Stage Fluctuations Resulting from Discharge Variations Due to Load Changes

Studies are being undertaken to determine the discharge and stage variations at significant locations resulting from various constraints on maximum change in powerhouse discharge and maximum rate of change of discharge. The values to be considered include:

Maximum Rate of Release Change	Maximum Weekly Release Variation
cfs/hr	cfs (±)
500	1000
	2000
	3000
	5000
1000	1000
	2000
	3000
	5000
2000	1000
	2000
	3000
	5000

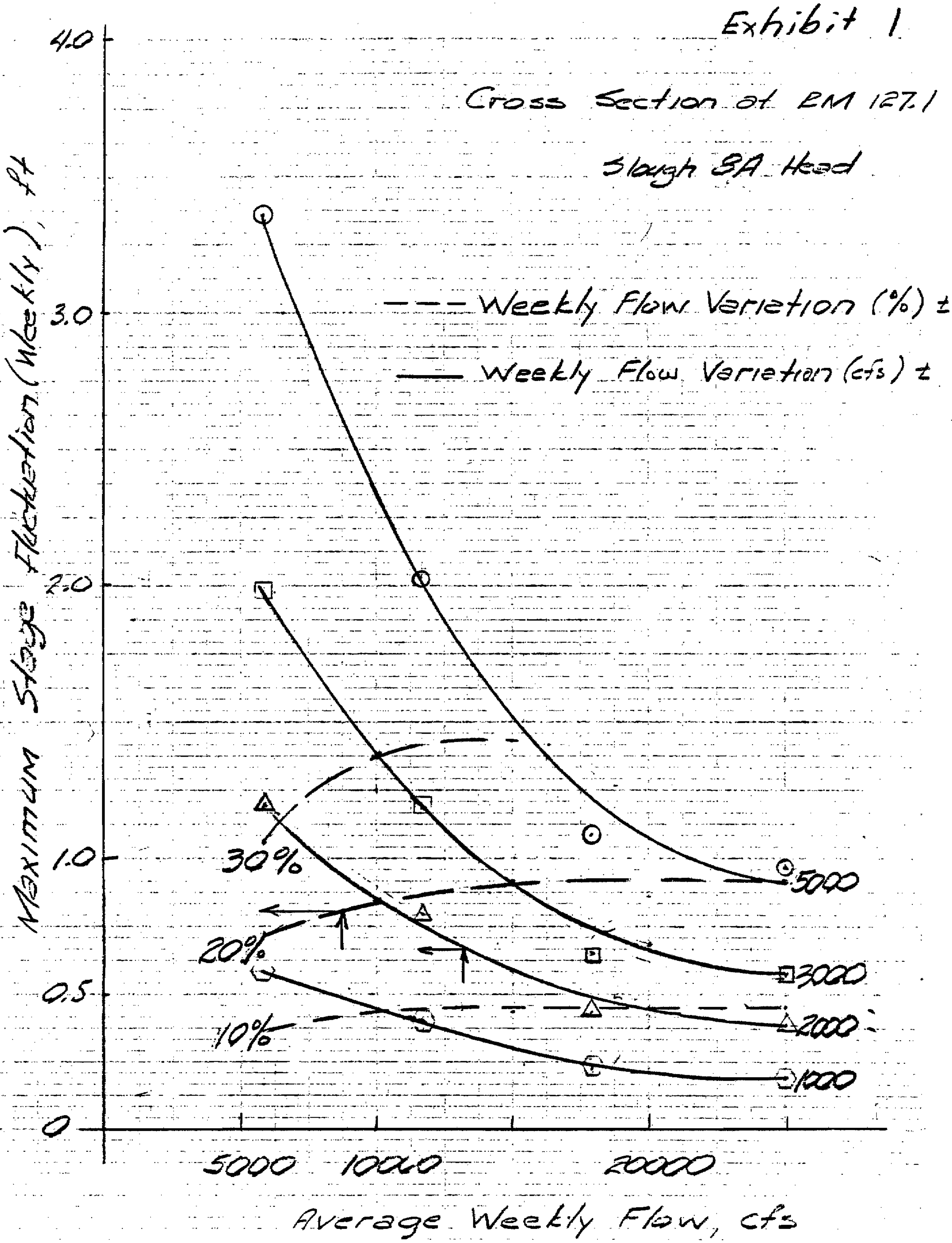
The analysis will involve a dynamic routing of weekly powerhouse releases between Watana and Gold Creek for spring, summer, fall and winter periods. Dynamic routing will not be considered under an ice cover. Instead, a survey is underway to determine winter operating policies at other northern hydroelectric projects and downstream effects.

The purpose of the study is to provide information necessary to make a decision on allowable discharge variations from Watana operating alone or Devil Canyon when operating with Watana. Preliminary studies indicate that, for discharge fluctuations greater than shown in the table, downstream attenuation of the powerhouse release pattern is minimal. The difference between maximum and minimum discharges at a point near Sherman would be similar to the difference at the powerhouse. If this holds true for smaller release variations the stage fluctuations can be estimated on a worst case basis from steady state rating curves already developed.

Exhibits 1 through 4 may be used to determine the maximum weekly stage variation resulting from fluctuations in discharge about a given weekly average flow. These curves are based on steady state rating curves at the noted locations. Daily flow fluctuations resulting from changing powerhouse loads might not result in as large stage fluctuations since channel storage and friction would result in some attenuation. The maximum rate of stage fluctuation can also be estimated using these curves at a given weekly average flow using a given time rate of flow change.

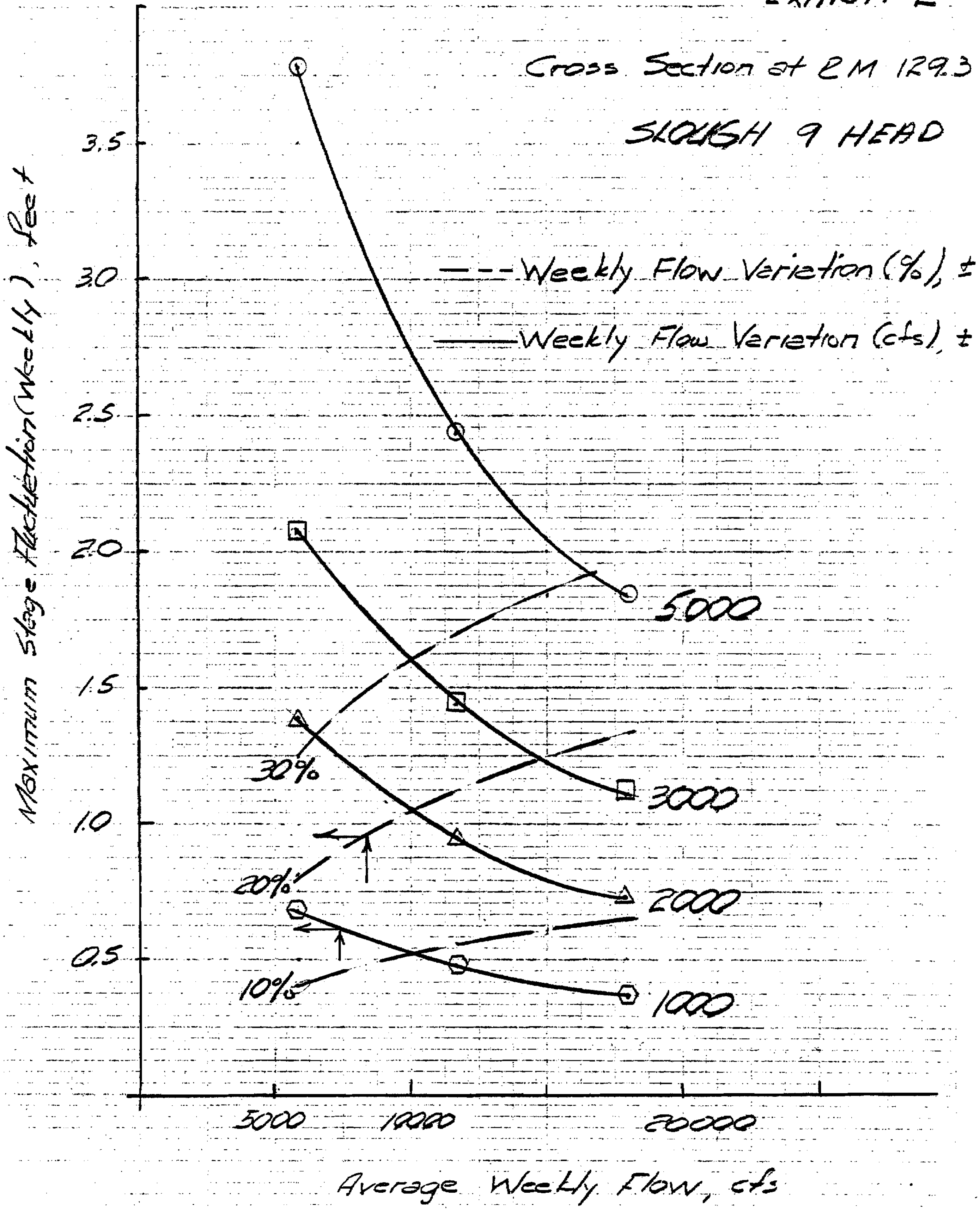
For example, at RM 127.1 for a weekly average flow of 10,000 cfs the maximum weekly stage fluctuation for a 1000 ± cfs or 10% ± flow variation would be 0.44 ft (0.22 ft ±). The corresponding fluctuation at RM 136.68 would be 0.6 feet (0.30 ft ±).

Exhibits 1 through 4 have been drawn for locations near the upstream ends of Sloughs 8A, 9, 11 and 21. Examination of water surface profiles in the report "Susitna Hydroelectric Project - Middle and Lower River Water Surface Profiles and Discharge Rating Curves" (HE, 1984) indicates these are representative of the range in stage fluctuations in the Middle Reach of the Susitna River. The rating curve at the Slough 11 head appears to give near maximum stage fluctuations while those at Sloughs 8A and 21 give near minimum stage fluctuations.



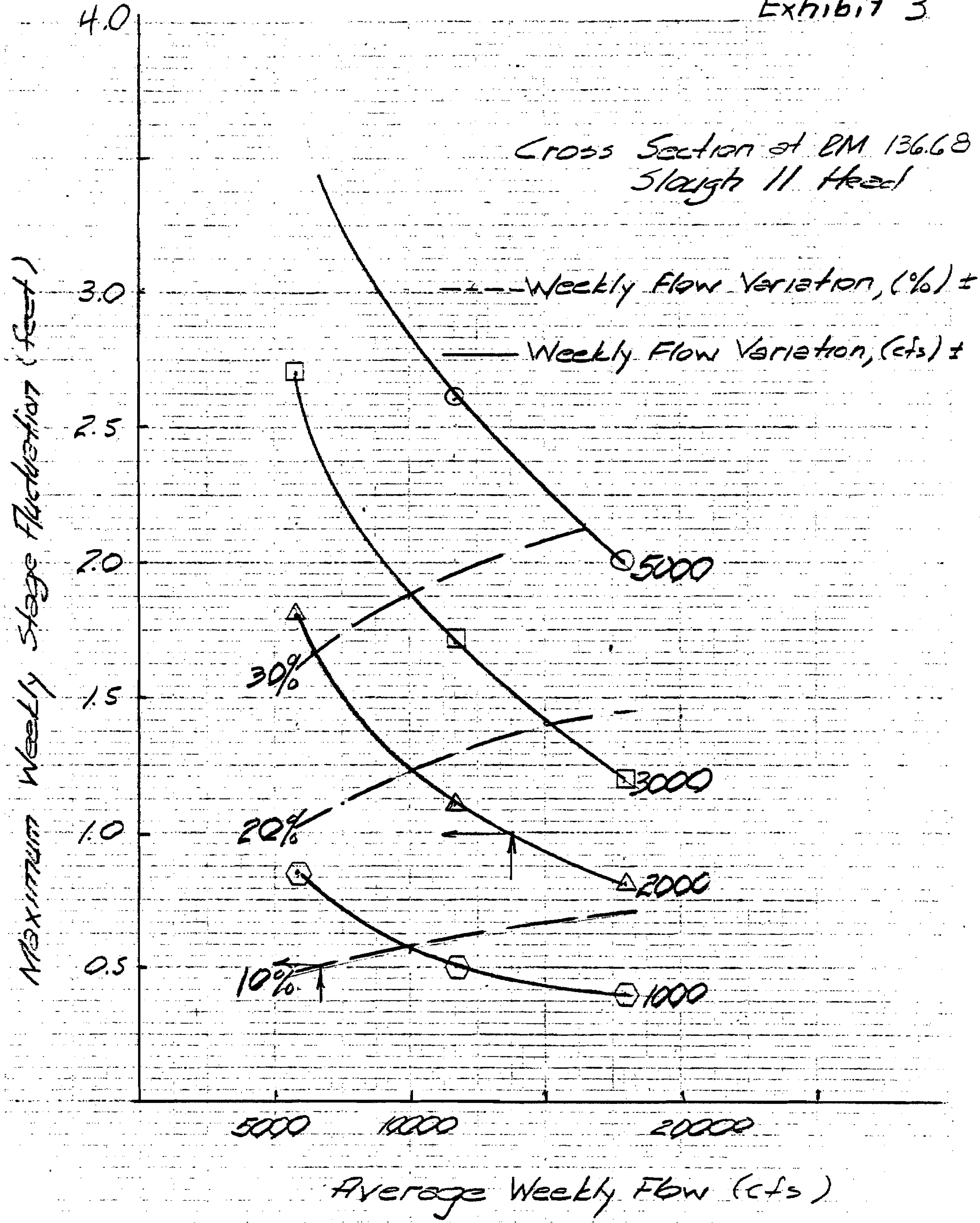
HARZA-EBASCO SUSITNA JOINT VENTURE

Exhibit 2



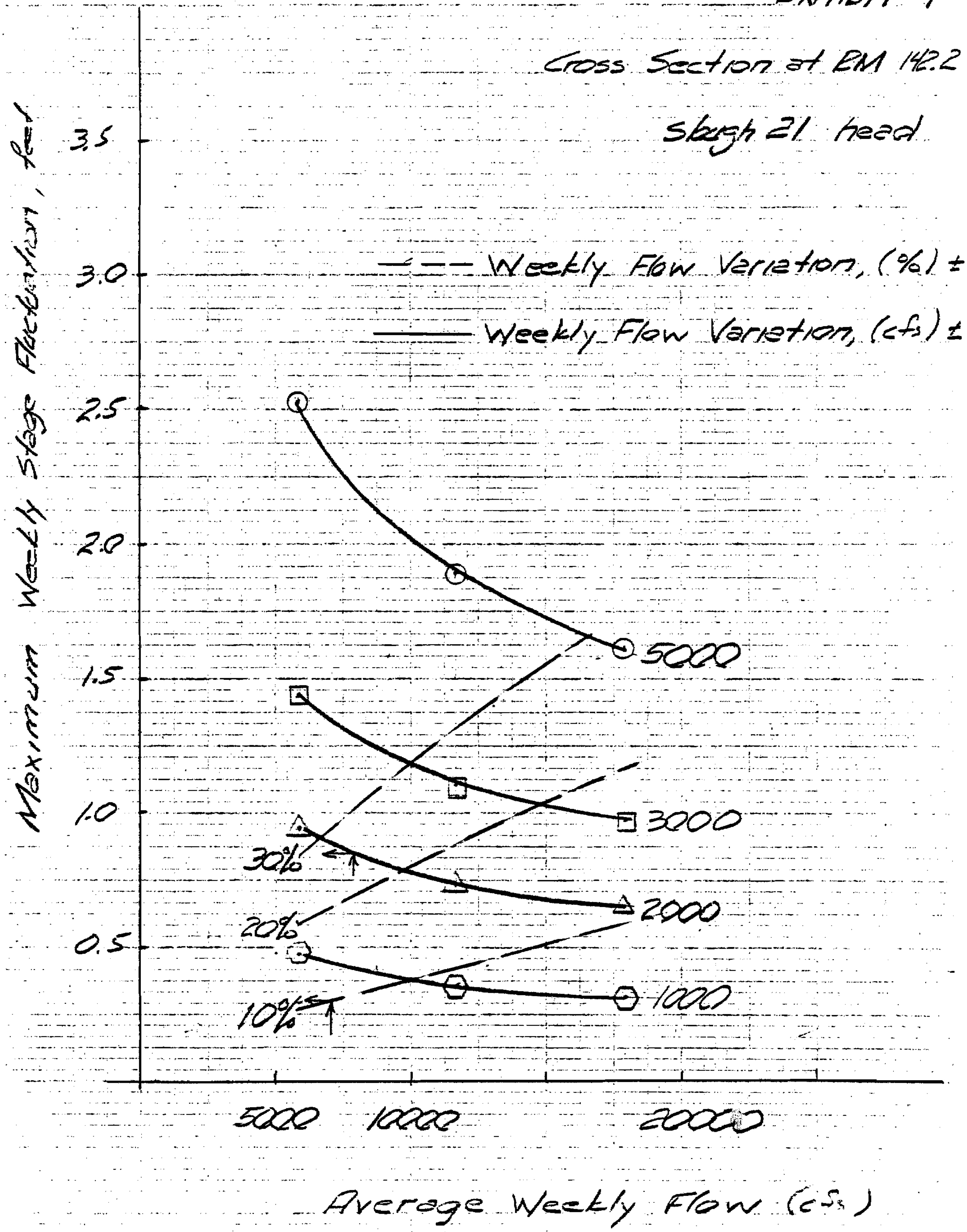
HARZA EBASCO SUSITNA JOINT VENTURE

Exhibit 3



HARZA-EBASCO SUSITNA JOINT VENTURE

Exhibit 4



HARZA-EBASCO SUSITNA JOINT VENTURE

WATANA FILLING WITH E-IV and E-VI

An analysis was made to determine the effects on filling of Watana Reservoir and Susitna River discharges at Gold Creek of the Case E-IV and E-VI Environmental Flow Constraints. The analysis was similar to that in the License Application (p E-2-79). Three year sequences of Susitna River flows representing high flow (10% exceedance) average flow (50% exceedance) and low flow (90% exceedance) were used. The Watana Dam was assumed to be constructed by the same schedule as in the License Application. The Case E-IV and E-VI flow constraints and reservoir rule curves used in the analysis are shown on Table 1. The results of the analysis are shown on the attached Exhibit.

The computations indicate that with Case E-IV Environmental Flow Constraints the Watana Reservoir could be filled to its normal maximum water level (El. 2185) for wet and average sequences in a similar time frame to the filling using Case C. By August of the third summer of filling the reservoir would be full. In a dry sequence, using Case E-IV, the reservoir water level would only reach El. 2155 at the end of the third summer of filling. This is 10 feet below a dry sequence filling with Case C and represents about 350,000 ac-ft of water or about 200,000 gwh of electrical energy.

Case E-VI Filling Environmental Flow Constraints are keyed to reservoir water levels expected to be exceeded in all but the dryest 10% of 3-year flow sequences during filling. Using these flow constraints, which are 1000 cfs less than for Case E-IV at all times during the summer, the final reservoir water level during the third summer of filling can be raised to El. 2175, an increase of 20 feet over Case E-IV or 10 feet over Case C. This results in a benefit of approximately 400,000 gwh of electrical energy over Case E-IV.

Susitna River discharges at Gold Creek are also shown on the attached Exhibit and Table 2. Reservoir filling would begin in the summer of 1991. The discharges shown for 1990 represent the natural conditions. During

1991 discharges at Gold Creek would exceed the Case E-IV flows at almost all times since the flows during this period would be controlled by the height of Watana Dam in order to provide an adequate volume to store the 250 year flood. During the second summer of filling discharges during a wet sequence would also be controlled by the height of the dam and would exceed the Case E-IV constraints. During dry and average sequences the flows would be controlled by the Case E-IV or E-VI flow constraints. For a dry sequence the E-VI constraints would control flows at 1000 cfs less than the E-IV constraints beginning in June of the second summer of filling. During 1993 a wet sequence of inflows would result in filling of the reservoir in early August and Gold Creek flows would then be constrained by Case E-VI and power generation requirements. An average sequence of flows would fill the reservoir in September. Flows at Gold Creek for both average and dry sequences would be controlled by minimum flow requirements.

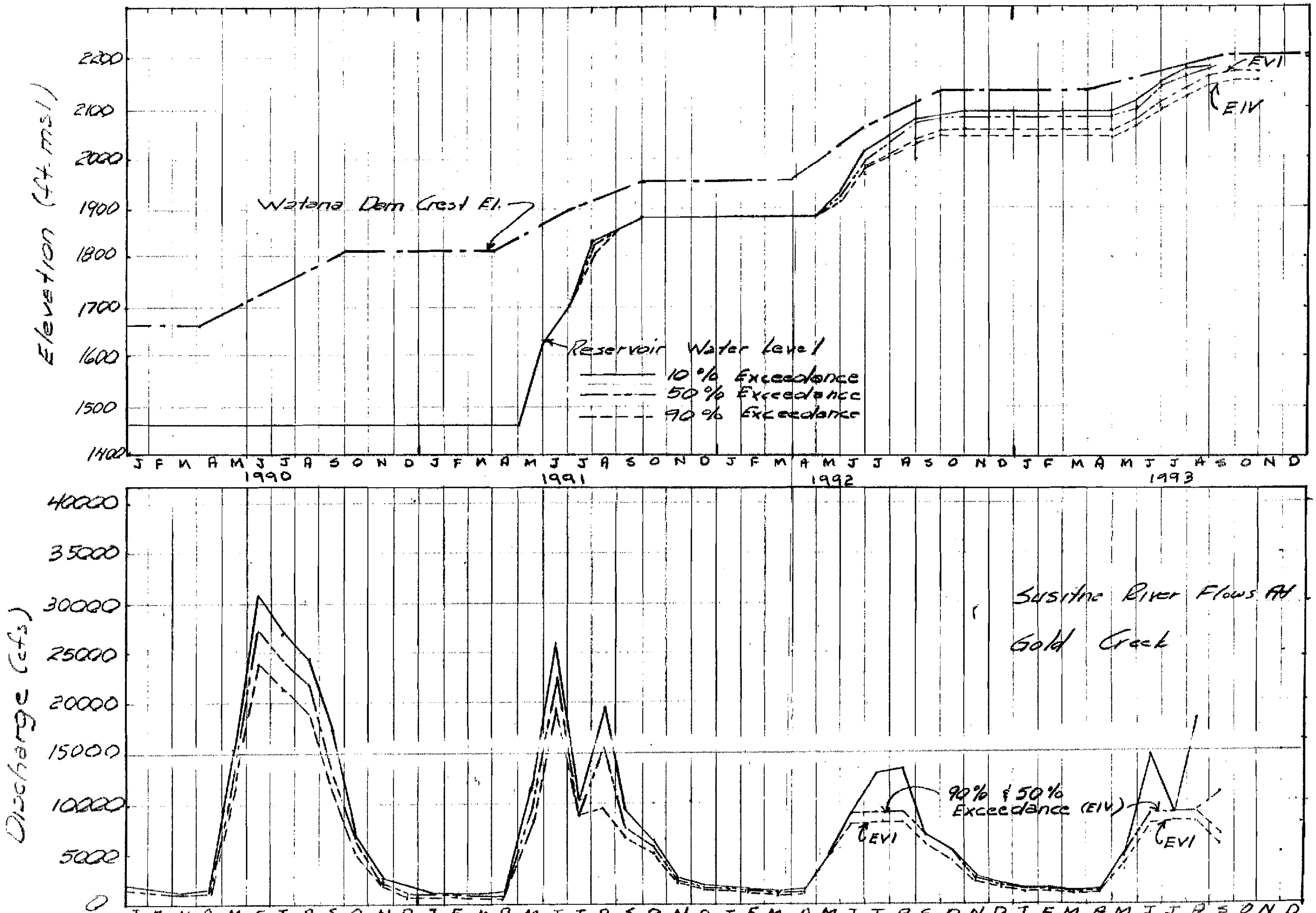
Table 1

Filling with E-VI Rule Curve

Water Week	Date	Watana Target Res. Elev. Second Summer	Watana Target Res. Elev. Third Summer	Gold Creek Target Flow If Target Met	Gold Creek Target Flow If Target Not Met
1	Oct 1-7			6000	5000
2	Oct 8-14			6000	5000
3	Oct 15-21			5000	4000
4	Oct 22-28			4000	3000
5	Oct 29-Nov 4	2055 1/		3000	2000
6	Nov 5			Natural	Natural
thru					
30	Apr 28			Natural	Natural
31	Apr 29-May 5			2000	2000
32	May 6-May 12			4000	3000
34	May 13-May 19			6000	5000
35	May 27-June 2	1908 3/	2074 3/	6000	5000
36	June 3-June 9			9000	8000
37	June 10-June 16			9000	8000
38	June 17-June 23			9000	8000
39	June 24-June 30	1965 4/	2110 4/	9000	8000
40	July 1-July 7			9000	8000
41	July 8-July 14			9000	8000
42	July 15-July 21			9000	8000
43	July 22-July 28			9000	8000
44	July 29-Aug 4	2006 5/	2140 5/	9000	8000
45	Aug 5-Aug 11			9000	8000
46	Aug 12-Aug 18			9000	8000
47	Aug 19-Aug 25			9000	8000
48	Aug 26-Sept 1	2037 6/		9000	8000
49	Sept 2-Sept 8			8000	7000

Table 2
Susitna River Discharges (cfs)
Measured at Gold Creek
Watana Filling Cases

Year	Month	Wet Sequence 10% Exceedance E-IV	Avg. Sequence 50% Exceedance E-IV	Dry Sequence 90% Exceedance E-IV	Dry Sequence 90% Exceedance E-VI
1991	April	1544	1371	1214	1214
	May	11414	9753	8231	8231
	June	25680	22220	19650	19050
	July	10312	9000	9000	9000
	August	19506	15016	9701	9701
	Sept	9446	7799	6800	6800
1992	Oct	6453	5732	5032	5032
	Nov	2879	2557	2263	2263
	Dec	2010	1785	1580	1580
	Jan	1640	1457	1290	1290
	Feb	1393	1238	1096	1096
	Mar	1258	1118	990	990
	Apr	1544	1371	1214	1214
	May	4903	4903	4903	4903
	June	8800	8800	8800	7800
	July	12800	9000	9000	8000
	Aug	13162	9000	9000	8000
	Sept	6800	6800	6800	5800
	Oct	5032	5032	5032	4032
1993	Nov	2879	2557	2263	2263
	Dec	2010	1785	1580	1580
	Jan	1640	1457	1290	1290
	Feb	1393	1238	1096	1096
	Mar	1258	1118	990	990
	Apr	1544	1371	1214	1214
	May	4903	4903	4903	3903
	June	14633	8800	8800	7800
	July	9000	9000	9000	8000
	Aug	17375	9000	9000	8000
	Sept		11099	6800	5800


Elevation (ft msl)
2200
2100
2000
1900
1800
1700
1600
1500
1400
Watana Dam Crest El.
Reservoir Water Level
10 % Exceedance
50 % Exceedance
90 % Exceedance
EVI
EIV
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1990
1991
1992
1993
Discharge (cfs)
40000
35000
30000
25000
20000
15000
10000
5000
0
Susitna River Flows At
Gold Creek
90% & 50%
Exceedance (EIV)
EVI
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

WINTER STAGE FLUCTUATIONS

Fluctuating water levels during winter periods when an ice cover is forming, melting out or breaking up may tend to destabilize the ice cover. This could result in consolidation of the ice cover, thicker ice covers, higher water levels or ice jams. Permissible stage fluctuations (and corresponding flow fluctuations), with an ice cover on the river, to minimize these possibilities, depend on rate of flow change, amount of flow change, proximity of ice front to discharge point and strength of ice cover. The strength of the ice cover depends on air temperature and thickness of solid ice versus slush ice.

Tests done by Acres Consulting Services Limited on the Peace River indicate that a daily flow change of the order of ± 50%, near the end of winter, with the front already melting out, will result in consolidation of the front located about 100 miles downstream of the power plant, with subsequent rise of the ice cover about 1.5 ft a distance of 100 miles further downstream. The open-water surface fluctuation was about 3 ft near the powerplant, attenuating to about 2 ft. 60 miles downstream.

Based on the limited data we have, only a judgement is possible for the middle reach of the Susitna River. Effects of project flow changes on the Lower River ice cover will be minimal because of tributary flows and vast overbank relief areas. It seems reasonable that a flow change of the order of 10-20% over a 4 hour period should be no problem in mid-winter (February) in the Middle Reach. In January, when the front is advancing in the Middle Reach, flow changes should be minimized since the cover has no strength at this time. Similarly, in March and April when the cover is melting, flow changes should be minimized because the weakened cover can break, resulting in consolidation jams.

In summary, if freeboard is a problem anywhere on the Middle Reach, then flow fluctuations exceeding ± 10% in a day should not be permitted in the winter. A survey of experience in operating hydroelectric projects in cold regions is being made in order to better define the most acceptable manner of Susitna Project operation. Initial results of this study indicate that experience and tests during project operation are the normal manner of defining the allowable limits on discharge fluctuations in the winter.

LOW LEVEL OUTLET AT WATANA

Studies are being made to determine effects of drawing winter power flows from an intake located near El. 1800. This is approximately 200 feet below the bottom of the proposed multi-level intake. Use of this mid level intake in winter would allow water near 4°C to be discharged in many cases and would cause the ice cover to be as far downstream of the project as possible. Operation of the proposed multi-level intake in winter normally results in outflow temperatures between 2°C and 3°C depending on prevailing weather conditions. Removal of 4°C water in winter will reduce the total heat content of the reservoir. This could cause somewhat later warming of river temperatures in the spring and slightly reduced summer river temperatures than if winter outflow temperatures were near 2°C to 3°C. Ongoing studies will address both winter and summer impacts . Other considerations include possible reductions in water quality (deficient O_2 levels and increased turbidity) near El. 1800 as compared to the higher level intakes. Preliminary indications are that winter use of an intake at El. 1800 would move the ice front downstream to the vicinity of Slough 11 in the coldest winters for Watana operating alone.

Effect of Cone Valve Operation on River Temperatures

The Susitna Hydroelectric Project is being designed to provide a reliable source of electrical energy to the Railbelt Area of Alaska. This means that the project will be operated to provide a firm amount of electricity even in years when river flows, the source of electrical energy, are low. The greatest need for energy in the Railbelt Area occurs in winter while the greatest river flows are in summer. Therefore, in order to provide the reliable energy during the winter the project will be operated to fill the reservoirs by early October, even in dry years. The operating policy which is developed to meet this goal is conservative in that it ensures a firm amount of energy. It results in early filling of the reservoir in average and wet years. In these years water in excess of power requirements must be released from the reservoirs in July and August to prevent overtopping of the dams.

Additionally, in the early years of project operation, summer electrical energy requirements may not be large enough to require powerhouse releases equal to the minimum environmental flow requirements. In this period powerhouse flows will be augmented by the additional release required to meet the environmental flow requirements.

In both of these cases, reservoir releases will be made through the cone valves. These valves are expected to minimize the possibility that nitrogen saturation in excess of that allowed by state regulation or detrimental levels will occur. The intakes to these cone valves are located approximately 180 feet below the water surface at Watana and 450 feet below the water surface at Devil Canyon. The intakes are located at these levels:

1. To provide a means for evacuating the Watana Reservoir to El. 2065 if maintenance on a submerged structure is required, and

?

421481
841206

2. To provide for diversion of Susitna River flows during construction of Devil Canyon Dam, and to provide for evacuation of Devil Canyon reservoir in the case that maintenance on a submerged structure is required.

?

During the periods when these cone valves will operate, the water temperature at the level of the cone valve intakes will be lower than the temperature of the water being released through the powerhouse. This is because the operating powerhouse intakes will be in the warm epilimnion water while the cone valve intakes will be in the thermocline (Watana) or the hypolimnion (Devil Canyon).

It is anticipated that the cone valves would be opened gradually in accordance with the need to pass flood flows or to augment power flows. This would minimize any sudden temperature drops resulting from cone valve operation. However, there would still be a reduction in outflow temperatures which could be as high as 5°C. This temperature reduction will be greatest in the early years of Devil Canyon operation for two reasons:

1. The Devil Canyon cone valve intakes are located in the hypolimnion,

2. During the early years of Devil Canyon operation the energy demand on the project will be less than the project can supply requiring larger releases through the cone valves.

The attached Exhibits 1 and 2 show the simulated outflow temperatures from:

1. Watana operating alone in a wet year with 1996 energy demands.

2. Devil Canyon with both Devil Canyon and Watana operating for a wet year with 2002 energy demands.

The simulations were prepared for Case C environmental flow constraints. Case E-VI constraints are not expected to result in a significant change in cone valve flows during wet years. The temperature effects of cone valve operation will be similar.

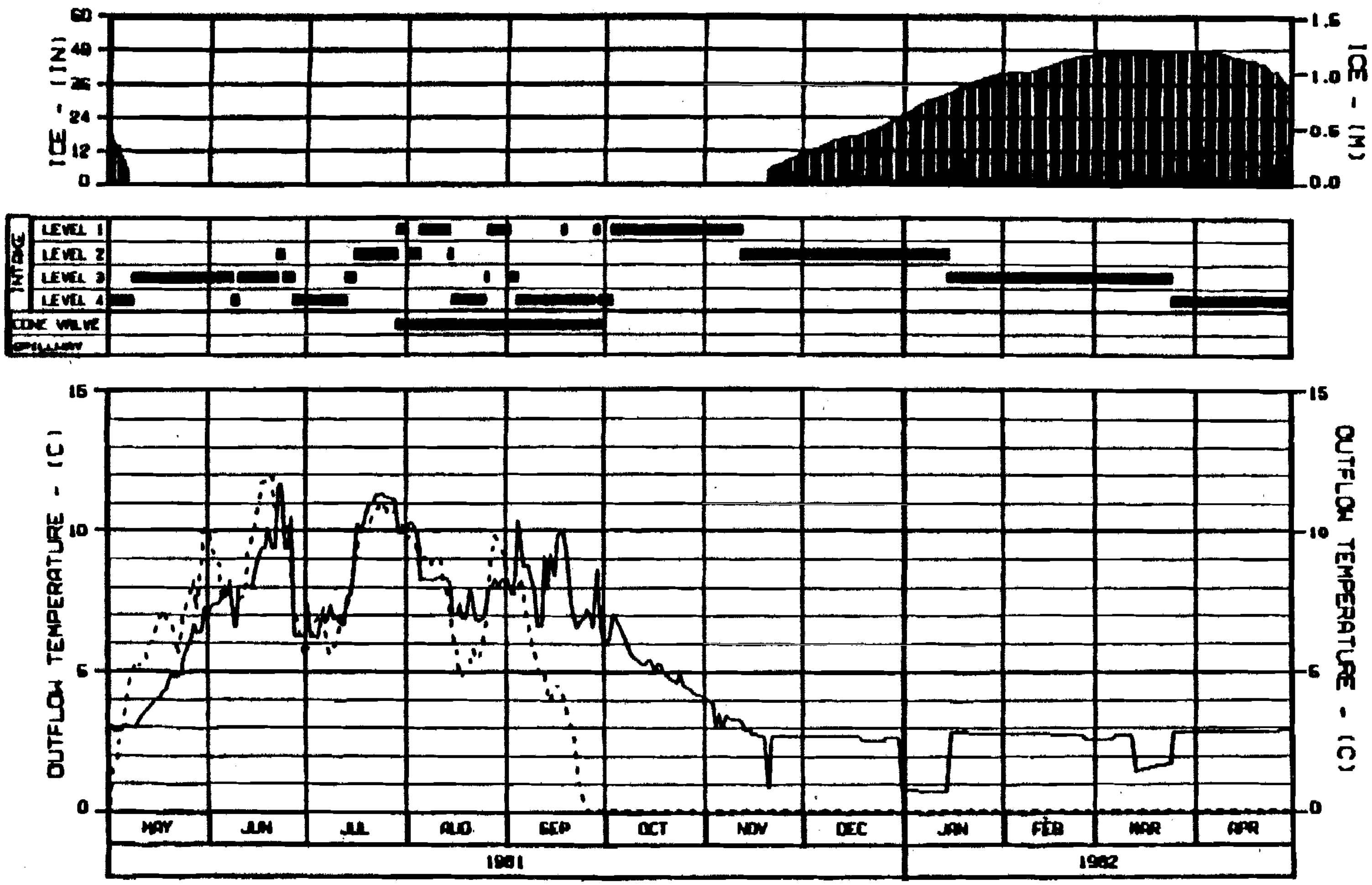
Exhibits 3 and 4 show simulated weekly average temperatures at RM 130 corresponding to the reservoir temperature simulations in Exhibits 1 and 2 respectively. Note the effect of cone valve operation on temperature, especially in 2002 with Devil Canyon and Watana operating. Exhibits 5 and 6 show simulated weekly average temperatures at Sunshine, downstream of the Susitna-Chulitna-Talkeetna confluence. Note the reduction in temperature drop at this location. Exhibits 7 and 8 compare simulated river temperatures at RM 130 with fish temperature tolerance levels for the periods simulated.

Further studies of river and reservoir temperatures are being undertaken:

1. To verify that Case E-VI temperatures are not significantly different than Case C.

2. To determine the feasibility and impacts of having a high intake to the Devil Canyon cone valves.

These studies will be reported when available.



LEGEND: CASE: ** WA81182196E - WATANA OPERATION IN 1996 **

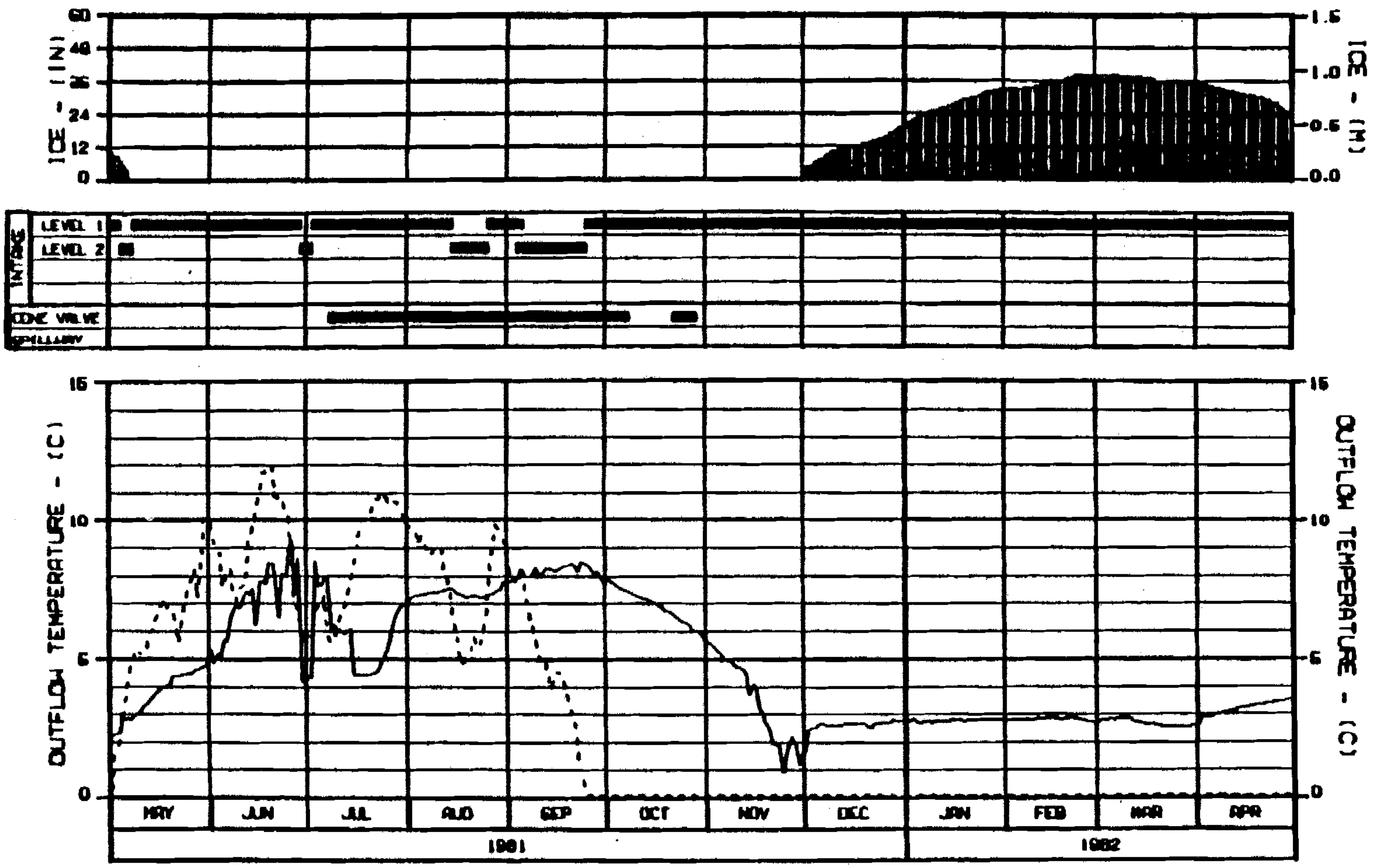
——— PREDICTED OUTFLOW TEMPERATURE
- - - - INFLOW TEMPERATURE

NOTES: 1. INTAKE PORT LEVEL 1 AT ELEVATION 2151 FT (655.6 M)
2. INTAKE PORT LEVEL 2 AT ELEVATION 2114 FT (644.3 M)
3. INTAKE PORT LEVEL 3 AT ELEVATION 2077 FT (633.1 M)
4. INTAKE PORT LEVEL 4 AT ELEVATION 2040 FT (621.8 M)
5. CONE VALVE AT ELEVATION 2040 FT (621.8 M)
6. SPILLWAY CREST AT ELEVATION 2140 FT (654.7 M)

ALASKA POWER AUTHORITY	
SUSITNA PROJECT	DYRESM MODEL
WATANA RESERVOIR OUTFLOW TEMPERATURE AND ICE GROWTH	
HARZA-EBASCO JOINT VENTURE	

Exhibit 1

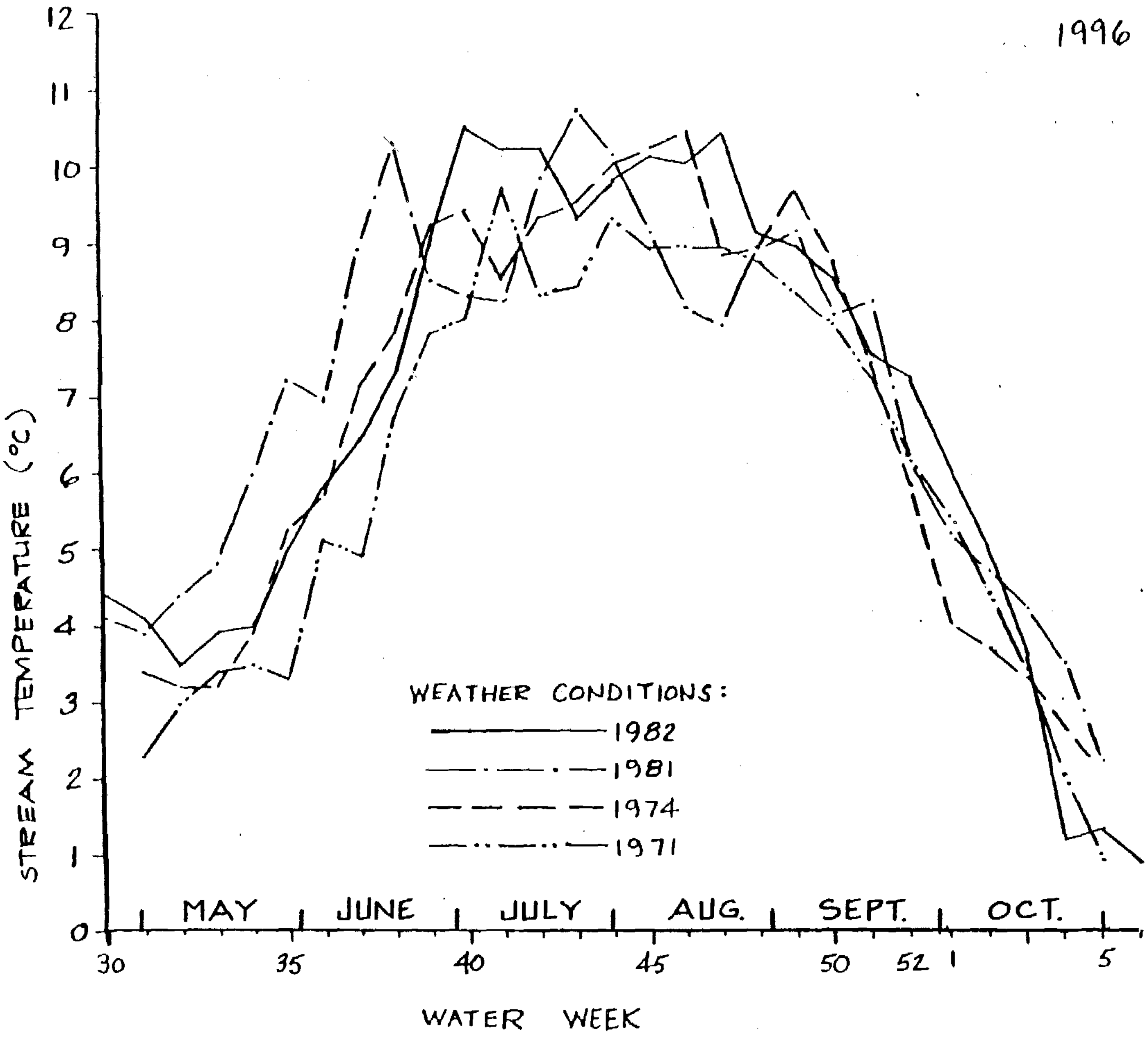
Exhibit 2



LEGEND: CASE: ** DC81182102D - DEVIL CANYON OPERATION WITH WATANA IN 2002 **
- WATANA WEATHER STATION DATA
——— PREDICTED OUTFLOW TEMPERATURE FROM DEVIL CANYON RESERVOIR
- - - - INFLOW TEMPERATURE TO WATANA RESERVOIR

NOTES:
1. INTAKE PORT LEVEL 1 AT ELEVATION 1425 FT (434.34 M)
2. INTAKE PORT LEVEL 2 AT ELEVATION 1375 FT (419.10 M)
3. CONE VALVE AT ELEVATION 990 FT (301.76 M)
4. SPILLWAY CREST AT ELEVATION 1404 FT (427.94 M)

ALASKA POWER AUTHORITY	
SUSITNA PROJECT	DYRESM MODEL
DEVIL CANYON RESERVOIR OUTFLOW TEMPERATURE AND ICE GROWTH	
HARZA-EBASCO JOINT VENTURE	



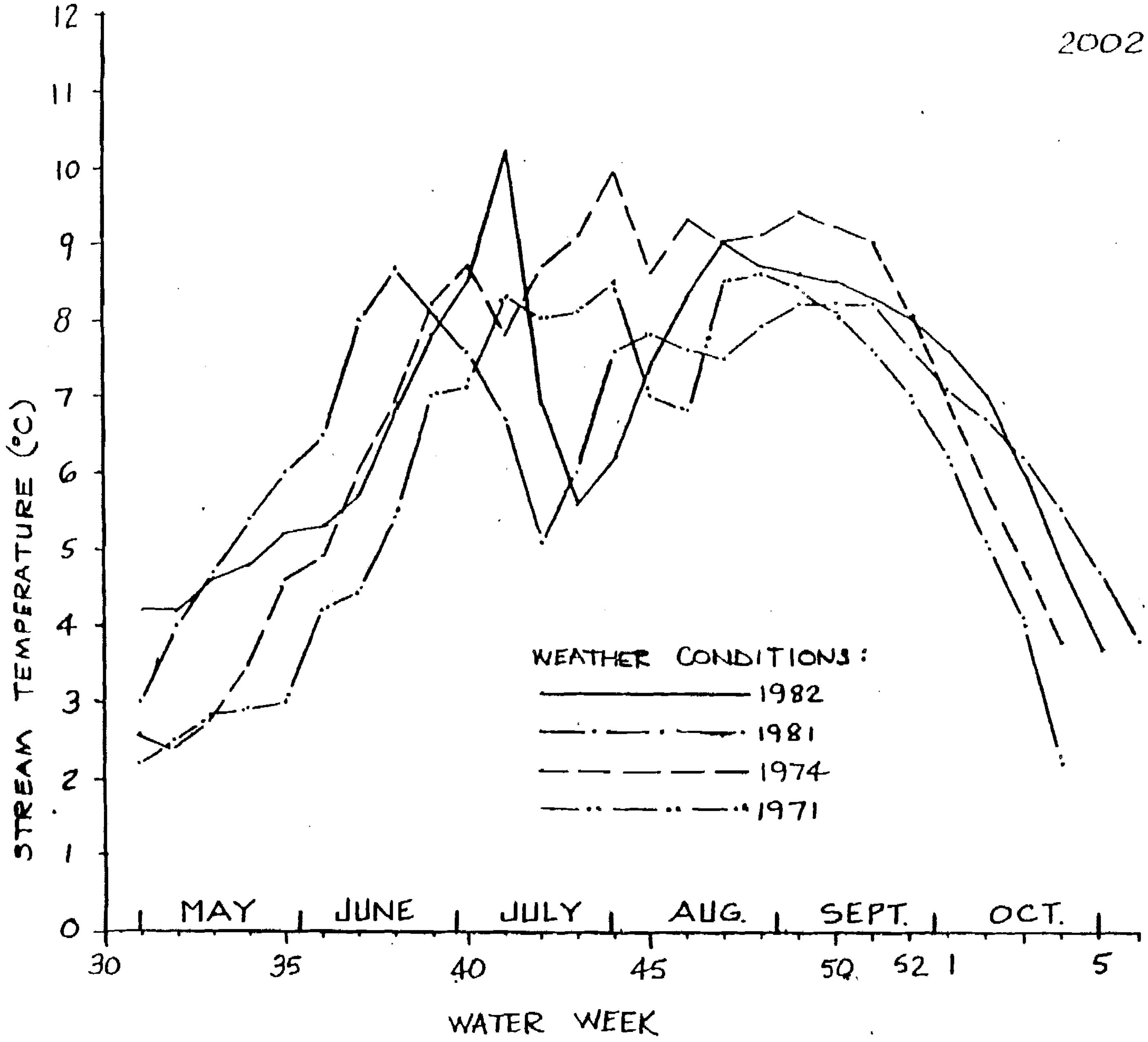
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA RIVER TEMPERATURES
AT RIVER MILE 130
WATANA OPERATING

ANCHORAGE, ALASKA

EXHIBIT 3



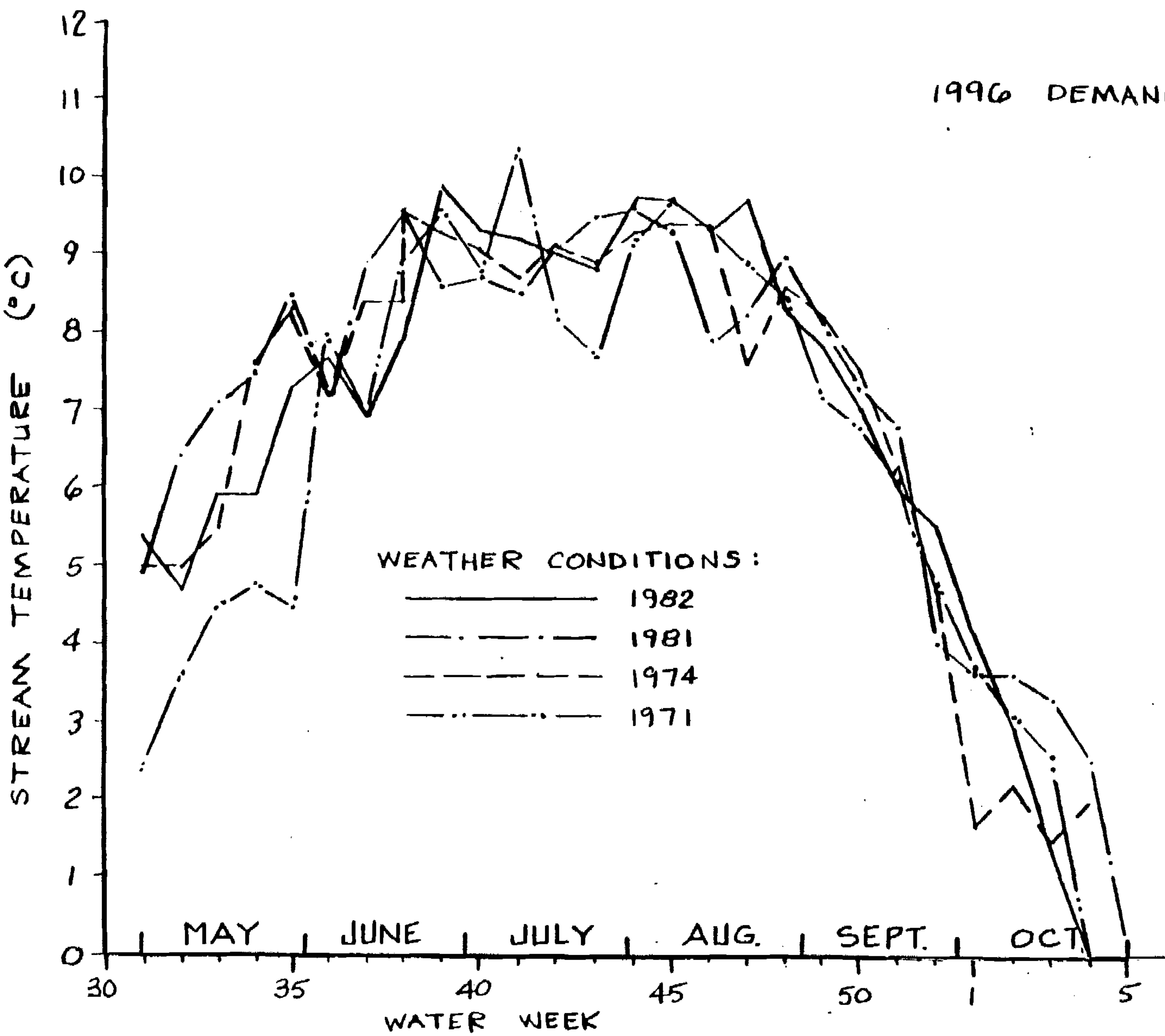
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA RIVER TEMPERATURES AT RIVER MILE 130 WATANA AND DEVIL CANYON OPERATING

ANCHORAGE, ALASKA

EXHIBIT 4



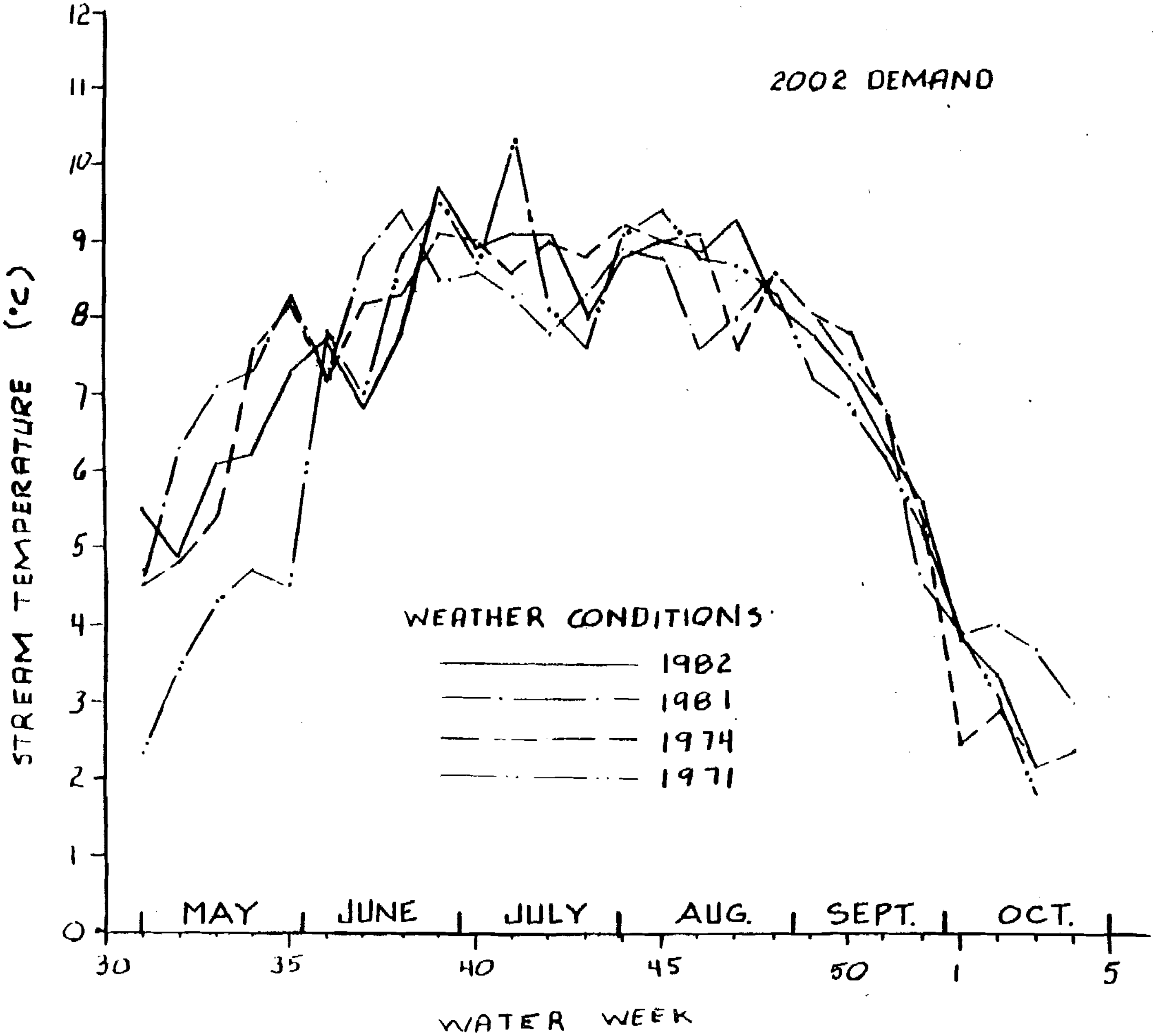
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA RIVER TEMPERATURES
AT RIVER MILE 84
WATANA OPERATING

ANCHORAGE, ALASKA

EXHIBIT 6



ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA RIVER TEMPERATURES AT RIVER MILE 84 WATANA AND DEVIL CANYON OPERATING

APPROVED

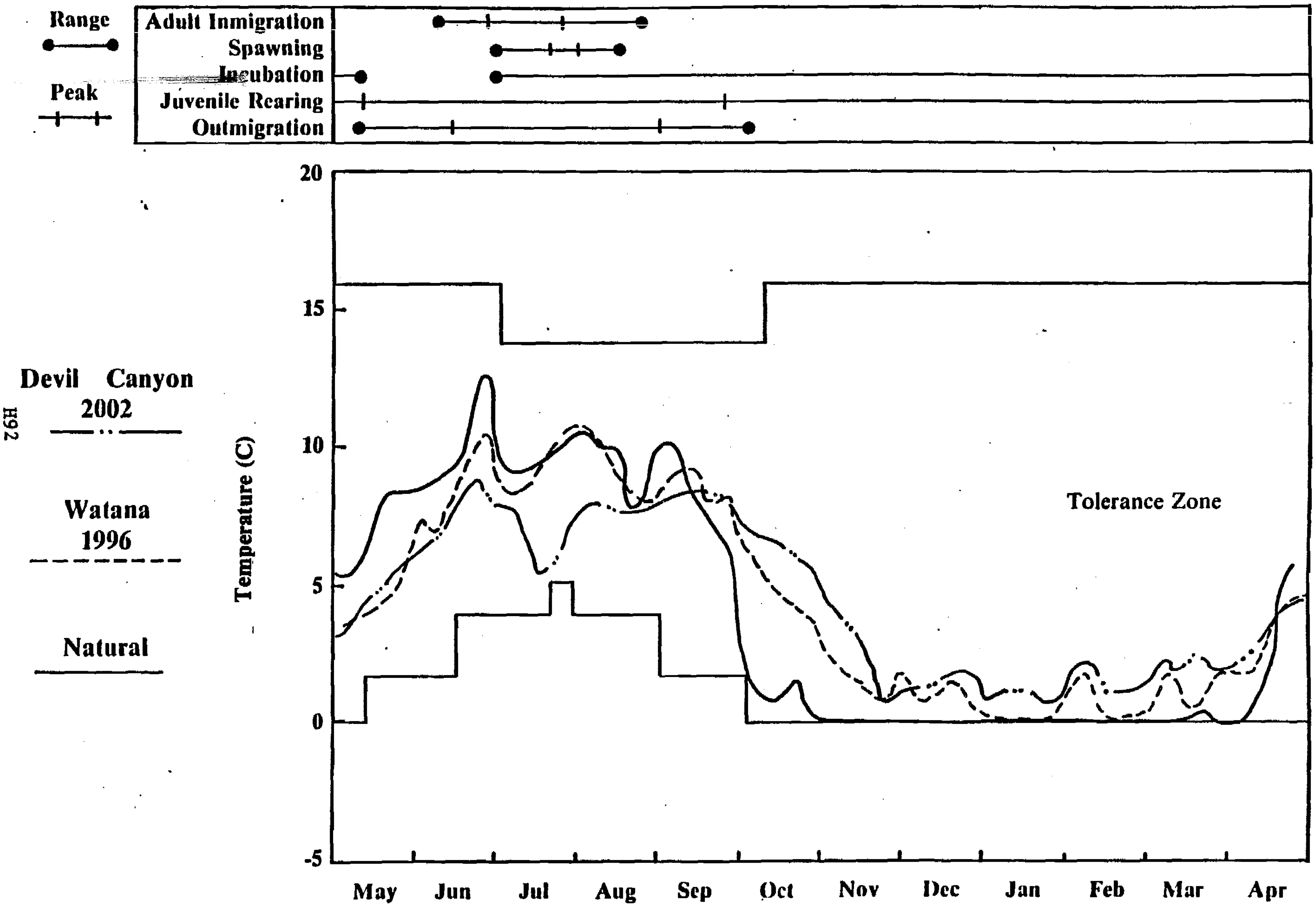
DATE

DRAWING NO.

ANCHORAGE, ALASKA

EXHIBIT 6

CHINOOK SALMON



1981-1982
River Mile 130

H92

Exhibit 7

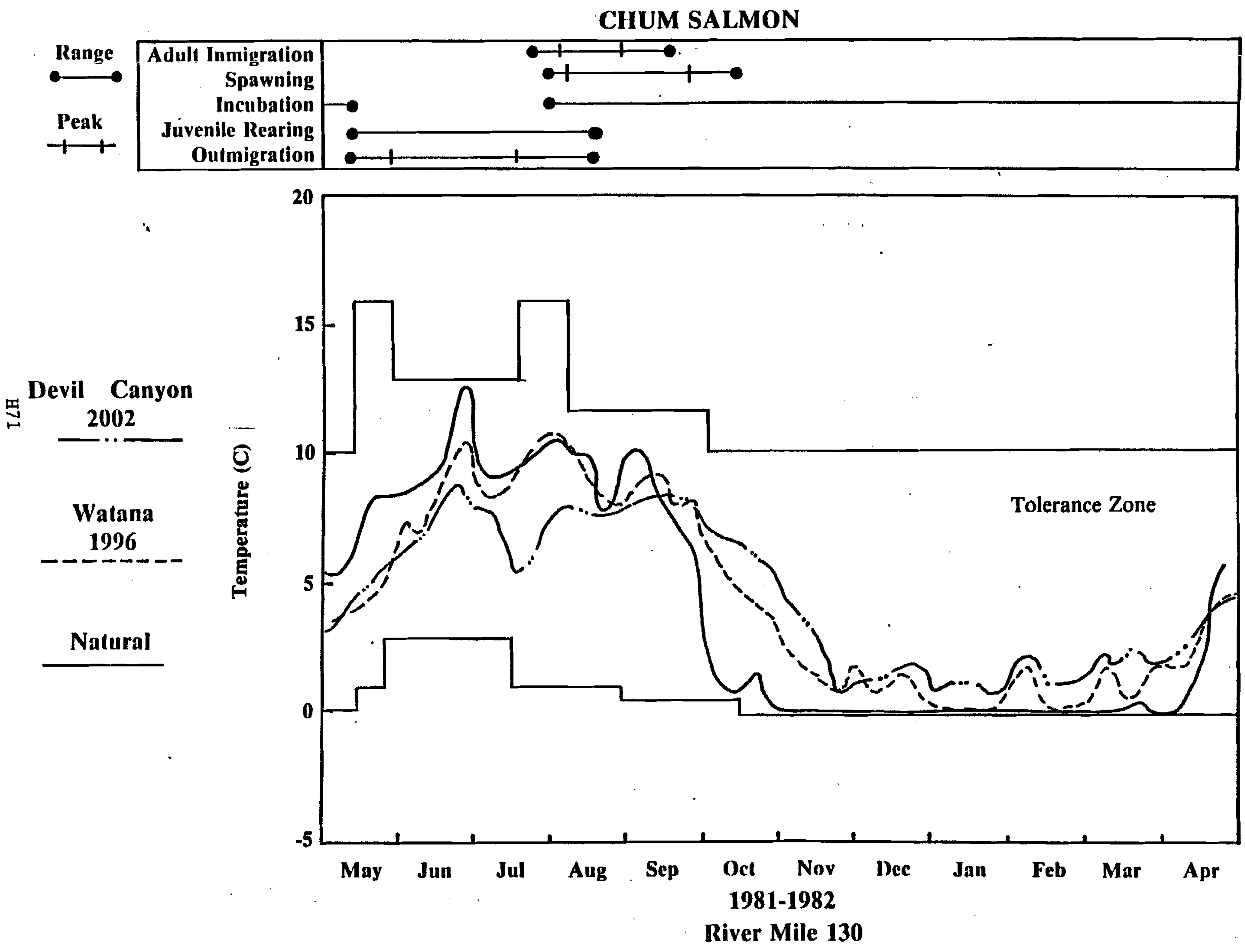

CHUM SALMON
Range
Peak
Adult Inmigration
Spawning
Incubation
Juvenile Rearing
Outmigration
20
15
10
5
0
-5
Temperature (C)
Tolerance Zone
Devil Canyon
2002
Watana
1996
Natural
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
1981-1982
River Mile 130
H71

Exhibit 8

HABITAT SUBSTRATE STABILITY

SUMMARY

Under natural conditions the bed material size distribution in the Susitna River depends upon the magnitudes and durations of high flows occurring during a flood season. These flows tend to sort out the bed material and shape the channel configuration. Bed material samples taken during 1983 at five main channel study sites in the Middle Reach of the Susitna River are well graded having a maximum size (D_{90} - the equivalent diameter that 90% of the material, by weight, is finer than) of approximately 3 inches, an average size (D_{50}) of 1 inch and a minimum size (D_{10}) of about 0.05 inch. The streambed at these sites appears to be in a stable regime over a long period. Material of less than approximately 3 inches is constantly being removed from the areas and replaced with similar size material from the bed load sediment transported by the river.

The mean annual or dominant discharge is generally considered as a measure of the ability of a stream to shape the channel configuration. This discharge, if allowed to flow continuously, would have the same overall channel shaping effect as the naturally fluctuating discharges would. With project, the dominant discharge in the river will be reduced, and bed load sediment transport movement will depend on the magnitude and duration of the spiking flows which may be implemented. Bed load sediment from upstream of the project will be trapped in the reservoirs. Material finer than transportable sizes for the project flows will not be replaced once removed from the bed. Therefore, the streambed at these study sites will degrade. It is estimated that the degradation will be between one ft. and three ft. depending on the magnitude and length of the spiking flows. As the spiking flow increases toward 50,000 cfs, the material will become less well graded and will approach a uniform size of 3 inches. If spiking flows are not implemented the bed material at these sites will be more well graded.

The studies presented herein are preliminary and pertain only to Middle River mainstem study sites. Additional studies of substrate stability in sloughs are being made. No generalization can be made from the studies herein to the sloughs because of the different nature of the hydraulics and sediment transport characteristics.

DISCUSSION

Studies are being made to determine the stability of habitat substrate material under project conditions, including potential spiking flows. These studies should be completed in the near future and a report will be issued. Mainstem and side slough habitat areas are being considered.

Preliminary analyses have been completed for the following areas:

1. Main channel near cross section 4, RM 99.0 to 100.0 (Exhibit 1).

2. Main channel between cross sections 12 and 13, RM 108.5 -110.0 (Exhibit 2).

3. Main channel upstream from Lane Creek, RM 113.6 - 114.2 (Exhibit 3).

4. Main channel upstream from 4th of July Creek, RM 131.2 - 132.2 (Exhibit 4).

5. Main channel between cross sections 46 and 48, RM 136.9 - 137.3 (Exhibit 5).

These areas are considered typical of Middle River main channel spawning areas because of the well graded substrate material.

Exhibits 6 through 10 show the measured bed material size distributions at the respective study sites. Exhibits 11 through 15 show the transportable bed material sizes (armoring sizes) at the study sites for various flows. The theory of dominant discharge explained in the U.S. Bureau of Reclamation publication "Design of Small Dams" was used to determine stable material sizes at the given study sites.

The dominant discharge under natural conditions is the mean annual flood of approximately 50,000 cfs. With project the dominant discharge has been estimated to be approximately 15,000 cfs due to regulation of flood events by the reservoir. Spiking flows were not considered in this determination. The following table shows the armoring size at natural and with project dominant discharges at the study sites.

Existing Substrate Material and Natural and With Project Armoring Sizes at Five Main Channel Study Sites

Main Channel Near	Existing Subs rate Materials[1]			Armoring Size[2]				
				Natural Conditions	With Project			
	D_{10} in	D_{50} in	D_{90} in	(50000 cfs)[3] in	(15000 cfs)[3] in	(25000 cfs)[3] in	(35000 cfs)[3] in	(45000 cfs)[3] in
Cross Section 4	0.02	0.8	2.6	1.8	1.1	1.4	1.6	1.7
Cross Sections 12 and 13	0.05	1.3	3.0	2.8	1.5	1.9	2.2	2.5
Upstream from Lane Creek	0.06	1.3	3.0	2.7	1.5	1.9	2.2	2.5
Upstream from 4th of July Creek	0.03	1.1	3.2	2.7	1.6	2.0	2.2	2.5
Cross Sections 46 annd 48	0.04	0.8	3.0	3.5	1.9	2.4	2.9	3.3

1/ From Exhibits 6 to 10
2/ From Exhibits 11 to 15
3/ Corresponding discharge from which armoring size is estimated.

Under natural conditions the armor layer is in a state of dynamic equilibrium (stable regime over a long period), that is, material in the armor layer may be displaced by some flows and replaced by bed load sediment moving downstream. Large flood events tend to disturb the equilibrium and tend to degrade or aggrade the stream channel at various locations. Bed load sediment transported from upstream as a result of the flood or following the flood could deposit in areas degraded by the flood. This counteracts degradation and depending on downstream hydraulic and sediment processes may increase bed elevations. In this case the armoring process will be renewed and the river bed will reach equilibrium at a new elevation when the armoring process has been completed.

There is some evidence from an examination of photographs of the Susitna River between 1949 and the present that some areas of the Middle Reach of the river are currently in a state of long term degradation. (Draft report by AEIDC, "Geomorphic Change in the Devil Canyon to Talkeetna Reach of the Susitna River Since 1949").

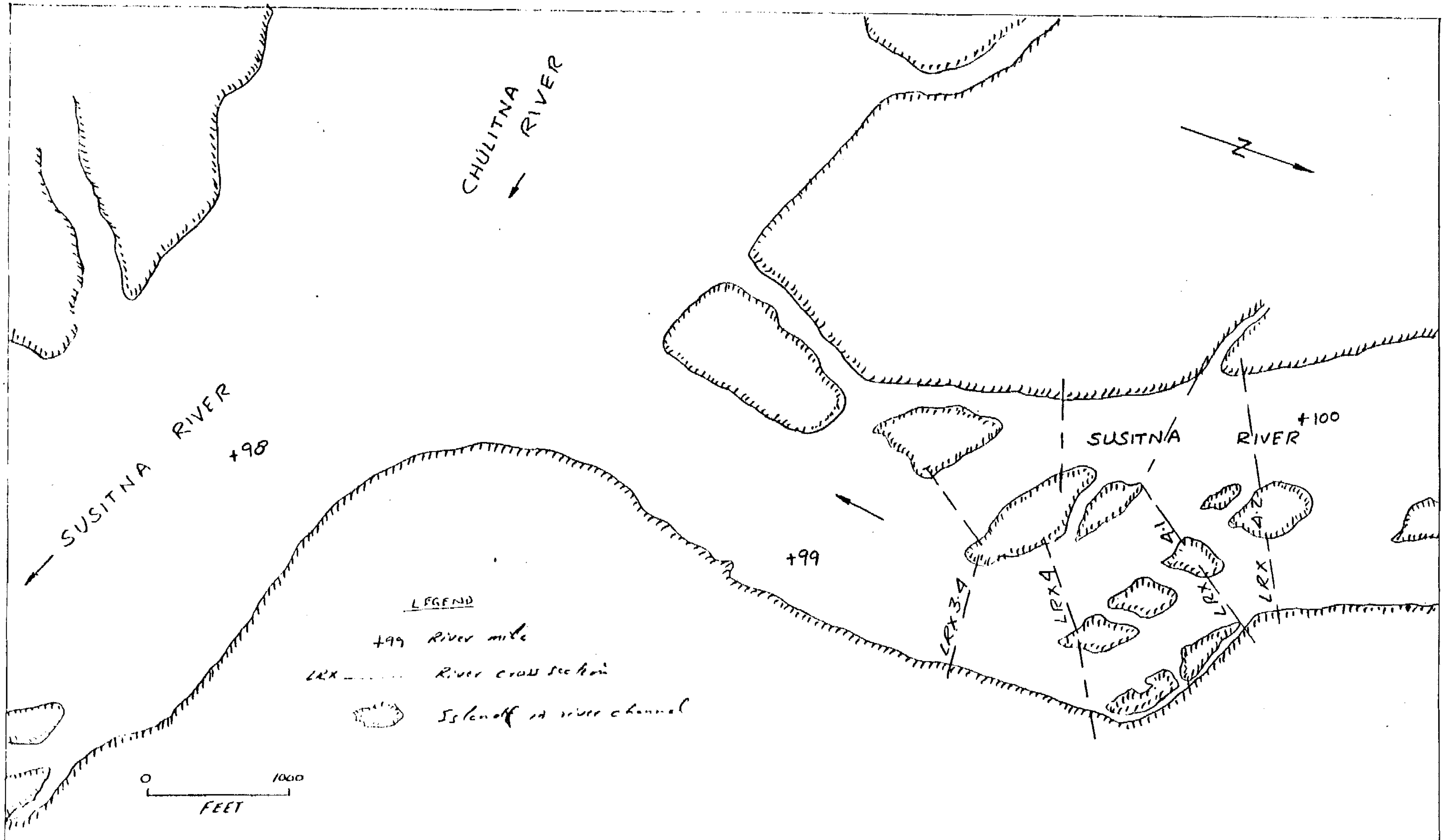
The construction and operation of the Susitna Hydroelectric Project will substantially reduce the transport of bed load in the Middle Reach of the Susitna River. Most bed load sediment will be trapped in the reservoirs and will be eliminated as a replacement for fine material removed from the bed downstream of the dams. In time, the minimum size of material at these study sites will increase toward the armoring size. Additionally, the streambed will degrade until it is armored. The Harza-Ebasco Report "Reservoir and River Sedimentation" indicates that long-term average bed degradation in the Middle Reach, with project, will not exceed 0.3 feet and will average 0.1 to 0.2 feet. Localized degradation may be higher or lower depending on bed material composition as indicated in the preliminary results contained herein.

The following table shows the expected armoring sizes and amounts of degradation at the study sites for various discharges. If spiking flows of these magnitudes are implemented, the expected degradations will approach the values given in the table. These are conservative values because they are based on given discharges assuming currently available bed material size distribution. Spiking flows may change from year to year or may not be used annually. Higher spiking flows may only be used occasionally. Under such conditions, the magnitude of degradation for higher flows is likely to be less than shown in the table because lower spiking flows will make the bed material coarser than assumed.

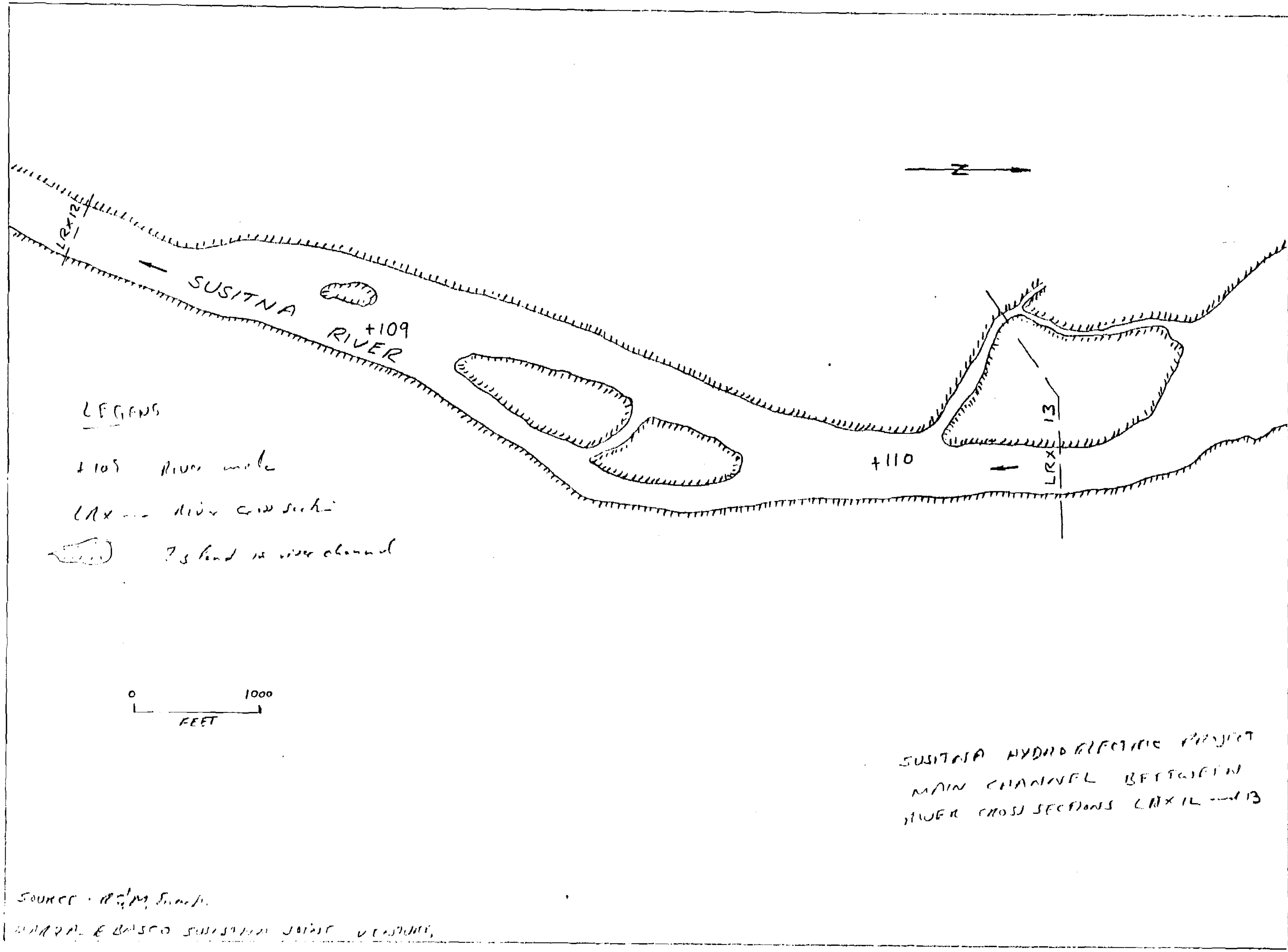
Estimated Armoring Sizes and Degradation
For Various Dominant Discharges

Main Channel Near	15,000 cfs Armoring Size in	15,000 cfs Degradation in	25,000 cfs Armoring Size in	25,000 cfs Degradation in	35,000 cfs Armoring Size in	35,000 cfs Degradation in	45,000 cfs Armoring Size in	45,000 cfs Degradation in
Cross Section 4	1.1	12	1.4	18	1.6	23	1.7	28
Cross Sections 12 and 13	1.5	7	1.9	11	2.3	16	2.6	26
Upstream from Lane Creek	1.5	7	1.9	11	2.2	17	2.5	26
Upstream of 4th of July Creek	1.6	10	2.0	13	2.2	19	2.5	29
Cross Sections 46 to 48	1.9	12	2.4	20	2.9	30	3.3	43

EXHIBIT 1



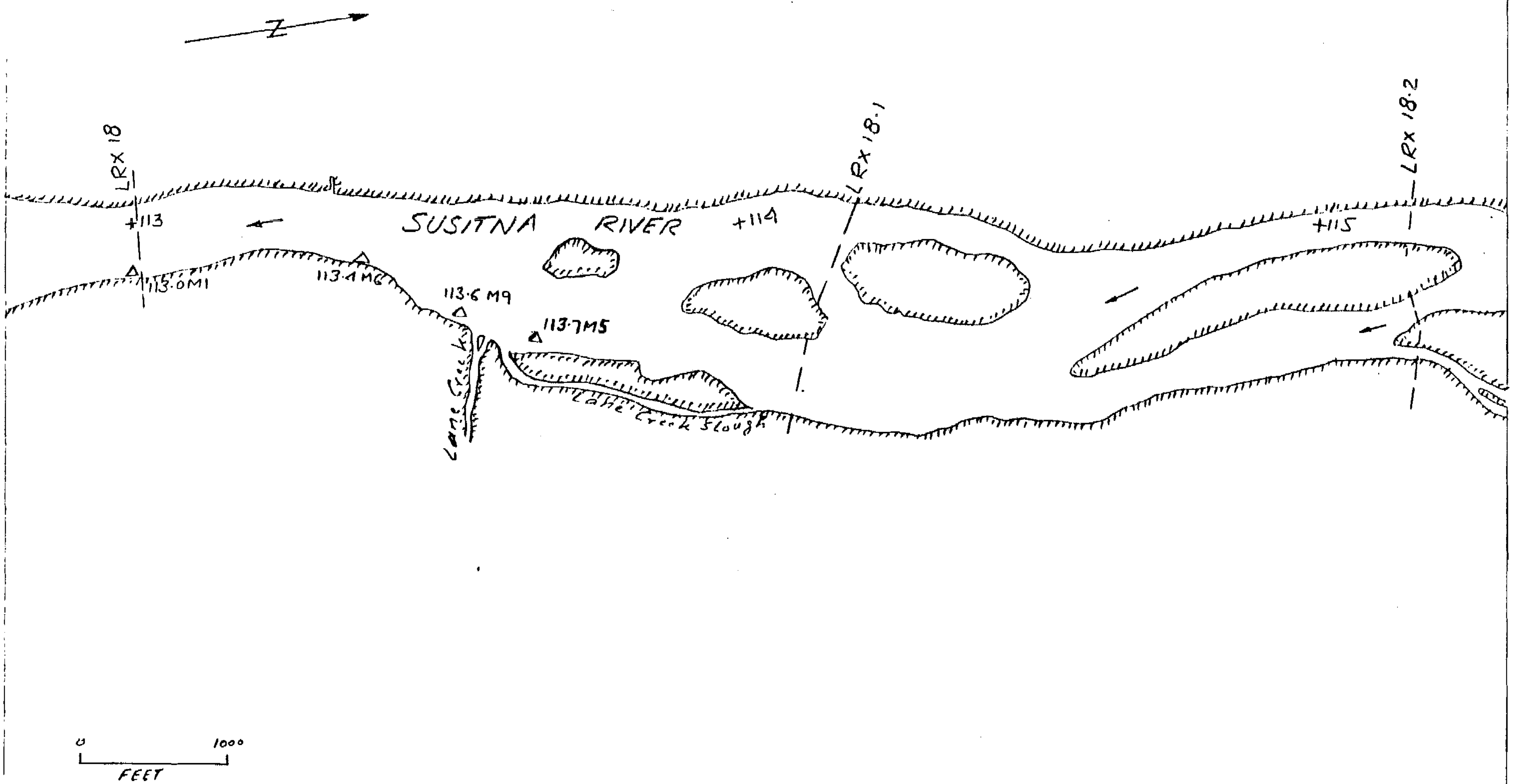
SUSITNA HYDROELECTRIC PROJECT
MAIN RIVER CHANNEL NEAR
RIVER CROSS SECTION LRX 4



SUSITNA RIVER
+109
+110
LRX 12
LRX 13
N
LEGEND
+105 River mile
0
1000
FEET
SUSITNA HYDROELECTRIC PROJECT
MAIN CHANNEL BETWEEN
RIVER CROSS SECTIONS LRX 12 and 13
SOURCE: R&M Consult.
HARZA EBASCO SUSITNA JOINT VENTURE

EXHIBIT 2

EXHIBIT 3

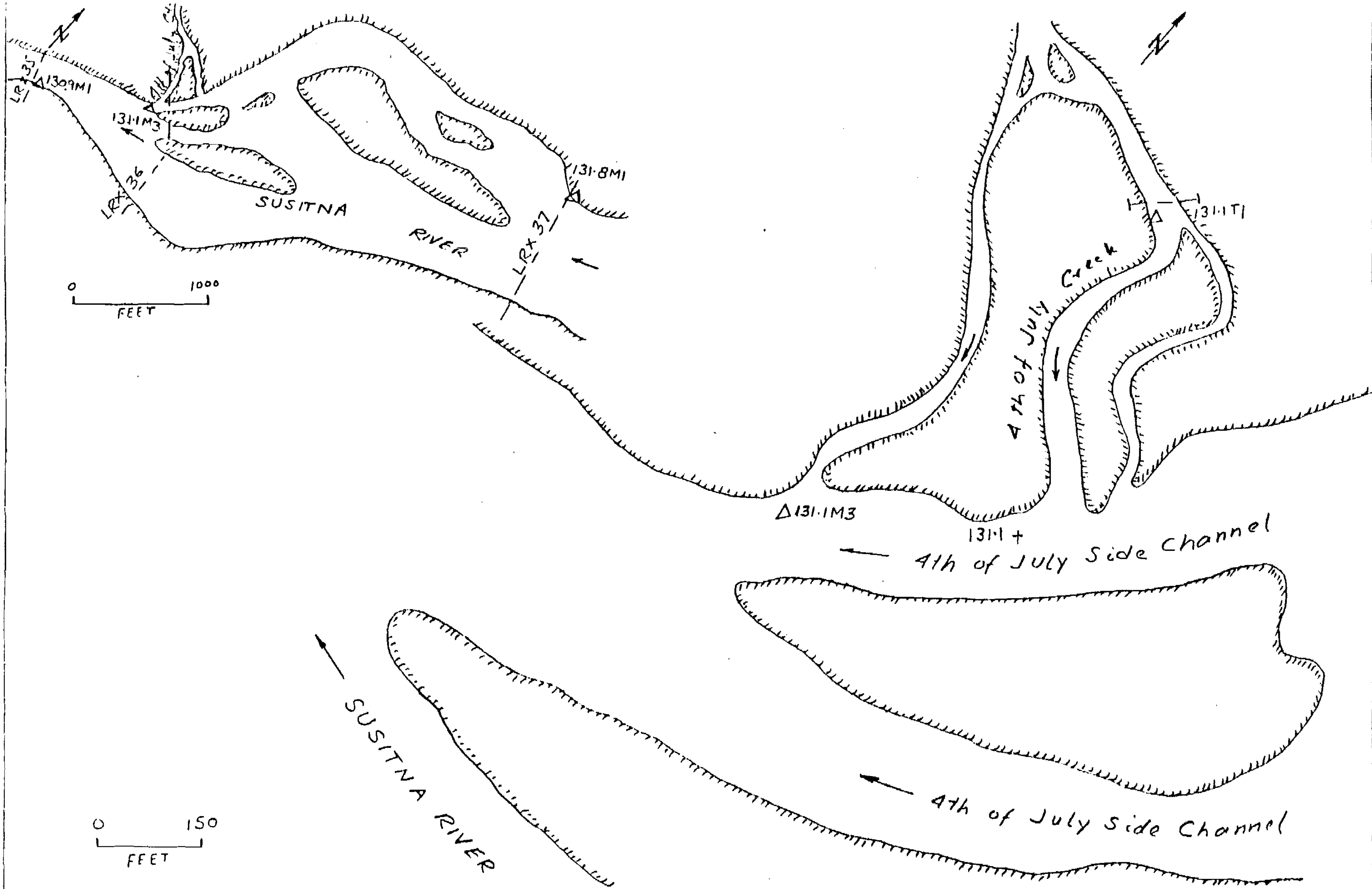


SUSITNA HYDRO ELECTRIC PROJECT
MAIN CHANNEL UPSTREAM
FROM LANE CREEK

Source: R&M Incorporated.

HARZA-EBASCO SUSITNA JOINT VENTURE

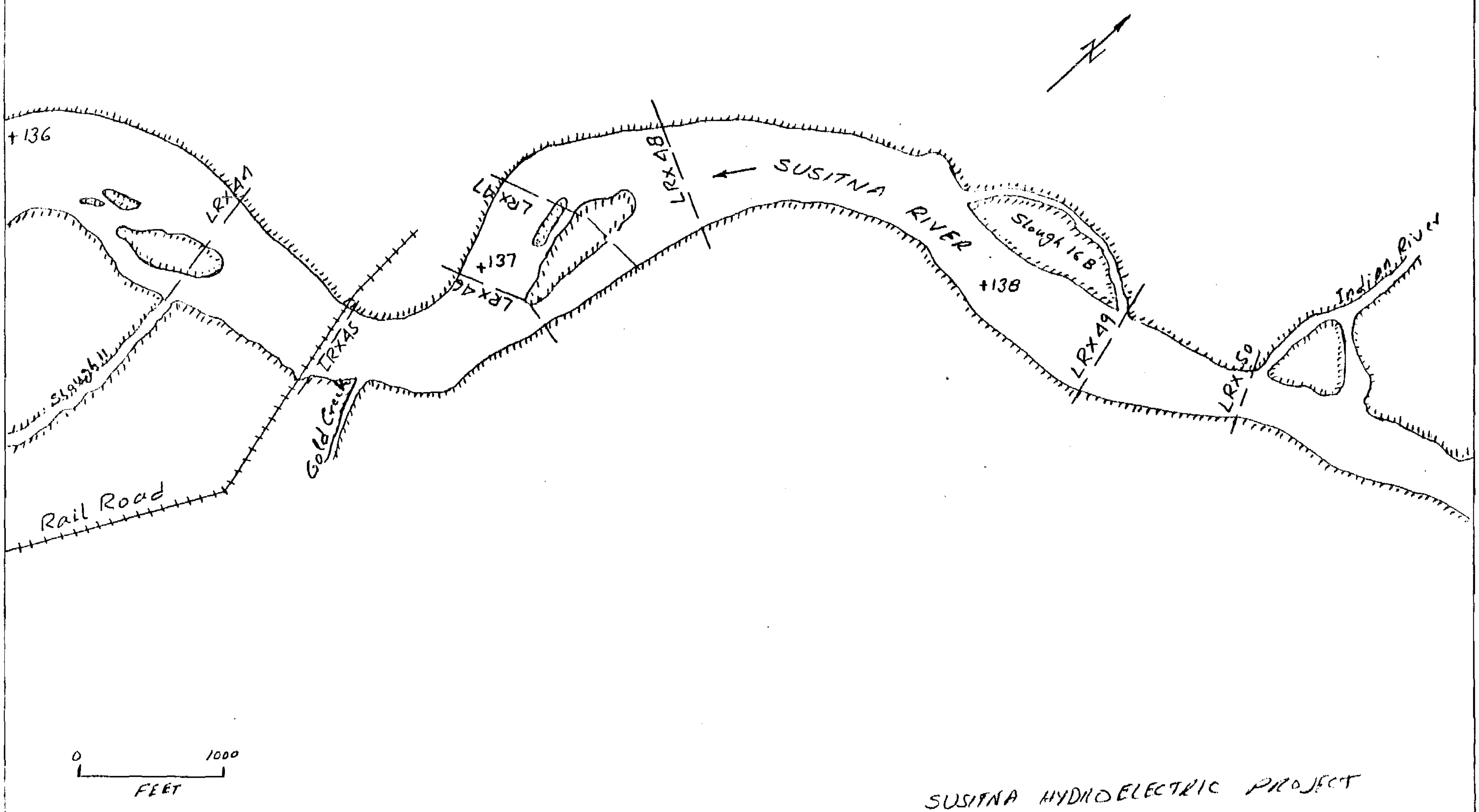
EXHIBIT A



SUSITNA HYDROELECTRIC PROJECT
MAIN CHANNEL NEAR MILL
UPSTREAM FROM 4TH OF JULY CREEK

SOURCE

HARZA-EBASCO SUSITNA JOINT VENTURE

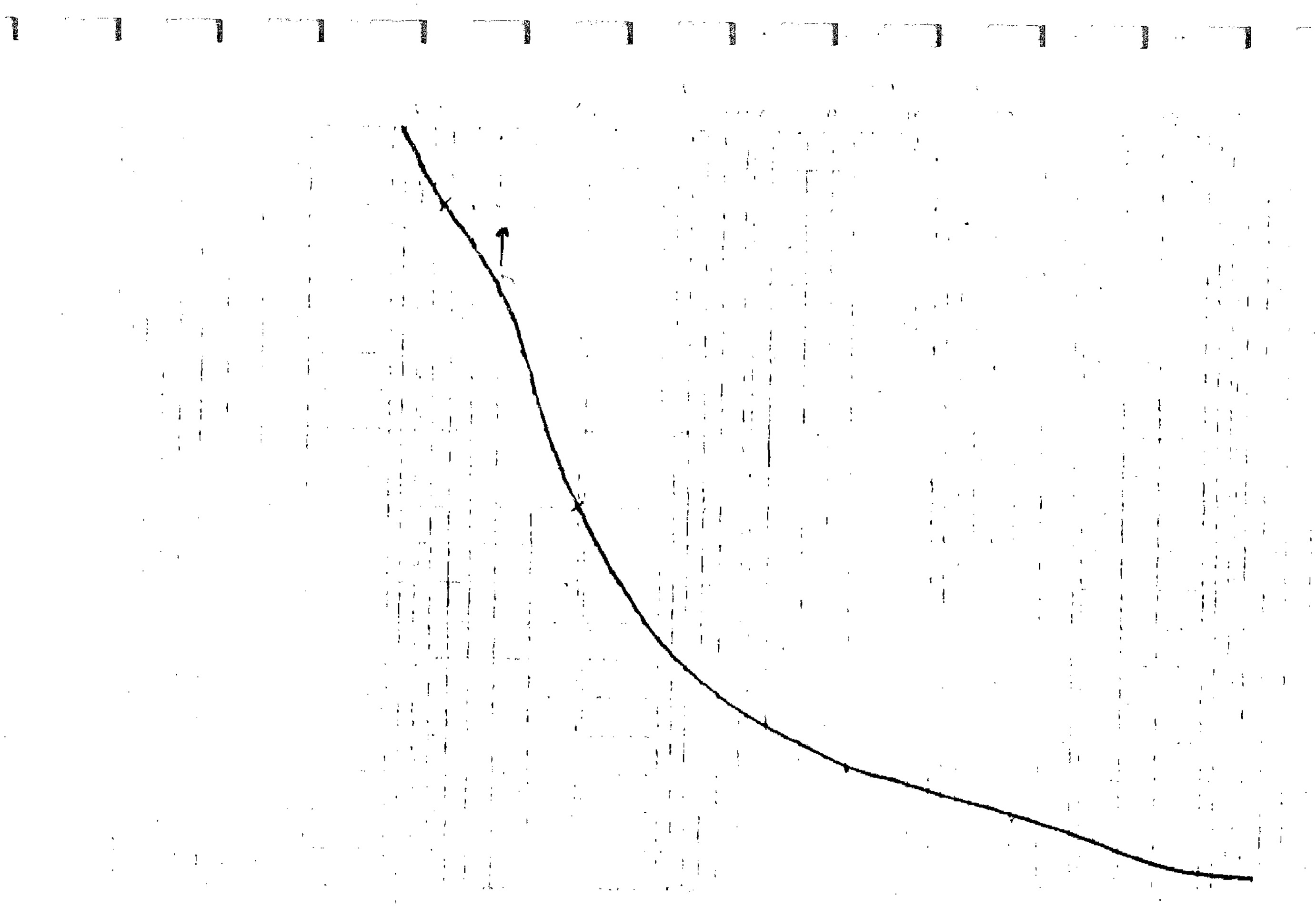


SUSITNA HYDROELECTRIC PROJECT
MAIN CHANNEL BETWEEN RIVER
CROSS SECTIONS 46 AND 48

SOURCE: R&M Incorporated

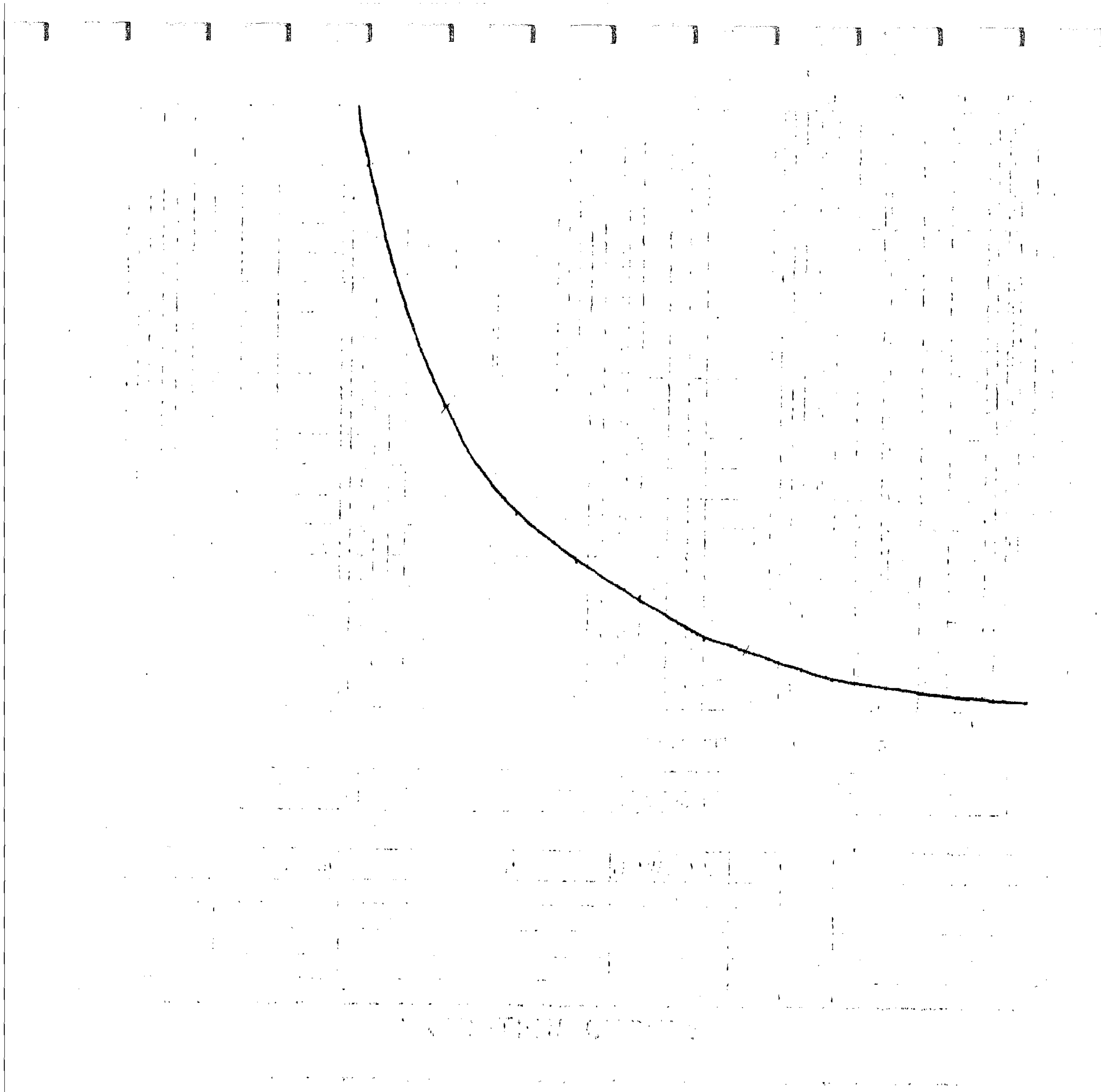
HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 6

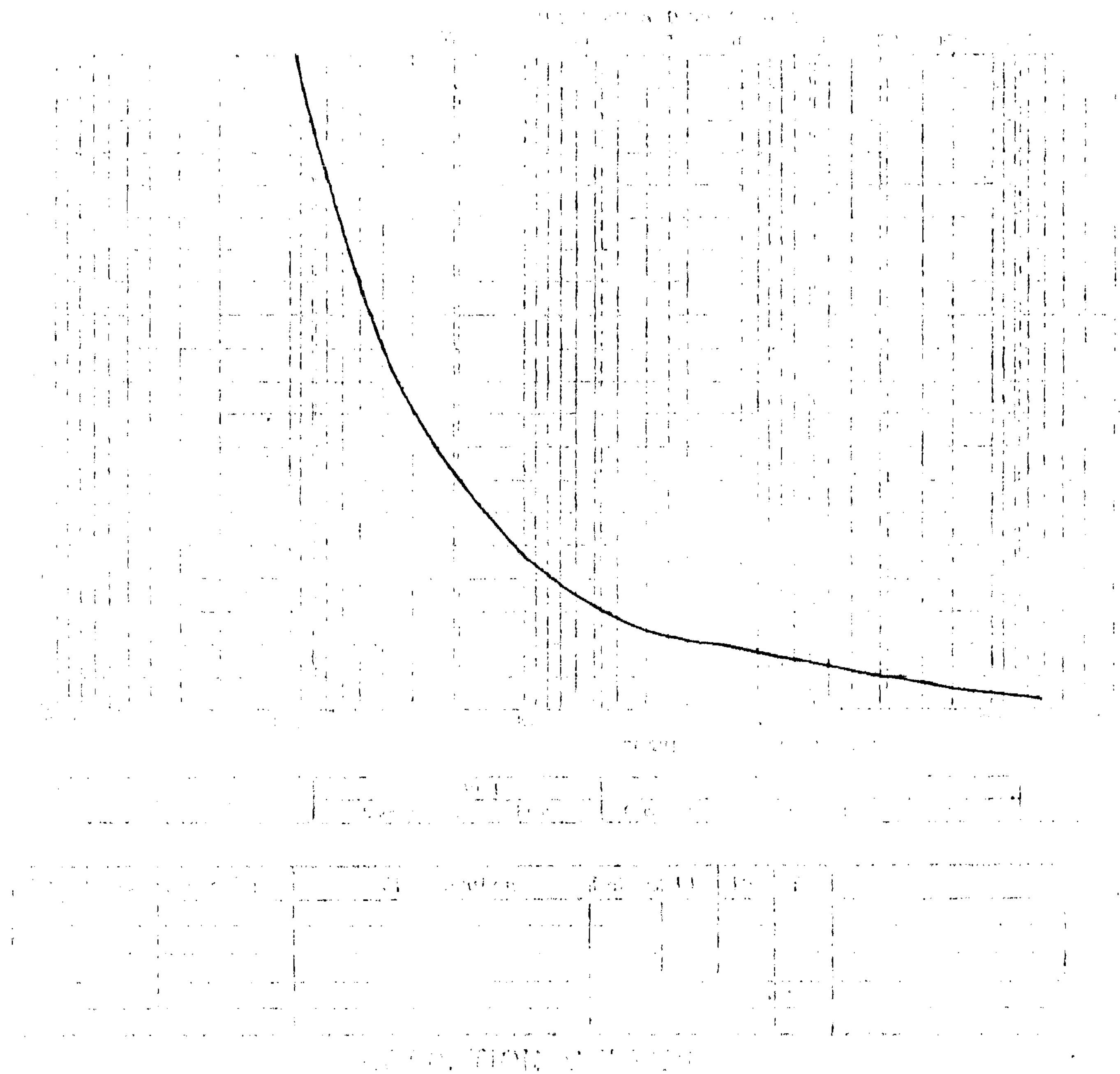


SUSITNA HYDROELECTRIC PROJECT
SIZE DISTRIBUTION OF BED
MATERIAL IN MAIN CHANNEL
NR. CROSS SECTION 4.0

Exhibit 7

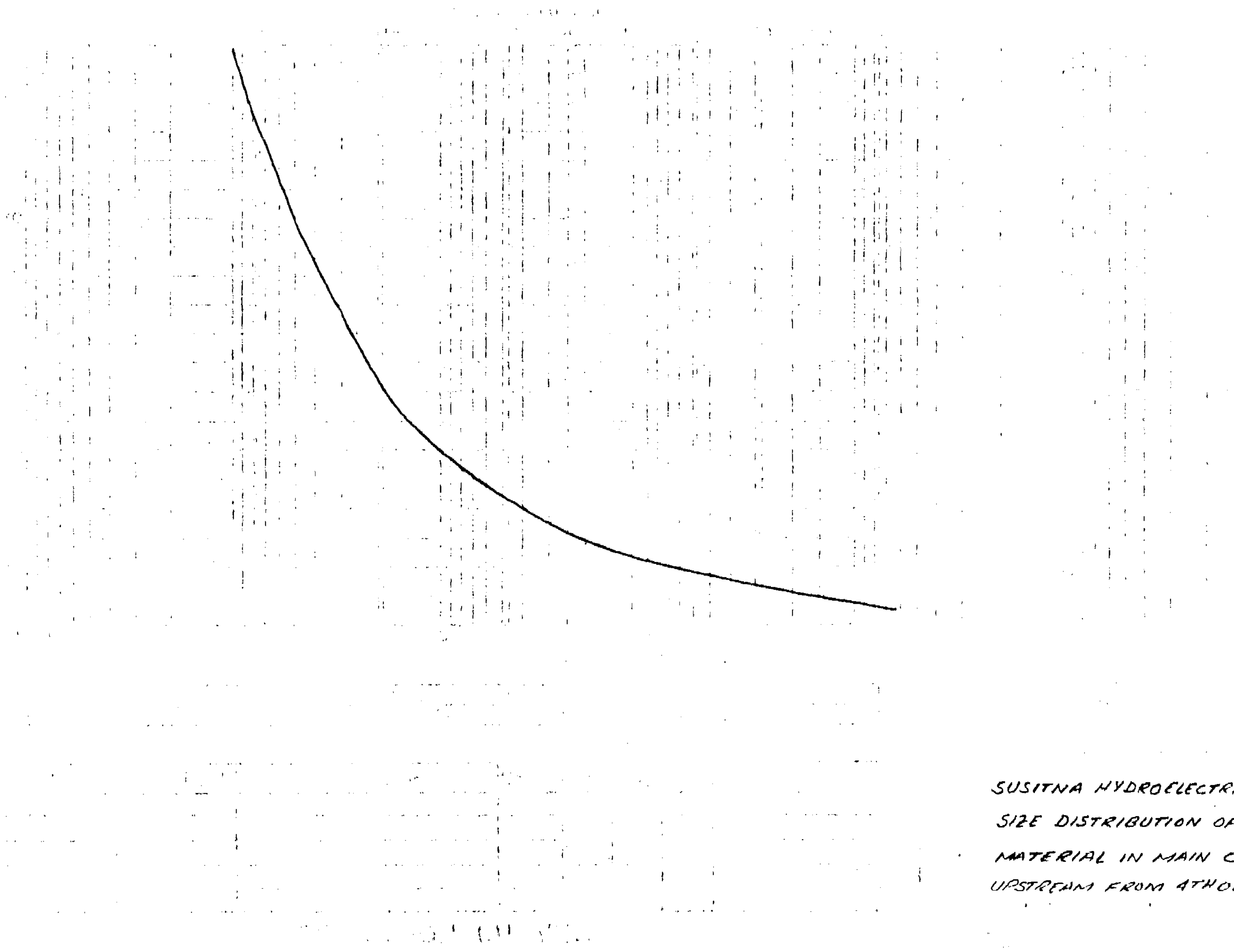


SUSITNA HYDROELECTRIC PROJECT
SIZE DISTRIBUTION OF BED
MATERIAL IN MAIN CHANNEL
NR. CROSS SECTIONS 12 AND 13

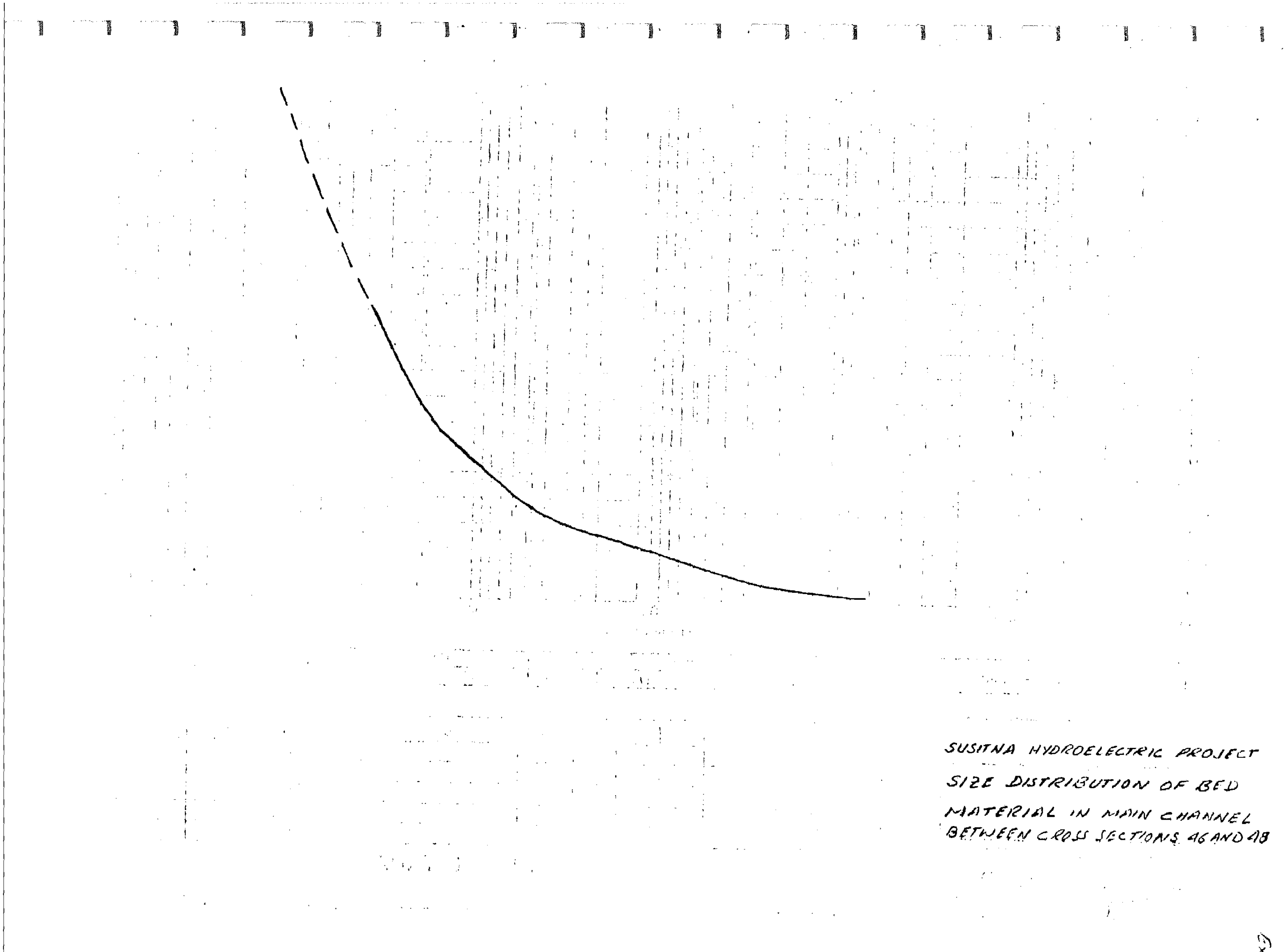


SUSITNA HYDROELECTRIC PROJECT
SIZE DISTRIBUTION OF BED
MATERIAL IN MAIN CHANNEL
NR. LANE CREEK (UPSTREAM)

Exhibit d

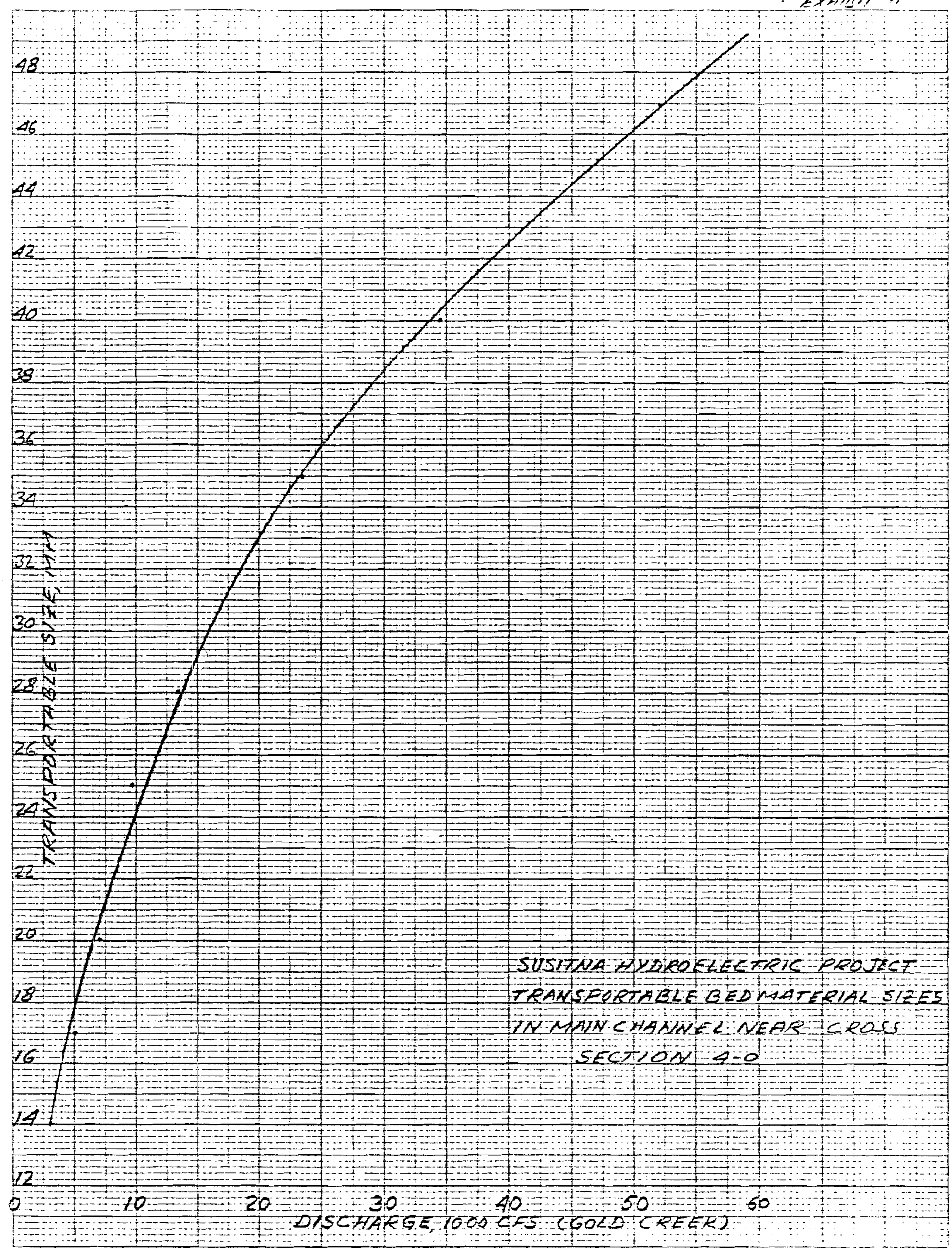


SUSITNA HYDROELECTRIC PROJECT
SIZE DISTRIBUTION OF BED
MATERIAL IN MAIN CHANNEL
UPSTREAM FROM 4TH OF JULY CREEK



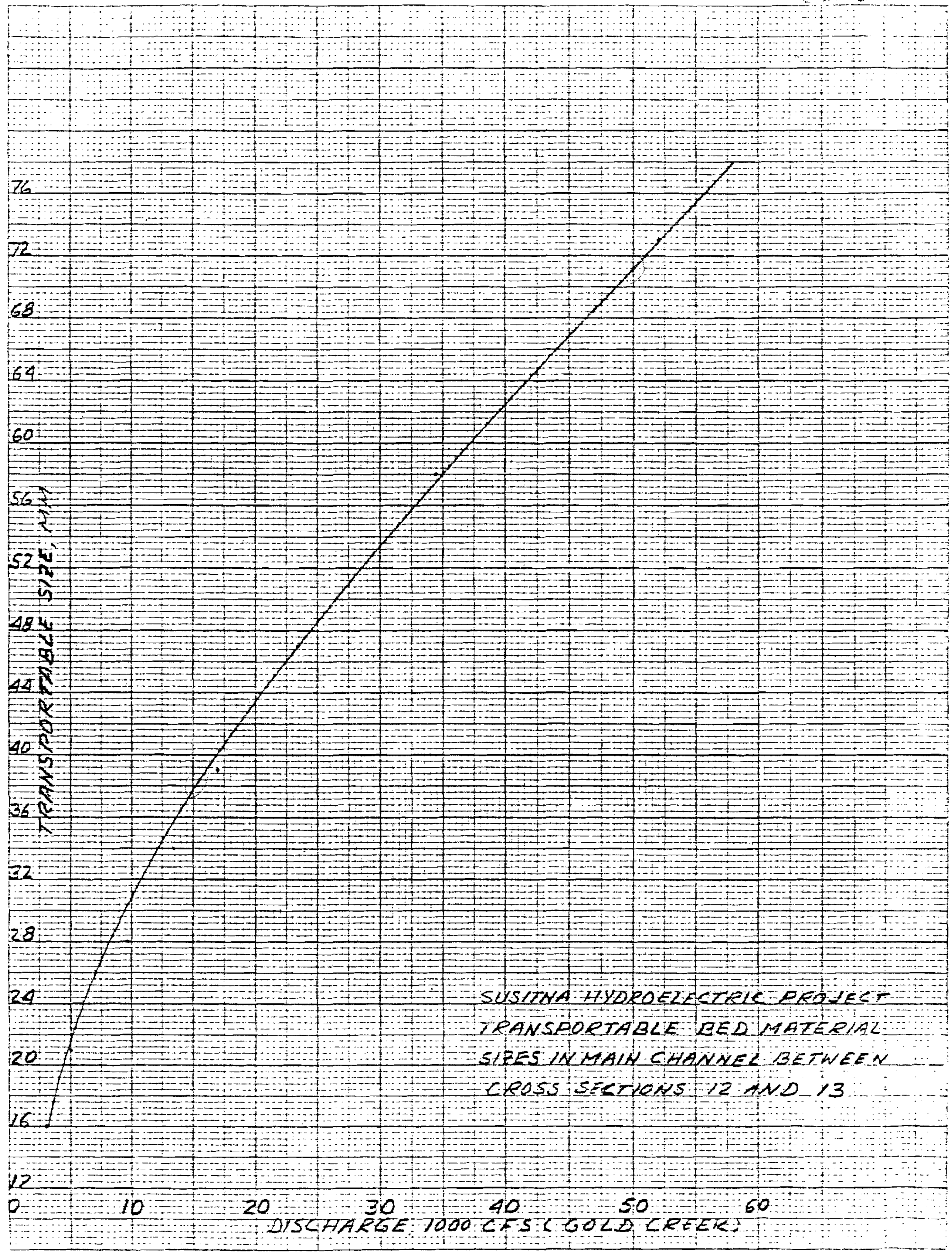
SUSITNA HYDROELECTRIC PROJECT
SIZE DISTRIBUTION OF BED MATERIAL IN MAIN CHANNEL BETWEEN CROSS SECTIONS 46 AND 48

EXHIBIT 11



48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
0
10
20
30
40
50
60
TRANSPORTABLE SIZE, MM
DISCHARGE, 1000 CFS (GOLD CREEK)
SUSITNA HYDROELECTRIC PROJECT
TRANSPORTABLE BED MATERIAL SIZES
IN MAIN CHANNEL NEAR CROSS
SECTION 4-0

EXHIBIT 12



SUSITNA HYDROELECTRIC PROJECT
TRANSPORTABLE BED MATERIAL
SIZES IN MAIN CHANNEL BETWEEN
CROSS SECTIONS 12 AND 13
TRANSPORTABLE SIZE, MM
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
0
10
20
30
40
50
60
DISCHARGE 1000 CFS (GOLD CREEK)

EXHIBIT 13

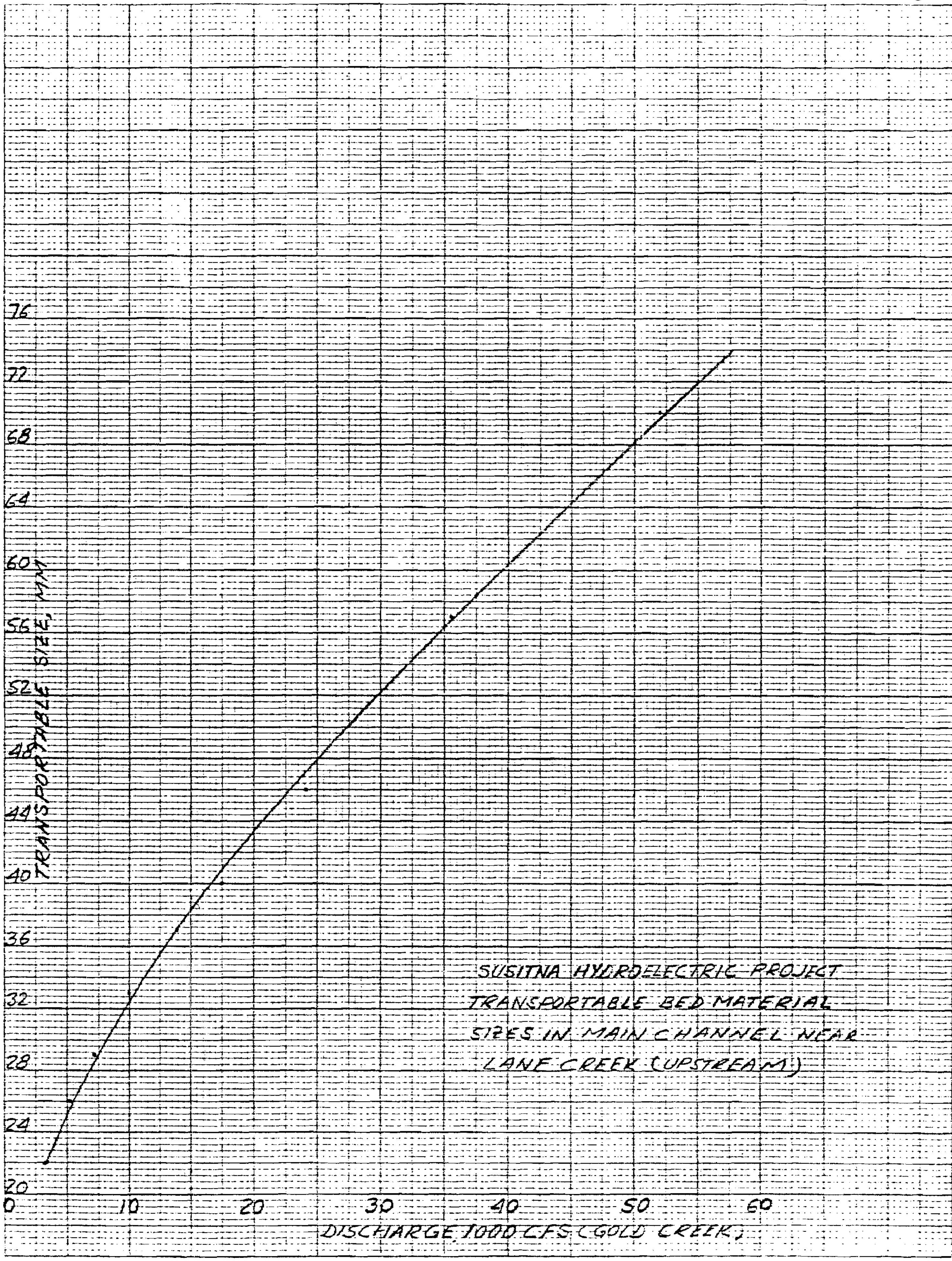
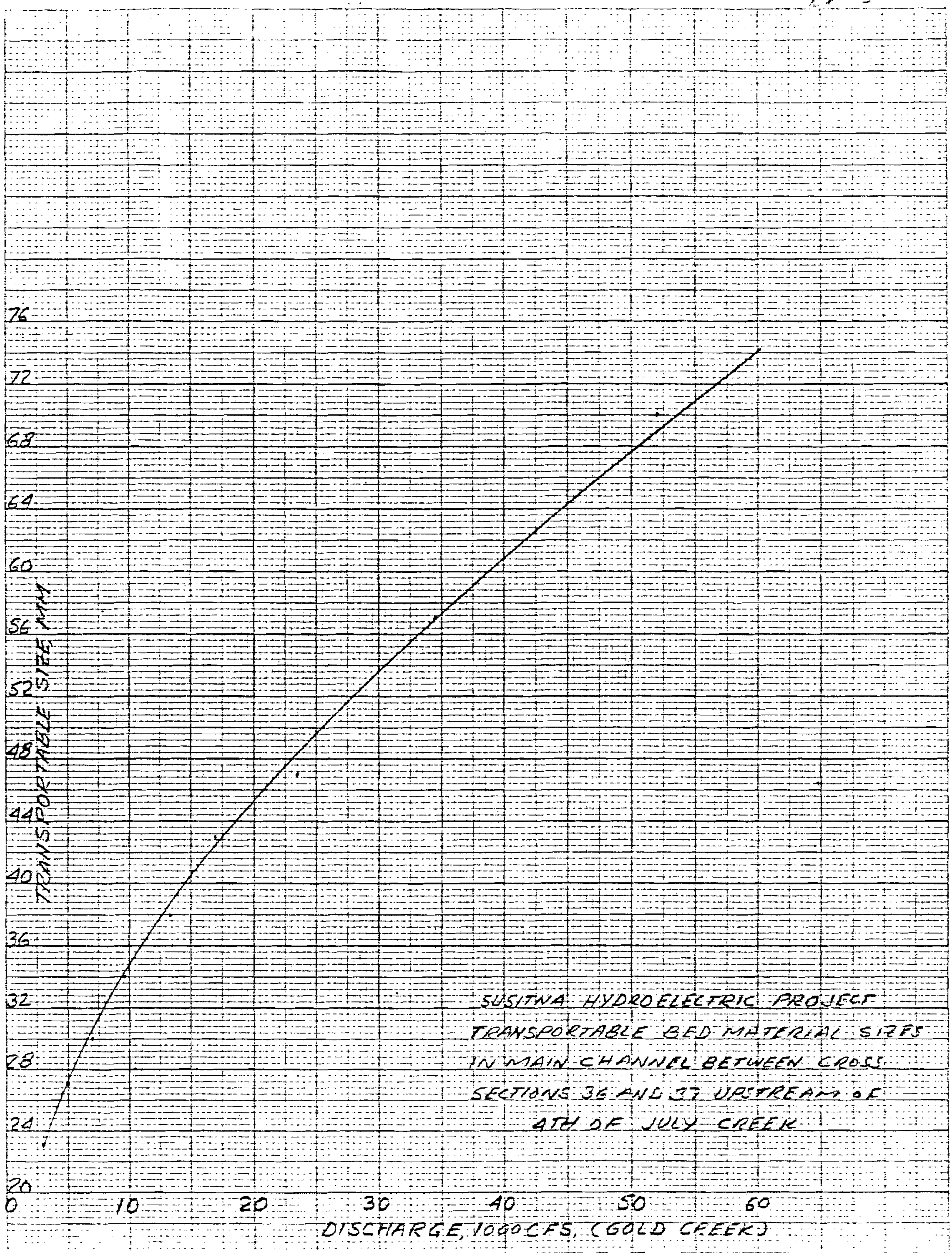
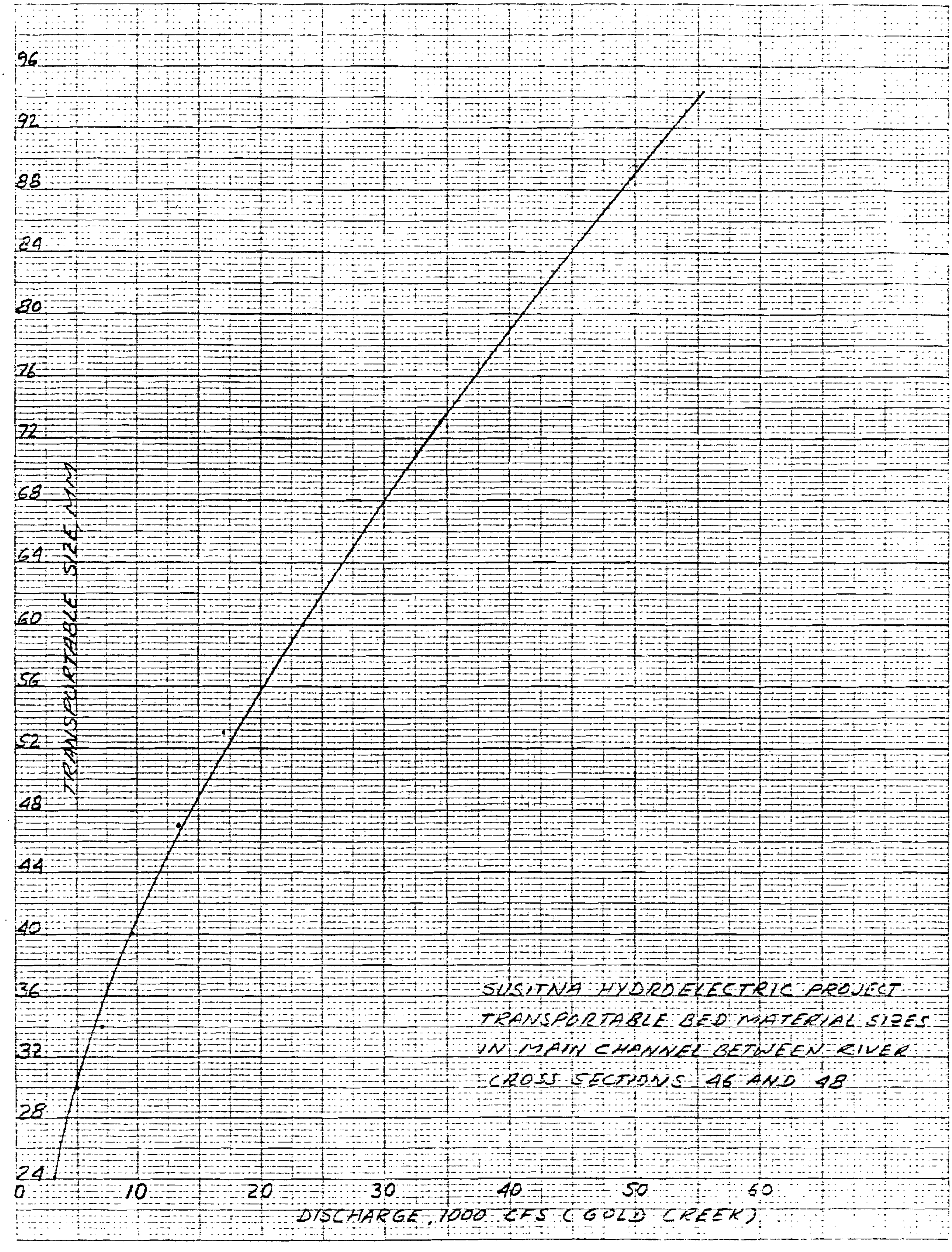

SUSITNA HYDROELECTRIC PROJECT
TRANSPORTABLE BED MATERIAL
SIZES IN MAIN CHANNEL NEAR
LANE CREEK (UPSTREAM)
TRANSPORTABLE SIZE, MM
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
0
10
20
30
40
50
60
DISCHARGE 1000 CFS (GOLD CREEK)

EXHIBIT 10



SUSITNA HYDROELECTRIC PROJECT
TRANSPORTABLE BED MATERIAL SIZES
IN MAIN CHANNEL BETWEEN CROSS
SECTIONS 36 AND 37 UPSTREAM OF
4TH OF JULY CREEK
TRANSPORTABLE SIZE, MM
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
0
10
20
30
40
50
60
DISCHARGE, 1000 CFS, (GOLD CREEK)

Exhibit 15



96
92
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
TRANSPORTABLE SIZE, MM
0
10
20
30
40
50
60
DISCHARGE, 1000 CFS (GOLD CREEK)
SUSITNA HYDROELECTRIC PROJECT
TRANSPORTABLE BED MATERIAL SIZES
IN MAIN CHANNEL BETWEEN RIVER
CROSS SECTIONS 46 AND 48

HARZA-EBASCO SUSITNA JOINT VENTURE

INTRA-OFFICE MEMORANDUM

LOCATION Anchorage DATE December 7, 1984

TO L. Gilbertson NUMBER 4.3.16/4.3.1.1

FROM J. Bizer Page 1

SUBJECT Interpretation of ADF&G SuHydro Mainstem and Local Flow Values for Successful Passage Conditions

Sautner et al (1984) presents results of a study to define mainstem and local slough discharge requirements to allow passage of adult chum and sockeye salmon to spawning areas in sloughs and side channels. Estimates of mainstem discharge were calculated assuming a negligible slough discharge and, conversely, estimates of slough discharges were calculated assuming negligible influence of mainstem discharges. For passage reaches near the mouths of the sloughs and side channels, the estimated mainstem flow requirements are extremely conservative since they neglect local flow contribution. In fact, both mainstem discharge and local slough discharge interact to provide water depth in those passage reaches. The analysis presented by Sautner et al (1984) makes no attempt to integrate the two sources of water which present passage conditions. The purpose of this memorandum is to present a first approximation of how local slough discharge and mainstem discharge may interact to provide adequate passage conditions at mainstem discharges considerably less than the independent estimates of mainstem discharge backwater effects.

In the evaluation of the effects of the proposed Susitna Project on aquatic resources downstream of the dams, a principle question centers on the maintenance of salmon populations which utilize habitats which are directly affected by mainstem discharge. The maintenance of these populations depends upon the effects of mainstem discharge on the immigration of adult salmon through the main channel of the Susitna River, the movement of adult salmon into spawning areas, and the use of various habitat types of salmon for spawning, incubation and rearing.

The evaluation of conditions necessary for salmon to gain access to spawning areas is a key step in the overall evaluation of the effects of the proposed project on existing salmon populations and their habitats. Approximately 15-25 percent of the chum salmon (approximately 5000 fish), which enter the Devil Canyon to Talkeetna reach of the Susitna River to spawn, utilize side slough and side channel habitats (Barrett, et al. 1984). Nearly 100 percent of the sockeye salmon (approximately 1500 fish) which enter the Devil Canyon to Talkeetna reach to spawn utilize side slough and side channel for spawning.

Side sloughs are overflow channels of the mainstem which convey turbid mainstem water when mainstem discharge is relatively high. This occurs during the summer open water months. When mainstem discharge is lower, the upstream ends of the sloughs are not overtopped and are similar to small tributaries which convey clear, local surface runoff and groundwater upwelling. These sources of water together are termed local flow or local discharge. During low mainstem discharge conditions, side

12/10 CH

slough discharges range from about 1-2 cfs to more than 10 cfs depending upon whether or not small tributaries enter the sloughs. When the upstream ends of the sloughs are overtopped, slough discharges range upward of several hundred cubic feet of water per second.

Side channels are similar to side sloughs in structure and hydrologic relationships with the mainstem. The principle distinction between these two habitats is that the proportion of time which a side channel conveys mainstem water is considerably greater than that for side sloughs. Klinger and Trihey (1984) distinguish between side sloughs and side channels based on whether the channel is conveying mainstem water. A given channel is considered a side channel when it is conveying mainstem water and is considered a side slough when it is not. For purposes of this discussion, channels will be referred to as sloughs in this sense.

The ability of salmon to gain access to spawning areas within sloughs is dependent upon the depth of water within a given reach of the slough. In general, the shallower the water, the more difficult the passage conditions are for movement of salmon through the reach. The degree of difficulty is dependent not only upon the absolute depth of the water but also upon the length of the reach which must be traversed. Thus, salmon are able to negotiate very shallow water if the reach is short. However, somewhat greater depths are required if the reaches are longer. Reaches of the slough channels in which the water depths are sufficiently shallow to restrict movement of fish are termed passage reaches. Generally, passage reaches are located in riffle areas within the sloughs. For most sloughs, the depth of water through most passage reaches is dependent upon the slough discharge. Slough discharge, in turn, is provided by local surface runoff and groundwater upwelling. (This disregards the influence of mainstem discharge sufficiently great to overtop the upstream end of the channel).

For passage reaches located near the downstream ends of the sloughs, water depth is influenced not only by discharge from the slough, but also by backwater effects of the mainstem. The backwater effect on the depth of water in a given passage reach is evident when the water surface elevation of the mainstem at that passage reach is greater than that which can be solely attributed to local slough discharge.

Studies conducted by ADF&G SuHydro during 1982 (ADF&G 1983a,b) resulted in estimates of the access conditions corresponding to various mainstem discharges and water surface elevations at a limited number of sloughs.

Results presented for the 1983 studies (Sautner et al. 1984) expand the number of sloughs and side channels studied and provide independent estimates of local flow and mainstem discharges corresponding to threshold values for successful and unsuccessful passage conditions. These results have raised several questions regarding the local and mainstem discharges necessary to provide successful passage conditions for chum and sockeye salmon.

The results presented by ADF&G SuHydro (Sautner et al. 1984) are the first attempts to show the relationship between mainstem and local flows in providing adequate access conditions to the sloughs and side channels for chum and sockeye salmon. Previous reports (ADF&G 1983a, b and Trihey 1982) evaluated passage conditions only on the basis of mainstem flow. In some cases, this led to a relatively low mainstem discharge requirement since it did not account for local flow contribution to passage depths for salmon access into the sloughs. In other cases, the analyses resulted in high estimates of mainstem discharges required to provide adequate passage conditions for adult salmon. The latest report presents results of independent calculations of flows, either mainstem or local, which provide successful or unsuccessful passage conditions.

In understanding these values, it must be kept clearly in mind that mainstem flows and local flows required to provide successful passage conditions were calculated independently of each other. In the report (Sautner et al. 1984), the mainstem flow determined to provide successful passage conditions was calculated under the assumption of negligible local flow, likewise, the local flow required to provide the same passage conditions was calculated assuming no direct mainstem backwater influence. A similar rationale was used to calculate mainstem and local flows to meet the unsuccessful/successful-with-difficulty threshold criterion. By integrating the mainstem and local flow calculations, a somewhat better appraisal of passage conditions relative to mainstem flow becomes apparent.

To provide a basis for comparing conditions for a passage reach at various mainstem discharges, ADF&G (Sautner et al. 1984) established three passage conditions: unsuccessful, successful with difficulty, and successful. These correspond to the terms acute, restricted and unrestricted, respectively, as previously used by ADF&G (1983a, b). The three passage conditions are distinguished by threshold depths within the passage reaches. The specific threshold passage depths for the three passage conditions are also dependent upon the length of the passage reach; that is, the threshold depths are greater for long passage reaches than for short passage reaches. Two sets of criteria curves were developed by ADF&G and are presented in the latest report as Figures 6-4 and 6-5 (Sautner, et al. 1984). Two curves were developed to account for two different types of passage reaches: uniform channel and non-uniform channel.

An explanation of the results obtained for Passage Reaches (PR) I and II at Slough 11 is provided below to demonstrate how these results can be integrated into an analysis of access conditions.

In the 1983 ADF&G Reports (1983 a, b), it is estimated that a mainstem discharge of 6,700 cfs is sufficient to provide successful (unrestricted) access conditions into Slough 11. Results of the 1984 analysis indicate that mainstem discharges of 16,200 cfs and 33,200 cfs are required to provide successful passage conditions at Passage Reaches I and II respectively. These results were obtained by determining the streambed elevations at the highest points of the thalweg profile 1/ in the passage reaches, determining the water depths and water surface elevations required to meet the passage criteria, and then determining what mainstem discharge is necessary to provide those water surface elevations (depths). This portion of the analysis was based upon the assumption of a negligible local flow from the slough itself.

For PR I, the critical point in the passage reach (that is, the highest point along the thalweg) is at an elevation of 667.75 ft, mean sea level, (MSL). This is shown on Figure 6-E-7 of the ADF&G report (reprinted here as Figure 1) at approximately Station 3+50. By adding the passage depths which distinguish unsuccessful from successful-with-difficulty and successful-with-difficulty from successful, (0.32 and 0.41 ft, respectively) the water surface elevations for unsuccessful and successful conditions are less than El. 668.09 and greater than El. 668.16, respectively. (The passage depth requirements are from Curve I, Figure 6-4 and assume a passage reach length of 250 ft). The water surface elevations and thalweg elevation are depicted in Figure 2 as constants over the range of mainstem discharges.

1/ The thalweg elevation is defined as the lowest elevation or the deepest point of a cross-section through a water channel. A thalweg profile is constructed by connecting the deepest points of several cross-sections along the length of the channel.

HARZA-EBASCO SUSITNA JOINT VENTURE

INTRA-OFFICE MEMORANDUM

LOCATION Anchorage DATE December 7, 1984

TO L. Gilbertson NUMBER 4.3.16/4.3.1.1

FROM J. Bizer

SUBJECT Interpretation of ADF&G SuHydro Mainstem and Local Flow Values for Successful Passage Conditions

By superimposing the stage-discharge relationship from the data obtained from a staff gage located at the mouth of Slough 11 (ADF&G Gage 135.3W1) (Quane, et. al 1984), it is possible to determine the mainstem discharges corresponding to unsuccessful and successful passage threshold conditions. The staff gage data are plotted on Figure 2. Based upon this curve along, and assuming no influence of local flow, mainstem discharges less than 15,200 cfs result in unsuccessful (acute) access conditions at PR I and mainstem discharges greater than 16,200 cfs result in successful (unrestricted) passage conditions.

A second superimposition of local flow vs water surface elevation within PR I onto Figure 2 requires the definition of the relationship between local flow and mainstem flow for values of mainstem discharge less than that which will overtop of the upstream berm. This relationship is highly variable since the local slough flow is a composite of local surface runoff and groundwater upwelling.

A relationship between mainstem discharge and groundwater upwelling has been defined for Slough 11 (Beaver 1984). The relationship is based on discharge data recorded at the R&M recording station in Slough 11 near PR III (Figure 1). Since there is little local runoff into Slough 11 (it has a small drainage basin), it was assumed that all local flow was due to groundwater upwelling. The relationship between slough groundwater flow (S) and mainstem discharge measured at Gold Creek (G) is:

$$S = 1.51 + 0.000102G \qquad (1)$$

For various mainstem dischrges, this equation defines the corresponding groundwater discharge at the recordig station in Slough 11. At points further downstream from the recording station, e.g. within PR I, additional local flow is acquired from further groundwater upwelling. Woodward-Clyde (1984) estimated that the local flow at PR I is approximately 145 percent of the flow calculated at the Recording Station. (This assumes a linear increase in slough reach and also assumes the discharge at the recording station is 100 percent). Therefore, local slough flow at PR I can be scaled to mainstem discharge by the following equation:

$$S(PR\ I) = 1.45\ (1.51 + 0.000102G) \qquad (2)$$

Use of Equation 2 allows scaling of slough flow to the corresponding mainstem discharge. The scaling for PR I in Slough 11 is shown as the bottom x-axis scale in Figure 2.

Based upon field observations and estimates (Sautner et al. 1984), the local flows which present unsuccessful and successful passage conditions at PR I in Slough 11 (assuming no mainstem backwater effects) are less than 3 cfs and greater than 4 cfs, respectively. By converting these to mainstem discharges using equation 2, 3 cfs corresponds to a mainstem discharge of 5,480 cfs and 4 cfs corresponds to a mainstem discharge of 12,240 cfs.

By plotting these values on Figure 2, where 3 cfs is the unsuccessful threshold criterion (at WSEL 668.07) and 4 cfs is the successful threshold criterion (at WSEL 668.16), a relationship between local flows and mainstem discharges which provide various access conditions is described. Successful access conditions are provided through the groundwater mechanism when mainstem discharge is greater than 12,200 cfs. In contrast mainstem discharge provides successful passage conditions through backwater effects alone at PR I only when mainstem discharge exceeds 16,000 cfs.

A similar analysis for PR II within Slough 11 is presented in Figure 3. In this case the thalweg reference elevation is at El. 670.0 ft MSL and the passage depths corresponding to the unsuccessful and successful threshold criteria are 0.32 and 0.41 from Figure 6-4 (ADF&G 1984) for a passage reach length of 745 ft. The corresponding water surface elevations are 670.32 ft. MSL and 670.41 ft MSL, respectively. The mainstem stage discharge relationship used in Figure 3 is the same as for Figure 2, at Staff Gage 135.3W1. A staff gage is located within PR II. However, the stage-discharge relationship at the gage is highly influenced by slough discharge and does not define a representative relationship between mainstem discharge and water surface elevation assuming negligible slough flow. For this reason, the stage discharge relationship for staff gage 135.3W1 is used.

As derived in the ADF&G Report (Sautner et al. 1984) mainstem discharges of 31,900 and 33,200 cfs are required to meet the WSELs corresponding to the unsuccessful and successful passage criteria thresholds, assuming no influence of local flow.

The mainstem discharges required for the respective passage depths via the groundwater mechanism are less than those which are required to provide passage depth via the backwater mechanism. Scaling of slough discharge to mainstem discharge assumes that slough discharge at PR II is 127 percent of the discharge at the recording station (Woodward-Clyde 1984). Therefore, the following equation was used to scale slough discharge (S) to mainstem discharge (G):

$$S\ (PR\ II) = 1.27\ (1.51 = 0.000102G) \quad (3)$$

Local flows at the unsuccessful and successful passage condition thresholds are estimated to be 3 and 4 cfs, respectively (Sautner et al. 1984). These local groundwater flows correspond to mainstem discharges of 8,350 and 16,075 cfs, respectively.

A somewhat different relationship between groundwater upwelling in slough discharge and mainstem discharge is presented by Woodward Clyde (1984). The equation presented by Woodward-Clyde for Slough 11 is more conservative and includes data collected during the summer of 1984. The equations used by Woodward-Clyde for PR I and PR 11 in Slough II are:

$$S = 1.45\ (1.43 + .000087G) \quad \text{for PR I} \quad (4)$$

$$S = 1.27\ (1.43 + .000087G) \quad \text{for PR II} \quad (5)$$

The corresponding mainstem flows for 3 and 4 cfs flows through PR I and PR II are:

		Passage Conditions	
		Unsuccesful	Successful
PR I	Local Discharge	$<$ 3 cfs	$>$ 4 cfs
	Mainstem Discharge	$<$ 7340 cfs	$>$ 15270 cfs
PR II	Local Discharge	$<$ 3 cfs	$>$ 4 cfs
	Mainstem Discharge	$<$ 10715 cfs	$>$ 19765

The above analyses and comparisons for PRs I and II in Slough 11 are summarized in Table 1. It is evident that passage conditions are dependent on mainstem discharge in one of two ways: directly as a function of the backwater effect and indirectly as a function of mainstem discharge influence on the rate of groundwater upwelling. From the information presented in Table 1, it is concluded that successful passage conditions are present at PR I when mainstem discharge is 12,240 cfs or greater. Similarly, it is concluded that successful passage conditions

HARZA-EBASCO SUSITNA JOINT VENTURE

INTRA-OFFICE MEMORANDUM

LOCATION Anchorage DATE December 7, 1984

TO L. Gilbertson NUMBER 4.3.16/4.3.1.1

FROM J. Bizer Page 8

SUBJECT Interpretation of ADF&G SuHydro Mainstem and Local Flow Values for Successful Passage Conditions

are present at PR II when mainstem discharge is 16,075 cfs. In both cases presented above, the influence of mainstem discharge in providing successful conditions is via the groundwater mechanism. In other passage reaches in other sloughs, the influence of the mainstem via the backwater mechanism may be predominant. This determination of mainstem discharges required for each passage reach would provide a more comprehensive evaluation of effects of the project on adult salmon passage into spawning areas.

hg

cc: E. Marchegiani, APA
J. Thrall, HE

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Table 1

Susitna Hydroelectric Project
Summary of Mainstem Discharge Relationships
to Slough 11 Passage Conditions

Passage Reach	Threshold	Passage Depth Criteria	Thalweg Elevation	Threshold Water Surface Elevation	Threshold Mainstem Discharge Corresponding to WSEL via Backwater	Threshold Local Flow Corresponding to WSEL	Threshold Mainstem Discharge Corresponding to WSEL via Local flow (Equations 2 and 3)
		(ft)	(ft MSL)	(ft MSL)	(cfs)	(cfs)	(cfs)
I	Unsuccessful	0.32	667.75	668.07	15,200	3	5,480
I	Successful	0.41	667.75	668.16	16,200	4	12,240
II	Unsuccessful	0.32	670.00	670.32	31,900	3	8,350
II	Successful	0.41	670.00	670.41	33,200	4	16,075

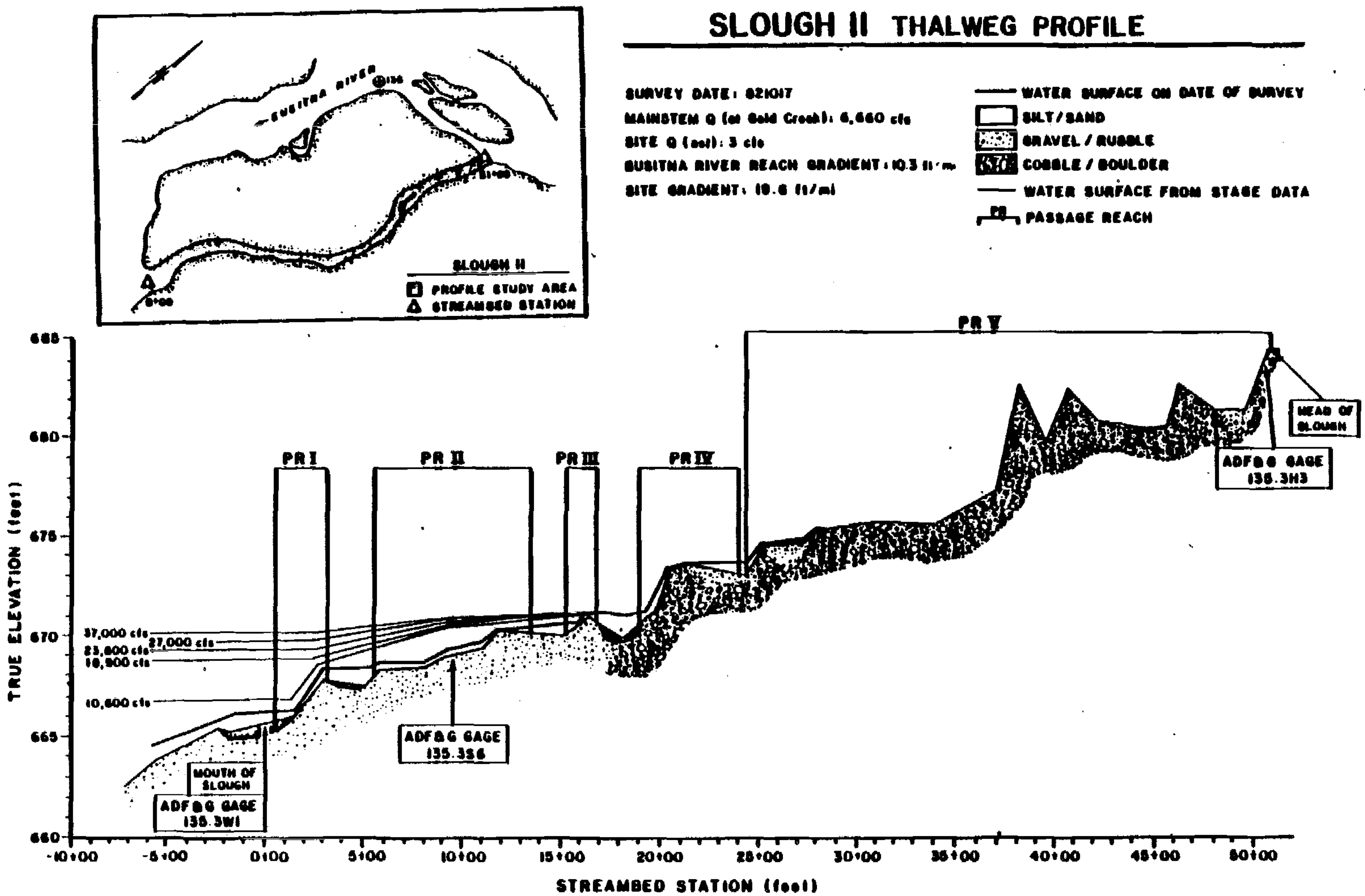


Figure 6-E-7. Thalweg profile of Slough 11.

FIGURE 2: Discharge and Passage Conditions at Passage Reach I in Slough 11

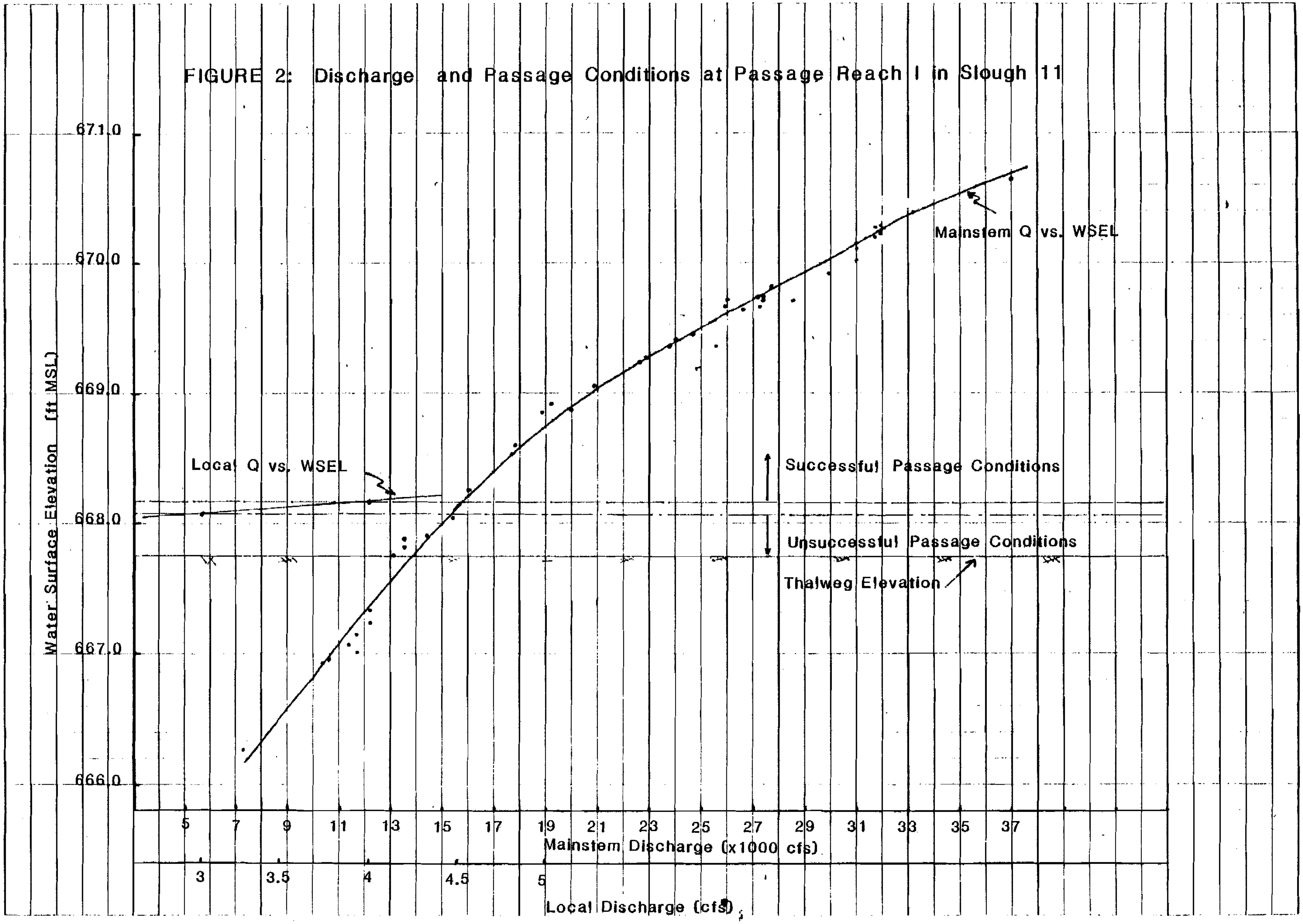
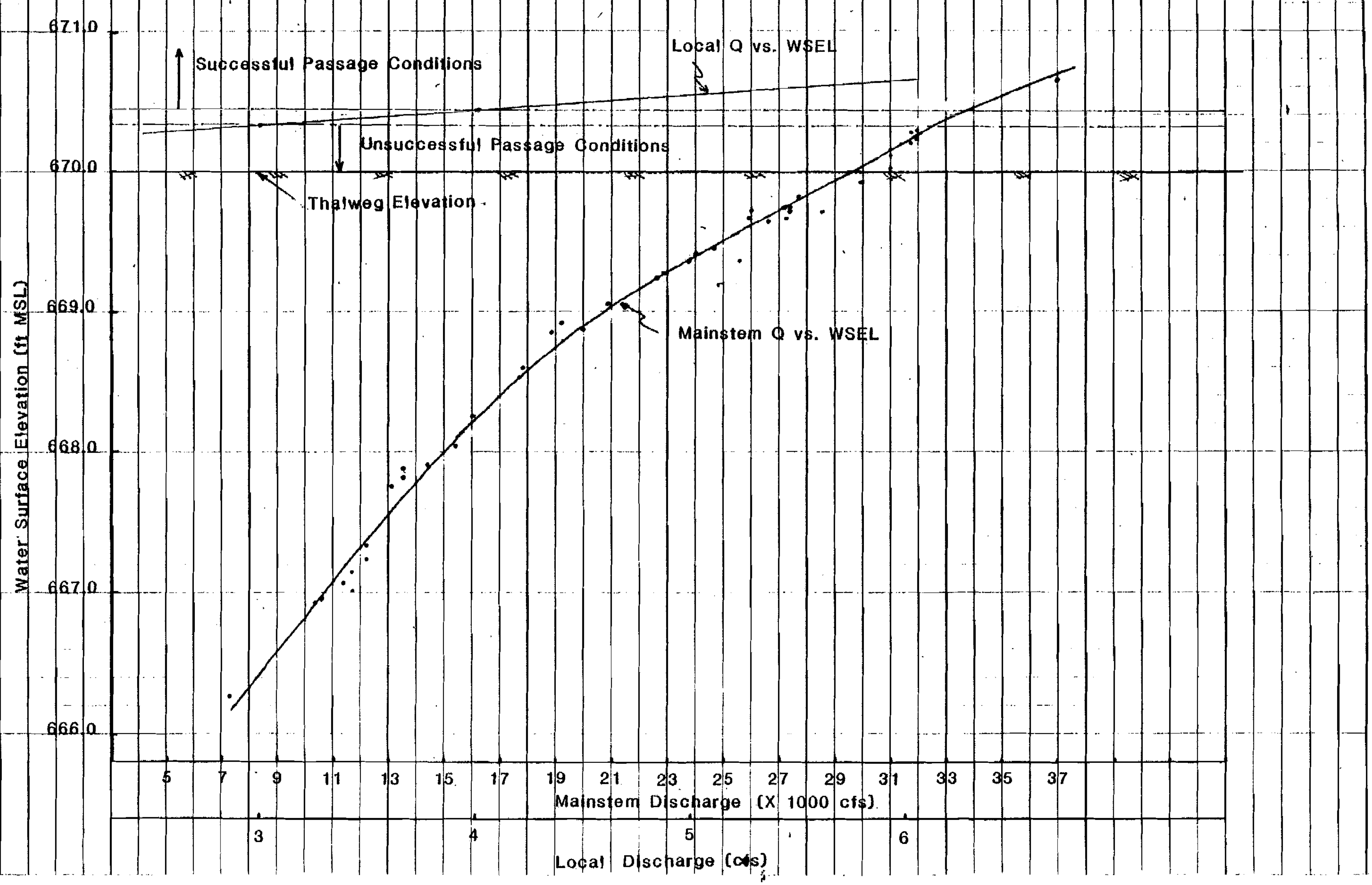


FIGURE 3: Discharge and Passage Conditions at Passage Reach II in Slough 11



HARZA-EBASCO SUSITNA JOINT VENTURE

INTRA-OFFICE MEMORANDUM

LOCATION: Anchorage

DATE: December 12, 1984

TO: File

NUMBER: 4.3.41

FROM: W. M. Dyok

SUBJECT: Susitna Hydroelectric Project
Cost to Provide Spiking Flows to Flush Sloughs

Detailed costs of spiking flows will be obtained by use of a combination of the weekly reservoir operations computer program, the hourly operations computer program and the Multi-Area Production Simulation computer program. Since this information is not expected to be available for several months, the cost of the spiking flows for the period when Watana operates alone (1996-2002) was estimated for the Case EI June spike by the following procedure.

(1) From 1983 historical hourly load data, the average daily minimum summer demand was determined (200 MW) along with the average daily maximum summer demand (340 MW).

(2) These summer demands were factored up to 1996 and 2002 by multiplying by the ratio of the annual peaks to the 1983 annual peak demand (1.64 and 1.84 respectively). Since the resulting average maximum and minimum daily demands were reasonably similar for 1996 and 2002, (minimum 328 and 368 MW respectively), the averaged values for 1996 and 2002 were assumed to apply to all years between 1996 and 2002.

(3) A conversion factor of 2000 cfs per 100 MW of power at Watana was developed to relate flow to power production (this factor assumes an average reservoir level of 2140 feet). In early June the reservoir would be lower than this resulting in approximately 5 percent greater flow per 100 MW (i.e., 2100 cfs per 100 MW) whereas in late summer these would be about 5 percent less flow per 100 MW (i.e., 1900 cfs per MW).

It was assumed that energy which could have been stored in summer would be generated at a uniform rate throughout. (This would yield an average flow of 2000 cfs per 100 MW during winter.)

(4) Intervening flows between Watana and Gold Creek during the June spike were determined to be 2000 cfs, 5000 cfs and 9000 cfs for dry, average, and wet hydrological conditions.

(5) The intervening flows were subtracted from the Case EI flow requirements at Gold Creek to yield flow requirements at Watana.

(6) The volume of flow to be discharged at Watana during the spiking period was calculated (135,000 cfs days).

(7) The flow volume which would be used to generate usable energy was calculated for each day of the spike, summed and subtracted from the total volume contained in the spike.

(8) The resultant flow volume release was assumed available for winter generation. (This implies the Watana reservoir would not be filled to elevation 2105 feet by the end of summer, thereby allowing storage of the volume released.) The equivalent energy contained in the spike was determined.

(9) Assuming a value of 6 cents/kWh (1982 dollars), the cost of each spike was calculated. This was determined to be $6,900,000, $5,700,000, and $4,500,000 for high, average, and low intervening flows respectively, during the time of the spike.

(10) The present worth of the annual spikes in 1982 for the period 1996 to 2002 was calculated. This was determined to be $21,500,000 for average intervening flow conditions.

In this analysis, no account was taken of the potential benefit of fuel savings by generating part of the usable energy in the June spike at another time of the year when less efficient generation units would be operating.

A similar analysis could be undertaken for the period that both Watana and Devil Canyon are operating. The spiking flow volume would be expected to come from Devil Canyon during Watana/Devil Canyon operation. During Watana/ Devil Canyon operation, the probability of flow releases is high in the early years of operation because of the energy production capability of the project relative to the railbelt load. Because of this high probability, the cost of spiking in the early years of Watana would be reduced and would need to be considered in the cost analysis. As the railbelt load increases, the probability of filling the Watana and Devil Canyon reservoirs and then having to release water decreases, resulting in higher costs to provide the spiking flows.

HARZA-EBASCO SUSITNA JOINT VENTURE

INTRA-OFFICE MEMORANDUM

LOCATION Anchorage

DATE December 12, 1984

TO File

NUMBER 42.2.1

FROM W.M. Dyok

SUBJECT Susitna Hydroelectric Project
Maximum Hourly Flow Variation and
Minimum Flow Requirements

In a September 4, 1984 memorandum from W.M. Dyok to W.E. Larson, it was proposed that during the period when Watana is operating alone, discharge variations of plus or minus 10 percent of the mean weekly discharge as measured at Gold Creek would be allowed. In varying the discharge between the allowable maximum and minimum flows for a given week, it was also proposed that the maximum hourly rate of change of discharge would be 10 percent of the weekly average discharge when discharge is being increased and 500 cfs per hour when discharge is being reduced. (The more stringent requirement during flow reductions minimizes the possiblity of stranding fish).

If the weekly average discharge is changed at the beginning of the week, the above rates of change of discharge would govern. Therefore, in changing flow from one week to the next, flow could be increased from 10 percent less than the past weekly average to 10 percent greater than the present weekly average at a maximum rate of 10 percent per hour of the weekly average flow. Conversely, the flow could be decreased from 10 percent greater than the past weekly average to 10 percent less than the present weekly average at a maximum rate of 500 cfs per hour.

It is anticipated that future studies will refine the allowable hourly flow variations on both a seasonal and daily basis. The change in wetted channel geometry with changing discharge may also lead to a series of allowable hourly flow changes for given discharge ranges. However, until such studies are completed, the above maximum hourly flow variations will be assumed in reservoir and energy studies.

In reservoir operation studies, it has been assumed that the minimum flow requirements relate to the mean weekly flow. Therefore, if the mean weekly flow is equal to or slightly greater than the minimum flow requirement for a given week, it is possible to have flows up to 10 percent less than the minimum flow requirement for a part of the week. If further studies indicate that the minimum requirements should not be violated at any time during the week, reservoir operation will be modified to ensure that the weekly minimum flow requirements are not violated.

pb

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