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Environmental Engineering Studies associated with the Aishihik River Hydroelectric Development

by
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Northern Operations Branch
Pacific Region

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Fisheries and Marine Service
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Habitat Protection Unit
Pacific Region

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ENVIRONMENTAL ENGINEERING STUDIES ASSOCIATED WITH THE AISHIHIK RIVER HYDROELECTRIC DEVELOPMENT

1. INTRODUCTION

As part of the overall assessment of the effects of hydroelectric development on the fisheries resource of the Aishihik River system, various engineering surveys have been conducted in the area over the past two years by the Habitat Protection Unit, Northern Operations Branch. The nature and location of these surveys were as follows:

- Summer of 1972
  - water surface profile between Sekulmun and Aishihik lakes.
  - Depth soundings of Aishihik Lake, Canyon Pond and Otter Pond.
  - Terrestrial and aquatic terrain classification of the Aishihik Lake shoreline.
  - Water surface profiles of the lower reaches of Giltana Creek and major tributary streams of Aishihik Lake.
  - Water surface profile of the upper Aishihik River between Aishihik Lake and Canyon Pond.
- Summer of 1973
  - controlled stadia survey of Sekulmun River between Sekulmun and Aishihik lakes.
  - Aquatic terrain classification of the Aishihik Lake shoreline (sections extended from 15 foot depth to 30 foot depth).
  - Controlled stadia survey of the upper Aishihik River between Canyon Pond and Canyon Lake at a discharge of 570 cfs.
- Summer of 1974
  - controlled stadia survey of the upper

Aishihik River between Canyon Pond and Canyon Lake at a discharge of 70 cfs. Staff gauges were erected to aid biological staff in establishing water surface profiles at intermediate discharges.

This report deals with the surveys of the Sekulmun and upper Aishihik rivers and the terrestrial and aquatic terrain classification of the Aishihik Lake shoreline. Other surveys indicated above were discussed in the Fisheries Service interim report of January 1973 entitled "Fisheries Problems Associated with the Proposed Aishihik River Power Development."

2. SEKULMUN RIVER

2.1 General:

The Northern Canada Power Commission has been granted a licence to regulate water levels in Aishihik Lake between the natural historic low and high lake levels. These levels have been computed to be at elevations 2996.5 and 3002.5, respectively.[1] However, for greater optimization of powerplant flows the Commission has applied for increased storage on Aishihik Lake. A decision has not yet been made on the ultimate storage range but the Water Board has stipulated that the lake will not be regulated below elevation 2992.5 or above elevation 3007.5

Biological studies conducted during 1972 concluded that Sekulmun River acts as a rearing area and migrational route for several species of fish. Concern was therefore expressed that regulation of

1. Personal communication with Dr. A. B. Hollingshead.

Aishihik Lake beyond its natural storage levels may lead to degradation of the aquatic environment of the Sekulmun River with a resultant adverse effect on these fish stocks. Engineering surveys were then conducted to determine the physical changes that may ensue as a result of either a drawdown of 4 feet below the natural historic low level of Aishihik Lake or an increase in storage to 5 feet above the natural historic high. These were conducted during the summer of 1973 and were comprised of the following:

a) a control traverse from Sekulmun to Aishihik Lake providing vertical and horizontal control over the entire length of river;

b) a detailed topographical survey of 4 representative study areas over the length of the river;

c) water surface and river bed profiles between Sekulmun and Aishihik lakes;

d) measurement of river discharge;

e) random sampling of riverbed material within each study area; and

f) identification of marginal vegetation.

Round steel pins were set at intervals of 300 to 600 feet along the riverbanks and tree benchmarks were established at convenient locations for

future reference. All levels during the survey were based on the NCPC bench-mark at Sekulmun Lake, BM.2, geodetic elevation 3006.94.

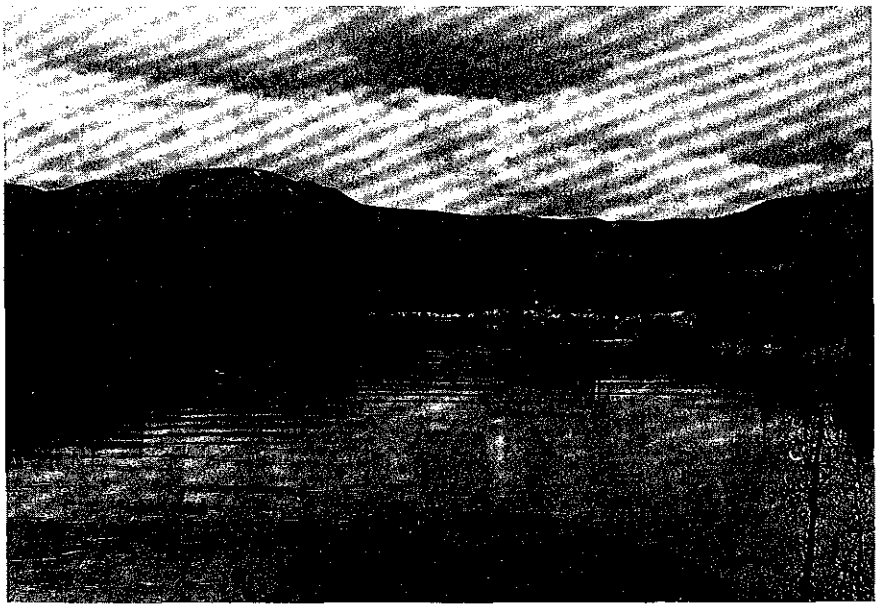
2.2 River Morphology:

The Sekulmun River is a 5 mile long stream meandering through a flat to undulating area between Sekulmun and Aishihik lakes (Figure 1). The river has a low gradient over most of its length with practically all of the head differential between the lakes occurring in the upper one mile (Figure 2). Depth of flow varies from quite shallow below the outlet of Sekulmun Lake to as much as 14 feet at the outside of bends and in deep pools throughout the lower 4 miles of river. The river becomes very shallow as it enters Aishihik Lake (Figure 3).

The composition of the riverbed changes from fine gravel and sand in the area above P13 to fine sediments of sand, silt or clay in the lower reaches of the river. A relatively heavy growth of aquatic vegetation occurs throughout the lower third of the river. Grain size compositions of the samples obtained in each study area are shown on Figure 4.

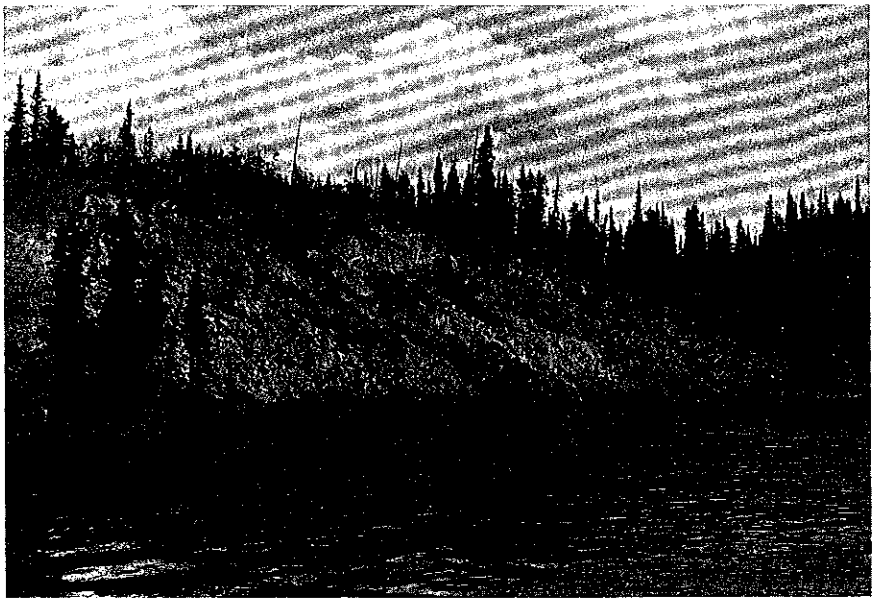
Riverbanks vary substantially over the length of the river. In the lower reaches the banks rise steeply and are often more than 10 feet above water level. The banks are composed of clay or silty material and the higher ones are generally devoid of vegetation and subject to erosion in the

PLATE 1



Sekulmun River looking upstream from hub P6. Banks are low and the surrounding terrain is generally quite flat. For location of hubs refer to Figure 1.

Left bank of Sekulmun River between hubs P10 and P11. Note block slumping which is believed to be caused by frost melt.



Left bank of Sekulmun River near hub P23. Clay cut banks sometimes rising to more than 80 feet in height are common to the central reaches of the river.

Active erosion occurring at the base of the left bank of the Sekulmun River near hub P23.

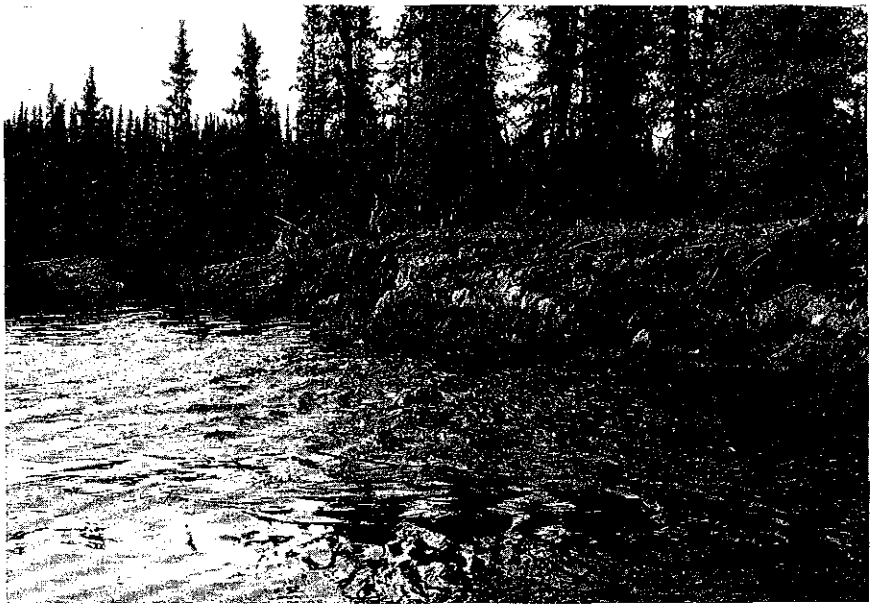
form of sloughing or block slumping. Willow, white spruce and grasses provide some bank stability in certain areas over the lower reaches of the river. In the upper reaches the banks are generally quite low and are occasionally overtopped by high flows. Banks are composed of granular material in the upper 1/4 mile of river and this appears to be the only source of gravel recruitment for the entire river. Extensive erosion was occurring at several points along the low banks between hubs P1 and P20. This is believed to be a slow but continuing process brought on by the combined action of water scour and frost melt.

Several large ponds drain into the river over the lower two miles. These are flat-bottomed, shallow ponds generally not more than 6 feet in depth.

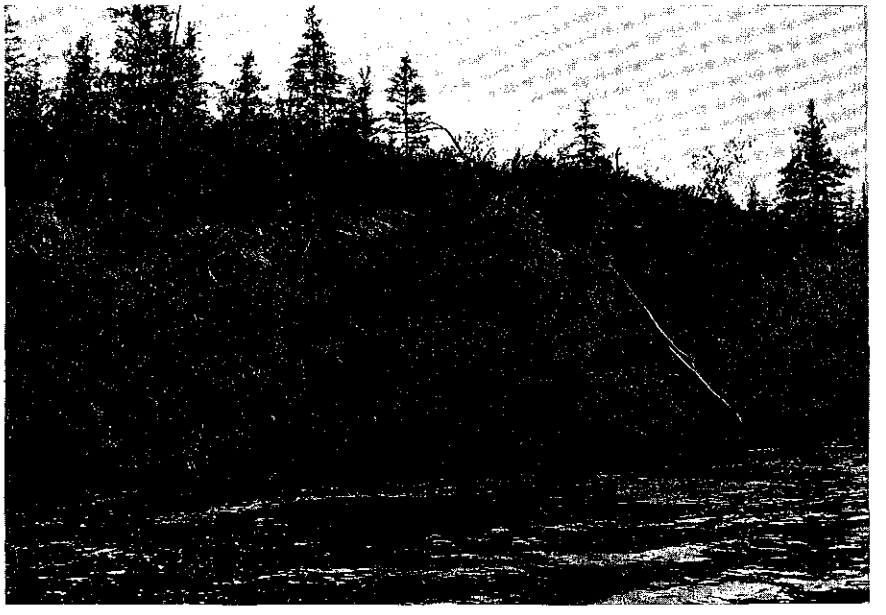
2.3 Hydrology:

The Sekulmun River water surface gradient changes naturally as Sekulmun and Aishihik Lakes fluctuate. Level profiles run between these lakes indicates that the drop varies between 3 and 5 feet. Approximately 50 percent of this difference occurs in the upper mile.

Discharges recorded by NCPC in the Sekulmun River between 1971 and 1973 show a variation between 66 cfs and approximately 800 cfs. However, discharges were never recorded between November and May and it is likely that the minimum discharge falls well below 66 cfs. The discharge measured while the topographical surveys were being conducted



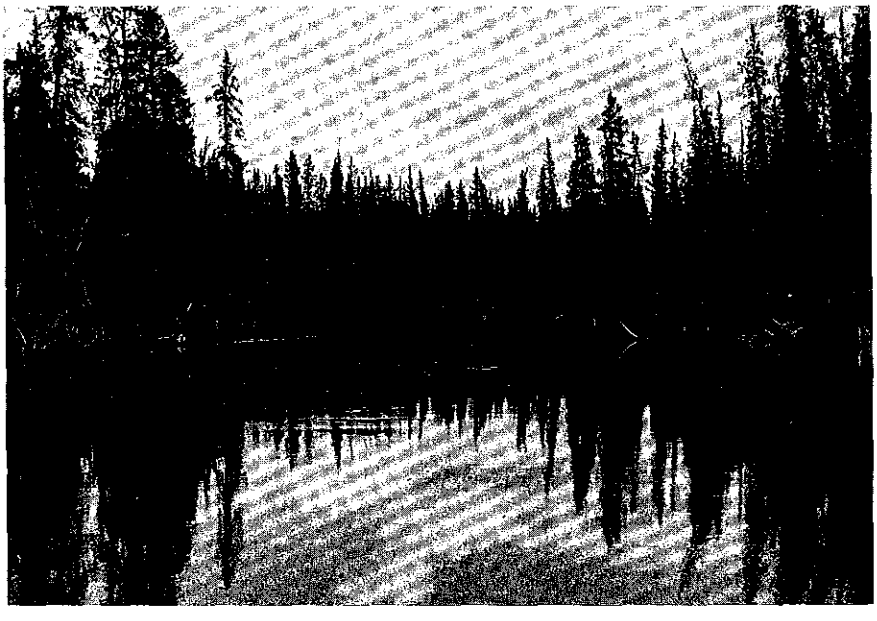
Block slumping occurring along left bank of the Sekulmun River approximately 400 feet upstream of hub P30.



Sloughing of left bank of the Sekulmun River near hub P37.

PLATE 4

Sloughing of left bank of the Sekulmun River near hub P40.



Sekulmun River looking downstream from hub P50. This is typical of the lower reaches of the river. A dense growth of grasses, stunted willow and mature white spruce occur to the rivers edge. The river is deep with a very low gradient.

was 566 cfs.

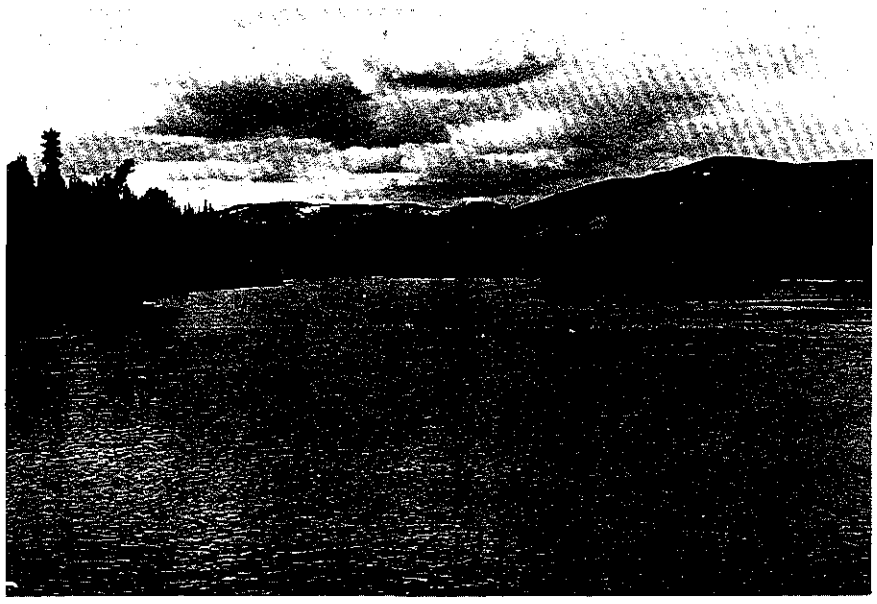
River velocities are in the order of 2 fps near the outlet of Sekulmun Lake. The flow is much more sluggish in the lower four miles with velocities seldom above 1 fps.

In their Supplementary Report of December 20, 1972, G. E. Crippen and Associates indicate a total drainage area of 1080 sq. miles above the outlet of Aishihik Lake. The drainage area above the outlet of Sekulmun Lake makes up 485 sq. miles (45%) of this total. The surface areas of Aishihik and Sekulmun lakes are 57.0 and 19.3 sq. miles, respectively. The respective ratios of surface area to drainage areas for each of the lakes are therefore .096 and .040, which indicates that Sekulmun Lake is filled more quickly during spring run-off than Aishihik Lake. Thus, it is reasonable to believe that at some time during the spring run-off, Sekulmun Lake would be at its highest level, while Aishihik Lake is still at a low stage, a condition which would control the erosional processes in the Sekulmun River.

2.4 Implications of Power Development

a) Raising Aishihik Lake to elevation 3007.5:

The level of Sekulmun Lake normally ranges between elevations 3003 and 3006. Therefore, increasing the level of Aishihik Lake to 3007.5 would flood the entire length of the Sekulmun River and its adjacent low-lying terrain. Velocities within

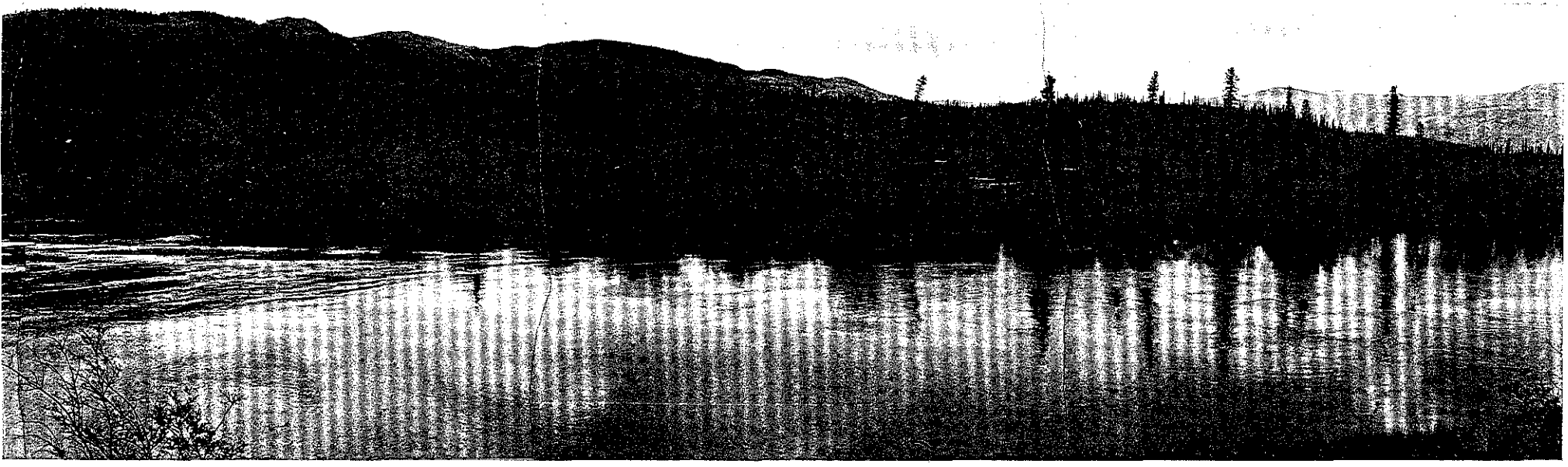


Sekulmun River looking upstream
from hub 1C

Sekulmun River looking downstream
from Sekulmun Lake

STUDY AREA NO. 1

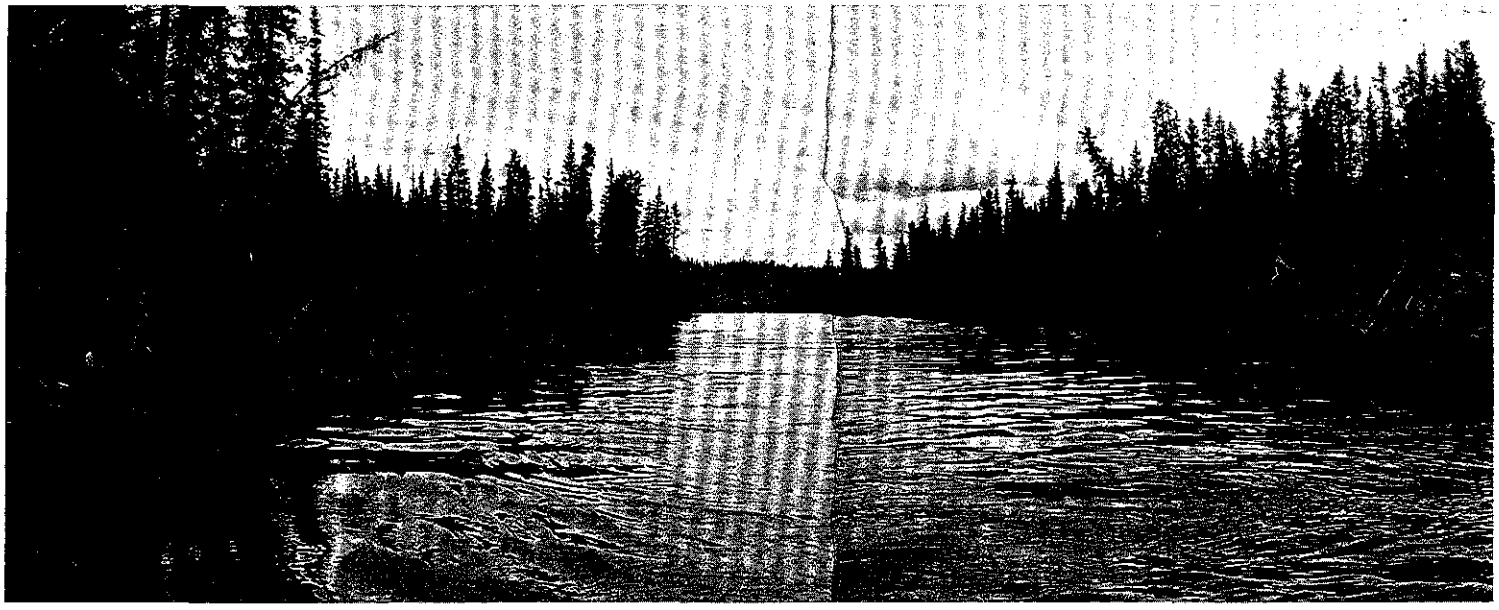
This area lies in very flat terrain. Banks are low and the river is generally quite shallow. The stream is approximately twice as wide and has a steeper gradient than the remainder of the river. The riverbed is composed of fine, clean gravel due to the higher velocity throughout this area. Stunted willow, white spruce, shrubs, and grasses tend to stabilize the fine soil composition of the banks.



Sekulmun River looking at right bank from opposite hub P19

STUDY AREA NO. 2

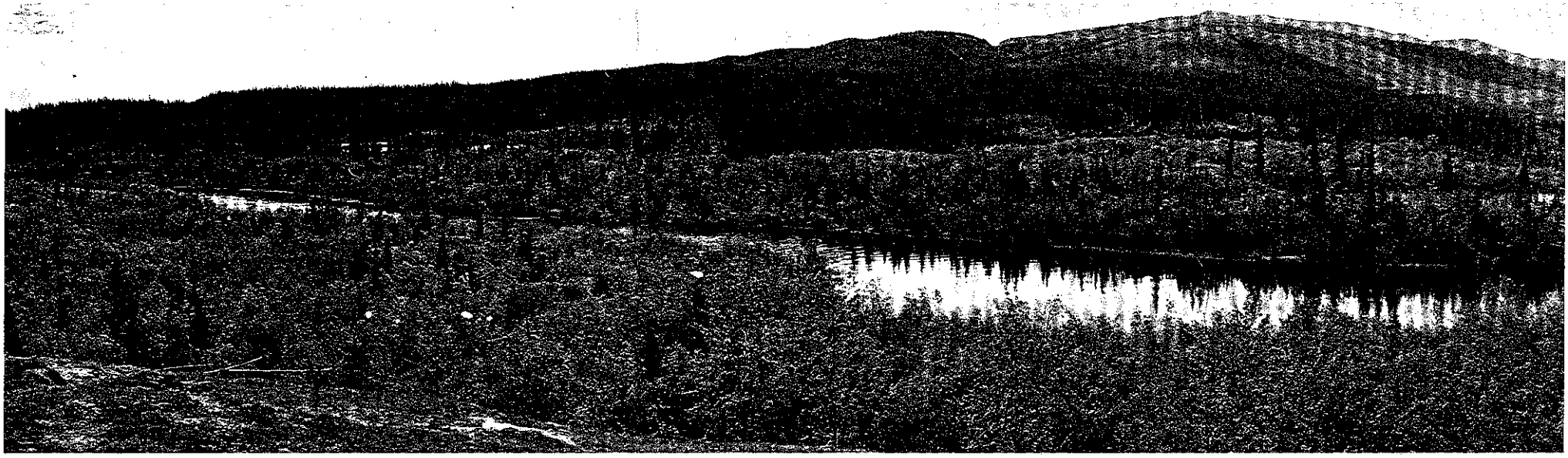
Riverbanks are low and the surrounding terrain is generally quite flat between this point and Sekulmun Lake. Steep clay banks begin to occur a short distance downstream. The stream is narrower than in study area No. 1 and the gradient is much flatter. The riverbed is composed of sandy clay material and velocities are low.



Sekulmun River looking downstream
adjacent to hub P32

STUDY AREA NO. 3

This area has banks rising 8 - 12 feet from the water surface and an undulating terrain. Dense stands of mature white spruce and stunted willow crowd the riverbanks. Gradient and velocity is low, resulting in a sandy, clay river bottom. Signs of bank sloughing is very common throughout this area.



Sekulmun River looking at right bank from above hub 3A

STUDY AREA NO. 4

This area is typical of only a short section of the river. Although more open than Study Area No. 3, it contains a similar dense growth of vegetation to the river edge. The riverbed is composed of a sandy clay material with patches of aquatic vegetation. The river is up to 16 feet in depth and the water surface gradient and velocity are extremely low.

the present river channel would be substantially reduced or even eliminated.

It is understood that operation of the Aishihik powerplant will be integrated with the Whitehorse Rapids plant. This will require that flows from the outlet of Aishihik Lake be reduced during the summer to allow as much storage as possible for winter operation of the Aishihik powerplant. Therefore, water levels within the Aishihik and Sekulmun lakes will be increasing throughout the summer months, reaching their peak in October when operation of the powerplant is expected to commence.

Extensive erosion and slumping of high riverbanks would undoubtedly occur in the Sekulmun River following flooding to elevation 3007.5. It is expected that most of this erosion would take place within the first few years after reaching the upper lake levels and would continue over a number of years on a reducing scale until a new equilibrium was reached. Projected water levels on typical cross sections of each study area are shown on Figure 5. In estimating the water levels at each section with Aishihik Lake raised to elevation 3002.5, a constant gradient was assumed between Sekulmun and Aishihik lakes. It was assumed that the water surface would remain level over the entire length of river when Aishihik Lake is at elevation 3007.5

b) Lowering Aishihik Lake to elevation 2992.5:

Since glaciation, the Sekulmun River has undergone an adjustment of its riverbed profile

to conform to its peak discharges and the level of Aishihik Lake. The very low water surface gradient which presently exists over the lower four miles is controlled to a large extent by the level of Aishihik Lake. Velocities are quite low in this section of river and bed degradation is probably quite limited. It is believed that further erosion would rarely occur and only when a major flood through the Sekulmun River coincides with a low Aishihik Lake level.

The immediate and temporary effect of lowering Aishihik Lake to elevation 2992.5 would be to steepen the water surface gradient within the Sekulmun River so that it becomes controlled by the bank and bed resistance within the river. The fine sediments in the lower reaches of the river could not remain stable under the increased velocities accompanying this increase in gradient and bed degradation would occur until a new equilibrium was reached at a lower level. Bedrock outcroppings or heavy boulders are not present in the river to prevent this from happening. The river would also have a tendency to adjust to its present width and it is therefore expected that extensive bank erosion would also occur.

The estimated water levels at typical cross-sections of each study area are shown on Figure 4. These represent the levels which would prevail under the discharge measured during the surveys with Aishihik Lake drawn down to elevation 2996.5 and 2992.5. In estimating these levels it was assumed that the water surface over the entire length of river would eventually stabilize at its present gradient.

It is unknown how long it might take to reach this new equilibrium, but erosion would probably continue for several years.

It is unlikely that the coarser material in the upper one mile of the river could remain stable under these conditions and bed degradation would probably continue through to Sekulmun Lake. This would lower Sekulmun Lake and initiate erosion in the lower reaches of each of its tributary streams.

Widespread erosion above the outlet of the Sekulmun River could be prevented by placing a layer of coarse granular material or a series of underwater weirs near the outlet of the Sekulmun River. These would have to be designed in a manner to ensure that fish could easily migrate upstream from Aishihik Lake under any condition of discharge and lake level.

3. UPPER AISHIHIK RIVER

3.1 General:

The Whitehorse Rapids powerplant can be operated at full capacity during the summer months when flow in the Yukon River is relatively high. However, sufficient storage is not available in the system for maximum power production throughout the winter. On the other hand, the Aishihik River development has ample storage, but limited discharge. Present plans are therefore to operate the Aishihik powerplant for base loads

during the winter months and the Whitehorse Rapids powerplant during the summer months. The Aishihik powerplant will not normally be operated during the summer so as to allow maximum storage for the winter.

To optimize power production from the Aishihik system, NCPC are therefore interested in storing as much water as possible during the summer on Aishihik Lake. However, a complete cessation of flows below the outlet of Aishihik would destroy fish populations which utilize the pool and river environment between Aishihik and Canyon Lakes. Details of these fish populations are contained in reports prepared by the Northern B. C. and Yukon Division, (Walker, Brown, 1974).

Studies were conducted by the Fisheries and Marine Service during 1973 and 1974 to determine the minimum summer flows required below Aishihik Lake to sustain fish populations. Hydraulic studies were conducted by the Habitat Protection Unit to provide support data for the biological assessment. These consisted primarily of topographical surveys and water surface profiles between Canyon Pond and Canyon Lake for a range of flow releases from Aishihik Lake of 70 to 570 cfs.

3.2 Canyon Pond:

The small pool area a short distance below Aishihik Lake has been designated as Canyon Pond for purposes of this study. The pond has been found to be an important rearing area for several

species and sizes of fish. Some of these depend upon the aquatic vegetation which grows in the marshy area along the east side of the pond. This area is normally wetted during the summer, but is dewatered during low winter flows.

Water levels within Canyon Pond are controlled by its outlet into the upper Aishihik River. A stage discharge curve for this outlet is shown on Figure 7. In using this curve, it is to be noted that the discharge includes flow from Giltana Creek.

3.3 Upper Aishihik River Below Canyon Pond:

Biological studies carried out during 1973 concluded that the upper Aishihik River between Canyon Pond and Canyon Lake was extensively utilized by several species and sizes of fish. Since most of the water in this river originates from Aishihik Lake, cessation of summer flows following the construction of the Aishihik Lake dam could have a serious impact on these fish populations. Further studies were therefore undertaken during 1974 with controlled flow releases from Aishihik Lake to determine the minimum flow necessary to sustain fish stocks in this river. The controlled flows were provided after closure of the cofferdam at the outlet of Aishihik Lake early in July, 1974.

It was originally planned to study the river with outflows of 25, 50 and 100 cfs from Aishihik

Canyon Pond looking upstream towards Aishihik Lake.

Upper Aishihik River immediately below Canyon Pond.

Lake. However, during the course of the study it became obvious that a discharge of 70 cfs below Canyon Pond (58 cfs from Aishihik Lake and 12 cfs from Giltana Creek) would not be ample to meet the basic hydraulic requirements of depth and velocity needed to sustain fish populations. All subsequent studies were therefore conducted at discharges of 70 to 220 cfs below Canyon Pond.

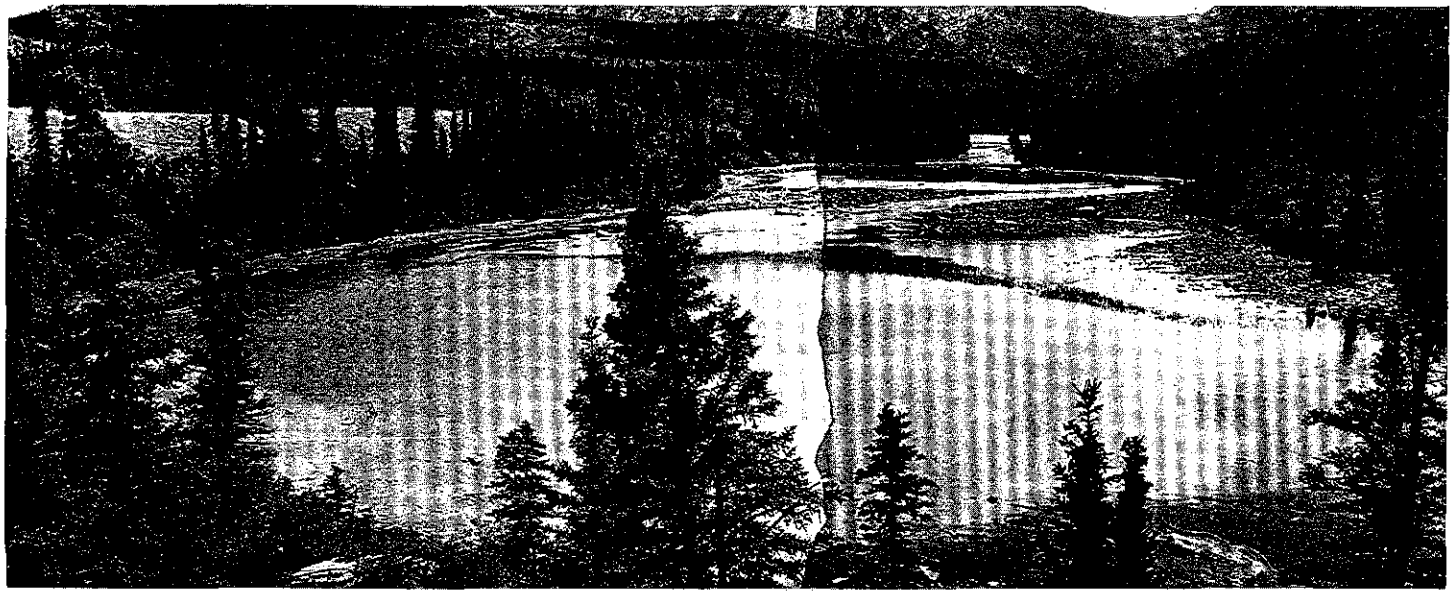
A topographical survey was carried out to provide a detailed contour map of the area (Figure 6). Eleven cross-sections were established over the length of the river and water levels were monitored at each section at discharges of 70, 220 and 570 cfs. This information was then used to determine a discharge rating curve and a theoretical velocity distribution for each section. Individual cross-sections, rating curves and velocity distributions are shown on Figure 7 to 11. The velocity distributions were computed at approximately 10 foot increments across the width of the river using the Mannings equation,

$$v = \frac{1.486}{n} \quad R^{\frac{2}{3}} \quad S^{\frac{1}{2}} \quad \text{where}$$

n = Mannings coefficient, which was computed for each discharge at each section.

R = hydraulic radius, which is approximately equal to the depth of flow for wide, shallow channels such as the Aishihik River.

S = slope of the water surface, which was determined for each section from actual field measurements.



Upper Aishihik River looking downstream towards Canyon Lake.

Upper Aishihik River - Pool 1 in background, Pool 2 in foreground.
(See Figure 7)

Although the theoretical velocities do not account for minor irregularities due to protruding cobbles or boulders, they were found to be very representative of the velocity distributions measured in the field at Section 6.

Biological studies carried out during 1974 have tentatively concluded that the most productive area within the river occurs between Sections 1 and 7. This area is comprised of a relatively deep trench near mid-channel bounded on either side by a wide, shallow shelf area. The larger species of fish were observed in and adjacent to the trench where water was deeper and of higher velocity, while juvenile fish were found to rear along the shelf areas where they have an abundant food supply and are less vulnerable to predation by the larger fish.

The productivity of a stream is related largely to the depth and velocity of flow. As a basis for assessing the effect of discharge on depth and velocity on the wetted area between Sections 2 and 6, distribution curves were plotted for each of these parameters for various discharges. These were plotted for the individual sections and then combined to produce depth and velocity composites for the entire area (Figure 12). As an example of how these curves are interpreted it can be seen that at least 93% of the area is covered to a depth of 1 foot at a normal summer discharge of 570 cfs, whereas only 18% of the area is covered to this depth when the discharge is reduced to 70 cfs. Similarly, the area subject to a velocity

of 1 fps is reduced from 93% to 6% with a reduction in discharge from 570 cfs to 70 cfs.

Observations carried out by the biologists during 1974 found that a flow of 100 cfs would not provide a sufficient depth of water over the shelf area between Sections 1 and 7 to sustain fish populations (Memorandum of August 22, 1974 by C. E. Walker). It was concluded that depths would have to be increased to be more representative of those occurring at 150 cfs. However, it is considered that corrective measures could be adopted to increase the depth of flow at 100 cfs. These should be in the form of small weirs placed across the trench at the locations and to the crest elevations shown on Figure 13. Installation of these weirs would also result in a slight increase in velocity throughout the shelf area.

4. AISHIHIK LAKE SHORELINE STUDY

4.1 General:

The shoreline study was undertaken to provide an inventory of shoreline characteristics on Aishihik Lake and some insight into the possible consequences of lake storage or drawdown on shallow bays and low land areas around the lake. A primary purpose of the study was also to provide support data for the biological assessment of the effects of storage or drawdown on lake productivity.

The entire lakeshore was classified and related to twelve typical lakeshore sections.

During 1972, these sections were surveyed to 15 feet below and at least 10 feet above water surface. Physical features, such as substrate composition, vegetation and soil conditions were described and catalogued. One or two test pits were hand excavated at each section to a depth of 2.5 feet for visual identification of surficial soil composition. The height, location and type of vegetation was documented. Underwater substrate was initially identified to a depth of 15 feet using dredge samples and photographed by the use of a periscope. Other photographs documented the terrestrial vegetation and the condition of the bank and beach area.

Limnological surveys carried out during 1972 indicated that productive substrate areas generally extend beyond a 15 foot depth. It was therefore decided to extend the soundings and identify the substrate composition to a depth of 30 feet at each section. This was done during the summer of 1973.

4.2 1972 Survey:

A reconnaissance survey of the entire shoreline was carried out and 12 sections were selected to represent all existing shoreline conditions. The location of these sections are shown on Figure 14. Sketches of the shoreline profiles together with the pertinent information and photographs obtained at each section are shown on Figure 16 to 27. The various symbols and soil classifications used in these sketches are shown on Figure 15. It is to be noted that the shore-

line profiles are extended only to a maximum of 15 feet below water level and pertain only to the surveys conducted during 1972. The information obtained during 1973 is discussed later in this report.

Similarities exist in the physical features of several of the shoreline sections. Therefore the 12 sections were grouped into 6 distinct shoreline classifications on the basis of the following physical characteristics:

Class A - Very steep, unstable foreshore with shallow, flat littoral zone.

Class B - Steep, stable foreshore with shallow, flat littoral zone.

Class C - Very steep, exposed bedrock foreshore with steep, rocky littoral zone.

Class D - Steep, stable foreshore with steep gravel littoral zone.

Class E - Low, stable foreshore with moderately flat littoral zone.

Class F - Very flat foreshore with moderately flat littoral zone.

The proportion of the total shoreline perimeter represented by each of the above classifications and the sections assigned to each classification are as follows:

CLASS	SECTION	SHORELINE LENGTH IN MILES	PERCENT OF TOTAL SHORELINE LENGTH
A	1, 6	4.0	4.2
B	2	10.8	11.3
C	9	5.7	5.9
D	11, 12	8.2	8.5
E	3, 4, 7, 8, 10	66.9	69.7
F	5	0.4	0.4
TOTAL		96.0	100.0%

Except in the case of Class A shoreline, flooding of Aishihik Lake to elevation 3007.5 should not have a major impact on the shallow littoral zone. Increased turbidity can be expected adjacent to soil based slopes, but the beaches should quickly adjust to the increased water levels. Some of the fine grained soil common to most of the shoreline will accumulate on the lake bottom within the littoral zone, but most of it will likely be taken into suspension and distributed by wave action throughout the lake.

Extensive erosion will, however, occur along the Class A shoreline with flooding to elevation 3007.5. This includes the 3 miles of steep clay banks along the north end of the lake, as represented by Section 1, and the 1 mile of steep gravel banks at Section 6. The instability of the clay banks is apparent by the large cracks and slumping occurring near Section 1. Wide beaches have formed at the toe of the banks but a certain amount of erosion probably occurs

naturally with high water levels and intense wave action. Raising the lake to elevation 3007.5 would inundate these beaches, leaving the banks vulnerable to severe wave attack.

In attempting to quantify the probable extent of erosion along these steep banks with the lake raised to elevation 3007.5, it has been assumed that the banks are now in equilibrium with the historic high water level of 3002.5 and that they will recede with increased water level until the beaches and littoral zone reach their present profile relative to the water level. On the basis of this premise, a recession of 140 feet and 150 feet has been estimated for Sections 1 and 6, respectively (Figure 28). It is expected that the recession would progress rapidly during the initial stages of flooding and would continue for many years before stabilizing.

Drawdown of Aishihik Lake to elevation 2992.5 would dewater some of the substrate areas which may be important for the production of benthic organisms. The areas which would be particularly affected by drawdown are the shallow regions around the north end of the lake; the deltas of the Sekulmun River, Creeks A2, A3 and A9; and the shallow substrate below the gravel banks at Section 6. An approximation of the area that would be dewatered below elevation 3002.5 for each of the shoreline classifications is indicated below:

SHORELINE CLASSIFICATION	AVERAGE WIDTH OF SUBSTRATE DEWATERED BELOW ELEV. 3002.5, FEET	LENGTH OF SHORELINE, MILES	AREA DEWATERED BELOW ELEV. 3002.5, ACRES
A	230	4.0	112
B	210	10.8	275
C	30	5.7	21
D	50	8.2	50
E	100	66.9	811
F	120	0.4	6
TOTAL			1275

The actual area dewatered will be somewhat greater than 1275 acres since the shoreline classifications do not account for all of the shallow bays and delta areas around the lake.

4.3 1973 Survey:

The biological investigations during 1972 found that benthic organisms often originated at depths well below 15 feet (Kussat, 1973). Therefore, during 1973 it was decided to continue the soundings and identify the substrate composition at each section to a depth of 30 feet. A standard Ponar dredge was used in identifying the substrate. The information obtained in this survey is summarized below:

Section 1: The substrate continues at a constant gradient beyond the 15 foot depth, reaching a depth of 30 feet approximately 1400 feet from

shore (Station 0). Between 15 and 30 feet in depth the substrate is comprised of sand and silt.

Section 2: The substrate continues at a constant gradient beyond the 15 foot depth, reaching a depth of 30 feet approximately 1300 feet from shore (Station 0). Substrate is again comprised of sand and silt in the area between 15 and 30 feet in depth.

Section 3: The substrate gradient remains reasonably constant to a depth of 30 feet, which occurs approximately 300 feet from shore. Sand and silt occur at the 30 foot depth but it is unknown where the transition from rock occurs, as shown on Figure 18.

Section 4: The substrate gradient remains constant beyond 15 feet, reaching a depth of 23 feet at 330 feet from shore and then flattens out to the 30 foot depth at 700 feet from shore. Sand and silt occurs at a depth of 30 feet.

Section 5: The substrate continues at a constant gradient for 200 feet from shore, levels off at an 18 foot depth for a further 55 feet and then drops steeply to a 30 foot depth at 310 feet from shore. The substrate is composed of sand and silt at 30 feet.

Section 6: The substrate gradient remains relatively constant beyond 15 feet, reaching a

depth of 30 feet at 770 feet from shore. Sand and silt was found at the 30 foot depth.

Section 7: The substrate gradient remains constant beyond 15 feet, reaching a depth of 30 feet at 260 feet from shore. Fine silt occurs at this depth.

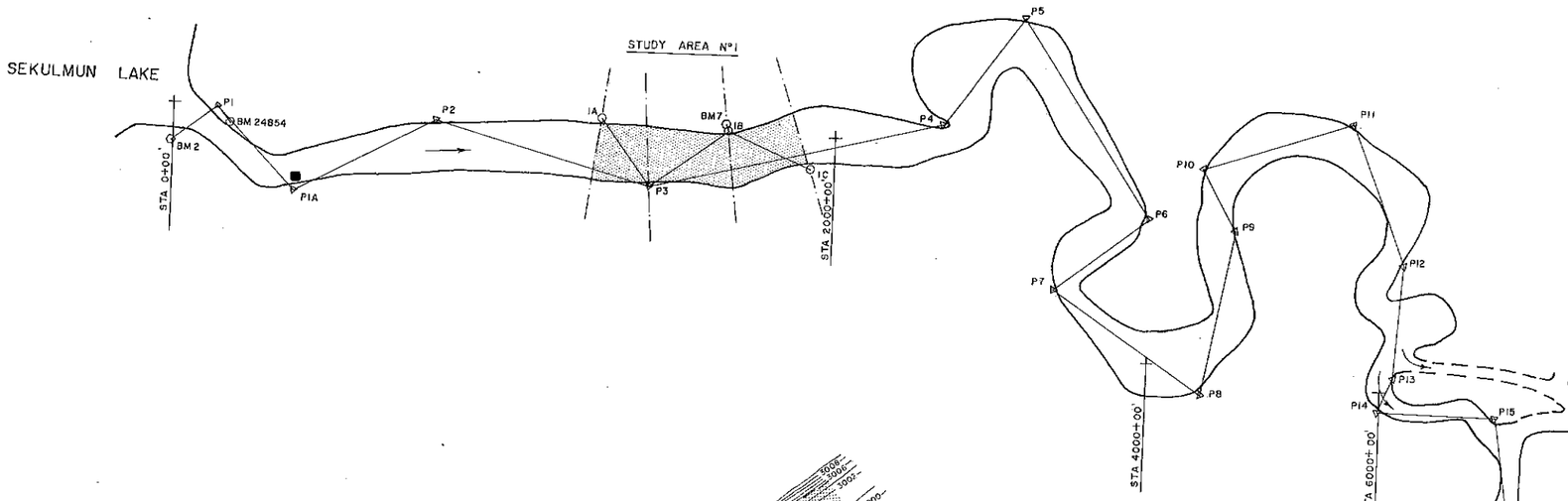
Section 8: The substrate gradient remains constant beyond 15 feet, reaching a depth of 30 feet at 340 feet from shore. A mixture of sand and silt was found at the 30 foot depth.

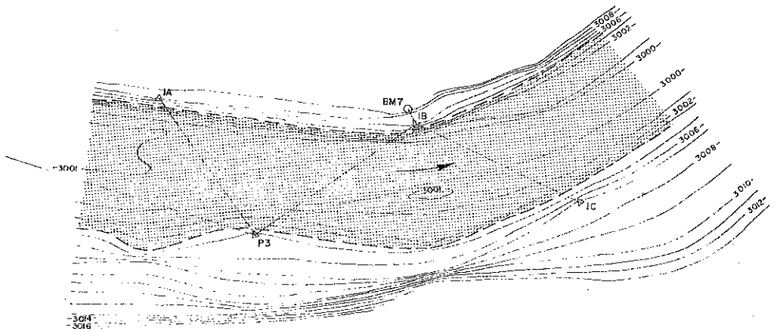
Section 9: The substrate gradient remains relatively constant to a depth of 17 feet and then flattens out slightly, reaching a depth of 30 feet at 125 feet from shore. Silt was found at the 30 foot depth.

Section 10: The substrate gradient remains constant beyond 15 feet, reaching a depth of 30 feet at 140 feet from shore. The substrate at 30 feet is comprised of silt.

Section 11: The substrate gradient remains constant to a depth of 17 feet at 85 feet from shore and then flattens considerably, reaching a depth of 30 feet at 750 feet from shore. Silt was found at the 30 foot depth.

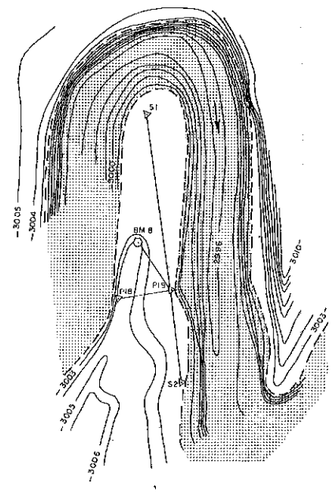
Section 12: The substrate gradient remains constant to a depth of 19 feet at 83 feet from shore and then flattens considerably, reaching a depth of 30 feet at 640 feet from shore. Silt was found at the 30 foot depth.





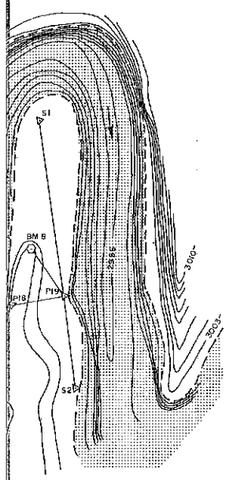
STUDY AREA N°1

SCALE (B)



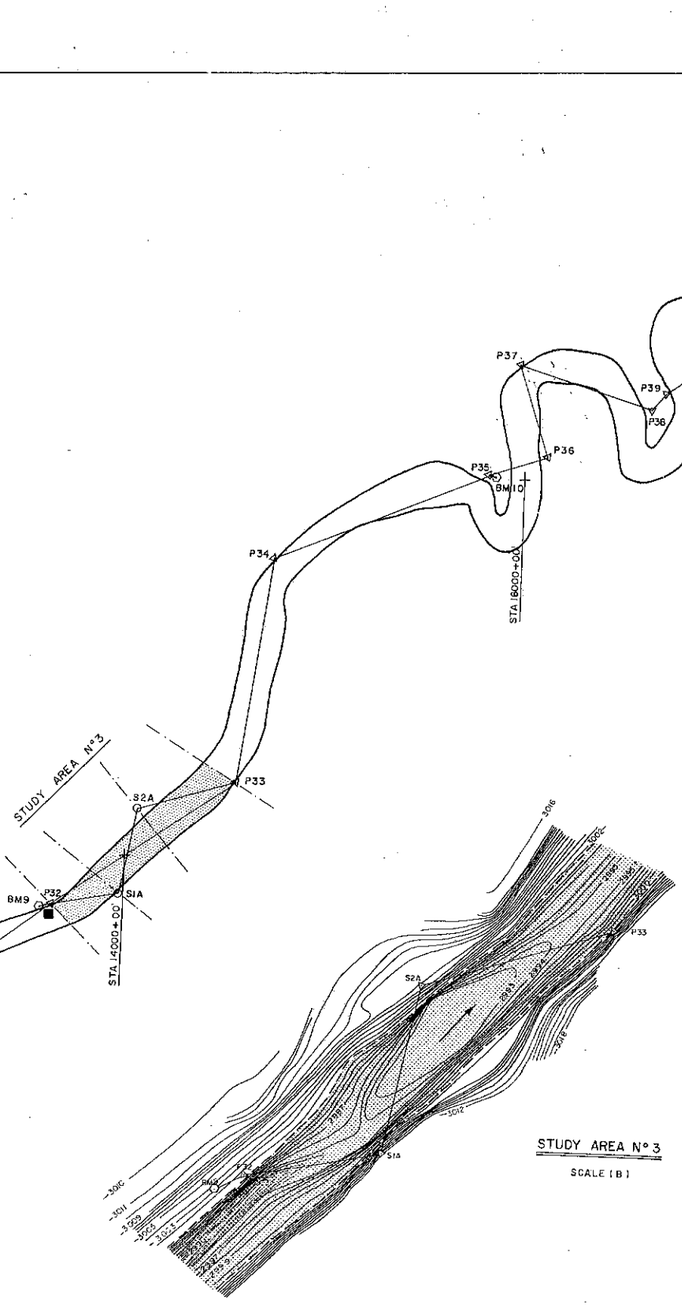
STUDY AREA N° 2

SCALE (B)



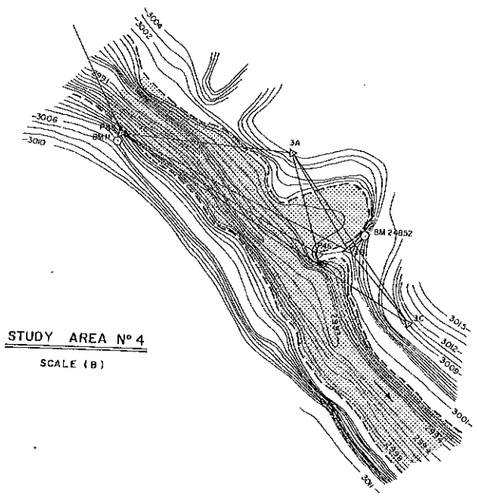
AREA Nº 2

SCALE (B)



STUDY AREA Nº 3

SCALE (B)

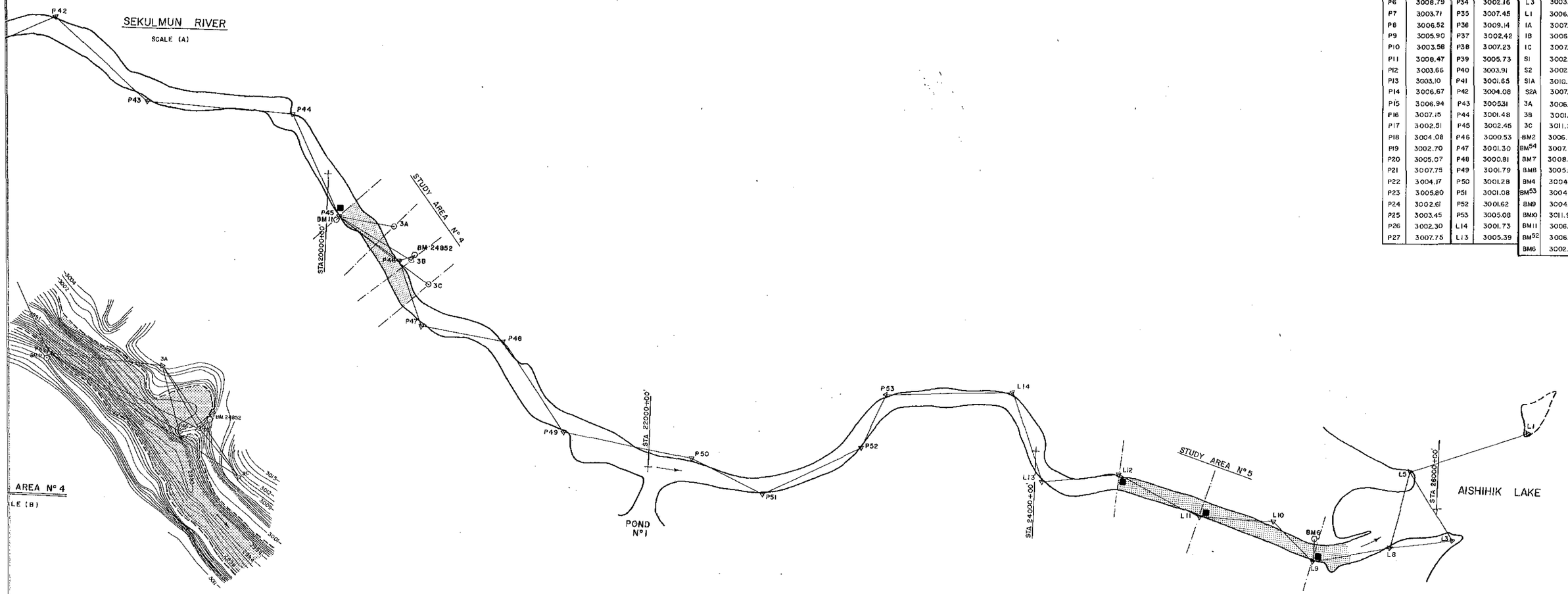


STUDY AREA Nº 4

SCALE (B)

FIGURE 1

GEODETIC ELEVATIONS					
STA	ELEV	STA	ELEV	STA	ELEV
P1	3006.72	P28	3005.11	L12	3001.41
P1A	3006.77	P29	3005.02	L11	3003.19
P2	3007.83	P30	3003.93	L10	3002.97
P3	3005.59	P31	3002.28	L9	3001.39
P4	3003.84	P32	3001.83	L8	3004.91
P5	3005.70	P33	3003.64	L5	3007.80
P6	3008.79	P34	3002.16	L3	3003.64
P7	3003.71	P35	3007.45	L1	3006.23
P8	3006.52	P36	3009.14	1A	3007.95
P9	3005.90	P37	3002.42	1B	3006.58
P10	3003.58	P38	3007.23	1C	3007.50
P11	3008.47	P39	3005.73	S1	3002.47
P12	3003.66	P40	3003.91	S2	3002.64
P13	3003.10	P41	3001.65	S1A	3010.28
P14	3006.67	P42	3004.08	S2A	3007.56
P15	3006.94	P43	3005.31	3A	3006.61
P16	3007.15	P44	3001.48	3B	3001.52
P17	3002.51	P45	3002.45	3C	3011.20
P18	3004.08	P46	3000.53	BM2	3006.94
P19	3002.70	P47	3001.30	BM54	3007.48
P20	3005.07	P48	3000.81	BM7	3008.64
P21	3007.75	P49	3001.79	BM8	3005.01
P22	3004.17	P50	3001.28	BM4	3004.97
P23	3005.80	P51	3001.08	BM53	3004.08
P24	3002.61	P52	3001.62	BM3	3004.27
P25	3003.45	P53	3005.08	BM10	3011.91
P26	3002.30	L14	3001.73	BM11	3006.12
P27	3007.75	L13	3005.39	BM52	3006.03
				BM6	3002.34



LEGEND

- △ HUB (IP)
- ⊙ HUB (wood)
- ⊙ BENCH MARK
- ■ BED SAMPLE

NOTE - SECTION NUMBERS CORRESPOND TO HUB NUMBERS.

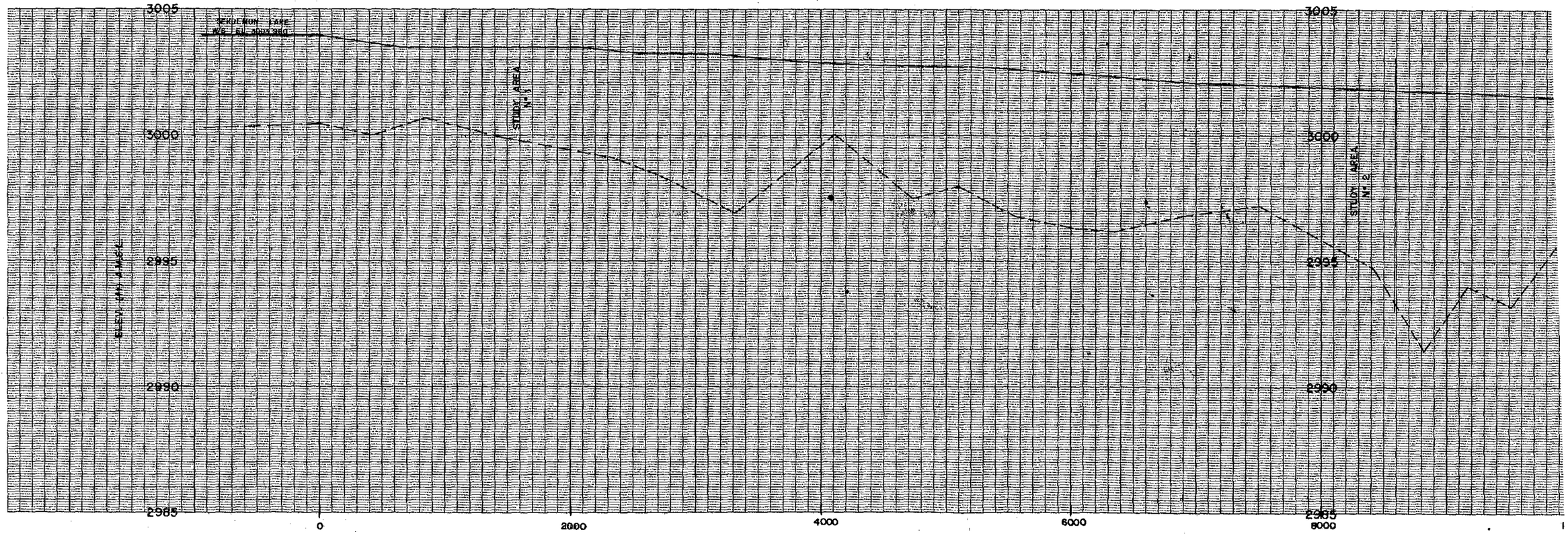
100 50 0 200 400
SCALE (A) ft.

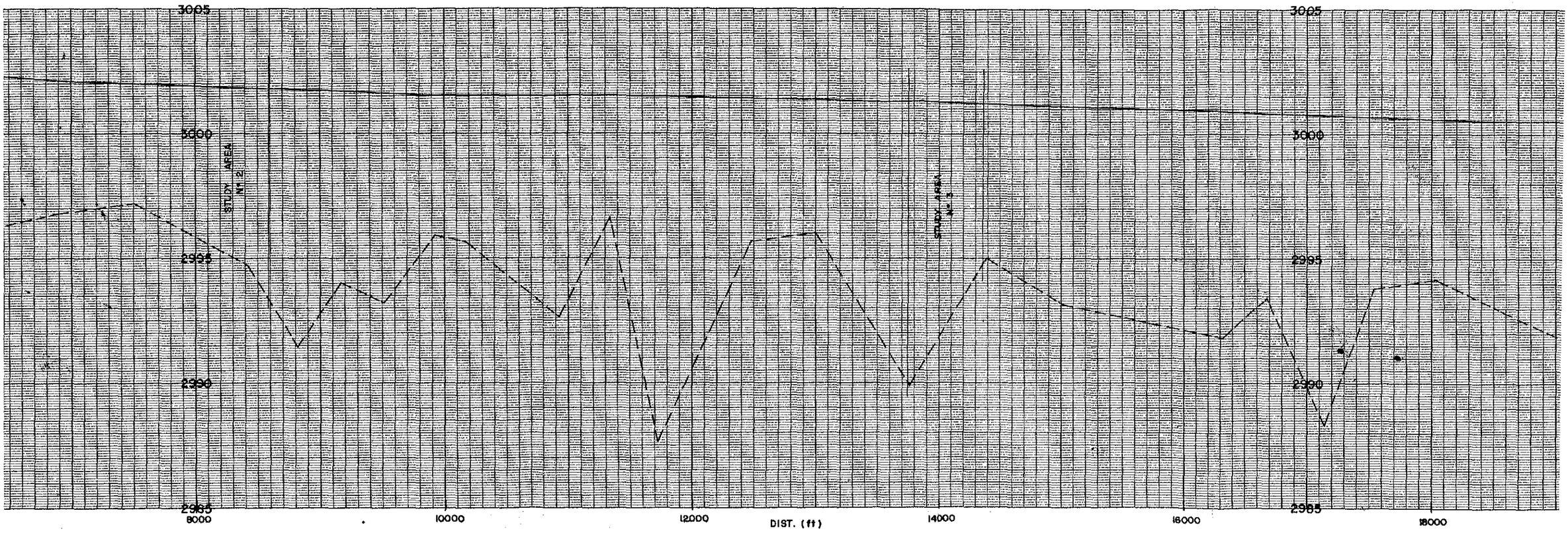
50 25 0 100 200
SCALE (B) ft.

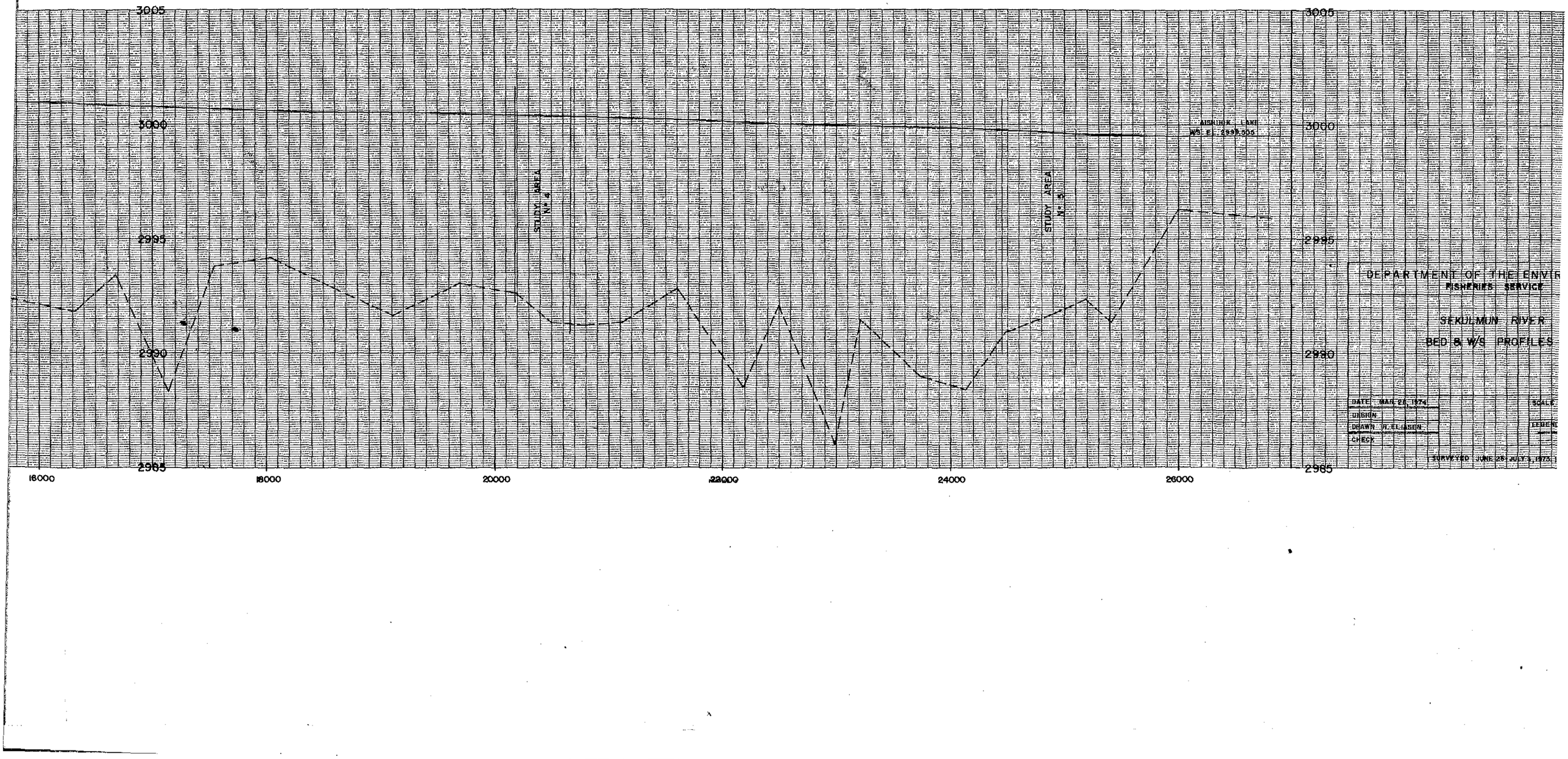
DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

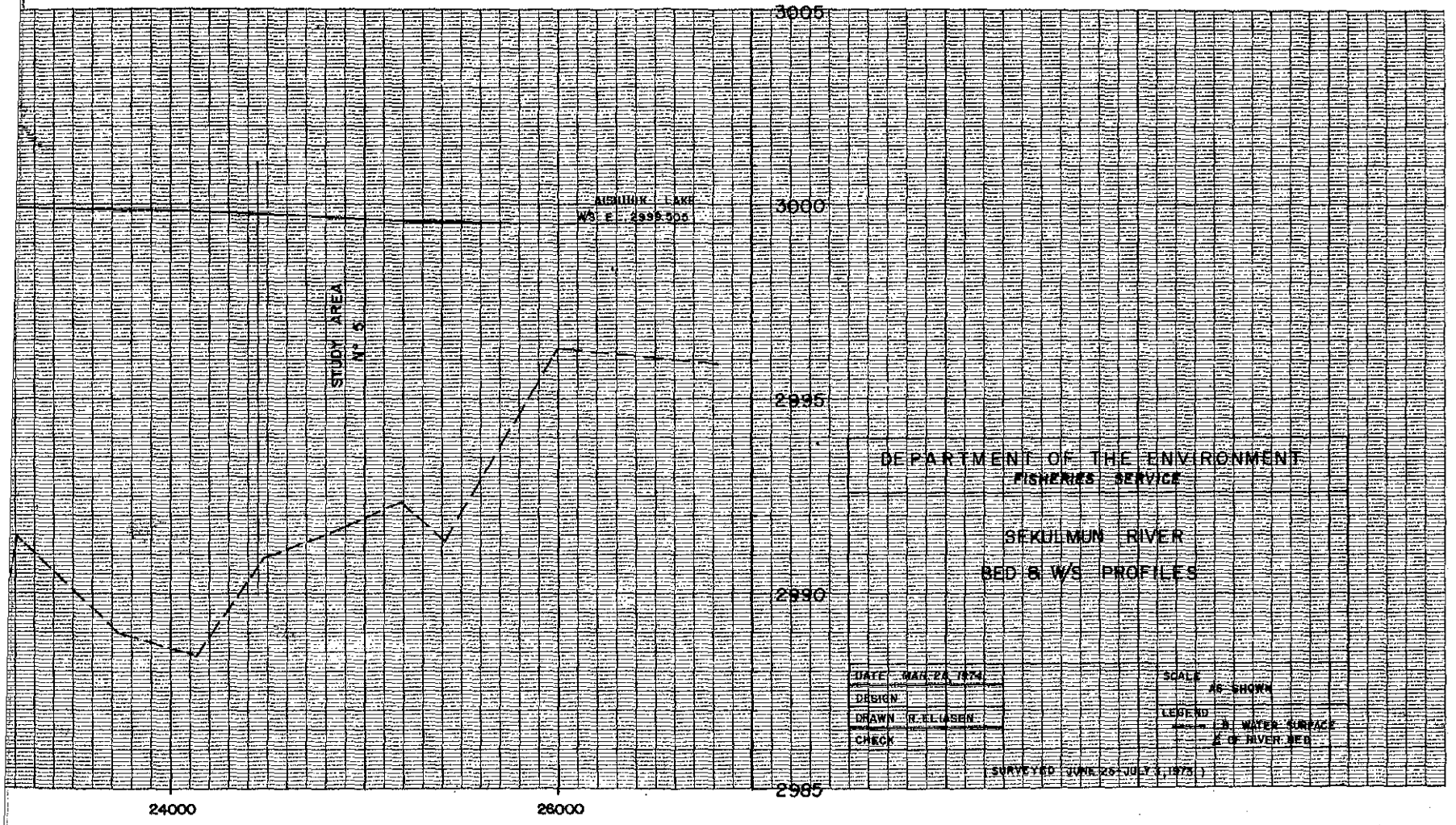
SEKULMUN RIVER
AISHIHIK DEVELOPMENT STUDIES

DATE	FEB. 8, 1974.		SCALE AS SHOWN
DESIGN			
DRAWN	R. ELIASEN		DWG. NO.
CHECK			


3005
3000
2995
2990
2985
ELEV. IN FEET ABOVE M.S.L.
SCHEMATIC LAKE W.S. EL. 3002.380
STUDY AREA N° 1
STUDY AREA N° 2
0
2000
4000
6000
8000


3005
3000
2995
2990
2985
STUDY AREA No. 2
STUDY AREA No. 3
8000
10000
12000
14000
16000
18000
DIST. (ft)


3005
3000
2995
2990
2985
STUDY AREA N° 4
STUDY AREA N° 3
AISHIHIK LAKE
W.S. E. 2998.500
16000
18000
20000
22000
24000
26000
DEPARTMENT OF THE ENVIR
FISHERIES SERVICE
SEKULMUN RIVER
BED & W/S PROFILES
DATE MAR 25, 1974
DESIGN
DRAWN R. ELIASEN
CHECK
SURVEYED JUNE 28- JULY 1, 1973



DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

SEKULMUN RIVER

BED & W/S PROFILES

DATE	MAR 28 1974
DESIGN	
DRAWN	R.ELLASEN
CHECK	

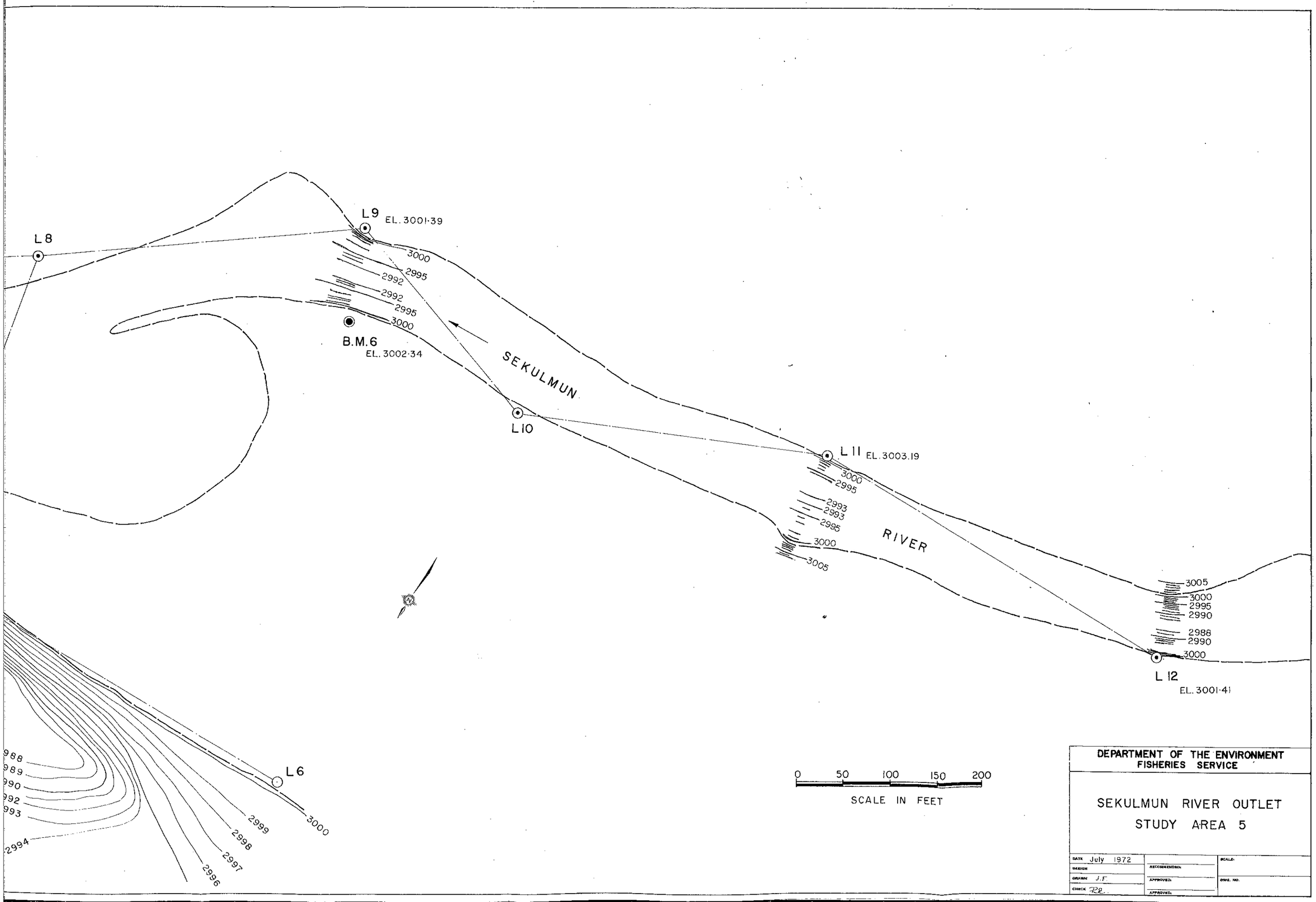
SCALE AS SHOWN

LEGEND
—— L.B. WATER SURFACE
—— ℄ OF RIVER BED

(SURVEYED JUNE 26-JULY 3, 1973)


2994
2995
2996
2997
L3
L8
L9
EL. 3001·39
3000
2998
2995
2992
2992
2995
3000
B.M.6
EL. 3002·34
SEKULMUN
L10
2996
2995
2994
2993
2992
2991
2997
L5
2992
2993
2995
2996
2997
3000
L1
2988
2989
2990
2992
2993
2994
2997
2999
2998
2997
2996
L6
3000

FIGURE 3

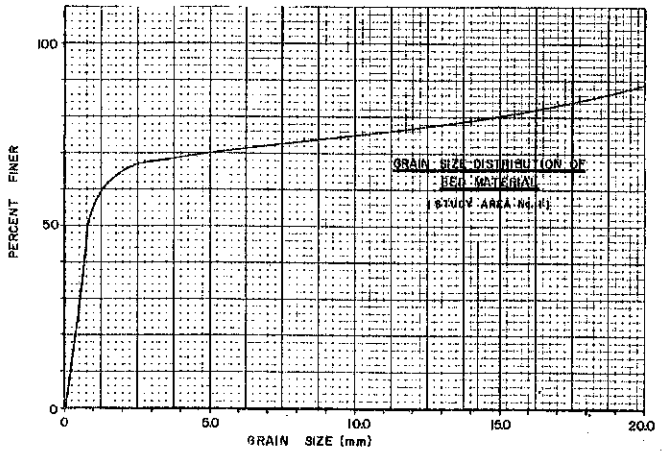


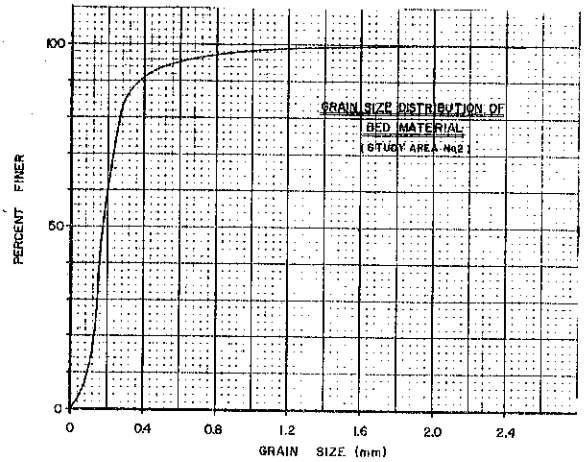
DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

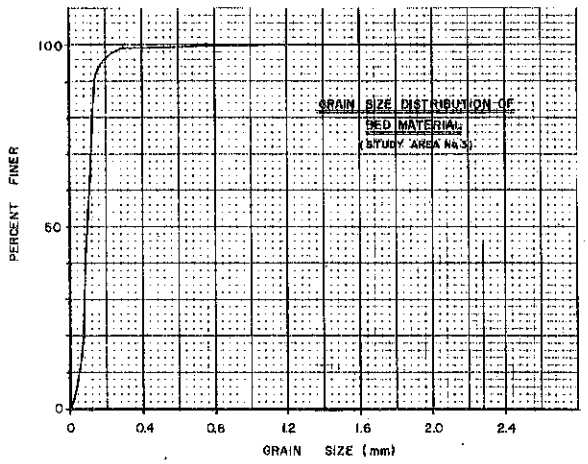
SEKULMUN RIVER OUTLET
STUDY AREA 5

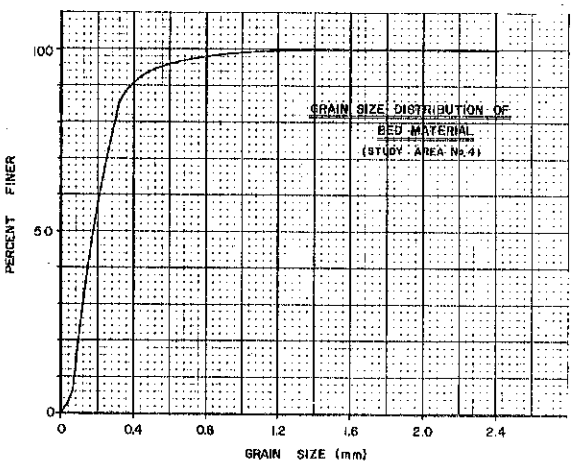
DATE July 1972	RECOMMENDED	SCALE
DESIGN	APPROVED	DWG. NO.
DRAWN J.F.	APPROVED	
CHECK RR.		

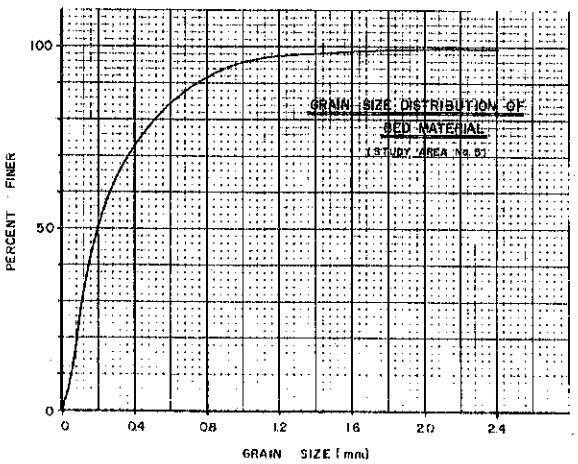
SEKULMUN RIVER GRADATION CURVES
STUDY AREA 1-5.



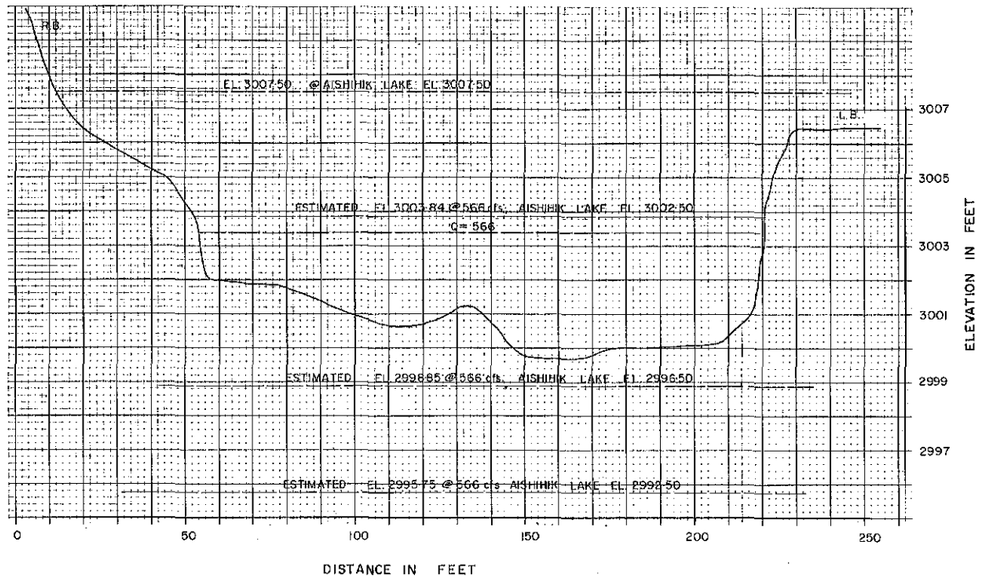




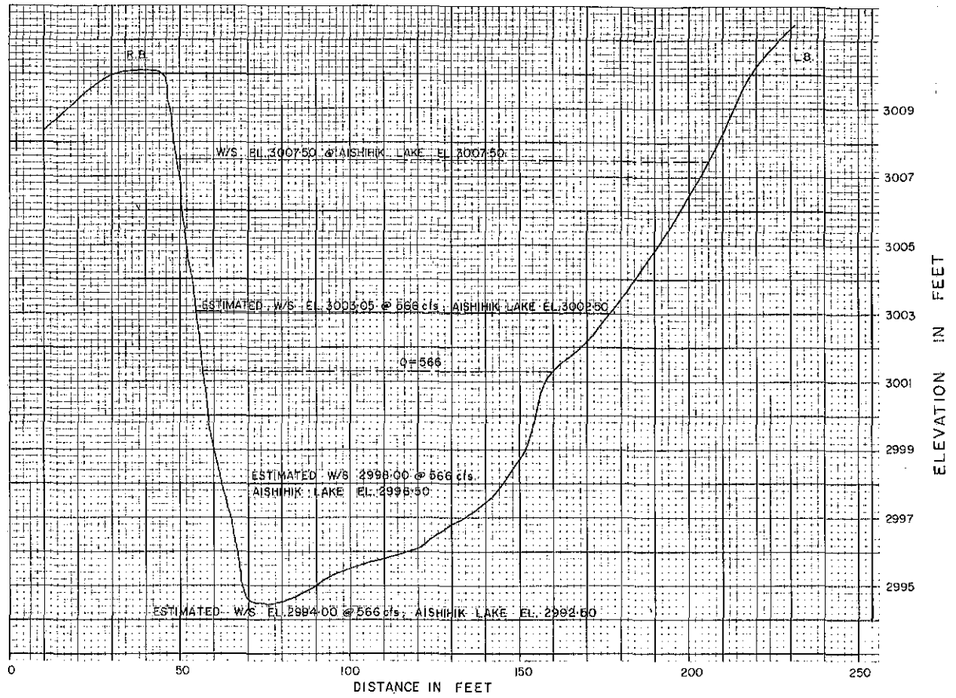




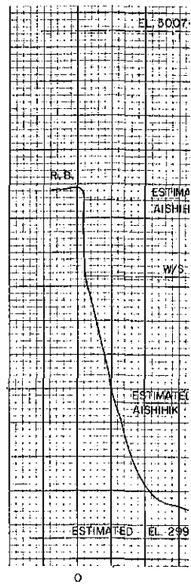
SECTION IB ; STUDY AREA NO. I, SEKULMUN RIVER



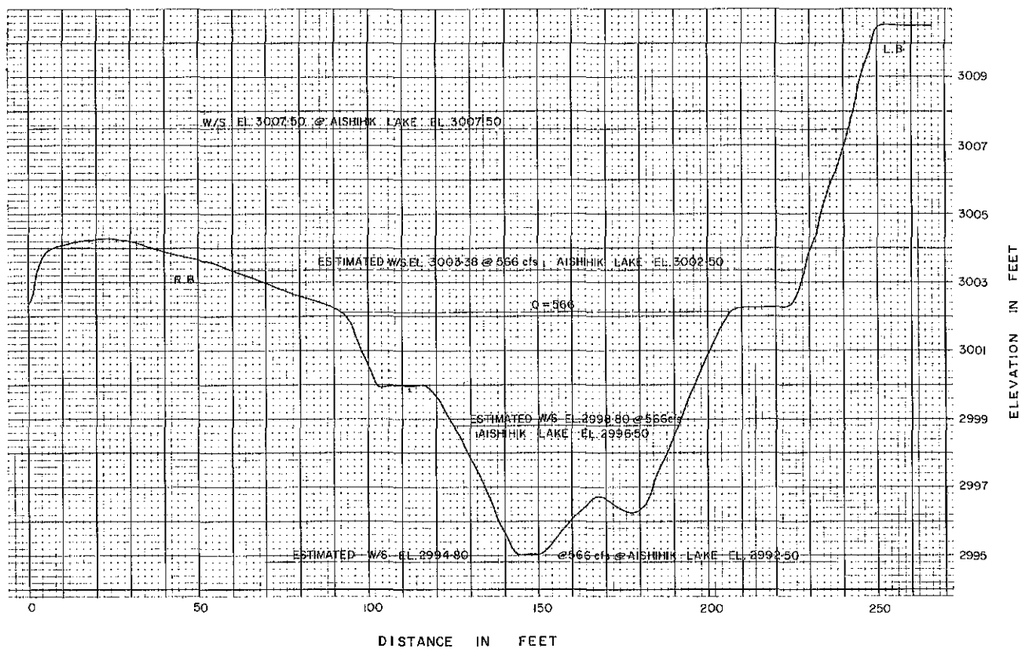
SECTION SI-A; STUDY AREA NO. 3, SEKULMUN RIVER



SECTION L-II;



SECTION P19; STUDY AREA NO.2, SEKULMUN RIVER



SECTION 3B; STUDY AREA NO. 4, SEKULMUN RIVER

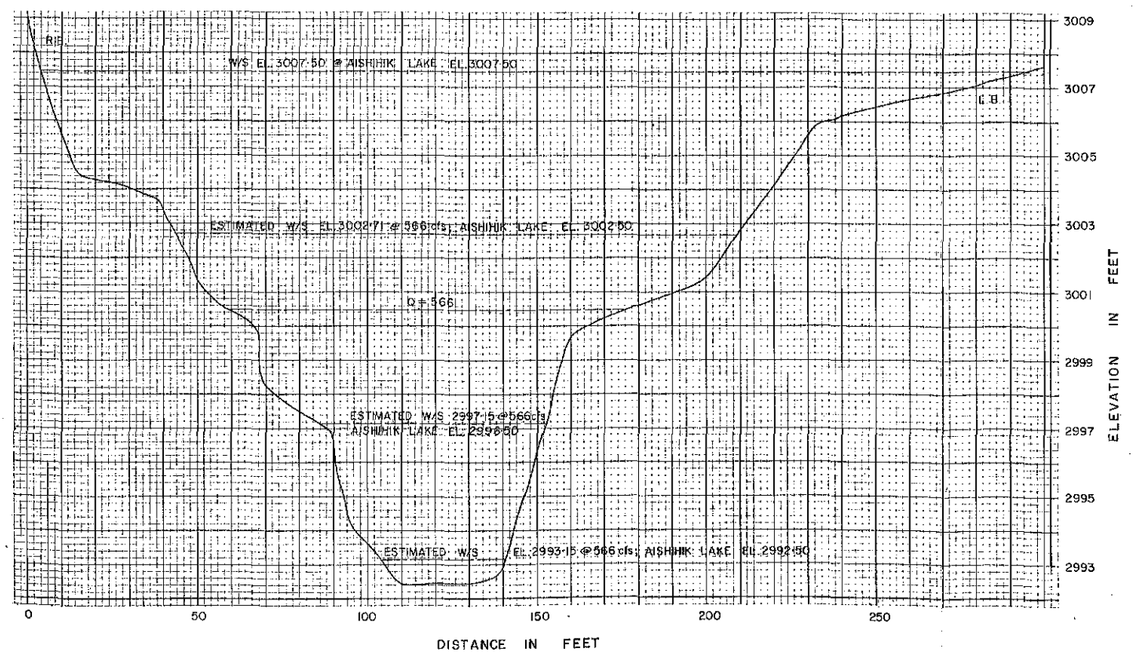
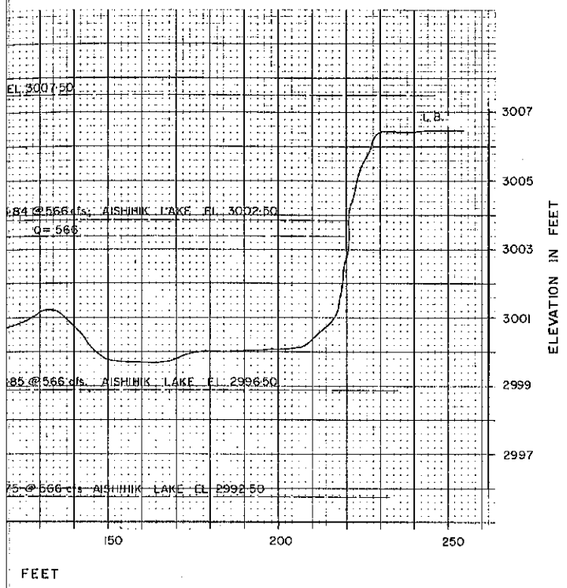
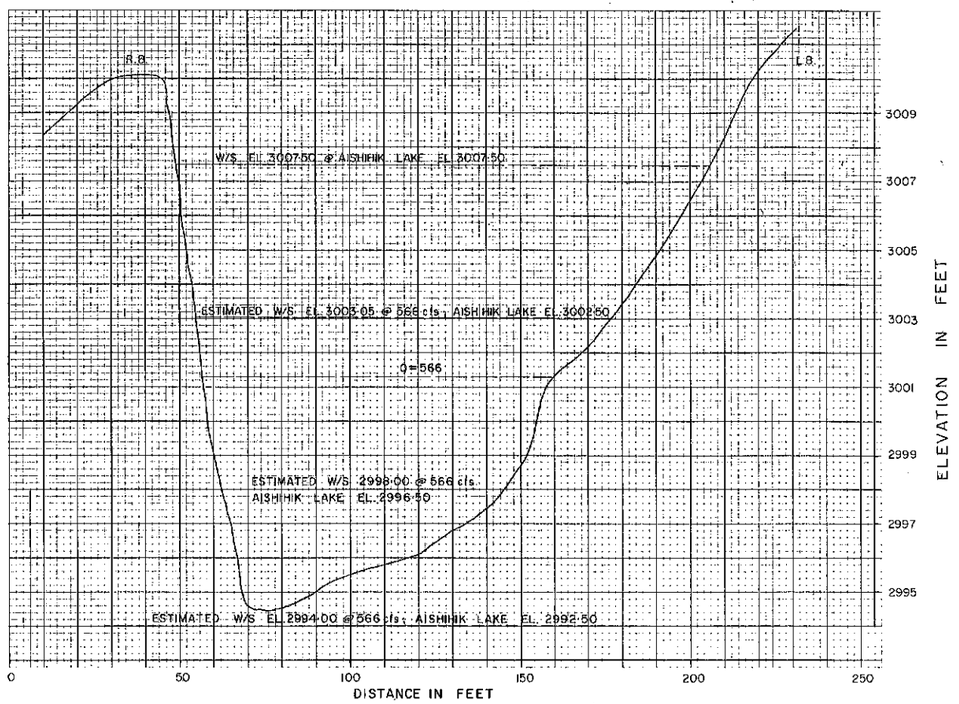


FIGURE 5

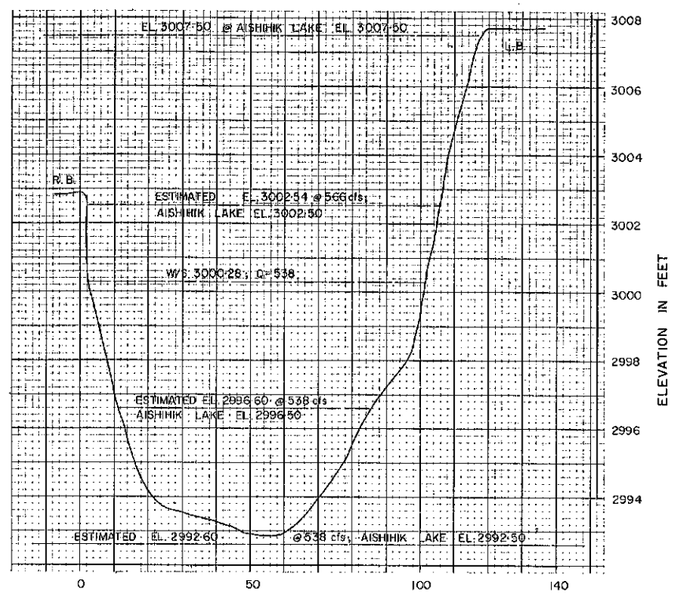
Y AREA NO. 1, SEKULMUN RIVER



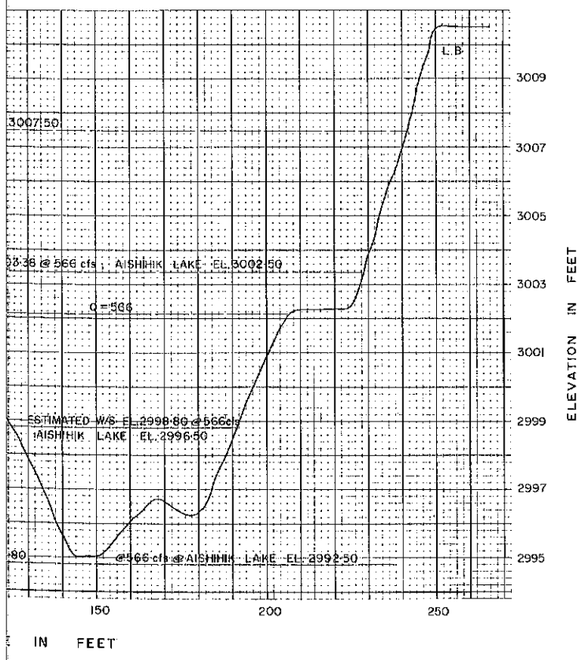
SECTION SI-A; STUDY AREA NO. 3, SEKULMUN RIVER



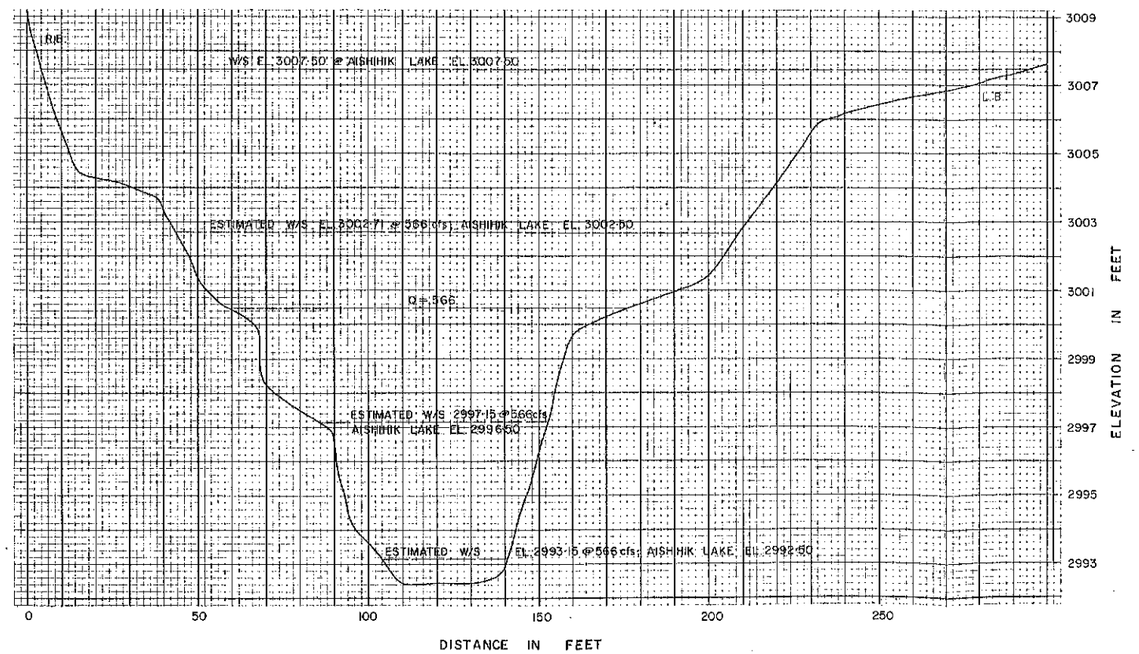
SECTION L-II; STUDY AREA NO. 5, SEKULMUN RIVER



REA NO. 2, SEKULMUN RIVER



SECTION 3B; STUDY AREA NO. 4, SEKULMUN RIVER



DATE	NO.	REVISION	BY

DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

SEKULMUN RIVER

TYPICAL STUDY AREA SECTIONS

DATE AUG. 1974	RECOMMENDED:	SCALE: AS SHOWN
DESIGN	APPROVED:	
DRAWN JF	APPROVED:	DWG. NO.
CHECK RE		

CANYON
POND

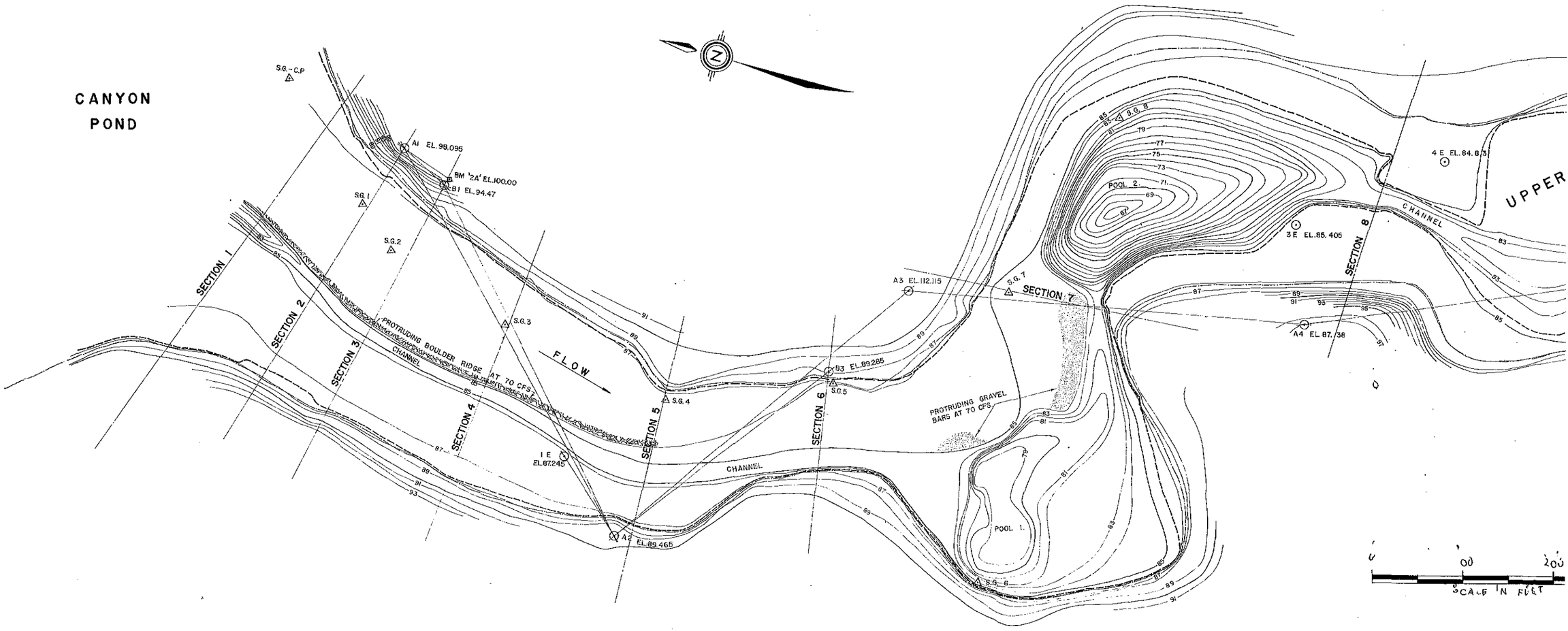
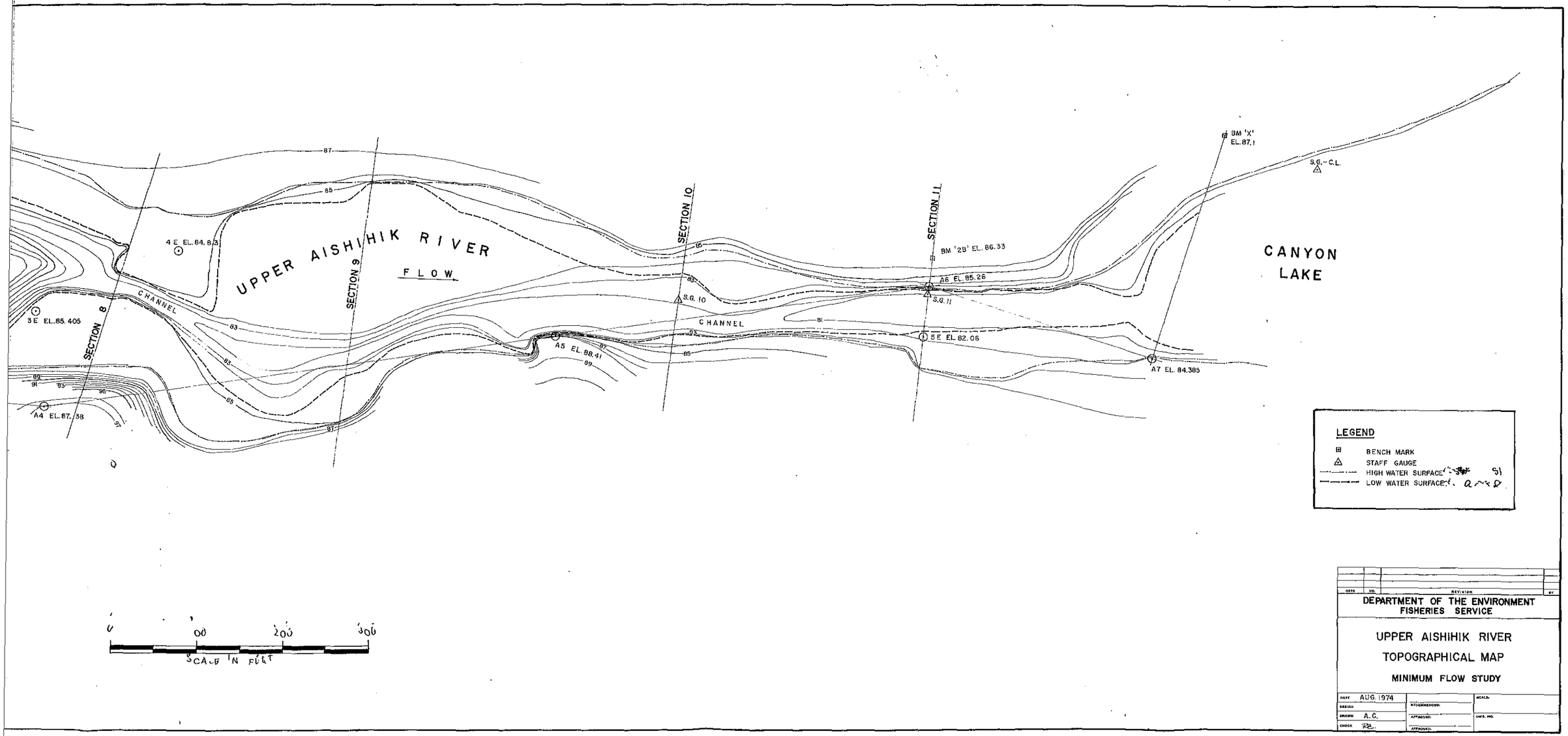

S.G.-C.P
A1 EL. 98.095
BM '2A' EL.100.00
B1 EL. 94.47
S.G.1
S.G.2
S.G.3
S.G.4
S.G.5
S.G.6
S.G.7
S.G. 8
SECTION 1
SECTION 2
SECTION 3
SECTION 4
SECTION 5
SECTION 6
SECTION 7
SECTION 8
FLOW
PROTRUDING BOULDER RIDGE AT 70 CFS
CHANNEL
1 E EL.67.245
A2 EL.89.465
B3 EL.89.285
A3 EL.112.115
PROTRUDING GRAVEL BARS AT 70 CFS
POOL 1
POOL 2
3 E EL.85.405
4 E EL.84.873
A4 EL.87.38
UPPER
CHANNEL
SCALE IN FEET

FIGURE 6

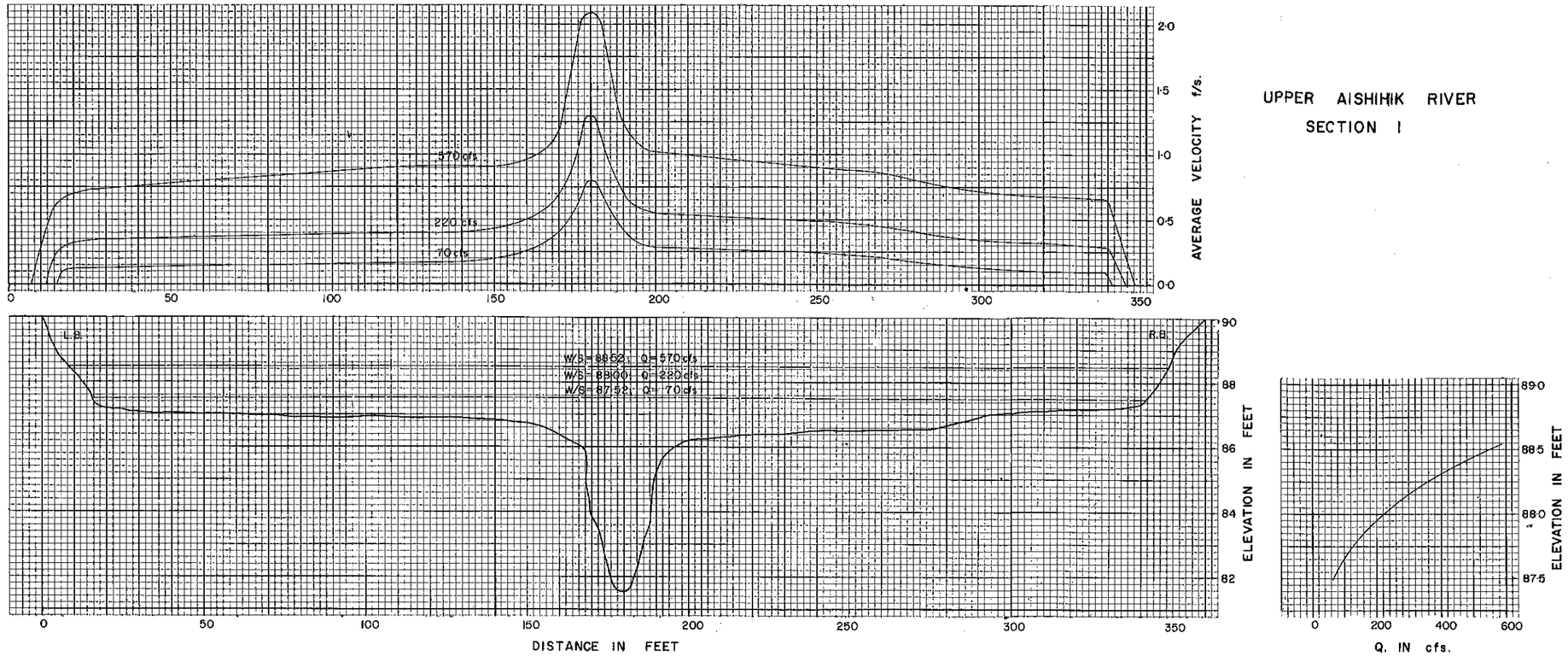


DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

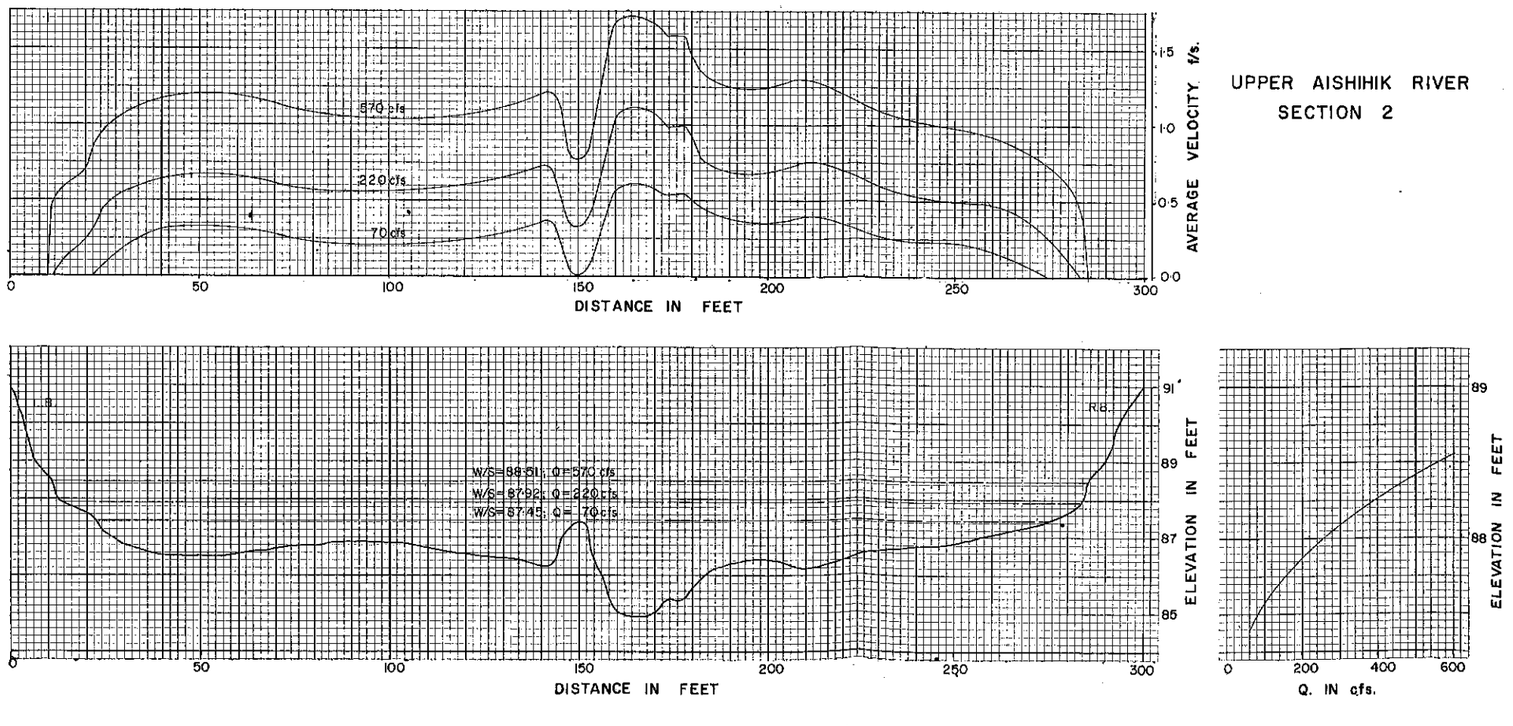
UPPER AISHIHIK RIVER
TOPOGRAPHICAL MAP
MINIMUM FLOW STUDY

DATE	AUG. 1974
DESIGN	
DRAWN	A.C.
CHECK	
RECOMMENDED	
APPROVED	
APPROVED	
SCALE	
DWG. NO.	

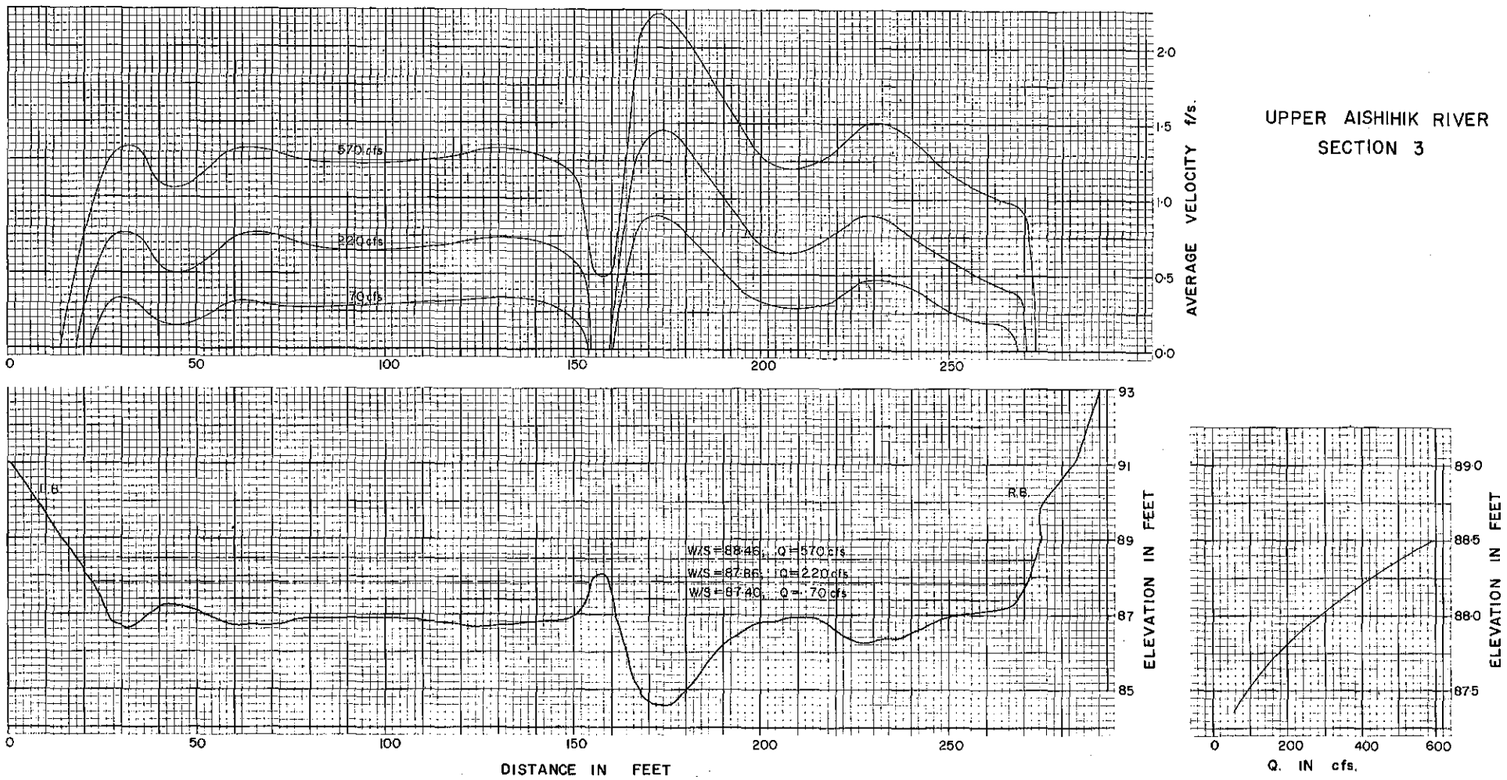
FIGURE 7



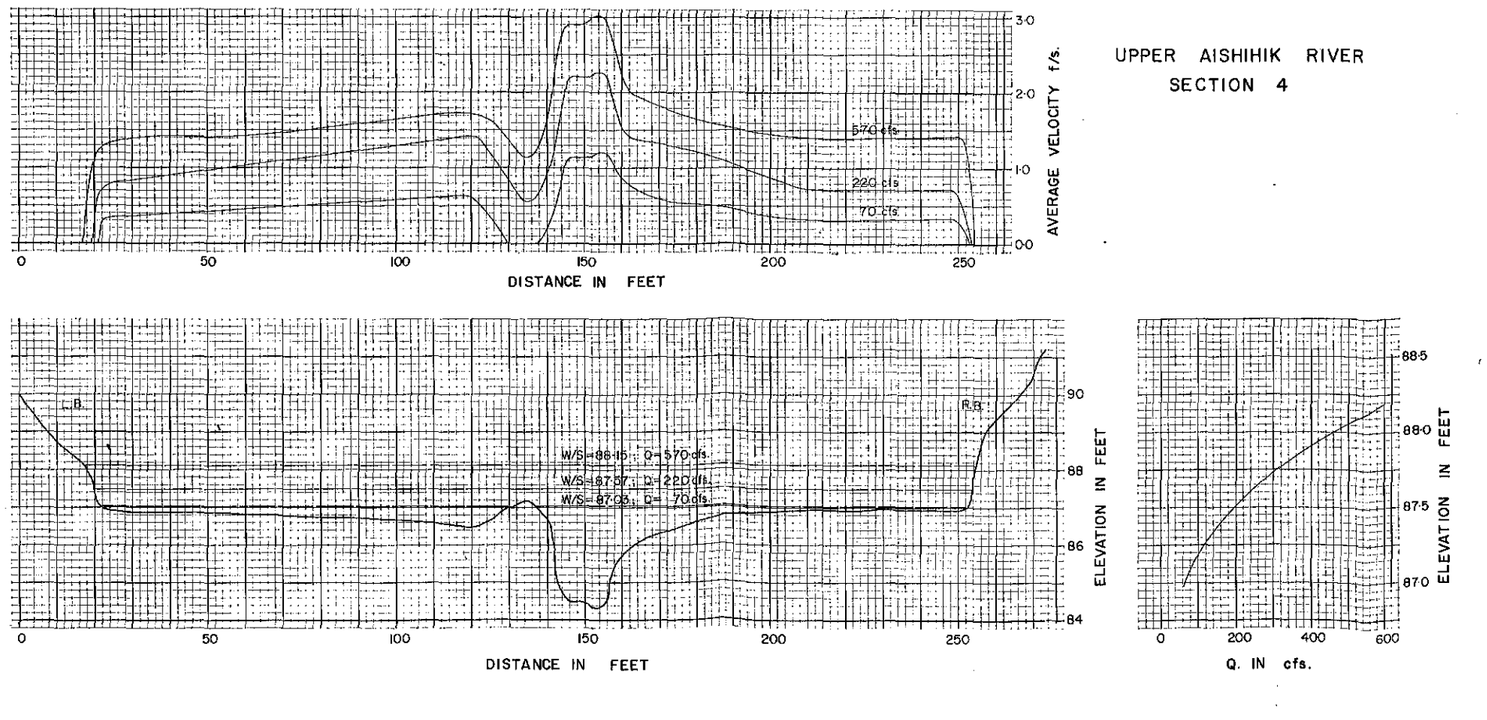
UPPER AISHIHIK RIVER
SECTION 1



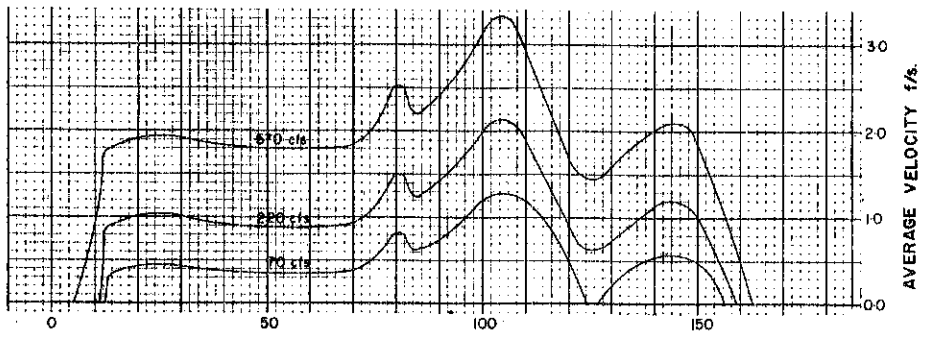
UPPER AISHIHIK RIVER
SECTION 2



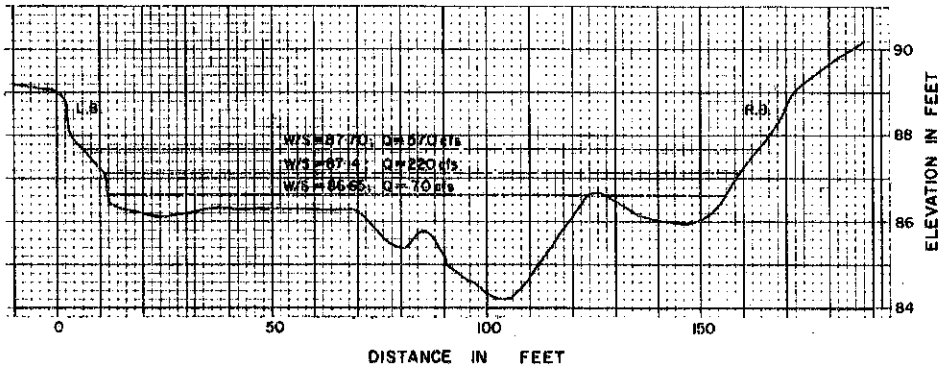
UPPER AISHIHIK RIVER
SECTION 3

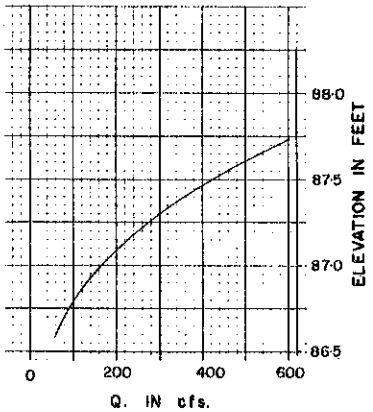


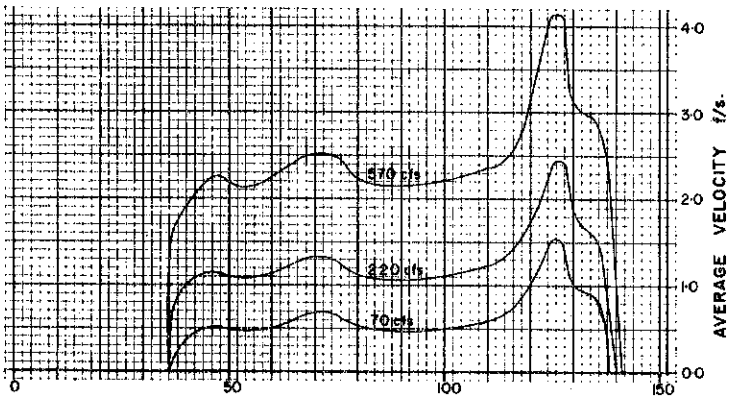
UPPER AISHIHIK RIVER
SECTION 4



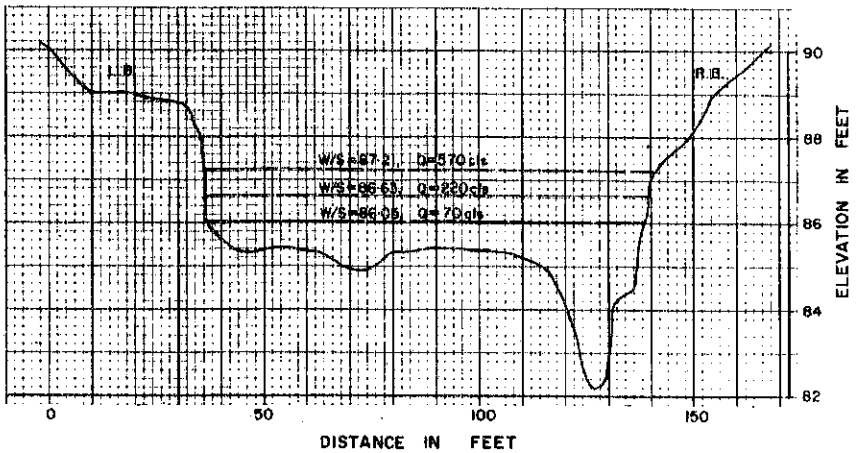
UPPER AISHIHIK RIVER
SECTION 5

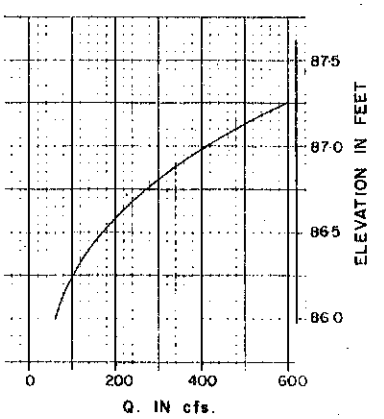


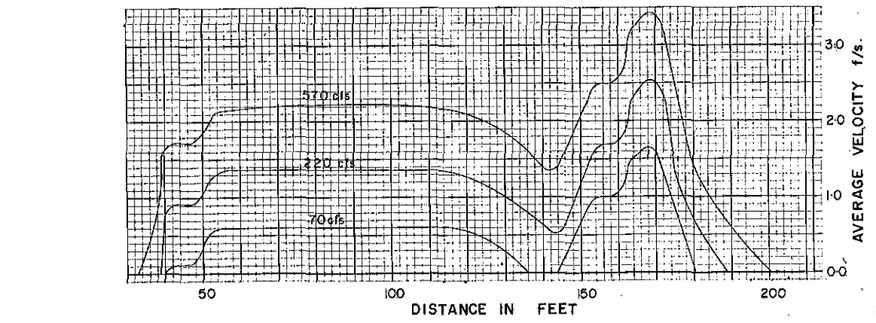




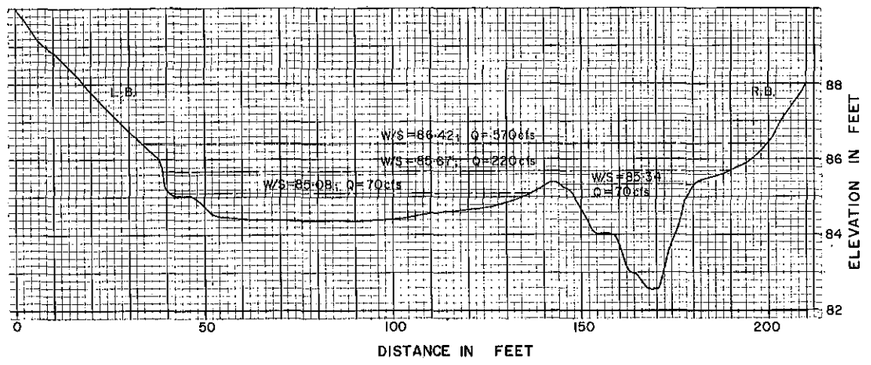
UPPER AISHIHIK RIVER
SECTION 6

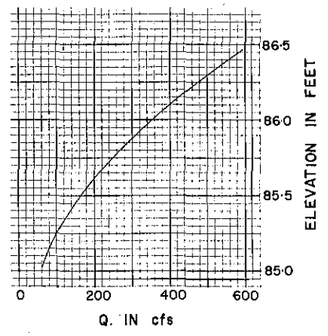


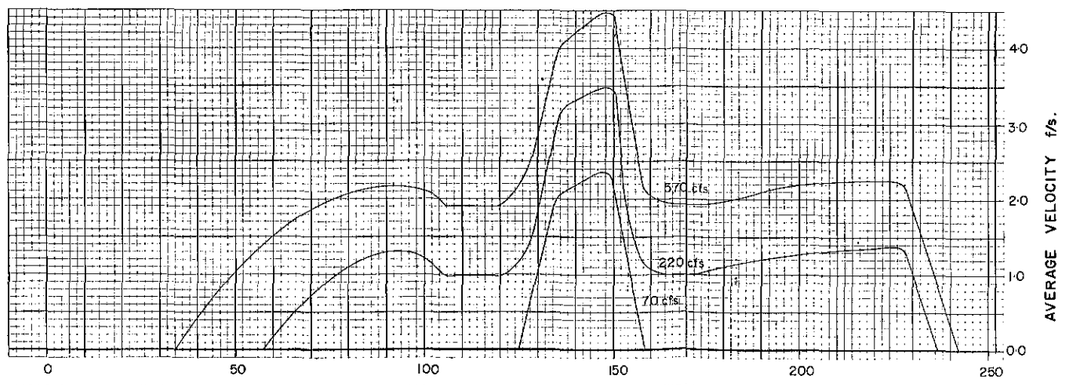




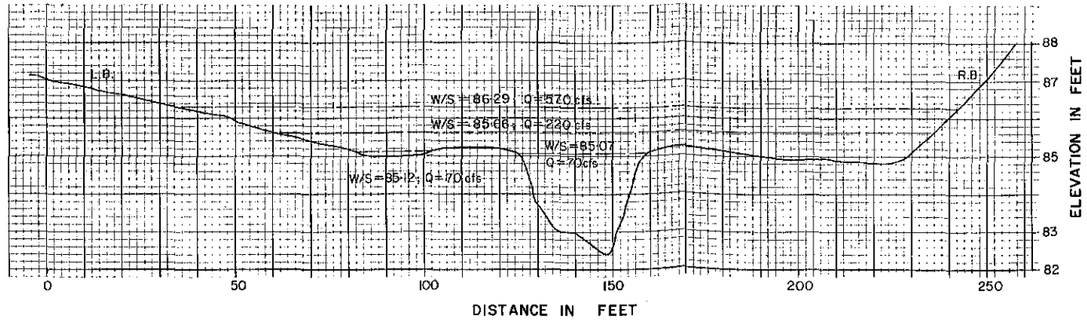
UPPER AISHIHIK RIVER
SECTION 7







UPPER AISHIHIK RIVER
SECTION 8



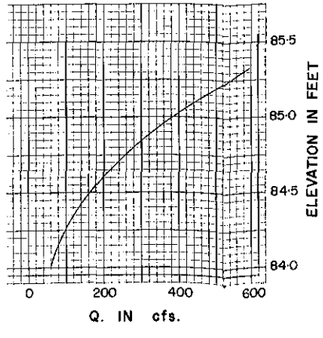
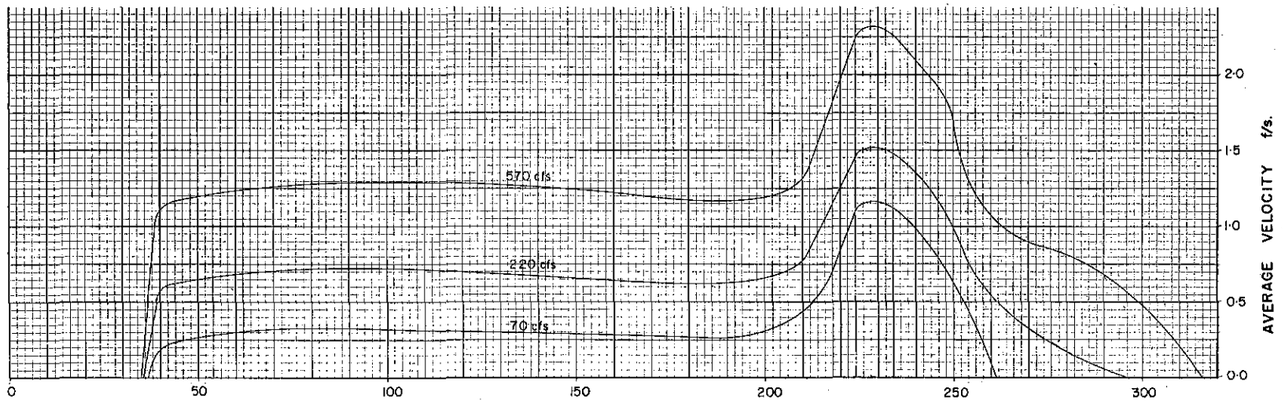
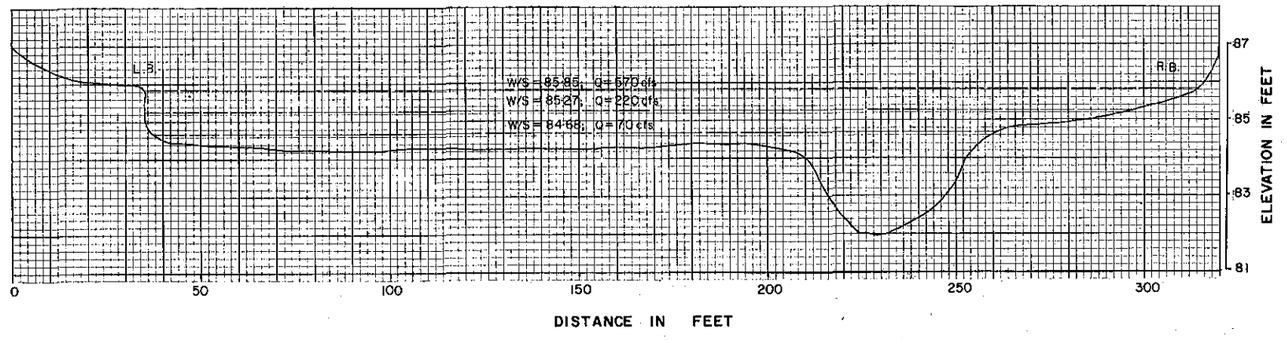
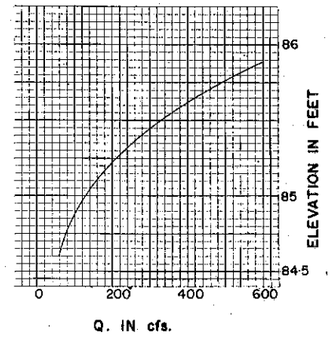


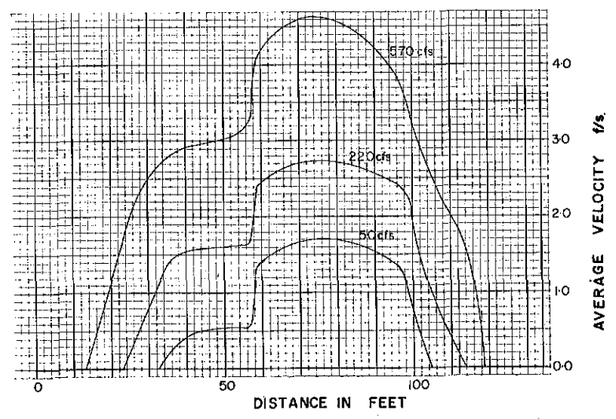
FIGURE 11



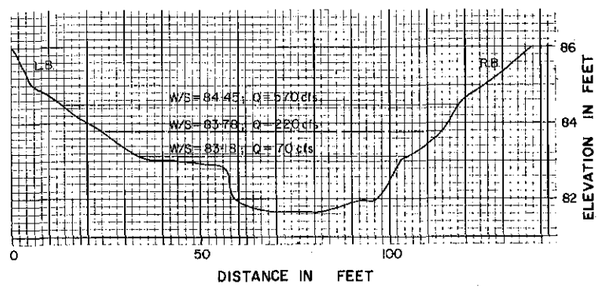
UPPER AISHIHIK RIVER
SECTION 9

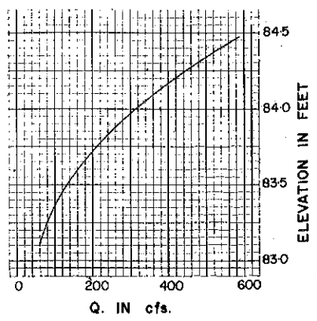


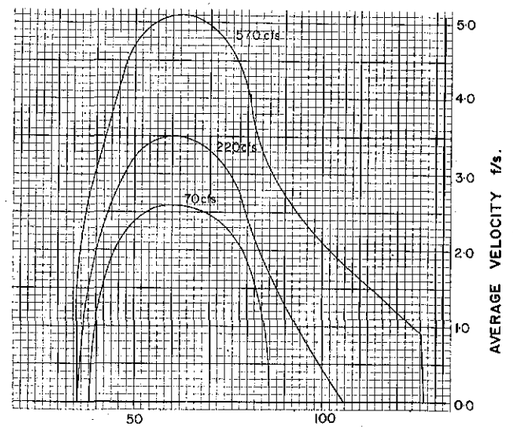




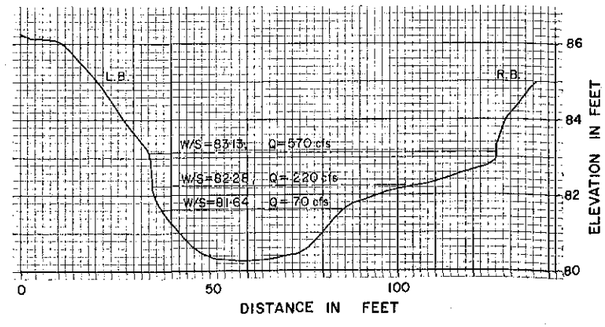
UPPER AISHIHIK RIVER
SECTION 10

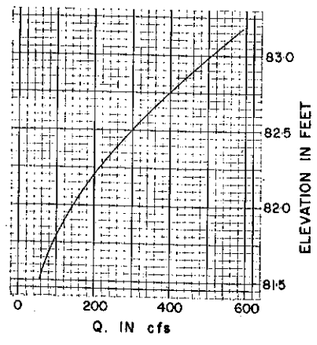


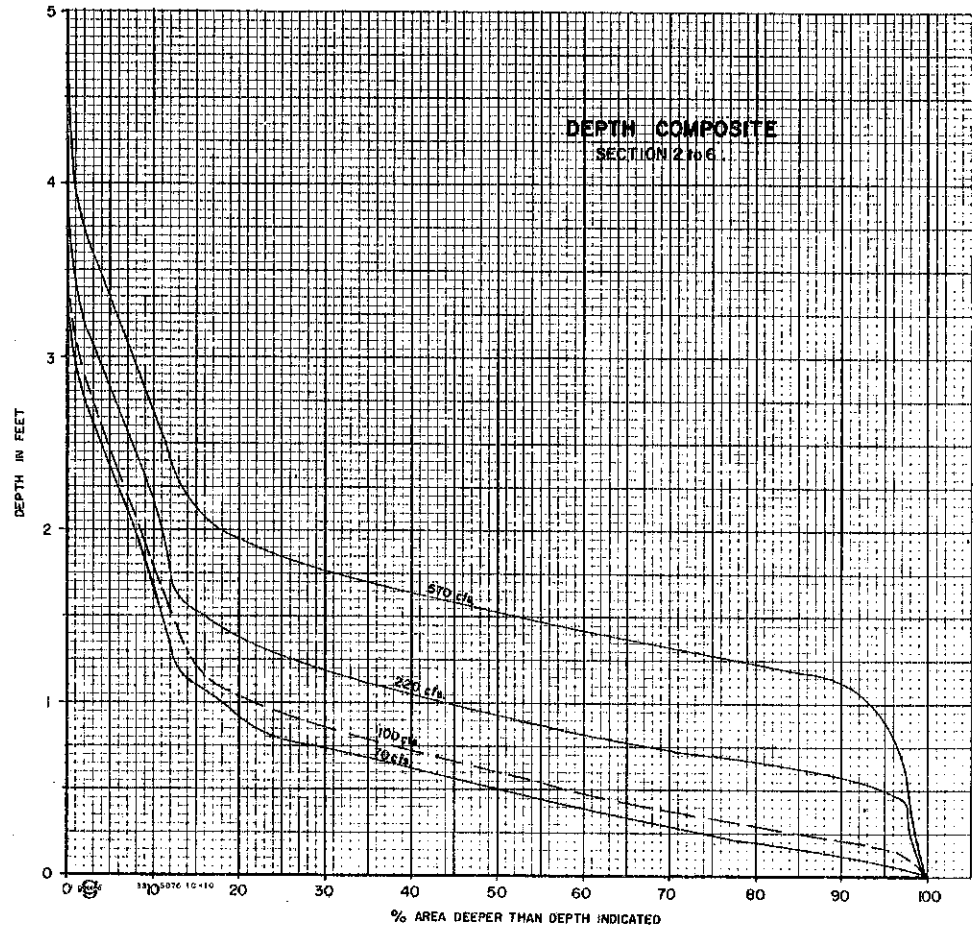




UPPER AISHIHIK RIVER
SECTION 11






DEPTH COMPOSITE
SECTION 2 to 6.
DEPTH IN FEET
0
1
2
3
4
5
570 cfs
250 cfs
100 cfs
70 cfs
0
10
20
30
40
50
60
70
80
90
100
% AREA DEEPER THAN DEPTH INDICATED

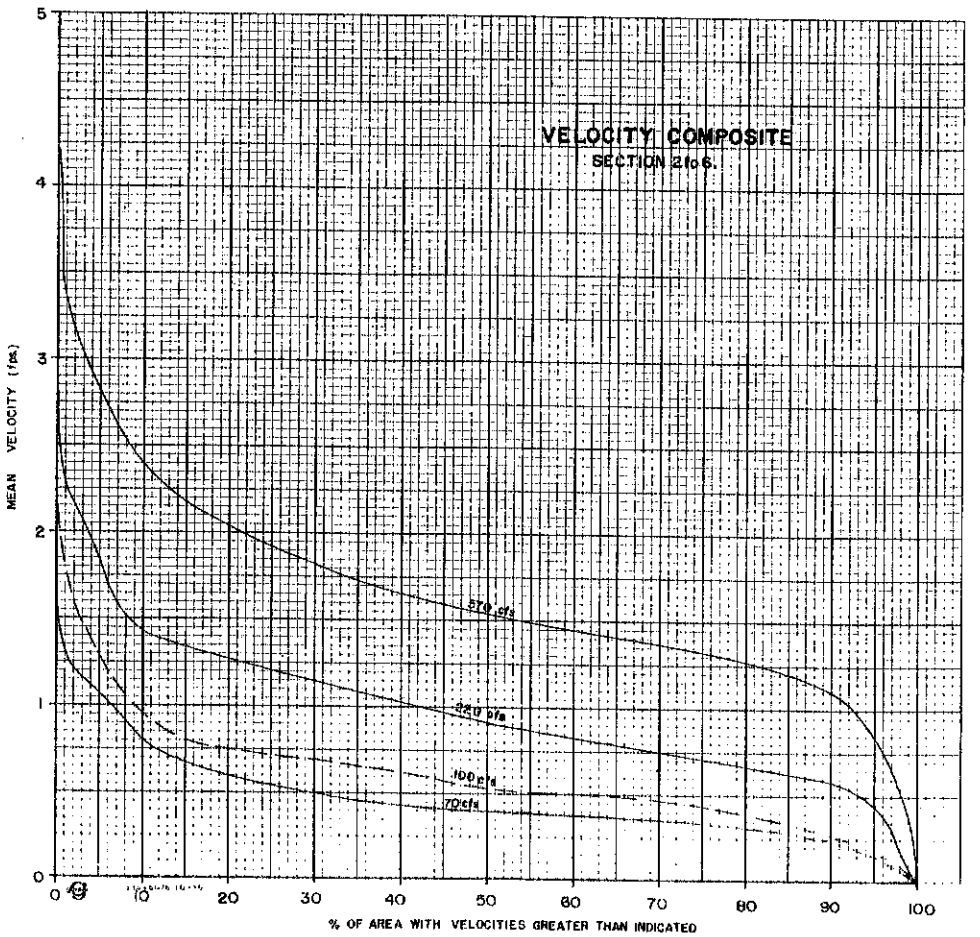
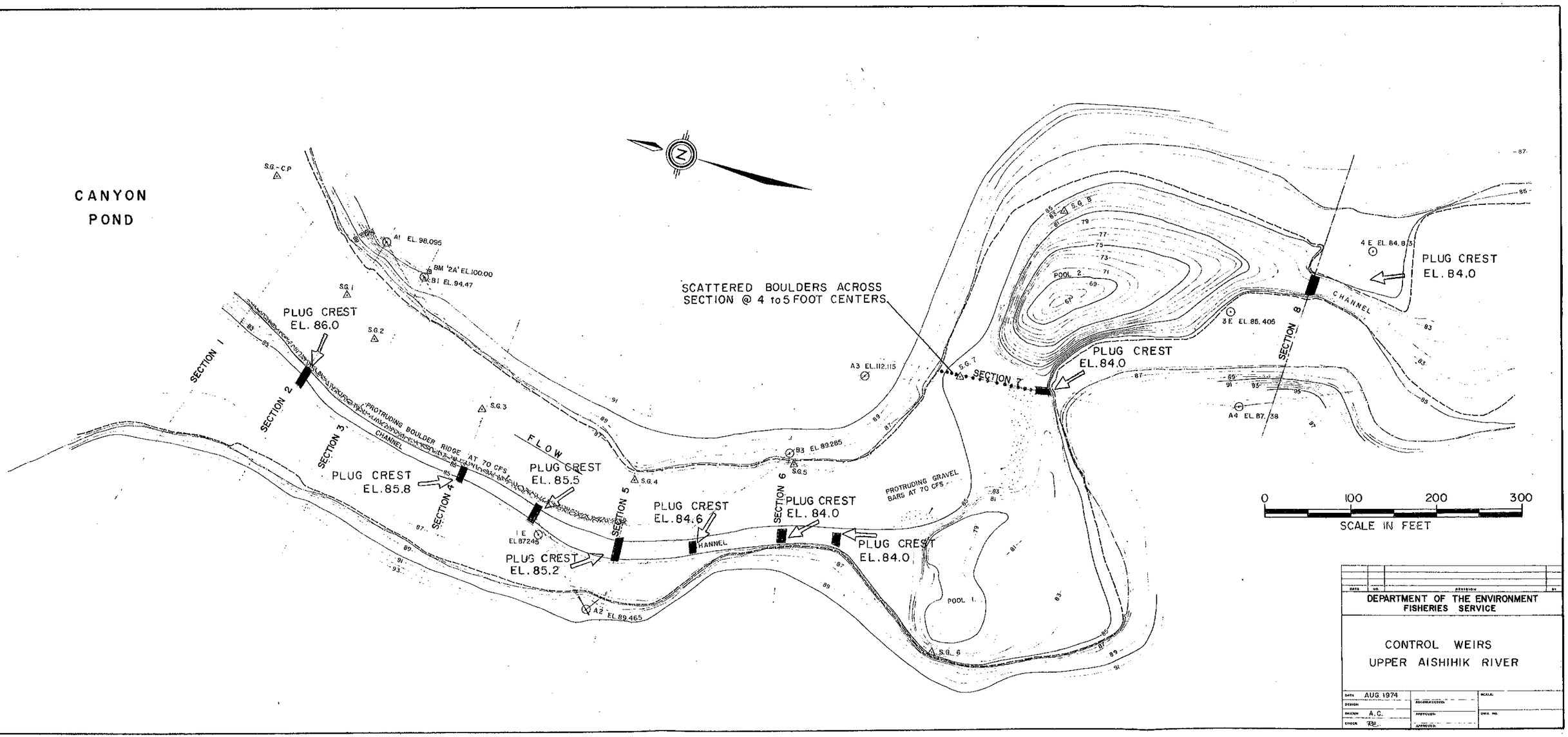

VELOCITY COMPOSITE
SECTION 2 to 6.
MEAN VELOCITY (fps)
0
1
2
3
4
5
570 cfs
250 cfs
100 cfs
70 cfs
0
10
20
30
40
50
60
70
80
90
100
% OF AREA WITH VELOCITIES GREATER THAN INDICATED

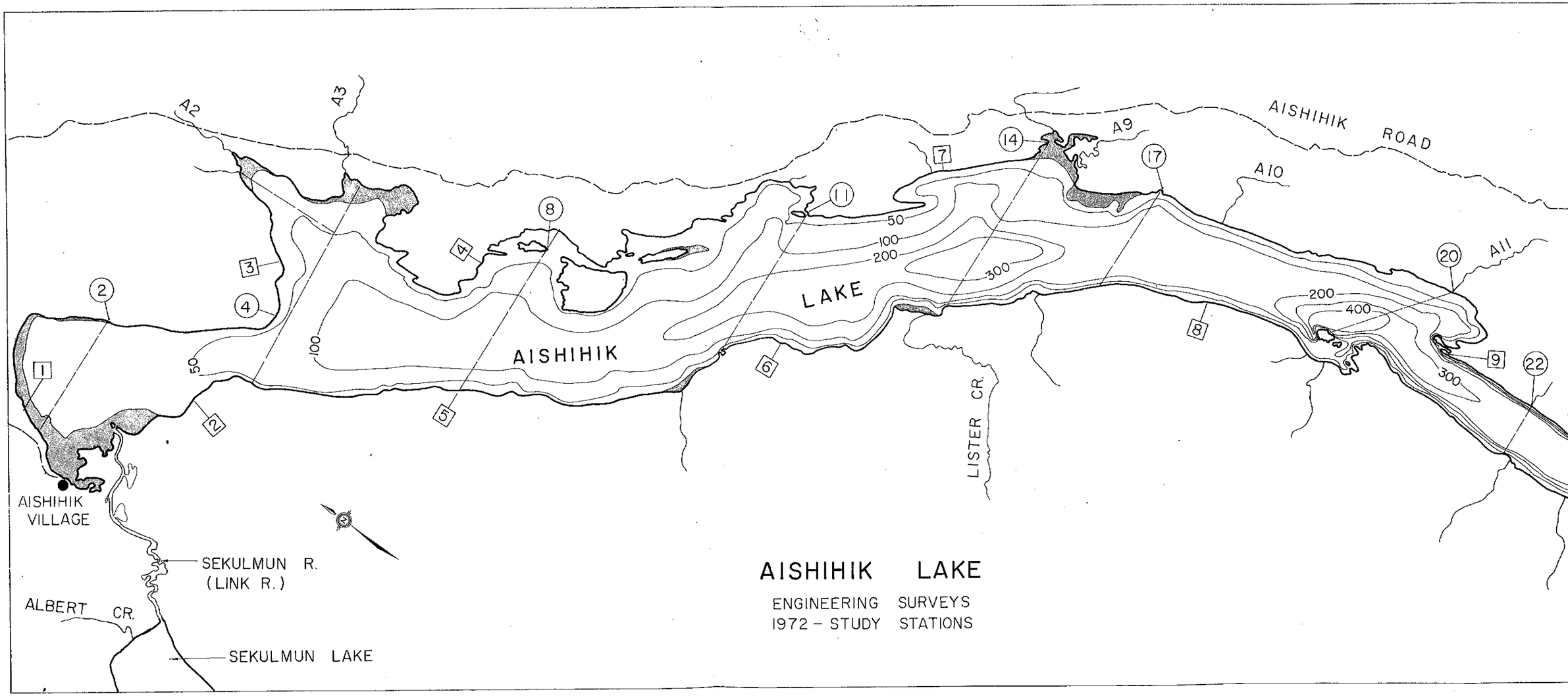
FIGURE 13



DEPARTMENT OF THE ENVIRONMENT
FISHERIES SERVICE

CONTROL WEIRS
UPPER AISHIHIK RIVER

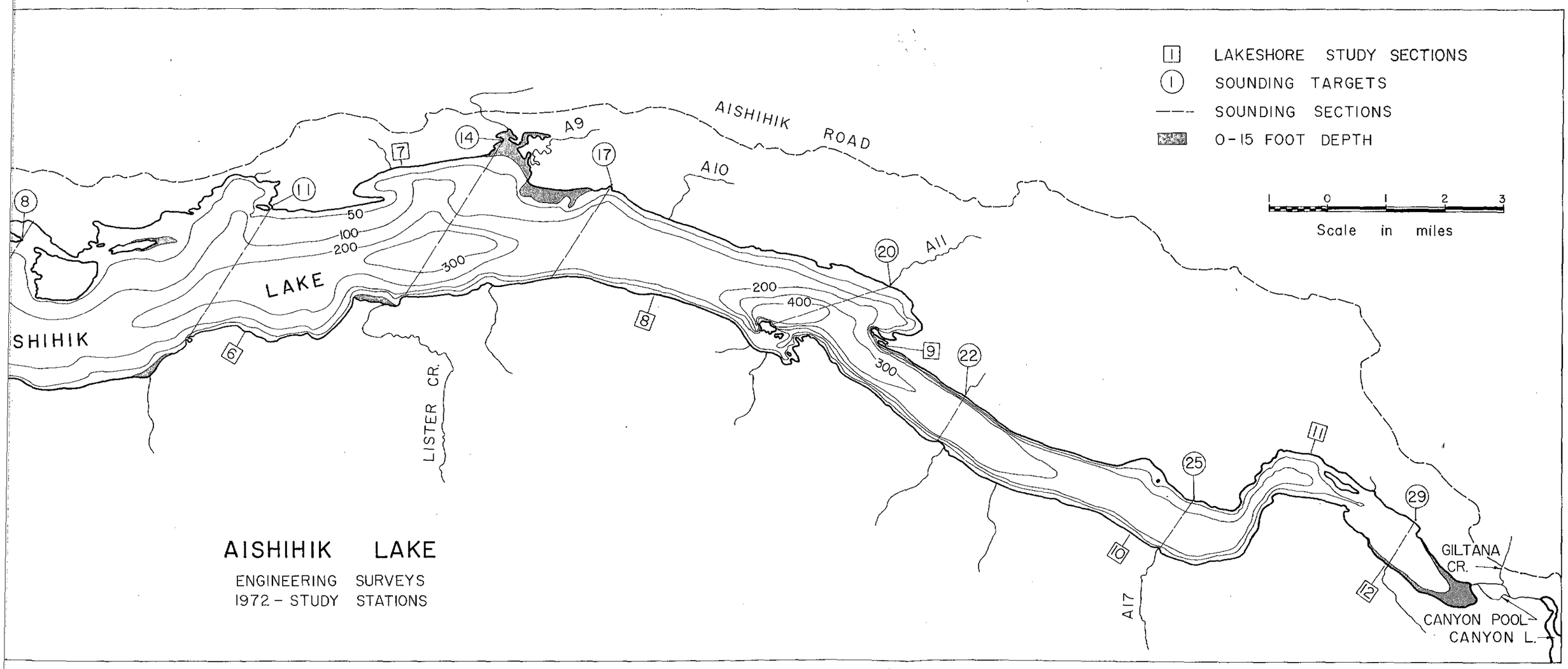
DATE	AUG. 1974
DESIGN	
DRAWN	A.C.
CHECK	
RECOMMENDED	
APPROVED	
APPROVED	
SCALE	
DWG. NO.	



AISHIHIK LAKE

ENGINEERING SURVEYS
1972 – STUDY STATIONS

FIGURE 14


LAKESHORE STUDY SECTIONS
SOUNDING TARGETS
SOUNDING SECTIONS
0-15 FOOT DEPTH
0 1 2 3
Scale in miles
AISHIHIK ROAD
A9
A10
A11
A17
LAKE
SHIHIK
LISTER CR.
50
100
200
300
200
400
300
GILTANA CR.
CANYON POOL
CANYON L.
AISHIHIK LAKE
ENGINEERING SURVEYS
1972 - STUDY STATIONS

SHORELINE STUDY REFERENCE PAGE

PHOTOGRAPHS:

(A) Shoreline from 100 feet

(B) Shoreline close up

(C) Shoreline perpendicular to section

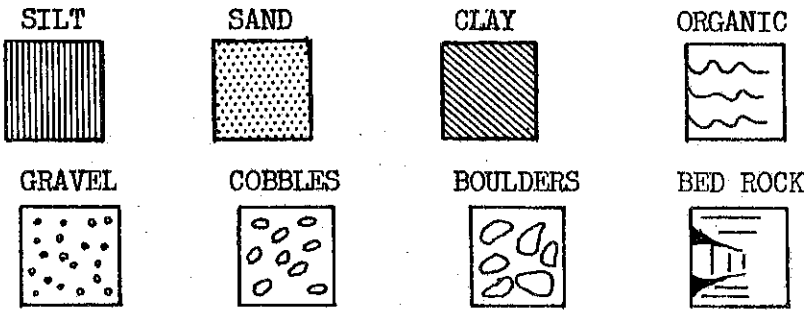
(D) Submerged shoreline substrate using periscope.

SURVEY:

(1) Lake sounded to -15 feet, except
Section 2 sounded only to -10.5 feet

(2) Survey identification target (4' x 4').

SYMBOLS AND TERMS USED FOR SOILS.



CLASSIFICATION BY PARTICLE SIZE:-

BOULDERS - larger than 8 inches

COBBLES - 3 inches to 8 inches

GRAVEL - # 4 sieve to 3 inches

SAND - # 200 sieve to # 4 sieve

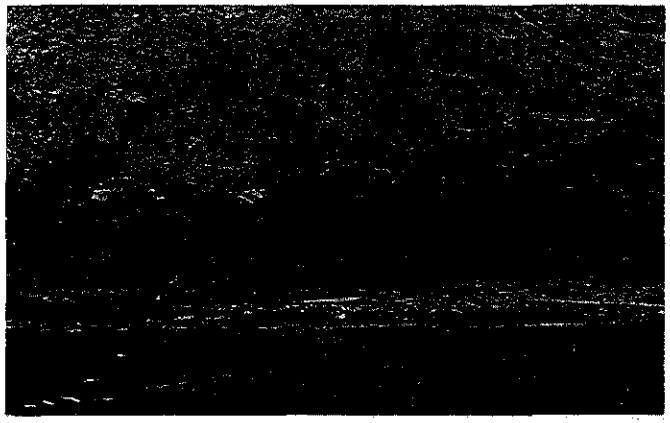
SILT - 0.002mm to # 200 sieve

CLAY - finer than 0.002 mm.

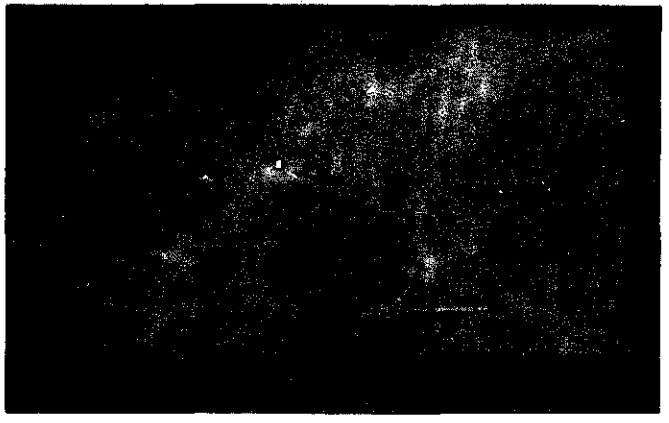
SECTION 1

Clay bank at north end of
Aishihik Lake from 100'

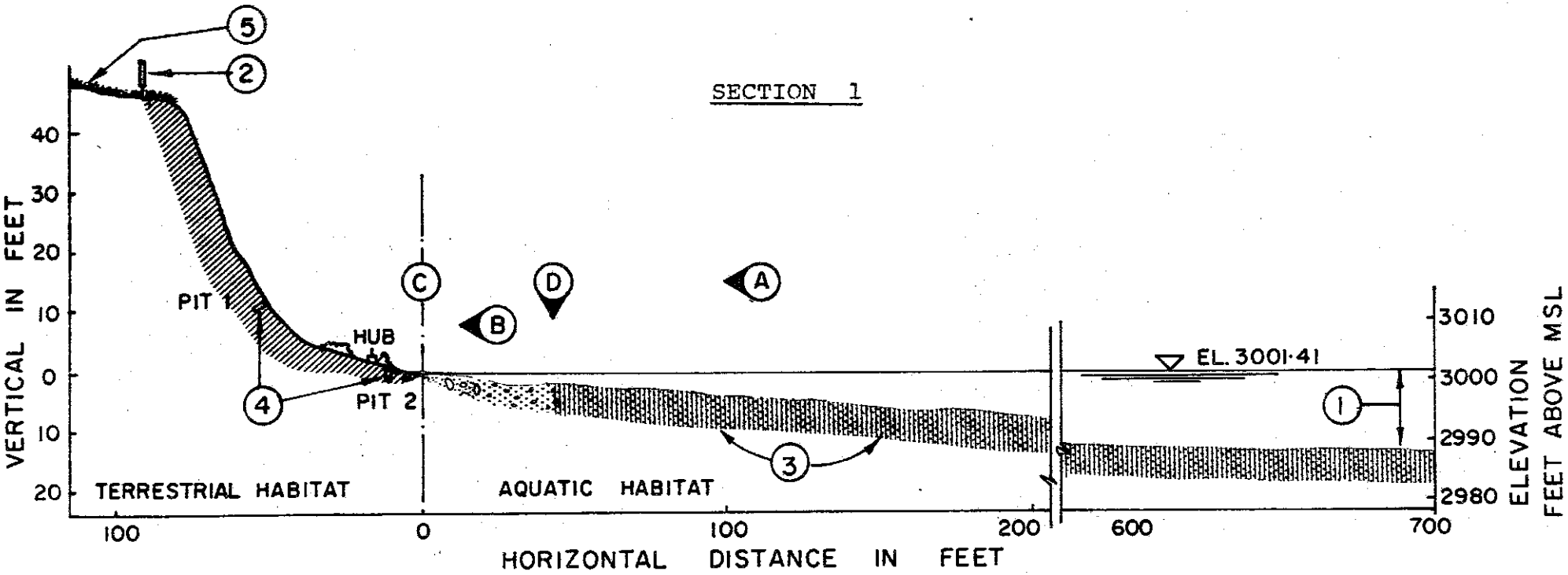
Shoreline perpendicular to section.



Close-up view of clay bank
and beach area.



Sandy bottom Photographed through
periscope 40' from shoreline.



(3) UNDERWATER SUBSTRATE:-

- first 15' mainly gravel, cobbles, boulders.
- next 25' mainly sand with some gravel.
- remainder to 15' depth - sand and silt.

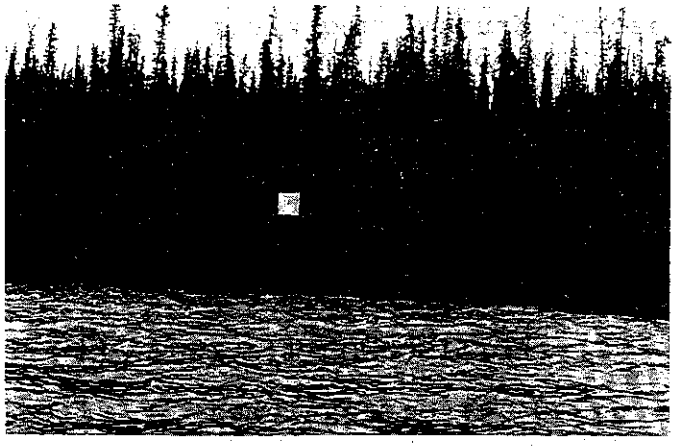
(4) TEST PIT COMPOSITION:-

- 2.5' depth - mainly grey clay with small amounts of fine sand (both pits similar in composition)

(5) VEGETATION:-

- intermittent low shrubs terminating 30' - 40' from water surface at base of bank.
- bank has no vegetation.
- above bank mainly grasses for first 30' - 60', then changing to white spruce.

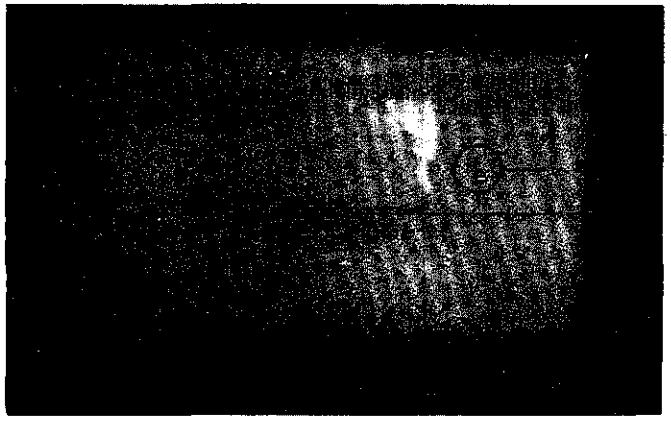
FIGURE 16



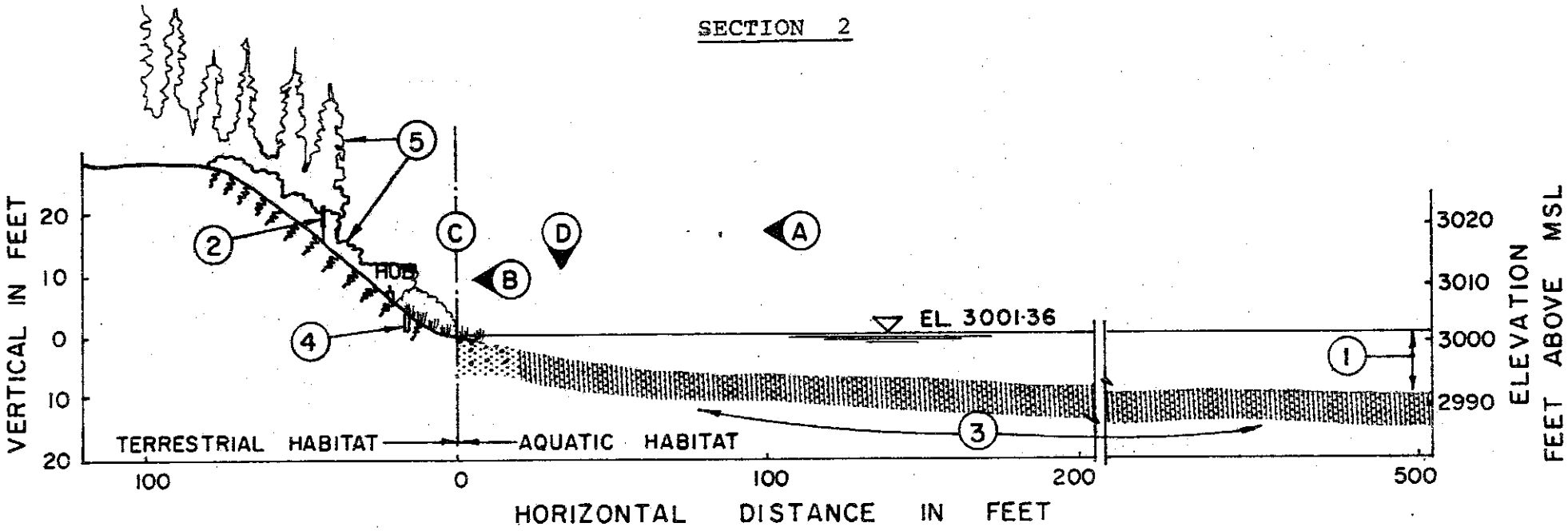
Shoreline terrain
from 100!

Shoreline perpendicular to section showing dense vegetation.

Close-up view of mosses
and lichen on bank.



Sandy bottom photographed through
periscope 30' from shoreline.



(3) UNDERWATER SUBSTRATE:-

- first 15' mainly fine gravel and sand.
- remainder to 10.5' depth, sand and silt.

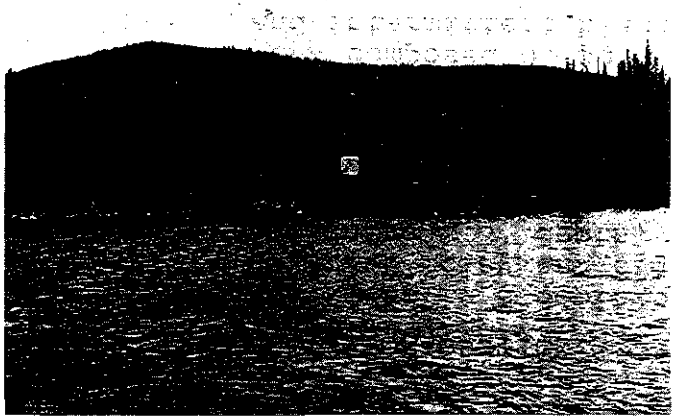
(4) TEST PIT COMPOSITION:-

- peat moss to a depth of 0.2 feet.
- next 1.0' clay and organic material.
- remaining 1.3' depth, sand and gravel.

(5) VEGETATION:-

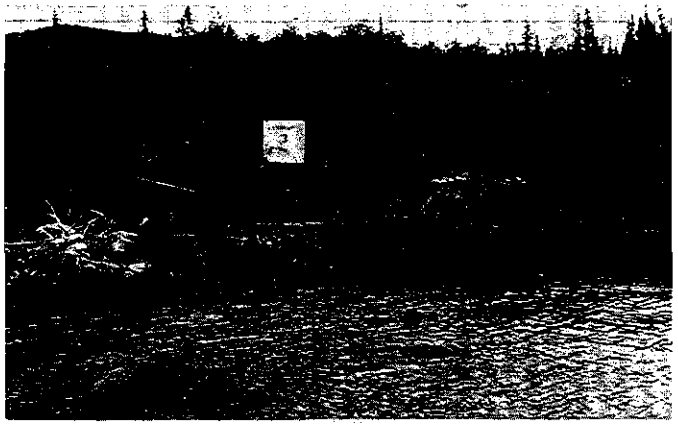
- low shrubs, stunted willow and grasses terminating 30' - 40' from water surface.
- bank composed of peat moss with lichen (fungus) and intermittent black and white spruce.

FIGURE 17



General view of shoreline from 100' showing very dense community of stunted willow.

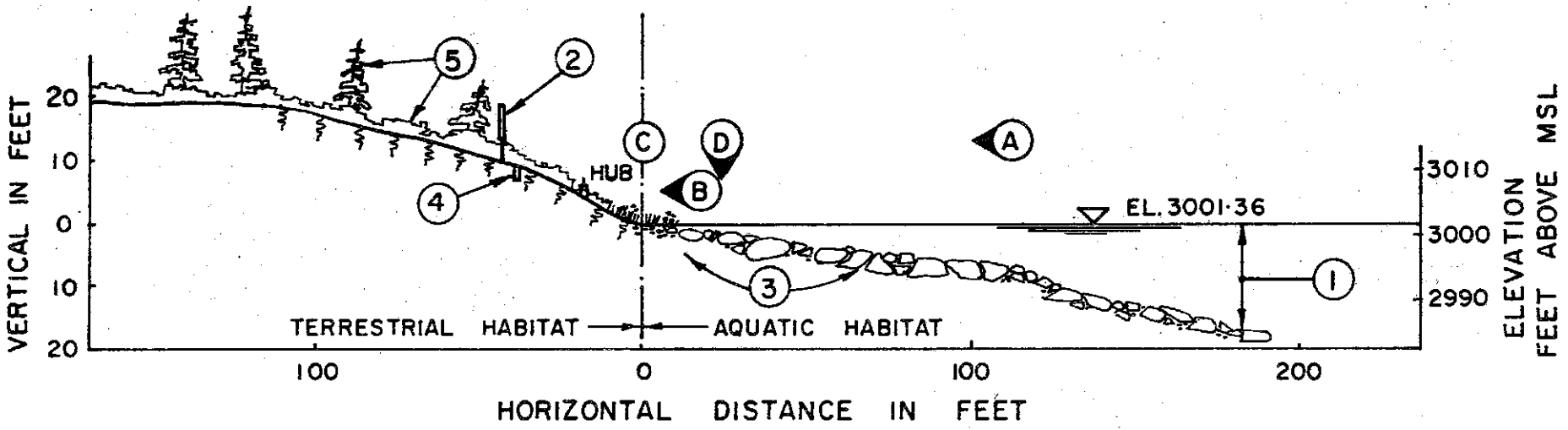
Shore perpendicular to section showing bouldery lower section area with low shrubs and stunted willow.



Close-up of rocky beach area.

Cobbles and boulders common. Photographed 20' from shoreline.

SECTION 3



(3) UNDERWATER SUBSTRATE:-

- cobbles and boulders to 15' depth.

(4) TEST PIT COMPOSITION:-

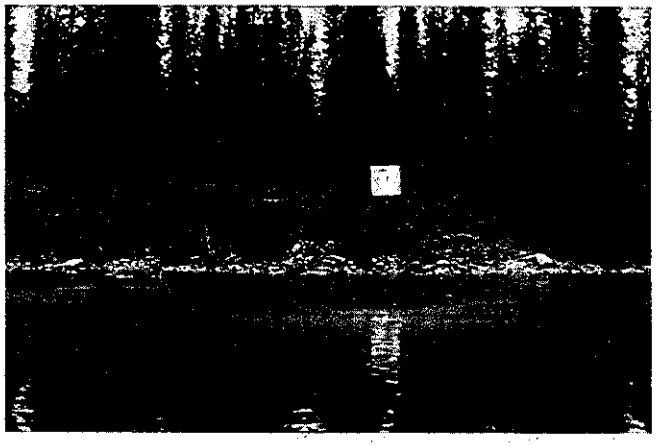
- top 0.5' organic soil with fine sand.
- next 2.0' clay with organic material.
- remaining 0.5' depth, clay and gravel.

(5) VEGETATION:-

- low shrubs, stunted willow and grasses terminating 20' - 30' from water surface.
- remainder very dense stunted willow with occasional white spruce.

FIGURE 18

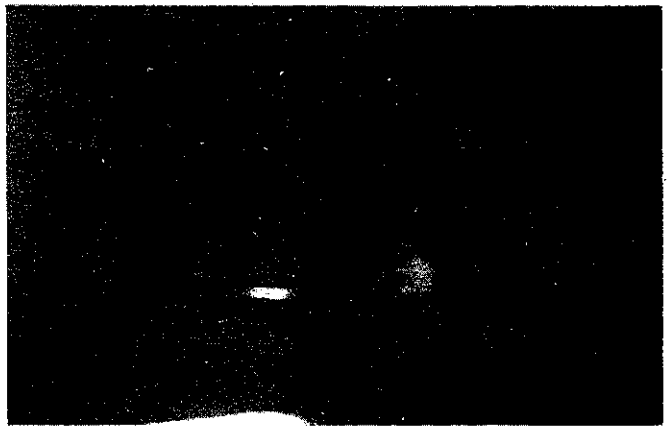
SECTION 4



Shoreline terrain from 100'.

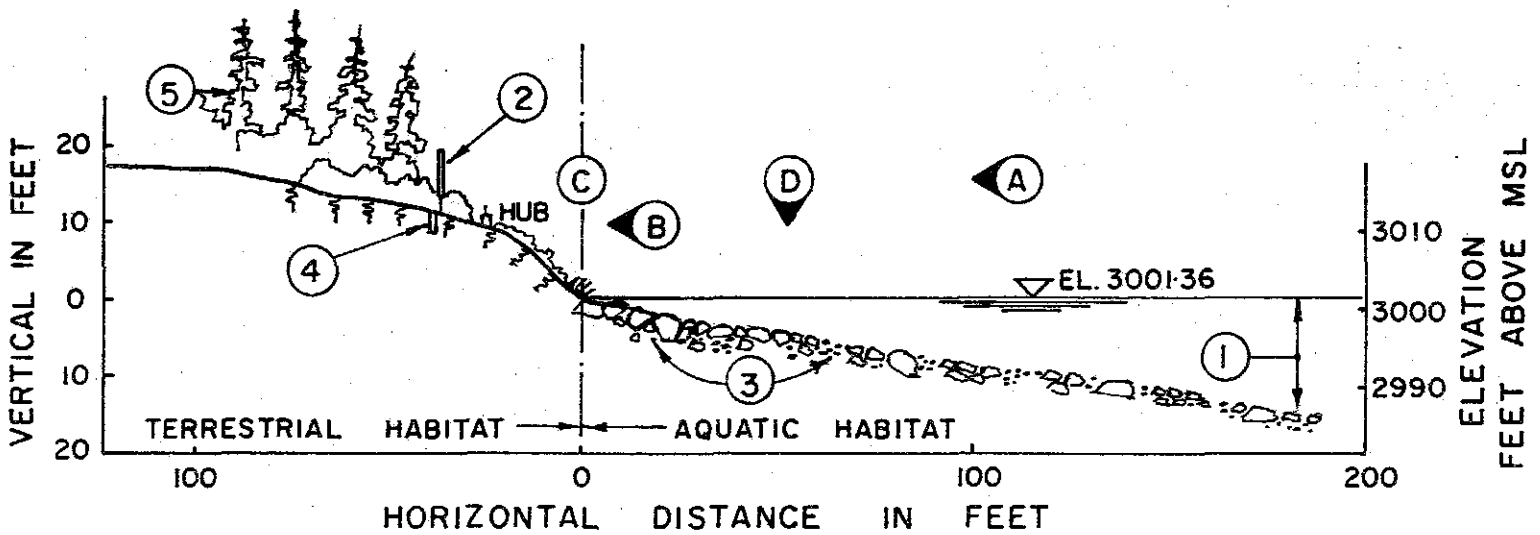
Shoreline perpendicular to section showing bouldery beach area, low shrubs and white spruce.

Close-up view of bank.



Boulders and cobbles common. Photographed 50' from shoreline.

SECTION 4



(3) UNDERWATER SUBSTRATE:-

- first 25' mainly large boulders, cobbles and sand.
- remainder to 15' depth, mainly cobbles, but with some gravel and sand.

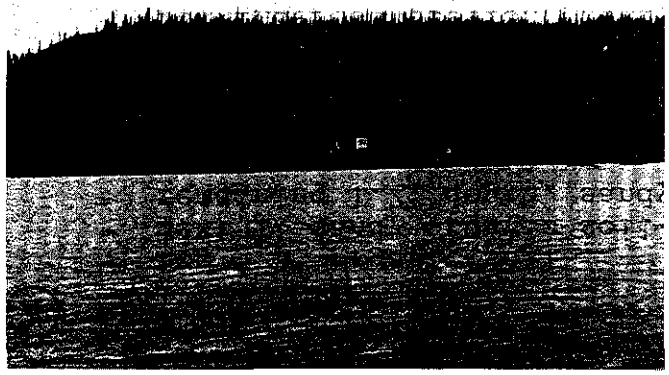
(4) TEST PIT COMPOSITION:-

- top 0.3' organic soil
- next 1' sandy organic soil (loam).
- remaining 1.2' depth, sandy soil with some traces of clay.

(5) VEGETATION:-

- stunted cottonwood and willow, cranberry bushes, lichen (fungus) and other shrubs terminating 30' - 40' from water surface.
- remainder of section mostly white spruce and low shrubs.

FIGURE 19

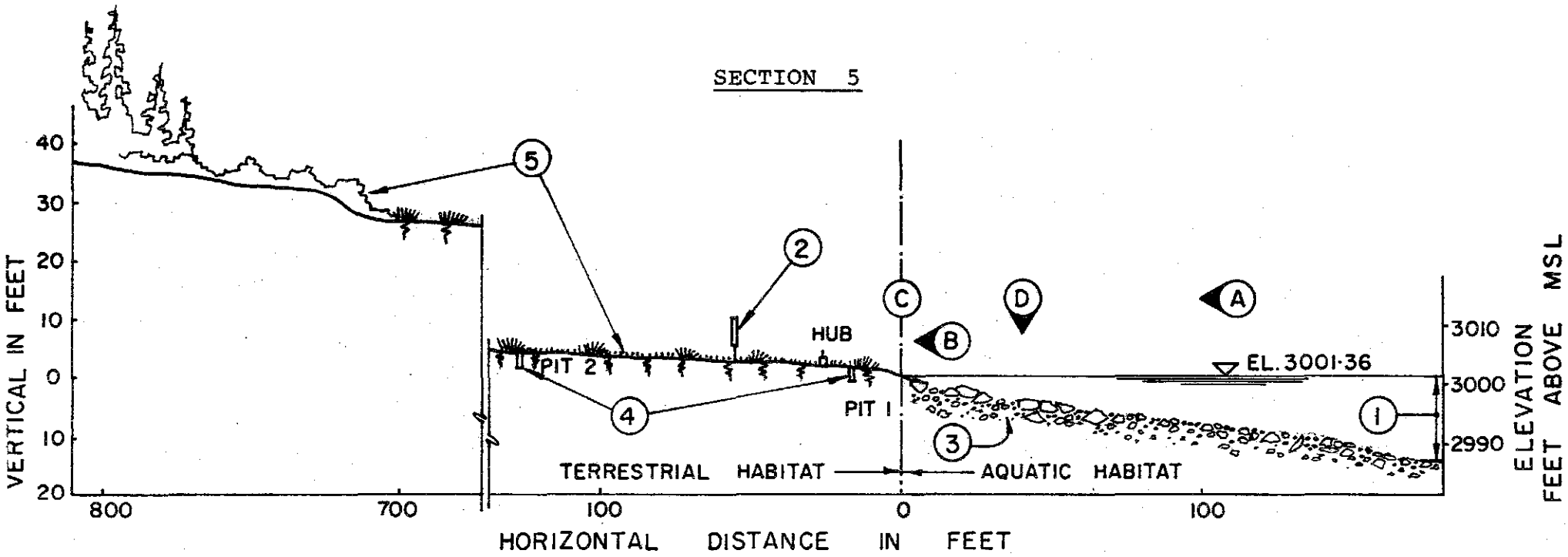


General view of shoreline terrain.

Shoreline perpendicular to section showing extensive flat semi-alpine tundra area with spruce in background.

Close-up view of beach area and tundra type vegetation.

Cobbles and gravel bottom photographed 40' from shoreline.



(3) UNDERWATER SUBSTRATE:-

- first 65' mainly mixed cobbles, gravel and sand.
- remainder to 15' depth, sand and gravel.

(4) TEST PIT COMPOSITION:-

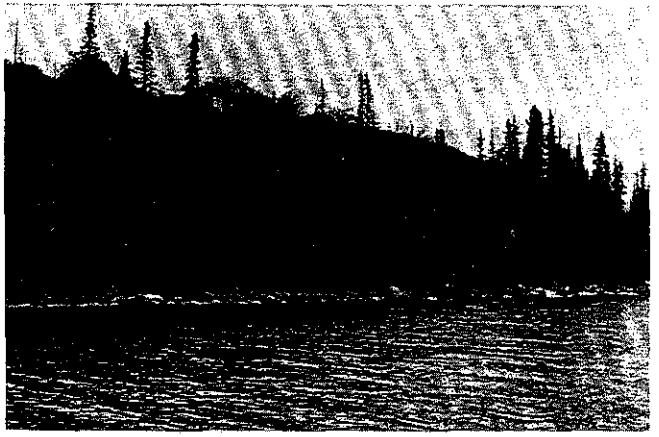
- top 0.2' organic soil (tundra).
- next 1', sandy clay with some gravel and organic material.
- remaining 1.3' depth, sandy clay.
  (both pits similar in composition)

(5) VEGETATION:-

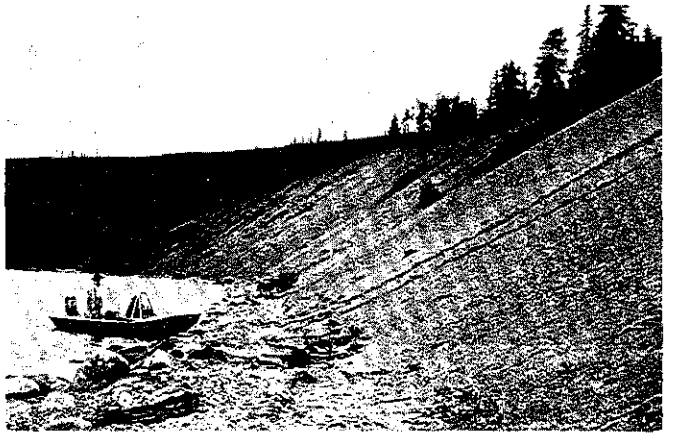
- first 25' beach, no vegetation.
- 25 - 700' tundra-like terrain interspersed with numerous small streams.
- +700' stunted willow and then mainly a mixture of black and white spruce.

FIGURE 20

SECTION 6

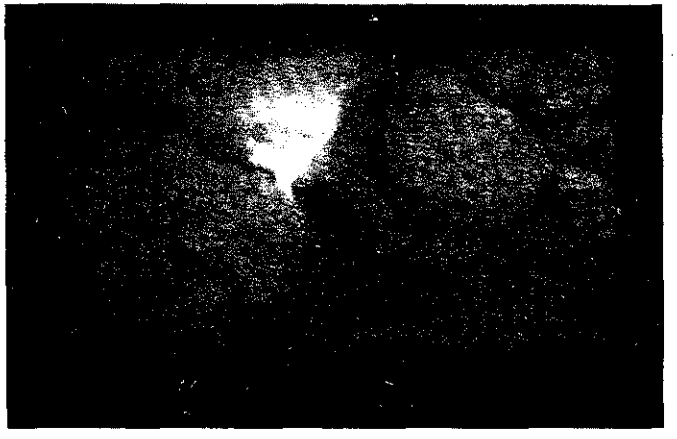


General view of sandy bank area on west side of lake from 100'

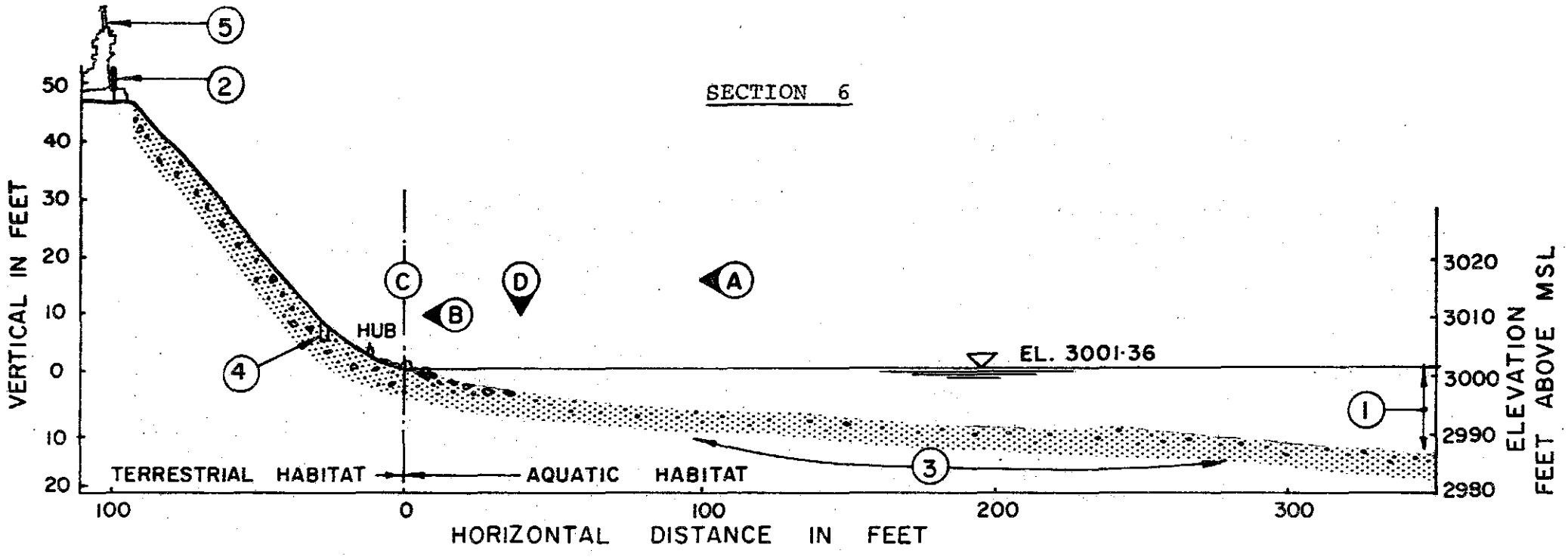


Shoreline perpendicular to section showing steepness and height of bank.

Close-up view of bank and beach area.



Boulders and gravel bottom photographed 40' from shoreline.



(3) UNDERWATER SUBSTRATE:-

- first 45' gravel and sand with some boulders.
- remainder to 15' depth, mainly sand and some gravel.

(4) TEST PIT COMPOSITION:-

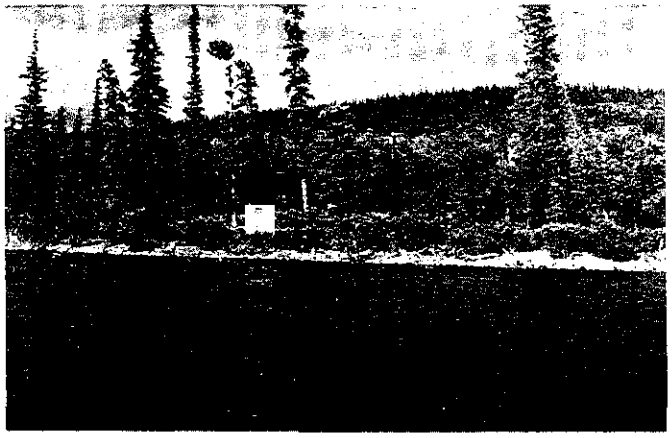
- 2.5' depth - coarse sand with some gravel mixed.

(5) VEGETATION:-

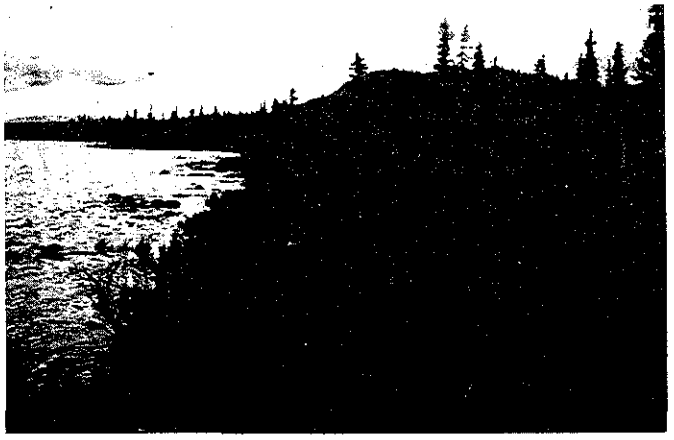
- no vegetation on or below bank.
- above bank balsam, poplar, willow, white spruce, and low shrubs.

FIGURE 21

SECTION 7

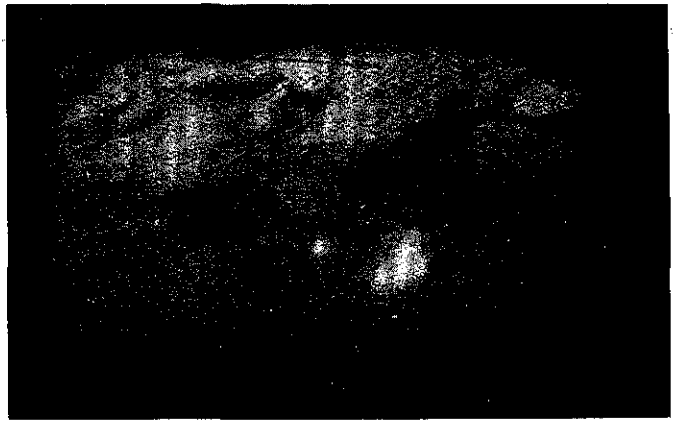


View of shoreline from 100'



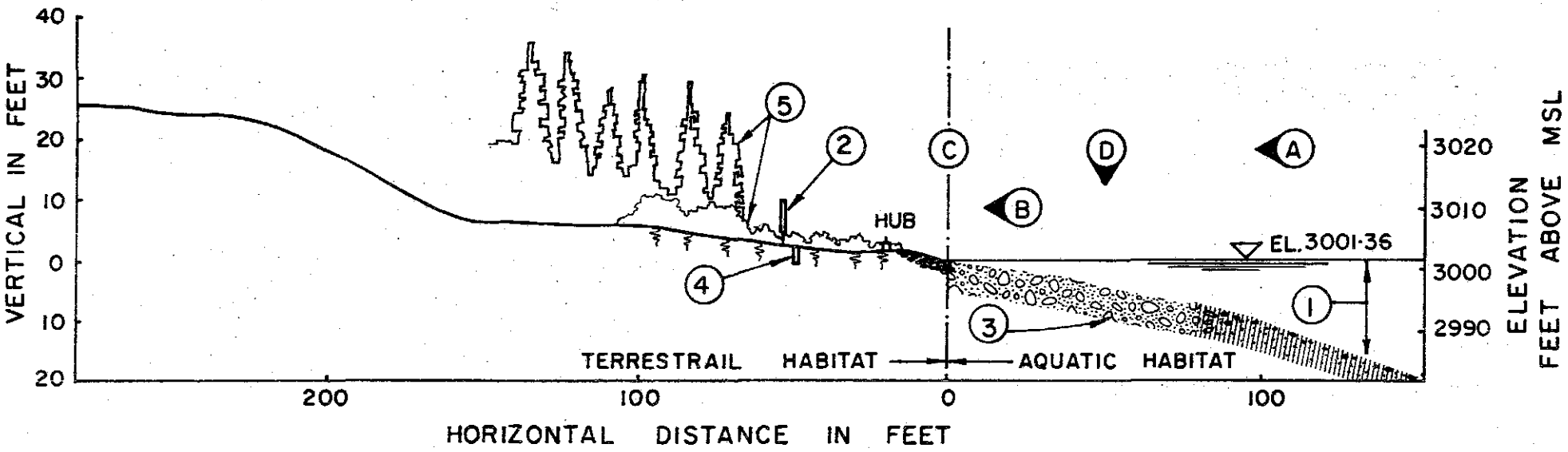
Shoreline perpendicular to section.

Close-up view showing sedge and mosses.



Cobbles and gravel bottom photographed 50' from shoreline.

SECTION 7



(3) UNDERWATER SUBSTRATE:-

- first 80' cobbles and gravel.
- remainder to 15' depth, mainly sand and fine gravel and silt.

(4) TEST PIT COMPOSITION:-

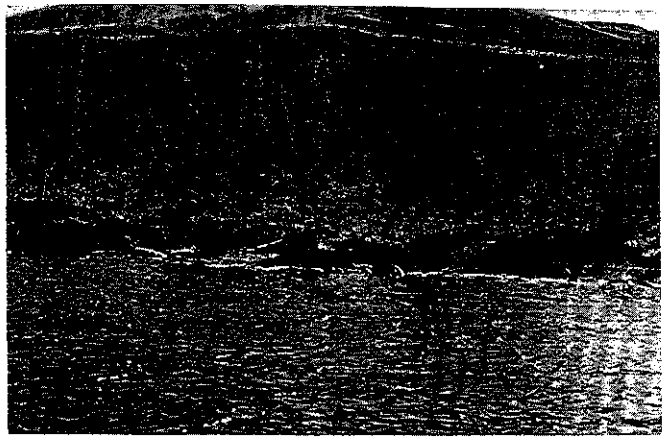
- top 0.7' black organic soil.
- next 0.3' silt and sandy clay.
- remaining 1.5' depth, clay with organic material.

(5) VEGETATION:-

- first 20' beach, no vegetation.
- next 50' mainly sedge and mosses.
- remainder mainly white spruce, willow and shrubs.

FIGURE 22

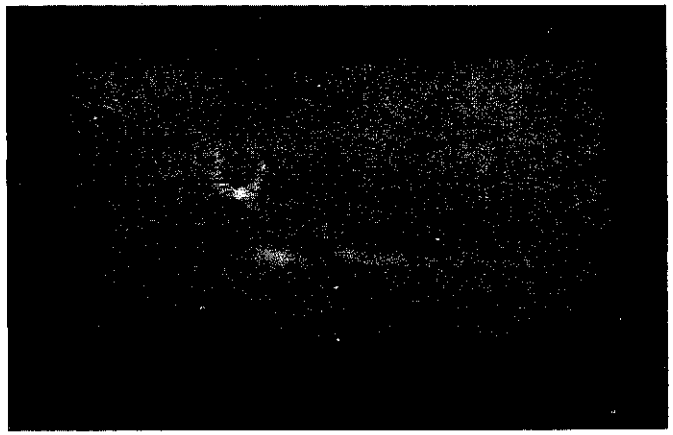
SECTION 8



General view of shoreline from 100'

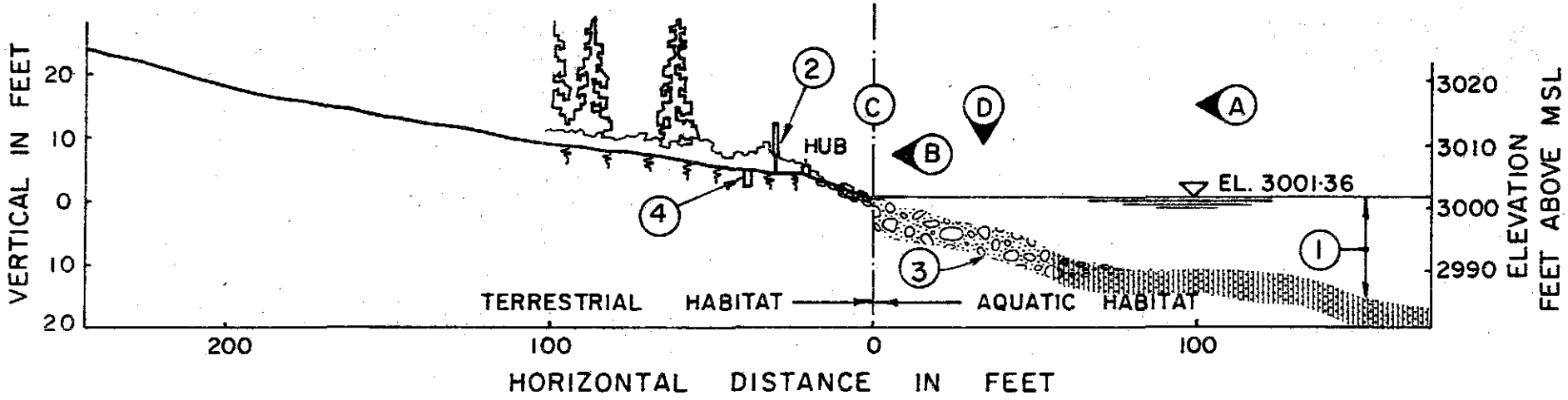
Shoreline perpendicular to section showing shrubs and white spruce.

Close-up view of beach and vegetation.



Sandy bottom photographed 30' from shoreline.

SECTION 8.



(3) UNDERWATER SUBSTRATE:-

- first 25' mainly boulders with cobbles and sand.
- remainder to 15' depth, sand and silt.

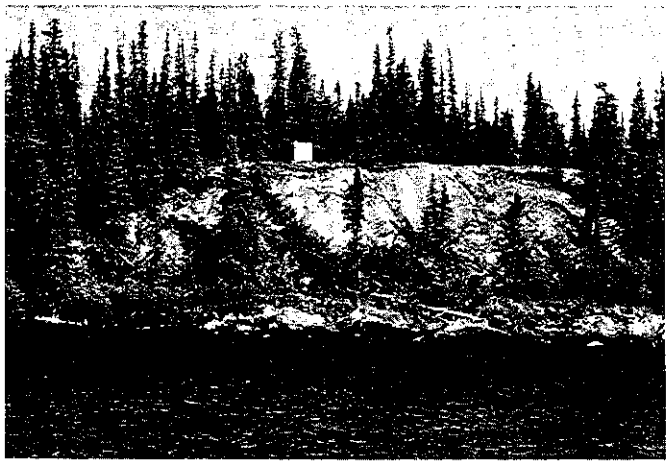
(4) TEST PIT COMPOSITION:-

- top 0.3' organic, fibrous soil.
- next 0.3' sandy, organic soil.
- remaining 1.9' depth, silty clay.

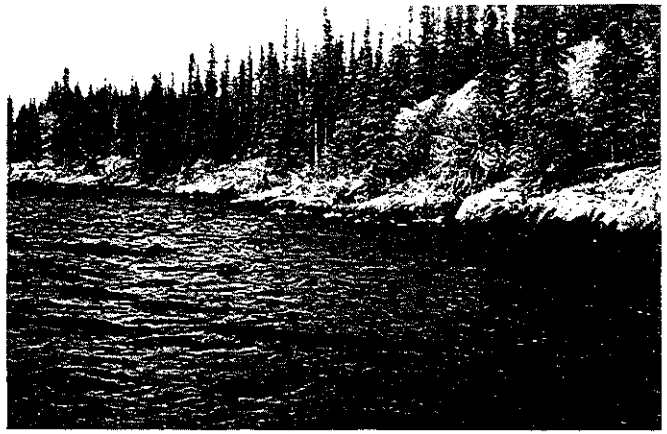
(5) VEGETATION:-

- first 10' beach, no vegetation.
- remainder mosses and low shrubs spotted with white spruce.

FIGURE 23



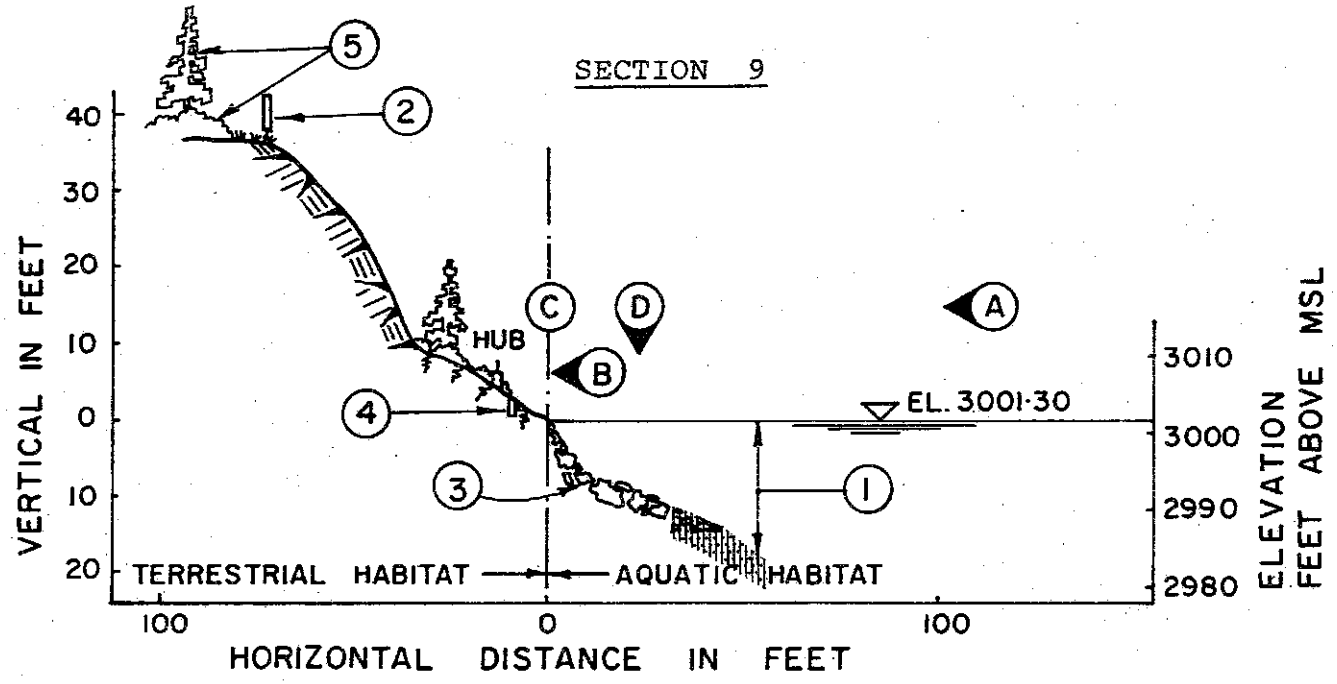
Viww of shoreline from 100' showing bed rock and white spruce.



Shoreline perpendicular to section showing steepness and height and bank.

Close-up view rock cliff and vegetation.

Jagged boulders and cobbles photographed 25' from shoreline.



(3) UNDERWATER SUBSTRATE:-

- boulders and cobbles over first 45 feet.
- remainder to 15' depth, sand and silt.

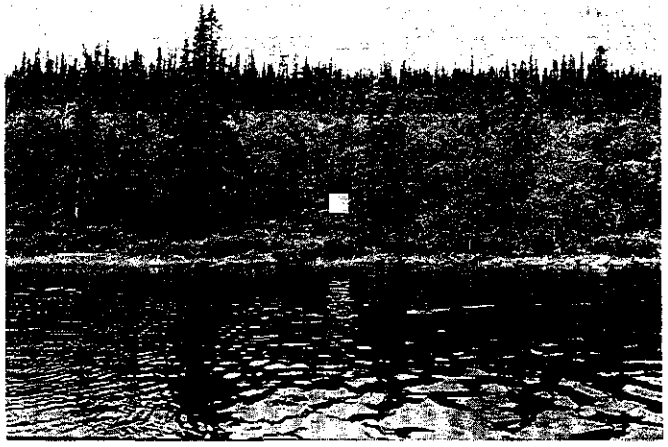
(4) TEST PIT COMPOSITION:-

- top 0.1' organic, fibrous soil.
- next 1.0' white, sandy clay with organic material.
- next 2.0' sandy clay.
- remainder bed rock.

(5) VEGETATION:-

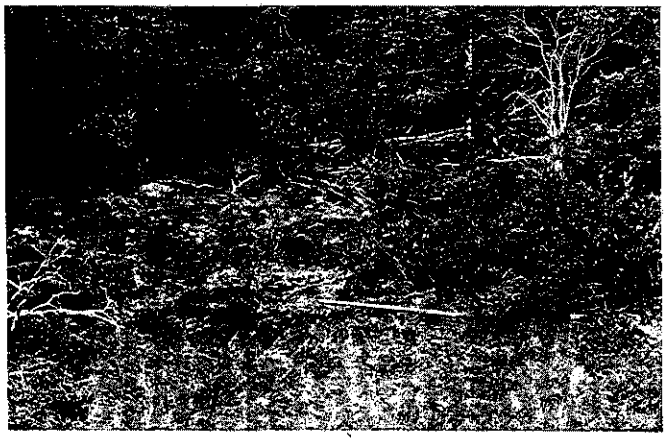
- first 8' bed rock (no vegetation)
- next 25' mosses, low shrubs and stunted white spruce.
- next 40' bed rock cliff with mosses growing in cracks.
- remainder mainly white spruce and low shrubs.

FIGURE 24



View of shoreline from 100'

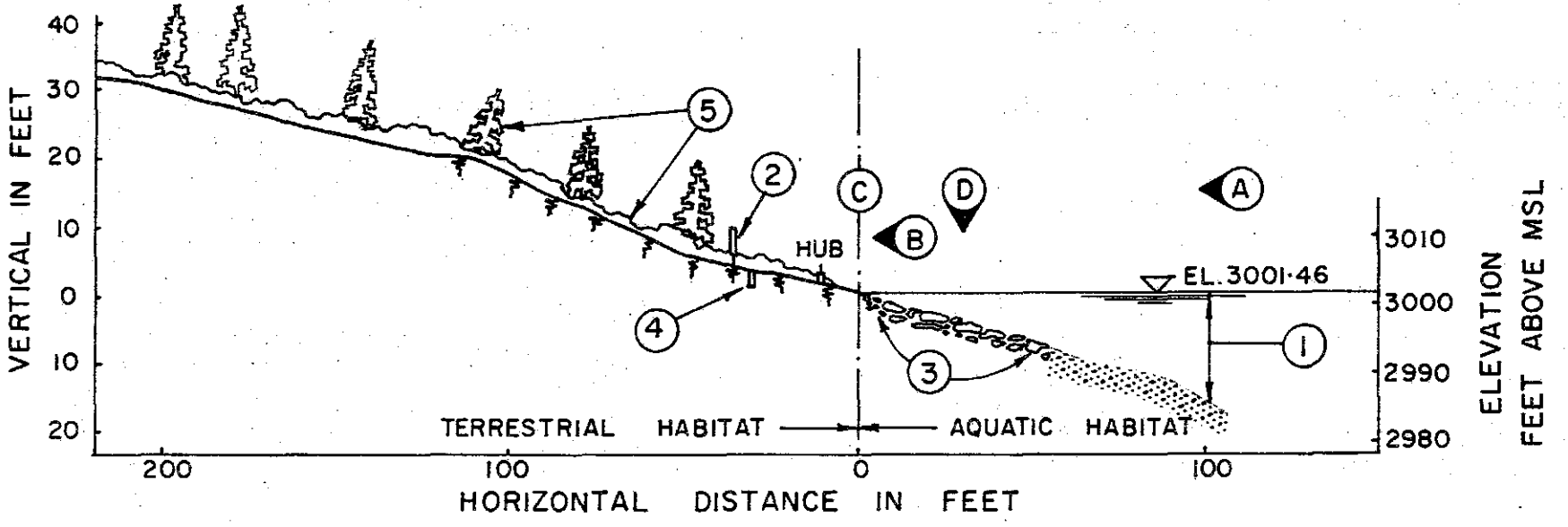
Shoreline perpendicular to section showing beach area, grasses, and white spruce.



Close-up view of vegetation in test pit area.

Sandy bottom photographed 20' from shoreline.

SECTION 10



(3) UNDERWATER SUBSTRATE:-

- first 50' mainly boulders, cobbles and some gravel.
- remainder to 15' depth, coarse sand.

(4) TEST PIT COMPOSITION:-

- top 1.0' black organic soil.
- remaining 1.5' depth, consists of coarse grey, sandy clay.

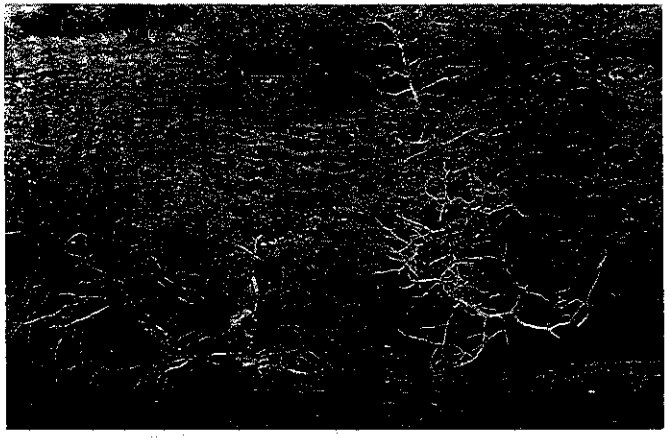
(5) VEGETATION:-

- first 100' mainly mosses, low shrubs, dwarf willow and grasses with lichen (fungus).
- next 100' mainly aspen, willow, white spruce and low shrubs.

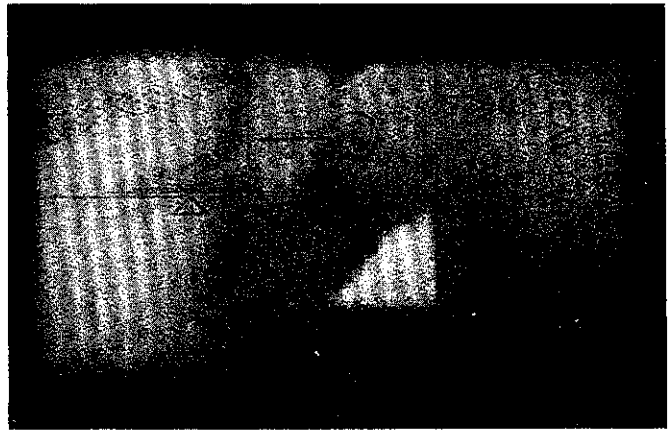
FIGURE 25

View of shoreline from 50' showing mosses, balsam poplar, willow, and white spruce.

Shoreline perpendicular to section showing vegetation.

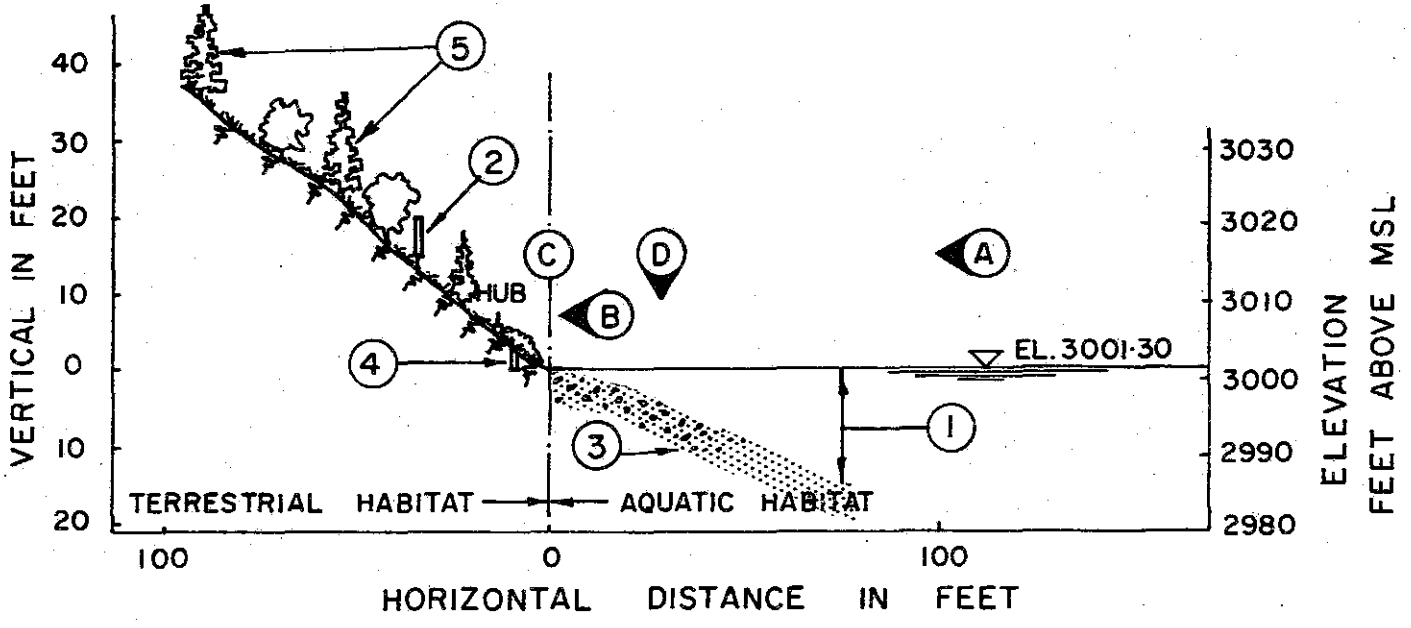


Close-up view of vegetation on bank and beach area.



Cobbles and gravel bottom photographed 25' from shoreline.

SECTION 11



(3) UNDERWATER SUBSTRATE:-

- first 45' mainly cobbles, gravel, sand with some silt.
- remainder to 15' depth, sand.

(4) TEST PIT COMPOSITION:-

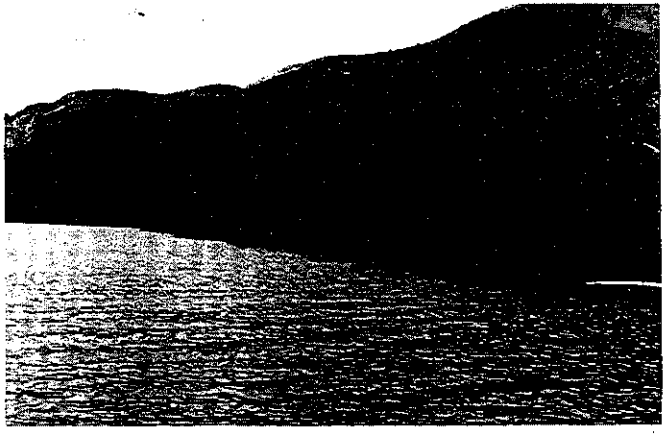
- 2.5' depth - organic soil with gravel and sand.

(5) VEGETATION:-

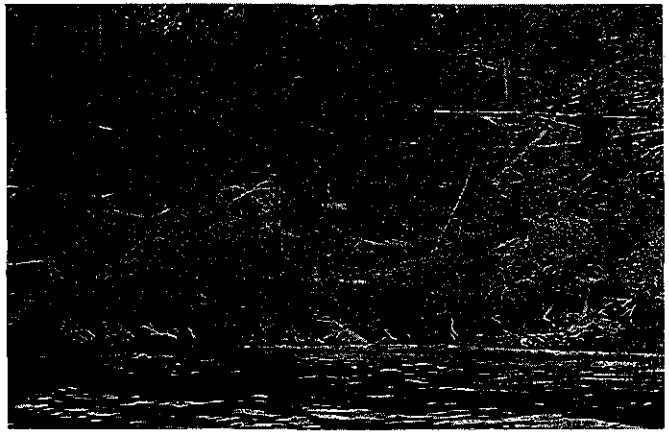
- ferns, mosses, flowers and low bush cranberries throughout bank.
- bank spotted with balsam poplar, willow and white spruce.

FIGURE 26

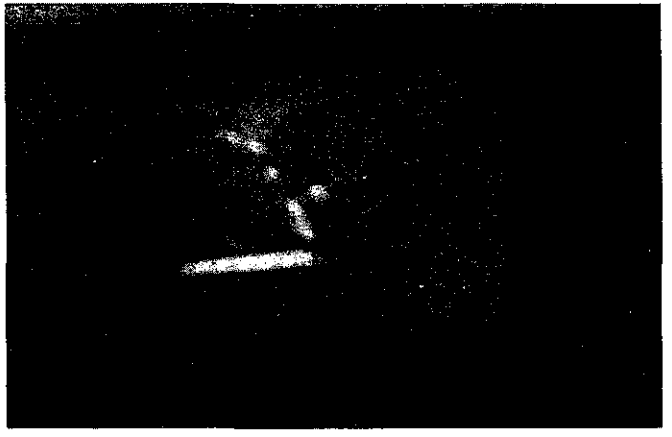
General view of shoreline showing past burnt-off area.



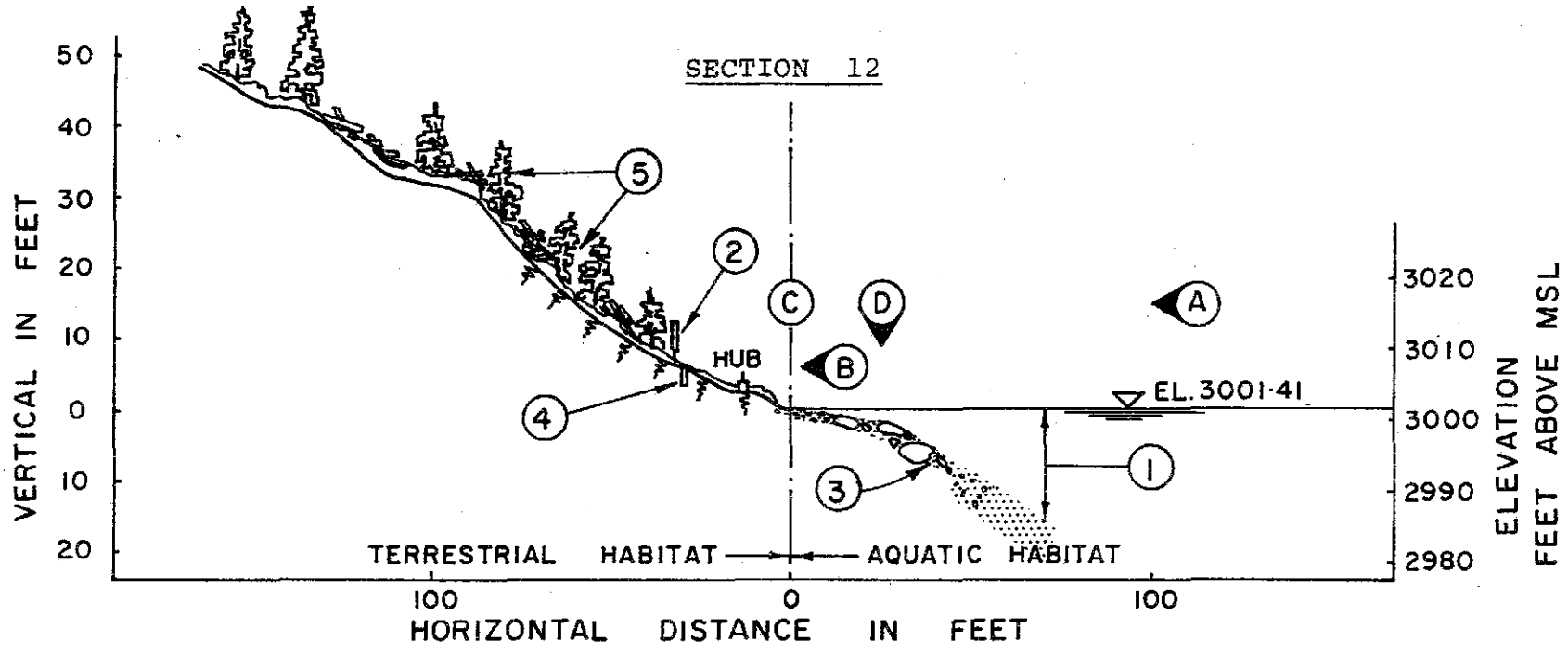
Shoreline perpendicular to section showing bouldery beach area.



Close-up view showing new growth of white spruce and willow.



Sandy bottom photographed through periscope 20' from shoreline .



(3) UNDERWATER SUBSTRATE:-

- first 15' mainly boulders, cobbles and gravel.
- next 40' gravel and sand.
- remainder to 15' depth, sand.

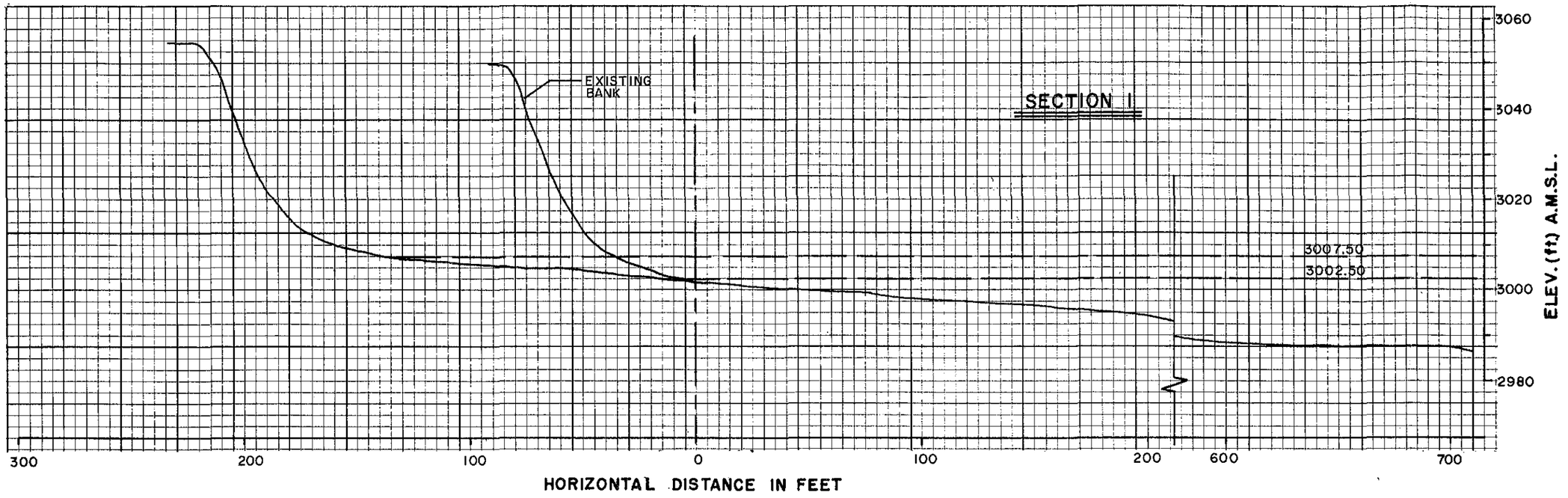
(4) TEST PIT COMPOSITION:-

- top 0.4' black organic soil with thin layers of clay and sand.
- remaining 2.1' depth mainly fine gravel with some sand and cobbles.

(5) VEGETATION:-

- first 30' low shrubs and mosses.
- remainder mainly white spruce, willow and mosses (burnt-off area containing small size trees).

FIGURE 27



PROBABLE BANK RE
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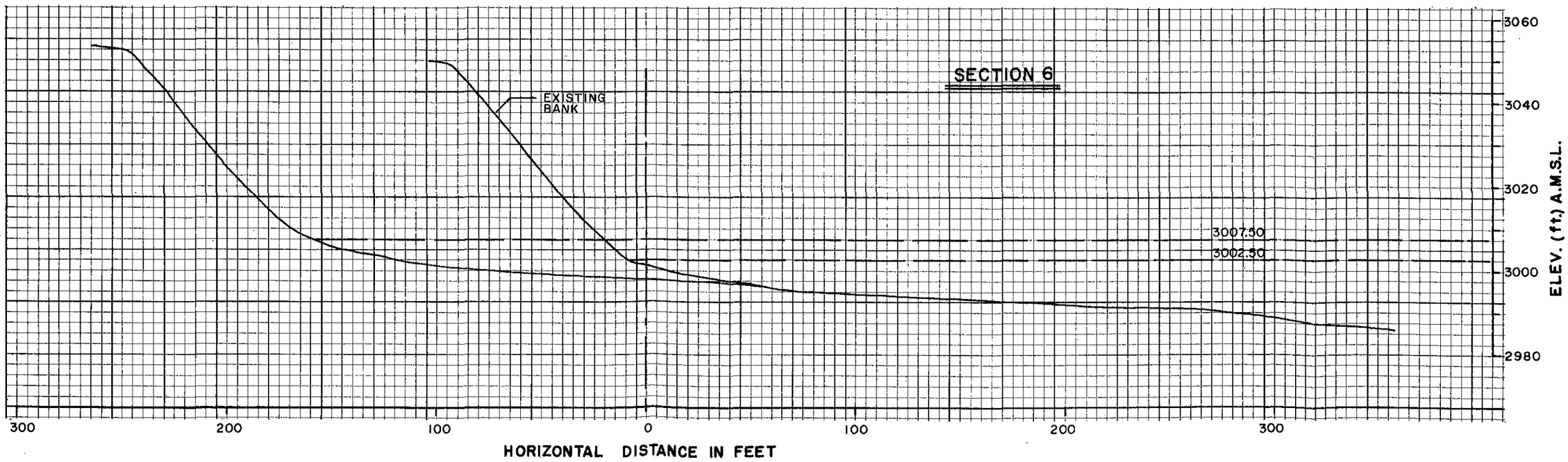
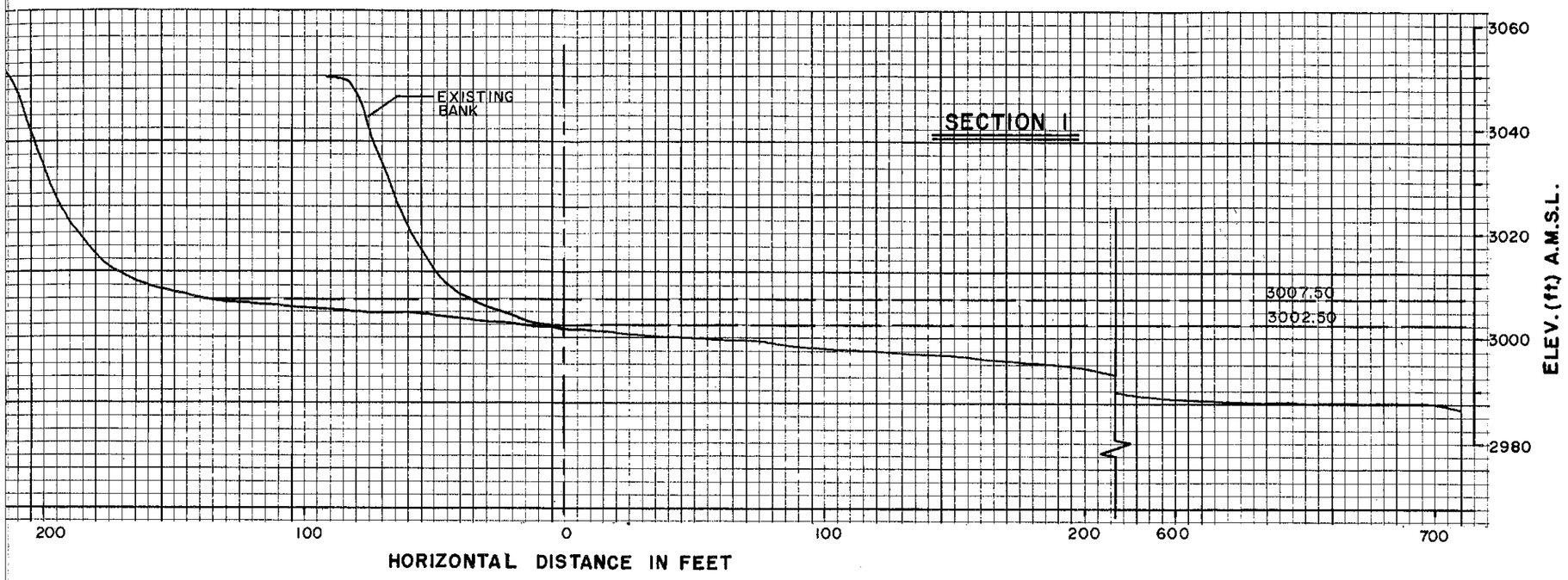
SECTIONS I AND 6.





PROBABLE BANK RECESSION RESULTING FROM INCREASED STORAGE LEVELS AT SECTIONS 1 AND 6.