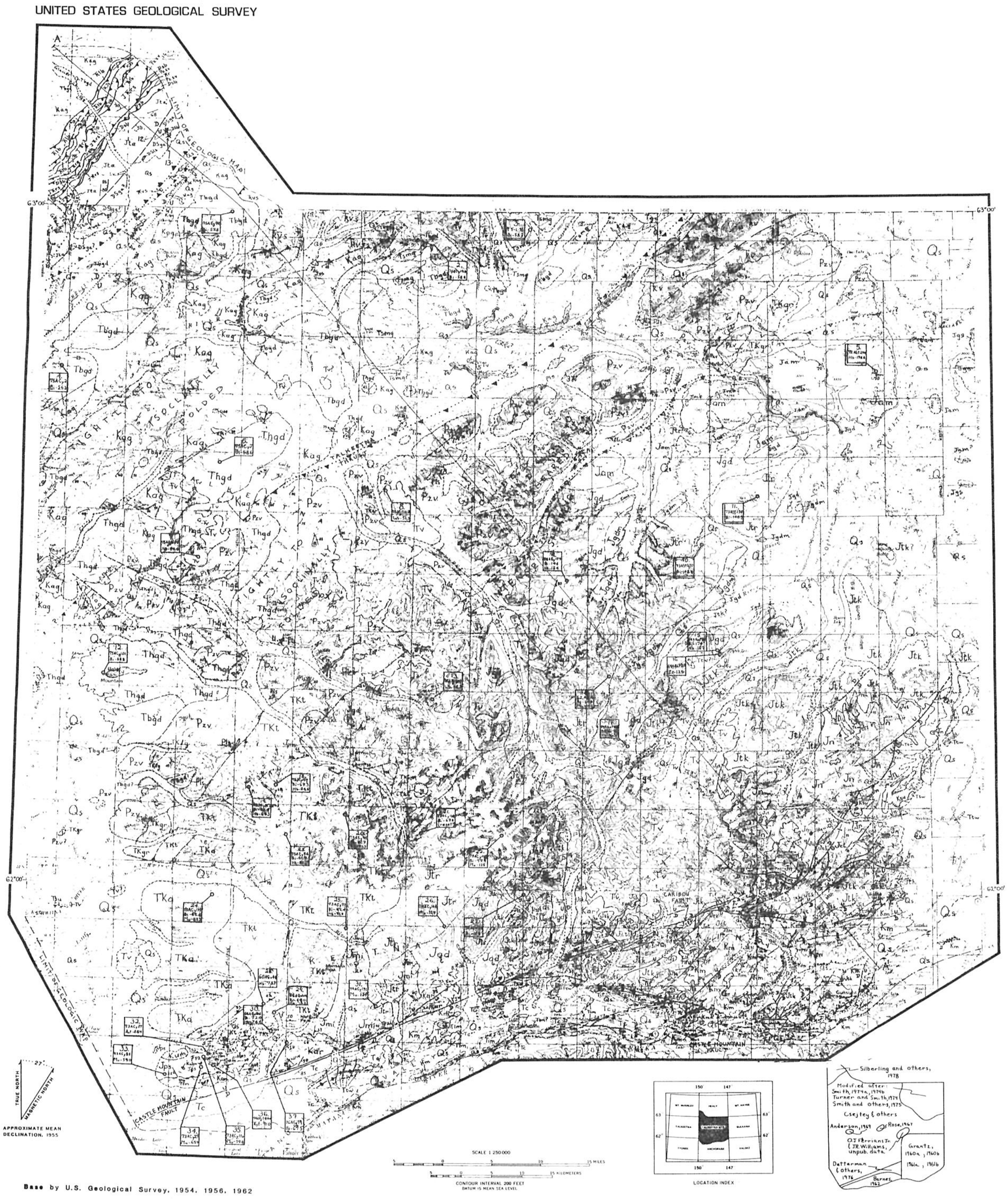
Map no.	Location		Field no.	Rock type	Apparent age (m.y.)	References
	Lat. (N)	Long. (W)				
15	62°21'22"	147°49'18"	59AGzM58	Granodiorite	165±20	Grantz and others (1973)
16	62°21'17"	147°49'12"	59AGzM57	Granodiorite	125±15	Grantz and others (1973)

Table 3.--List of fossils from selected map units (units TRv, Pls, and DSls) in the northwest half of the Talkeetna Mountains quadrangle and the southwest corner of the Healy quadrangle, Alaska

Map number and map unit	Field number	Fossils	Age	Identification and age determination	Reference
1 TRv	73ASt- 63	*Halobia* cf. *H. Symmetrica* Smith	Latest Karnian or Early Norian	K. M. Nichols and N. J. Silberling	T. E. Smith, written commun., 1974.
2 Pls	76ACy- 47	Crinoid columnals 2 cm in diameter; echinoderm and brachiopod debris, indet.	Late Paleozoic	D. L. Jones	This report.
3 Pls	73ASt- 1400	Echinoderm debris, indet. Platycrinitid, indet. (partial cup and columnals). Horn coral, indet. Fenestrate and ramose bryozoans, indet. (abundant). *Sulcoretepora*? sp. Rhynchonelloid brachiopod, indet. Productoid brachiopod (large, indeterminate). Spiriferoid brachiopod (perhaps *Spiriferella*). Martinioid brachiopod (perhaps *Pseudomartinia*). Phricodothyrid brachiopod fragments, indet. Punctate brachiopod (perhaps *Hustedia*). Pelecypods, indet. (several kinds). Pectenoid pelecypods, indet.	Late Paleozoic, probably Permian	T. J. Dutro, Jr.	T. E. Smith, written commun., 1974.
4 Pls	72ACy- 15, 72ACy- 21	Crinoid columnals as much as 1.6 cm in diameter. Bryozoan, indet. Brachiopod and coral fragments.	Probably late Paleozoic	A. K. Armstrong	Csejtey, 1974.
5 Pls	73ASt- 309	Echinoderm debris, indet. Fenestrate and ramose bryozoans, indet. Horn coral, indet. Productoid brachiopod (indeterminate).	Late Paleozoic, possibly Permian	J. T. Dutro, Jr.	T. E. Smith, written commun., 1974.
6 Pls	74ACy- 7	Crinoid columnals 1 cm in diameter.	Probably Paleozoic	A, K. Armstrong	This report.
7 Pls	75ANw- 10	*Horridonia*? sp. Spiriferoid brachiopod. Crinoid columnals as much as 1.5 cm in diameter.	Late Paleozoic, probably Permian	A. K. Armstrong	-----Do.----
8 Pls	74ACy- 16	*Arctitreta* sp. *Horridonia* sp. *Spiriferella* sp. Echinoderm debris, indet. Crinoid columnals as much as 2.5 cm in diameter.	Early Permian	J. T. Dutro, Jr.	Csejtey, 1976.
9 Pls	74ACy- 80	Crinoid columnals as much as 1.5 cm in diameter.	Probably Paleozoic	A. K. Armstrong	This report.
10 Pls	74ACy- 21	Crinoid columnals as much as 1 cm in diameter.	------do-------	-------do------	-----Do.----
11 Pls	74ACy- 43	-----------------do----------------	------do-------	-------do------	-----Do.----
12 DSls	75ANw- 75	*Dendrostella*? sp. Massive stromatoporoid, indet.	Devonian, probably Middle Devonian	W. A. Oliver, Jr.	-----Do.----
13 DSls	75ANw- 76	*Labechia* sp. *Favosites* sp.	Silurian or Devonian	-------do--------	-----Do.----

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

OPEN FILE REPORT
78-558A

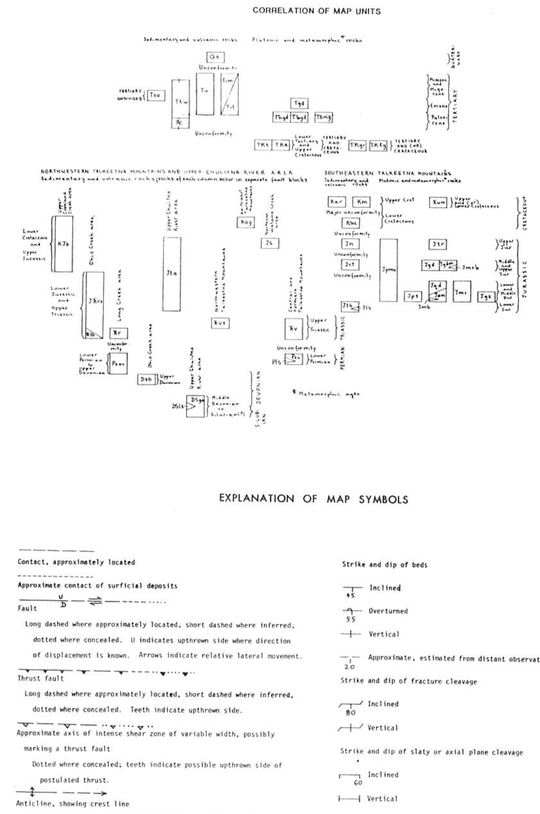


Base by U.S. Geological Survey, 1954, 1956, 1962

LOCATION INDEX

INDEX TO GEOLOGIC MAPPING

CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Contact, approximately located

Approximate contact of surficial deposits

Fault

Long dashed where approximately located; short dashed where inferred; dotted where concealed. U indicates upthrown side where direction of displacement is known. Arrows indicate relative lateral movement.

Thrust fault

Long dashed where approximately located, short dashed where inferred, dotted where concealed. Teeth indicate upthrown side.

Approximate axis of intense shear zone of variable width, possibly marking a thrust fault

Dotted where concealed; teeth indicate possible upthrown side of postulated thrust.

Anticline, showing crest line

Long dashed where approximately located; arrow indicates plunge.

Syncline, showing trough line

Long dashed where approximately located; arrow indicates plunge

Location of sample dated by the U.S. Geological Survey using the potassium-argon or the lead-alpha method, showing map number, field number, and the calculated mineral age. Map number refers to sample number in table 1 or table 2. Bi - biotite, Hb - hornblende, Mu - muscovite, Act - actinolite, Zr - zircon, wr - whole rock.

Location of sample dated by Turner and Smith (1974) using the potassium-argon method, showing map number, field number, and the calculated mineral age. Map number refers to sample number in table 1. Bi - biotite, Hb - hornblende.

X 4

Fossil locality in units TRv, Pls, and DSls. Map number refers to sample number in table 3

Strike and dip of beds

- 45 Inclined
- 55 Overturned
- Vertical
- 20 Approximate, estimated from distant observations

Strike and dip of fracture cleavage

- 80 Inclined
- Vertical

Strike and dip of slaty or axial plane cleavage

- 60 Inclined
- Vertical

Strike and dip of shear planes, metamorphic foliation or schistosity

- 30 Inclined
- Vertical

Strike and dip of igneous flow foliation

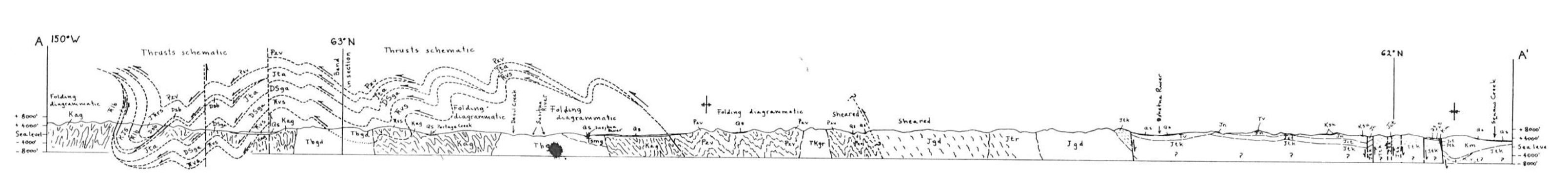
- 30 Inclined
- Vertical

Bearing and plunge of lineation

- 30 Inclined
- Horizontal

Strike and dip of joints

- 60 Inclined
- Vertical



RECONNAISSANCE GEOLOGIC MAP AND GEOCHRONOLOGY, TALKEETNA MOUNTAINS QUADRANGLE, NORTHERN PART OF ANCHORAGE QUADRANGLE, AND SOUTHWEST CORNER OF HEALY QUADRANGLE, ALASKA

By

Béla Csejtey, Jr., W.H. Nelson, D.L. Jones, N.J. Silberling, R.M. Dean, M.S. Morris, M.A. Lanphere, J.G. Smith, and M.L. Silberman

1978

SECTION E

ENVIRONMENTAL ASSESSMENT

SECTION E

ENVIRONMENTAL ASSESSMENT

TABLE OF CONTENTS

INTRODUCTION

In the almost 4 years since the original environmental assessment (EA) was prepared, much new information has been made available through the efforts of various Federal and State agencies. Some of the information would result in minor changes in the EA if incorporated. These minor changes would not substantially alter the reader's perception of the proposed project or its environmental impacts. Such information has therefore not been incorporated in this supplement. Some of the new information, however, could substantially alter the reader's perception of the proposed project or its environmental impacts. This type of new information has been summarized in this supplement. It should be noted, however, that the information obtained to date is only preliminary and lacks needed details and that additional biological and social information remains to be gathered in the future in order to complete an adequate and meaningful assessment of environmental impacts.

SUMMARY OF CHANGES

There is new biological information related to moose. In general, moose occupy the upper Susitna River basin to a greater degree than previously thought.

Also, archeological studies conducted by the Alaska District have resulted in archeological finds of potentially significant cultural value.

As a result of this new information, the potential for additional environmental impacts has been recognized, and the importance of previously identified impacts has been reevaluated. Impacts to moose will probably be far more significant than previously believed. Impacts on archeological resources could be potentially significant if not properly mitigated.

A discussion of the recognition of the need for a Section 404(b) evaluation has been added to address the requirements of the Federal Water Pollution Control Act and the Clean Water Act. An evaluation of flood plain considerations as per Executive Order 11988 has also been added.

Land use is in a constant state of change because of the Alaska Native Claims Settlement Act, the Federal Land Policy and Management Act, and various other regulations related to wilderness. A short update on these land use considerations has been added.

ENVIRONMENTAL SETTING

BIOLOGICAL CHARACTERISTICS

Mammals - Moose

Moose range throughout the entire Susitna River basin, and their numbers in the basin have fluctuated widely since the early 1900's. The population reached a peak in the early 1960's, then began a decline that has continued to the present time. Factors contributing to the decline have included loss of productive browse habitat as a result of effective fire suppression over the past two decades, a rapid increase in predator populations following cessation of control efforts in the mid-1950's, and a number of severe winters with deep accumulations of snow.

The preliminary movement data gathered thus far by the Alaska Department of Fish and Game (ADF&G) indicate that moose from several surrounding areas migrate across or utilize the portion of the upper Susitna River basin adjacent to the river during some portion of the year. ADF&G recorded observations of 2,037 moose during the fall 1977 counts. Studies indicate that an observer generally sees between 43 to 68 percent of the moose in an area during an aerial survey. Using 50 percent to extrapolate roughly, the resident population using the upper Susitna basin probably falls between 4,000 and 5,000 moose. This is a substantial increase when compared with 1973 figures which estimated the upper basin population at approximately 1,800 animals. This wide diversity in population estimates can be attributed to better research techniques and improved population estimating methods.

Present information indicates that moose depend heavily upon the river bottom and adjacent areas for winter habitat and calving areas, both above and below the Watana and Devil Canyon damsites. Increasing snow depths above timberline trigger moose migrations to the wintering areas in the lowlands. Additional observations of moose during normal and severe winter conditions are necessary to determine the importance of the area as critical winter range.

CULTURAL CHARACTERISTICS

Archeological Resources

An archeological reconnaissance was conducted by the Corps of Engineers in 1978 for the purpose of clearing specific sites within the project area so that geological investigations could be conducted. Four sites were found in the Watana damsite area which range in age from 3,700 to 12,000 years old. These sites, generally located on top of small knolls, were probably associated with the hunting activities of primitive man. No base camps or kill sites were found but they must also exist. The number of sites found shows that the potential for other finds is extremely high and indicates that prehistoric use of the area appears to have been considerable. At the present time, the sites found have not been nominated for inclusion on the National Register.

ENVIRONMENTAL IMPACTS OF THE DEVIL CANYON - WATANA HYDROPOWER PLAN

MAMMALS - MOOSE

According to ADF&G surveys conducted in 1977, construction of the Watana dam would have a highly detrimental effect on moose populations in that inundation of the lower, spruce-covered reaches of the Watana Creek valley, which are probably critical moose habitat, would substantially reduce the carrying capacity of the area. In addition, construction of the Devil Canyon dam would also adversely impact moose populations and substantially reduce the carrying capacity of a major portion of the Devil Creek drainages. The Devil Canyon impacts are not expected to be as significant as the Watana impacts because of the marginal habitat and limited moose populations in the Devil Canyon area.

Present information indicates moose depend heavily upon the river bottoms and adjacent areas for winter habitat both above and below the Watana and Devil Canyon damsites. Lack of adequate wintering areas in the lower Susitna valley below the Devil Canyon damsite has been a major limiting factor to moose population growth in the past. Most existing winter range is along the major rivers where periodic flooding has caused rechanneling of the main stream, allowing riparian willow to colonize the dry streambeds. Regulating the flow of water from the dam at Devil Canyon may have a highly detrimental effect on growth of riparian vegetation downstream to the mouth of the Susitna. It is possible that maintaining a steady flow of 8,000 to 10,000 cubic feet per second from the Devil Canyon dam would effectively prevent the flooding activity that presently occurs periodically. This could create a short-term abundance of winter range along the riverbanks that might last 30 or more years. The net long-term effect could well be a negative one, however, as it is suspected that the present natural flooding activity of the Susitna River produces favorable conditions for browse production. Without the annual floods, these riparian areas could become mature stands of hardwoods after 25 or 30 years and provide little or no winter forage. Research on riparian vegetation habitat types and associated moose usage downstream of dam construction is essential to determine potential impacts on moose populations.

Construction of the Devil Canyon dam would flood approximately 7,500 acres. The riverbanks along this portion of the river are generally steep and provide marginal moose habitat. Since water levels in the Devil Canyon reservoir will remain fairly constant, low mortality rates associated with ice shelving and steep mudbanks would be expected.

Construction of the Watana dam would result in the flooding of approximately 43,000 acres along Watana Creek and the Susitna River. Approximately 35,000 acres sustain moderate to heavy utilization by moose during an average winter. Data gathered by ADF&G indicate that moose from several surrounding areas of the Susitna basin migrate across or utilize this portion of the river during some period of the year. Effects of the construction of the Watana dam on moose populations could be substantial. The resident nonmigratory segment of the population could be eliminated. Migratory moose could also be substantially effected in that the reservoir could be an effective barrier to migrations during some seasons. Due to large fluctuating water levels, ice shelving and steep mud banks could be expected to cause high mortality among moose, especially calves.

This discussion of impacts on moose populations within the upper Susitna River basin is substantially different from the discussion contained in the 1976 Interim Feasibility Report, which predicted that the proposed project "would affect only a small percentage of the upper Susitna moose population." The newly gathered information has resulted in the reevaluation of previously identified impacts and the recognition that additional impacts potentially exist which may be important.

ARCHEOLOGICAL RESOURCES

An archeological reconnaissance conducted by the Corps of Engineers in 1978 resulted in the finding of several previously unknown archeological sites in the Watana damsite area. This reconnaissance indicates that the potential for other finds is extremely high. Intensive archeological surveys will be conducted during the project feasibility analysis to conform with cultural resource regulations. If the project is determined to be feasible, a program will be conducted to salvage archeological sites which will be impacted by the project.

SECTION 404(b) EVALUATION

To date a Section 404(b) evaluation (Discharge of Dredged or Fill Materials into Waters of the United States) under the Federal Water Pollution Control Act of 1972 (Public Law 92-500) as ammended has not been performed. A 404(b) evaluation will be performed with data gathered during the project feasibility analysis.

EXECUTIVE ORDER 11988 (FLOOD PLAIN) EVALUATION

In compliance with Executive Order 11988 the items under Paragraph 8 of General Procedures have been considered as follows:

1. The project is designed to impound water behind two dams in the natural channel of the river. The basic conditions of this hydropower project present no economically feasible alternatives.

2. The construction of the project will cause only minor induced development in the immediate area since the product (energy) will be transmitted to existing population centers far removed from the project site.

3. The natural and beneficial values of the flood plain will be disrupted only at the site of the reservoir and powerplant. Revegetation programs will be adopted to restore slopes along construction sites and roadways.

4. As the project progresses from its initial phase to the design and construction phases, there will be a continuing evaluation and dialogue with local interests and concerned agencies who will have constant input to the study.

RELATIONSHIP OF THE PROPOSED DEVELOPMENT TO LAND USE PLANS

Lands within the upper Susitna River basin are essentially in large block ownership with the majority under the control of the Department of the Interior, Bureau of Land Management (BLM). These lands are generally in their natural state and undeveloped with improvements or land access routes. Air transportation is the primary means of access to and within the area. There are some scattered small parcels of land in private ownership as homestead sites or mining claims. Many of these private parcels have no developed overland access. For the most part, development in the area is concentrated along the established transportation routes such as the Parks Highway and the Alaska Railroad on the west and the Denali Highway on the north.

Because of the absence of roads and other development in the basin, the area is subject to Section 603 of P.L. 94-579, "The Federal Land Policy and Management Act of 1976." This section provides for the protection and study by BLM of roadless areas of public land containing 5,000 or more acres. The intent is the protection of potential wilderness area values pending a determination of the ultimate classification and use of such lands. During the allotted 15 year study period, any use of the lands is subject to BLM authorization and must be conducted "...in a manner so as not to impair the suitability of such areas for preservation as wilderness...". Consequently, any development or construction in the area would be precluded pending a determination and classification by BLM.

Most of the public lands in the basin have been selected by Native corporations under the Alaska Native Claims Settlement Act (ANCSA), as amended of 18 December 1971. These selected lands remain under the jurisdiction of BLM pending final conveyance of fee simple title to the various Native corporations. Any use of these lands prior to conveyance of title is subject to specific permission from BLM with the concurrence of the various concerned Native groups.

The gross land area required (lands which must be acquired) for containment of the proposed Devil Canyon and Watana reservoirs is approximately 157,440 acres. Of this land, 67,200 acres are to be conveyed to the Cook Inlet Region, Incorporated (CIRI) for later reconveyance to various village corporations. This transfer of lands is directed by a 1976 amendment to ANCSA, P.L. 94-456 and will include both the surface and subsurface interests. This transfer also includes lands within Power Site Classification No. 443 which was established in 1958 for potential future development of the Susitna River for hydroelectric power production.

In addition to the lands discussed above, as many as 53,760 acres have been selected for conveyance to satisfy any deficiencies that may exist in total acreage entitlements under ANCSA. These "deficiency" selections in the area have a selection priority of nine (9) and, in all probability, will not be conveyed to CIRI on behalf of the village corporations. These lands have, however, been overselected by CIRI for its own benefit and could conceivably be conveyed to CIRI. A portion of these lands south of the Susitna River (24,686 acres) has been made available for selection by the State of Alaska pursuant to the agreement titled "Terms and Conditions for Land Consolidation and Management in the Cook Inlet Area" (Cook Inlet Land Swap Agreement). The State's right to select these lands for conveyance is superior to that of CIRI but is inferior to valid village corporation selections. Since the village corporation selections are priority nine (9) it is probable that the State could receive the title to the lands.

The remaining area within the proposed reservoir boundaries (36,480 acres) is controlled by BLM and has been withdrawn from appropriation for either study and classification or for selection by CIRI as a "deficiency" selection area. Again, this "deficiency" selection is an excess, or overselection, to make lands available for satisfaction of total acreage entitlements. Conveyance of any portion of such selected lands is limited to fulfillment of acreage entitlements and is indeterminable at this time. As discussed above, the State of Alaska will have a right to select a portion of this area south of the Susitna River (5,120 acres), and such a selection would be superior to that of CIRI.

LITERATURE CITED

Bacon, Glenn. Archeology in the Upper Susitna River Basin 1978. Army Corps of Engineers, Alaska District, 1978.

Riis, James C., and Nancy V. Friese. "Fisheries and Habitat Investigations of the Susitna River--A Preliminary Study of Potential Impacts of the Devils Canyon and Watana Hydroelectric Projects," Preliminary Environmental Assessment of Hydroelectric Development on the Susitna River. Alaska Department of Fish and Game for the U.S. Fish and Wildlife Service, March 1978.

Taylor, Kenton P. and Warren B. Ballard. "Moose Movements and Habitat Use Along the Upper Susitna River--A Preliminary Study of Petential Impact of the Devils Canyon Hydroelectric Project," Preliminary Environmental Assessment of Hydroelectric Development on the Susitna River. Alaska Department of Fish and Game for the U.S. Fish and Wildlife Service, March 1978.

U.S. Army Corps of Engineers, Alaska District. Plan of Study for Susitna Hydropower Feasibility Analysis. Prepared for the State of Alaska, June 1978.

SECTION F

RECREATIONAL ASSESSMENT

None of the OMB comments were directed at the recreational aspects of the project. Therefore, no additional recreation studies were undertaken.