TABLE OF CONTENTS

DRAFT

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

As described in the work plan of Task 42 of Susitna Hydroelectric Project, the reservoir temperature/ice studies are required for supporting the environmental studies. These studies will determine the hydrothermal behavior of the Watana and Devil Canyon reservoirs as affected by the design and operation of the project and provide necessary information for optimal design and operation of the reservoirs. It will also determine the thermal characteristics of the reservoir outflow for the downstream river temperature and ice studies and the subsequent assessment of the potential environmental impacts due to project operations. The dynamic reservoir simulation model DYRESM as developed by Imberger, Patterson and others of the University of Western Australia (13)[1/] was selected to simulate the hydrothermal behavior of the reservoirs. To simulate the winter condition with ice formations, an ice subroutine as developed by Patterson and Hamblin for Canadian Lakes has been incorporated in the model. To calibrate the model and to verify its applicability to the Watana and Devil Canyon reservoirs under south-central and interior Alaskan climatic conditions, the Eklutna Lake study has been carried out. In this report, the results of the Eklutna Lake study and the calibration of the DYRESM model are discussed.

2.0 EKLUTNA LAKE STUDY: DYRESM MODEL CALIBRATION

The DYRESM model simulates average reservoir hydrothermal behavior through parameterization of various physical processes such as inflow and outflow dynamics, mixed layer dynamics, vertical transport in the hypolimnion and surface heat and mass exchanges. The basic time increment of one day is set by the model to predict daily thermal structure. However, a smaller subdaily time increment ranging between one quarter hour and twelve hours is

---

1/ Refers the numbers in "Reference" at the end of text.

used to simulate the more complicated mixed layer dynamics. This procedure allows small time increments when the dynamics so require and, in less critical periods, the time increment expands without reduction in accuracy. Hence, detailed daily meteorological and hydrological data are required in the DYRESM simulation. A data collection program was established in June, 1982 for Eklutna Lake to collect data on the thermal structure of the reservoir, inflow and outflow. Eklutna Lake is located apparoximately 30 miles northeast of Anchorage (Fig. 1). A weather station (Fig. 2) located near the southern end of the lake was also established to provide the necessary meteorological data to DYRESM.

2.1 Data Collection

The average daily meteorological data include:

- Mean air temperature (°C);
- Mean wind speed (m/s);
- Air vapor pressure (mb);
- Precipitation (mm);
- Cloud cover (sky fraction in tenths) or,
- Long-wave atmospheric radiation (kilojoules/m^2); and
- Total short-wave radiation (insulation) (kilojoules/m^2).

The six-hour averaged wind speeds along the major axis of the lake are also required to calculate the internal mixing due to internal waves.

In addition to meteorological data, the quantity and temperature of inflow to the lake and outflow from the lake are required to simulate the reservoir dynamics (1). The inflow data including temperature and stage was obtained by establishing two gaging stations on the major tributaries, East Fork and Glacier Fork (Fig. 2) (1). For calibrating the DYRESM model, measurements of lake temperature profiles were made at seven locations on an approximate two-week interval (1). Detailed descriptions of the input data collection program are given by R&M (11). The quantity and temperature of the daily outflow through the Eklutna Hydroelectric plant turbines were furnished by the Alaska Power Administration of the U.S. Dept. of Energy.

These data have been collected, reduced, compiled, and reported by the R&M Consultants, Inc. (3, 11). The monitoring system and the accuracy of the measurements were also described by R&M (1, 3, 11). The data collection program began in June, 1982 and will be terminated in early 1984. Periodic malfunctioning of instruments have been experienced, especially in July and August of 1982 where many days of data are not recorded (11), and consequently, estimations of these data were required based on nearby stations at Palmer and Anchorage. The ice thickness measurements were taken approximately once a month.

A comparison of the relative humidities measured at Anchorage and Talkeetna by the National Oceanic and Atmospheric Administration (NOAA) indicates that the Eklutna relative humidity data are generally too low and are not in good agreement with other climatic (especially precipitation) data measured at Eklutna Lake Station. Therefore, the Anchorage relative humidities published by NOAA were used to compute the vapor pressures.

The data records available at Eklutna Lake station are plotted and shown on Figs. 3 and 4. The period of recorded data at the Eklutna Lake Station are shown in Figs. 5-8.

2.2 Previous Studies

A previous effort by ACRES on the calibration and verification of the DYRESM model with the observed data had concentrated on the period of June, 1982 through December 1982 during which the field data were measured.

Adjustments were made on all wind speed data. In DYRESM, the wind speeds are assumed to be measured at a height of six meters while the field instrument measures wind speed at about two meters above surrounding scrub vegetation. Therefore, the wind speeds were corrected based on the velocity distribution in the boundary layer of the air current. The adjustment produces an increase of 17 percent in measured wind speeds.

It was noted that the July and August field measurements were quite incomplete and significant amount of the meteorological data had to be estimated (12). Therefore, the Eklutna Lake temperature/ice simulation was made for the periods June 1 to August 25, 1982 and August 25 to December 31, 1982 to minimize the effect of data gap.

The simulated temperature profiles did show reasonable agreement with the measured temperatures except under severe wind conditions such as the high wind periods which occured between September 9 and September 21. Under severe wind condition, significant mixing can occur and warmer water can be expected in the hypolimnion. In addition, the one-dimensionality of the reservoir hydrothermal behavior is not strictly valid. The problem was resolved by increasing the vertical diffusion coefficient which represents the efficiency of the transport of mass and momentum from 0.048 to 0.096 based on the Wedderburn number criterion (13, 14). The Wedderburn number characterizes the one-dimensionality of the reservoir dynamics, with the value less than 3 indicating a departure from the one-dimensional assumption.

The key constants used in the DYRESM simulation are given in Table 1. These constants are related to well identified physical processes and are determined from experimental or field data (13, 14). The simulated and measured temperature profiles at Station 9 in the approximate center of the lake are given in Figs. 9 to 11. In general, most profiles are modeled to within 0.5°C with few exceptions that the difference was up to about 2°C.

The simulated and measured outflow temperature of the Eklutna Lake are given in Figs. 12 and 13. The predicted outflow temperature is, in general, 1 to

2°C below the measured temperature during the period of July to mid-September. From mid-September to December, the predicted and measured temperatures match relatively well. The simulation also indicates that the ice-cover formation will begin in mid-November and predicted 21 inches of ice-cover near the end of December. On January 13, 1983, an ice-cover of about 16 inches was measured near the center of the lake. Hence, the simulation overestimates the ice-cover thickness by about 5 inches in early January 1983.

2.3 Present Study

2.3.1 DYRESM Model Enhancements

The Eklutna Lake temperature and ice analyses conducted in the previous study indicate that the DYRESM model performs relatively well in duplicating the average field condition of the lake thermal structure. However, upon further examination of the previous results, field data, and the configuration of the intake structure, several enhancements and/or modifications of the DYRESM model were made and they are discussed as follows:

The "Swinbank" equation used in the DYRESM model may be significantly underestimating the incoming long wave atmospheric radiation on the Lake. Such observation was made independently by both Dr. P.F. Hamblin, the consultant to the reservoir temperature and ice study, and R&M. Additional analyses indicate that the empirical equation given by Anderson (4) agrees well with the measured values at Watana and was incorporated in the DYRESM model (Fig. 14). The Anderson's equation is given as

$$H_{L.W.} = E_a \sigma T^4$$

where $H_{L.W.}$ is the long-wave atmospheric radiation (KJ/day), E_a is the atmospheric emissivity, σ is the Stephen Boltzman constant (4.979 x 10^{-6} KJ/day), and T is the air temperature (° Kelvin). The atmospheric emissivity is dependent upon the cloudiness of the sky and the relative humidity or vapor pressure (3). The emissivity increases as the cloud cover or vapor pressure increase.

Using the Anderson's equation, closer matches to measured temperature profiles taken near the center of the lake (Station 9) were obtained as shown in Figs. 15 to 24.

With regard to outflow temperature predictions there are two modifications. One for the geometry of the intake structure and the other for wind forcing effects. The local bathymetric condition and the configuration of the intake structure are quite different from the conditions assumed in the DYRESM model. The model assumes that a vertical wall such as a dam is located at the downstream end of the reservoir and the offtakes are located at the center of the dam width. However, the intake structure of the Eklutna powerhouse is located near the north end of the lake on a mild sloping bottom and resembles a horizontal outfall structure situated on an excavated area. Hence, the Eklutna intake may draw most of the water from the layers above. With the combined effects of the sloping bottom, the horizontal outfall type intake and the local excavation, the outflow temperature may not be treated accordingly by theory. The wind effect, especially in the months of July, August and September, is clearly shown in the outflow temperature and 6-hr wind plots, given in Fig. 25. It is understood that such outflow thermal behavior has also been observed by the powerhouse personnel. When a downlake wind (toward the intake area) occurs, a warmer than normal outflow temperature is observed. Such temporal deviation of the outflow temperature from its normal trend can be attributed to not only the surface wind shear stress but also the behavior of the internal waves of the stratified fluid, the depth of the epilimnion, the relative position of the intake to the thermocline and the local bathymetric configuration. Since the present time frame does not permit further development of the DYRESM model to take into account all the variables identified above, only the surface wind and the bottom effects are considered in the current study and are discussed as follows:

The bathymetric information indicates that the bottom slope near the intake area is about 1 vertical to 100 horizontal. Hence, the withdrawal layer (outflow) distribution must be modified in the outflow dynamics calculation. Through several numerical experiments, it was found that satisfactory outflow temperatures can be obtained by assuming that the offtake draws water mainly from layers above the intake and the withdrawal from the lower layers is insignificant.

The strong downlake winds tend to increase the mixing locally near the intake. The strength of such wind induced mixing is considered proportional to the magnitude of the wind along the major axis of the lake toward the intake. The effect is considered equivalent to the deepening of the epilimnion at the intake area. The equivalent deepening of the epilimnion, H is computed by the following emperical equation:

$$H = (\text{Intake depth}) \times \frac{W}{C1} \times \left[\left(1 - \frac{W}{C1}\right) \times C2\right]^2$$

Where W is the 6-hr wind in the downlake direction and C1 and C2 are empirical constants for adjusting the magnitude of the responses. It was found that values of 20.0 and 0.25 for C1 and C2 respectively produce satisfactory results for summer, and 7.5 and 0.25 for fall. Since better agreements were obtained with these modifications, the adjustments based on Wedderburn criteria for high wind condition as described previously were not applied and a constant vertical diffusion coefficient of 0.048 was used.

The influence of ice and snow on the heat transfer across the water surface of a reservoir is taken into account by simulating the percentage of snow and ice cover and their thickness as a function of time. The effect of snow and ice is to reduce the amount of short wave radiation reaching the upper layers of the reservoir through the absorptive properties of ice and snow and to reduce the cooling of the reservoir surface that would otherwise occur by providing a covering layer of reduced thermal conductivity and by creating additional ice at the ice-water boundary.

Specific physical processes incorporated into the model of ice and snow are:

1. Minimum ice thickness of 10 cm.
2. Surface melting of either snow or ice as well as ice melting at the ice water interface.
3. Reduction of snow or ice thickness by surface evaporation
4. Account of ice or snow on surface vapor pressure
5. Snow albedo as a function of snow age and temperature
6. Short wave absorption in snow and ice
7. Ice-water heat flux due to molecular conduction across ice-water interface plus turbulent sensible heat flux due to inflow and outflow induced current in the upper layer of the reservoir.
8. Computation of surface temperature of the snow or ice from the surface heat budget.
9. Limitation of maximum snow thickness allowable based on ice buoyancy relative to snow loading
10. Incorporation of frazil ice input to total ice volume in the reservoir

2.3.2 Eklutna Lake Temperature and Ice Simulation

One of the major objectives in the Eklutna Lake calibration study is to develop an understanding of the capability, concept, and structure of the DYRESM Model. This understanding has led to the development of several program enhancements to calibrate the model under south-central and interior Alaskan climatic conditions as previously discussed. The Eklutna Lake study has also demonstrated the need for accurate climatic data to enable the model to properly simulate the hydrothermal behavior of the reservoirs.

Every effort should be made in the future to insure the accuracy and reliability of field measurement instruments and data collection procedures.

The study by Harza-Ebasco (H/E) considered the period of June, 1982 through June, 1983. The H/E simulation also included a 17% increase in measured windspeeds to correct the velocity to the height above vegetation assumed by the model. The Wedderburn number modification procedure was not used in lieu of the empirical equation to deepen the epiliminion at the intake area and the modification of the withdrawal dynamics.

The results of the H/E Eklutna Lake study are shown in the temperature profile plots, Figs. 15 to 24, and in the outflow temperature time history plots, Figs. 26 and 27. The results of the study demonstrate the capability for the DYRESM Model to properly simulate the hydrothermal behavior of a reservoir in the specific region of the Susitna Project. The results show the accurate prediction of winter outflow temperatures within an acceptable tolerance of ± 1 degree Celcius. The results also show that the summer outflow temperatures were simulated to within ± 1 to 2 degrees Celcius. The outflow temperature is a principle parameter in the river temperature and ice studies to determine the environmental impact of the project operations. The results also show an excellent correspondence between measured ice thickness and predicted ice thickness except for one point in March at Station 13 which is located near the north end of the lake. There were no ice measurements made near the center of the lake in March. The relatively thick ice measured at Station 13 in March may be considered due to local accumulation of snow caused by downlake winds. Therefore, the larger difference (Fig. 27) shown in March is not considered as a major concern.

It is understood that the Eklutna Lake reservoir data collection program will be terminated in early 1984. The additional data collected and compiled by R&M will then be available to extend the Eklutna Lake temperature simulation. The results from that study will be reported as a supplement to this report.

3.0 WATANA RESERVOIR TEMPERATURE

The DYRESM model was used to simulate Watana reservoir temperature behavior and outlet temperatures under the 1981 flow condition. The parameter values of the model used in the Eklutna Lake calibration has been applied. A field program was established in April, 1980 within the Susitna River Basin (Watana Camp) to collect meteorological data (5-12) for the DYRESM model. The climatic stations are shown in Fig. 28. The periods of the available records are shown in Figs. 29-32.

3.1 Data Collection

The required average daily meteorological data include:

- Mean air temperature (°C);
- Mean wind speed (m/s);
- Air vapor presence (mb);
- Precipitation (mm);
- Long-wave radiation (KJ/m^2) or cloud cover (sky fraction in tenths); and
- Total short-wave radiation (KJ/m^2).

3.2 Previous Study

As described in the License Application, daily simulations were made by Acres to predict the thermal behavior of the Watana reservoir operating under the year 2010 power demand (Case C; 12,000 cfs minimum August flow). The simulation period is six months (June 1 through December 31, 1981).

3.2.1 Reservoir Temperature Profiles

The simulated temperature profiles for the first day of each month of June through December 1981 are shown in Figs. 33 and 34. Stratification occurs during June, July and August. The maximum surface temperature simulated was 10.9°C on July 3 and August 28. Cooling in September results in the gradual destruction of summer stratification and the deepening of the epiliminion. The process continues until isothermal conditions occur in late October. Isothermal conditions continue until water reaches its maximum density, after which reverse stratification takes place. A weak stratification occurs in late November and remains relatively stable throughout December. A full ice cover occurs on November 22. Ice thickness on December 31 was estimated at 31 inches.

3.2.2 Outflow Temperatures

The multiple-level intake at Watana allows the utility to provide variable water temperatures within a range dictated by the thermal structure within the reservoir. The philosophy of operating this structure is to provide water temperatures as close to the ambient river temperatures as possible. In general, this results in the intake closest to the surface being used, provided hydraulic submergence criteria are met. However, on a few days, deeper intakes are used to provide water temperatures which are closer to those required. The simulated outflow temperatures are shown in Figs. 35 and 36.

The comparison of natural temperature and simulated outflow temperature shows that during summer months, the outflow temperature follows natural temperature trends but is cooler during July and slightly warmer in August. During September to mid-November, the results show a gradual reduction of outflow temperature from 9.5°C to 2°C while the inflow temperature drops much sooner to 0.5°C in mid-September. Stable outflow temperature of around 2°C start in mid-November and continue throughout December.

3.3 Present Study

The input data used in the previous study and the parameter values of the model used in the calibration study were used to simulate reservoir temperature profiles and outflow temperatures. The selective withdrawal capability which was not required in Eklutna study was implemented to simulate operation of the multi-level intakes.

The simulated temperature profiles and outflow temperatures are shown in Figs. 37, 38 and 39. The results indicate that the temperature profiles obtained in the two studies are relatively similar, and the difference in outflow temperatures between the two studies are within 0.5°C (average). Both studies also predicted an increase of about 6°C in the stream flow temperature in late September due to discharging of warmer stratified water from the reservoir. A full ice cover occurs on December 1, 10 days later than the previous study. Ice thickness on December 31 was estimated about 25 inches, 6 inches less than the previous study. Since the ice and snow model yielded better results in the Eklutna Lake Study, the results obtained in the present Watana Study are also considered more accurate.

4.0 SUMMARY

In this study we have simulated the Eklutna Lake thermal behavior and ice growth based on the DYRESM Model. Some of the input data have been improved for consistency with the nearby climatic stations. The outflow dynamics have also been modified to take into account the special configuration of the horizontal intake structure, the mild sloping bottom, and the wind forcing effect. All modifications made to the model for the Eklutna Lake study are not necessarily required for the Watana and Devil Canyon reservoir studies. Both reservoirs will have vertical multi-level power intake structures with approach channels. The approach channels will force the intakes to withdraw more water from the upper layers, therefore, the outflow algorithm has been modified to accomodate such effects. The longwave radiation formula presented by Anderson will be used in the Susitna Reservoir Studies as this equation seems to better apply to the project location. The modifications made to the ice and snow processes will also remain and others may be added to better model the effects of incoming frazil ice upon the total ice volume in the reservoir.

The results of the Eklutna Lake study establishes the applicability of the DYRESM model to accurately simulate thermal reservoir processes in the South-Central Alaskan climatic conditions. The study also demonstrated the need for accurate climatic and river data to insure the correctness of the model results.

The resulting DYRESM model calibrated through the Eklutna Lake Study is assumed to be applicable to Watana reservoir with minor modifications to take into account the effects of approach channels and frazil ice inflows. The parameter values of the Eklutna model were used to simulate Watana reservoir temperature profiles and outflow temperatures. The study yields improved results as compared with Acres'.

After the completion of the project, the parameters must be checked at regular intervals. The model should be re-calibrated after several years of project operations since the changes in morphology and nutrient condition may change the parameter values.

REFERENCES

NO.	TITLES

1. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Glacial Lake Studies," prepared for Acres American Incorporated and Alaska Power Authority, December, 1982.

2. R & M Consultants Incorporated, "Susitna Hydroelectric Project, DYRESM Input Data," prepared for Harza-Ebasco Susitna Joint Venture and Alaska Power Authority, August, 1983.

3. J.M. Raphael, "Prediction of Temperature in Rivers and Reservoirs," Proc., ASCE, J. Power Div., PO2, July, 1962.

4. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 1 - Susitna Glacier Station," prepared for Alaska Power Authority, December, 1982.

5. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 2 - Denali Station," prepared for Alaska Power Authority, December, 1982.

6. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 3 - Tyone River Station," prepared for Alaska Power Authority, December, 1982.

7. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 4 - Kosina Creek Station," prepared for Alaska Power Authority, December, 1982.

8. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 5 - Watana Station," prepared for Alaska Power Authority, December, 1982.

9. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 6 - Devil Canyon Station," prepared for Alaska Power Authority, December, 1982.

10. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 7 - Sherman Station," prepared for Alaska Power Authority, December 1982.

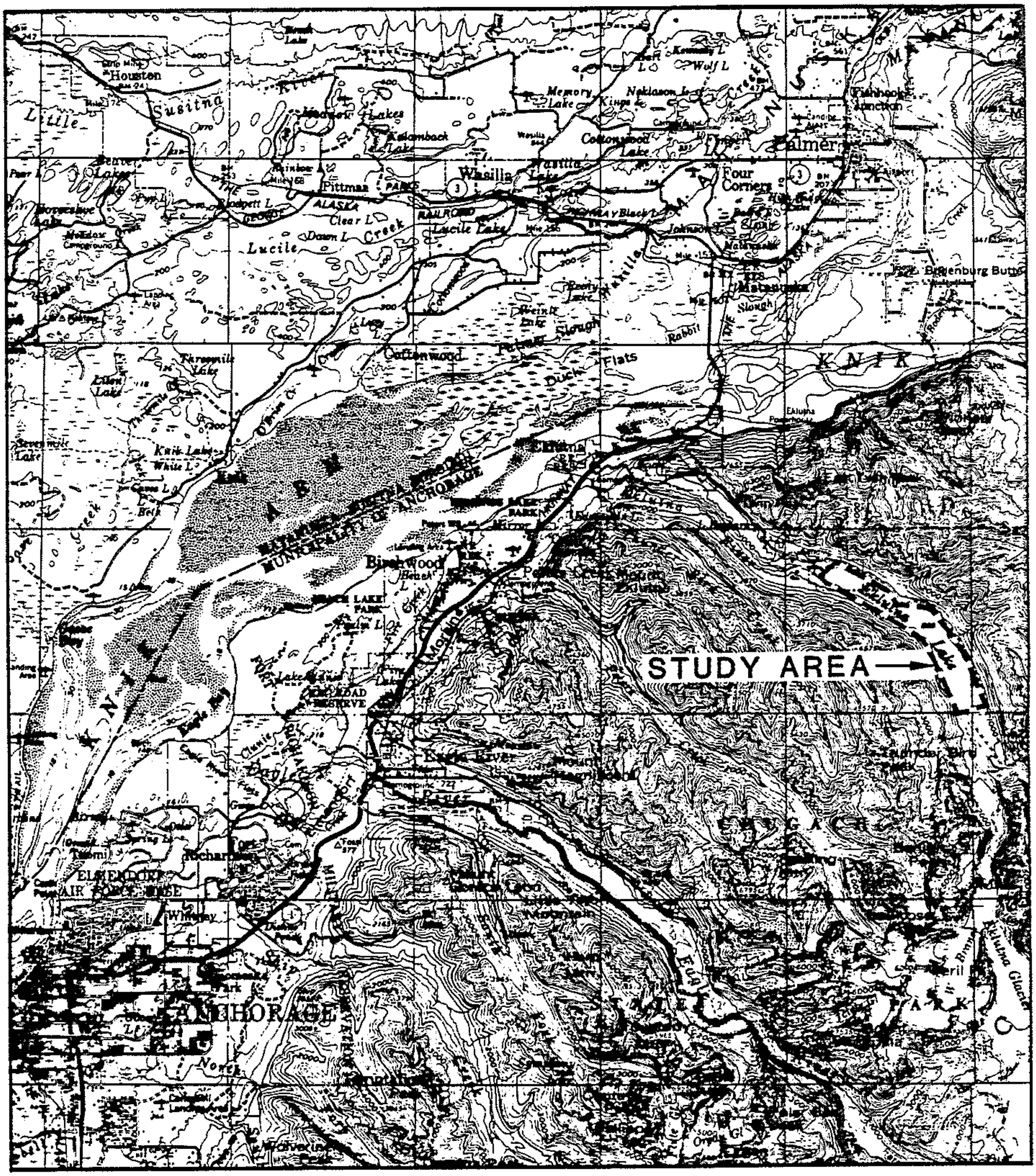
11. R & M Consultants Incorporated, "Susitna Hydroelectric Project, Processed Climatic Data, Volume 8 - Eklutna Lake Station," prepared for Alaska Power Authority, December, 1982.

NO.	TITLES
12.	R & M Consultants Incorporated, "Susitna Hydroelectric Project, Field Data Collection and Processing, Supplement 1," prepared for Alaska Power Authority, December, 1982.
13.	J. Imberger, and J.C. Patterson, "A Dynamic Reservoir Simulation Model - DYRESM:5," Transport Models for Inland and Coastal Waters, Chapter 9, Academic Press, 1981.
14.	Acres American Incorporated, "Susitna Hydroelectric Project, Feasibility Report - Supplement: Chapter 8," prepared for Alaska Power Authority, 1983.

TABLE 1 - DYRESM Parameters for Eklutna Lake

PARAMETER	VALUE
Convective overturn, CK	0.125
Mechanical stirring, ETA	1.230
Temporal effects, CT	0.510
Shear production, CS	0.200
Shear instability, AKH	0.300
Diffusion constant	0.048
Drag coefficient of river inflow	0.015

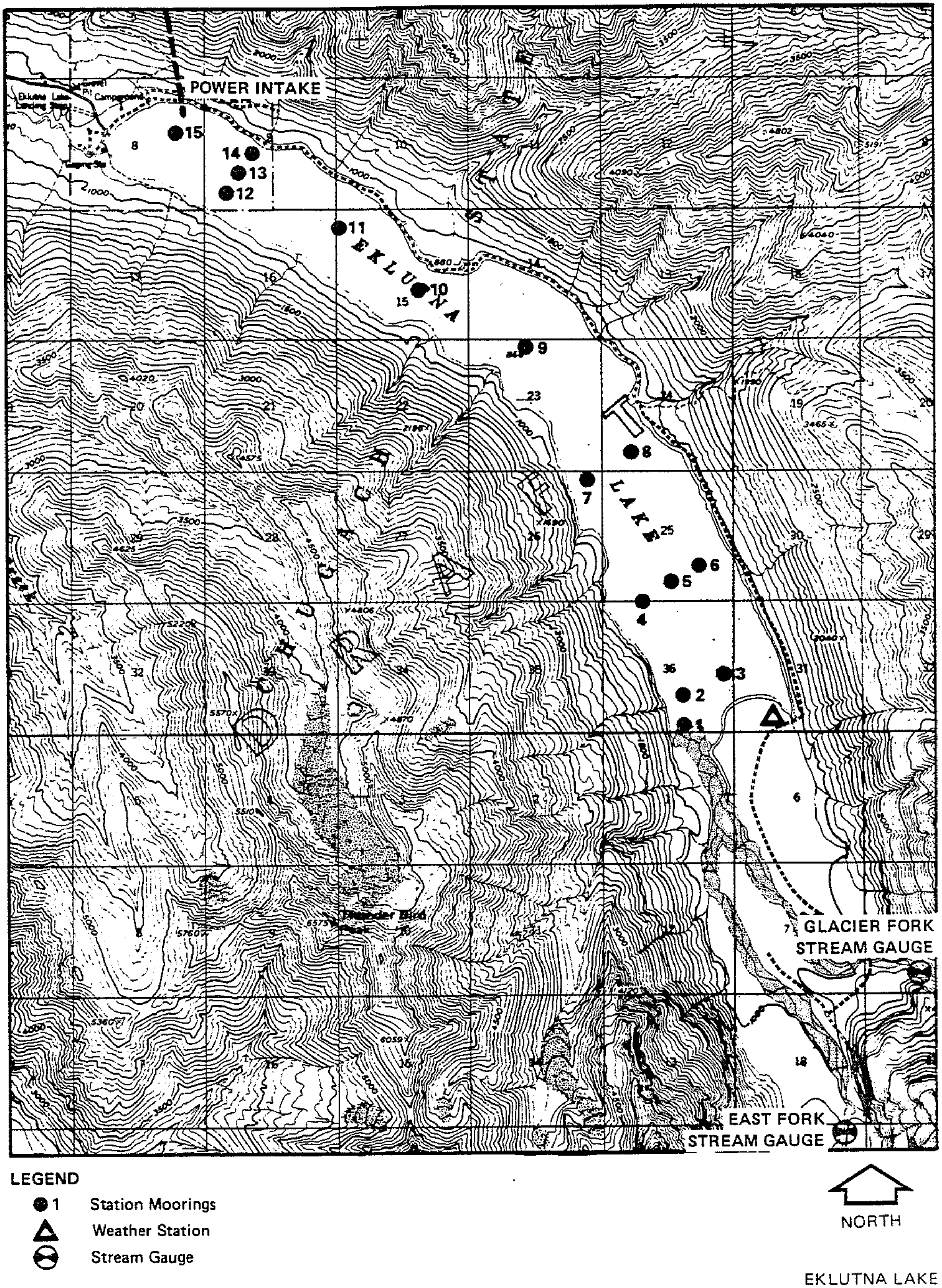
Figure 1



NORTH

EKLUTNA LAKE
LOCATION MAP

Figure 2



EKLUTNA LAKE
STATION LOCATIONS

HARZA–EBASCO Susitna Joint Venture • January 1984

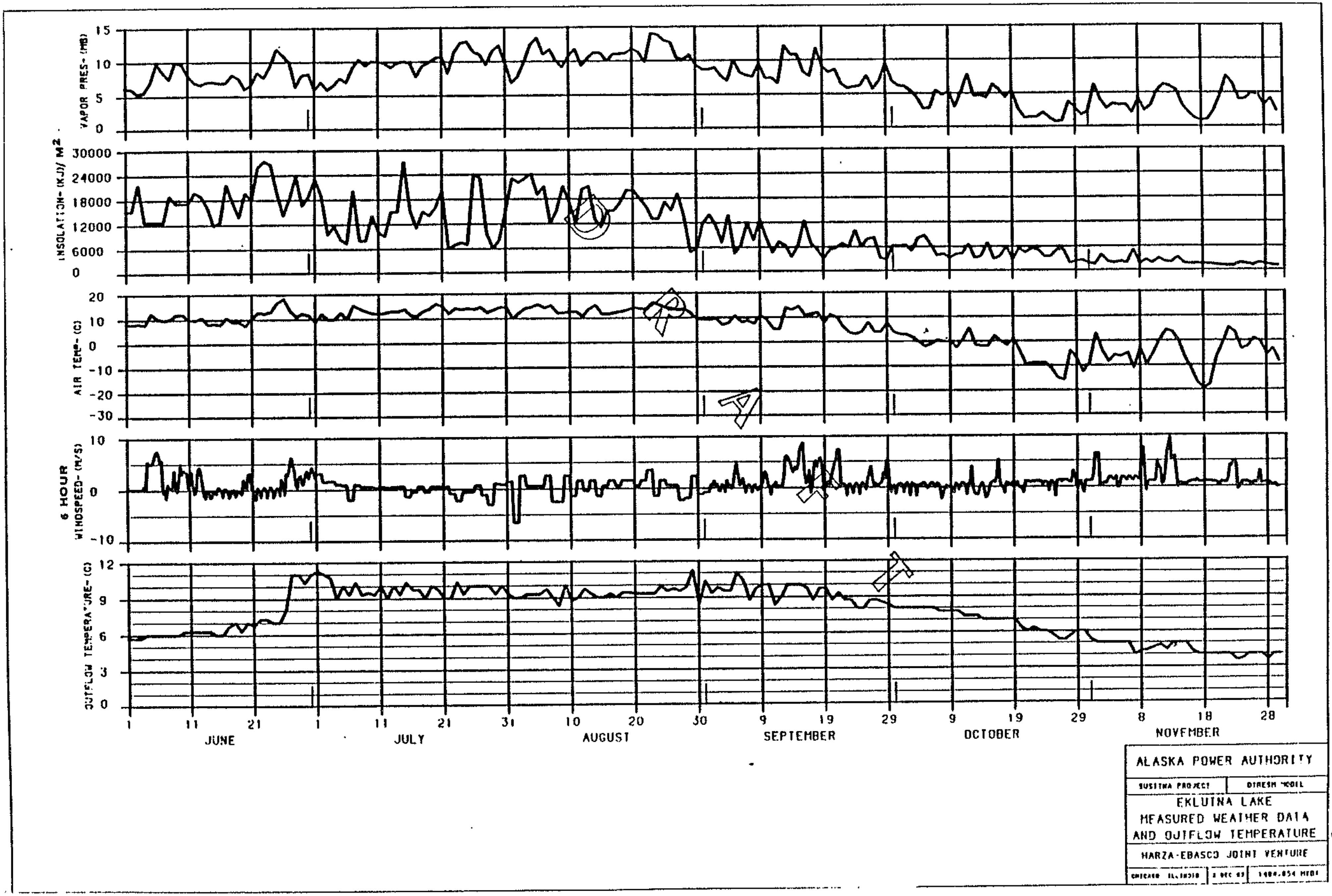
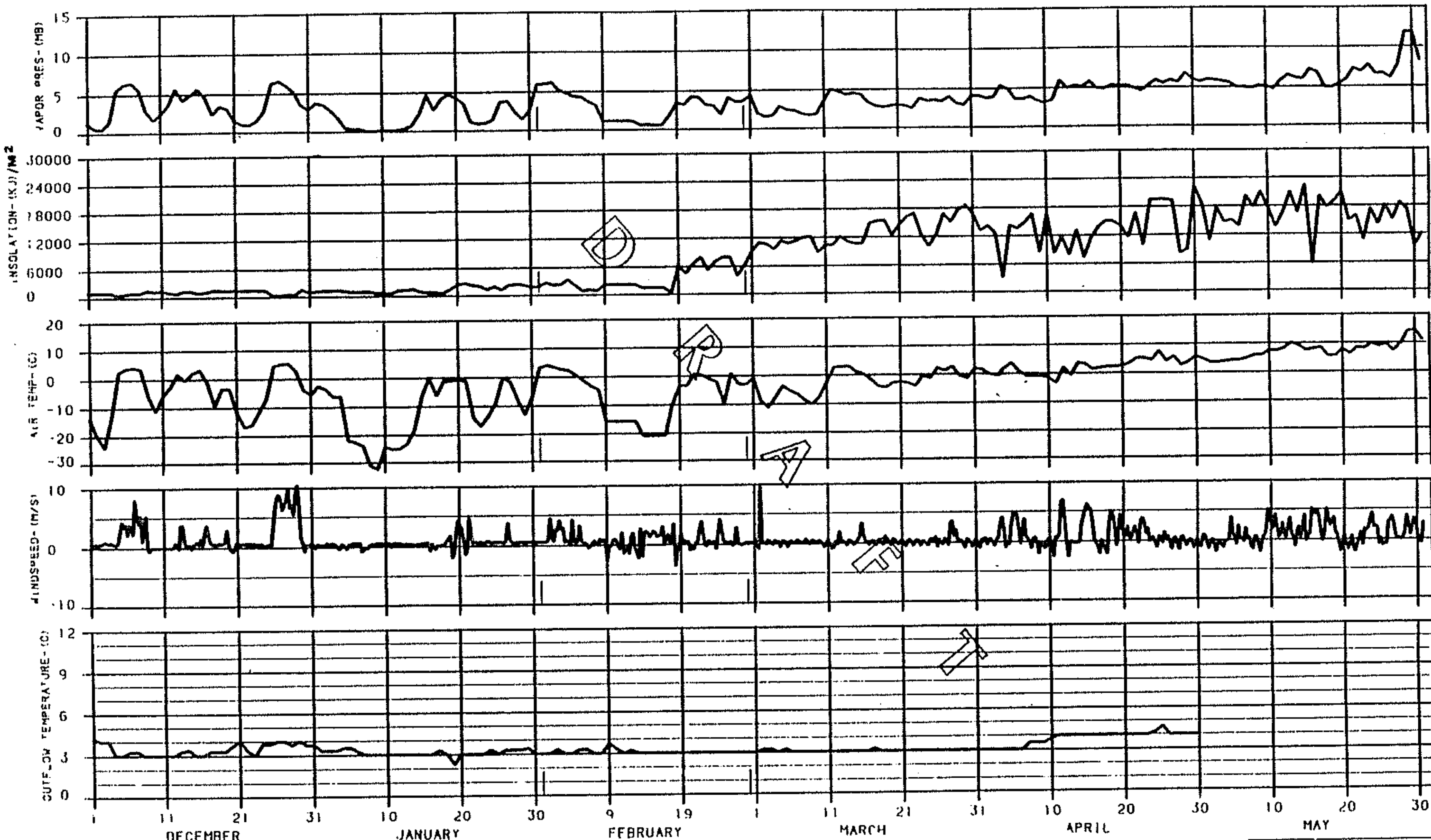

VAPOR PRES- (MB)
INSOLATION- (KJ)/ M2
AIR TEMP- (C)
6 HOUR WINDSPEED- (M/S)
OUTFLOW TEMPERATURE- (C)
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
ALASKA POWER AUTHORITY
SUSITNA PROJECT
EKLUTNA LAKE
MEASURED WEATHER DATA
AND OUTFLOW TEMPERATURE
HARZA-EBASCO JOINT VENTURE

Figure 3



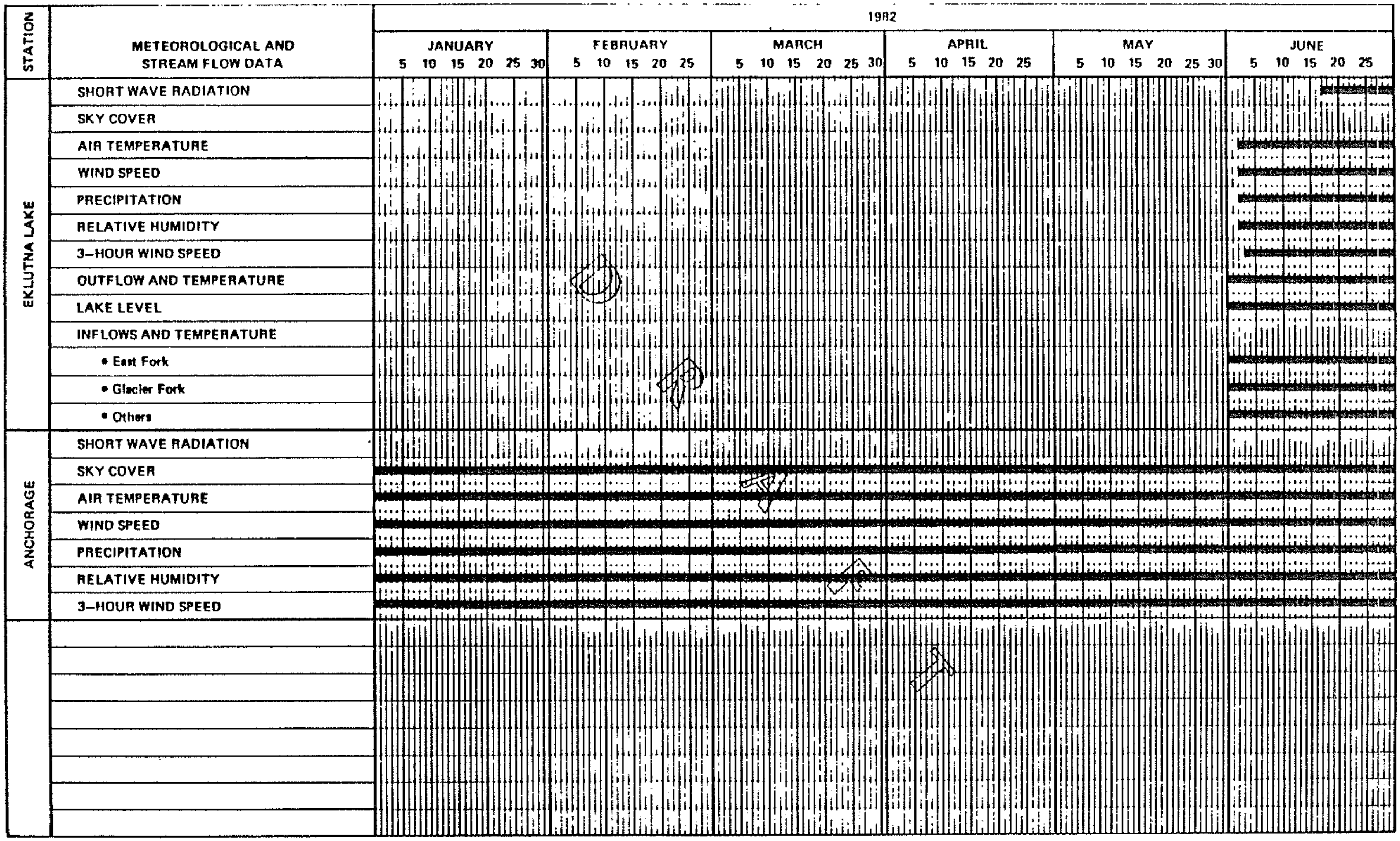
ALASKA POWER AUTHORITY

SUSITNA PROJECT	DYRESM MODEL

EKLUTNA LAKE
MEASURED WEATHER DATA
AND OUTFLOW TEMPERATURE

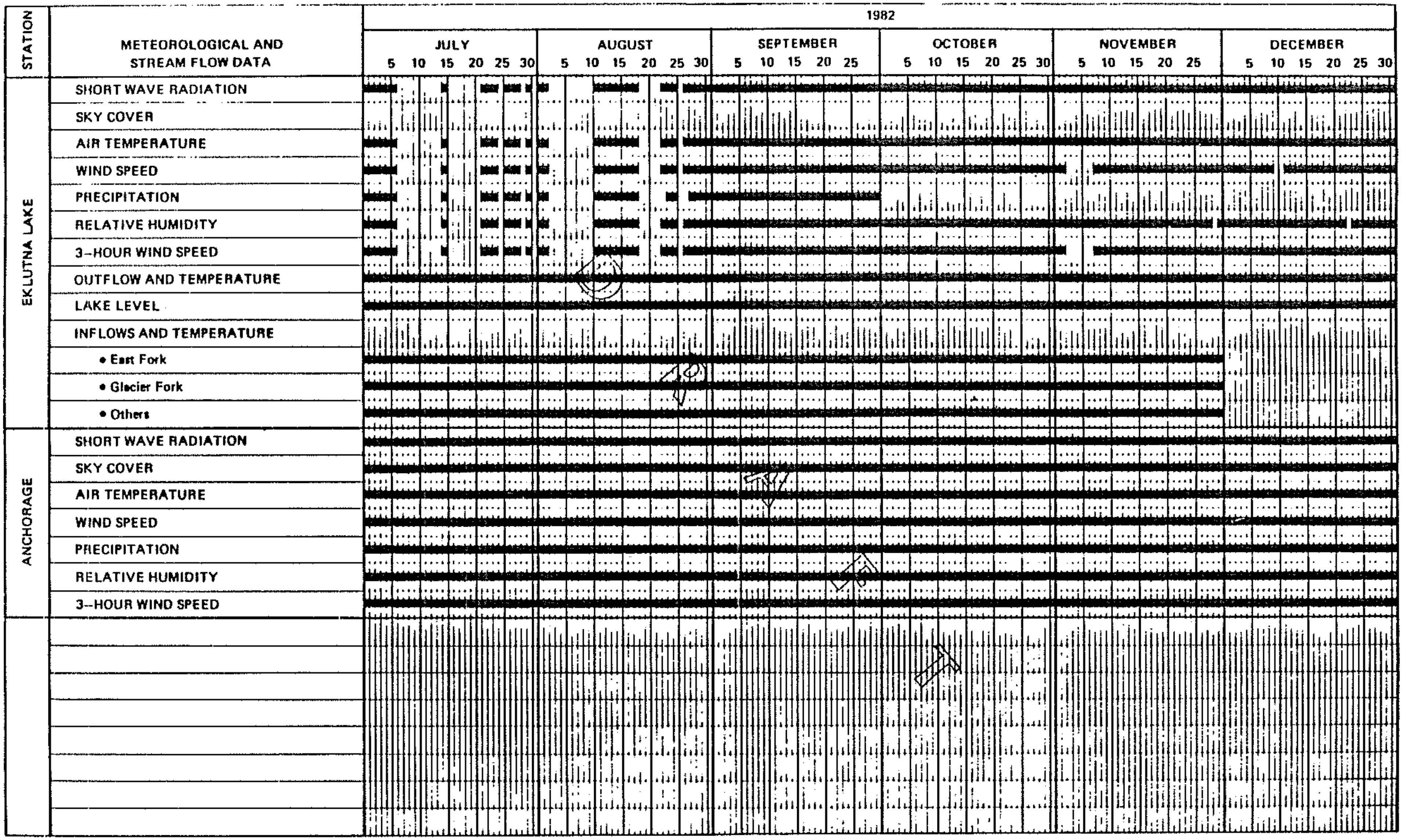
HARZA EBASCO JOINT VENTURE

Figure 4

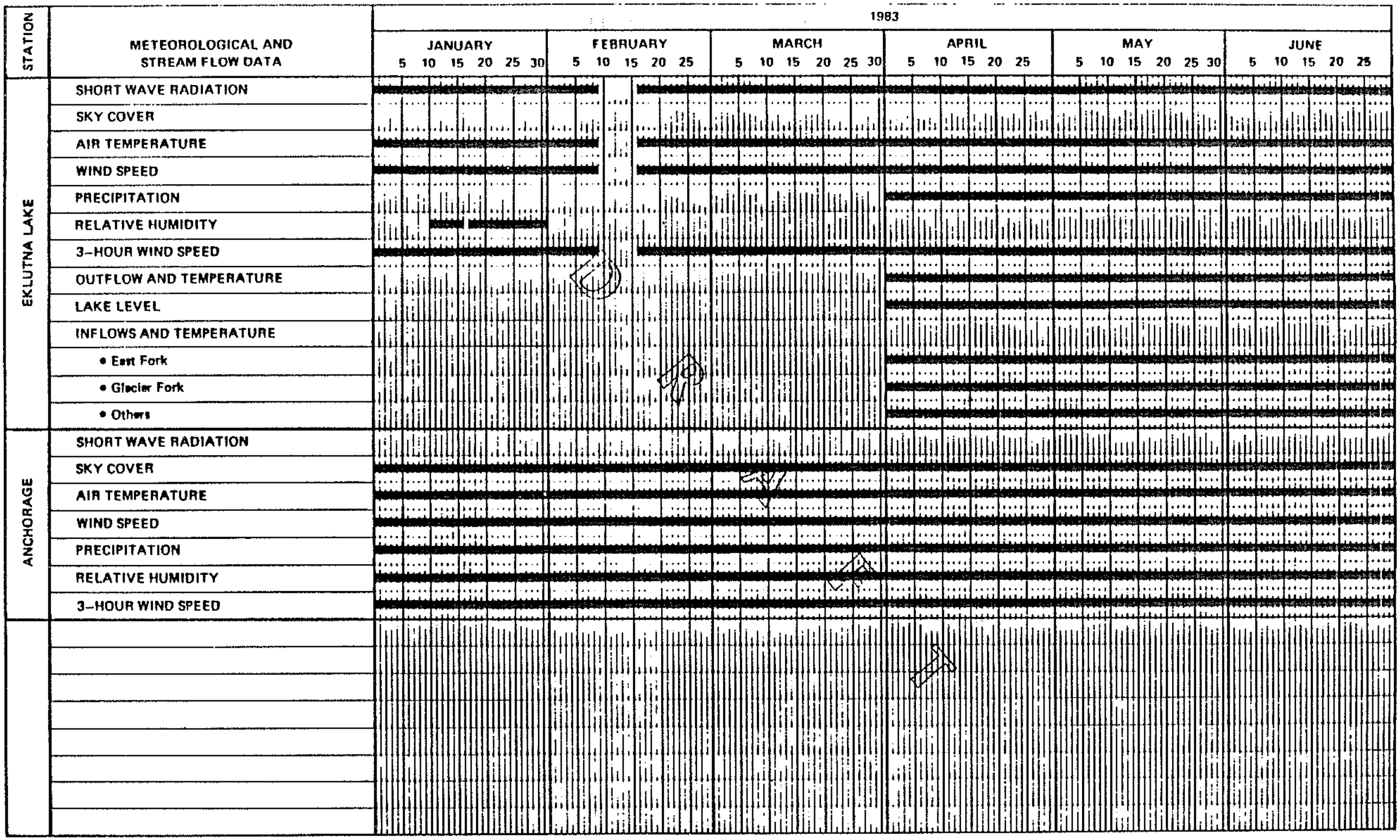


EKLUTNA LAKE
CLIMATIC DATA AVAILABILITY

Figure 5



EKLUTNA LAKE
CLIMATIC DATA AVAILABILITY
Figure 6



EKLUTNA LAKE
CLIMATIC DATA AVAILABILITY

Figure 7

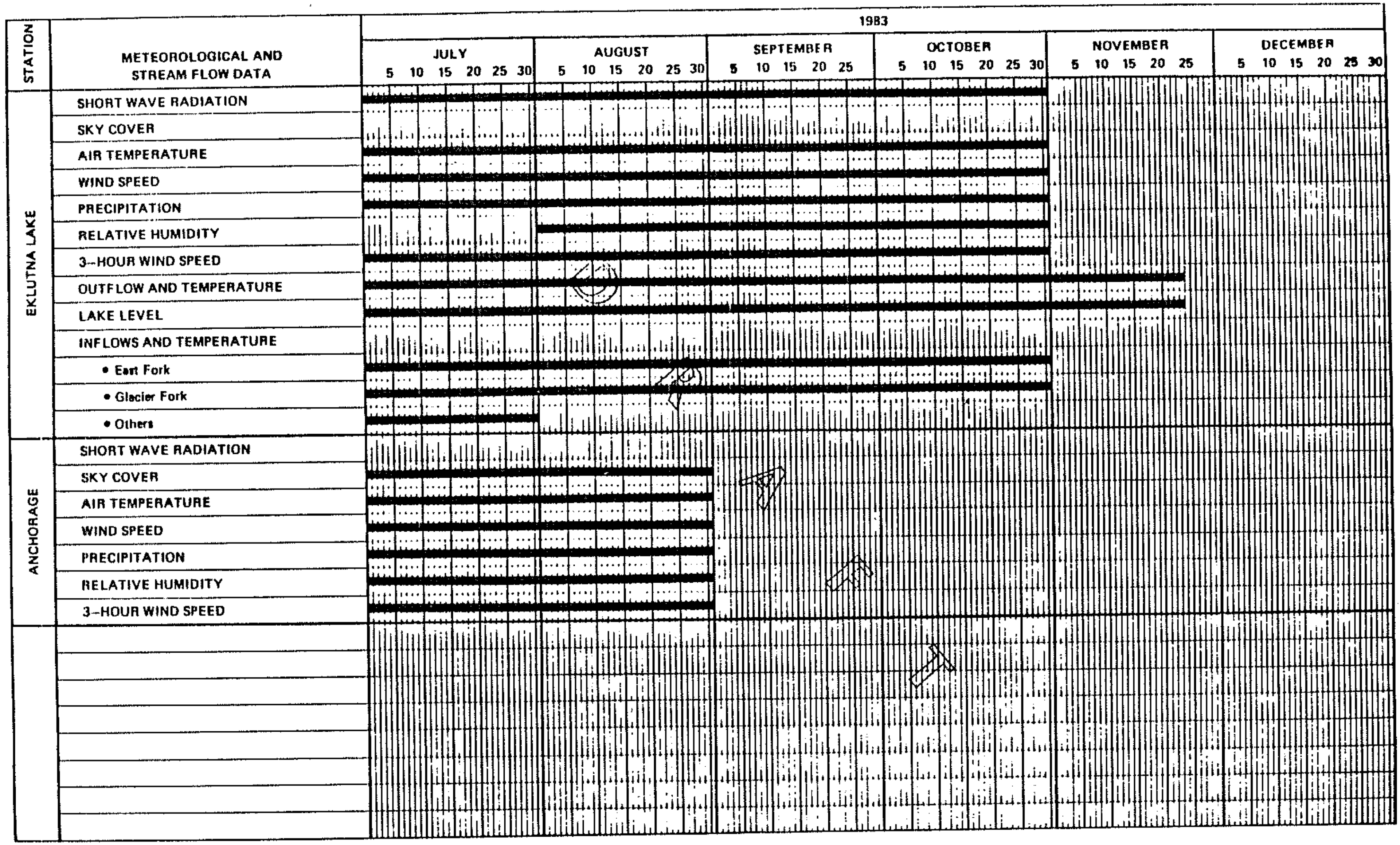
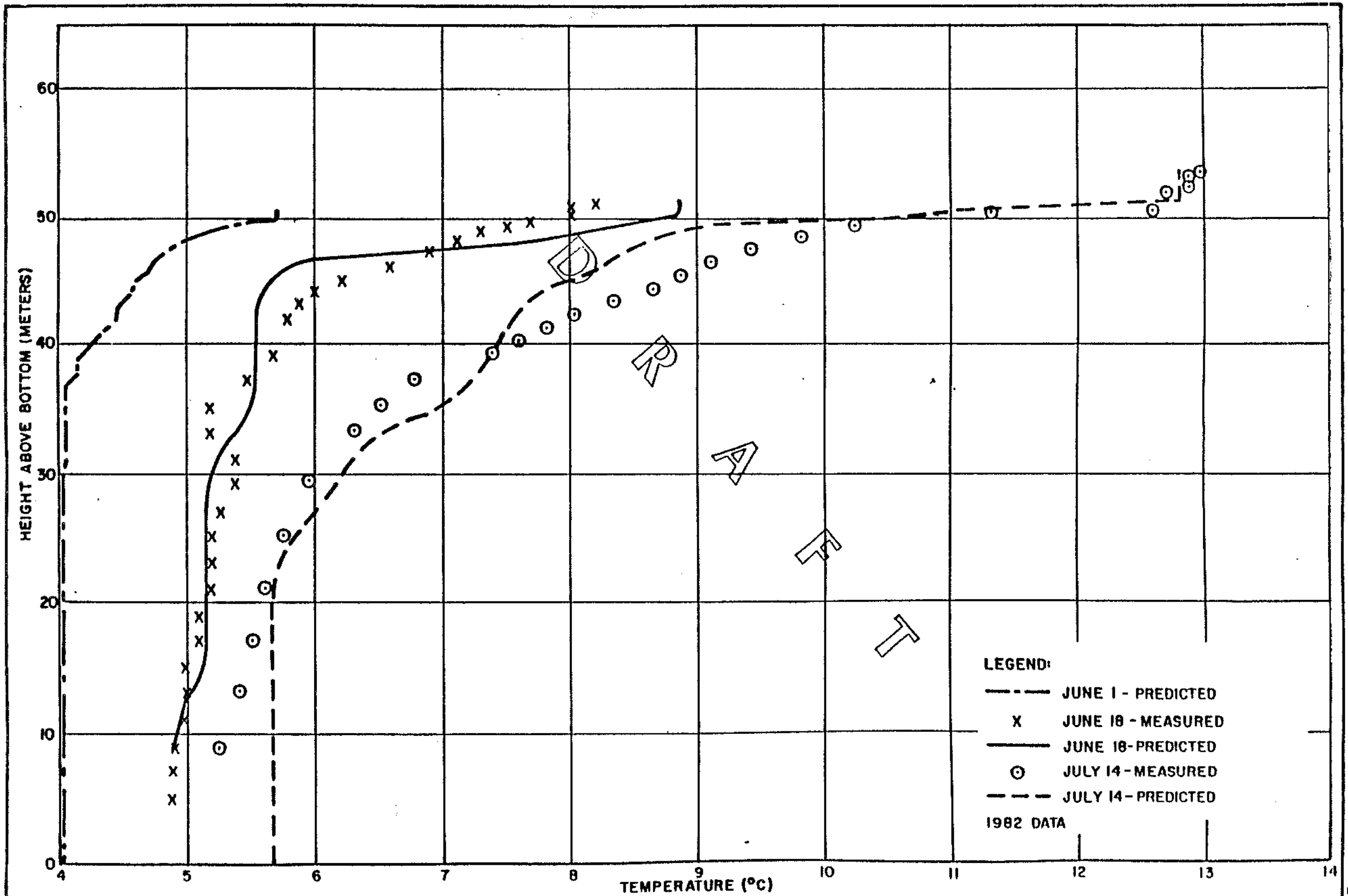


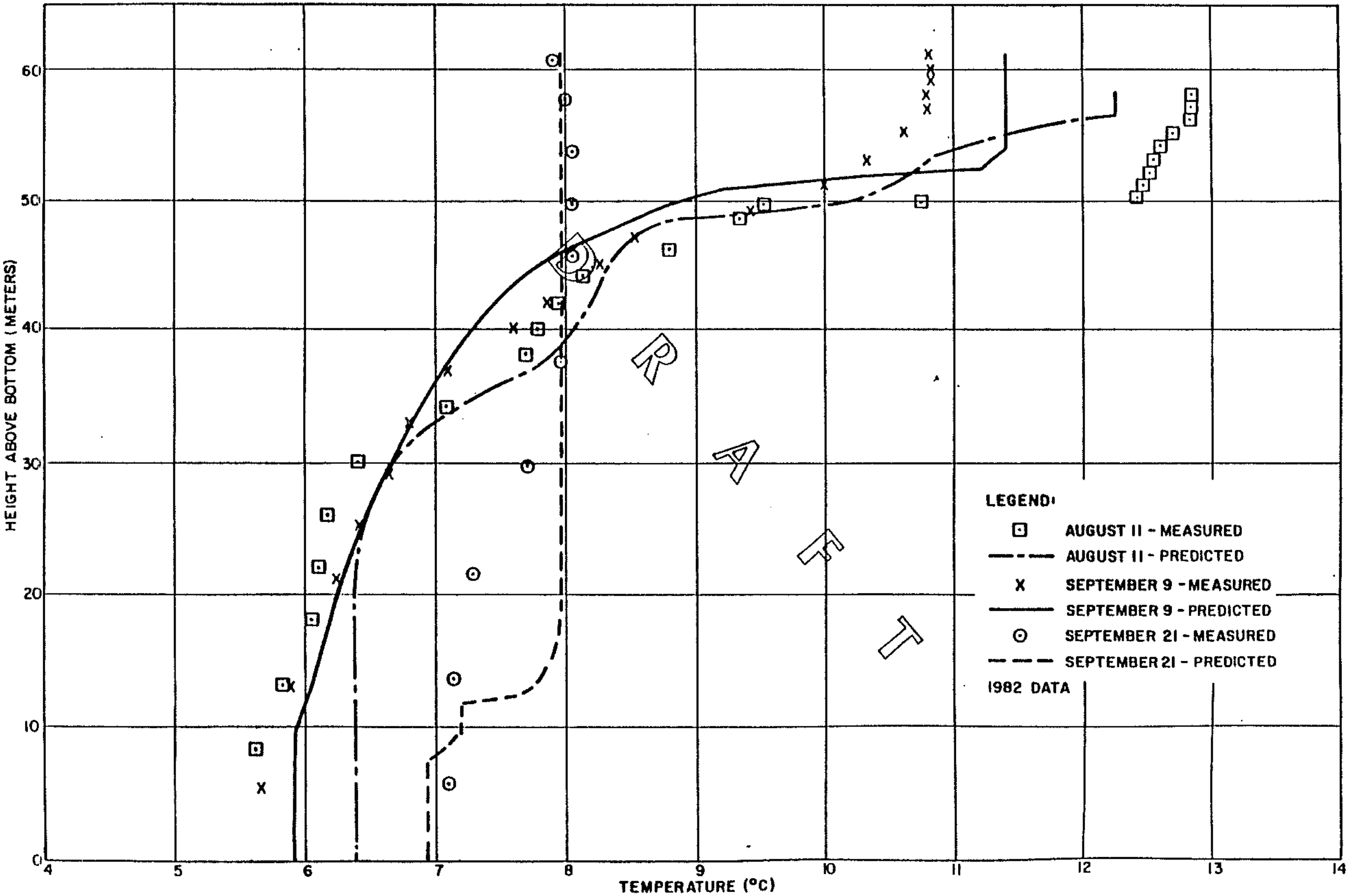
Figure 8

EKLUTNA LAKE
CLIMATIC DATA AVAILABILITY



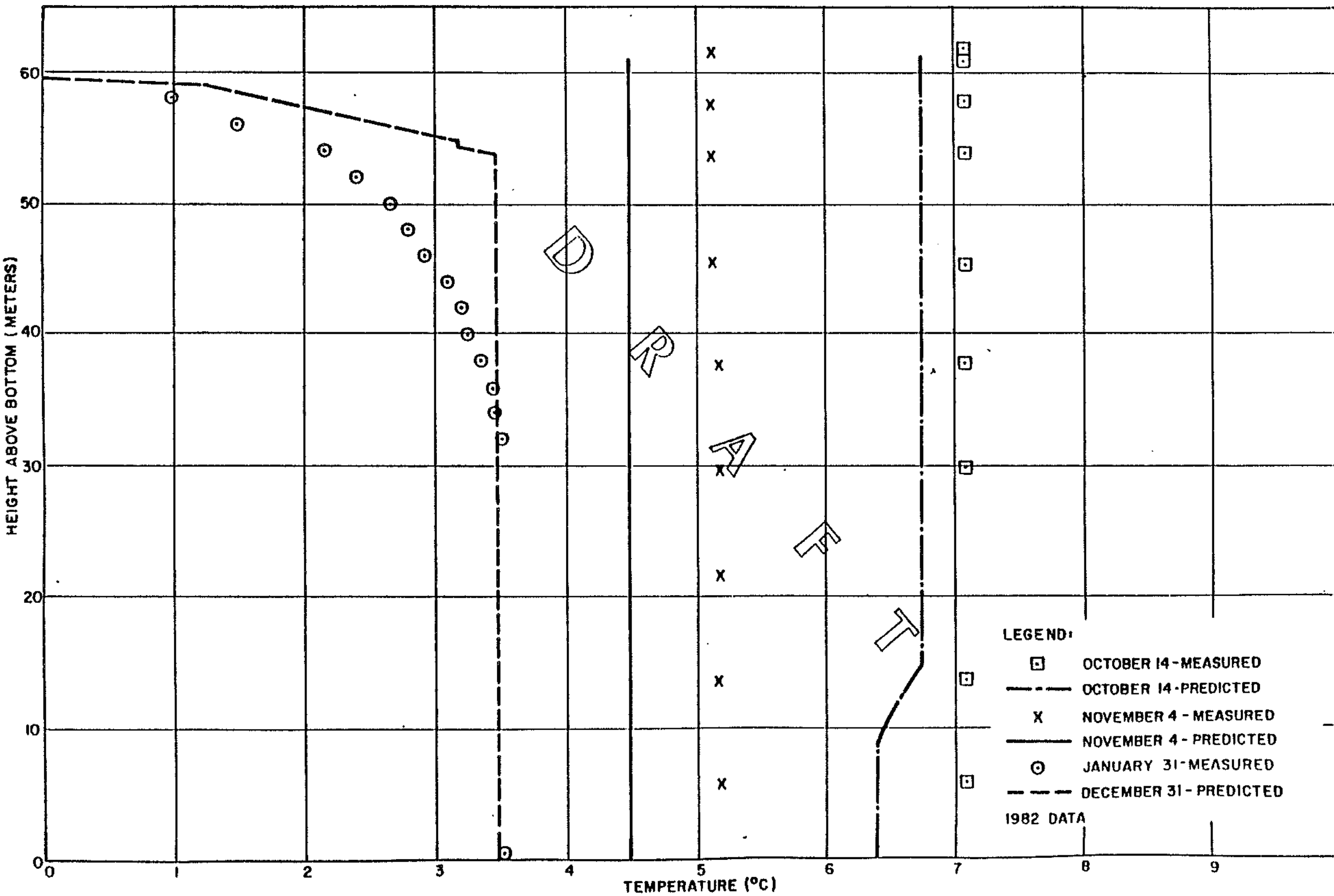
EKLUTNA LAKE OBSERVED AND PREDICTED TEMPERATURE PROFILES JUNE /JULY (Acres)

Figure 9



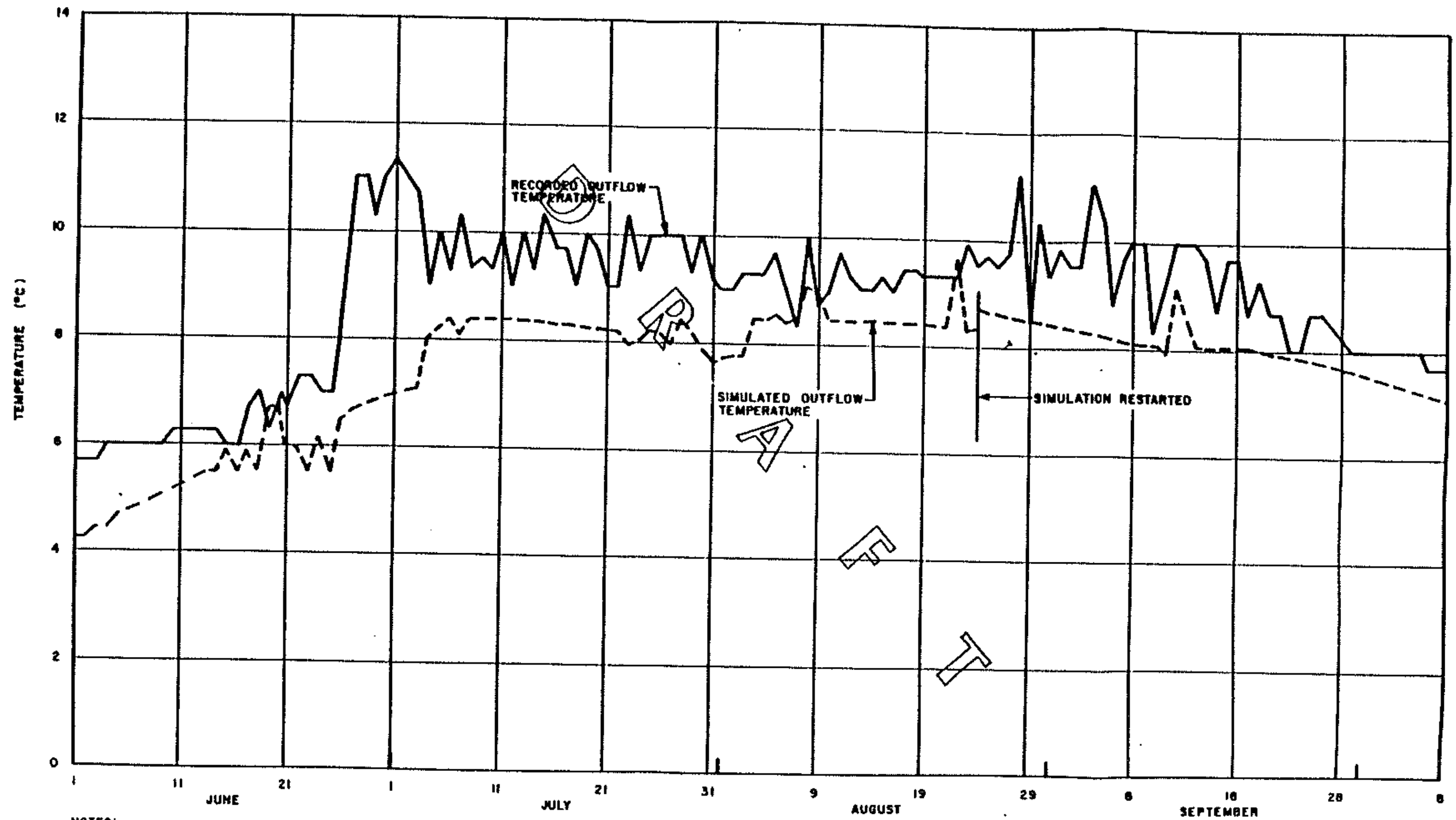
EKLUTNA LAKE OBSERVED AND PREDICTED TEMPERATURE PROFILES AUGUST / SEPTEMBER (Acres)

Figure 10



EKLUTNA LAKE OBSERVED AND PREDICTED TEMPERATURE PROFILES OCTOBER / DECEMBER (Acres)

Figure 11



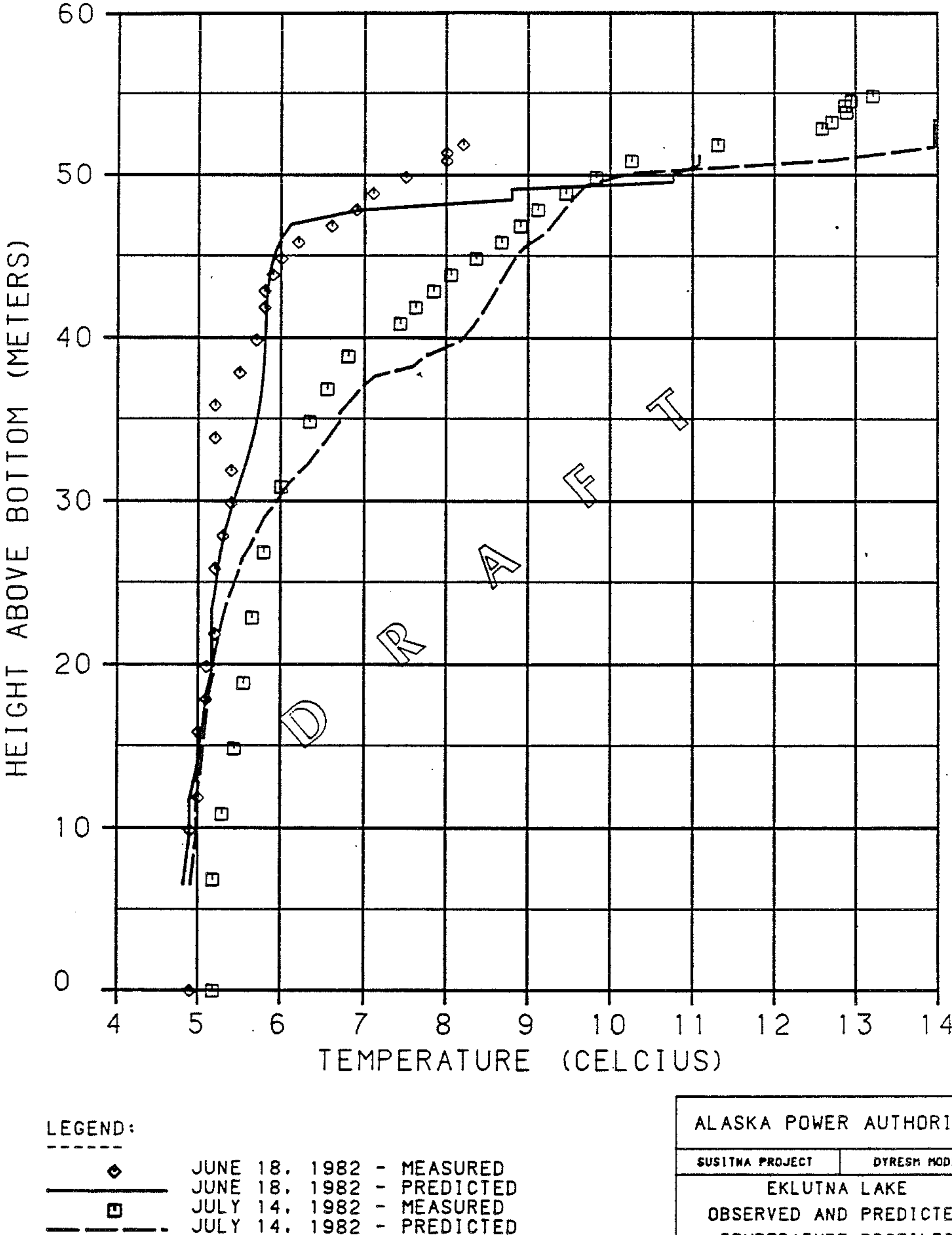
NOTES:

1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2) BASED ON 1982 DATA.

EKLUTNA LAKE RESERVOIR TEMPREATURE SIMULATION JUNE / SEPTEMBER
(Acres Study, 1982–1983)

Figure 12

Figure 15



ALASKA POWER AUTHORITY

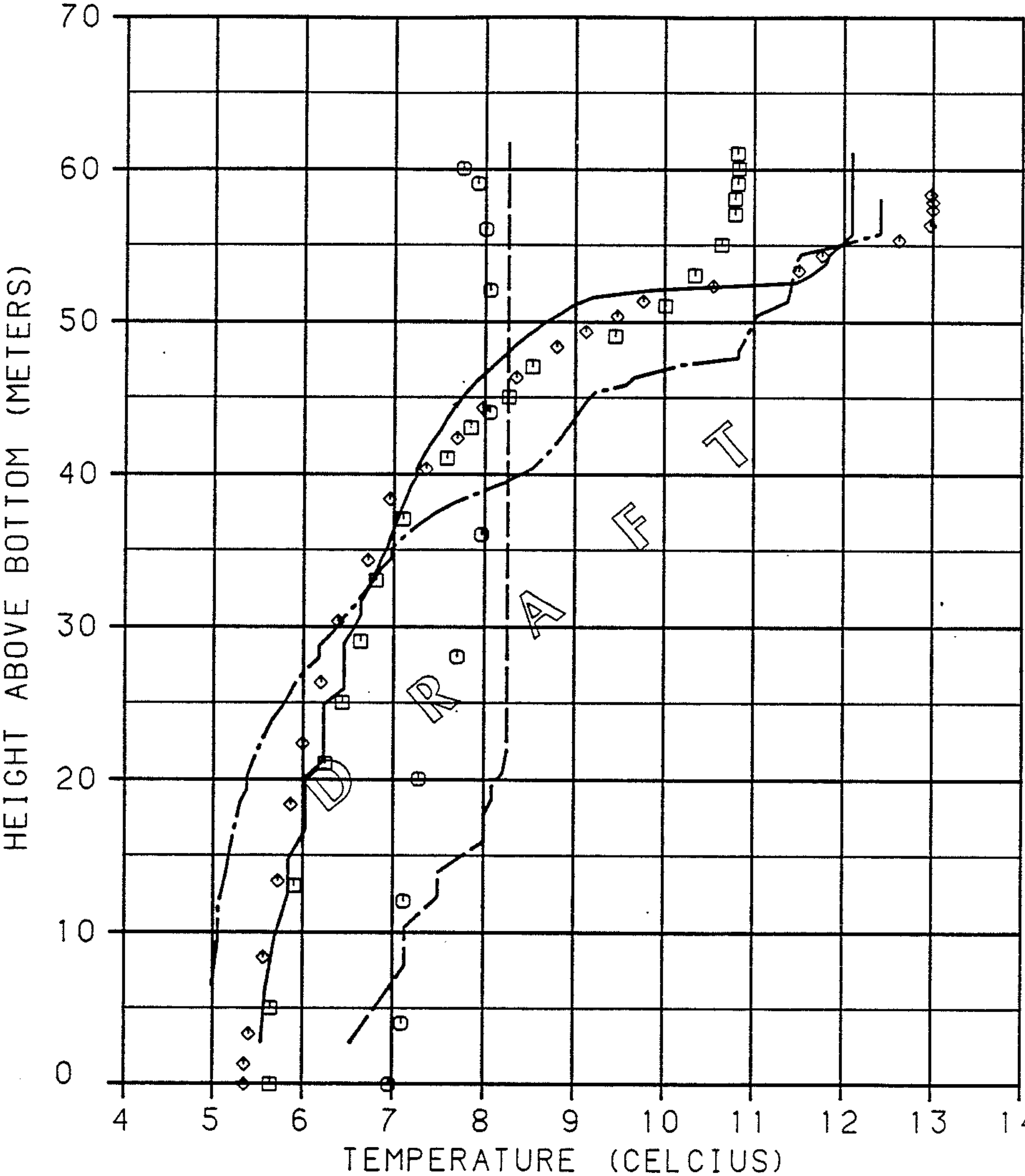
SUSITNA PROJECT | DYRESM MODEL

EKLUTNA LAKE
OBSERVED AND PREDICTED
TEMPERATURE PROFILES

HARZA-EBASCO JOINT VENTURE

CHICAGO, ILLINOIS | 30 DEC 83 | 1563.142 HYD13

Figure 16

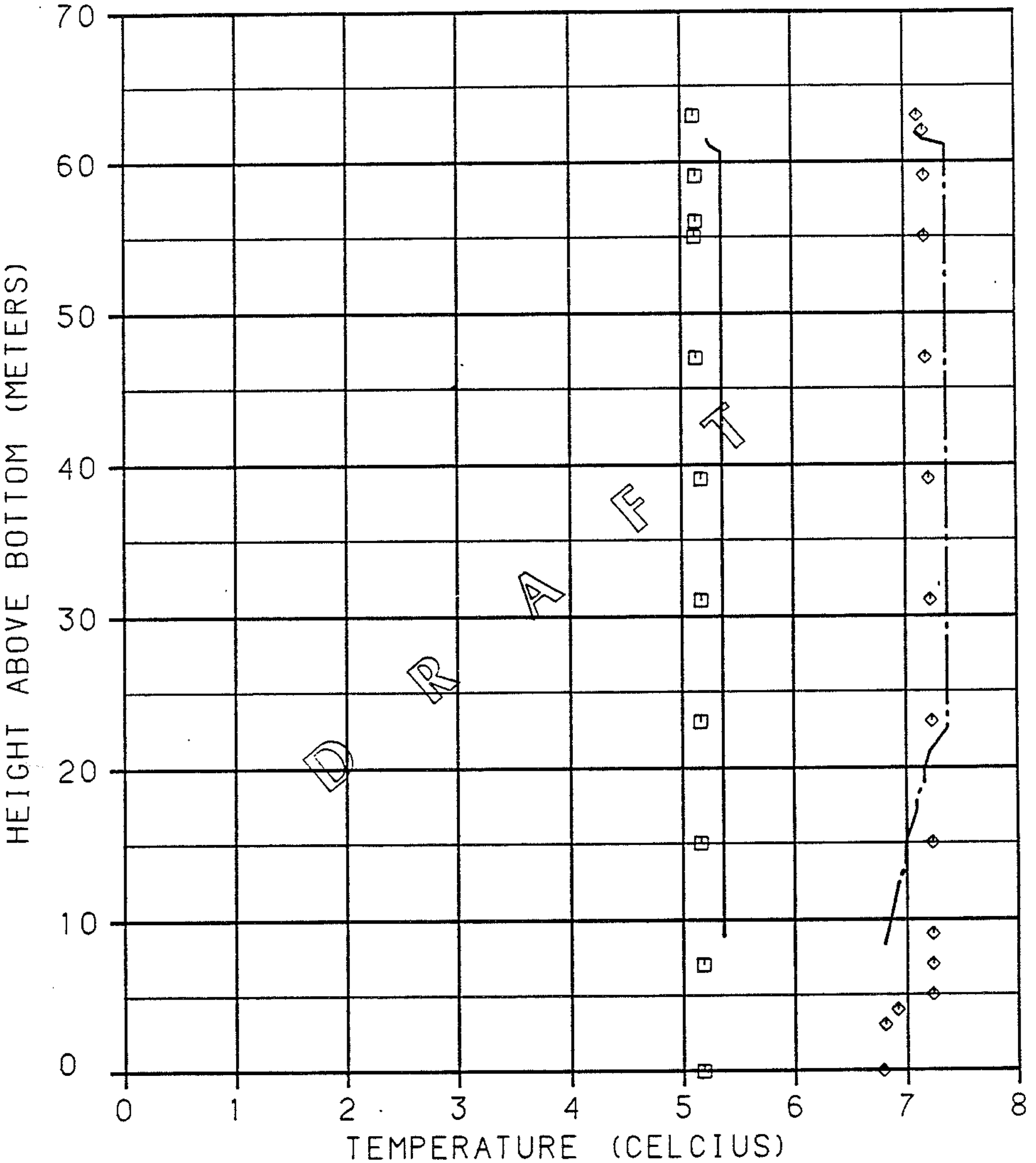


LEGEND:

- ◇ AUGUST 11, 1982 - MEASURED
- —·— AUGUST 11, 1982 - PREDICTED
- ⊞ SEPTEMBER 9, 1982 - MEASURED
- —— SEPTEMBER 9, 1982 - PREDICTED
- ⊖ SEPTEMBER 21, 1982 - MEASURED
- — — SEPTEMBER 21, 1982 - PREDICTED

ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE OBSERVED AND PREDICTED TEMPERATURE PROFILES		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	30 DEC 83	1563.142 MYD14

Figure 17

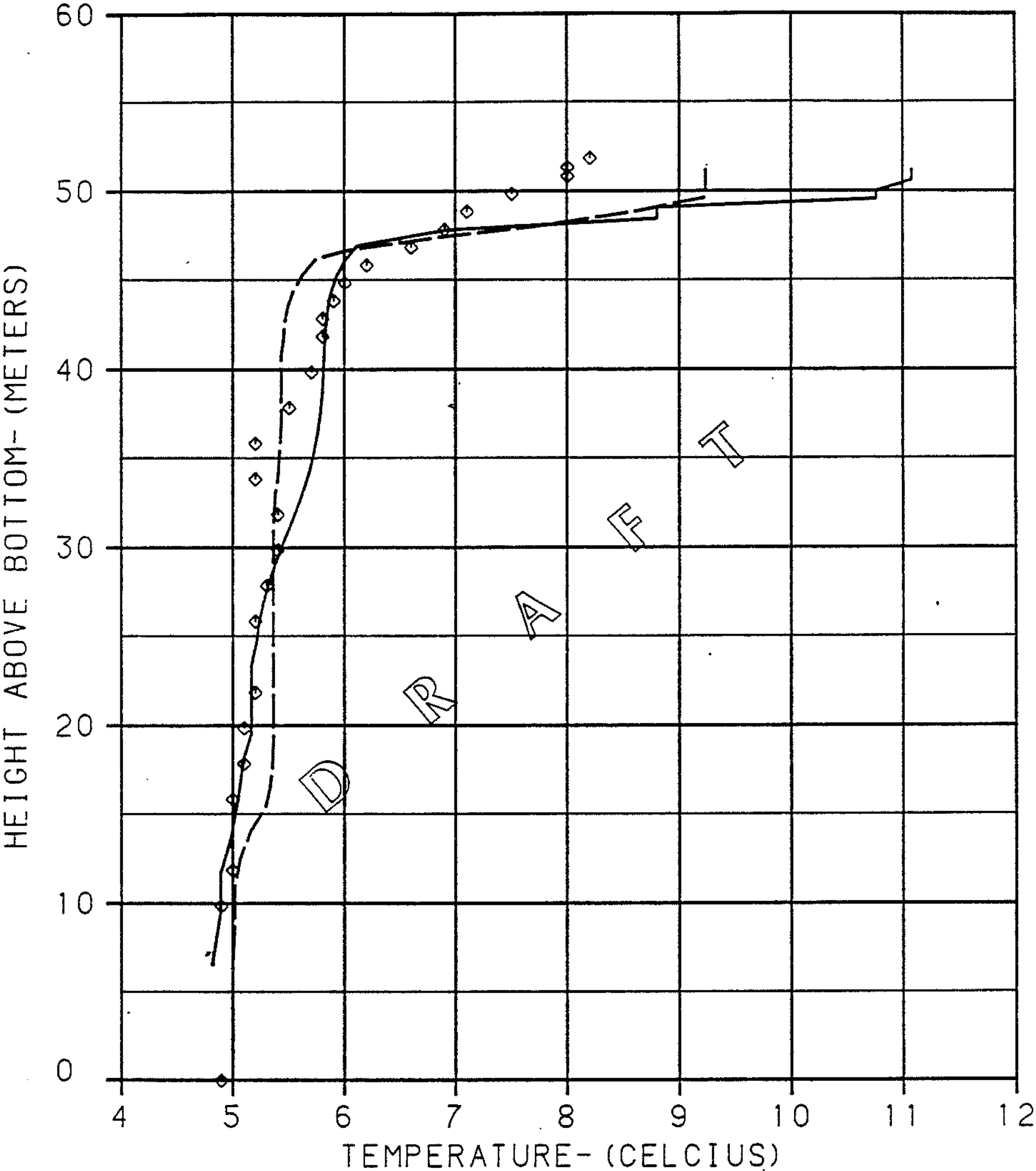


LEGEND:

- ◇ OCTOBER 14, 1982 - MEASURED
- —·— OCTOBER 14, 1982 - PREDICTED
- ⊡ NOVEMBER 4, 1982 - MEASURED
- —— NOVEMBER 4, 1982 - PREDICTED

ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE OBSERVED AND PREDICTED TEMPERATURE PROFILES		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	30 DEC 83	1563.142 HYDIS

Figure 18

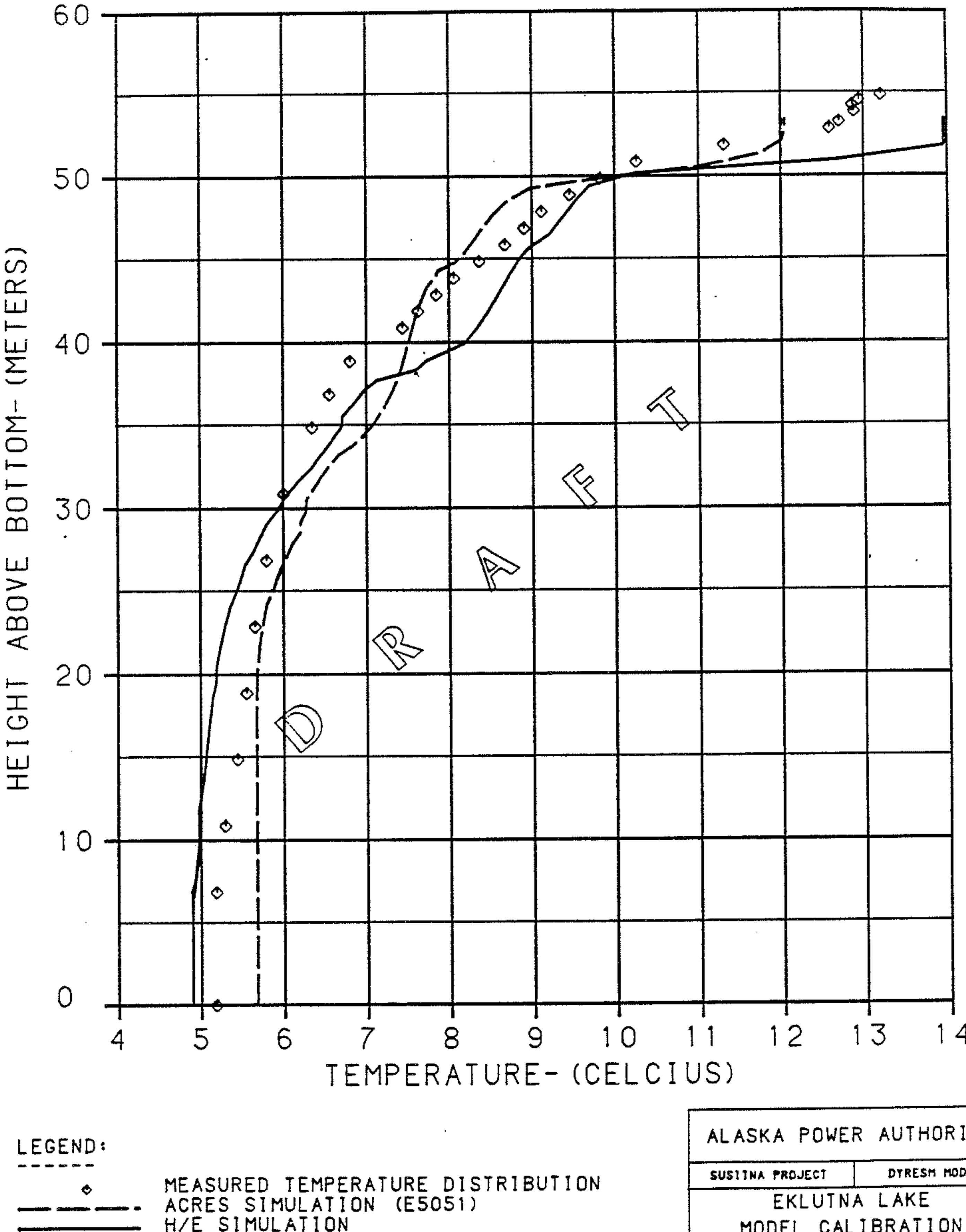


LEGEND:

- ◇ MEASURED TEMPERATURE DISTRIBUTION
- — — — ACRES SIMULATION (E5051)
- ——— H/E SIMULATION

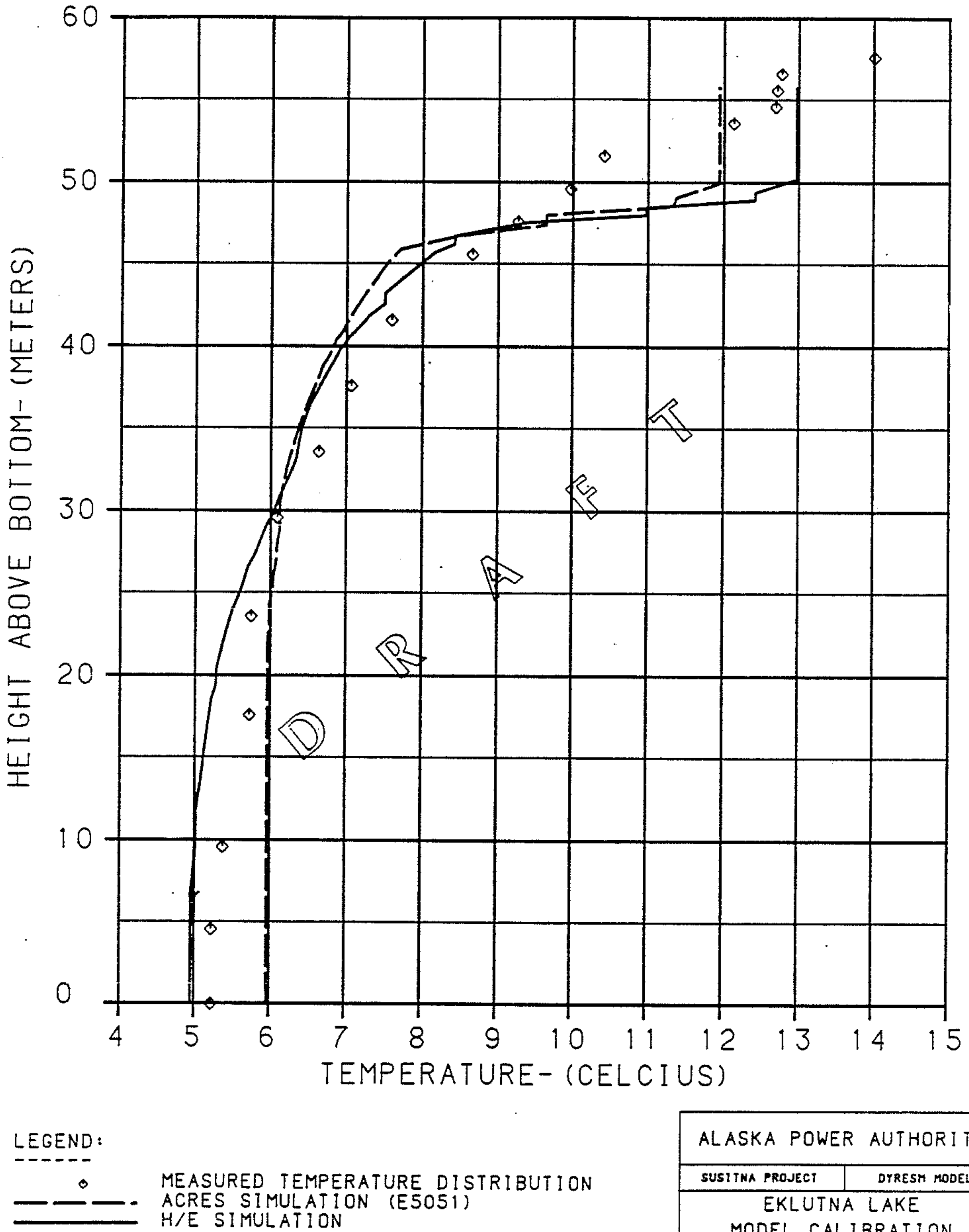
ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 18 JUNE 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 HYD1

Figure 19



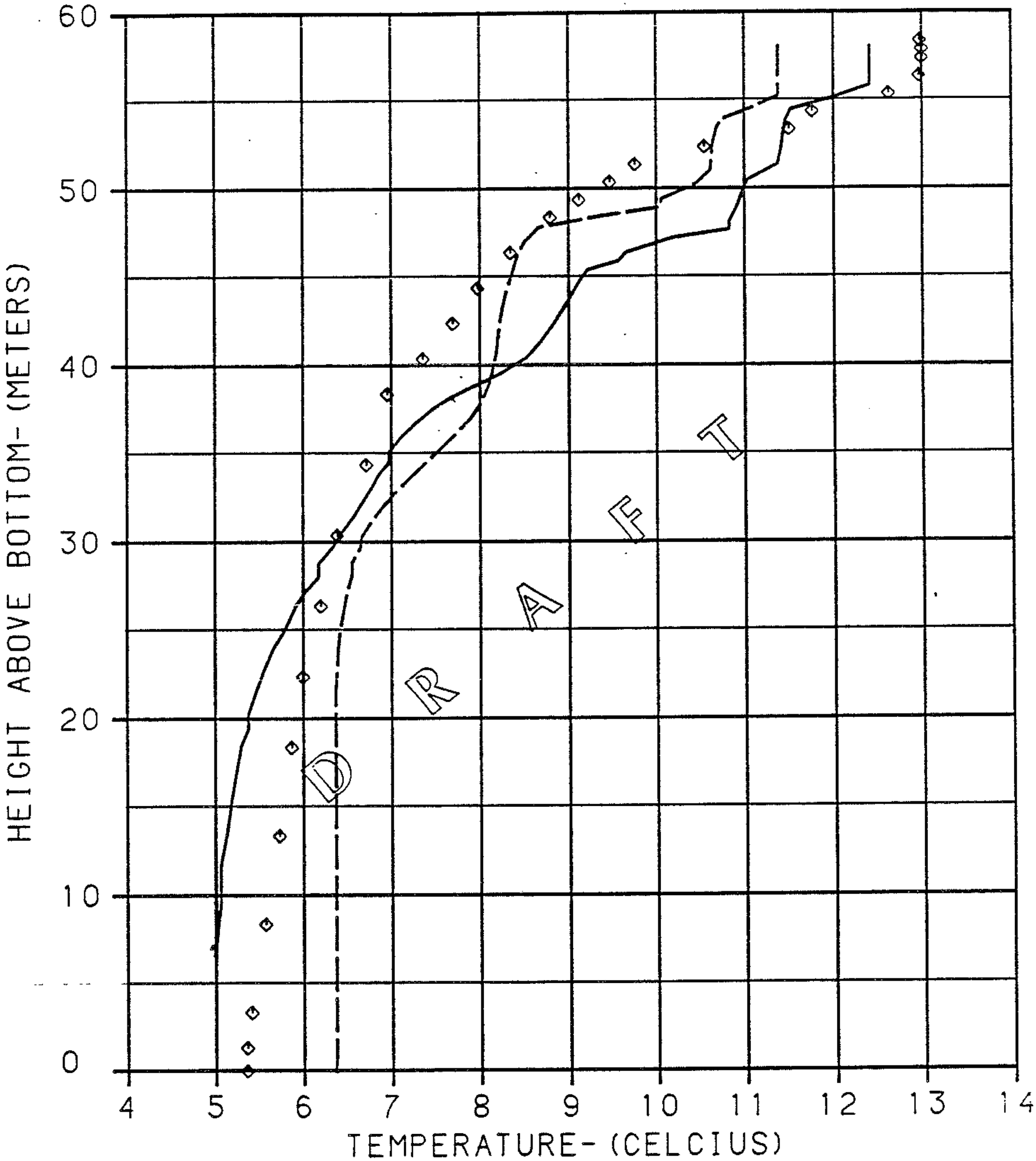
ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 14 JULY 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 HYD

Figure 20



ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 28 JULY 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 HYD3

Figure 21

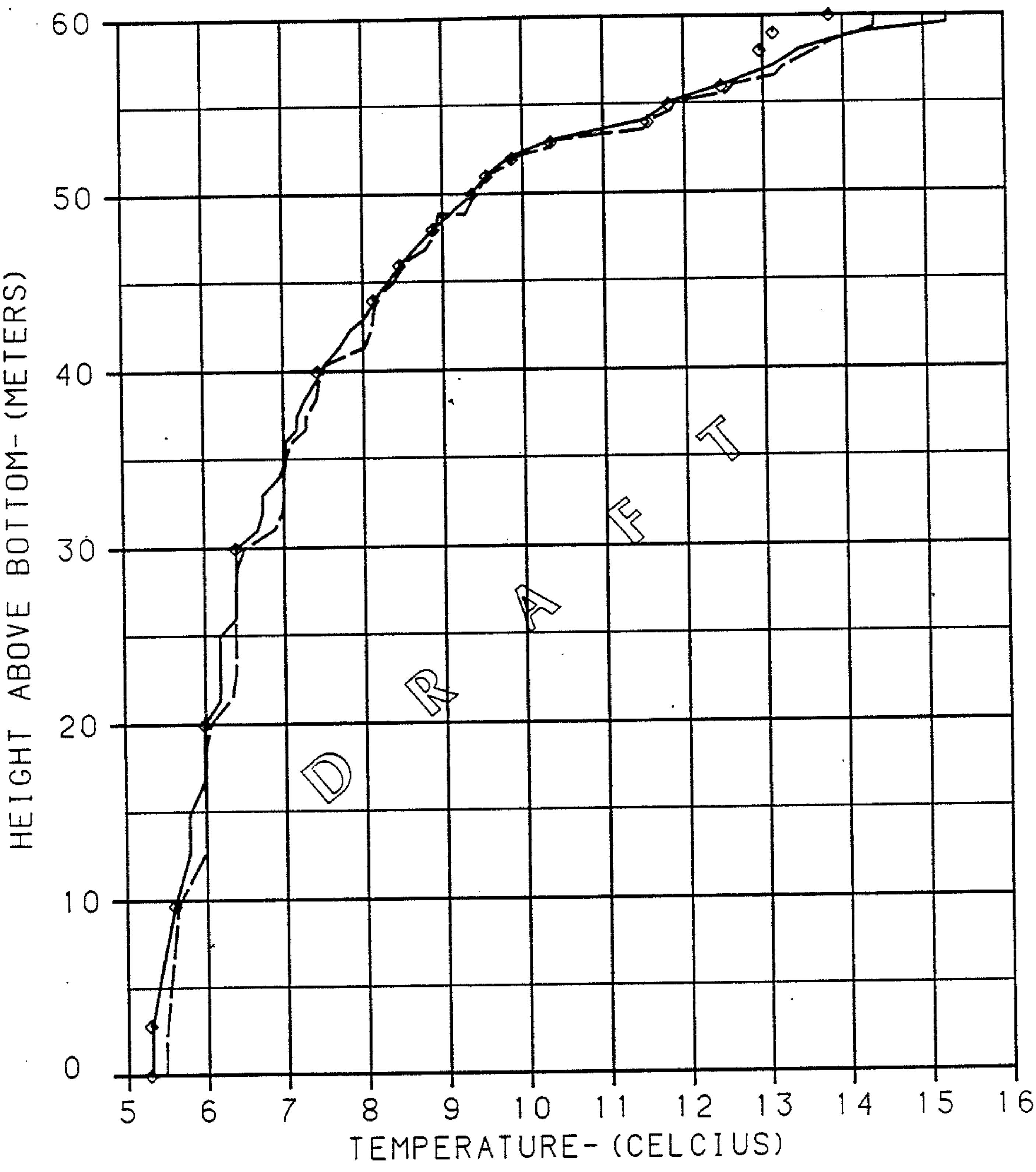


LEGEND:

- ◇ MEASURED TEMPERATURE DISTRIBUTION
- — — — ACRES SIMULATION (E5051)
- ——— H/E SIMULATION

ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 10 AUGUST 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 MTD4

Figure 22

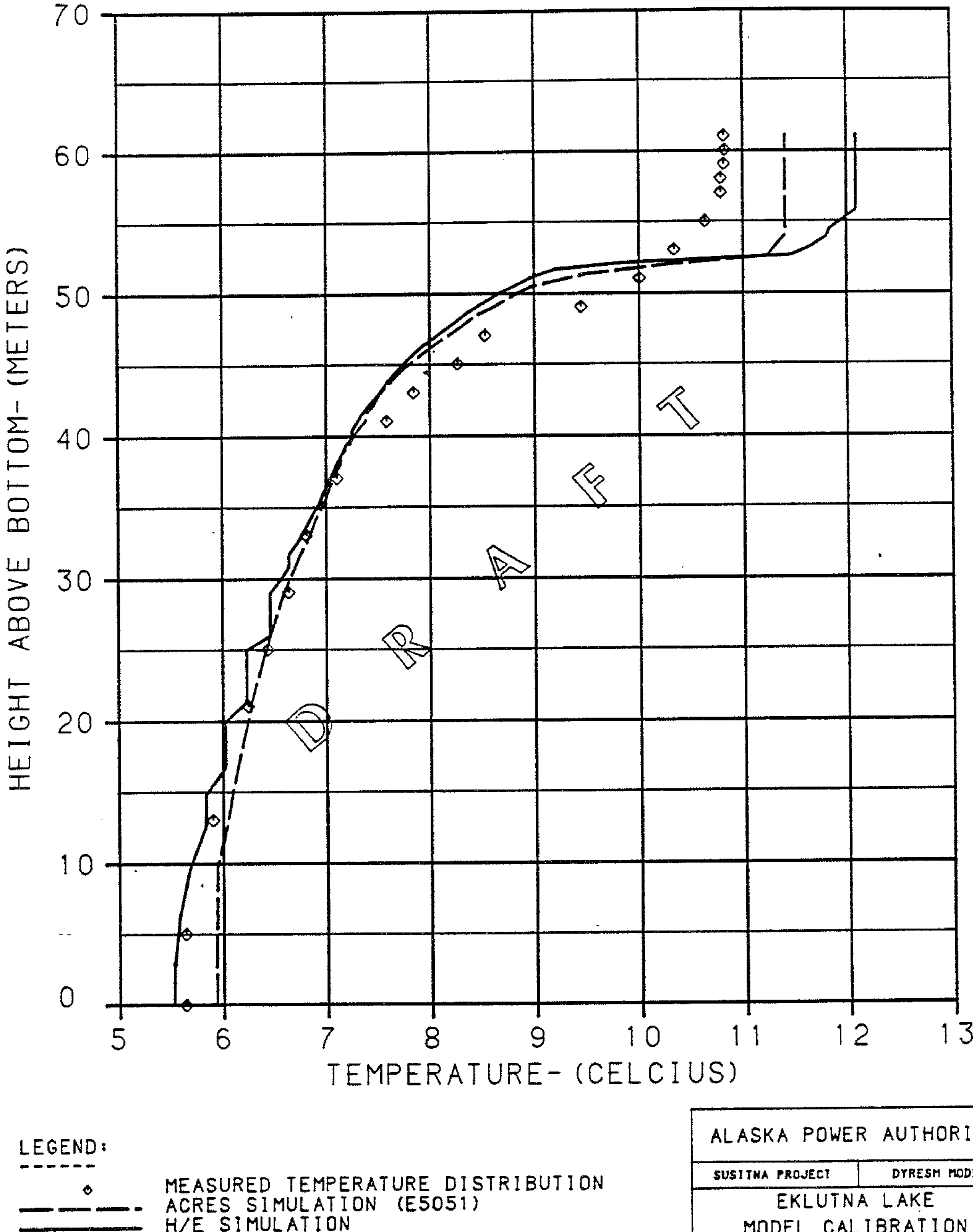


LEGEND:

- ◇ MEASURED TEMPERATURE DISTRIBUTION
- — — — ACRES SIMULATION (E5051)
- ——— H/E SIMULATION

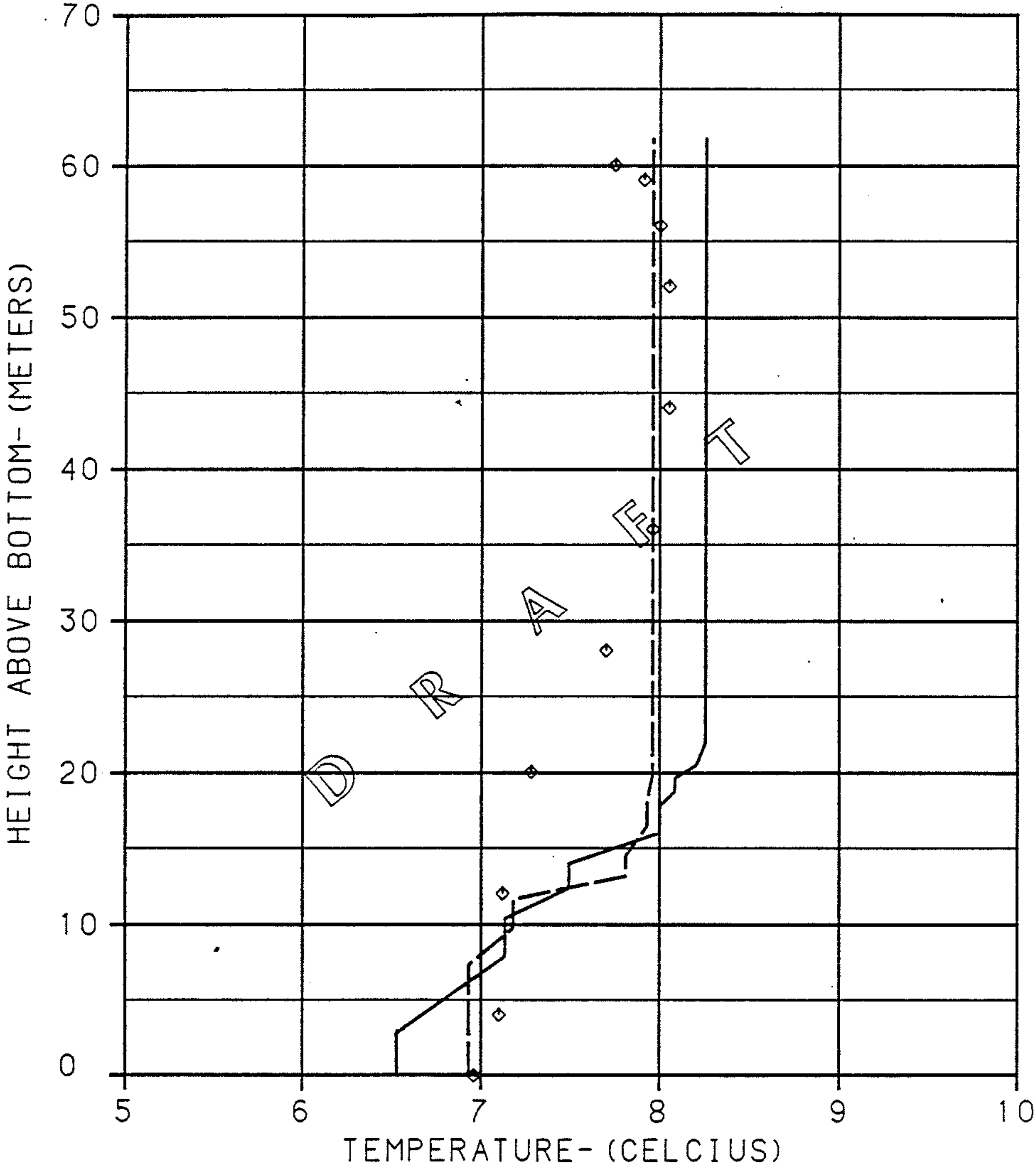
ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 25 AUGUST 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 HYDS

Figure 23



ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 9 SEPTEMBER 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 HYD6

Figure 24



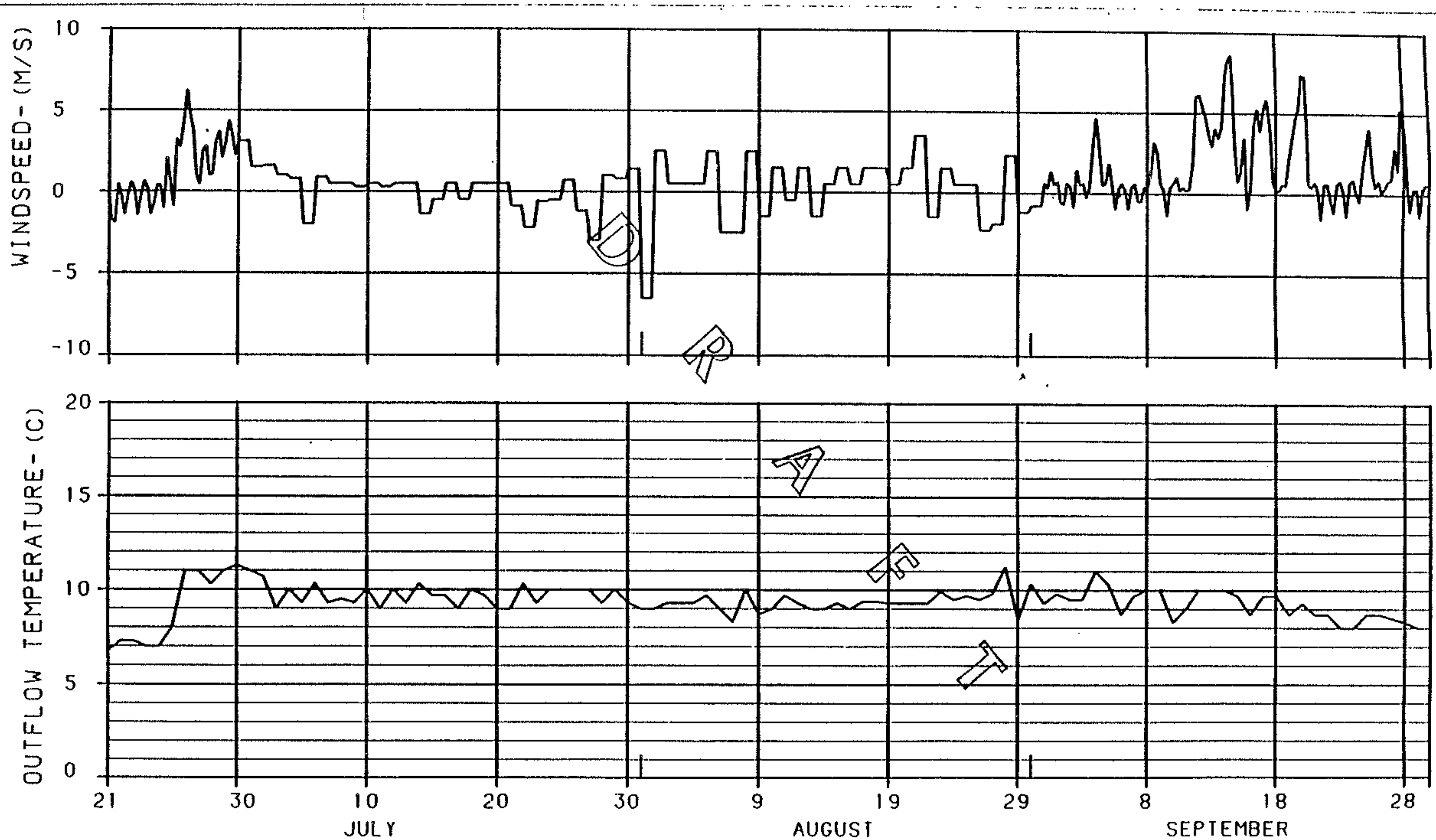
LEGEND:

◇ MEASURED TEMPERATURE DISTRIBUTION

— — — ACRES SIMULATION (E5051)

——— H/E SIMULATION

ALASKA POWER AUTHORITY		
SUSITNA PROJECT	DYRESM MODEL	
EKLUTNA LAKE MODEL CALIBRATION 21 SEPTEMBER 1982		
HARZA-EBASCO JOINT VENTURE		
CHICAGO, ILLINOIS	28 DEC 83	1563.142 HYD7



NOTE: MEASURED 6-HOUR WINDSPEED AND OUTFLOW TEMPERATURES FROM GLACIAL LAKES STUDIES PREPARED BY R & M CONSULTANTS.

ALASKA POWER AUTHORITY

SUSITNA PROJECT | DYRESM MODEL

EKLUTNA LAKE
MEASURED WINDSPEED AND
OUTFLOW TEMPERATURE

HARZA-EBASCO JOINT VENTURE

Figure 25

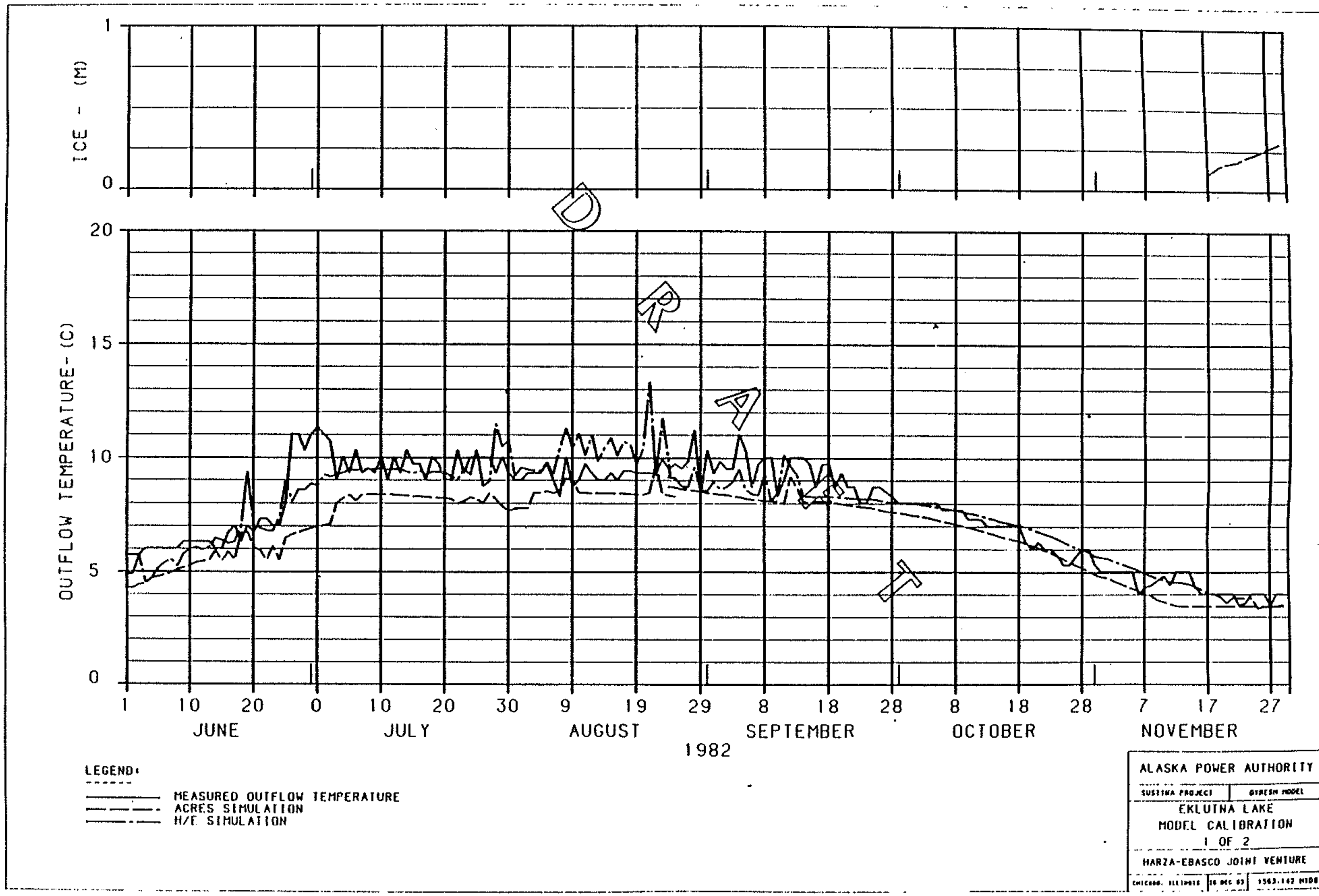
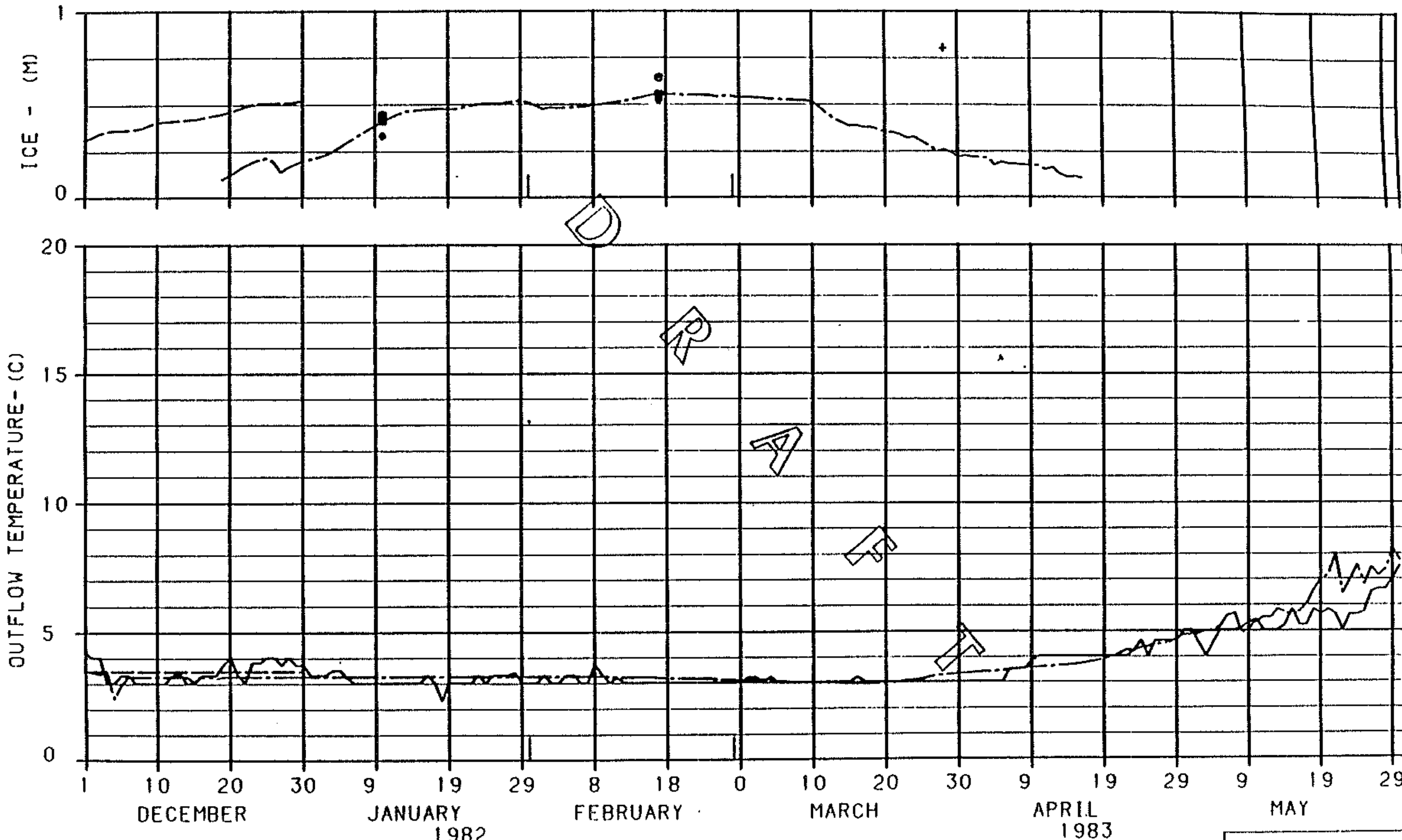

ICE - (M)
1
0
OUTFLOW TEMPERATURE - (C)
20
15
10
5
0
1 10 20 0 10 20 30 9 19 29 8 18 28 8 18 28 7 17 27
JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER
1982
DRAFT
LEGEND:
MEASURED OUTFLOW TEMPERATURE
ACRES SIMULATION
H/E SIMULATION
ALASKA POWER AUTHORITY
SUSITNA PROJECT
DYRESM MODEL
EKLUTNA LAKE
MODEL CALIBRATION
1 OF 2
HARZA-EBASCO JOINT VENTURE

Figure 26



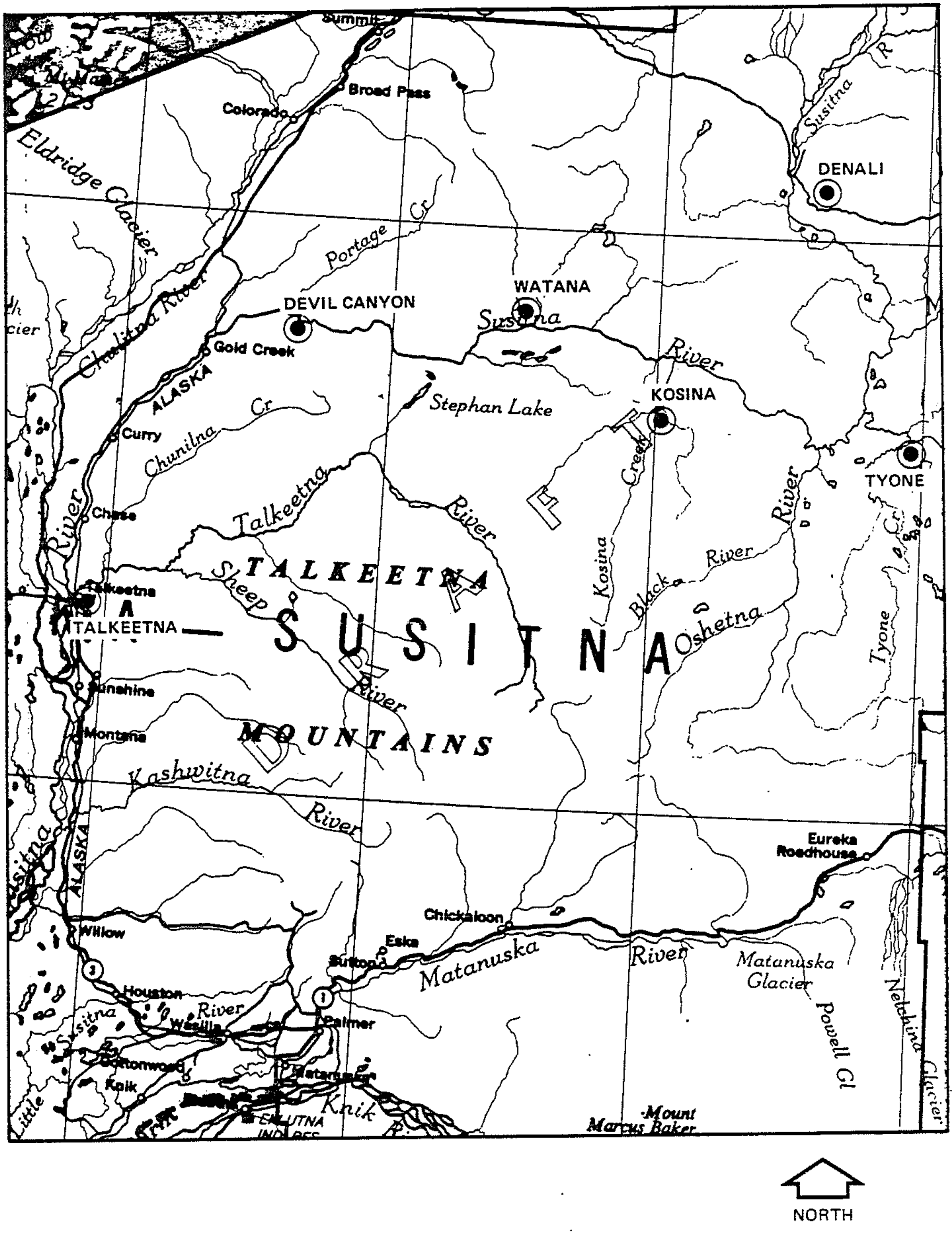
LEGEND:

MEASURED OUTFLOW TEMPERATURE
ACRES SIMULATION
H/E SIMULATION
● MEASURE ICE THICKNESS STATION 5
■ MEASURE ICE THICKNESS STATION 9
● MEASURE ICE THICKNESS STATION 11
+ MEASURE ICE THICKNESS STATION 13

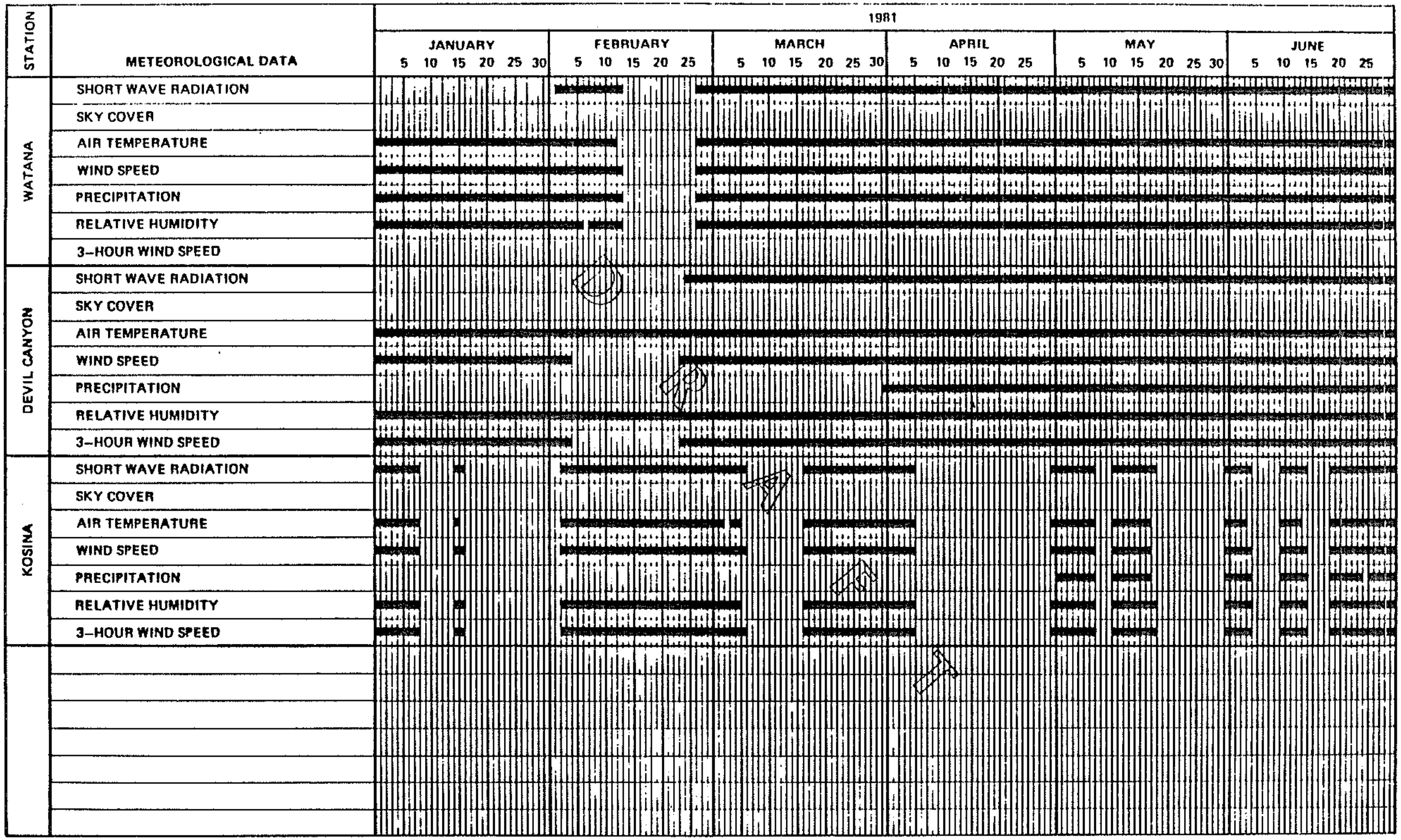
ALASKA POWER AUTHORITY	
SUSITNA PROJECT	DYRESM MODEL
EKLUTNA LAKE MODEL CALIBRATION 2 OF 2	
HARZA-EBASCO JOINT VENTURE	

Figure 27

Figure 28

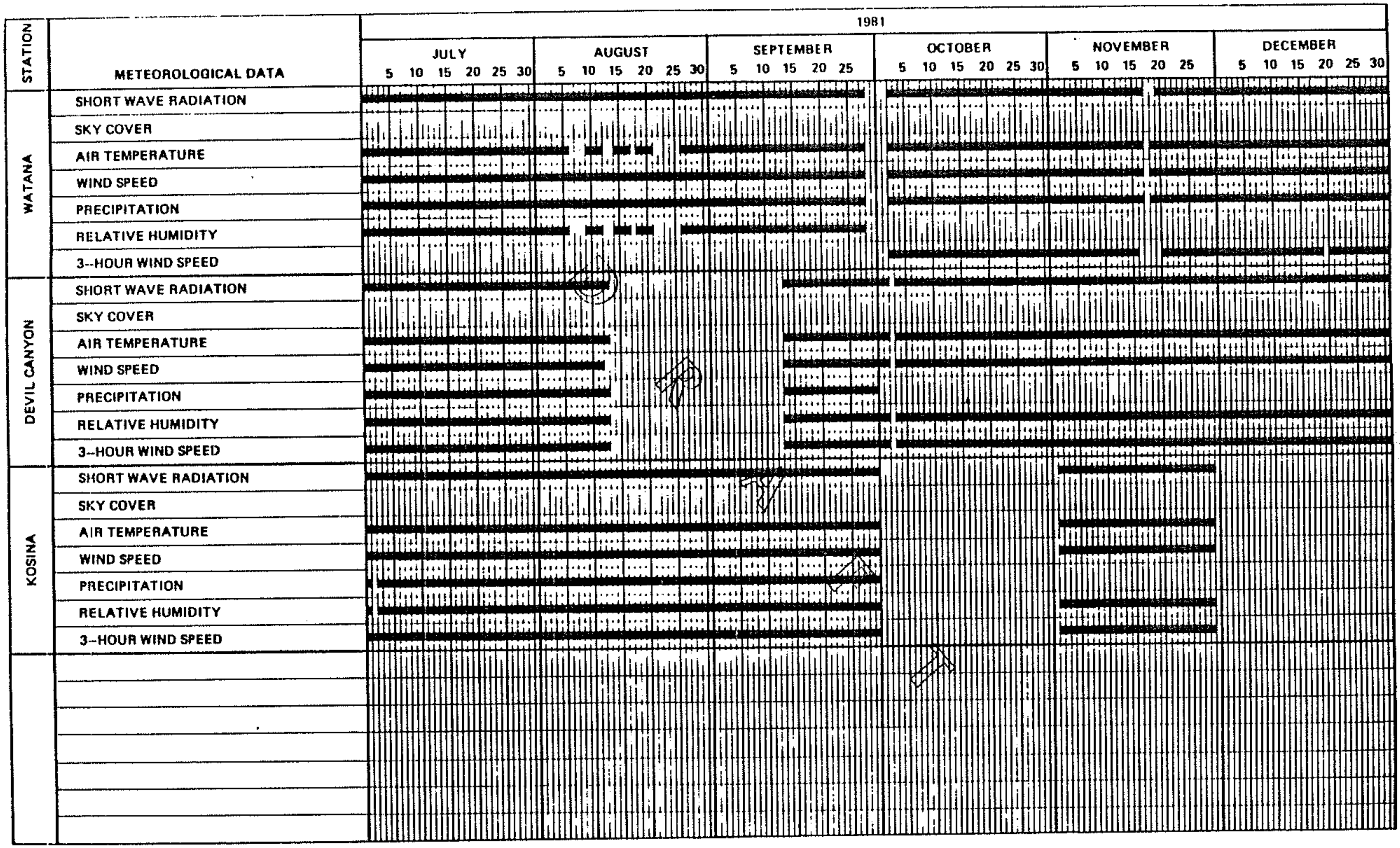


CLIMATIC STATIONS IN UPPER SUSITNA BASIN



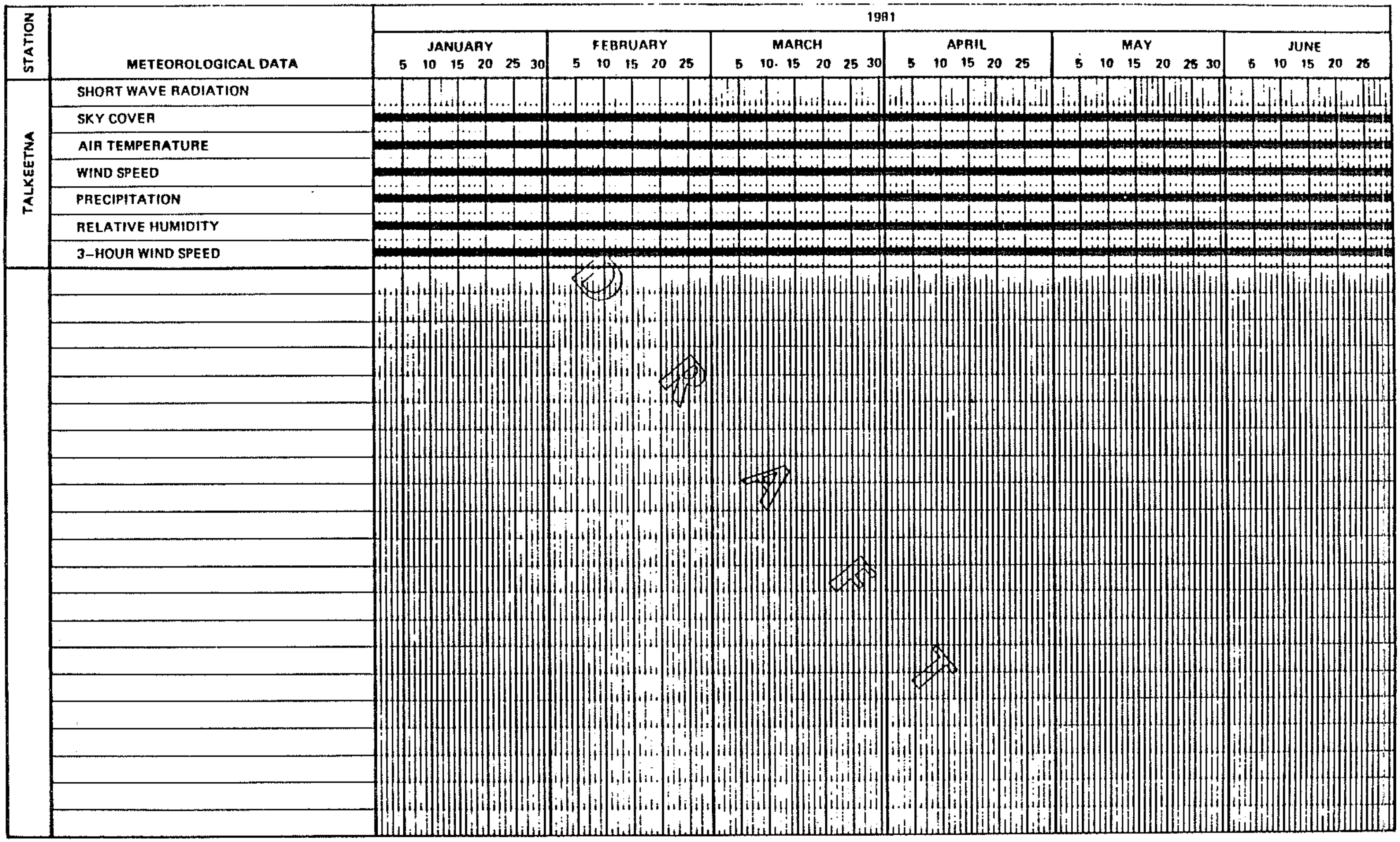
SUSITNA HYDROELECTRIC PROJECT
CLIMATIC DATA AVAILABILITY

Figure 29



SUSITNA HYDROELECTRIC PROJECT
CLIMATIC DATA AVAILABILITY

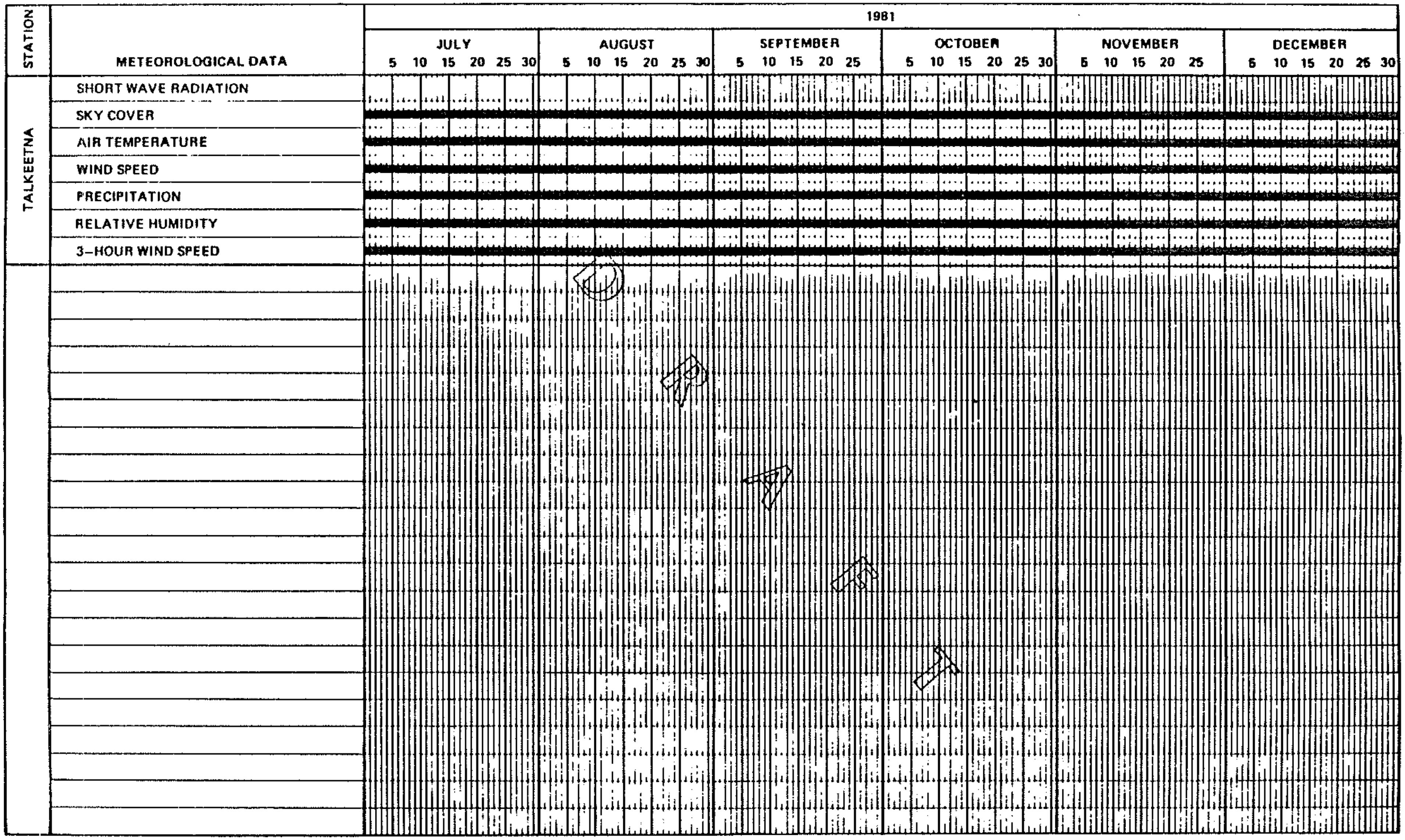
Figure 30



SUSITNA HYDROELECTRIC PROJECT

CLIMATIC DATA AVAILABILITY

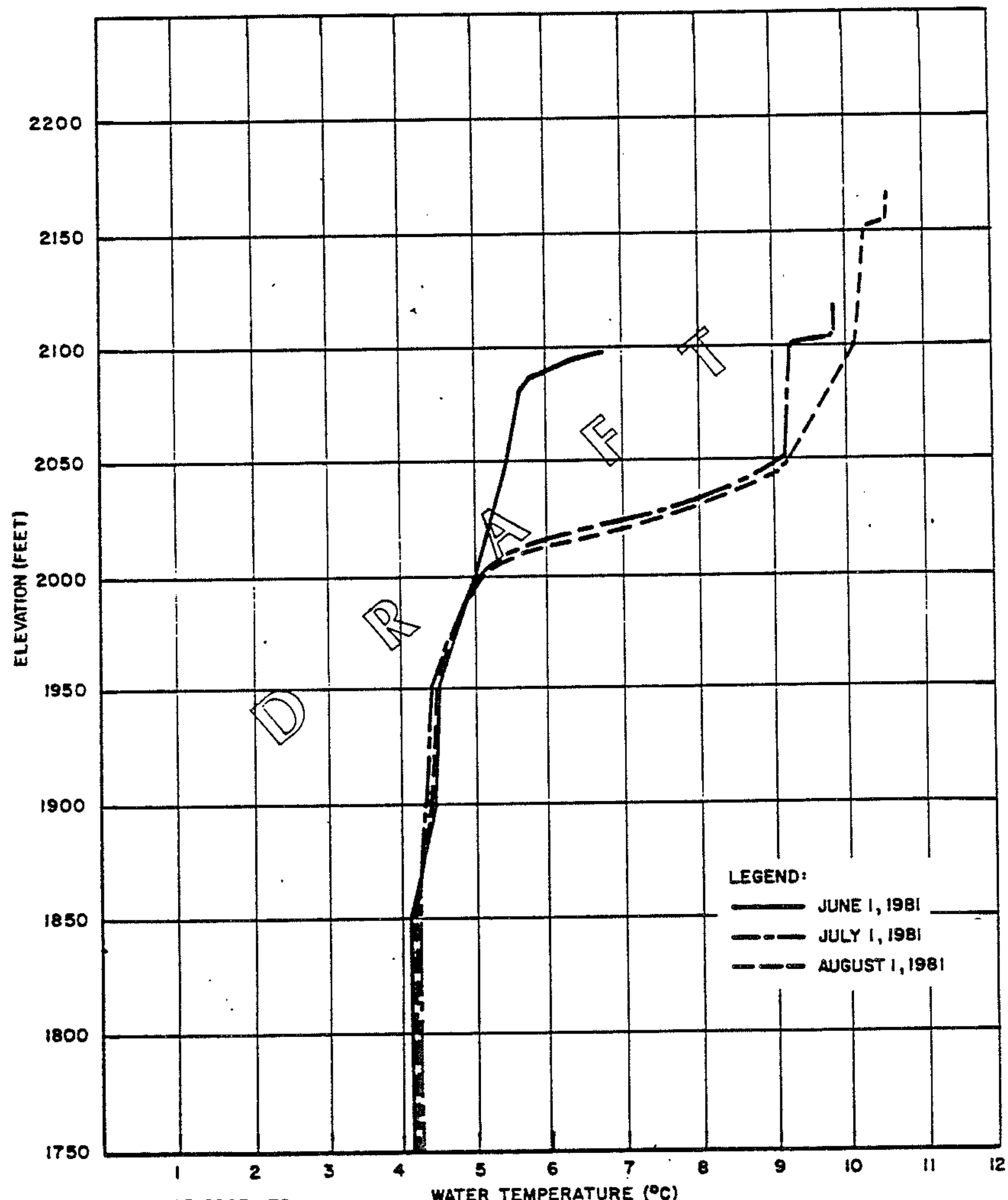
Figure 31



SUSITNA HYDROELECTRIC PROJECT

CLIMATIC DATA AVAILABILITY

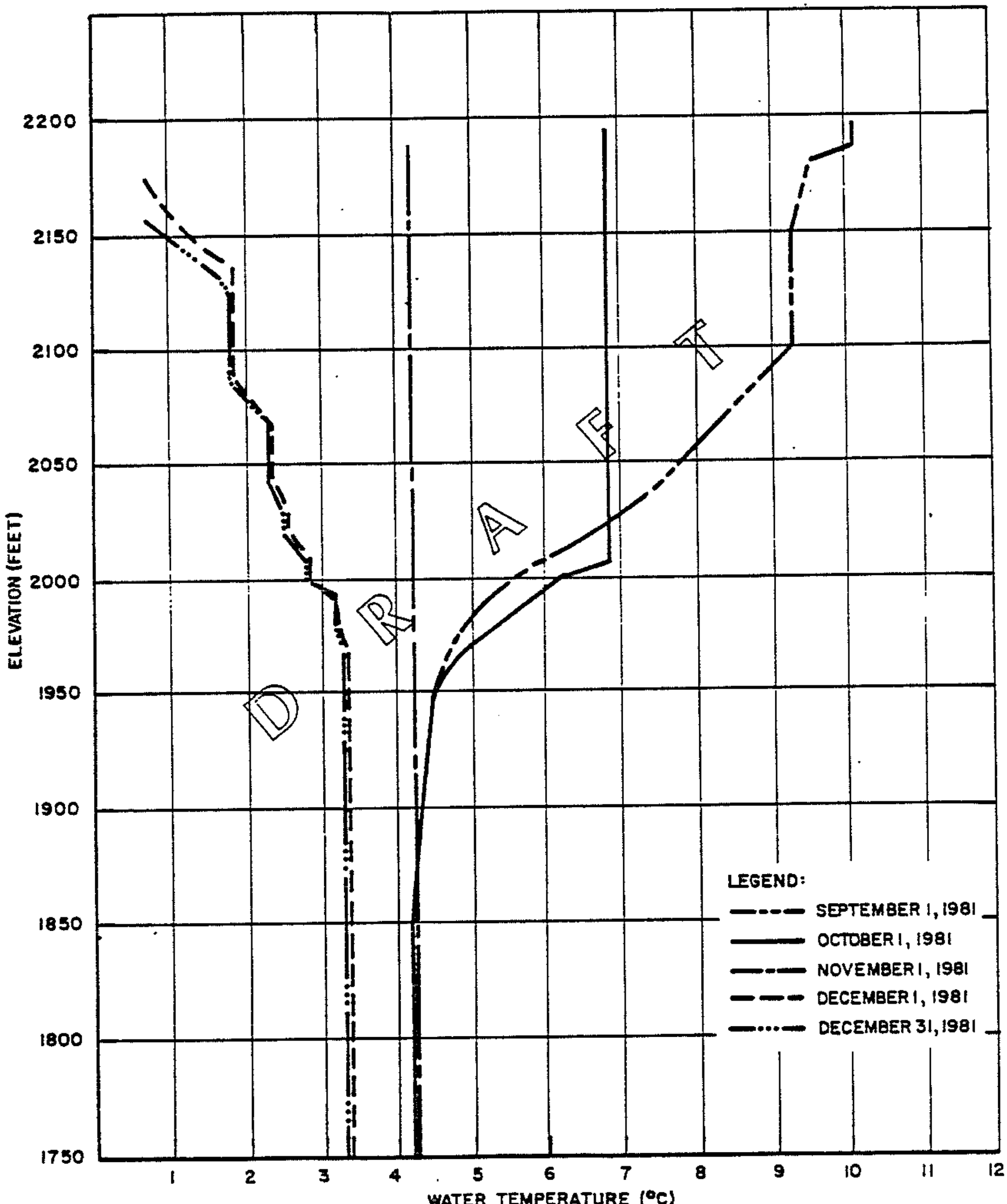
Figure 32



NOTE: TEMPERATURE PROFILES SIMULATED USING 1981 DATA.

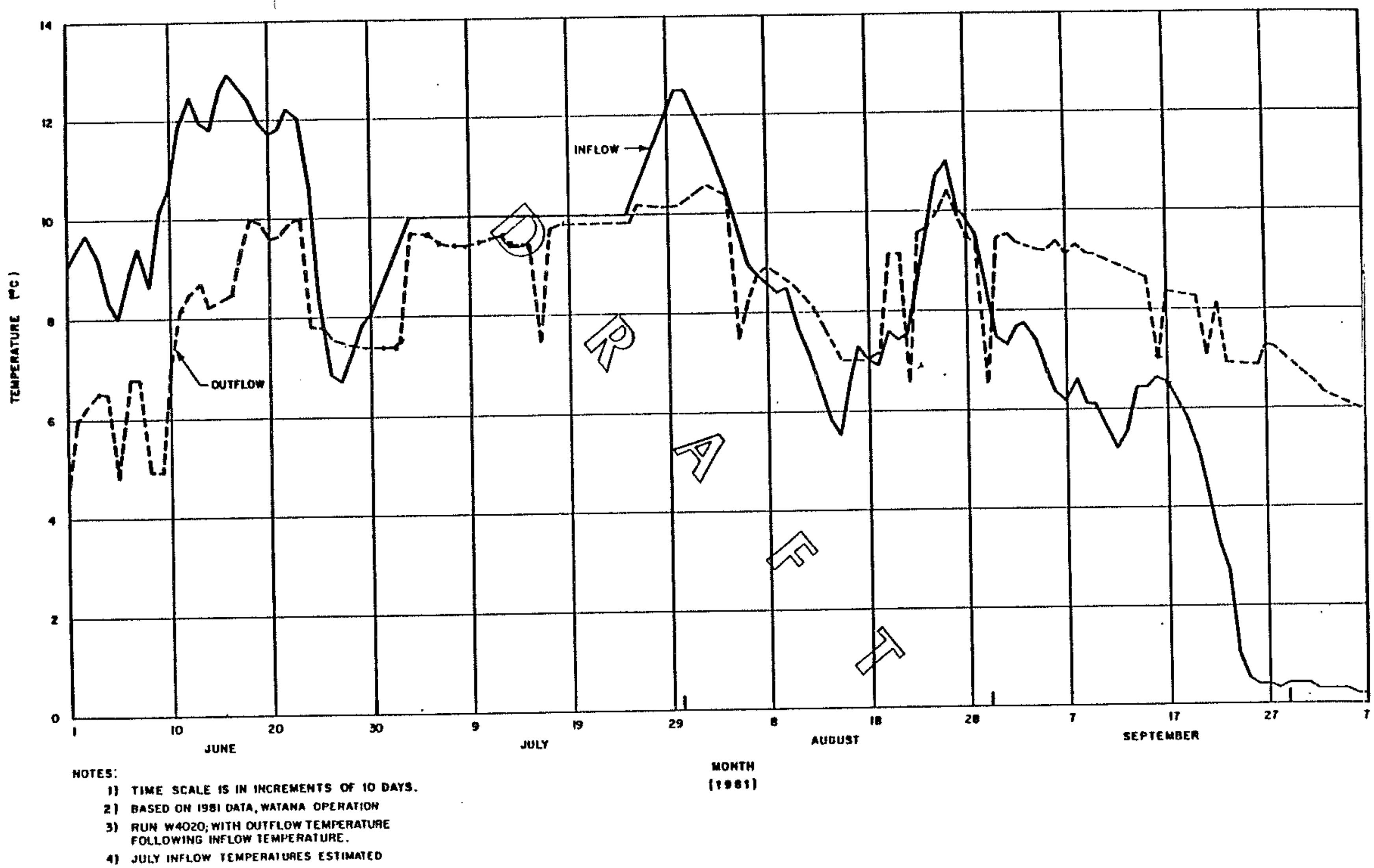
WATANA RESERVOIR TEMPERATURE PROFILES JUNE / AUGUST (Acres)

Figure 34



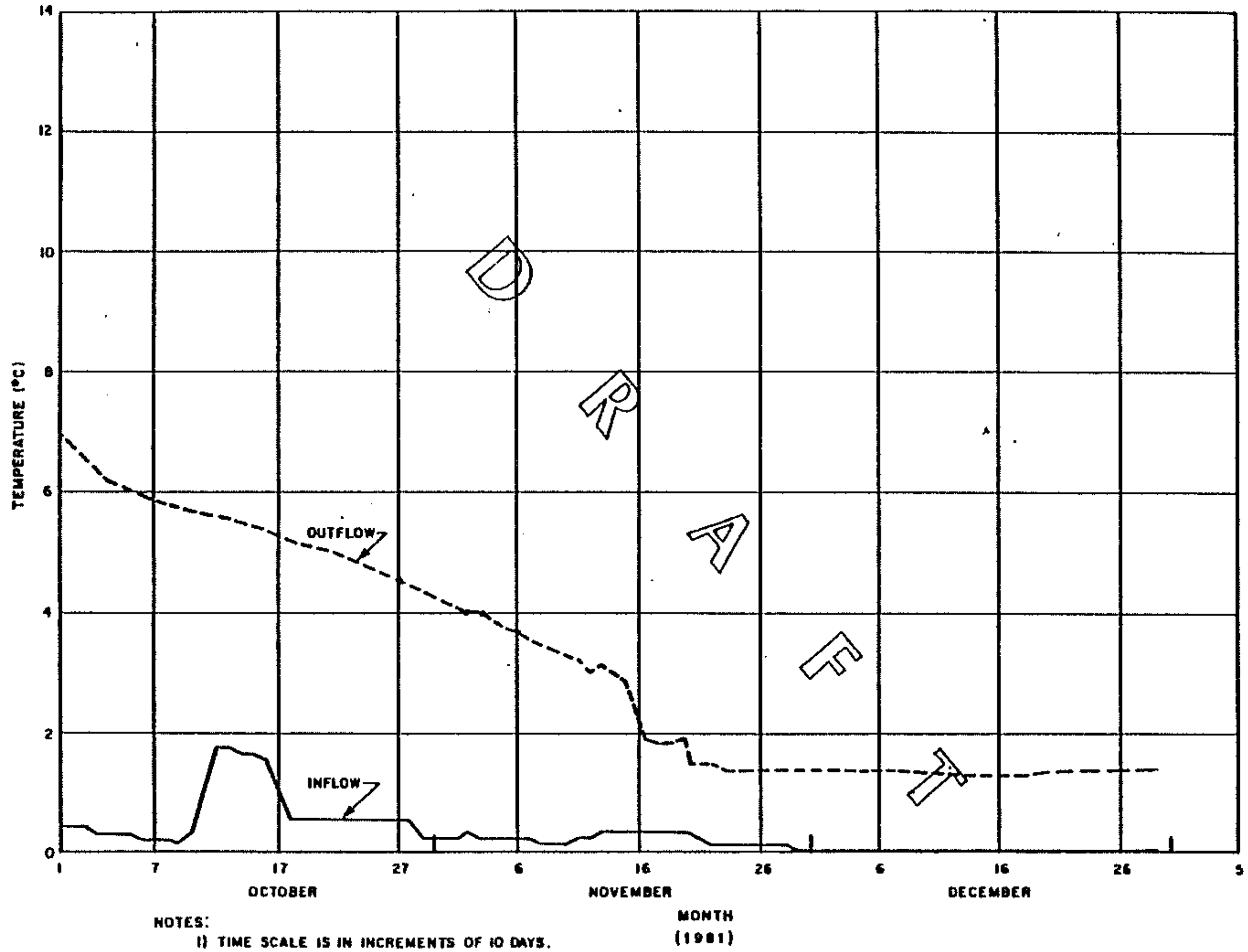
NOTE: TEMPERATURE PROFILES SIMULATED USING 1981 DATA.

WATANA RESERVOIR TEMPERATURE PROFILES SEPTEMBER / DECEMBER (Acres)



WATANA RESERVOIR INFLOW AND OUTFLOW TEMPERATURES JUNE / SEPTEMBER

Figure 35

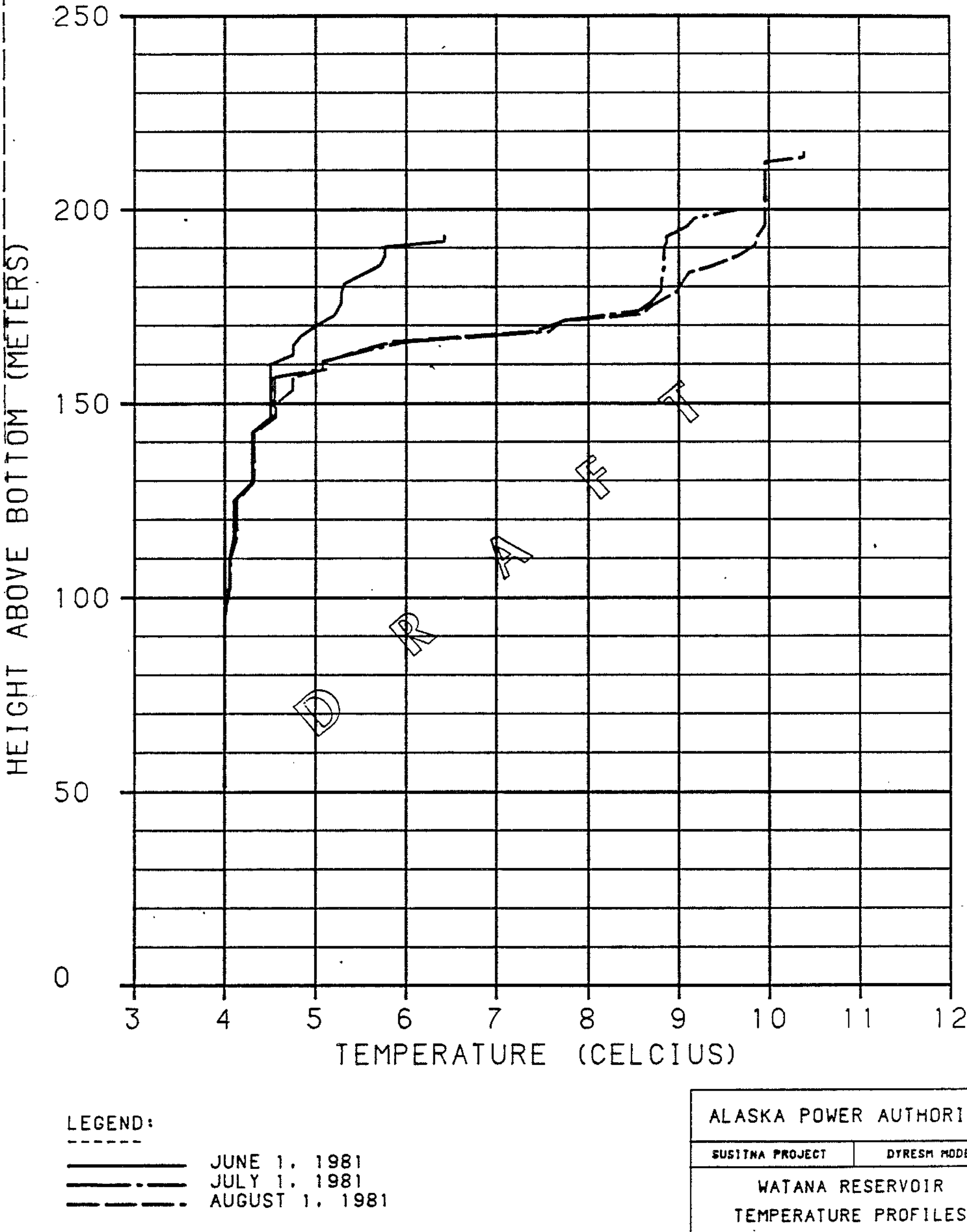


NOTES:
1) TIME SCALE IS IN INCREMENTS OF 10 DAYS.
2) BASED ON 1981 DATA, WATANA OPERATION
3) RUN W4020; WITH OUTFLOW TEMPERATURE FOLLOWING INFLOW TEMPERATURE.

WATANA RESERVOIR INFLOW AND OUTFLOW TEMPERATURES OCTOBER / DECEMBER

Figure 36

Figure 37



ALASKA POWER AUTHORITY

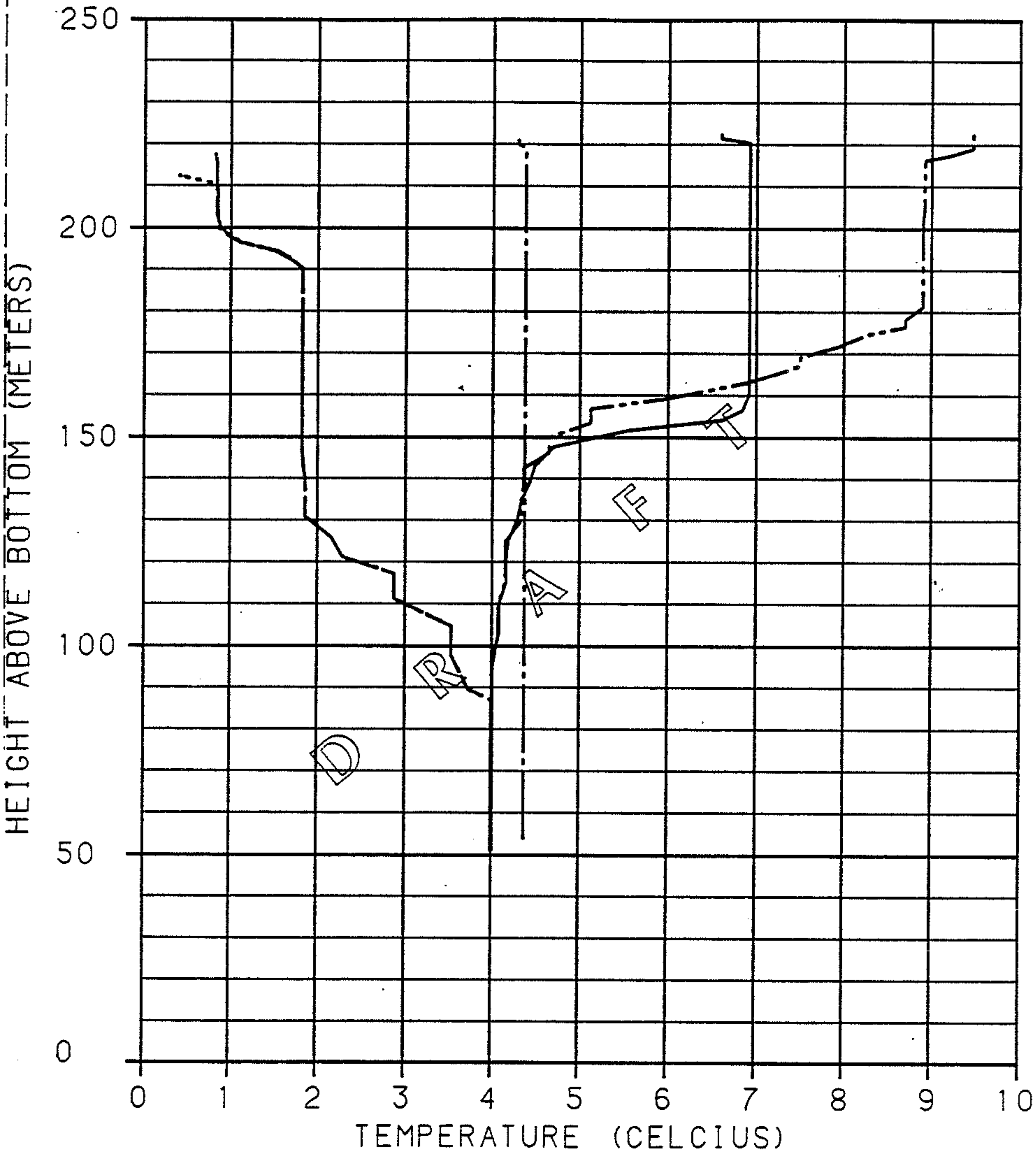
SUSITNA PROJECT | DYRESM MODEL

WATANA RESERVOIR
TEMPERATURE PROFILES

HARZA-EBASCO JOINT VENTURE

CHICAGO, ILLINOIS | 30 DEC 83 | 1563.142 HYD1

Figure 38



LEGEND:

- SEPTEMBER 1, 1981
- OCTOBER 1, 1981
- NOVEMBER 1,1981
- DECEMBER 1, 1981
- DECEMBER 31, 1981

ALASKA POWER AUTHORITY	
SUSITNA PROJECT	DYRESM MODEL
WATANA RESERVOIR TEMPERATURE PROFILES	
HARZA-EBASCO JOINT VENTURE	

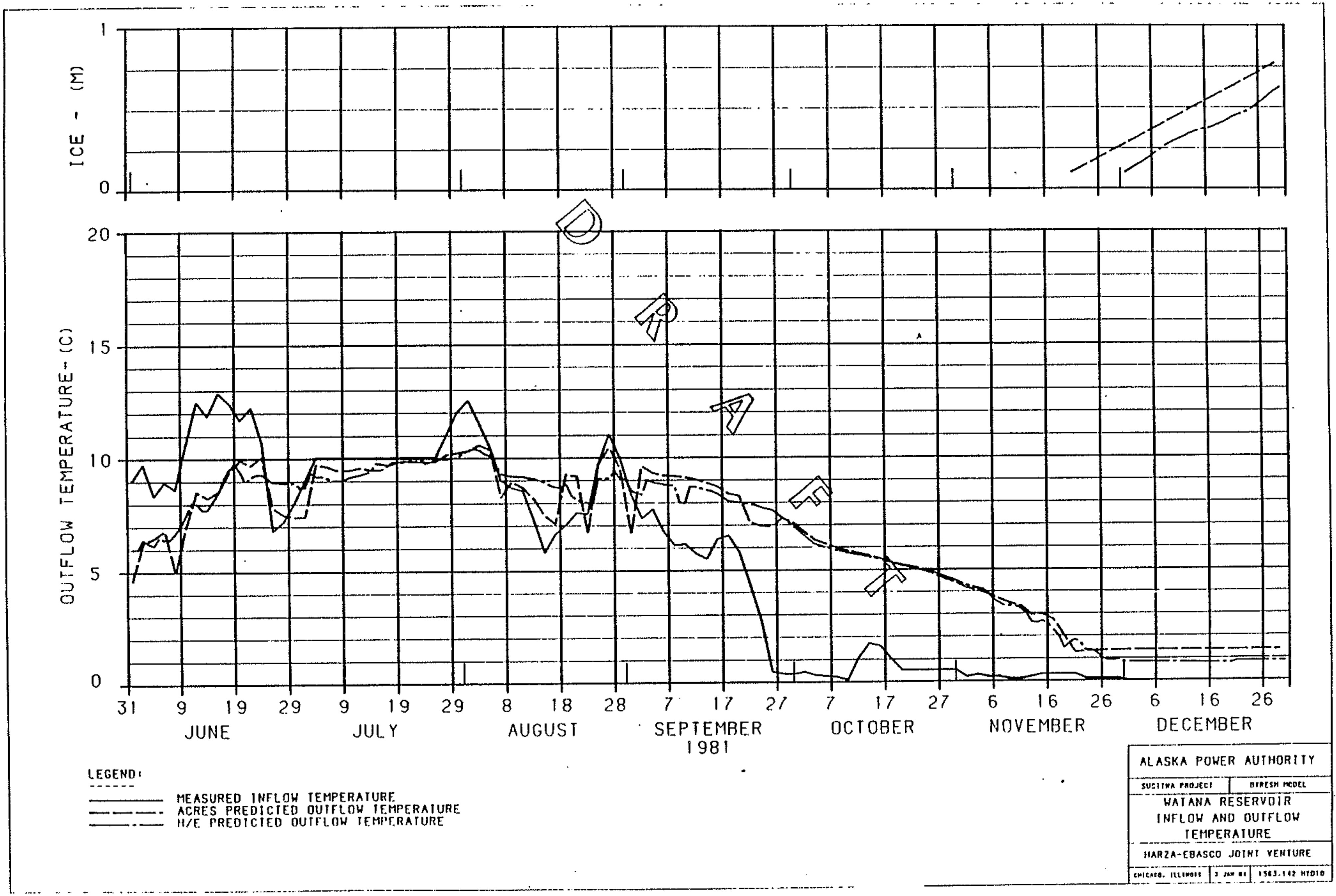

ICE - (M)
OUTFLOW TEMPERATURE- (C)
JUNE
JULY
AUGUST
SEPTEMBER
1981
OCTOBER
NOVEMBER
DECEMBER
LEGEND:
MEASURED INFLOW TEMPERATURE
ACRES PREDICTED OUTFLOW TEMPERATURE
H/E PREDICTED OUTFLOW TEMPERATURE
DRAFT
ALASKA POWER AUTHORITY
SUSITNA PROJECT
WATANA RESERVOIR
INFLOW AND OUTFLOW
TEMPERATURE
HARZA-EBASCO JOINT VENTURE
CHICAGO, ILLINOIS

Figure 39