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GOVERNOR SHEFFIELD

1982

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SUSITNA HYDROELECTRIC PROJECT

LOWER SUSITNA RIVER SEDIMENTATION STUDY
PROJECT EFFECTS ON
SUSPENDED SEDIMENT CONCENTRATION

Report by
Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

November 1984

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1.0 SUMMARY

The concentrations and particle size distributions of suspended sediment were determined for natural conditions at various locations on the Susitna River based on the data collected by the United States Geological Survey. Under with-project conditions, the concentrations were estimated for reservoir releases and at Gold Creek and Sunshine.

It is estimated that the average suspended sediment concentration of all flows entering Watana Reservoir will be about 830 milligrams per litre (mg/l). The reservoir will trap about 82 percent of the sediment. Particle sizes of about .004 mm and less will pass through. The concentration in the releases will vary from about 55 mg/l in the winter to about 250 mg/l in the summer.

The estimated mean monthly suspended sediment concentrations at Gold Creek and Sunshine are shown on Exhibits 12 and 13. Project operation would increase the concentration during winter and decrease that during summer. At Gold Creek, November through March concentrations would increase from about 5 to 60 mg/l. The increase at Sunshine also would be about the same. The concentrations in the months of April and October also will increase compared to those under natural conditions (Exhibits 12 and 13). The concentrations during May through September will decrease (Exhibits 12 and 13).

2.0 SCOPE OF THE STUDY

This is a second report by Harza-Ebasco Susitna Joint Venture on the evaluation of project effects on sediment transport in the Susitna River. The first report entitled "Reservoir and River Sedimentation (HE, April 1984)1/ primarily addressed the sediment accumulation in the Watana and

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1/ Indicates reference at the end of text.

Devil Canyon reservoirs and potential aggradation and degradation in the river reach between Devil Canyon and the confluence of the Susitna and Chulitna rivers (the confluence) and near the confluence.

The scope of this study includes the analysis of suspended sediment concentrations under natural conditions and changes in the concentrations due to project operation. The analysis is made for the Susitna River at the Watana site, Gold Creek and Sunshine stream gaging stations (see Exhibit 1 for the locations). The major tasks are:

1. to define the characteristics of suspended sediment at selected locations upstream of Sunshine stream gaging station (Sunshine gage);

2. to define the characteristics of suspended sediment entering Watana Reservoir;

3. to estimate probable suspended sediment concentrations of water released from the reservoir;

4. to evaluate effects on suspended sediment concentrations in the mainstem due to major tributaries entering the Susitna River above Sunshine gage; and

5. to provide a comparison of monthly suspended sediment concentrations at Gold Creek stream gaging station (Gold Creek gage) and at Sunshine gage for natural and with-project conditions.

3.0 SETTING

The Susitna River drains an area of about 19,600 square miles (mi^2) in the south central region of Alaska. The major tributaries include the Chulitna, Talkeetna and Yentna rivers with drainage areas of about 2,650, 2,040 and 6,200 mi^2 respectively.

The Susitna River originates in the West Fork, Susitna, East Fork and Maclaren glaciers of the Alaska Range (Exhibit 1) and traverses a distance of about 320 miles to its mouth at the Cook Inlet. The Chulitna River originates in the glaciers on the south slopes of Mount McKinley and joins the Susitna River from the west near Talkeetna at river mile 98 (river miles referenced from the Cook Inlet). The Talkeetna River originates in the Talkeetna Mountains and joins the Susitna River from the east near Talkeetna at river mile 97. The Yentna River originates in the Alaska Range and enters the Susitna River from the west at river mile 28.

The Susitna Hydroelectric Project will include two dams, Watana and Devil Canyon, located at river miles 184 and 152, respectively. The drainage areas at the two sites are about 5,180 and 5,810 mi^2, respectively.

Susitna streamflow is characterized by turbid high flows from May through September and clear low flows from October through April. High spring and summer flows are caused by snowmelt, glacial melt and storm rainfall.

4.0 SUSPENDED SEDIMENT

4.1 DATA SOURCES

Suspended sediment samples have been collected at a number of stream gaging stations in the Susitna River basin by the United States Geological Survey (USGS) (USGS Water Resources Data) and R&M Consultants (R&M, 1981). These samples have been analyzed for total suspended sediment concentration in mg/l. A number of samples also have been analysed for particle size distribution. Exhibit 1 shows the sampling stations for which the suspended sediment data are available. The number of samples collected at selected stations during the period of record are given in Table 1. R&M Consultants collected about 10 samples at Cantwell and 8 samples at Gold Creek stream gaging stations during 1980 and 1981.

4.2 CHARACTERISTICS OF SUSPENDED SEDIMENT

Sediment is transported in suspension, as bed load rolling or sliding along the bed and interchangeably in suspension and as bed load. The nature of movement depends on the particle size, shape and specific gravity in respect to the associated velocity and turbulence. Under some conditions of high velocity and turbulence (high flows in steep-gradient mountain streams) cobbles (64 to 256 mm size) can be carried intermittently in suspension. Conversely, silt size particles (.004 to .062 mm) may move as bed load in low-gradient, low-velocity channels.

4.2.1 At Selected Locations

Suspended sediment is the sediment that is transported outside of the bed layer in suspension by the turbulent components of the flow. In the Susitna River, fine material (silt and clays finer than 0.062 mm) and fine to medium sand particles (sizes between 0.062 mm and up to 1.00 mm) have commonly been observed in suspension.

The fine material, also known as wash load, is derived from sheet erosion, glacier melt and bank erosion. The quantity of wash load being transported depends upon its availability because for the observed range of flow the Susitna River can transport much larger quantities of wash load than has been measured. The sand particles are derived either from river bed erosion or from glacier melt and other erosion processes. The maximum quantity of sand being transported depends upon the magnitude of flow.

Suspended sediment samples at the USGS stream gaging stations generally have been collected during the months of May through October (Table 1). A few samples are available for some stations for the period from December through April but no sample has been collected in November at any station.

Since the suspended sediment consists of wash load and sand particles, its concentration varies both with the availablity of wash load and the capacity of flow to transport sand particles. Available data for Gold Creek and Sunshine gages are plotted on Exhibits 2 and 3, respectively, to show the variation of sediment concentration with water discharge. The maximum, minimum and median concentrations measured at various stream gaging stations are listed in Table 2. The maximum and minimum concentrations are not provided for the months for which only one or two samples are available. The median values in such cases are also not given.

The size distributions of suspended sediment at various stations are given in Table 3. Size distributions are available for the samples collected during the months of May through October. A few samples collected during the other months were not analysed for size distribution probably because of insufficient sediment quantity. The smoothed size distribution curves based on Table 3 are shown on Exhibit 4 through 11. The percentages of fine material and sand particles at various locations taken from these exhibits are given below.

PERCENTAGES OF FINE MATERIAL AND SAND
IN SUSPENDED SEDIMENT

Station	Fine Material (< .062 mm)	Sand (> .062 mm)	Median Dia. (mm)
Susitna R. nr. Denali	52	48	.056
Susitna R. nr. Cantwell	54	46	.049
Susitna R. at Gold Creek	61	39	.038
Susitna R. nr. Talkeetna (above confluence)	70	30	.015
Chulitna R. nr. Talkeetna	62	38	.024
Talkeetna R. nr. Talkeetna	51	49	.060
Susitna R. at Sunshine	69	31	.014
Susitna R. at Susitna Station	61	39	.030

The above table indicates an increase in the percentages of fine material from Denali to above the confluence of the Susitna and Chulitna rivers. Downstream from the confluence, the trend is not clear primarily because of sediment contributions from the major tributaries and partly because of limited number of samples available for Susitna River at Susitna.

A sufficient number of samples are not available to precisely define the concentration for each month. However, by comparing the data for various stations, some indicative values of monthly concentrations for the Susitna River at Gold Creek and at Sunshine were estimated and are shown on Exhibits 12 and 13, respectively. The values indicated on the exhibits are not related to specific discharges and approximately represent the median values from the range of observed concentrations under natural flow conditions.

4.2.2 Suspended Sediment Entering Watana Reservoir

The characteristics of the suspended sediment entering Watana Reservoir are best represented by those measured at the Cantwell station. This indicates that, on the average, the suspended sediment concentrations vary approximately between 2 to 20 mg/l from November through April and between 80 to 3,000 mg/l from May through October. The average size distribution based on the samples collected from May through October is shown on Exhibit 5. This indicates that about 18 percent of the sediment is less than .004 mm (clay sizes), about 36 percent is between .004 and .062 (silt sizes) and about 46 percent is larger than .062 mm (sand sizes). The average annual streamflow at Watana is about 8,000 cubic feet per second (cfs) (HE, January 1984). The suspended sediment inflow is estimated to be about 6,530,000 tons per year (ton/yr) (HE, April 1984). This gives an average concentration of about 830 mg/l for the flow entering the reservoir. The winter concentration may be about 0 to 10 mg/l (Table 2).

4.3 EFFECTS OF ICE COVER ON SEDIMENT TRANSPORT

A study made by W.W. Sayre and G.B. Song (Sayre, 1979) to evaluate the effects of ice-cover on alluvial channel flow and sediment transport processes indicates that ice causes a number of changes in alluvial channel flows by approximately doubling the wetted perimeter and thereby producing a redistribution of the boundary and internal shear stresses. The total depth of flow in the channel with a given unit discharge and slope is significantly increased (about 20 to 30 percent for a smooth cover and from 30 to 80 percent for rough cover, relative to the depth for a free surface condition). Due mainly to the lower velocities, sediment discharge is significantly reduced.

The above conclusions are applicable to the Susitna River for the period between early November and mid-May when an ice cover is generally present.

4.4 SEDIMENT TRANSPORT DURING FREEZE-UP

Field observations on the Susitna River show that freeze-up generally begins in October and may continue until break-up. The beginning of frazil ice (a spongy or slushy accumulation of ice crystals which form in supercooled water that is too turbulent to permit coagulation of the crystals into sheet ice) is marked by a rapid reduction in suspended sediment concentration. As the process continues, the river becomes clear within a day or two. The contributions of fine sediment from the erosion process and from glacial flour are stopped due to frozen ground and the elimination of glacier melt. The river remains practically clear until breakup.

The frazil crystals often flocculate into larger clusters having a porosity of about 60 percent. Since water can permeate through these clusters, they filter out the sediment particles which remain entrapped in the ice. During breakup, a significant quantity of sediment, mostly silt and clay, is observed to be mixed with ice. The sediment is concentrated at places rather than distributed over the whole mass.

Anchor ice, similar to slush ice but adhering temporarily to the river bottom, also has been observed to be mixed with sediment. The anchor ice probably catches sediment moving as bed load as well as suspended load. The anchor ice is generally formed at night and released during the day and then drifts downstream.

4.5 PROJECT EFFECT

4.5.1 Suspended Sediments Concentrations at Watana Reservoir Outlet

Peratrovich, Nottingham and Drage, Inc.; (PND), (PND, 1982) made analysis of turbidity levels in Watana Reservoir using a computer model DEPOSITS. The major conclusions made by PND that are pertinent to this study are given below.

1. It is likely that sediment particles of about .004 mm and less will remain in suspension;

2. Maximum turbidity levels at the outlet will be on the order of 50 NTU's, which corresponds to a sediment concentration of 200 to 400 mg/1;

3. Minimum turbidity level will be in the order of 10 NTU's which corresponds to a sediment concentration of 30 to 70 mg/l;

4. Turbidity levels at the reservoir outlet during each month appear to be primarily dependent upon the travel time for sediment slugs delivered to the reservoir during previous summers to reach the reservoir outlet; and

5. In spite of some limitations, the data gathered from outside sources support the conclusion that Watana reservoir turbidity level will be in the range of 10-50 NTU's.

Harza-Ebasco plans to study the suspended sediment in Watana reservoir and in the outflow from the reservoir. The purpose of the study will be to confirm or refine the analysis made by PND. The dynamic reservoir simulation model DYRESM (Imberger and Patterson, 1981), currently being used for the reservoir temperature and ice study, will be enhanced to include a subroutine to simulate quantitatively the vertical distribution of suspended sediments in the reservoir and the suspended sediment concentration in the outflow on a daily basis. The model will consider the sediment mixing due to meteorological forcing, turbulence, density currents and externally specified vertical settling velocities. The effect of the ice cover on the suspended sediment concentration also will be considered. Compared to DYRESM, the DEPOSITS model used monthly inflow data and thus, was not responsive to rapidly changing sediment inflows during floods. The effects of stratification, density currents and ice cover also were not considered.

PND's analyses show that sediment particles of about .004 mm and less will remain in suspension and pass through the reservoir. Using the size distribution curve shown on Exhibit 5, about 18 percent of the sediment is finer than .004 mm. Therefore, it can be expected that about 18 percent of the inflowing sediment will pass through the reservoir.

The turbidity level at the outlet is estimated to be about 10 to 50 NTU's by PND. In terms of suspended sediment, PND estimated the concentration to be about 55 to 250 mg/l. However, recent studies by Harza-Ebasco indicate that the relationship between suspended sediment concentration and turbidity used by PND is not valid for glacial outflow. Data are being collected from the Susitna River and several south central Alaska glacial lakes to revise this relationship. The results and conclusions made in this study will be revised when the refined estimates of reservoir release suspended sediments become available.

In the absence of any better information on reservoir turbidity and suspended sediment concentration, the PND results are used in this study. Therefore, it is assumed that the operation of Watana reservoir would increase the suspended sediment concentration in winter from about 5 to about 55 mg/l. The summer concentration would be significantly reduced. The extents of reductions would vary from month to month.

4.5.2 River Temperatures

The extent of formation of ice cover on the Susitna River downstream from the reservoirs will depend upon the reservoir outflow temperatures and their effect on river temperatures. Because the formation of ice cover affects the sediment transport as discussed under sub-section 4.3, an evaluation of with-project river temperatures was made based on the on-going studies.

Harza-Ebasco is conducting a temperature and ice study for Watana and Devil Canyon reservoirs and a river ice study between Devil Canyon and the Chulitna confluence. The preliminary study results indicate that the outflow temperatures at Watana will be about 1° to 3°C higher than those under natural conditions both for an average and an extreme winter. The Arctic Environmental Information and Data Center (AEIDC), Alaska, is conducting a river temperature study to investigate with-project temperatures at various locations in the reach below Watana and Devil Canyon. The final results of this study are not yet available. However, the preliminary results (see Exhibits 14 through 31) indicate that between 15 and 30 miles of the river downstream from Devil Canyon would be ice free during the winter period depending on winter weather conditions when Devil Canyon and Watana are operating. With Watana operation only, the ice cover will be between 10 and 25 miles downstream of Devil Canyon. Frazil and anchor ice formation may occur upstream of the ice cover where the river temperature is above 0°c.

4.5.3 Suspended Sediment Concentration between Watana and the Confluence

The suspended sediment concentration in this reach will be controlled by the concentration in the reservoir releases (about 55 to 250 mg/l) and any sediment contribution from the reach. During summer flood periods, the concentration will be somewhat higher than 250 mg/l because of intervening flows but much less than those observed under natural conditions.

Simulation of river temperatures for various winter scenarios (Exhibits 14 through 31) indicate approximate locations of ice front for natural and with-project conditions. The 1971-72, 76-77, 81-82 and 82-83 winter climate data used in the simulation represents cold winter preceded by wet summer, very warm winter preceded by dry summer, average winter preceded by wet summer and warm winter preceded by average summer, respectively. The formation of frazil ice or anchor ice will occur in the reach immediately upstream of the ice front while further upstream these activities will be practically eliminated because of above freezing temperatures of reservoir releases.

The suspended sediment concentration in the reach above the ice front will be nearly the same as in the releases. Any reduction caused by frazil and anchor ice will be compensated by sand particles picked up from the river bed because of higher winter flow. The formation of ice in the reach between the ice front and the confluence will reduce the sediment transport capacity of the river and some sediment could be trapped by ice. However, the reduction in the concentration will be relatively small. The approximate monthly distributions of suspended sediment concentrations for with-projects conditions are shown on Exhibit 12.

4.5.4 Suspended Sediment Concentration between the Confluence and Sunshine

In this reach two major tributaries, the Chulitna and the Talkeetna rivers join the Susitna River. These rivers carry little sediment during winter (Table 2). The increased winter flow will pick up sand particles from river bed. However, some of the sediment will be trapped by the ice and net increase in sediment concentrations will be insignificant. The concentration during winter will, therefore, be controlled by the concentration in the Susitna River above the confluence. During summer months, low concentration in the Susitna above the confluence will reduce the concentration at Sunshine compared to the natural conditions. The monthly concentrations were estimated at Sunshine gage based on monthly suspended sediment concentrations and discharges observed on the Chulitna and Talkeetna rivers, with-project monthly discharges and concentrations on the Susitna River above the confluence and flow contributions from the intervening area. The monthly discharges used for the Susitna River were those for with-project and scenario 'C' of License Application. The monthly discharges for the Chulitna and Talkeetna rivers were for the water years from 1950 through 1981 computed by ACRES (ACRES, 1982).

Exhibit 13 show the approximate increase or decrease in the suspended sediment concentrations during various months at Sunshine. This can be used to estimate changes in turbidity levels.

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Sayre, W.W; and G.B. Song, February 1979: Effects of Ice Covers on Alluvial Channel Flow and Sediment Transport Processes, prepared for U.S. Geological Survey, IIHR Report No. 218, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, Iowa.

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Table 1

SUSPENDED SEDIMENT SAMPLES
COLLECTED AT USGS STREAM GAGING STATIONS

Stream Gaging Stations	Period	J	F	M	A	M	J	J	A	S	O	N	D
		Months											
		No. of Samples											
Susitna River nr. Denal	1961-62; 1964-66 1968; 1974-75; 1977; 1979-82	-	-	1	1	7	8	12	9	8	3	-	-
Susitna River nr. Cantwell	1962-72; 1980-82	1	-	1	-	3	11	14	9	12	3	-	-
Susitna River at Gold Creek	1962; 1974-82	3	1	4	-	9	7	9	9	8	5	-	-
Susitna River nr. Talkeetna	1982	-	-	-	-	-	5	4	5	1	-	-	-
Chulitna River nr. Talkeetna	1967-72, 1980-82	1	1	4	2	4	10	10	8	9	2	-	-
Talkeetna River nr. Talkeetna	1966-82	8	1	7	7	12	13	16	23	12	7	-	-
Susitna River at Sunshine	1971; 1977; 1981-82	-	-	2	-	1	7	7	8	3	1	-	-
Susitna River at Susitna Station	1975-81	2	-	3	2	3	4	6	4	1	2	-	2

Table 2

SUSPENDED SEDIMENT CONCENTRATIONS

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					Months							
Susitna R. nr. Denali												
Max.	–	–	–	–	1190	1600	2770	5690	3600	1400	–	–
Min.	–	–	–	–	102	302	886	350	124	85	–	–
Median	–	–	–	–	570	840	1350	890	293	104	–	–
Susitna R. nr. Cantwell												
Max.	–	–	–	–	726	1860	2790	1040	770	140	–	–
Min.	–	–	–	–	132	172	632	380	34	6	–	–
Median	–	–	–	–	661	417	1090	755	138	84	–	–
Susitna R. at Gold Creek												
Max.	8	–	3	–	1110	1400	130	938	812	22	–	–
Min.	<1	–	1	–	65	151	100	158	23	7	–	–
Median	2	–	2	–	498	574	394	420	68	10	–	–
Susitna R. nr. Talkeetna												
Max.	–	–	–	–	–	769	768	341	–	–	–	–
Min.	–	–	–	–	–	181	145	219	–	–	–	–
Median	–	–	–	–	–	438	422	285	–	–	–	–
Chulitna R. nr. Talkeetna												
Max.	–	–	21	–	1040	1600	2200	1260	1680	–	–	–
Min.	–	–	4	–	500	90	717	694	129	–	–	–
Median	–	–	12	–	675	820	1165	817	396	–	–	–
Talkeetna R. nr. Talkeetna												
Max.	15	–	11	48	503	1340	1160	3530	310	29	–	–
Min.	2	–	1	2	21	171	90	38	13	8	–	–
Median	8	–	3	8	123	309	359	466	80	16	–	–
Susitna R. at Sunshine												
Max.	–	–	–	–	–	1630	1430	3510	–	–	–	–
Min.	–	–	–	–	–	360	503	424	–	–	–	–
Median	–	–	–	–	–	702	713	715	?	–	–	–
Susitna R. at Susitna Station												
Max.	–	–	5	–	572	918	1490	1490	–	–	–	–
Min.	–	–	3	–	378	326	561	483	–	–	–	–
Median	–	–	3	–	417	503	852	943	–	–	–	–

Table 3

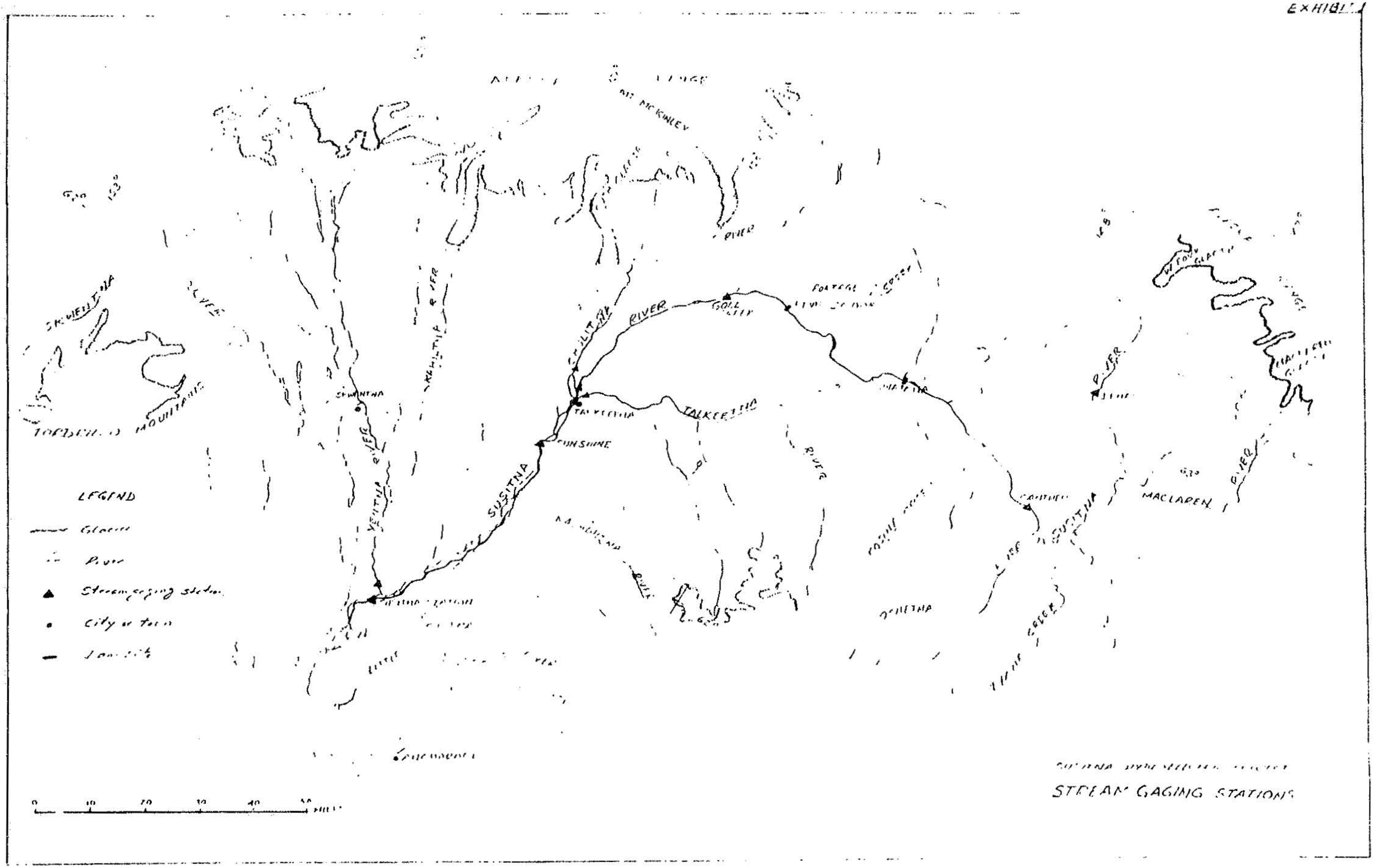
PARTICLE SIZE DISTRIBUTION OF SUSPENDED SEDIMENT

Stream Gaging Station	No. of Sample 1/	.002	.004	Particle Size (mm) .008	.016	.031	.062	.125	.250	.500	1.000
				Percent Finer Than 2/							
Susitna River nr. Denali	34	12	16	23	31	41	53	64	81	96	100
Susitna River nr. Cantwell	27	12	18	25	33	43	54	67	86	97	100
Susitna River at Gold Creek	24	15	19	27	35	47	61	75	86	98	100
Susitna River nr. Talkeetna	13	29	35		53		72	79	90	100	
Chulitna River nr. Talkeetna	36	21	31	37	46	55	62	72	85	99	100
Talkeetna River nr. Talkeetna	16	9	16	22	31	41	53	65	85	99	100
Susitna River at Sunshine	17	22	33	43	53	62	67	79	90	100	
Susitna River at Susitna Station	9	16	23	33	43	52	60	82	94	100	

1/ Samples for which full range of size distributions were analyzed.

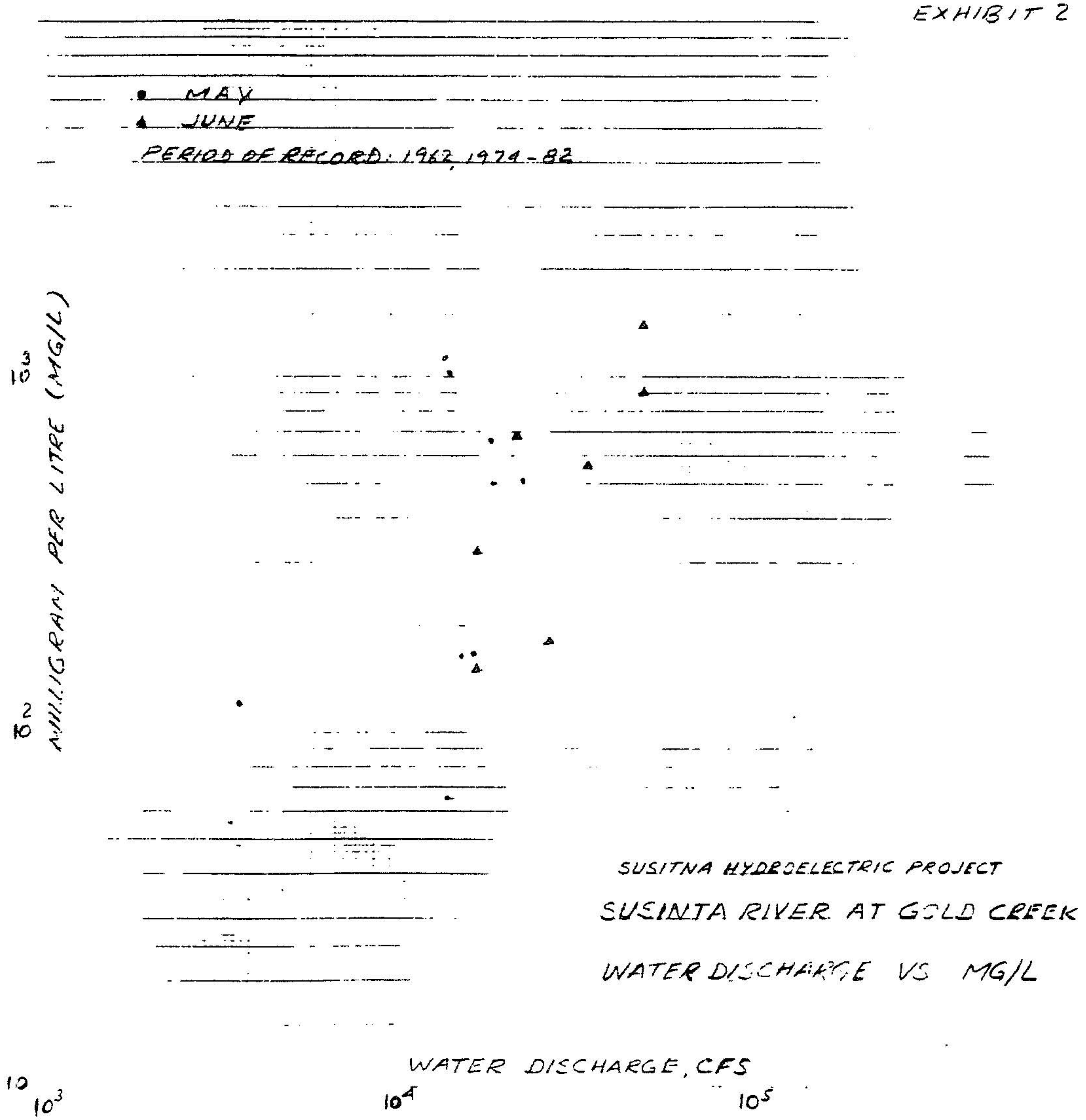
2/ The percentages given are the median values from a range of oberved percentages for various sizes.

EXHIBI



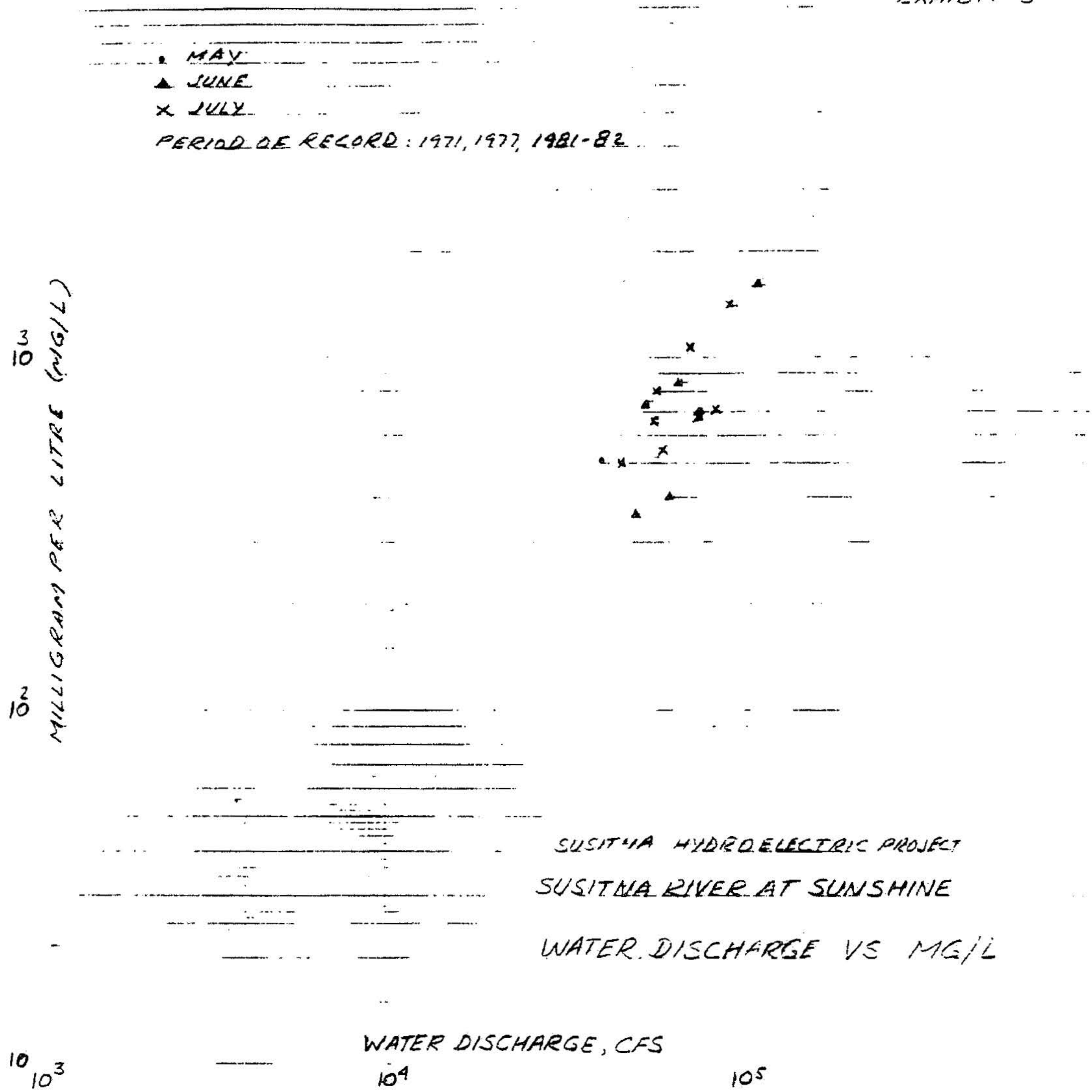
MT. MCKINLEY
RIVER
TALKEETNA
SUNSHINE
SUSITNA
MACLAREN
LEGEND
River
City or Town
STREAM GAGING STATIONS

EXHIBIT 2



MAY
JUNE
PERIOD OF RECORD: 1962, 1974-82
MILLIGRAM PER LITRE (MG/L)
10³
10²
10
SUSITNA HYDROELECTRIC PROJECT
SUSINTA RIVER AT GOLD CREEK
WATER DISCHARGE VS MG/L
WATER DISCHARGE, CFS
10³
10⁴
10⁵

EXHIBIT 3



• MAY
▲ JUNE
× JULY
PERIOD OF RECORD: 1971, 1977, 1981-82
MILLIGRAM PER LITRE (MG/L)
10^3
10^2
10
SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT SUNSHINE
WATER DISCHARGE VS MG/L
WATER DISCHARGE, CFS
10^3
10^4
10^5

K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6212

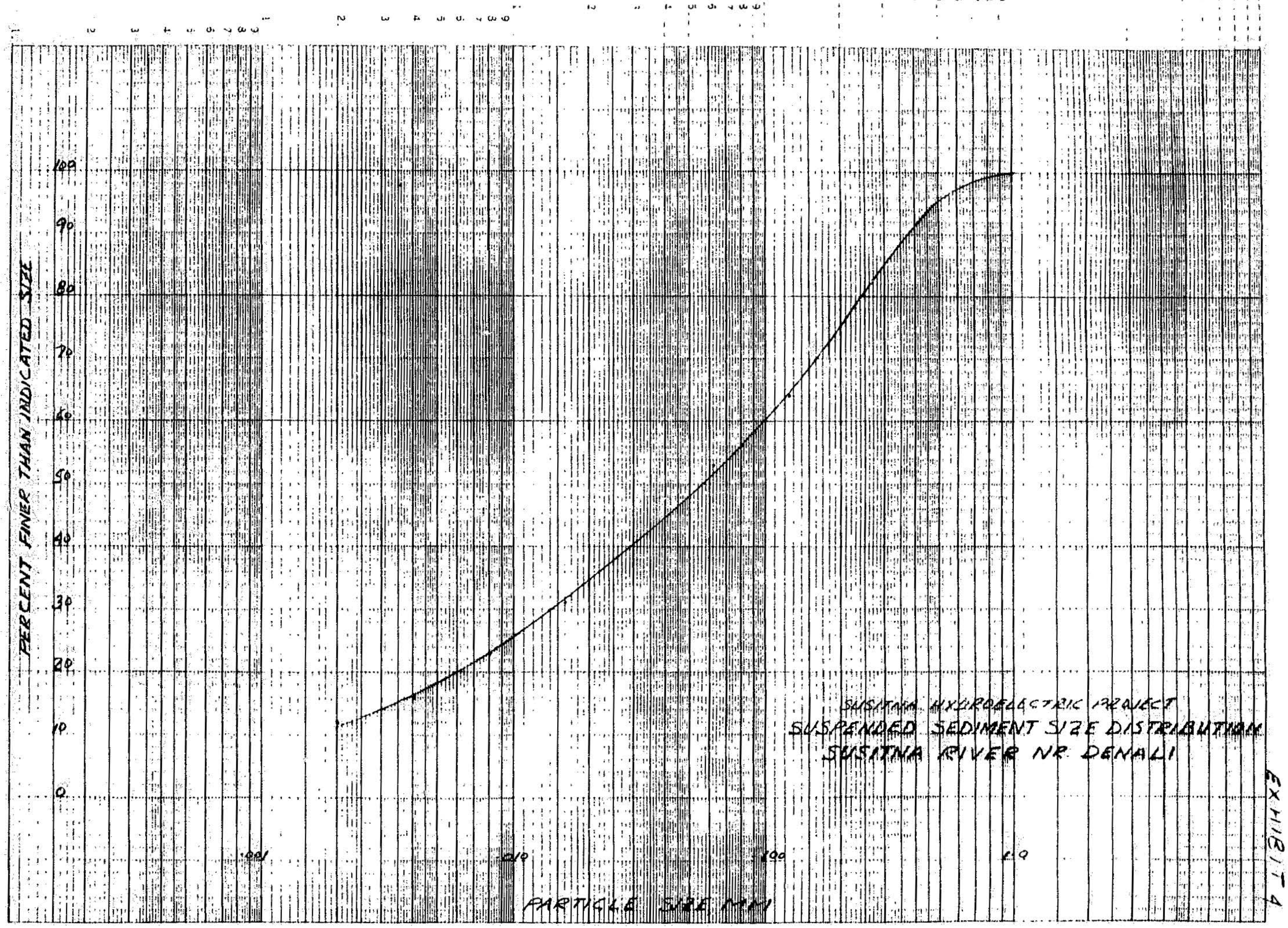
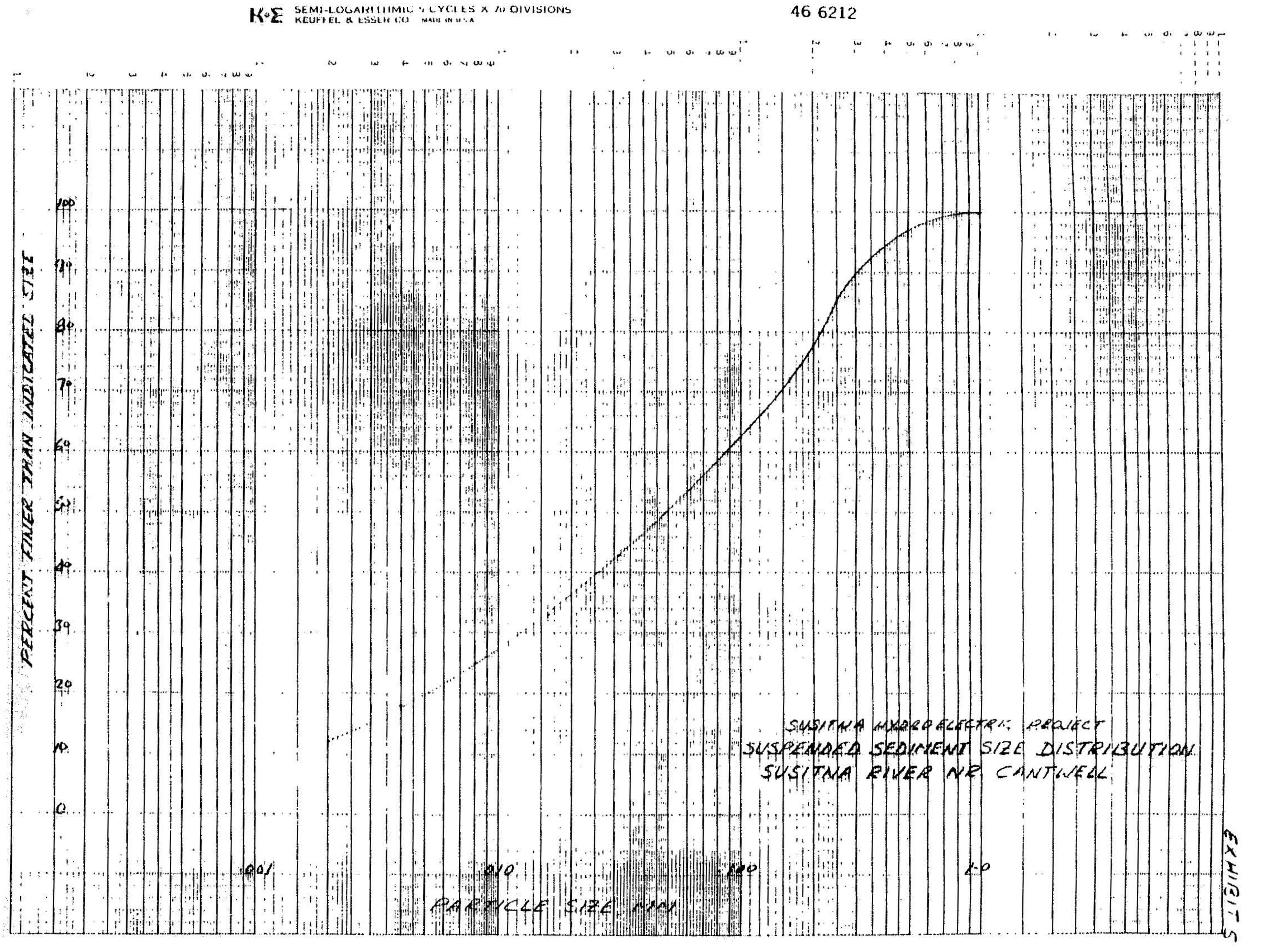
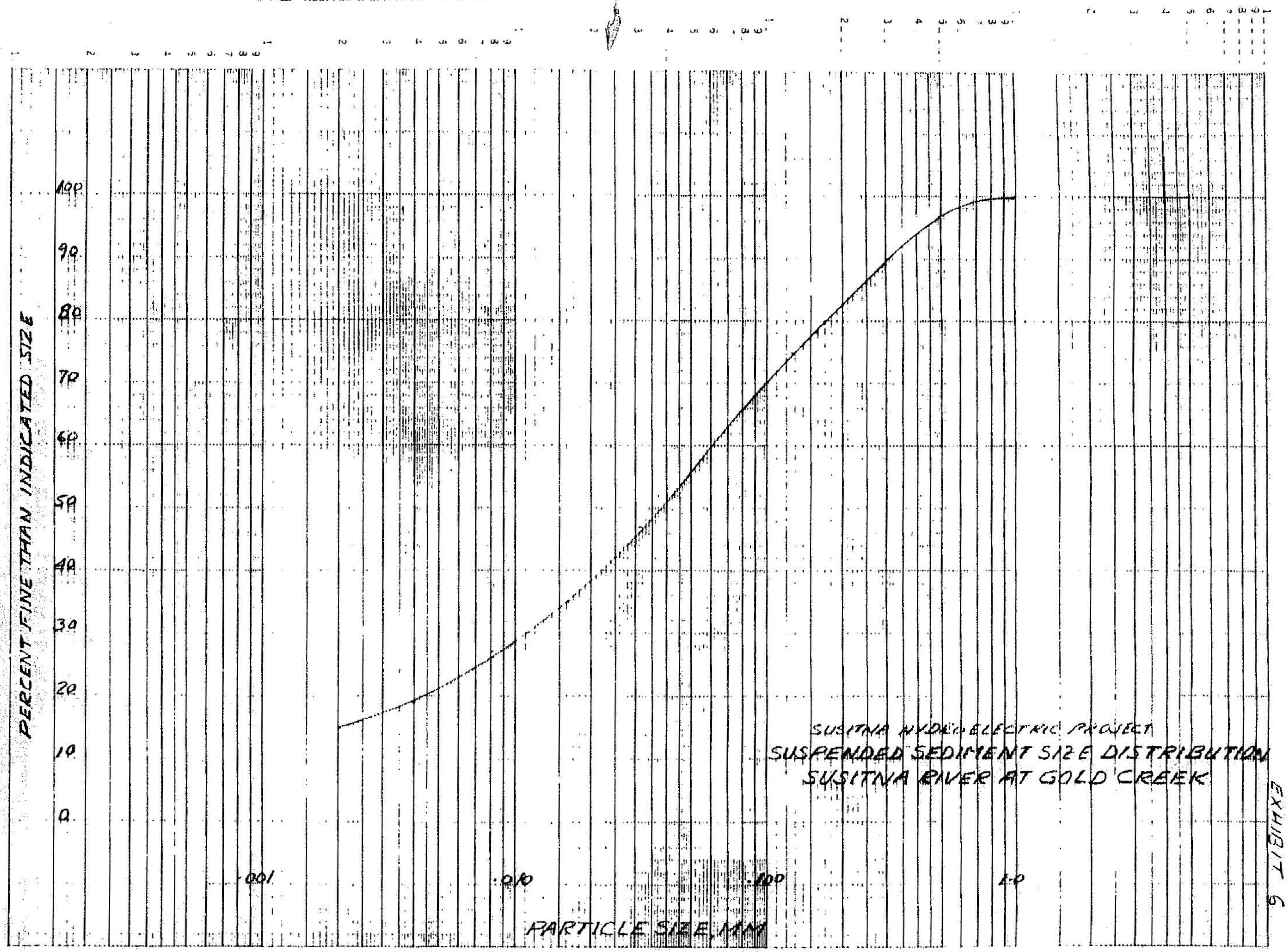


EXHIBIT 4


K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
PERCENT FINER THAN INDICATED SIZE
100
90
80
70
60
50
40
30
20
10
0
.001
.010
.100
1.0
PARTICLE SIZE MM
SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
SUSITNA RIVER NR CANTWELL
EXHIBIT 5

K·E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 6212



K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

46 6212

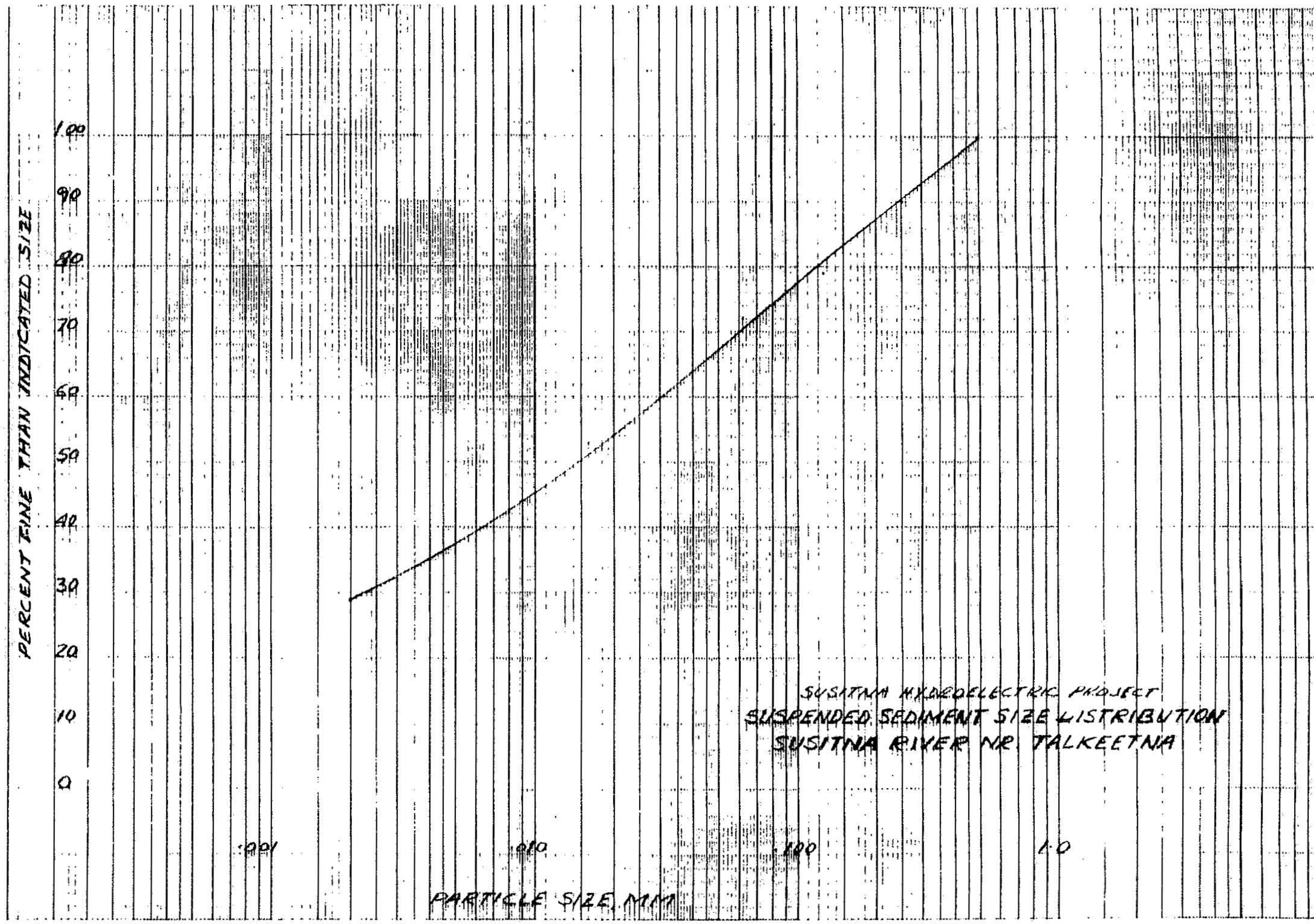


EXHIBIT 7

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

46 6212

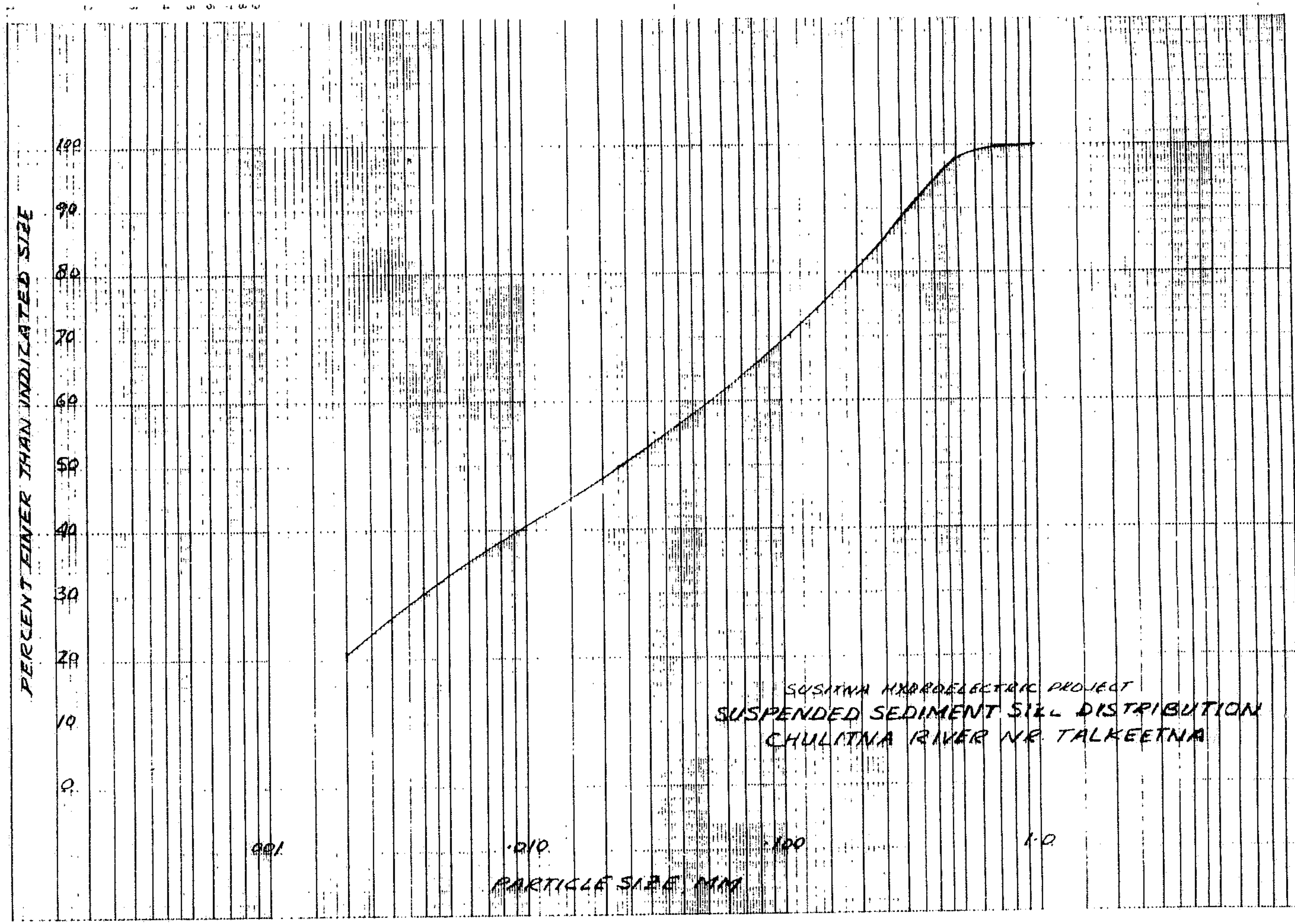


EXHIBIT 8

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

46 6212

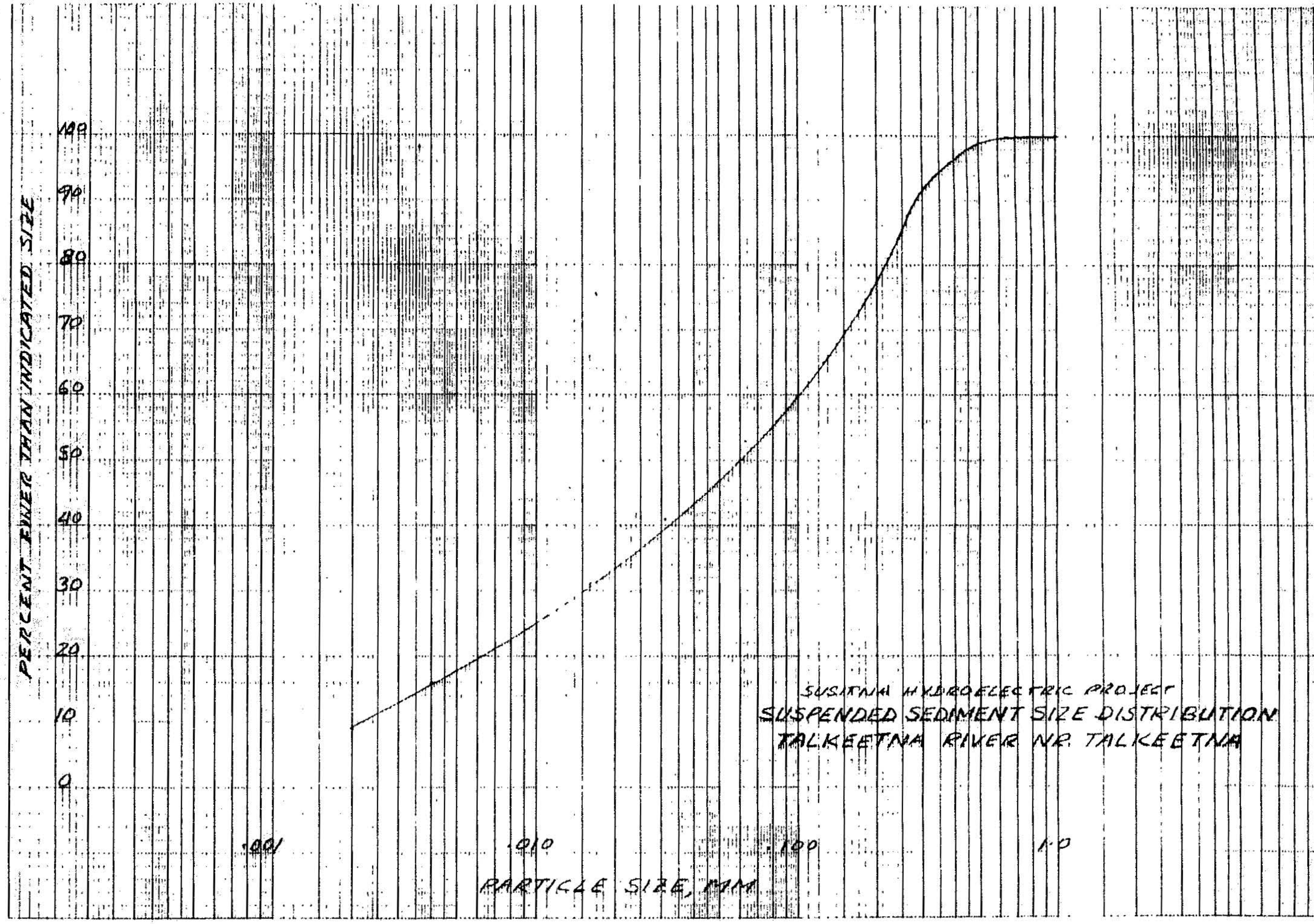


EXHIBIT 3

K·E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

46 6212

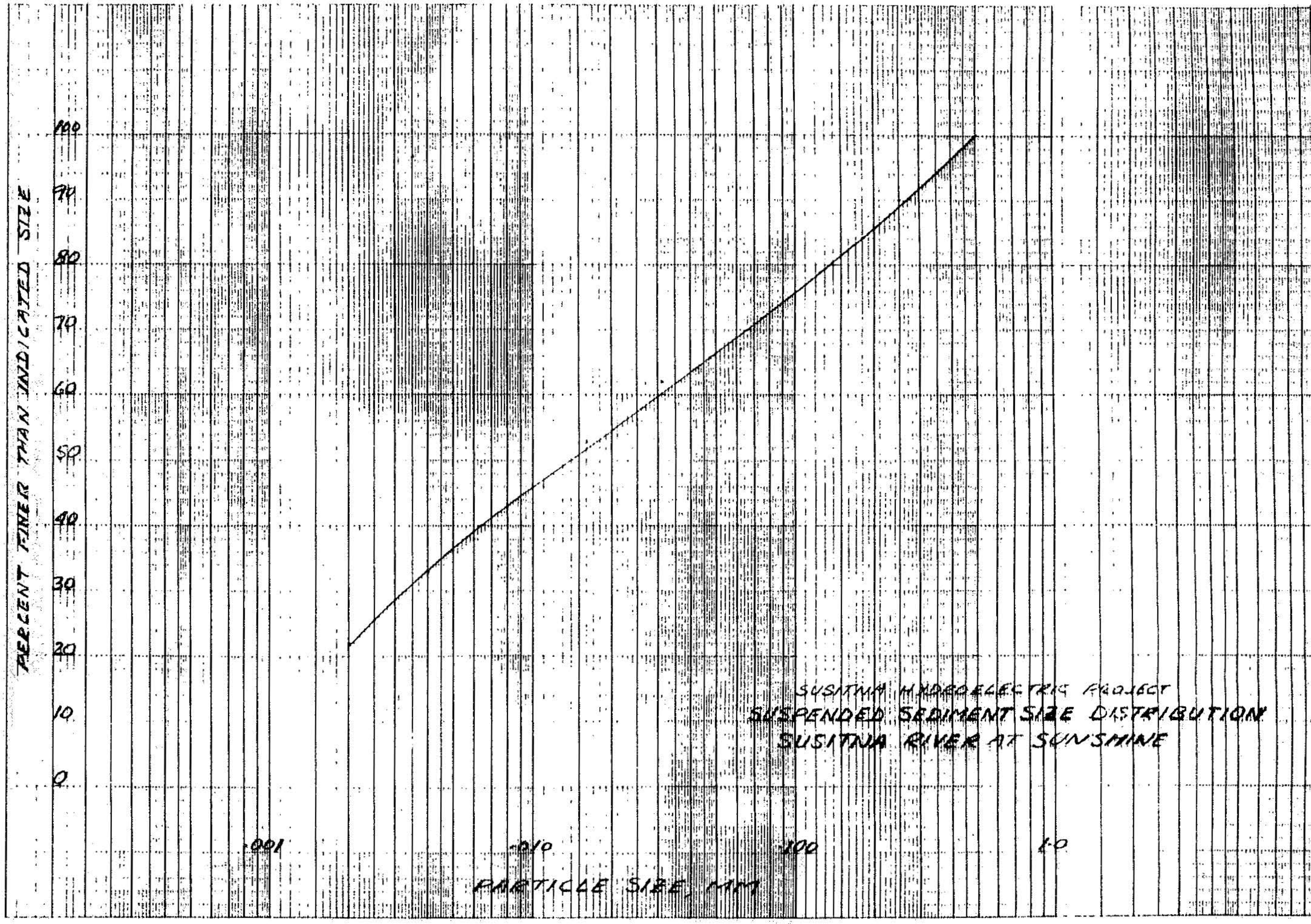


EXHIBIT 10

K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6212

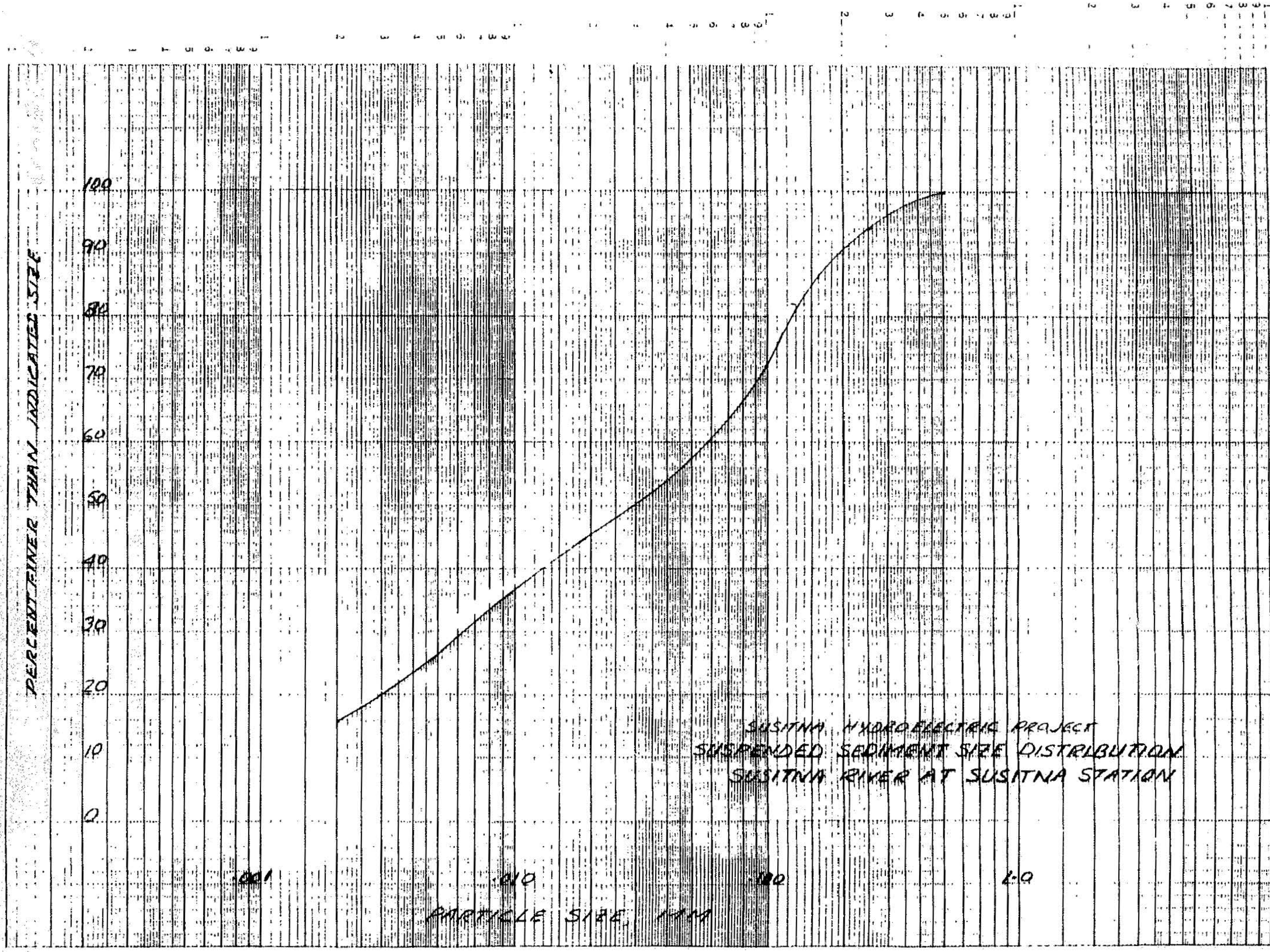
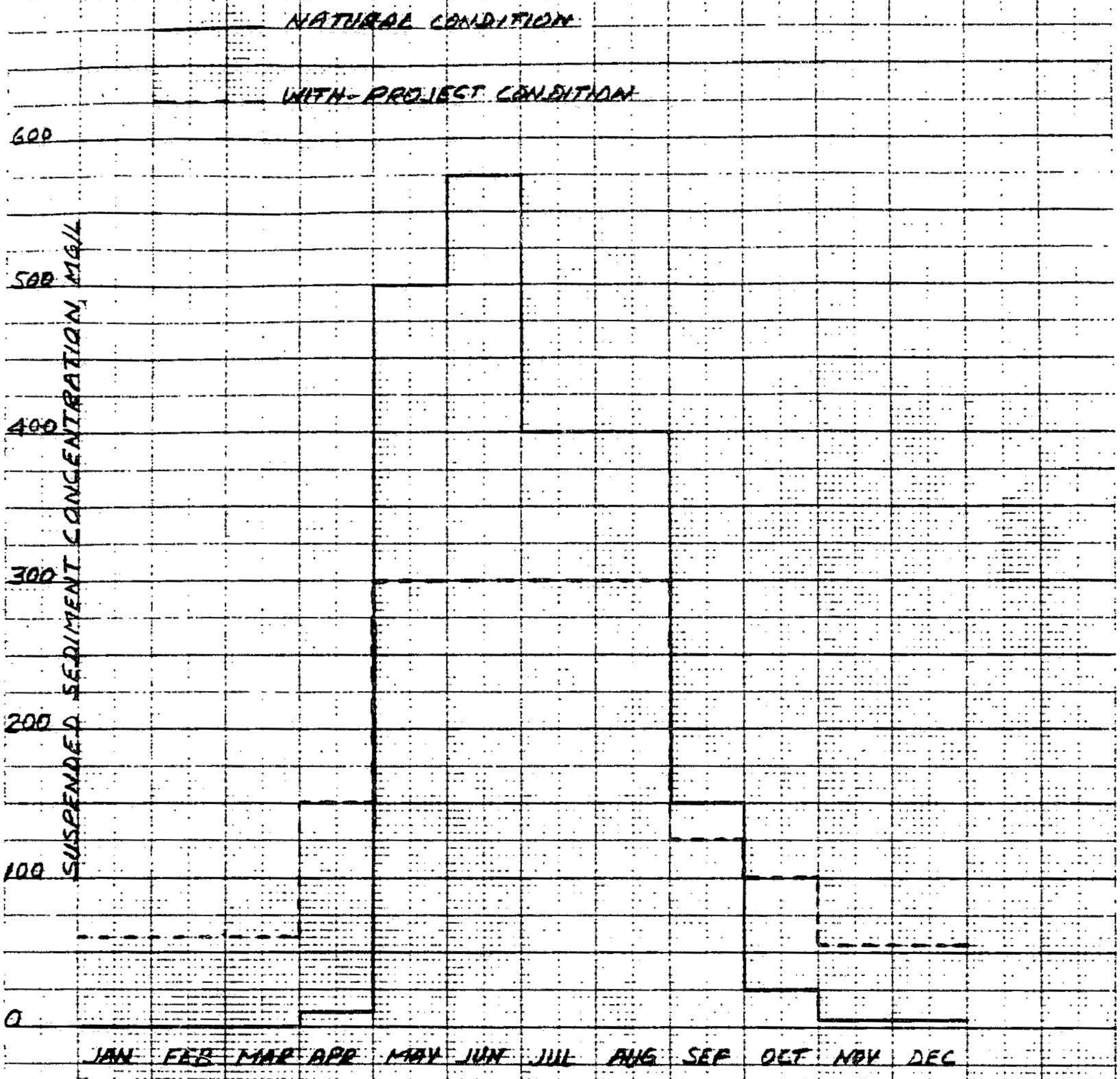
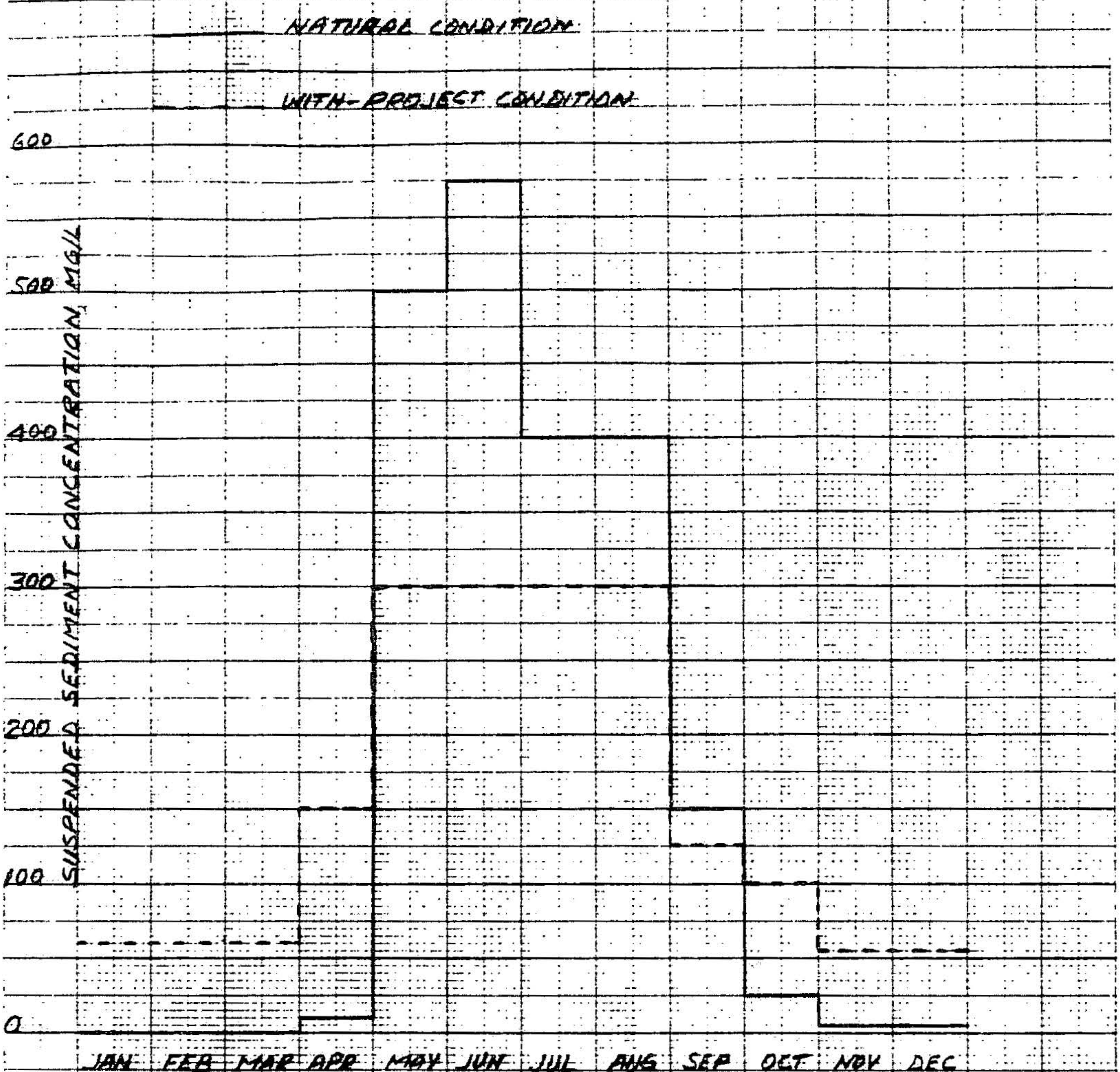


EXHIBIT 11



SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT GOLD CREEK
MONTHLY SUSPENDED
SEDIMENT CONCENTRATIONS

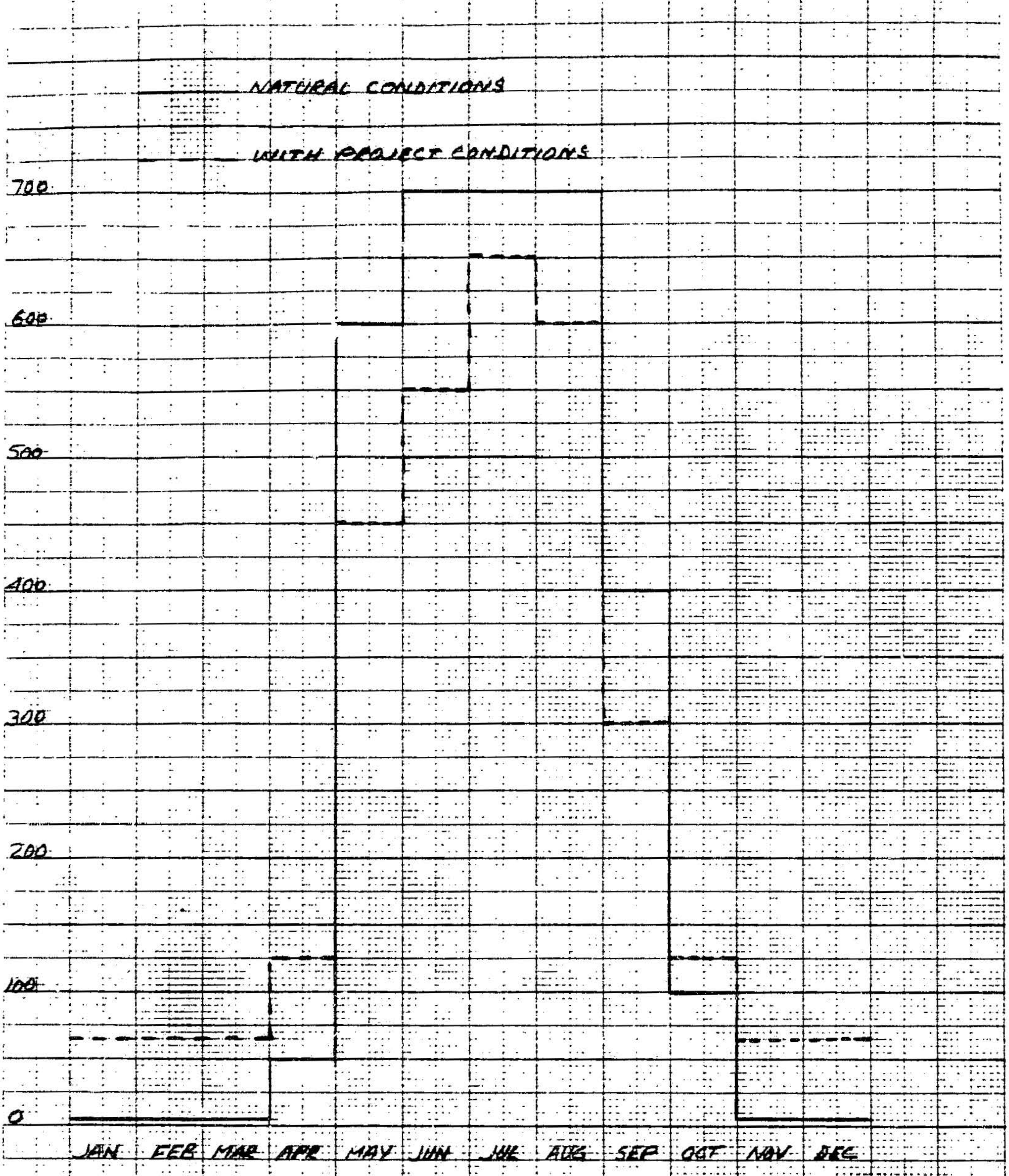
HARZA-EBASCO SUSITNA JOINT VENTURE, SEP. 1984



SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT GOLD CREEK
MONTHLY SUSPENDED
SEDIMENT CONCENTRATIONS

HARZA-EBASCO SUSITNA JOINT VENTURE, SEP. 1984

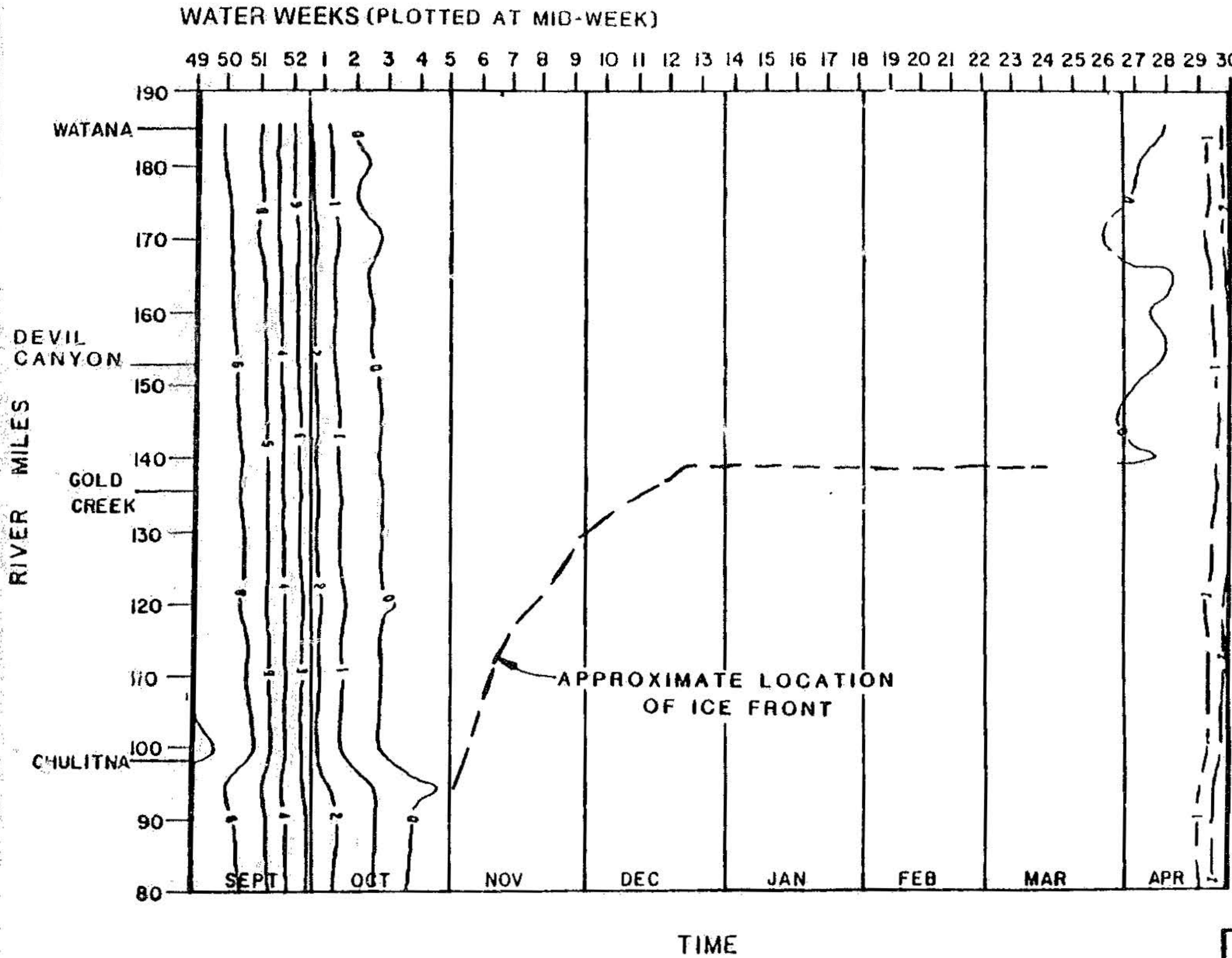
EXHIBIT 13



SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT SUNSHINE
MONTHLY SUSPENDED
SEDIMENT CONCENTRATIONS

HARZA-EBASCO SUSITNA JOINT VENTURE, SEP 1984

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.
   SIMULATED TEMPERATURES FOR MARCH AND APRIL SHOULD NOT BE USED.
3. ICE FRONT PROGRESSION UPSTREAM OF RIVER MILE 139 NOT MODELED FOR NATURAL CONDITIONS

NATURAL CONDITIONS

WINTER 1971-1972 CLIMATE DATA

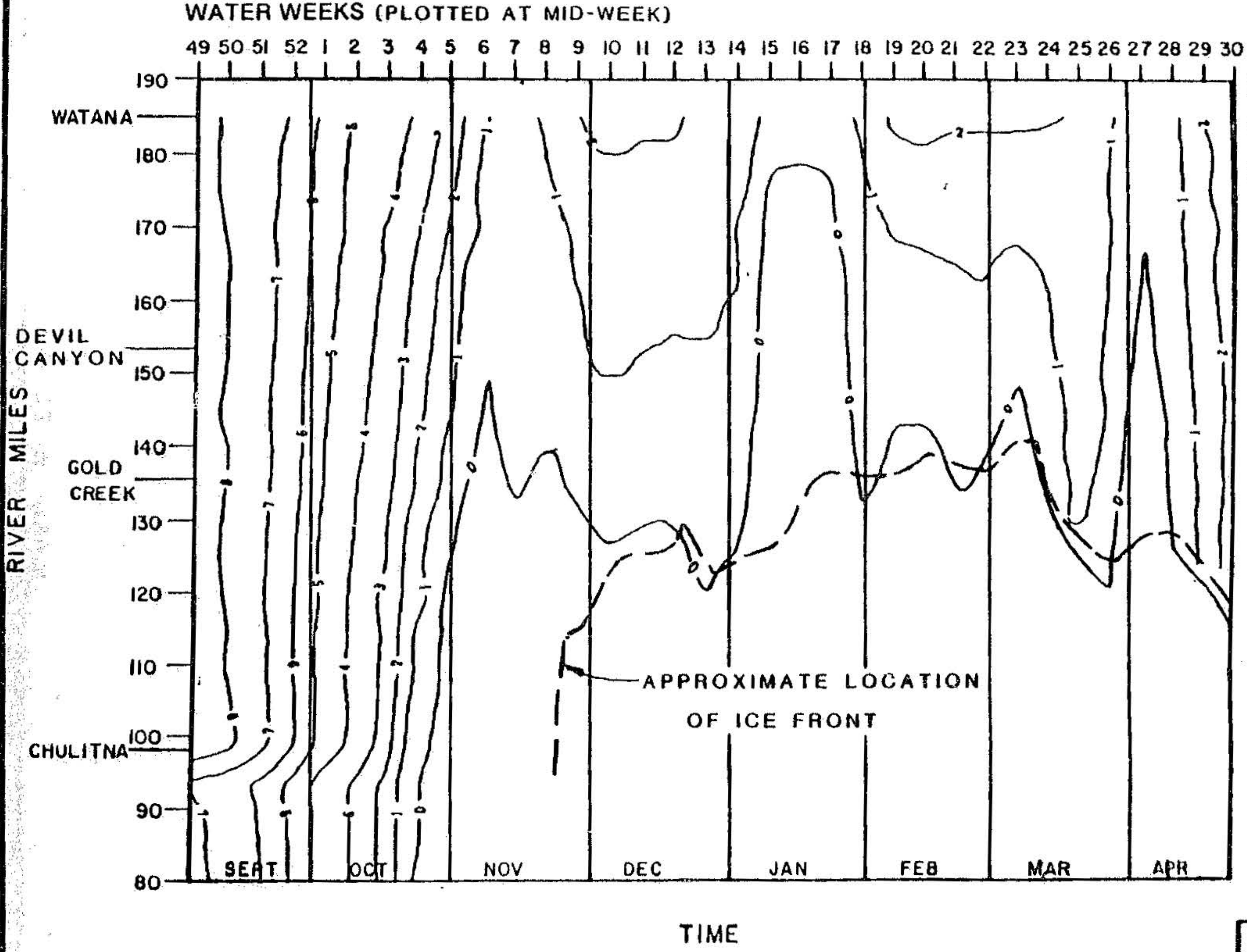
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 14

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA ONLY, 1996 ENERGY DEMAND

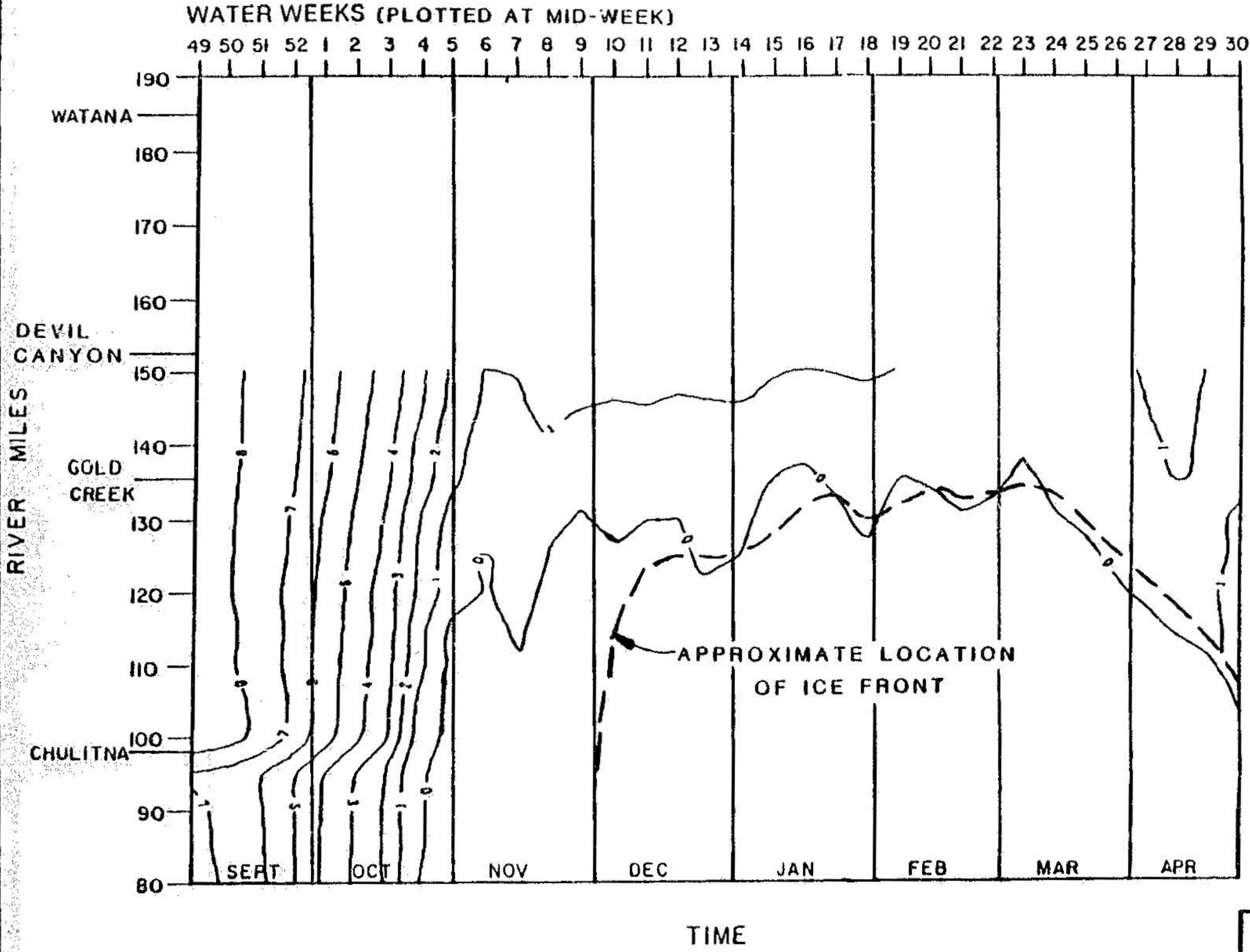
WINTER 1971-1972 CLIMATE DATA

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER | HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 15

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA/DEVIL CANYON, 2002 ENERGY DEMAND

WINTER 1971-1972 CLIMATE DATA

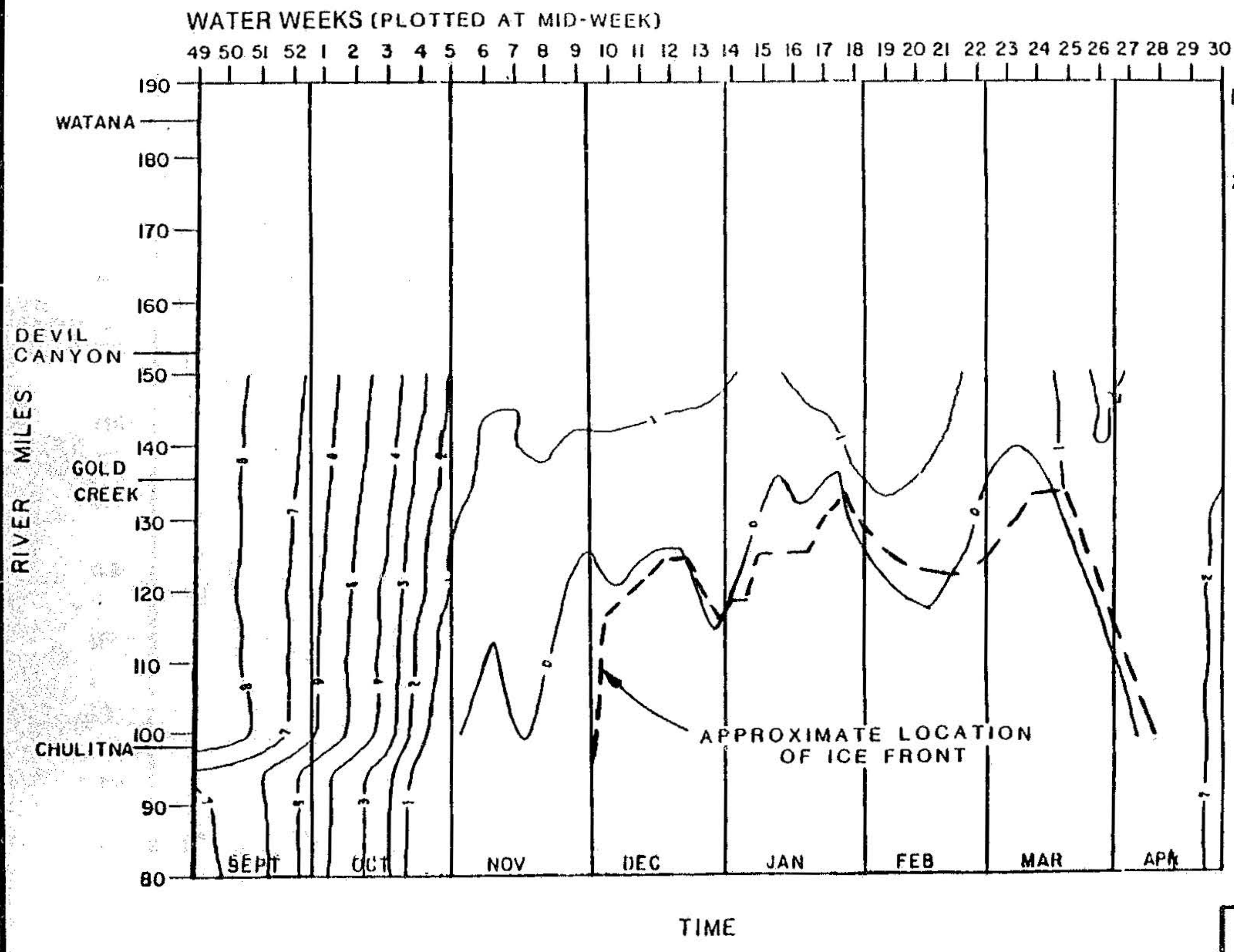
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 16

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA/DEVIL CANYON, 2020 ENERGY DEMAND

WINTER 1971-1972 CLIMATE DATA

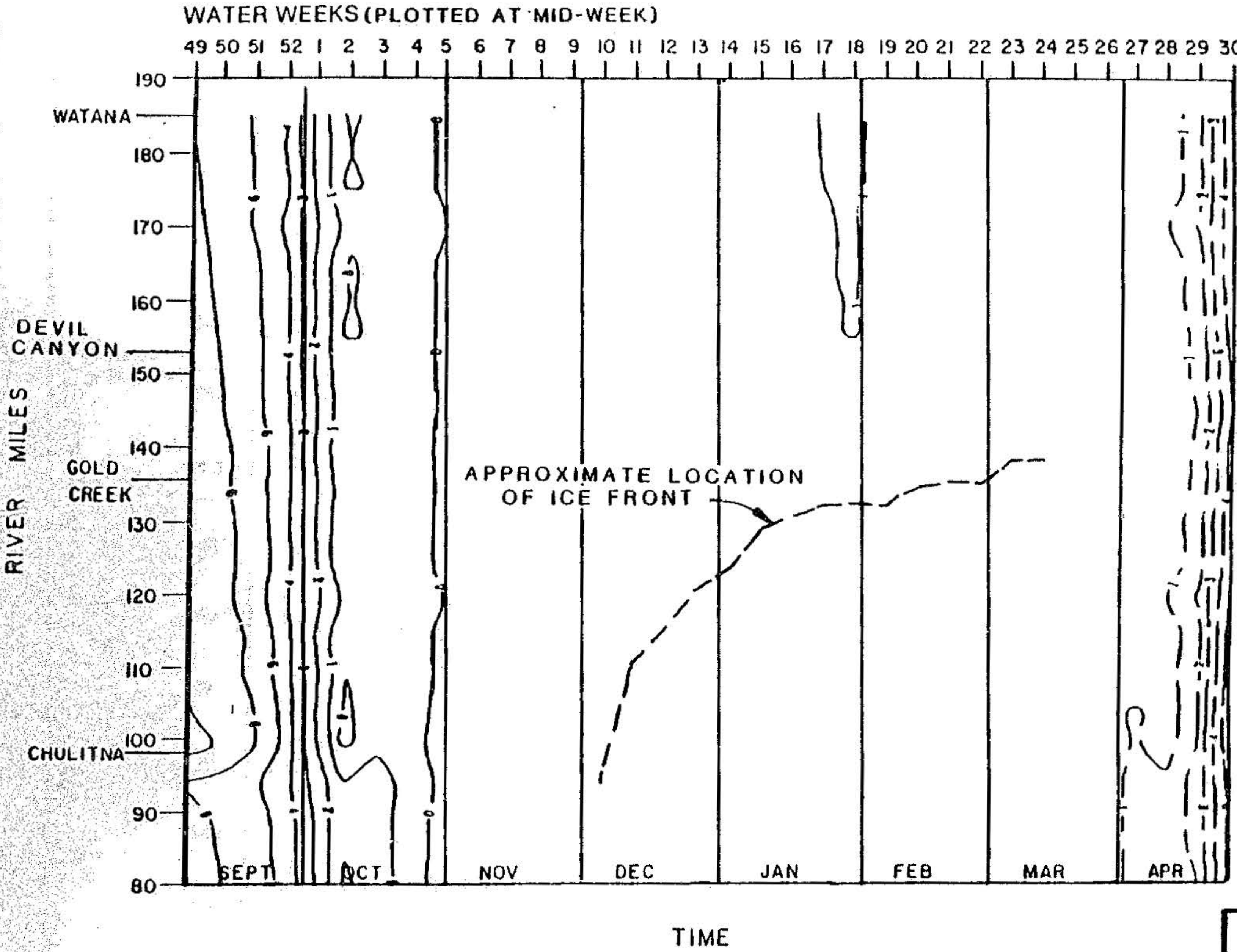
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 17

MIDDLE SUSITNA RIVER - ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.
3. ICE FRONT PROGRESSION UPSTREAM OF RIVER MILE 139 NOT MODELED FOR NATURAL CONDITIONS

NATURAL CONDITIONS

WINTER 1976-1977 CLIMATE DATA

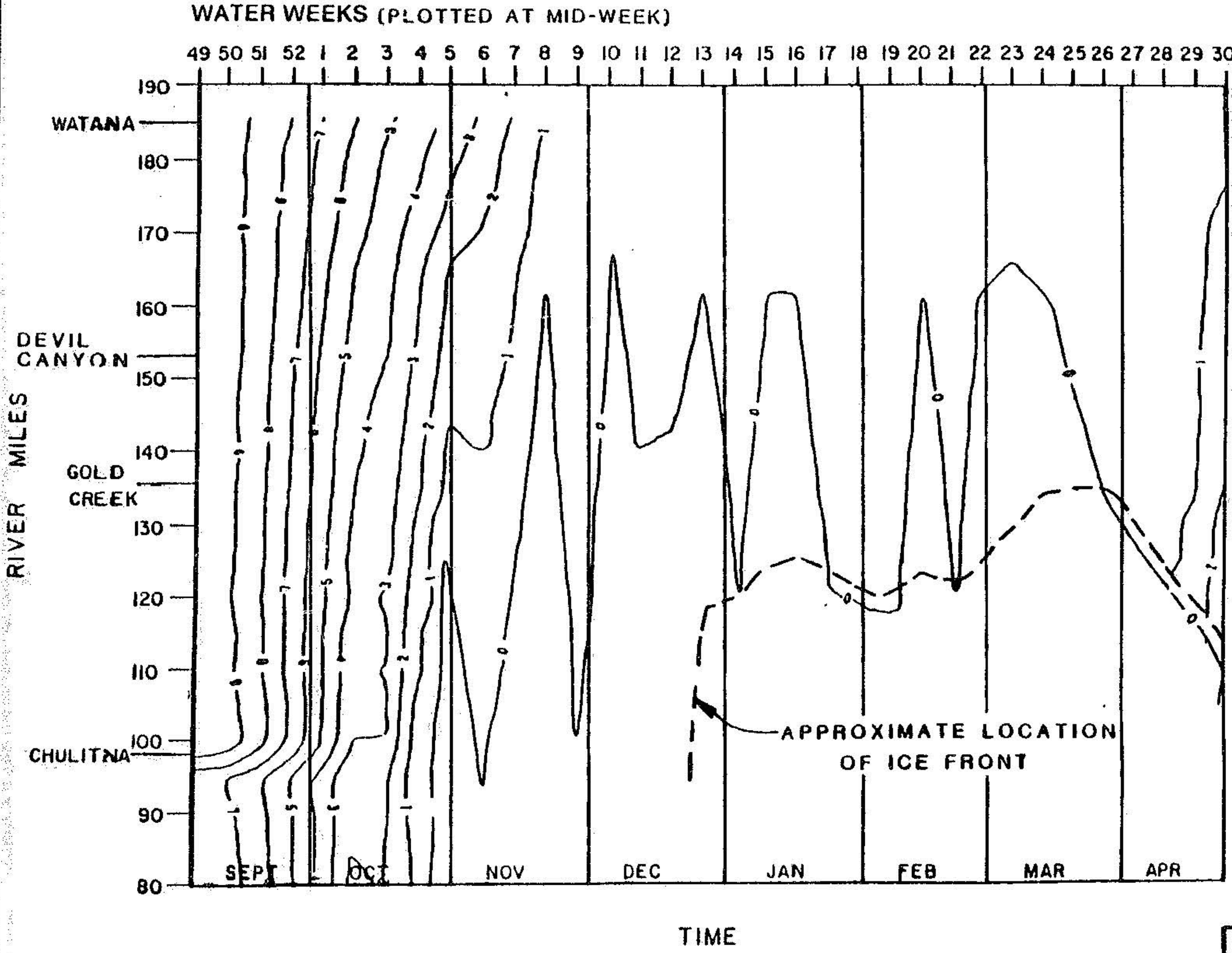
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 18

MIDDLE SUSITNA RIVER - ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA ONLY, 1996 ENERGY DEMAND

WINTER 1976-1977 CLIMATE DATA

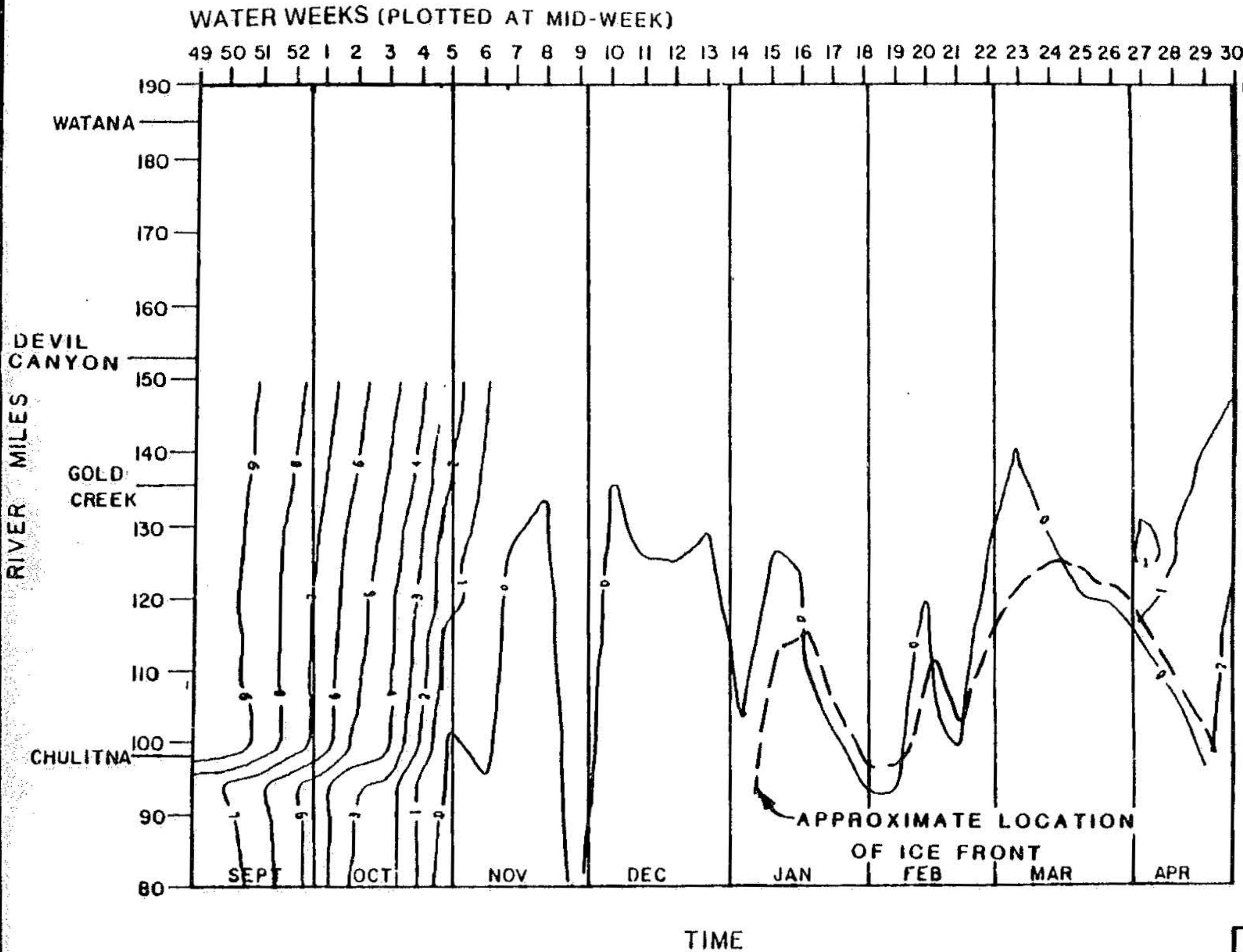
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 19

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA/DEVIL CANYON, 2002 ENERGY DEMAND

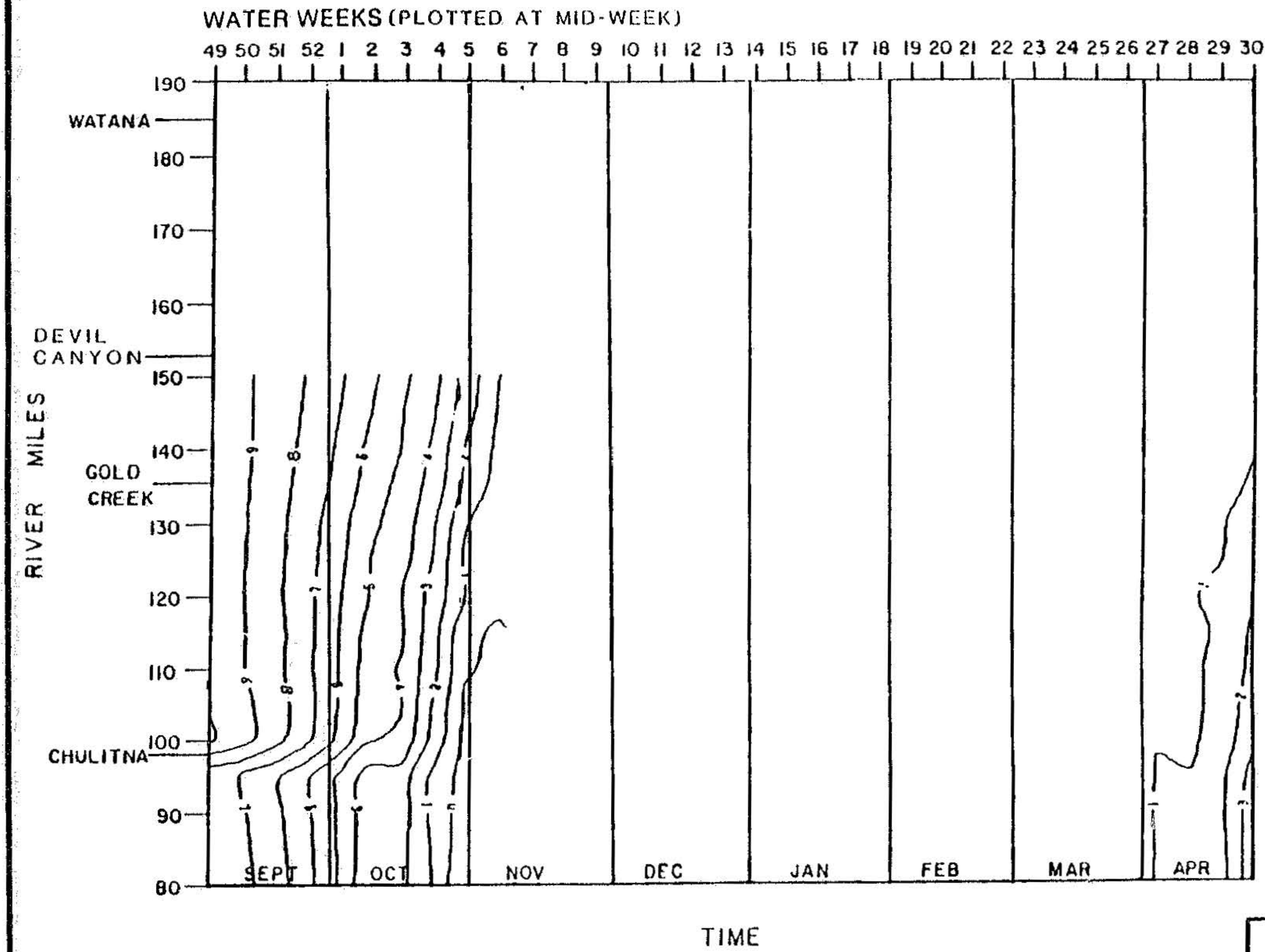
WINTER 1976-1977 CLIMATE DATA

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER | HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 20

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. ICE SIMULATION NOT MADE FOR THIS CASE. TEMPERATURES FROM NOVEMBER THROUGH APRIL SHOULD NOT BE USED.

WATANA/DEVIL CANYON, 2020 ENERGY DEMAND

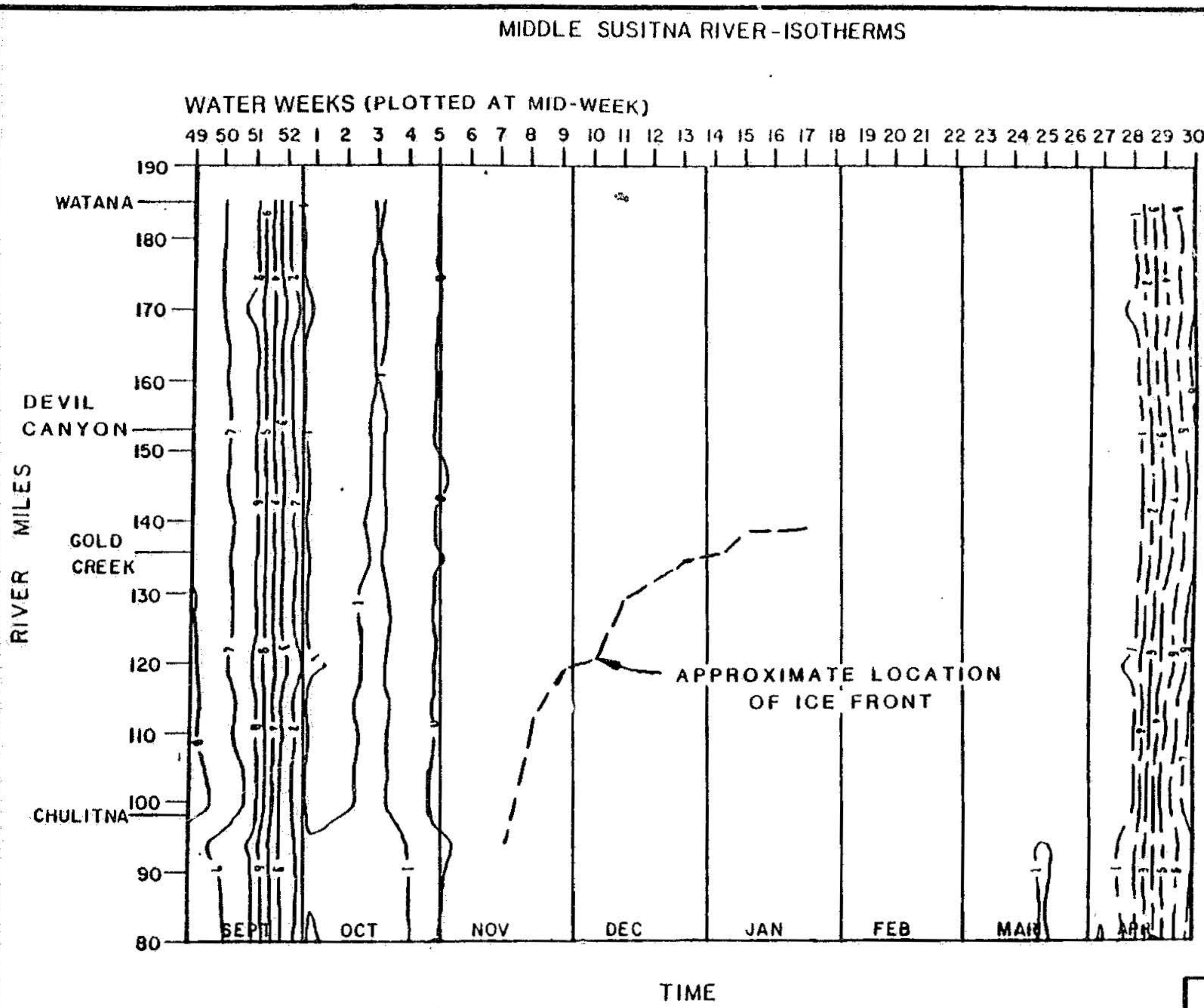
WINTER 1976-1977 CLIMATE DATA

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 21



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.
3. ICE FRONT PROGRESSION UPSTREAM OF RIVER MILE 139 NOT MODELED FOR NATURAL CONDITIONS

NATURAL CONDITIONS

WINTER 1981-1982 CLIMATE DATA

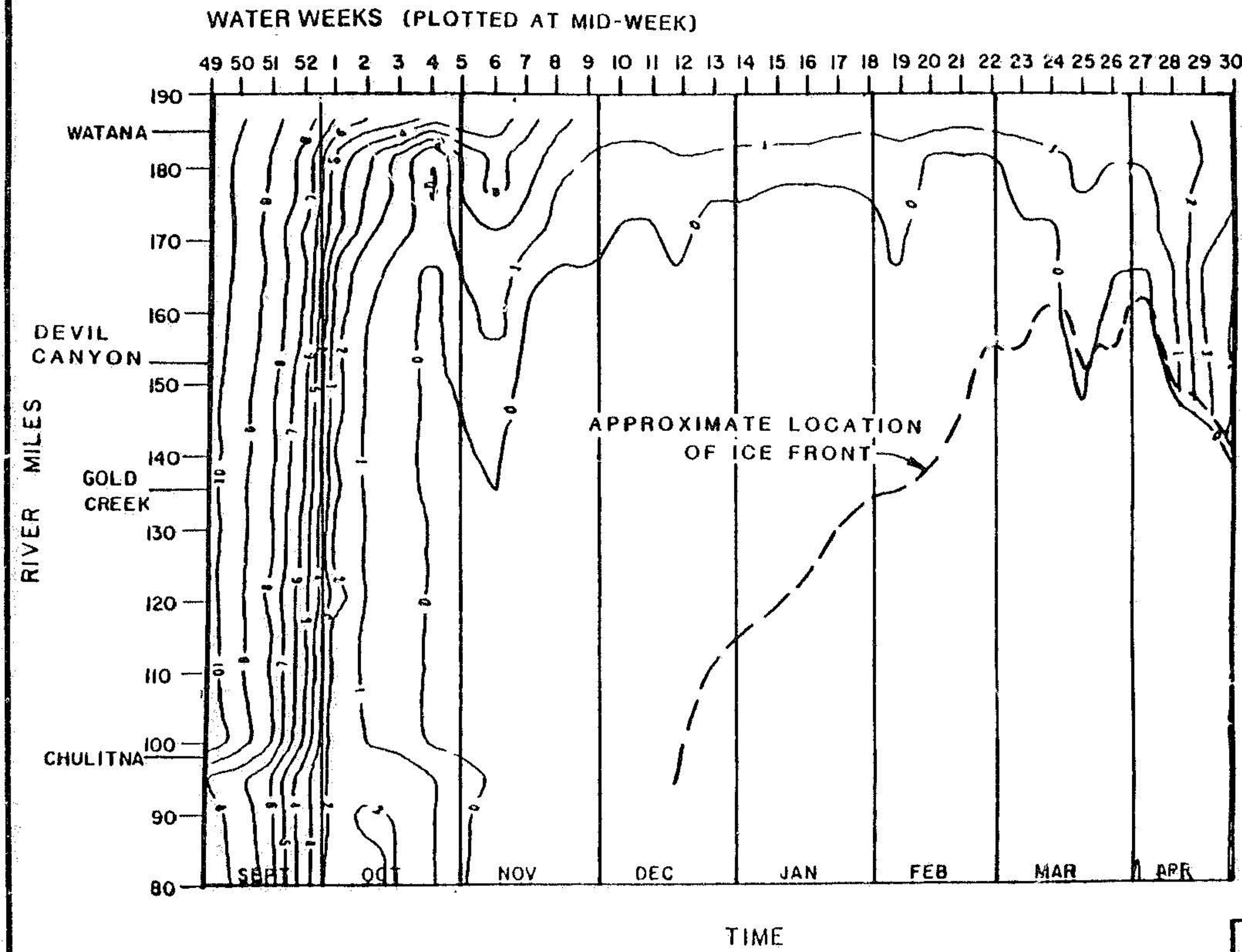
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 22

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.
3. ICE FRONT PROGRESSION UPSTREAM OF RIVER MILE 140 NOT CONSIDERED ACCURATE FOR FILLING CASE

WATANA FILLING, 1992-1993
2nd WINTER
WINTER 1981-1982 CLIMATE DATA

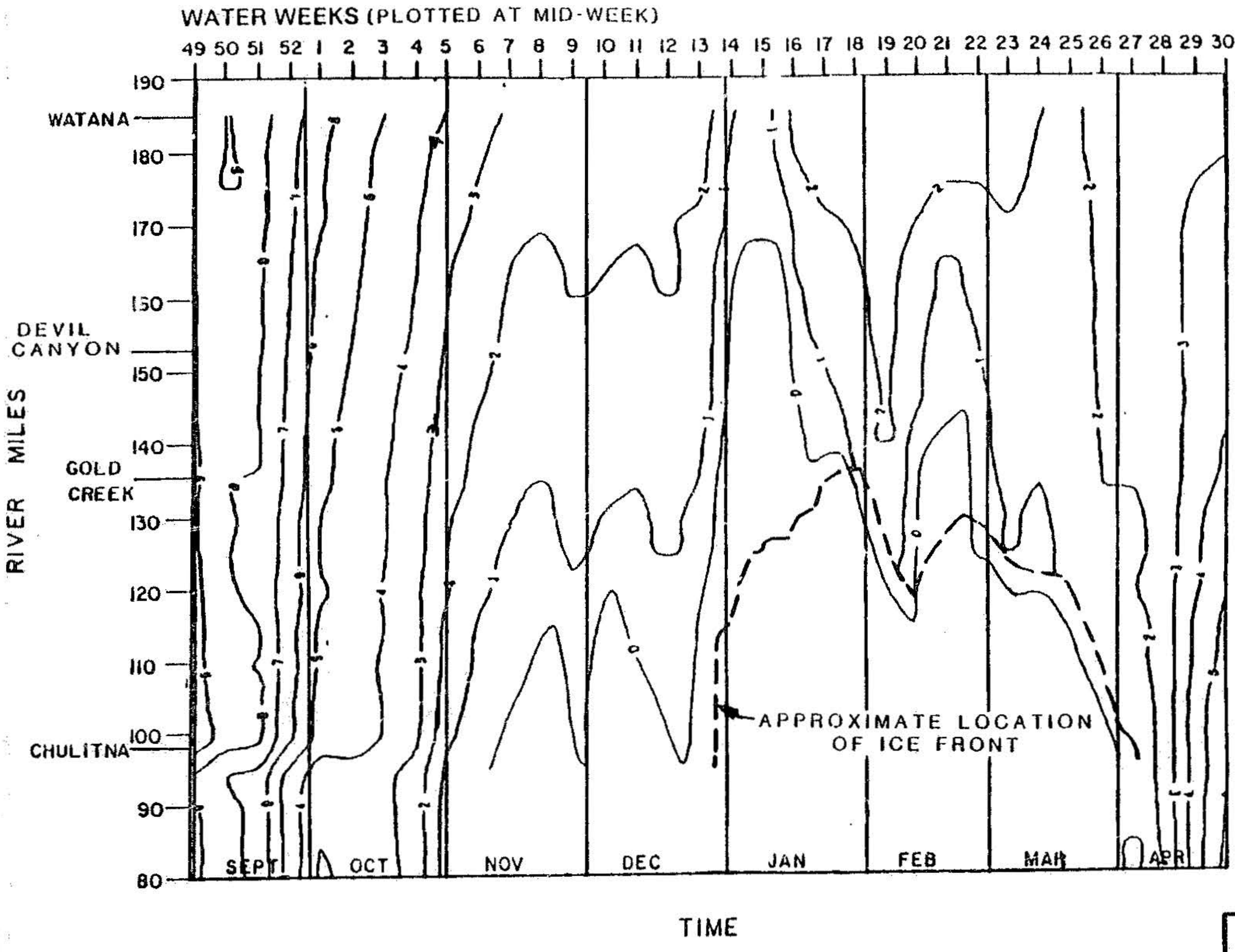
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO
SUSITNA JOINT VENTURE

EXHIBIT 23

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA ONLY, 1996 ENERGY DEMAND

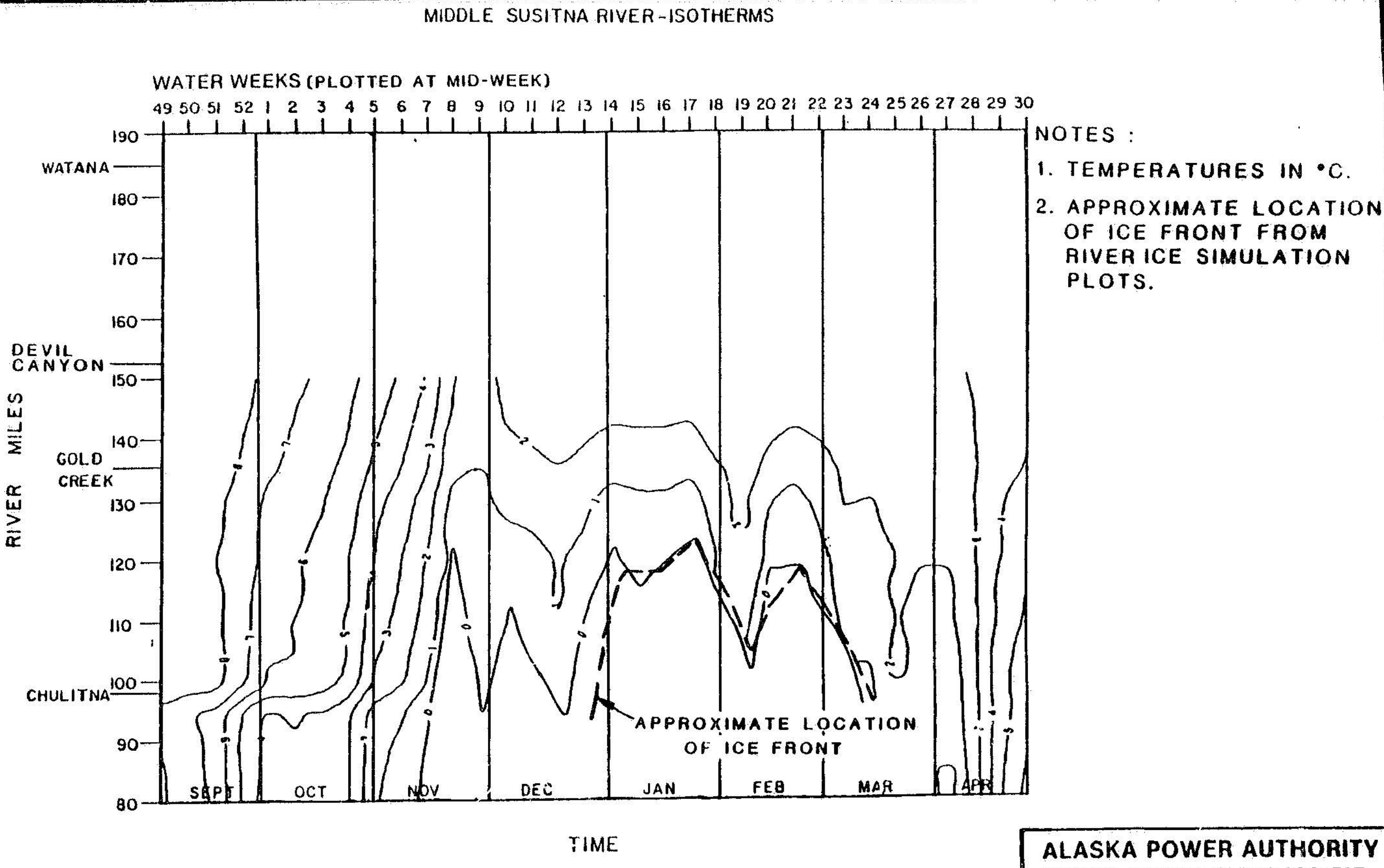
WINTER 1981-1982 CLIMATE DATA

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO
SUSITNA JOINT VENTURE

EXHIBIT 24



WATANA/DEVIL CANYON, 2002 ENERGY DEMAND

WINTER 1981-1982 CLIMATE DATA

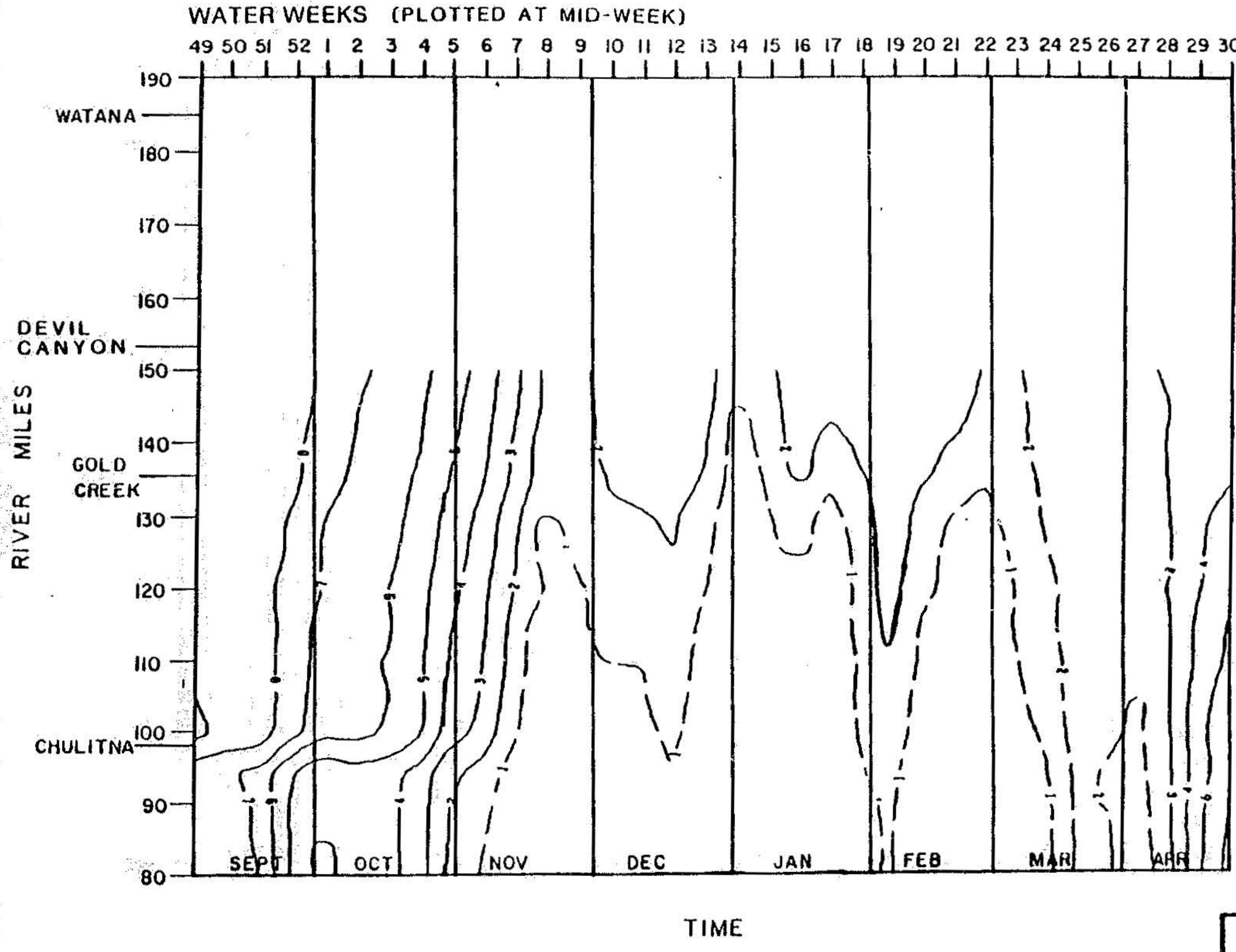
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 25

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. ICE SIMULATION NOT MADE FOR THIS CASE. TEMPERATURES FOR NOVEMBER THROUGH MARCH SHOULD NOT BE USED. NOTE SIMILARITY TO WATANA/DEVIL CANYON, 2002 WINTER 1981-1982.

WATANA/DEVIL CANYON, 2020 ENERGY DEMAND

WINTER 1981-1982 CLIMATE DATA

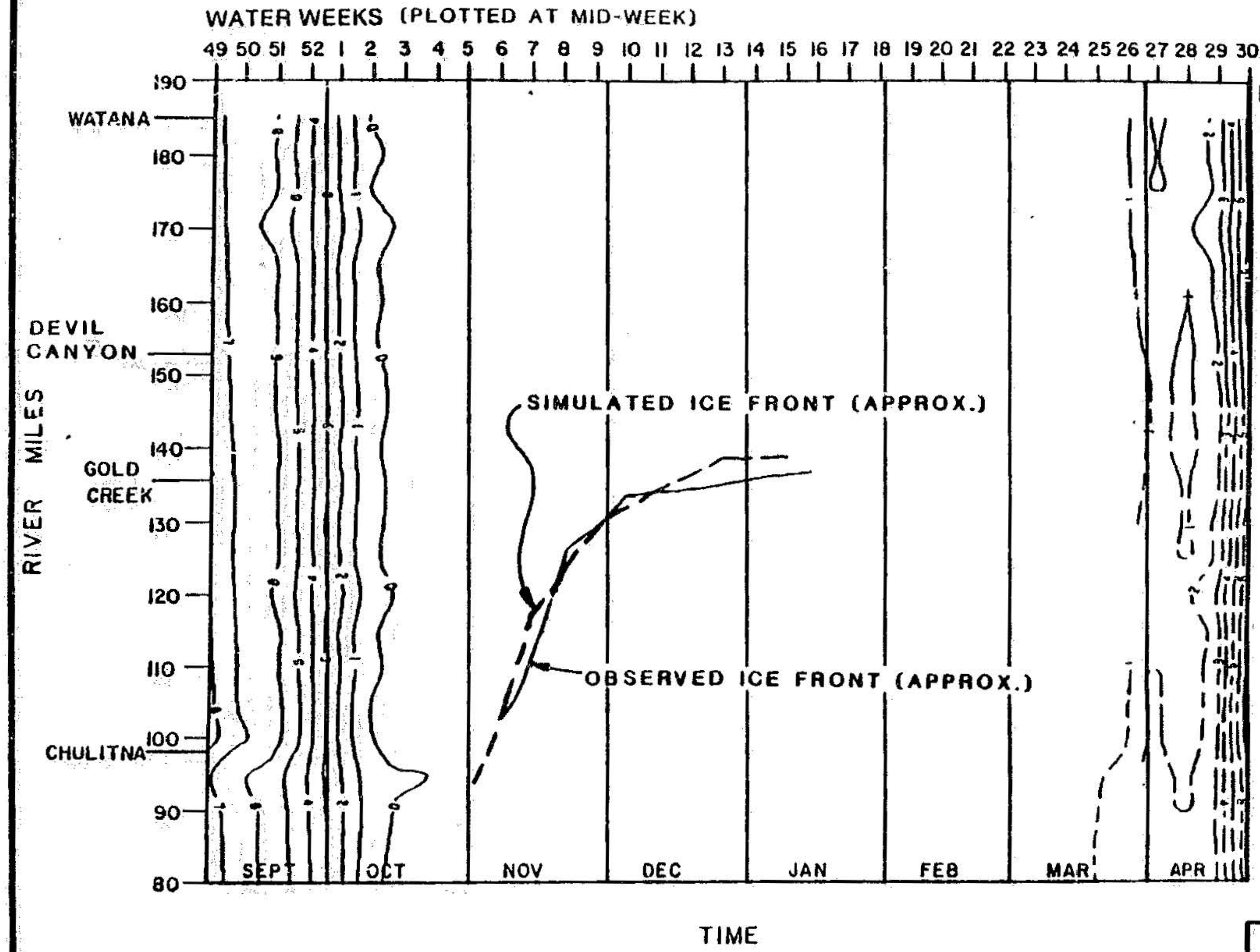
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 26

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

   SIMULATED TEMPERATURES FOR MARCH AND APRIL SHOULD NOT BE USED.
3. ICE FRONT PROGRESSION UPSTREAM OF RIVER MILE 139 NOT MODELED FOR NATURAL CONDITIONS

NATURAL CONDITIONS

WINTER 1982-1983 CLIMATE DATA

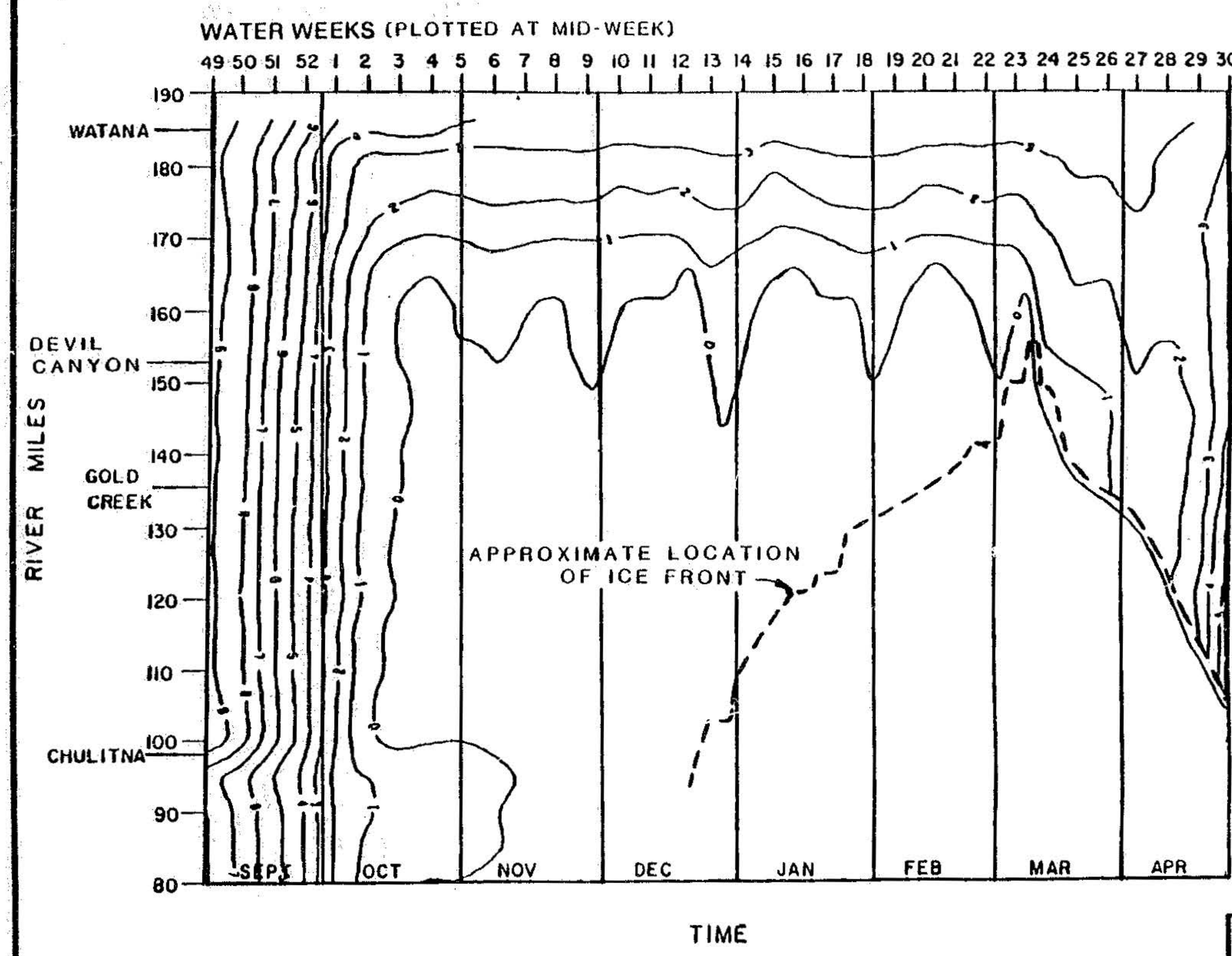
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO
SUSITNA JOINT VENTURE

EXHIBIT 27

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.
3. ICE FRONT PROGRESSION UPSTREAM OF RIVER MILE 140 NOT CONSIDERED ACCURATE FOR FILLING CASE

WATANA FILLING, 1991-1992
1st WINTER
WINTER 1982-1983 CLIMATE DATA

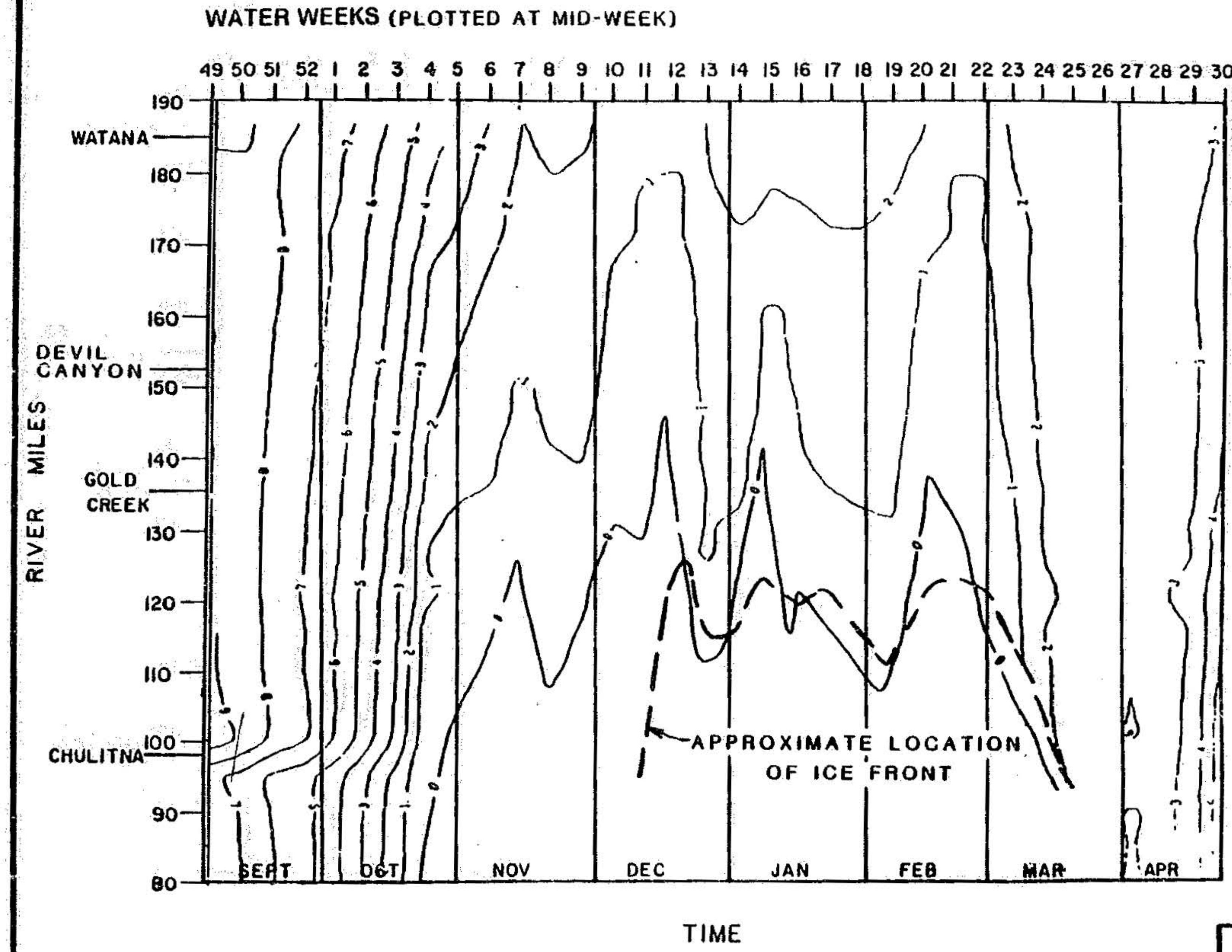
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO
SUSITNA JOINT VENTURE

EXHIBIT 28

MIDDLE SUSITNA RIVER - ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA ONLY, 1996 ENERGY DEMAND

WINTER 1982-1983 CLIMATE DATA

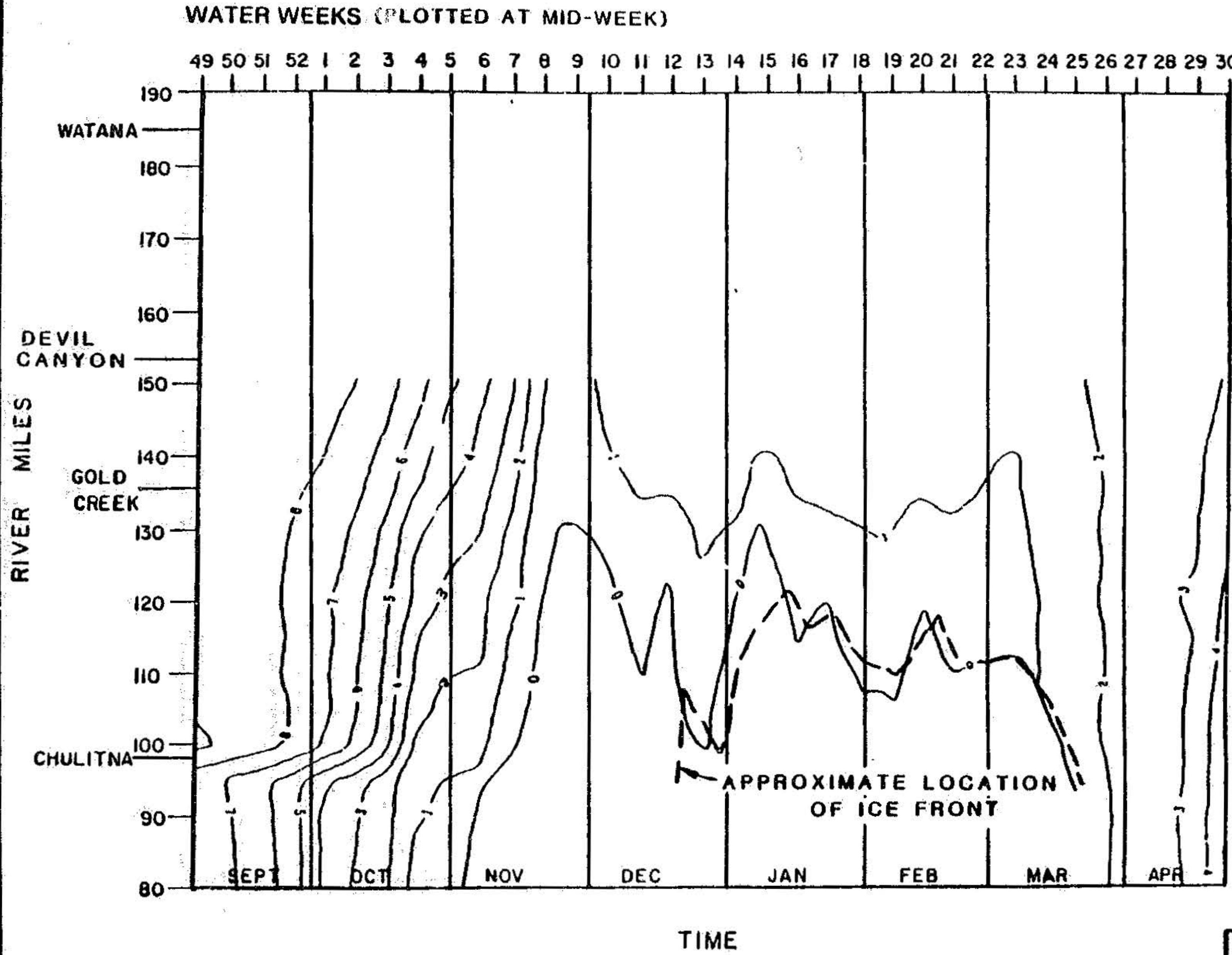
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 29

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA/DEVIL CANYON, 2002 ENERGY DEMAND

WINTER 1982-1983 CLIMATE DATA

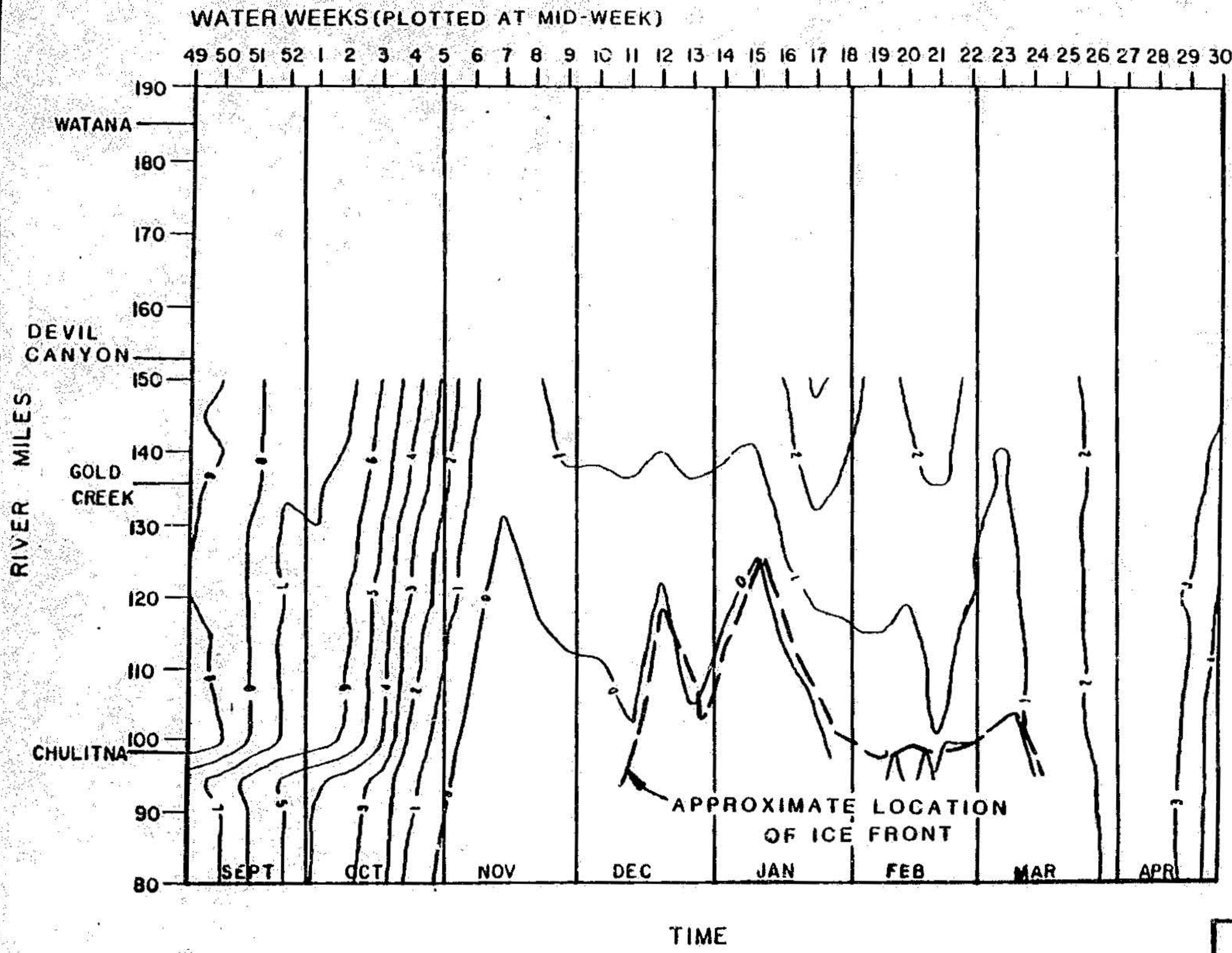
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO
SUSITNA JOINT VENTURE

EXHIBIT 30

MIDDLE SUSITNA RIVER-ISOTHERMS



NOTES :

1. TEMPERATURES IN °C.
2. APPROXIMATE LOCATION OF ICE FRONT FROM RIVER ICE SIMULATION PLOTS.

WATANA/DEVIL CANYON, 2020 ENERGY DEMAND

WINTER 1982-1983 CLIMATE DATA

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

ARCTIC ENVIRONMENTAL INFORMATION AND DATA CENTER

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 31