SUSITNA HYDROELECTRIC PROJECT

SUMMARY OF ALASKA POWER AUTHORITY DESIGN REFINEMENTS TO FEDERAL ENERGY REGULATORY COMMISSION LICENSE APPLICATION

1. Introduction

This report describes proposed design refinements to the Susitna Hydroelectric Project License Application filed by the Alaska Power Authority (Power Authority) in February, 1983, which have been developed by the Power Authority as a result of recently conducted geotechnical investigations.

1.1 Watana Dam Design Refinements

The proposed design refinements for Watana Dam are as follows:

1. Reduced bedrock and alluvium excavation treatment for the dam embankment foundation.
2. Revised configuration and composition of the dam and the cofferdams' internal zoning.
3. Revised vertical setting and size of diversion tunnels and increased cofferdam height.
4. Relocation and reorientation of the transformer gallery, powerhouse and surge chamber caverns.
5. Revised arrangement of power conduits and power intake.
6. Increase in size of main service spillway to pass the Probable Maximum Flood (PMF) and elimination of the emergency (fuse-plug type) spillway.
7. Revised layout of approach channels to the power intake and spillway.
8. Construction facilities reduced in accordance with reductions in construction work.

9. Rotational speed of turbine-generator units increased from 225 to 257.1 rpm.

10. Underground SF6 gas-insulated switchgear and SF6 gas-insulated bus to the ground surface selected instead of an open-air switchyard supplied by oil-filled main leads from the underground powerhouse.

11. Selection of open-cut trench instead of tunnel for spillway chute drainage.

1.1.1 Excavation and Foundation Treatment for Dam

The main dam foundation treatment, as refined, would reduce rock excavation beneath the core and shells and limit excavation of the river valley alluvium to the central 80% of the dam foundation.

The areas of the dam in proximity to the upstream and downstream toes of the embankment are now planned to be founded on the riverbed alluvium, with the central 80% to have a bedrock foundation.

The 1983 Winter Geologic Explorations have shown that the bedrock is of a better quality than originally anticipated. Therefore, only limited excavation of bedrock beneath the embankment is foreseen in the river channel. Fresh hard diorite in most instances exists from the bedrock surface. Removal or foundation treatment (dental excavation of concrete backfill) will be performed in local areas beneath the shells where erodible or otherwise unsatisfactory foundation bedrock is encountered. The quantity of rock to be removed under the embankment will be reduced from that estimated in the License Application by about 3.75 million cubic yards. The License Application cost estimates assumed a trench beneath the impervious core and filters averaging 40 feet deep, and an average excavated depth under the shells of 10 feet. The design refinement provides a core trench 10 feet deep in the river section, and 20 feet deep on the abutments. Excavation under the shells on the abutments averages one foot. A reduction in the total length of grout gallaries, grout drilling, and grouting was also made in view of the better quality foundation bedrock.

1.1.2 Dam and Cofferdam Configuration and Composition

The License Application design for the dam cross section has been essentially retained as it is considered to be satisfactory and will produce a stable structure. To increase safety against seismic shaking, the steepening of the exterior slopes near the embankment crest has been eliminated. This results in the same exterior slope from crest to toe both upstream and downstream. The embankment internal zoning design has also been modified to incorporate materials from the required excavations along with by-product materials from the processing operations. The refined layout includes the use of rock and processed granular materials in the shells outside the impervious core. This section increases the utilization of available materials and will reduce required borrow as well as reduce spoil requirements.

The cofferdam sections were revised to a more conservative design and a positive slurry trench cutoff to bedrock would be provided.

1.1.3 Vertical Setting and Size of Diversion Tunnels and Cofferdam Heights

The two diversion tunnels as shown in the License Application were 38 foot diameter concrete lined. The total discharge capacity is 80,500 cfs. One tunnel has an intake portal invert below the riverbed level, while the other is 70 feet higher. With the deep alluvium in the riverbed upstream, the low tunnel could result in sediment deposition during flood recession. This tunnel could be partially filled with gravel thereby reducing its hydraulic capacity for the next flood season. Therefore, the refinement consists of raising the intake portal invert of the lower tunnel to El. 1445. The refinements also consist of adjusting the location and orientation of the tunnels based on more recent geological information and lowering the upper tunnel for greater hydraulic efficiency which permits decreasing the diameters of both tunnels to 36 feet.

The cofferdam locations would simultaneously be adjusted to utilize the reduced excavation of alluvium in the dam foundation. The length of the upstream cofferdam would be reduced by relocating it further downstream. The freeboard of the cofferdam was increased to provide additional safety against ice pileup or higher water levels caused by ice jams.

A comparison of the refined design with the License Application follows:

	License Application	Refined Design
Tunnel 1 U/S Invert El.	1490	1468
Tunnel 1 D/S Invert El.	1450	1455
Tunnel 2 U/S Invert El.	1420	1445
Tunnel 2 D/S Invert El.	1405	1430
U/S Ice-Free Water Level El.	1535	1532
U/S Cofferdam Crest El.	1545	1550
U/S Cofferdam Freeboard (ft.)	10	18
D/S Ice-free Water Level El.	1468	1468
D/S Cofferdam Crest El.	1472	1495
D/S Cofferdam Freeboard (ft.)	4	27

1.1.4 Relocation and Reorientation of Caverns

A review of the site geology indicated a major set of fractures which trended N 50°W and a second minor set perpendicular to these. The caverns for the powerhouse, transformer gallery, and surge chamber, as shown in the License Application, trend in a direction approximately N 20°W, straddling between the major joint system and a subjoint system.

Excavation of the longitudinal walls would be improved if the major joint planes were to intersect the walls as near to the perpendicular as possible. Consequently, the caverns were rotated accordingly. This change will result in less over break of rock in the cavern faces, lessen construction problems and contribute to greater safety during construction. This change was also beneficial to the changes in the water conduit and access tunnel geometry described below.

1.1.5 Power Conduits and Intake

The License Application indicates a single structure power intake with six intake passages located approximately 1 000 feet upstream from the dam axis. The power conduits consist of six individual penstocks, tunnel and shafts with a developed length of about 1,500 feet each connecting the intake structure to the powerhouse, and two trailrace tunnels approximately 2,000 feet long connecting the powerhouse to the river. The downstream 300 feet of one of the trailrace tunnels utilized the downstream portions of one of the diversion tunnels.

To reduce the power conduit length in the design refinement, the intake structure was shifted to a location between the spillway and the river channel and nearer to the dam axis resulting in relocation and shortening of the power conduits. The number of penstock tunnels was reduced from six to three, each of which bifurcates to smaller penstock tunnels at a point approximately 200 feet upstream from the powerhouse. Guard valves will be provided for each turbine. The net head on the generating units will be greater, and the shorter, more efficient power conduits will provide better unit operation. Overall, the three power tunnel design will be more cost effective than the six penstock tunnel design. Vertical shafts are also recommended instead of sloping shafts because excavation and concreting of vertical shafts requires less time, personnel, and equipment, and given the geologic conditions, should result in less over break.

1.1.6 Spillways

The License Application shows provisions for dual spillways. In this concept, the service spillway, the outlet works, and two generating units would discharge flows corresponding to floods with 1:10,000 year occurrence probability (Exhibit E, pp. E-2-107 4.1.3, (a), (iii)). For larger floods, the reservoir would be surcharged to a maximum of El. 2201, during the PMF event. Prior to reaching that reservoir level the fuse-plug would begin to be breached and after a period of time, would be fully eroded. The service spillway and fuse-plug emergency spillway would then reach their peak discharge of 152,000 cfs and 120,000 cfs, respectively. This spillway concept would allow passing of the PMF without overtopping the dam. During the PMF, the minimum reservoir freeboard would be 4 feet.

An alternative spillway arrangement of a gated, single spillway has been studied, sized for the PMF with criteria of maintaining the same freeboard as the dual spillway scheme and the same safety against dam overtopping. Although this review process was initiated to seek lower costs, elimination of the fuse-plug was considered a benefit environmentally, aesthetically, and, to some extent, to dam safety. Questions had been raised by FERC in their request for supplemental information of April 12, 1983 (See Comment No. 2 regarding Exhibit F, at p. 34) as to the safety of the fuse plug against adverse conditions of freezing weather. While the response to the comment indicated that the design could be arranged with proper selection of granular materials to erode under freezing conditions successfully and thereby provide the desired flood release, elimination of the fuse-plug structure would eliminate all risk of the fuse-plug not operating.

Inasmuch as a gated spillway is required in both the single and dual spillway concepts, and the reliability of a given gate design is not materially affected by its size, the larger single spillway design, absent the fuse-plug, has equivalent or slightly enhanced safety over the dual spillway design in the License Application. A more tangible benefit of the single spillway design over the dual spillway design included in the License Application is its lower cost for the same total design capacity.

Moreover, the analyses led the Power Authority to conclude that a single spillway design had certain environmental advantages in addition to being as safe and as effective as the dual spillway design. Environmental advantages to the single spillway scheme are as follows:

a) Visual impact of the project would be reduced by eliminating the fuse-plug spillway. Because of the significant extent of the cut for this water passage, its elimination could be considered a major improvement in project aesthetics.

b) The overall ground surface areas that would be disturbed by construction would be reduced. Construction of the License Application main service spillway would entail disturbing approximately 13 acres, and construction of the emergency spillway would entail disturbing 55 acres, resulting in disruption to a total of 68 acres for the dual spillway scheme. The single spillway design would require disturbance of approximately 22 acres, thus resulting in a net reduction of 46 acres of ground surface to be disturbed by construction.

c) With either the single or dual spillway scheme, the main service spillway would be operated only for floods greater than the 1:50 year occurrence. For smaller floods, spill discharges in excess of power flows would be made with the fixed cone valves. Thus, there would be no difference in environmental consequences for either the single or dual spillway design for such flows.

d) For flows between the 1:50 and 1:10,000 year flood flow, only the gated service spillway would be operated with the dual spillway scheme (the fuse-plug would remain intact). Service spillway operation for the dual spillway scheme in this flow range would have environmental effects substantially equal to the larger gated service spillway being proposed in the single spillway scheme.

This statement can be amplified as follows:

FACTOR (For any given flow in the range considered)	ESTIMATED EFFECT OF SERVICE SPILLWAY OPERATION: SMALL SPILLWAY (License Application)	LARGE SPILLWAY (Proposed Refinement)
1. Operating Head	Same	Same
2. Height of spillway bucket exit above tailwater	Same	Same
3. Approximate width of spillway chutes exit	80 Feet	120 Feet
4. Chute exit velocity	Reference Value	Same or slightly less because of increased air and skin friction drag
5. Flow energy concentration (Energy per unit width of chute requiring dissipation)	Reference	Lower by approximately 33%
6. Plunge depth	Reference Value	Same or slightly less because of lower unit energy in the impact area
7. Gas supersaturation	Reference	Same or slightly less

8.	Riverbed erosion	Reference	Same or slightly less
9.	Riverbank erosion	Same	Same

While it can be argued that the absolute differences of the factors cited above may be infinitesimal in those cases which are presented as "slightly less," it is the intent of the above presentation to show, at the least, environmental equivalence between the two schemes in the flow range considered. For both spillway schemes and for any given flood flow between the 1:50 year up to the 1:10,000 year event, all flows higher than the hydraulic capacity of the turbines and the cone valves will be passed over the service spillway with resultant erosion and gas supersaturation effects. While logic clearly dictates that these effects will necessarily be less for the large spillway, the differences cannot be quantified in any meaningful way using existing state-of-the-art analyses.

e) For floods of the 1:10,000 year or greater recurrence interval, the proposed larger service spillway would eliminate severe erosion of about 60 acres which would be associated with operation of the fuse-plug spillway as described in the License Application. However, a 1:10,000 year or greater event which differentially impacts only 60 acres is not within a reasonable range of importance to be seriously considered from an environmental point of view.

Thus, a single spillway with the capacity to pass the PMF while maintaining the same reservoir surcharge criterion is recommended.

The design refinement also recommends use of radial gates instead of vertical lift gates as shown in the License Application. A radial gate installation would cost less than a vertical gate installation and is the usual choice for operation under subfreezing conditions.

1.1.7 Power Intake and Spillway Approach Channels

The hydraulic conditions of the approach channels to the power intake and spillway as shown in the License Application can be improved with the relocation of the powerhouse and the power conduits. In the License

Application, the power intake is located such that it appears to impede flow to the spillway. The design refinement location of the power intake will eliminate this effect. The approach channels as refined will require larger quantities of rock excavation; however, this material can be used to fill in the dam and for concrete aggregate.

1.1.8 Construction Facilities

The lower construction quantities will reduce labor requirements thereby reducing the size of the construction camp and catering services.

1.1.9 Turbine-Generator Unit Speed

The design refinement consists of increasing the synchronous speed of the turbine-generator units from 225 rpm as shown in the License Application to 257.1 rpm.

Basically, a higher speed unit requires a deeper setting of the turbine distributor below tailwater. The depth shown in the License Application is, however, lower than necessary for the 225 rpm turbine and is also sufficient for the 257.1 rpm turbine. This increase in speed will reduce the physical size and cost of the turbine-generator set and also may possibly result in some reduction in the powerhouse size at the time the final design is made.

1.1.10 Gas Insulated Switchgear and Bus

Revisions of the high voltage conductors from the main power transformers to the ground surface and elimination of the ground level switchyard by use of SF6 gas insulated switchgear and bus are proposed in the design refinement. These revisions include use of a single 9' -0" diameter vertical SF6 bus shaft instead of two vertical 7' -6" diameter cable shafts from the transformer gallery to the surface. All switching equipment will be underground thus simplifying maintenance. This refinement will provide an improved environment for operation and maintenance by elimination of the potential for icing of equipment in ground level switchboard. Substitution of SF6 buses for oil-filled cables will improve safety by removal of fire hazards from the cable shaft area. Elimination of the switchyard will also reduce environmental impact and improve aesthetics by the construction of fewer and smaller surface structures.

1.1.11 Spillway Chute Drainage

Drainage of the spillway chute as shown in the License Application consists of a drainage tunnel excavated 30 feet below the chute slab under the longitudinal centerline of the chute. Angled drainage holes would lead from box drains under the chute slab to the drainage tunnel. The design refinement consists of substituting for the drainage tunnel a gallery excavated in an open cut trench also along the longitudinal centerline of the chute. Box drains would then lead to this gallery. This refinement simplifies the construction procedure from that of a tunnelling operation to open cut excavation.

1.2 Devil Canyon Development Design Refinement

The design refinement proposed for Devil Canyon Development consists of increasing the main service spillway capacity to pass the PMF, thereby allowing elimination of the fuse-plug type emergency spillway shown in the License Application.

This refinement provides the following listed advantages to which the discussion provided under 1.1.6 for the same Watana development feature also applies:

a) The larger single spillway will be less costly than the dual spillways.

b) Eliminating the fuse-plug type emergency spillway will reduce visual impact and improve aesthetics.

c) The net ground surface areas to be disturbed by construction can be reduced. Construction of the License Application service and emergency spillways are approximately 12 and 15 acres, respectively for a total of 27 acres. The enlarged single spillway would require disturbance of approximately 15 acres resulting in a reduction by 12 acres of ground surface disturbance.

d) No net differential environmental impacts due to operation of the spillway will result for flows up to the 1:10,000 year flood, as previously described for Watana.

e) The wider gates, chute and flip bucket will pass the frequent floods with less intensity of discharge.

BEFORE THE

FEDERAL ENERGY REGULATORY COMMISSION

APPLICATION FOR LICENSE FOR

MAJOR PROJECT

SUSITNA HYDROELECTRIC PROJECT

(Project No. 7114-000)

Revised
Exhibit D
Tables
August, 1984

EXHIBIT D

SUMMARY OF COST ESTIMATE

(Prepared by Harza-Ebasco - August 1984)

ALL COSTS ARE AT JANUARY 1982 PRICE LEVEL

AND TRANSMISSION PLANT COSTS ARE AS ESTIMATED BY ACRES

REVISED TABLE D.1: SUMMARY OF COST ESTIMATE

JANUARY 1982 DOLLARS $ X 10^6

CATEGORY	WATANA	DEVIL CANYON	TOTAL
Production Plant	$2,053	$ 983	$3,036
Transmission Plant	456	105	561
General Plant	6	6	12
Indirect	379	171	550
Total Construction	$2,894	$1,265	$4,159
Overhead Construction	467	204	671
TOTAL PROJECT	$3,361	$1,469	$4,830

REVISED TABLE D.2: ESTIMATE SUMMARY - WATANA

JANUARY 1982 PRICE LEVEL

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
330	Land & Land Rights....................	$ 51		
331	Powerplant Structures & Improvements..	70		
332	Reservoir, Dams & Waterways...........	1,351		
333	Waterwheels, Turbines & Generators....	71		
334	Accessory Electrical Equipment........	21		
335	Miscellaneous Powerplant Equipment (Mechanical)........................	14		
336	Roads & Railroads.....................	214		
	Subtotal..............................	$1,792		
	Contingency...........................	261		
	TOTAL PRODUCTION PLANT................		$2,053	

PEVISED TABLE D.2 (Cont'd)

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 2,053	
	TRANSMISSION PLANT			
350	Land & Land Right	$ 8		
352	Substation & Switching Station Structures & Improvements	12		
353	Substation & Switching Station Equipment	131		
354	Steel Towers & Fixtures	131		
356	Overhead Conductors & Devices	100		
359	Roads & Trails			
	Subtotal	$ 395		
	Contingency	61		
	TOTAL TRANSMISSION PLANT		$ 456	
			$ 2,509	

REVISED TABLE D.2 (Cont'd)

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 2,509	
	GENERAL PLANT			
389	Land & Land Rights	$ –		Included under 330
390	Structures & Improvements	–		Included under 331
391	Office Furniture/Equipment	–		Included under 399
392	Transportation Equipment	–		Included under 399
393	Stores Equipment	–		Included under 399
394	Tools Shop & Garage Equipment	–		Included under 399
395	Laboratory Equipment	–		Included under 399
396	Power-Operated Equipment	–		Included under 399
397	Communications Equipment	–		Included under 399
398	Miscellaneous Equipment	–		Included under 399
399	Other Tangible Property	5		Included under 395
	Subtotal	$ 5		
	Contingency	1		
	TOTAL GENERAL PLANT		$ 6	
			$ 2,515	

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 2,515	
	INDIRECT COSTS			
61	Temporary Construction Facilities	$ -		See Note
62	Construction Equipment	-		See Note
63	Camp & Commissary	302		
64	Labor Expense	-		See Note
65	Superintendence	-		See Note
66	Insurance	-		See Note
68	Mitigation	29		
69	Fees	-		See Note
	Note: Costs under accounts 61, 62, 64, 65, 66 and 69 are included in the appropriate direct costs listed above.			
	Subtotal	$ 331		
	Contingency	48		
	TOTAL INDIRECT COSTS		$ 379	
			$ 2,894	

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 2,894	
	OVERHEAD CONSTRUCTION COSTS (PROJECT INDIRECTS)			
71	Engineering/Administration and Environmental Monitoring	$ 467		
72	Legal Expenses	-		Included in 71
75	Taxes	-		Not Applicable
76	Administrative & General Expenses	-		Included in 71
77	Interest	-		Not Included
80	Earnings/Expenses during Construction	-		Not Included
	Total Overhead		$ 467	
	TOTAL PROJECT COSTS - January 1982 Price Level.		$ 3,361	

REVISED TABLE D.3: ESTIMATE SUMMARY - DEVIL CANYON

JANUARY 1982 PRICE LEVEL

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	PRODUCTION PLANT			
330	Land & Land Rights	$ 22		
331	Powerplant Structures & Improvements	74		
332	Reservoir, Dams & Waterways	577		
333	Waterwheels, Turbines & Generators	42		
334	Accessory Electrical Equipment	14		
335	Miscellaneous Powerplant Equipment (Mechanical)	11		
336	Roads & Railroads	118		
	Subtotal	$ 858		
	Contingency	125		
	TOTAL PRODUCTION PLANT		$ 983	

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 983	
	TRANSMISSION PLANT			
350	Land & Land Rights	$ 0		Included in Watana Estimate
352	Substation & Switching Station Structures & Improvements	7		
353	Substation & Switching Station Equipment	21		
354	Steel Towers & Fixtures	29		
356	Overhead Conductors & Devices	34		Included in Watana Estimate
359	Roads & Trails	0		
	Subtotal	$ 91		
	Contingency	14		
	TOTAL TRANSMISSION PLANT		$ 105	
			$ 1,088	

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 1,088	
	GENERAL PLANT			
389	Land & Land Rights	$ -		Included under 330
390	Structures & Improvements	-		Included under 331
391	Office Furniture/Equipment	-		Included under 399
392	Transportation Equipment	-		Included under 399
393	Stores Equipment	-		Included under 399
394	Tools Shop & Garage Equipment	-		Included under 399
395	Laboratory Equipment	-		Included under 399
396	Power-Operated Equipment	-		Included under 399
397	Communications Equipment	-		Included under 399
398	Miscellaneous Equipment	-		Included under 399
399	Other Tangible Property	5		
	Subtotal	$ 5		
	Contingency	1		
	TOTAL GENERAL PLANT		$ 6	
			$ 1,094	

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL BROUGHT FORWARD		$ 1,094	
	INDIRECT COSTS			
61	Temporary Construction Facilities	$ –		See Note
62	Construction Equipment	–		See Note
63	Camp & Commissionary	145		
64	Labor Expense	–		See Note
65	Superintendence	–		See Note
66	Insurance	–		See Note
68	Mitigation	4		
69	Fees	–		See Note
	Note: Costs under accounts 61, 62, 64, 65, 66 and 69 are included in the appropriate direct costs listed above.			
	Subtotal	$ 149		
	Contingency	22		
	TOTAL INDIRECT COSTS		$ 171	
	TOTAL CONSTRUCTION COSTS		$ 1,265	

REVISED TABLE D.3 (Cont'd)

Line Number	Description	Amount (x 10^6)	Totals (x 10^6)	Remarks
	TOTAL CONSTRUCTION COSTS BROUGHT FORWARD		$ 1,265	
	OVERHEAD CONSTRUCTION COSTS (PROJECT INDIRECTS)			
71	Engineering/Administration and Environmental Monitoring	$ 204		
72	Legal Expenses	-		Included in 71
75	Taxes	-		Not Applicable
76	Administrative & General Expenses	-		Included in 71
77	Interest	-		Not Included
80	Earnings/Expenses during Construction	-		Not Included
	Total Overhead		$ 204	
	TOTAL PROJECT COSTS - January 1982 Price Level.		$ 1,469	

REVISED TABLE D.4: MITIGATION MEASURES - SUMMARY OF COSTS INCORPORATED IN CONSTRUCTION COSTS ESTIMATES

JANUARY 1982 PRICE LEVEL

	COSTS INCOPORATED IN CONSTRUCTION ESTIMATES	WATANA $\$ \times 10^3$	DEVIL CANYON $\$ \times 10^3$	Remarks
1.	Outlet Facilities			
	Main Dam at Devil Canyon		$ 12,600	
	Tunnel Spillway at Watana	$ 53,000		
2.	Restoration of Borrow Area D	-	-	Included in 5
3.	Restoration of Borrow Area F	-	-	Included in 5
4.	Restoration of Camp and Village	1,100	900	
5.	Restoration of Construction Sites	11,500	1,500	
6.	Fencing around Camp	300	200	
7.	Fencing around Garbage Disposal Area	-	-	Included in 6
8.	Multilevel Intake Structure	21,200	N.A.	
9.	Camp Facilities Associated with Trying to Keep Workers Out of Local Communities .	9,900	6,400	
10.	Restoration of Haul Roads	-	-	Included in 5
	SUBTOTAL	96,800	21,600	
	Contingency	14,200	3,200	
	TOTAL CONSTRUCTION	111,000	24,800	
	Engineering	14,000	3,100	
	TOTAL PROJECT	125,000	27,900	152,900

REVISED TABLE D.7 SUSITNA HYDROELECTRIC PROJECT

WATANA & DEVIL CANYON CUMMULATIVE AND ANNUAL CASH PLAN

January 1982 Dollars - in Millions

Year	Annual Cash Flow $			Cummulative Cash Flow (To End of Year)		
To	Watana	Devil Canyon	Combined	Watana	Devil Canyon	Combined
0	104.9*	45.8*	150.7*	104.9*	45.8*	150.7*
1	238.7		238.7	343.6	45.8	389.4
2	311.9		311.9	655.5	45.8	701.3
3	262.4		262.4	917.9	45.8	963.7
4	484.5		484.5	1,402.4	45.8	1,448.2
5	475.4		475.4	1,877.8	45.8	1,923.6
6	477.0	79.4	556.4	2,354.8	125.2	2,480.0
7	465.6	52.2	517.8	2,820.4	177.4	2,997.8
8	288.5	81.4	369.9	3,108.9	258.8	3,367.7
9	170.6	39.6	210.2	3,279.5	298.4	3,577.9
10	81.4	72.6	154.0	3,360.9	371.0	3,731.9
11		151.7	151.7		522.7	3,883.6
12		237.4	237.4		760.1	4,121.0
13		250.6	250.6		1,010.7	4,371.6
14		241.1	241.1		1,251.8	4,612.7
15		193.2	193.2		1,445.0	4,805.9
16		23.8	23.8		1,468.8	4,829.7

* Estimated costs related to engineering, administration and environmental studies expected to be incurred prior to issuance of FERC license and prior to beginning of construction.

REVISED TABLE D.7 SUSITNA HYDROELECTRIC PROJECT

WATANA & DEVIL CANYON CUMMULATIVE AND ANNUAL CASH PLAN
January 1982 Dollars - in Millions

Year	Annual Cash Flow $			Cummulative Cash Flow (To End of Year)		
To	Watana	Devil Canyon	Combined	Watana	Devil Canyon	Combined
0	104.9*	45.8*	150.7*	104.9*	45.8*	150.7*
1	238.7		238.7	343.6	45.8	389.4
2	311.9		311.9	655.5	45.8	701.3
3	262.4		262.4	917.9	45.8	963.7
4	484.5		484.5	1,402.4	45.8	1,448.2
5	475.4		475.4	1,877.8	45.8	1,923.6
6	477.0	79.4	556.4	2,354.8	125.2	2,480.0
7	465.6	52.2	517.8	2,820.4	177.4	2,997.8
8	288.5	81.4	369.9	3,108.9	258.8	3,367.7
9	170.6	39.6	210.2	3,279.5	298.4	3,577.9
10	81.4	72.6	154.0	3,360.9	371.0	3,731.9
11		151.7	151.7		522.7	3,883.6
12		237.4	237.4		760.1	4,121.0
13		250.6	250.6		1,010.7	4,371.6
14		241.1	241.1		1,251.8	4,612.7
15		193.2	193.2		1,445.0	4,805.9
16		23.8	23.8		1,468.8	4,829.7

* Estimated costs related to engineering, administration and environmental studies expected to be incurred prior to issuance of FERC license and prior to beginning of construction.

BEFORE THE

FEDERAL ENERGY REGULATORY COMMISSION

APPLICATION FOR LICENSE FOR MAJOR PROJECT

SUSITNA HYDROELECTRIC PROJECT

PROJECT NO. 7114-000

ADDENDUM

TO

EXHIBIT F

SUPPORTING DESIGN REPORT

(PRELIMINARY)

August 1984

FEDERAL ENERGY REGULATORY COMMISSION

PROJECT NO. 7114

LICENSE APPLICATION

SUSITNA HYDROELECTRIC PROJECT

ADDENDUM
TO
EXHIBIT F
SUPPORTING DESIGN REPORT

August 1984

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SUSITNA HYDROELECTRIC PROJECT
ADDENDUM TO
EXHIBIT F, SUPPORTING DESIGN REPORT

1. Introduction

This addendum to Exhibit F Supporting Design Report provides supplemental information concerning certain design refinement proposed for the Susitna Hydroelectric Project. The addendum focuses upon the refined dam embankment and the hydraulics of the proposed spillway revisions.

2. Watana Dam Embankment

2.1 General

The refined dam embankment will consist of a compacted core protected by fine and coarse filters on the upstream and downstream slopes. The outer shells will consist of rock fill. The upstream inner shell will consist of cleaned, processed alluvium gravel while the downstream inner shell will be constructed of processed sand fill. These feasibility designs will be further refined and updated during the detailed design period based on detailed stability analyses and known shear strengths. The dam will be designed to provide a stable embankment under all conditions.

2.2 Design Criteria

To insure that the impervious core meets the earthquake resistant design, the following design features will be incorporated into the main dam cross section:

- The core foundation contact will be widened near the ends of the embankment to ensure seepage control during normal operating conditions and during a seismic event.

- Thick filter zones will be placed upstream and downstream from the impervious core to prevent breaching of the core from either post-construction settlement and cracking or from any cracking resulting from a seismic event.

- The filters will be designed to be self-healing in case of transverse cracks in the core resulting from either post-construction settlement or a seismic event.

- Downstream fine filter and sand fill zones will be designed to be capable of handling any abnormal flows that could result from transverse cracking at the core from post-construction settlement or a seismic event.

- The proposed width of the core will prevent arching of the core caused by transfer of load from the core to the filter materials and shell.

- Compacted river alluvium gravel will be used to cover the downstream bedrock foundation, and compacted clean river alluvium gravel will be used to construct the upstream inner shell to minimize settlement and displacement that could be caused by a seismic event.

- Sufficient overburden foundation will be removed to insure embankment stability during potential seismic events.

2.3 Freeboard and Embankment Settlement

The design crest elevation is 2205 feet.

The potential seismic settlement of 0.5 percent of the height of the dam will be accounted for in the design by 5 feet of additional freeboard at the maximum section and 2 feet of additional freeboard at the abutments.

2.4 Dam Cross Section

The typical cross section is shown in Plate F6R. The upstream slope is shown as 2.4:1 and the downstream slope as 2:1. The upstream shell is composed of two zones, an outer zone of rock fill and an inner zone of processed gravel fill. Any oversize rock in the rockfill will be raked to the upstream slope. The central impervious core is symmetrical about the axis and has upstream and downstream slopes of 1:4; thus the maximum hydraulic gradient through the core will be less than two. Although this is amply conservative, it will be verified based on future laboratory testing.

The core is separated from the upstream gravel fill by a fine filter and a coarse filter, both of variable but ample thickness.

The downstream shell is composed of an outer zone of rockfill and an inner zone of sand fill which constitutes the minus 3/8 inch material removed from the processed upstream gravel zone. The sand fill is separated from the impervious core by a fine filter, and from the rockfill by a coarse filter.

Below El. 1500, a compacted gravel blankets the bedrock foundation except in areas that appear erodible where a 5 foot layer of fine filter will be placed. Detailed design of the embankment zoning, gradation, placement and compaction will be finalized after borrow explorations and testing are complete.

Th upstream and downstream filters are provided as protection against possible leakage through transverse cracks in the core that could occur as the result of settlement or displacement during a seismic event. The wide filter zones provide sufficient material for healing of any cracks in the core and the size of the downstream filter zones will ensure its capability to handle any abnormal leakage flows.

The exterior shells of the dam will consist of compacted rock fill. To ensure rapid dissipation of excess hydrostatic pressures during a seismic event, the saturated upstream shell will consist of clean river alluvium gravels. This material will be processed to remove fines less than 3/8" in size. The downstream shell beneath the sand fill will consist of compacted unprocessed alluvium gravels since it will not be affected by pore pressure generation during a seismic event.

To guard against piping, the sand fill will be completely confined to prevent migration of fines in any direction. A fine filter will be placed, as required, over areas of foundation bedrock where severe jointing, weathering or rock alteration exist.

Slope protection on the upstream slope will consist of a 40-foot rock raked zone of oversized material.

The typical crest detail is shown in Plate F7R. Because of the narrowing of the dam crest, the filter zones will be reduced in width and the upstream and downstream coarse filter replaced with carefully graded and selected shell materials above Elevation 2170.

2.5 Dam Material

- Core

The core material will be obtained from Borrow Site D, which consists of a series of glacial tills separated by alluvial and lacustrine materials. Processing and blending will be necessary to provide the required moisture content and gradation and to remove any oversize material. However, information to date indicates this can be accomplished by selection of a vertical-face mining method and on-fill processing.

Material will be placed in 9-inch uncompacted lifts at a maximum moisture content of 3 percent above optimum moisture content, and compacted to 95 percent of the maximum density obtained from the Modified Proctor Test (ASTM D698).

- Fine and Coarse Filters

Fine and coarse filter material will be obtained from Borrow Sites E, I, and J. Borrow Site E is the preferred primary borrow source for all the filter and shell fill material in the dam. The material will require processing to provide the proper gradations for the fine and coarse filters.

- Interior Shell Fill Material

The shell fill can be obtained from Borrow Areas E, I, and J. The upstream shell will be constructed using processed river alluvium gravel with no more than 10 percent of the material less than 3/8 inch. The downstream shell covering the bedrock foundation will be constructed using unprocessed alluvium fill material, with the sand fill accomplished by mixing of a carefully controlled byproduct resulting from production of the filters and processed gravels.

- Rock Fill Material

  The rock fill material will be obtained from Quarry A, and rock from required excavations. The rock raked material will be placed on the entire upstream slope, and in certain areas of the downstream slope of the dam as protection against wave overtopping and toe erosion.

2.6 Dam Embankment Stability Analysis

For seismic stability the dam embankment as designed is considered to satisfy all present day safety criteria. Moreover, proven effective defense measures against seismic action have been employed, such as large freeboard, large filter and drainage thicknesses, along with the use of a free draining gravel and rock fill zone at the vulnerable upstream slope. Static and dynamic stability analyses have been performed to establish the upstream and downstream slopes of the Watana Dam. The analyses indicate stable slopes under all conditions for a 2.40 horizontal to 1.0 vertical upstream slope. Therefore, these slopes have been adopted for preliminary design purposes. Although small portions of the sandy gravel and gravelly sand alluvium remain beneath the upstream and downstream toes, the dam will rest on bedrock over approximately 80 percent of its base. This will ensure that the dam will be stable even though inconsequential shallow slides could occur.

3. Watana and Devil Canyon Spillways

3.1 General

The proposed single service spillways at both Watana and Devil Canyon will be designed with hydraulically efficient approaches, which will pass the project PMC described in Exhibit F with the same or slightly greater freeboard on the dam crest as compared with that shown in the License Application. The spillway crests will be shaped to preclude subatmospheric pressures greater than one half the design head.

The abutments and piers will be shaped to maintain contraction coefficients no greater than 0.025 and 0.01 respectively. The spillway crest approach channel relationship will be such that the discharge coefficient (C_d), at design head, will be no less than 3.84.

$$Q = C_d \, L \, H_o^{1.5}$$

Where, Q = spillway discharge
L = net crest length
H_o = design head of spillway

The chute will be designed to smoothly transition the flow from the crest down the chute and to flip the discharge downstream to the river channel. Aeration slots will be located along the chute for air entrainment to reduce cavitation erosion.

The flood discharge and reservoir surface elevation at Watana and Devil Canyon are presented in Figures 1 and 2 respectively.

3.2 Hydraulic Structure Operation

The inflow hydrograph, at Watana and that routed through Watana at Devil Canyon, for all floods with a recurrence period of 50 years or less can be discharged without using the spillway, through the outlet facilities and two units of the powerhouse. At Watana the reservoir would surcharge no higher than El. 2193, whereas at Devil Canyon the reservoir would not exceed the normal maximum level of El. 1455. For events in excess of a 50 year flood, the spillway gates would begin to open once the reservoir passed El. 2193 at Watana or El. 1455 at Devil Canyon. The gate openings would be adjusted to maintain the preceding reservoir elevations. In the case of the PMF flood, the gates would eventually be fully open and the reservoir would begin to rise. When the reservoir begins to rise, the powerhouse discharge would be terminated in the routing study, leaving only the outlet works and spillway to discharge the flood inflow.