PRNC - 180

PUERTO RICO NUCLEAR CENTER

AERIAL INFRARED SCANNING OF DISCHARGE REGIONS OF PRESENT AND ALTERNATE POWER PLANT SITES

VOLUME I

Prepared for the Puerto Rico Water Resources Authority
By the Staff of Puerto Rico Nuclear Center of the
University of Puerto Rico

April 1975

OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT
NO. AT (40-1)-1833 FOR U S ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

TABLE OF CONTENTS

AERIAL INFRARED SCANNING OF DISCHARGE REGIONS OF PRESENT AND ALTERNATE POWER PLANT SITES

by

E.D. Wood

Puerto Rico Nuclear Center
Mayaguez, Puerto Rico
April 1, 1975

AERIAL INFRARED SCANNING OF DISCHARGE REGIONS OF PRESENT AND ALTERNATE POWER PLANT SITES.

INTRODUCTION

Most power plants are only 25 to 40% efficient, therefore, tremendous amounts of energy are dissipated into the atmosphere, either directly up the stack or indirectly, first into water and from there into the atmosphere. It is important to learn the extent and the effect of thermal discharges on life in the aquatic environment.

Surface temperatures of objects can be measured by directing infrared irradiation given off. Instantaneous measurement of water surface temperatures can be accomplished using an infrared scanner mounted in an aircraft which is then flown over the study region. Such flights were made over selected sites around the Island of Puerto Rico in 1973 and 1974. Measurements were taken by the Raytheon Corp. in February, 1973, using a Bendix Line Scanner. The Puerto Rico Nuclear Center, using an AGA Thermovision Scanner, measured water surface temperatures quarterly from July, 1973 through December, 1974.

Sites and Schedule

The sites of Jobos Bay, Guayanilla and San Juan Harbor were selected for scanning because they were receiving, or were about to receive, thermal effluents. Seven other possible future power plant sites were scanned for base line information (See Fig. 1). The Jobos Bay site was scanned on a two-week schedule of alternate morning flights plus four evening flights to cover tidal cycles and night vs. day wind conditions. The schedules for the various flights are given in Table 1.

The site code key is given below:

CMP	-	Cabo Mala Pascua	PHI	-	Pta. Higuero
CRP	-	Cabo Rojo Platform	PMA	-	Pta. Manati
GY	-	Guayanilla Bay	PVE	-	Pta. Verraco
ISL	-	Islote	SJS	-	San Juan Steam Plant
JB	-	Jobos Bay	TOR	-	Tortuguero Bay
PAS	-	Palo Seco			

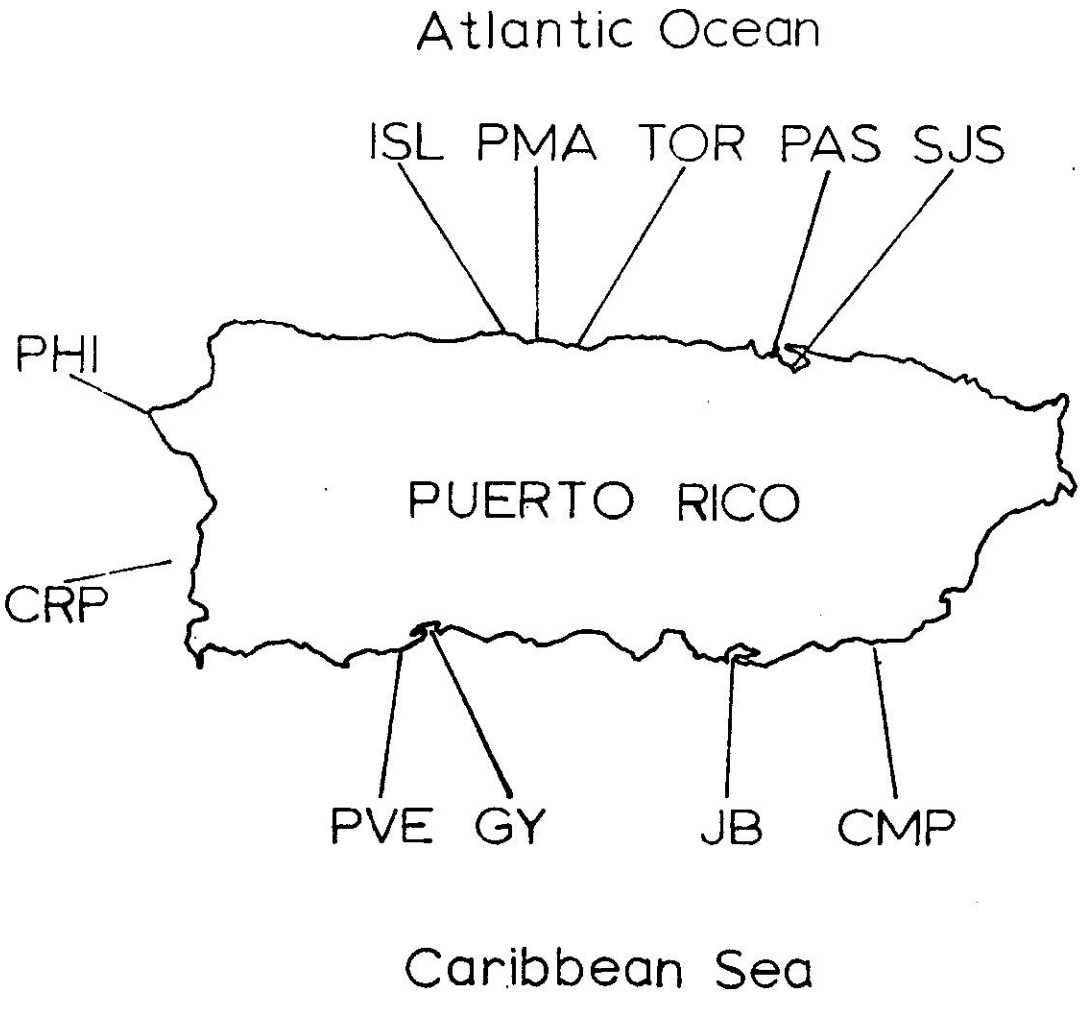


Fig. 1. Map showing infrared scanning sites around Puerto Rico.

Equipment

The infrared scanning equipment was supplied by AGA Corp. An instrumentation tape recorder was acquired from Sangamo Electric Co. Brief descriptions of the major components of the system follow.

Camera (-IR-): Infrared detection in the 2-5.6 μm band with various temperature ranges from 1° to 2000°C adjustable between -30°C to 2000°C. An indium antimonide (InSb) photovoltaic detector is cooled with liquid nitrogen. One fill lasts approximately four hours. The unit will focus from 1 m to infinity and is sensitive to 0.1°C differences in temperature through a 45°C lens (13.5 kg-30 lb).

Display Unit: Picture size is 9x9 cm (3.5x3.5), showing 16 frames per second. Temperature difference (Δ_t) setting is indicated on the side of the frame and a grey reference scale extends across the bottom. The display unit controls the level of temperature range selected. (23.7 kg-52 lb)

Color Monitor: Signals from the display unit are fed into the color monitor where the image is reproduced. The temperature range is divided into ten arbitrary colors. Picture size is 13x18 cm (5x7 in.). (18 kg-40 lb)

Camera-(35 mm): Motorized Nikon F, 35 mm with a 250 frame cassette operating off 12 VDC. A special lens and attachment photographs images displayed on the color monitor.

The camera is normally shot at 1 frame per 30 seconds, but will take up to 8 frames per second. (4.4 kg-21 lb)

Inverters: (Topaz) Inverts 13±2 VDC to 115±6 VAC 0 to 250 VA, sine wave with less than 5% total harmonic distortion and 60+.3 Hz frequency. (17.7 kg-39 lb)

Instrumentation Tape Recorder: Portable Saber III operating on either 24 or 28 VDC. It uses a 2.54x35.6 cm (1x14 in.) reel at 120 ips. Fourteen tracks allow 4 passes of 3 tracks each, with the two-edge tracks used for voice. A tape holds 12 minutes of scan data per pass. (50.0 kg-110 lb)

Batteries: Lead-acid batteries power the equipment, for periods of about 2 hours, separate from the aircraft's electrical system. (82.6-182 lb)

Aircraft: Four-place Cessna 182, 230 hp, constant speed propeller, equipped with camera hatch in the baggage compartment. This aircraft has a payload of over 230 kg (500 lb) in addition to the pilot, a technician and fuel.

Mounting

The infrared camera was shock mounted pointing aft in the forward area of the baggage compartment. A front-surface mirror was mounted at a 45°C angle over the camera hatch in front of the camera (See Fig. 2). This caused the incident image to be reversed. The direction of flight appeared at the top of the display screen, however, left and right of the image were reversed electronically in the display units.

METHOD

Two methods of recording data were used, each with its own configuration of equipment other than the infrared camera. These methods are discussed below as Methods A and B. A third method (C) could also be used, and is described briefly.

Method A-Film Record: The equipment used was arranged as shown in Figure 3. The color monitor was connected to the control unit and its images were recorded on 35 mm Ektachrome color film. The display unit and color monitor each operated from separate inverters. Each inverter was supplied 14 volts from a pair of batteries (6 & 8 v) in series. The 35 mm Nikon F camera operated off 12 v. Using the film recording system, a series of over-lapping pictures covering the scan path were taken. The exposed film was sent to Eastman Kodak for processing and mounting.

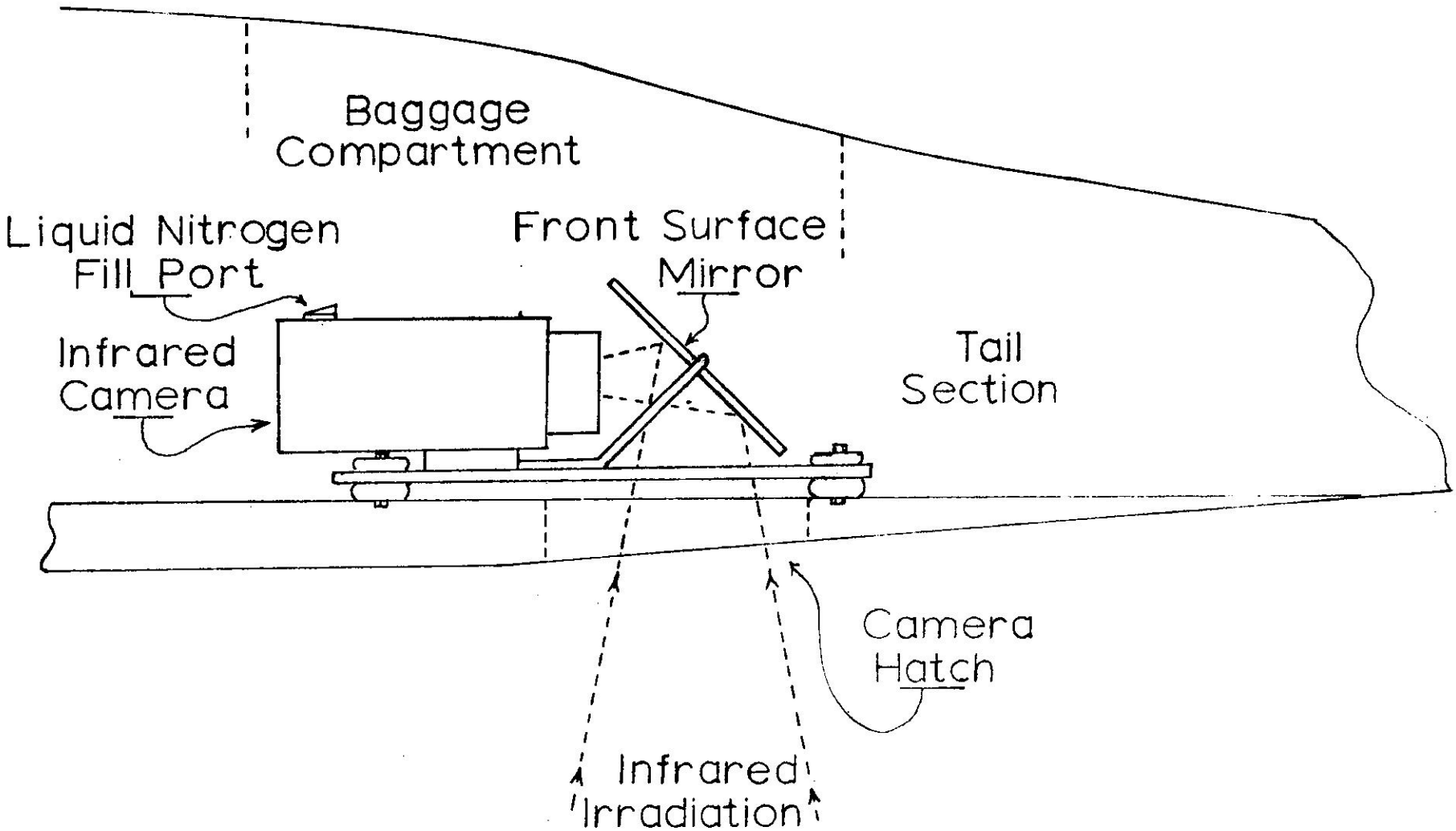


Fig. 2. Infrared camera mounted in the baggage compartment of aircraft as shown in a longitudinal section.

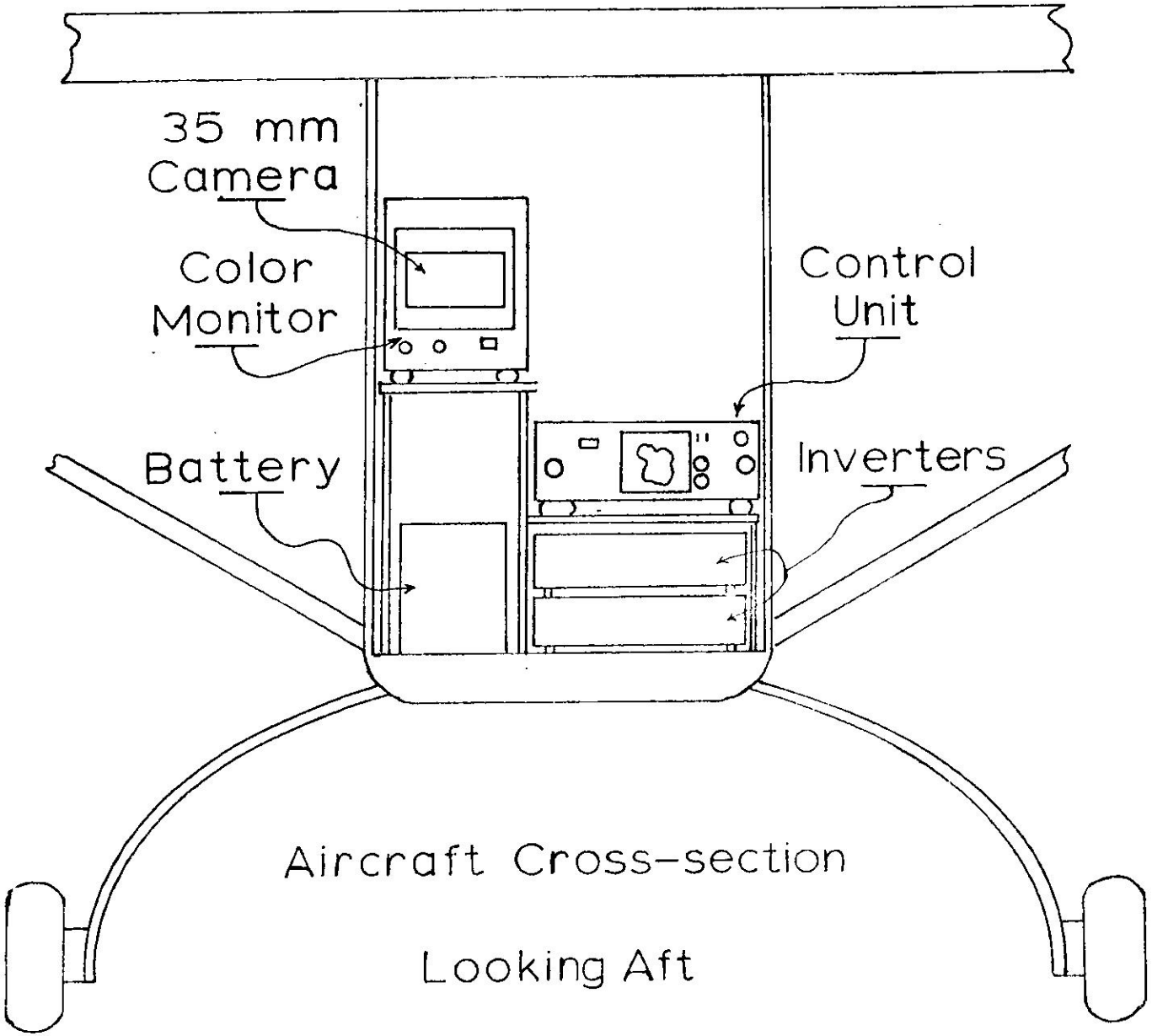


Fig. 3. Infrared equipment mounted in aircraft for film recording of data.

Method B: With the acquisition of the Saber III Instrumentation Tape Recorder, the color monitor, one inverter, and the 35 mm camera were replaced by the tape recorder and an extra battery (See Fig. 4). The signal from the IR camera then split between the control unit and the tape recorder. The recorder is capable of recording four passes of 12 minutes each on a 2.54x35.5 cm (1"x14") tape reel. A site can be covered in one pass. The tape can then be played back.

Method C: Data could be collected directly from the control unit using a Polaroid or 35 mm camera. The control unit displays an image in shades of grey from white (hot) to black (cold) with a graded grey scale for comparison. This method was not used by PRNC.

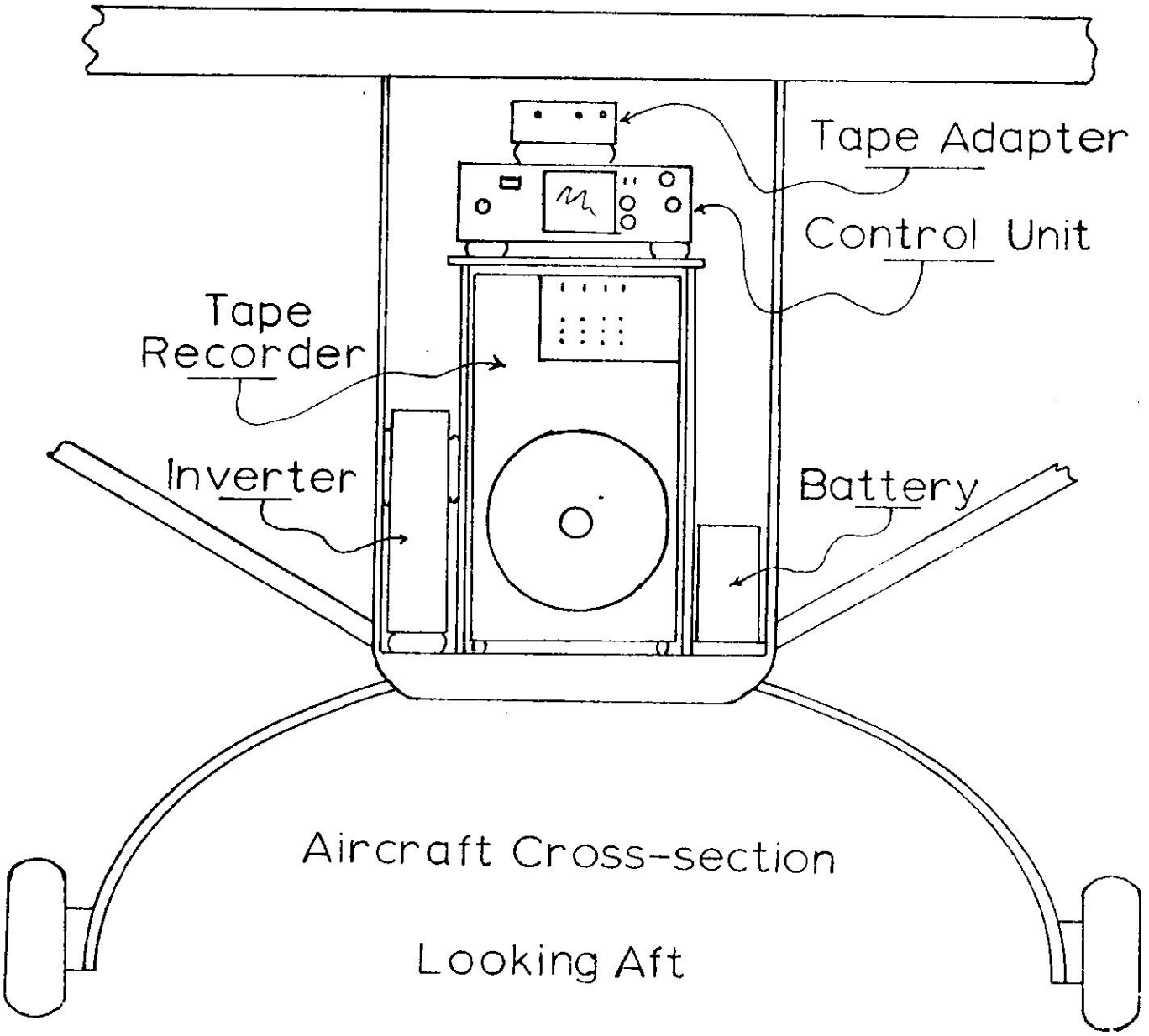


Fig. 4. Infrared equipment mounted in aircraft for magnetic tape recording of data.

DATA PROCESSING

The data recorded on slides were processed by projecting the image on a two-sided screen. A map of the area scanned, traced on a clear plexiglass sheet, was then placed on the screen side opposite the projector (See Fig. 5). The image was then fitted to the map by positioning the projector. Once aligned, the isotherms were traced onto the plexiglass with colored grease pencils.

When processing data recorded on magnetic tape, isotherms were drawn directly by watching the color monitor where low temperature gradients or little detail existed. Regions of interest or high detail were photographed with the 35 mm camera and projected on the two-sided screen. Isotherm temperatures were then assigned from temperatures measured independently at one or more surface locations and the isotherm setting. The plexiglass drawings were then traced on paper, followed by a second tracing, using an X-Y digitizer to computerize the data. These computerized data were then used to plot out site isotherms on page sized sheets, store data and compare scans.

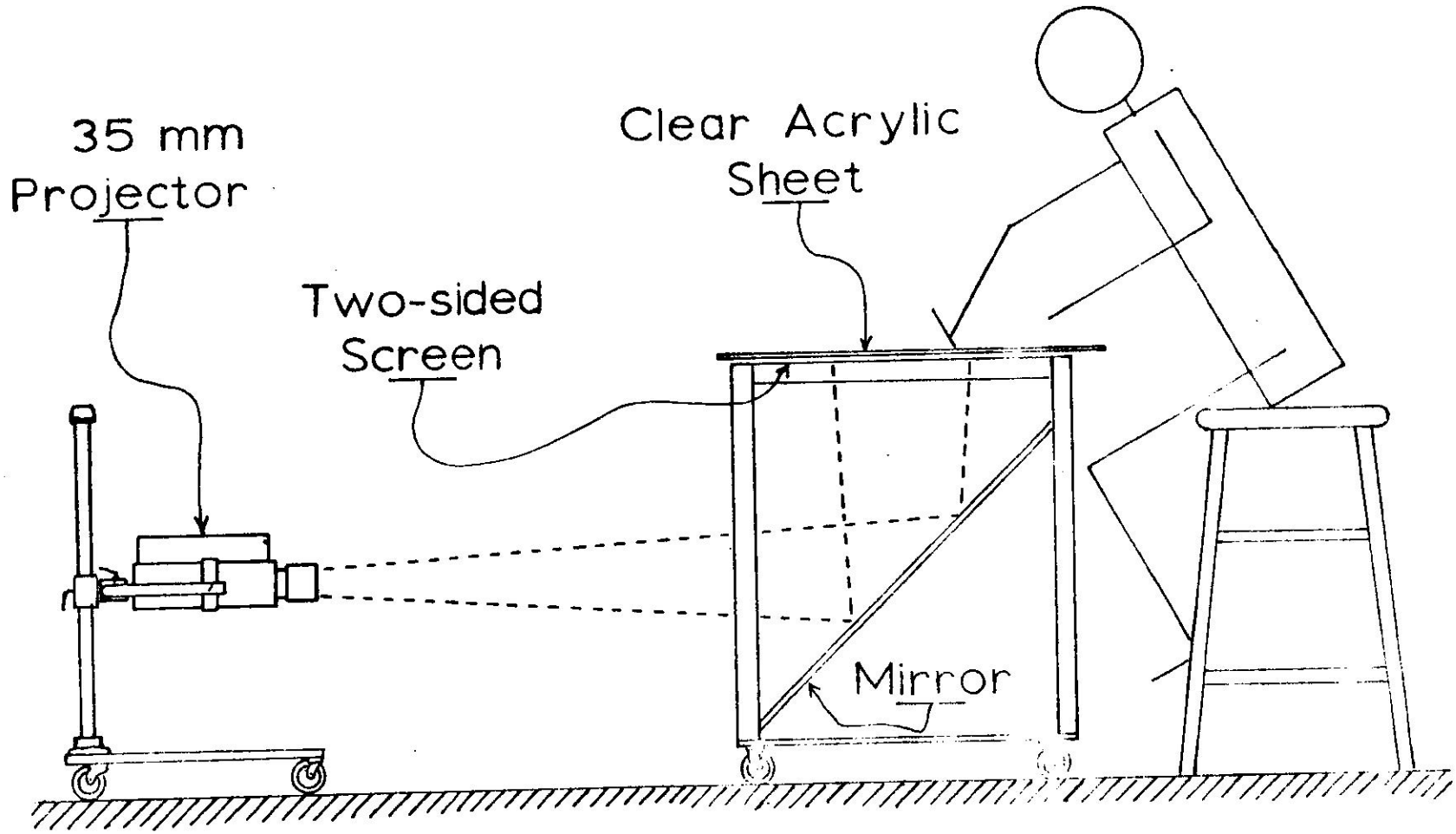
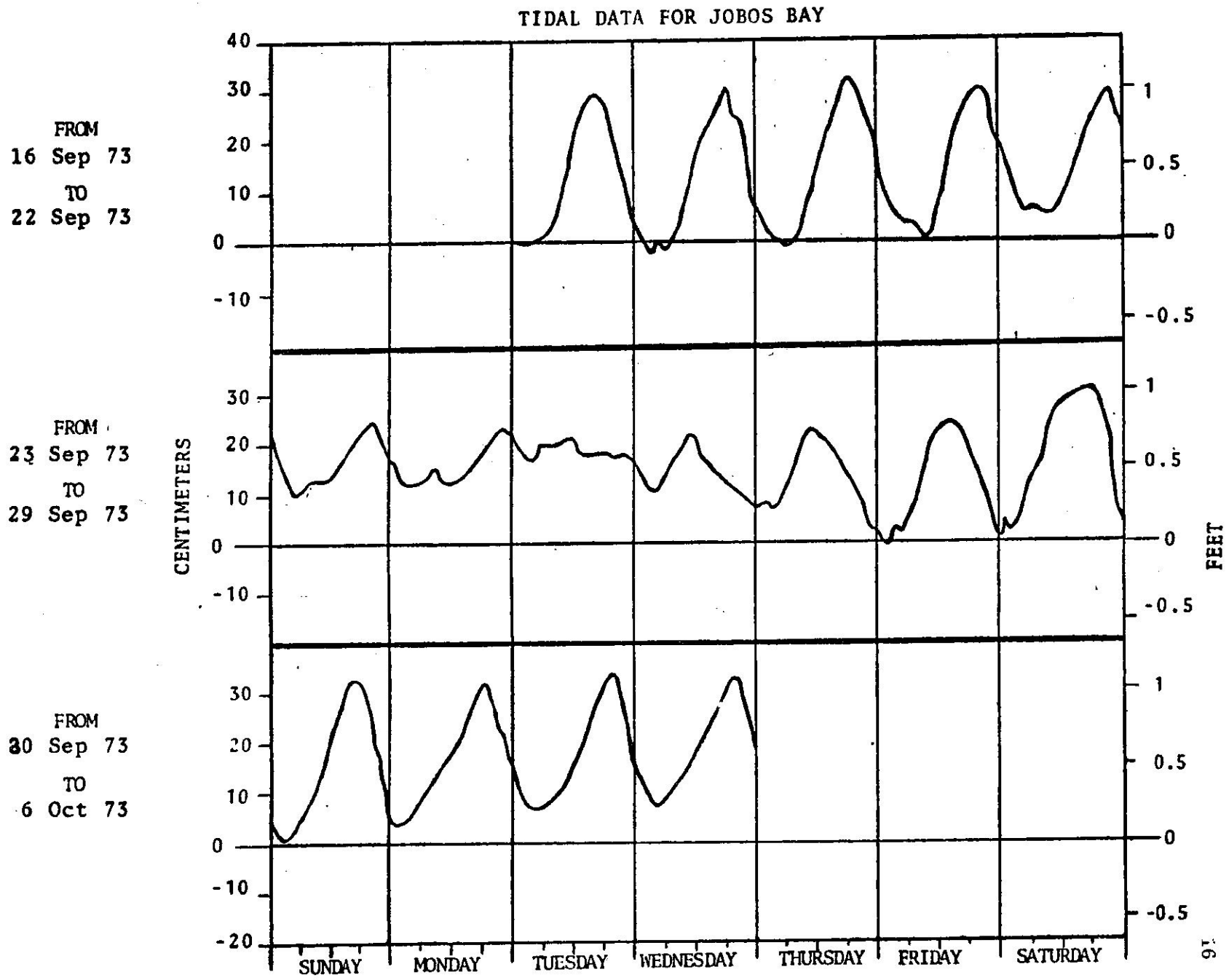


Fig. 5. Isotherms from infrared scans are traced on a clear acrylic sheet which has a map of the area scanned traced on the back side.

TABLE 1. Infrared Sampling Schedule

Scans/Quarters	73/3	73/4	74/1	74/2	74/3	74/4
JB 1	9/19 (0730)	11/12 (0630)	2/25 (0600)	6/2 (0517)	9/21 (0539)	12/3 (0558)
2	9/21 No data	11/14 (0605)	2/27 (0620)	6/4	9/23 (0546)	12/5 (0528)
3	9/23 (0805)	11/16 (0615)	3/1 (0555)	6/6 (0517)	9/25 (0552)	12/7 (0513)
4	9/25 (0800)	11/18 (0615)	3/3 (0553)	6/8 (0502)	9/27 (0629)	12/9 (0556)
5	9/27 (0630)	11/20 (0556)	3/5 (0545)	6/10(0516)	9/29 (0547)	12/11(0527)
6	9/29 (0615)	11/22 (0607)	3/7 (0553)	6/12(0522)	10/1 (0540)	12/13(0520)
7	10/2 (0615)	11/25 (0618)	3/9 (0645)	6/14(0526)	10/3 (0539)	12/15(0545)
JB 1	9/21 (1920)	11/15 (1745)	2/26 No data	6/5 (1955)	9/25 (1845)	12/4 (1743)
2	9/24 (1845)	11/16 (1748)	2/28 (1800)	6/7 (1957)	9/26 (1914)	12/6 (1816)
3	9/26 (1850)	11/19 (1748)	3/7 (1818)	6/9 (2014)	9/29 (1733)	12/10(1829)
4	9/28 (1830)	11/21 (1815)	3/10 (1828)	6/11(1952)	9/30 (1851)	12/13(1847)
CMP	9/24 (0650)	11/19 (0630)	3/7 (0633)	6/7 (0535)	9/29 (0623)	-
GY	9/20 (0630)	11/14 (0700)	2/26 (0550)	6/4 (0622)	9/26 (0549)	-
	9/1 (0710)	11/15 (1820)	3/9 (0730)		10/3 (0634)	
		11/16 (0655)				
PVE	9/20 (0630)	11/14 (0700)	2/26 (0550)	6/4 (0622)	9/26 (0549)	-
		11/16 (0655)				
CRP	-	-	3/9 (0735)	6/11(0525)	10/1 (0646)	-
PHI	9/26 (1950)	11/20 (0650)	3/10 (1828)	6/11(0607)	9/30 (1951)	-
	9/28 (0718)					
ISL	9/28 (0700)	11/17 (0605)	2/28 (0620)	6/5 (0557)	9/28 (0603)	-
PMA	9/28 (0700)	11/17 (0605)	2/28 (0620)	6/5 (0557)	9/28 (0603)	-
TOR	9/28 (0700)	11/17 (0605)	2/28 (0620)	6/5 (0557)	9/28 (0603)	-
PAS	9/28 (0625)	11/1 (0645)	2/28 (0550)	6/5 (0528)	9/29 (0806)	12/3 (1934)
SJS	-	-	2/28 (0550)	6/5 (0528)	9/29 (0806)	12/3 (1934)

TIDAL DATA FOR JOBOS BAY

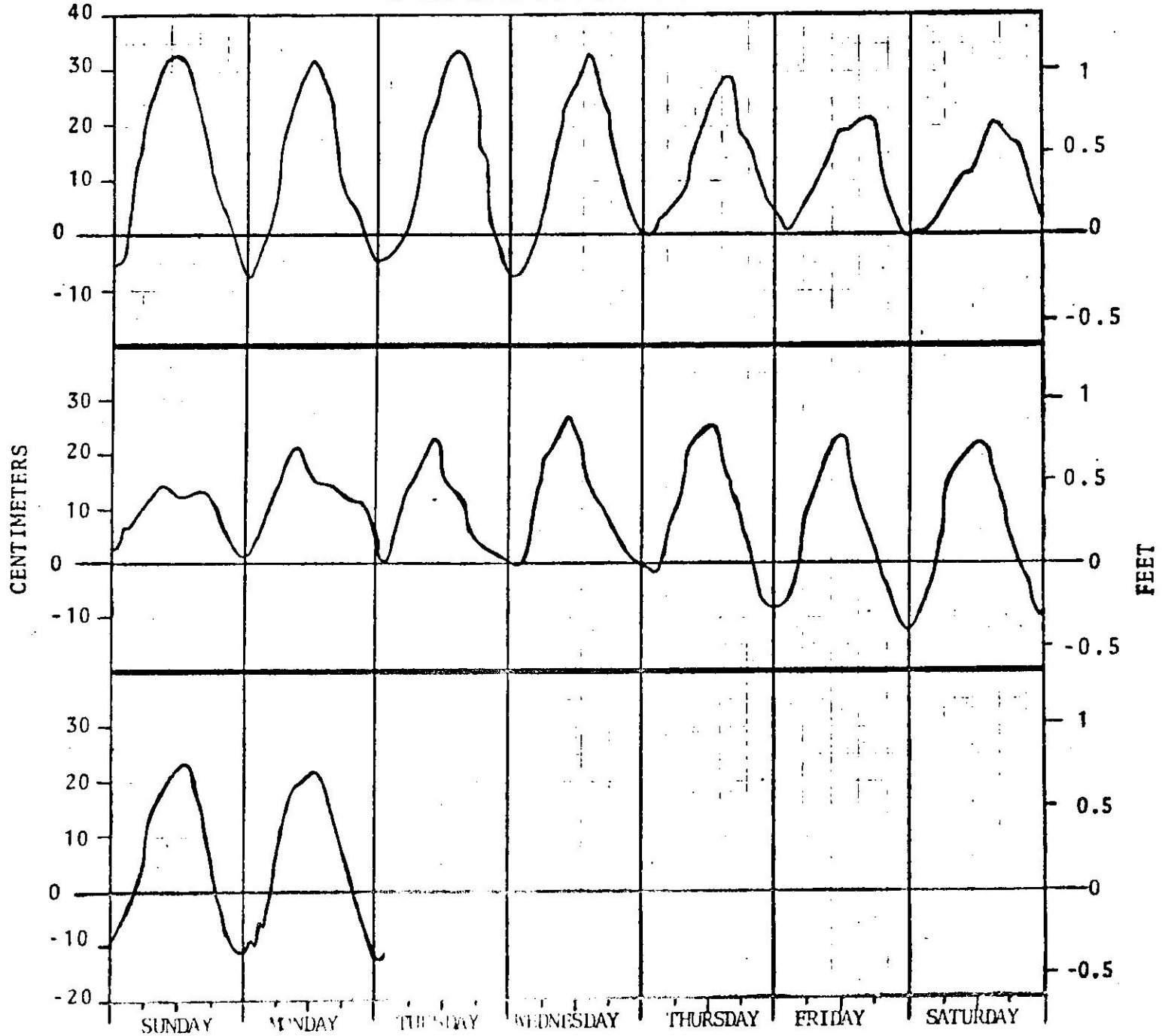

TIDAL DATA FOR JOBOS BAY
FROM
16 Sep 73
TO
22 Sep 73
FROM
23 Sep 73
TO
29 Sep 73
FROM
30 Sep 73
TO
6 Oct 73
CENTIMETERS
FEET
40
30
20
10
0
-10
-20
1
0.5
0
-0.5
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY

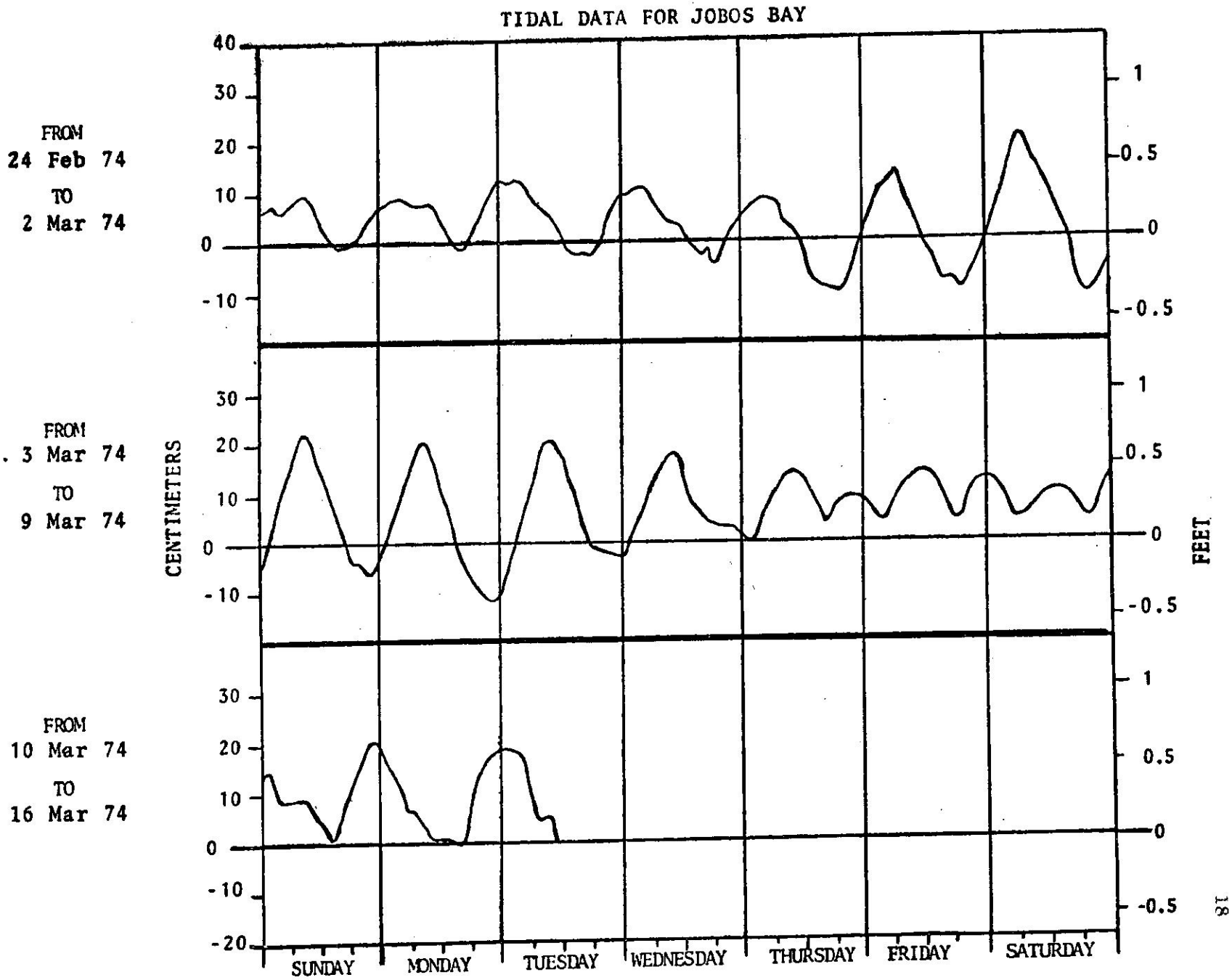
TIDAL DATA FOR JOBOS BAY

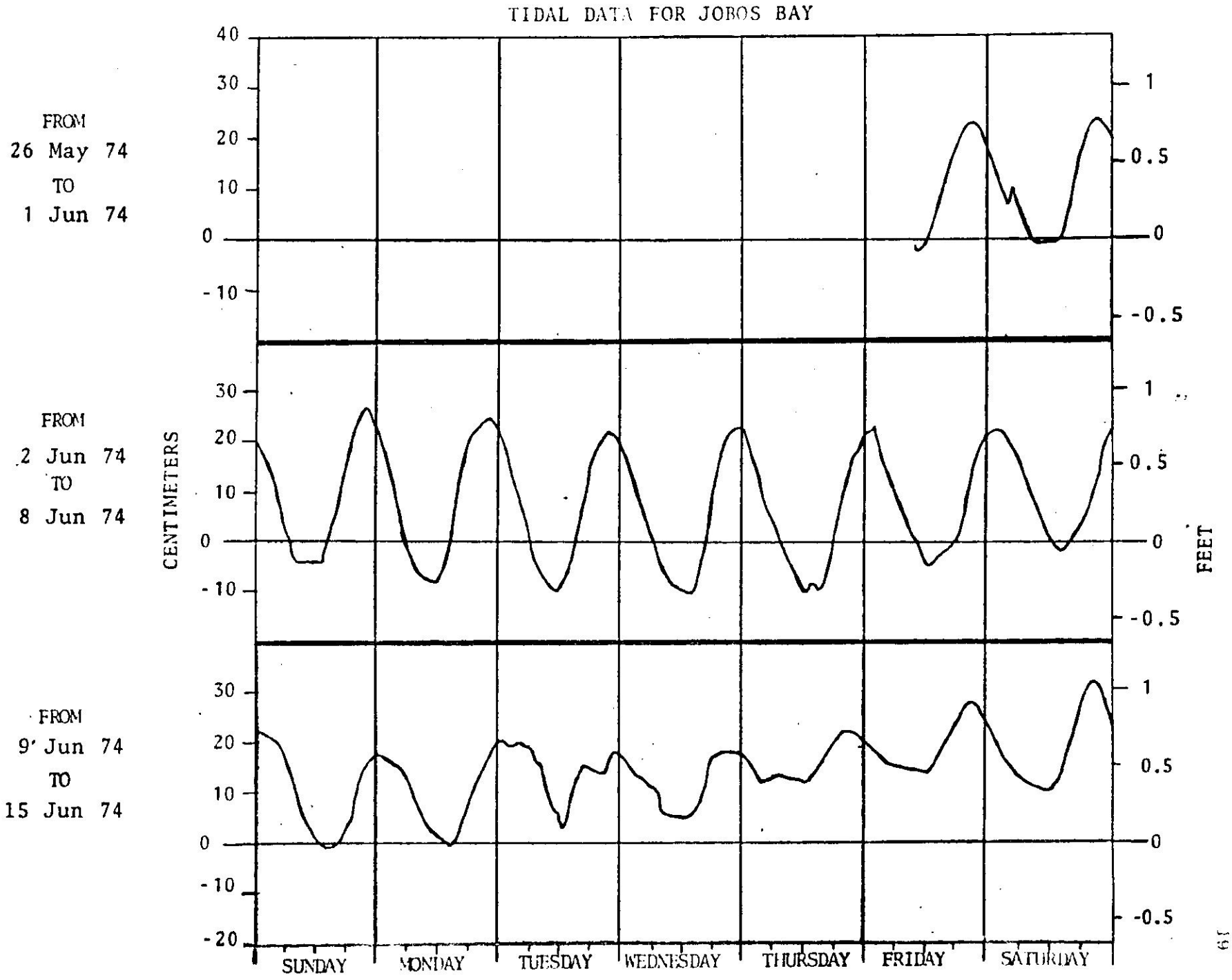
FROM
11 Nov 73
TO
17 Nov 73

FROM
18 Nov 73
TO
24 Nov 73

FROM
25 Nov 73
TO
1 Dec 73




TIDAL DATA FOR JOBOS BAY
FROM
24 Feb 74
TO
2 Mar 74
FROM
3 Mar 74
TO
9 Mar 74
FROM
10 Mar 74
TO
16 Mar 74
CENTIMETERS
FEET
40
30
20
10
0
-10
-20
1
0.5
0
-0.5
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY


TIDAL DATA FOR JOBOS BAY
FROM
26 May 74
TO
1 Jun 74
FROM
2 Jun 74
TO
8 Jun 74
FROM
9 Jun 74
TO
15 Jun 74
CENTIMETERS
FEET
40
30
20
10
0
-10
-20
1
0.5
0
-0.5
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY

POWER LEVELS OF ELECTRIC GENERATING PLANTS

POWER LEVELS OF ELECTRIC GENERATING PLANTS

(SAN JUAN STEAM PLANT)

DATE 1974	HOUR OF SAMPLE	LOAD HOUR	LOAD MW	LOAD (MW) IN PREVIOUS 12 HOURS (1) FROM DATE	FROM HOUR	TO DATE	TO HOUR	MW
2-28	0550	0500	141	2-27	1800	2-28	0500	183, 197, 232, 205 183, 179, 169, 148 148, 149, 148, 141
		0600	147					
6-5	0528	0500	163	6-4	1800	6-5	0500	178, 167, 179, 177 175, 179, 164, 150 151, 167, 172, 163
		0600	174					
9-29	0806	0800	93	9-28	2000	9-29	0800	124, 125, 124, 102 94, 97, 94, 94 94, 95, 95, 93
		0900	96					
12-3	1934	1900	259	12-3	0800	12-3	1900	199, 230, 251, 251 258, 257, 258, 252 247, 248, 249, 259
		2000	260					

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.

POWER LEVELS OF ELECTRIC GENERATING PLANTS

(PALO SECO STEAM PLANT)

DATE	HOUR OF SAMPLE	LOAD HOUR	LOAD MW	LOAD (MW) IN PREVIOUS 12 HOURS (1) FROM DATE	FROM HOUR	TO DATE	TO HOUR	MW
		0600	460					380, 415, 465, 310
9-28-73	0625			9-27	1900	9-28	0600	365, 285, 435, 450
		0700	465					450, 450, 455, 460
		0600	375					370, 380, 380, 385
11-1-73	0645			10-31	1900	11-1	0600	375, 375, 380, 375
		0700	380					375, 380, 380, 375
		0500	265					350, 350, 345, 345
2-28-74	0550			2-27	1800	2-28	0500	335, 330, 325, 330
		0600	260					325, 315, 295, 265
		0500	245					240, 240, 240, 240
6-5-74	0528			6-4	1800	6-5	0500	215, 205, 250, 245
		0600	245					245, 245, 250, 245
		0800	270					415, 395, 370, 320
9-29-74	0806			9-28	2100	9-29	0800	265, 260, 260, 260
		0900	295					265, 260, 250, 270
		1900	245					200, 200, 190, 230
12-3-74	1934			12-3	0800	12-3	1900	230, 230, 225, 220
		2000	245					230, 230, 230, 245

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.

POWER LEVELS OF ELECTRIC GENERATING PLANTS
(SOUTH COAST STEAM PLANT)

DATE	HOUR OF SAMPLE	LOAD HOUR	LOAD MW	LOAD (MW) IN PREVIOUS 12 HOURS (1) FROM DATE	FROM HOUR	TO DATE	TO HOUR	MW
9-20-73	0630	0600 0700	558 580	9-19	1900	9-20	0600	583, 595, 594, 581 574, 548, 553, 553 550, 551, 555, 558
10-1-73	0710	0700 0800	585 578	9-30	2000	10-1	0700	602, 592, 586, 578 565, 547, 546, 515 520, 494, 535, 585
11-14-73	0700	0700	603	11-13	1900	11-14	0600	625, 614, 609, 577 575, 566, 576, 581 572, 581, 578, 571
11-15-73	1820	1800 1900	819 792	11-15	0700	11-15	1800	664, 612, 596, 613 607, 595, 648, 745 805, 831, 827, 819
11-16-73	0655	0600 0700	696 737	11-15	1900	11-16	0600	792, 812, 805, 798 771, 719, 689, 675 681, 649, 644, 696
2-26-74	0550	0500 0600	665 730	2-25	1800	2-26	0500	988, 990, 1016, 1002 991, 926, 826, 759 704, 682, 678, 665
3-9-74	0730	0700 0800	854 881	3-8	2000	3-9	0700	1042, 1044, 1044, 1040 909, 846, 814, 796 802, 792, 797, 854
6-4-74	0622	0600 0700	627 679	6-3	1900	6-4	0600	963, 966, 824, 747 666, 615, 641, 629 600, 626, 611, 627
9-26-74	0549	0500 0600	640 640	9-25	1800	9-26	0500	847, 842, 823, 839 847, 785, 664, 630 609, 626, 608, 640
10-3-74	0634	0600 0700	727 784	10-2	1900	10-3	0600	907, 916, 894, 925, 838, 698, 639, 853 651, 656, 659, 727

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.

POWER LEVELS OF ELECTRIC GENERATING PLANTS

(AGUIRRE STEAM PLANT - 1) (JB 1-7)

DATE 1974	HOUR OF SAMPLE	LOAD HOUR	LOAD MW	LOAD (MW) IN PREVIOUS 12 HOURS (1) FROM DATE	FROM HOUR	TO DATE	TO HOUR	MW
2-25	0600	0600						
2-27	0620	0600						
		0700						
3-1	0555	0500						
		0600						
3-3	0553	0500						
		0600						
3-5	0545	0500						
		0600						
3-7	0553	0500						
		0600						
3-9	0645	0600						
		0700						
6-2	0517			Unit out of Service				
6-4	0542	0500	18	6-3	1800	6-4	0500	Unit out of service until 0100 of 6-4-74 Load from 0100 to 0500= 18, 19, 18, 18, 18 Unit out again at 0800
		0600	18					
6-6	0517	0500	228	6-5	1800	6-6	0500	339, 344, 346, 295 292, 289, 271, 256 223, 229, 228, 228
		0600	228					

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.

POWER LEVELS OF ELECTRIC GENERATING PLANTS

(AGUIRRE STEAM PLANT - II) (JB 1-7)

DATE 1974	HOUR OF SAMPLE	LOAD HOUR	LOAD MW	LOAD (MW) IN PREVIOUS 12 HOURS (1) FROM DATE	FROM HOUR	TO DATE	TO HOUR	MW
6-8	0502	0500 0600	185 181	6-7	1800	6-8	0500	5, 2, 19, 50 60, 102, 126, 164 186, 182, 186, 185
6-10	0516	0500 0600	156 152	6-9	1800	6-10	0500	150, 160, 200, 214 216, 184, 172, 150 157, 158, 159, 156
6-12	0522	0500 0600	284 269	6-11	1800	6-12	0500	299, 287, 294, 286 292, 279, 281, 284 280, 285, 282, 284
6-14	0526	0500 0600	249 249	6-13	1800	6-14	0500	300, 300, 290, 299 300, 298, 289, 267 255, 248, 251, 249
9-21	0539	0500 0600	260 253	9-20	1800	9-21	0500	266, 266, 269, 270 269, 258, 267, 270 257, 200, 245, 260
9-23	0546	0500 0600	270 232	9-22	1800	9-23	0500	255, 265, 270, 265 270, 276, 269, 273 270, 270, 268, 270
9-25	0552	0500 0600	258 255	9-24	1800	9-25	0500	230, 250, 265, 262 265, 256, 257, 253 255, 256, 258, 258
9-27	0629	0600 0700	229 252	9-26	1900	9-27	0600	230, 260, 240, 240 245, 245, 253, 247 226, 226, 229, 229
9-29	0547	0500 0600	142 145	9-28	1800	9-29	0500	152, 153, 153, 147 143, 145, 140, 141 142, 140, 141, 142
10-1	0540	0500 0600	245 245	9-30	1800	10-1	0500	176, 194, 229, 226 226, 225, 230, 240 245, 245, 240, 245

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.

POWER LEVELS OF ELECTRIC GENERATING PLANTS

(AGUIRRE STEAM PLANT - III) (JB 1-7)

DATE 1974	HOUR OF SAMPLE	LOAD HOUR	LOAD MW	LOAD (MW) IN PREVIOUS 12 HOURS (1) FROM DATE	FROM HOUR	TO DATE	TO HOUR	MW
10-3	0539	0500 0600	150 155	10-2	1800	10-3	0500	168, 187, 211, 204 162, 150, 158, 150 150, 150, 150, 150
12-3	0558	0500 0600	196 196	12-2 12-3	1800 0100	12-2 12-3	2000 0500	233, 240, 249, (4) 166, 198, 196, 196 196
12-5	0528	0500 0600	200 200	12-4	1800	12-5	0500	242, 228, 229, 245 249, 208, 204, 200 200, 200, 200, 200
12-7	0513	0500 0600	(2)	12-6	1800	12-7	0300	200, 243, 221, 200 207, 206, 215, 220 120, (2)
12-9	0556	0500 0600	(3)	12-8	1800	12-9	0500	(3)
12-11	0527	0500 0600	211 227	12-10	1800	12-11	0500	247, 263, 258, 260 252, 219, 212, 221 227, 226, 225, 221
12-13	0520	0500 0600	(5)	12-12	1800	12-12	2400	252, 262, 256, 262 260, 242, 49, (5)
12-15	0545	0500 0600	145 145	12-14	1800	12-15	0500	230, 254, 258, 252 197, 174, 145, 136 138, 144, 144, 145

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.
(2) Unit out of service from 0400 hours on.
(3) Unit out of service.
(4) No readings available for 2100, 2200, 2300 and 2400 hours on 12-2-74.
(5) Unit out of service from 0100 to 0900 hours on 12-13-74.

POWER LEVELS OF ELECTRIC GENERATING PLANTS
(AGUIRRE STEAM PLANT - IV) (JB 1-4)

DATE	HOUR OF	LOAD		LOAD (MW) IN PREVIOUS 12 HOURS (1)				
				FROM		TO		
1974	SAMPLE	HOUR	MW	DATE	HOUR	DATE	HOUR	MW
2-26	No Data	--	--	--	--	--	--	--
2-28	1800	1800						
3-7	1818	1800						
		1900						
3-10	1828	1800						
		1900						
6-5	1955	1900	344	6-5	0800	6-5	1900	248, 276, 339, 359
		2000	346					359, 364, 340, 171
								340, 346, 339, 344
6-7	1957	1900	2	6-7	0800	6-7	1100	240, 310, 350, 150
		2000	19	6-7	1600	6-7	1900	(2) 1, 5, 5, 2
6-9	2014	2000	200	6-9	0900	6-9	2000	153, 152, 153, 150
		2100	214					155, 150, 150, 152
								152, 150, 160, 200
6-11	1952	1900	287	6-11	0800	6-11	1900	283, 313, 339, 358
		2000	294					315, 330, 321, 316
								315, 316, 299, 287

(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.

(2) Unit out of service from 1200 to 1500 hours on 6-7-74.

POWER LEVELS OF ELECTRIC GENERATING PLANTS
(AGUIRRE STEAM PLANT - V) (JB 1-4)

DATE	HOUR OF	LOAD		LOAD (MW) IN PREVIOUS 12 HOURS (1)				
				FROM		TO		
1974	SAMPLE	HOUR	MW	DATE	HOUR	DATE	HOUR	MW
9-25	1845	1800	250	9-25	0700	9-25	1800	260, 256, 259, 265
		1900	250					246, 250, 236, 220
								178, 210, 230, 250
9-26	1914	1900	230	9-26	0800	9-26	1900	220, 215, 222, 216
		2000	260					208, 192, 192, 190
								190, 200, 200, 230
9-29	1733	1700	143	9-29	0600	9-29	1700	145, 143, 140, 143
		1800	143					136, 145, 145, 145
								131, 144, 142, 143
9-30	1851	1800	176	9-30	0700	9-30	1800	150, 150, 150, 170
		1900	194					190, 195, 167, 173
								188, 167, 174, 176
12-4	1743	1700	243	12-4	0600	12-4	1700	200, 229, 232, 250
		1800	242					245, 250, 248, 245
								247, 245, 253, 243
12-6	1816	1800	220	12-6	0700	12-6	1800	260, 270, 263, 270
		1900	243					274, 279, 273, 270
								268, 261, 255, 220
12-10	1829	1800	247	12-10	0700	12-10	1800	68, 102, 118, 172
		1900	263					190, 200, 200, 200
								200, 210, 240, 247
12-13	1847	1800	190	12-13	0900	12-13	1200	(2), 14, 60, 35
		1900	200		1500		1800	115, (3), 62, 91
								120, 190

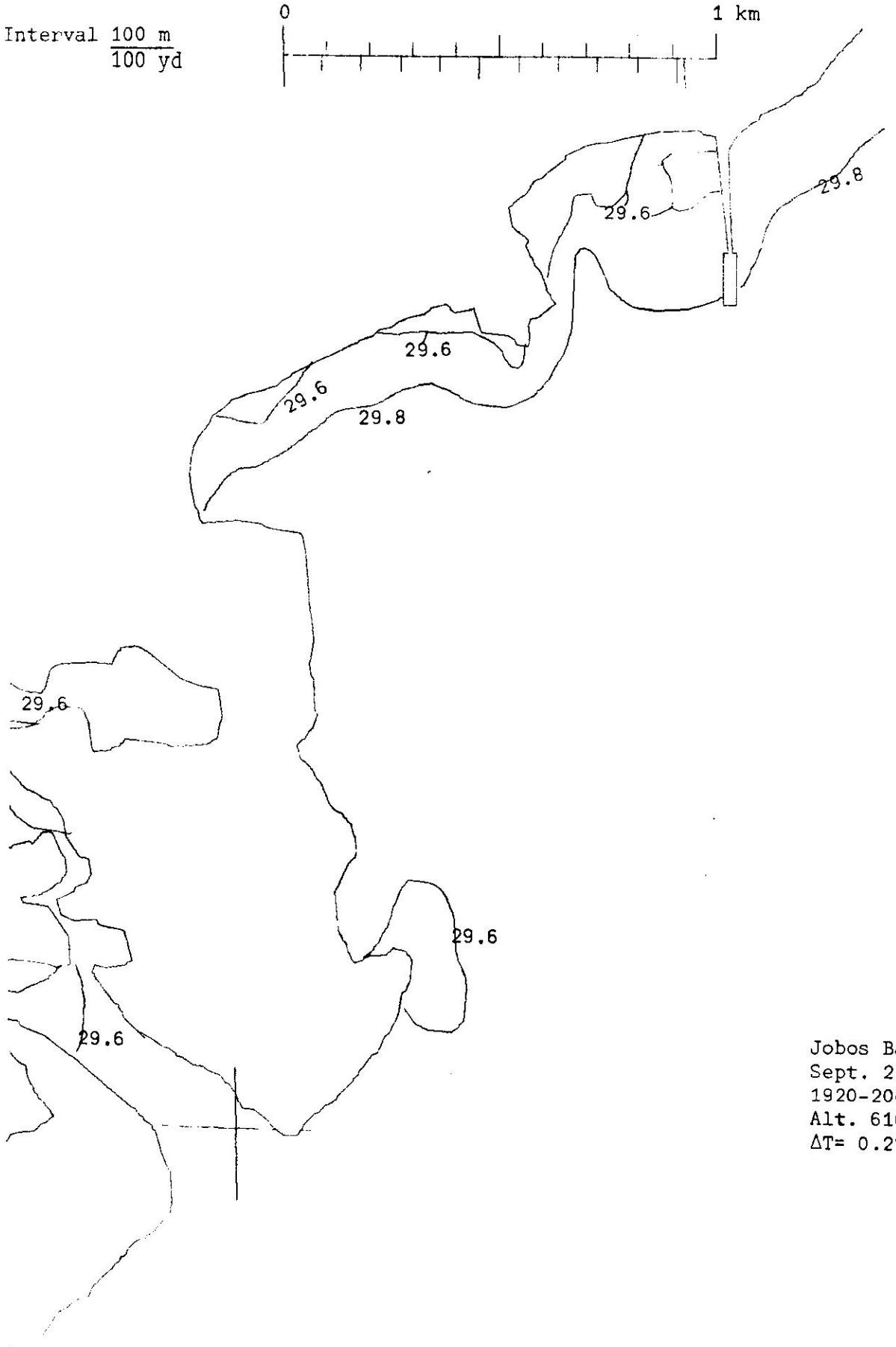
(1) Twelve (12) consecutive hourly readings from date and hour to date and hour indicated.
(2) Unit out of service until 0900 hours on 12-13-74.
(3) Unit out of service from 1300 to 1400 hours on 12-13-74.

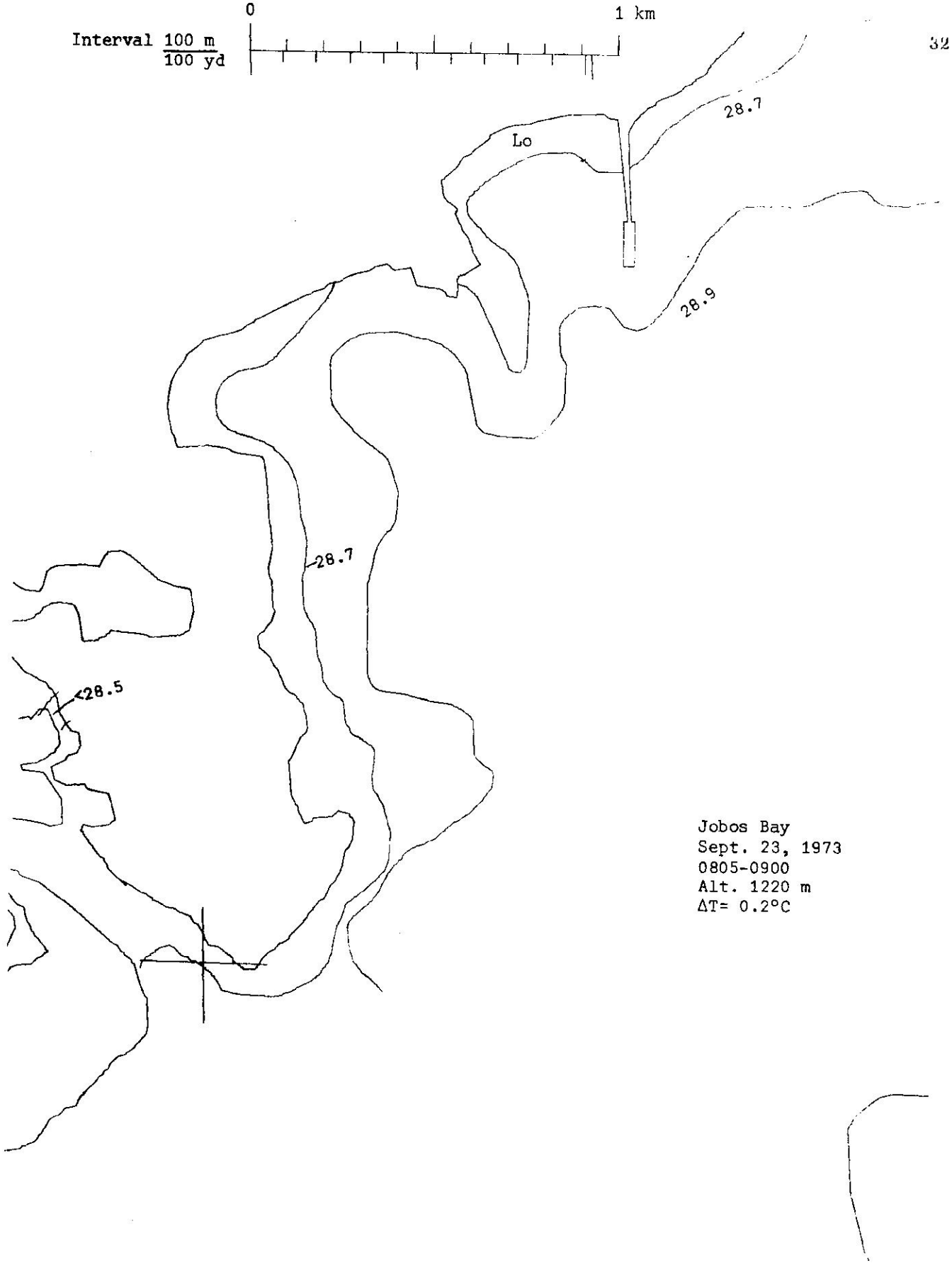
PLOTTED ISOTHERMS

Part 1

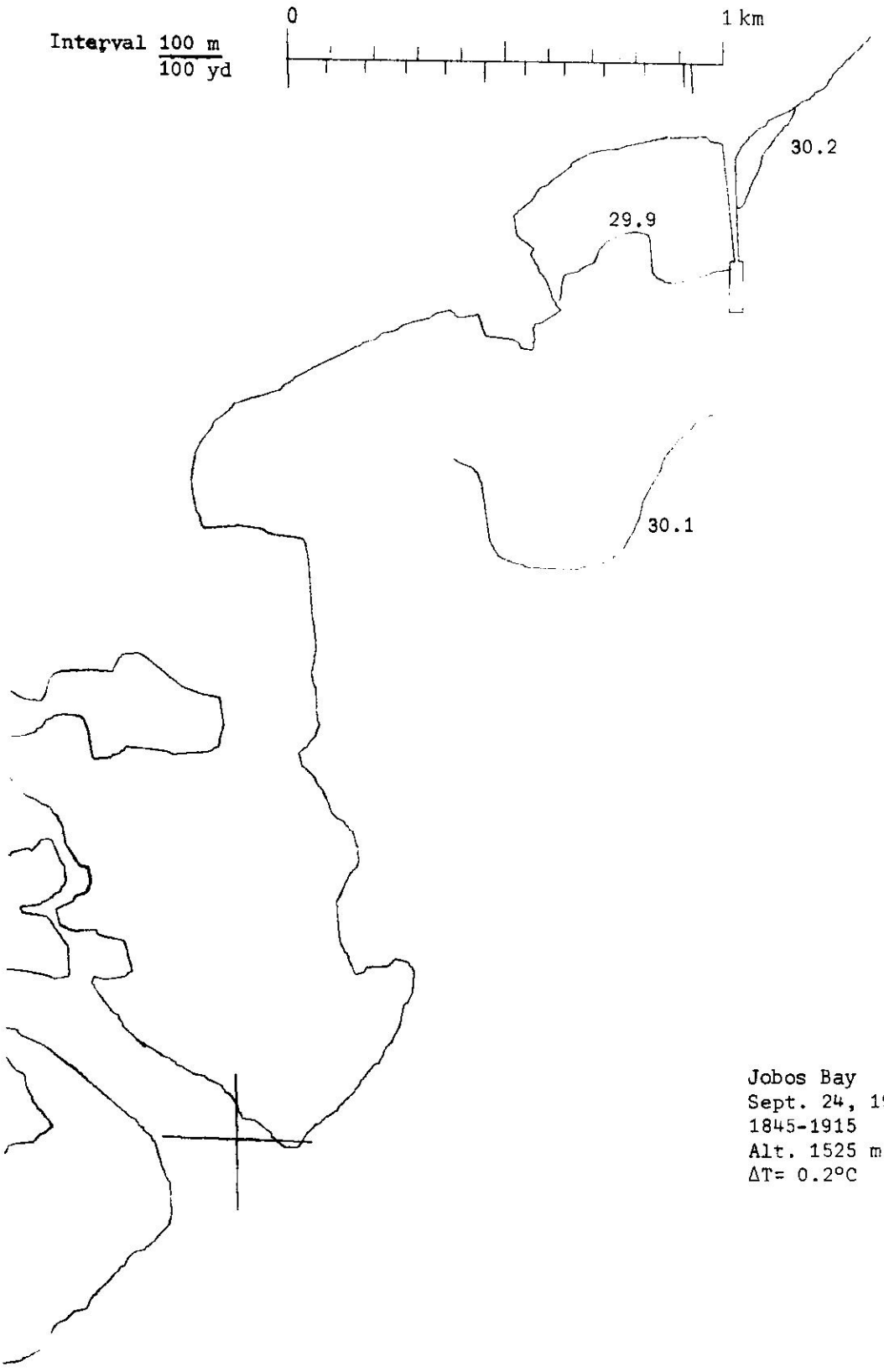
Jobos Bay
Palo Seco/San Juan
Tortuguero Bay
Punta Manati
Islote
Punta Higuero
Cabo Mala Pascua


Interval 100 m
100 yd
0
1 km
29.2
29.4
29.4
29.2
<29.4
>29.4
<29.6
<29.4
29.4
29.4
29.2
29.4
29.4
Jobos Bay
Sept. 19, 1973
0730-0850
Alt. 1068 m
ΔT= 0.2°C

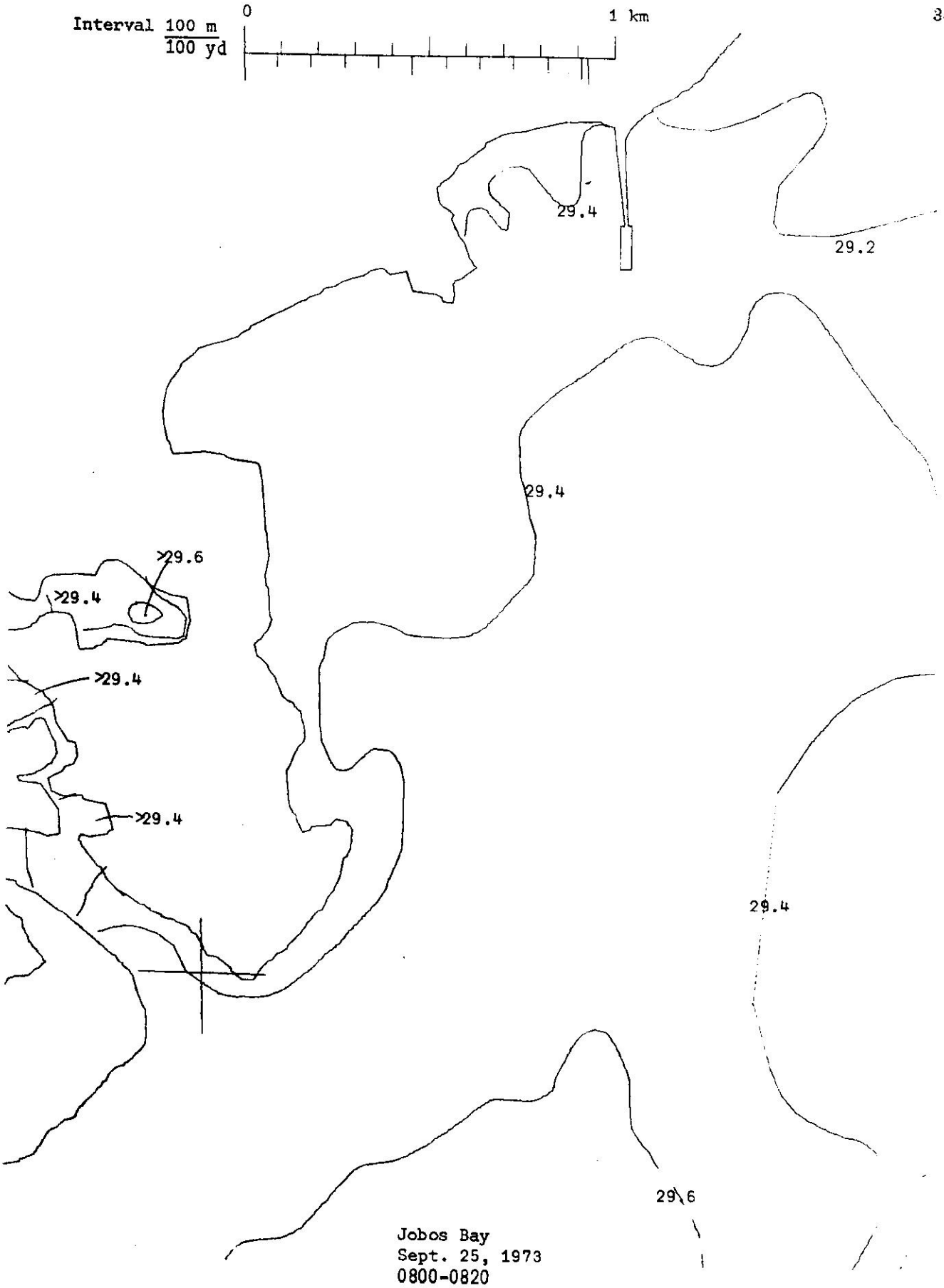

Interval 100 m
100 yd
0
1 km
29.6
29.8
29.6
29.6
29.8
29.6
29.6
29.6
Jobos Bay
Sept. 21, 1973
1920-2040
Alt. 610 m
ΔT= 0.2°C



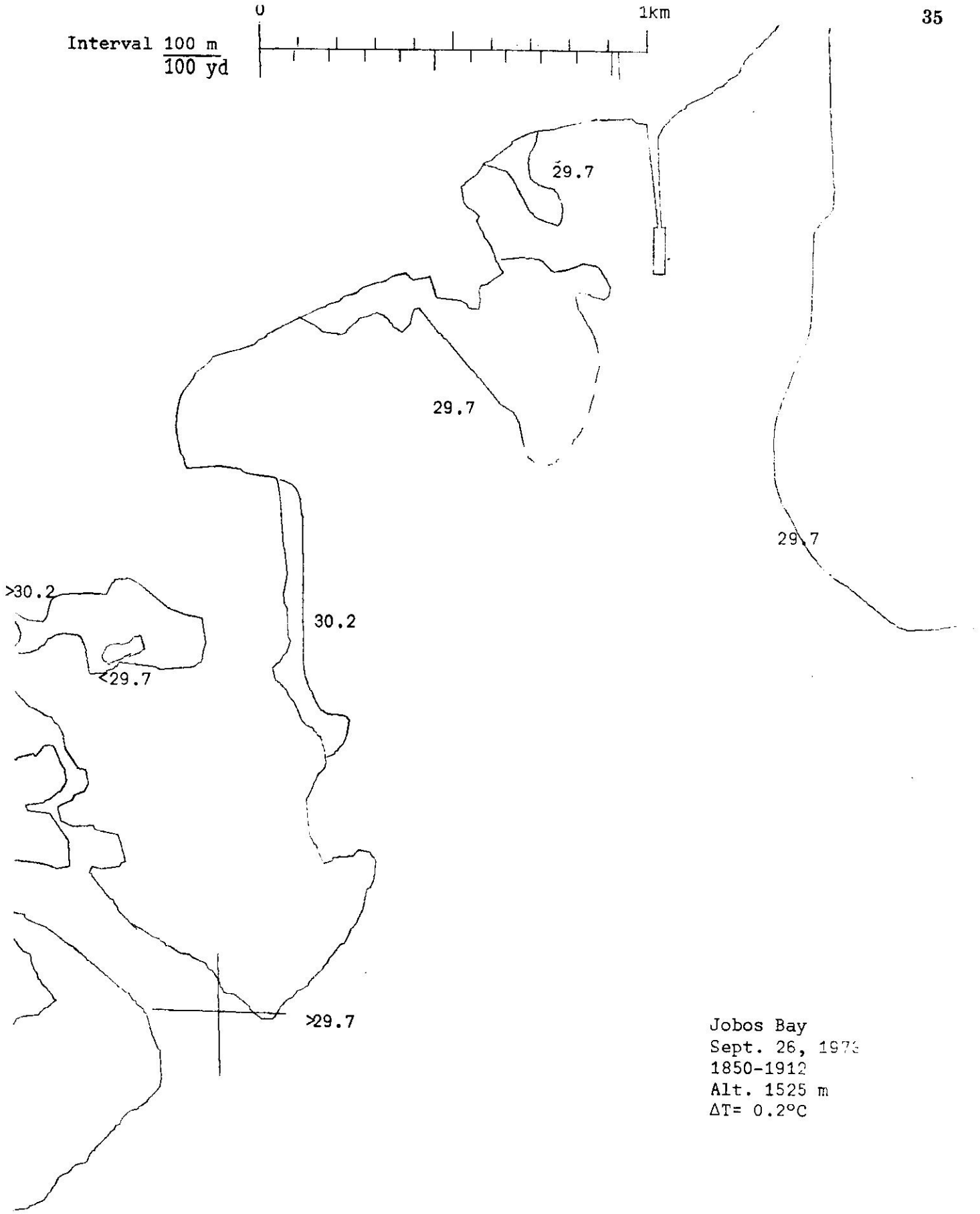
Jobos Bay
Sept. 23, 1973
0805-0900
Alt. 1220 m
ΔT= 0.2°C



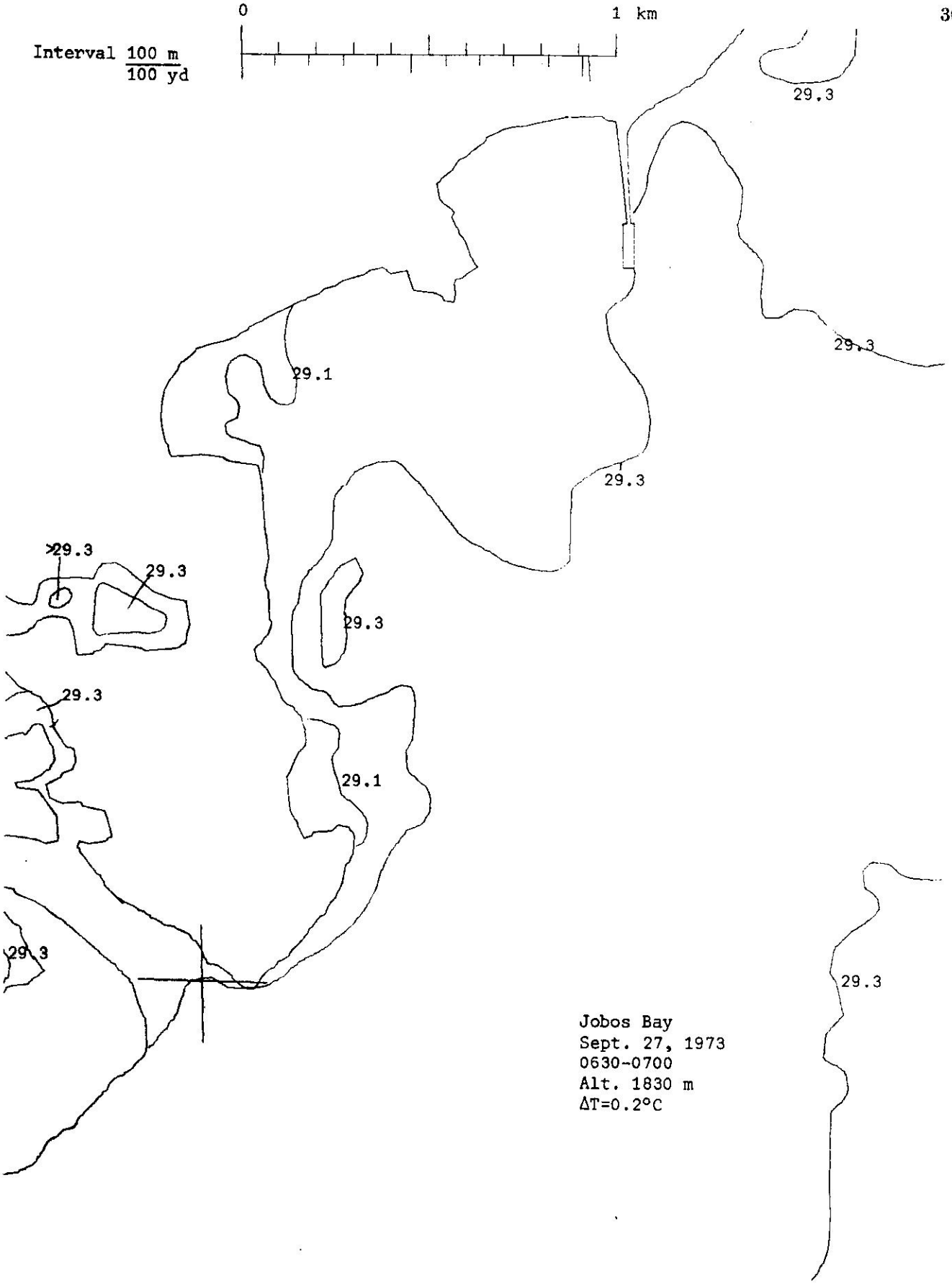
Jobos Bay
Sept. 24, 1973
1845-1915
Alt. 1525 m
ΔT= 0.2°C

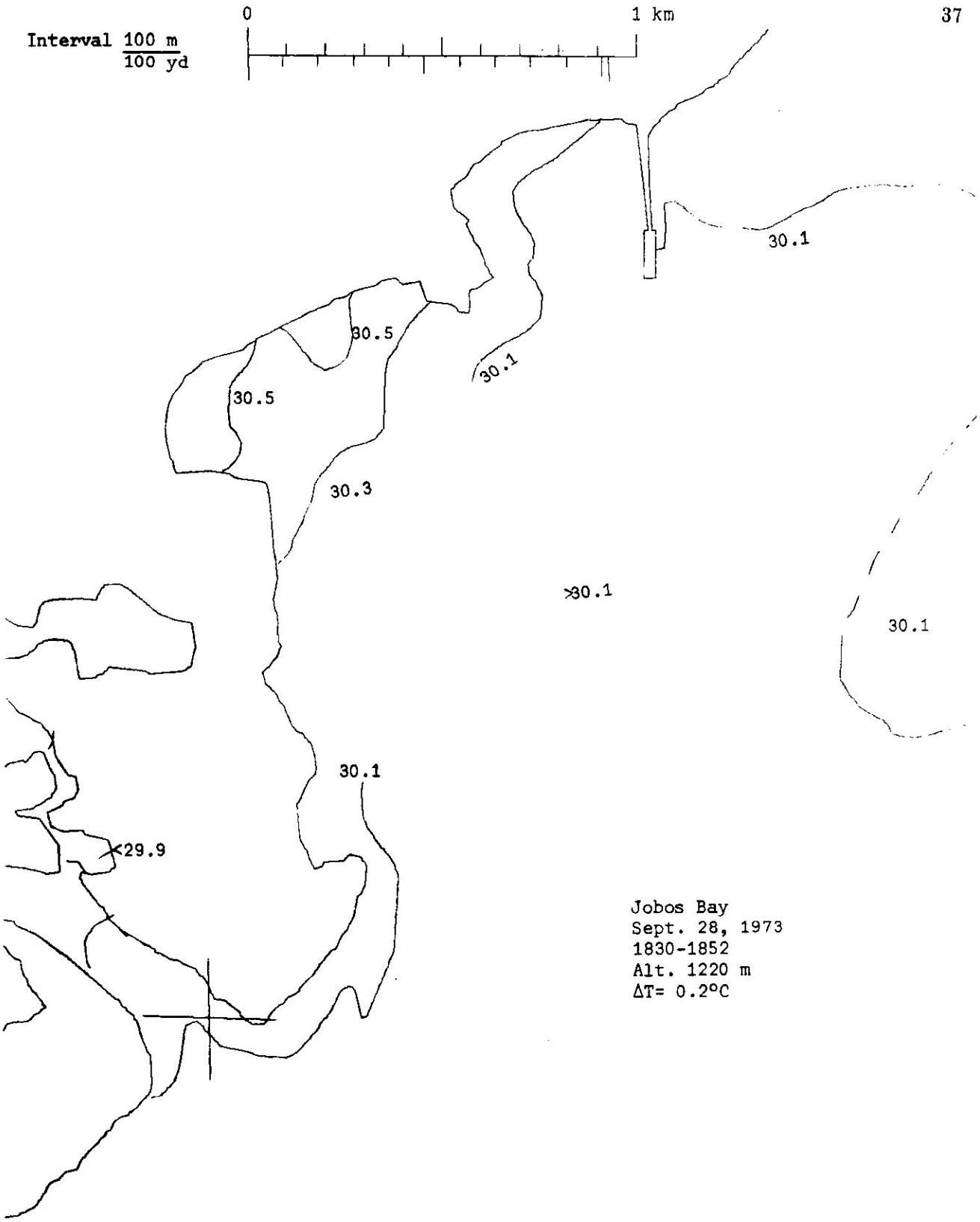


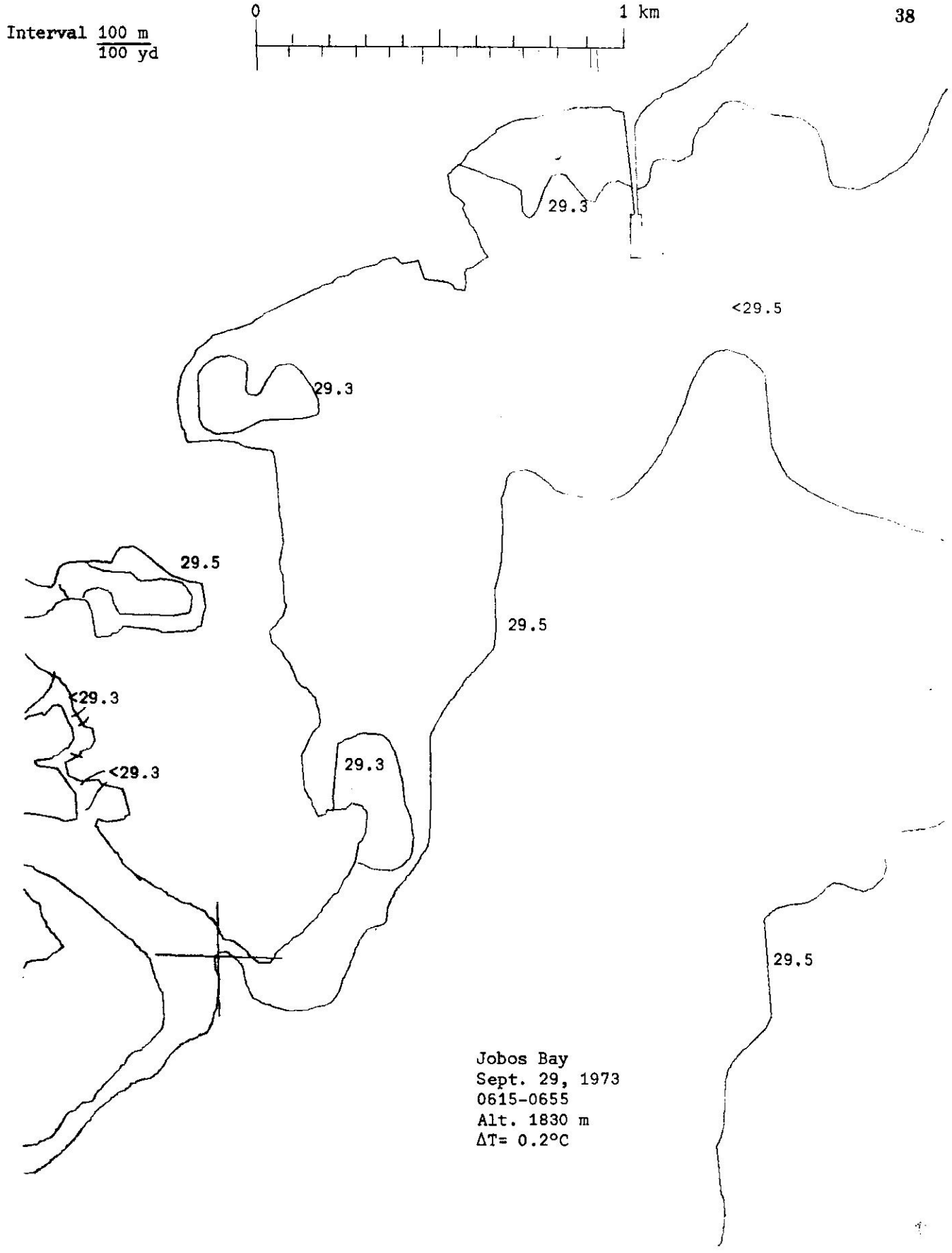
Jobos Bay
Sept. 25, 1973
0800-0820
Alt. 1983 m
ΔT= 0.2°C

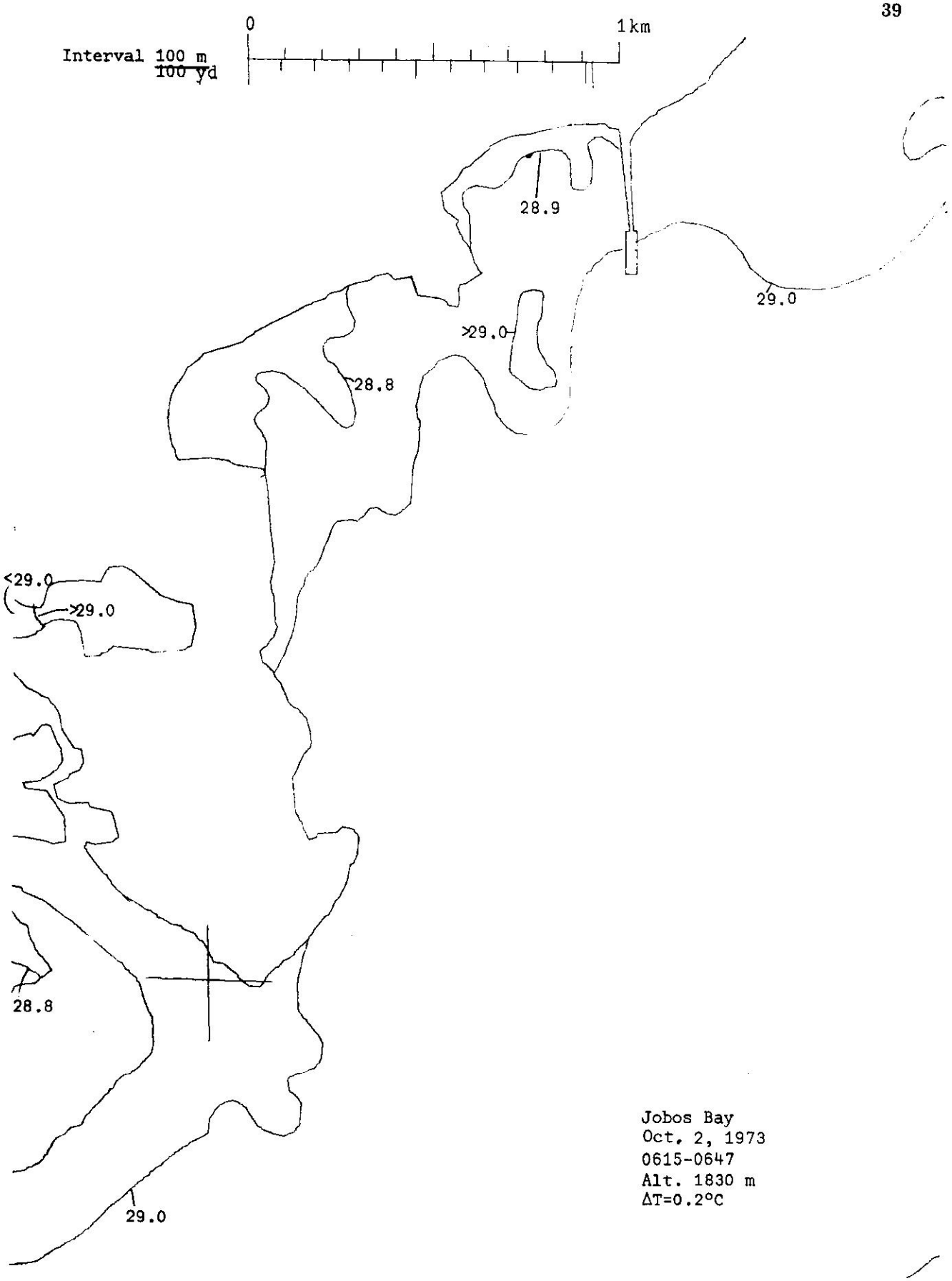


Jobos Bay
Sept. 26, 1973
1850-1912
Alt. 1525 m
ΔT= 0.2°C

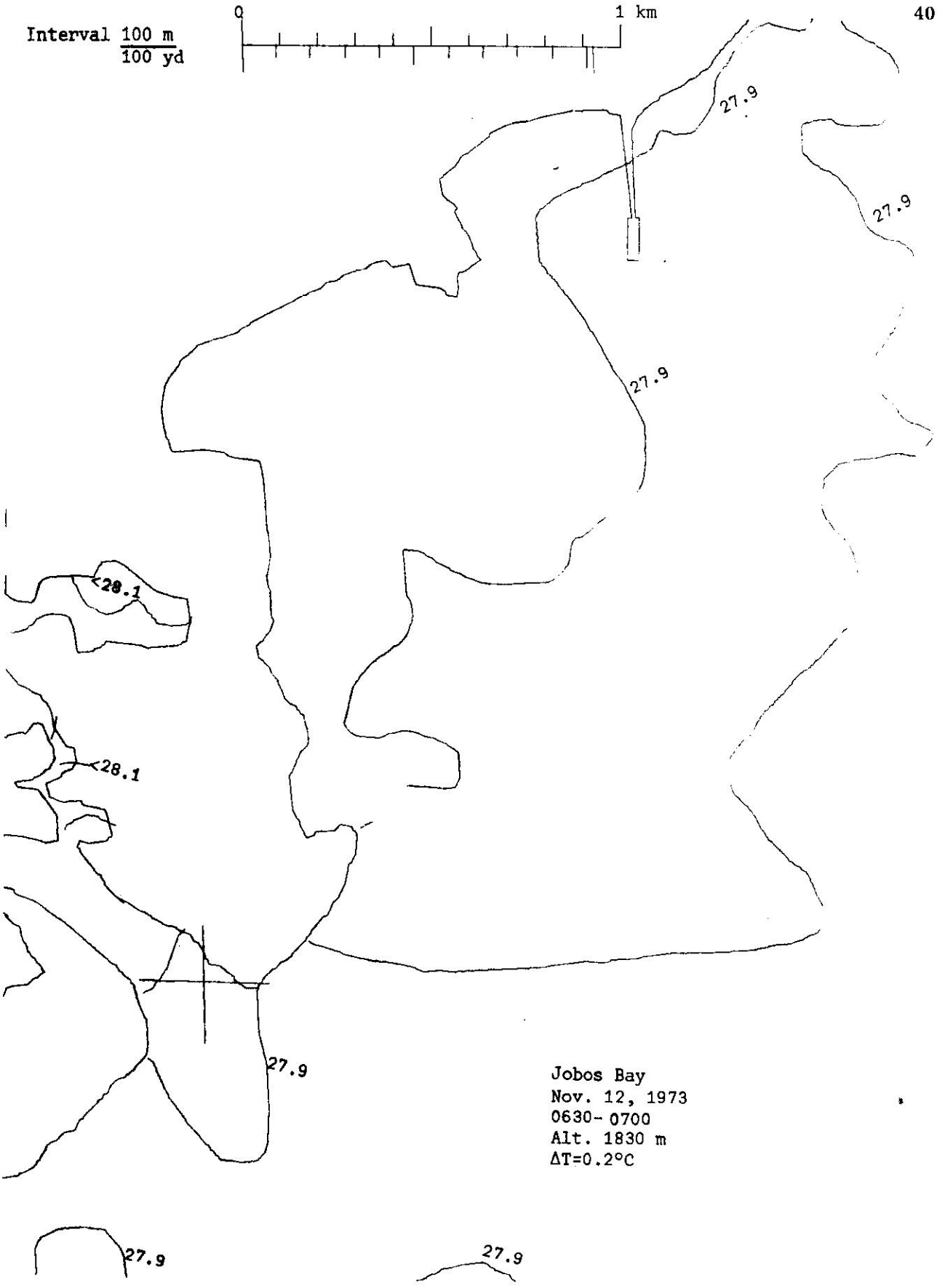

0
1 km
Interval 100 m
100 yd
29.3
29.3
29.1
29.3
29.3
29.3
29.3
29.3
29.1
29.3
29.3
Jobos Bay
Sept. 27, 1973
0630-0700
Alt. 1830 m
ΔT=0.2°C

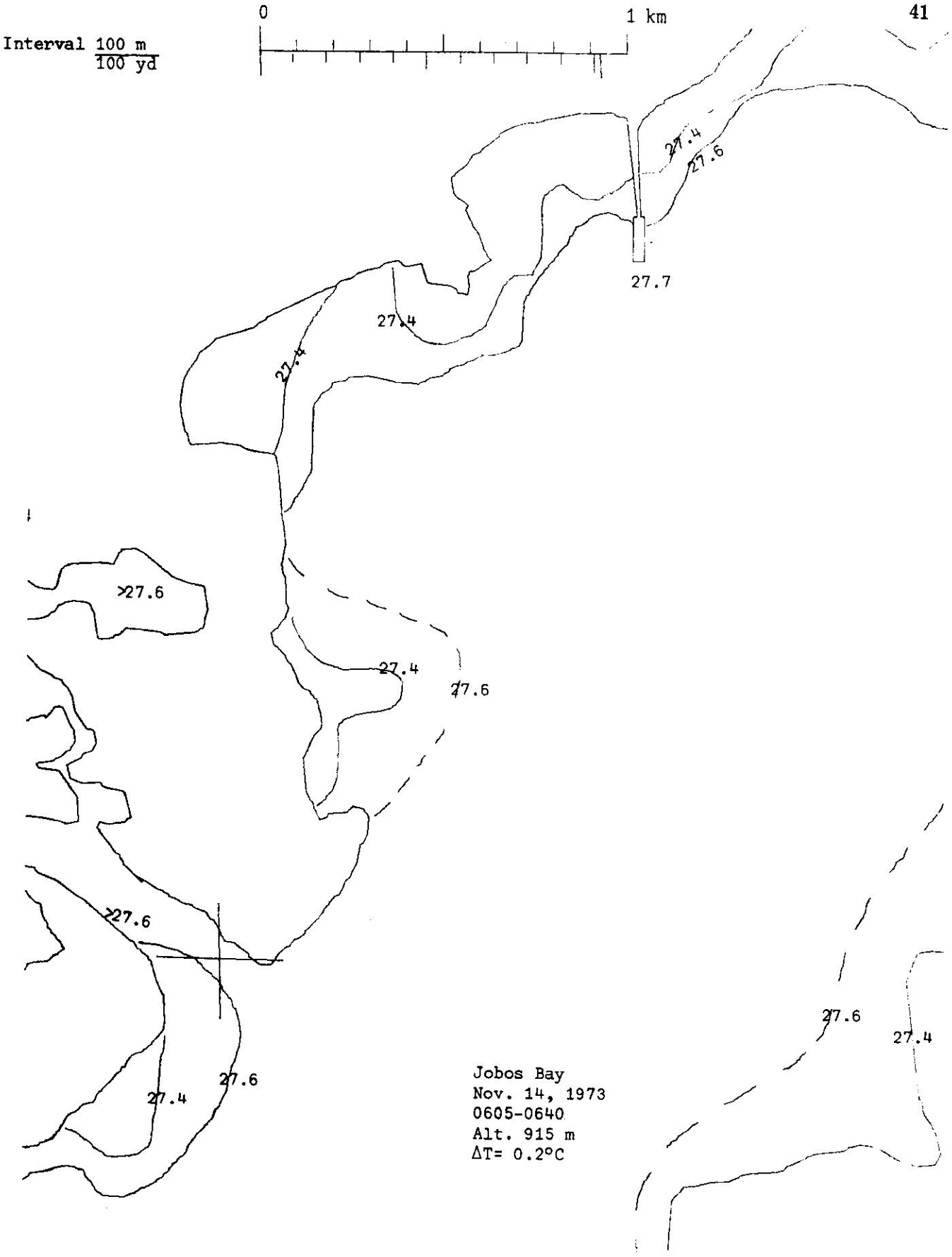

Interval 100 m
100 yd
0
1 km
30.1
30.5
30.1
30.5
30.3
>30.1
30.1
30.1
<29.9
Jobos Bay
Sept. 28, 1973
1830-1852
Alt. 1220 m
ΔT= 0.2°C

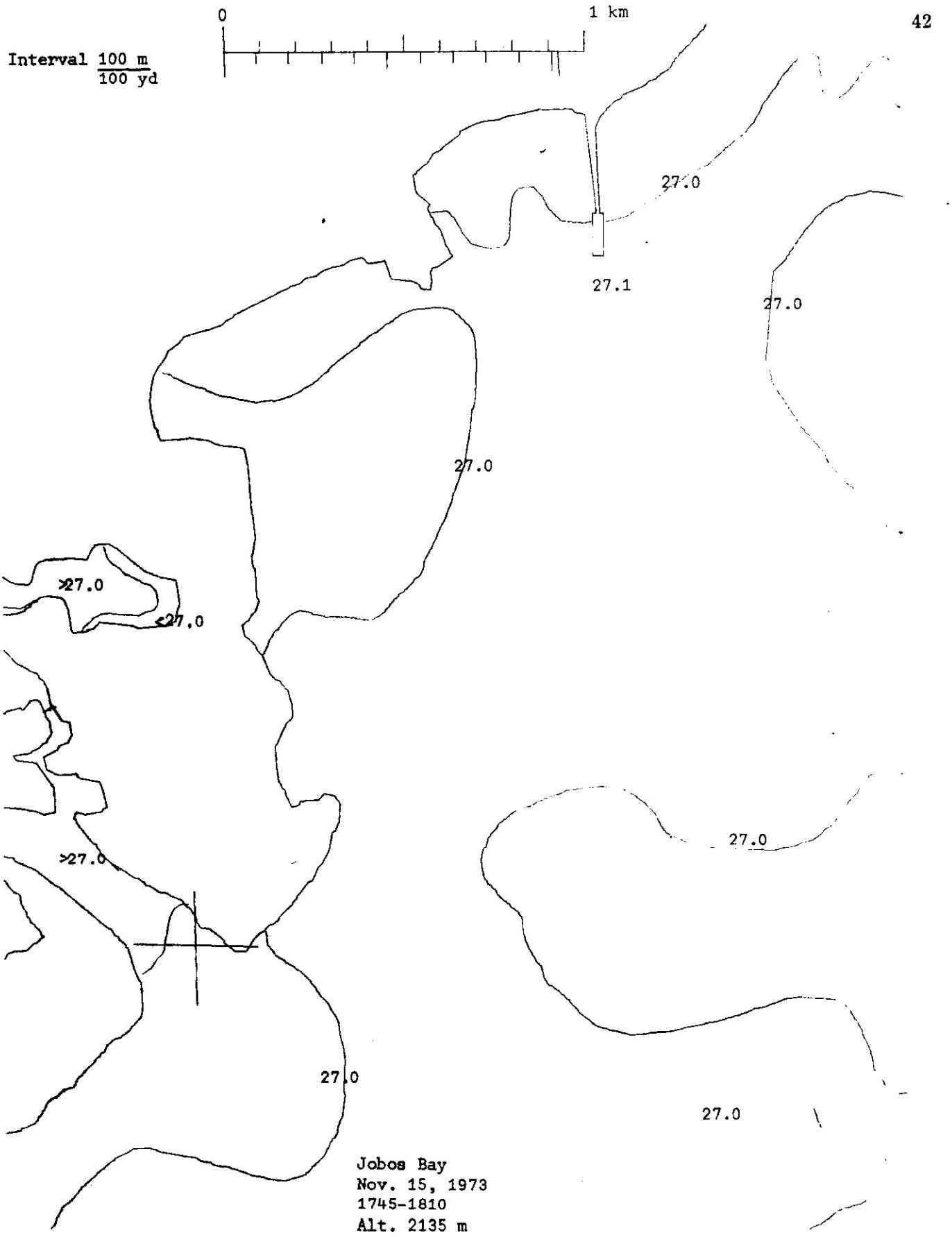

Interval 100 m
100 yd
0
1 km
29.3
<29.5
29.3
29.5
29.5
<29.3
<29.3
29.3
29.5
Jobos Bay
Sept. 29, 1973
0615-0655
Alt. 1830 m
ΔT= 0.2°C

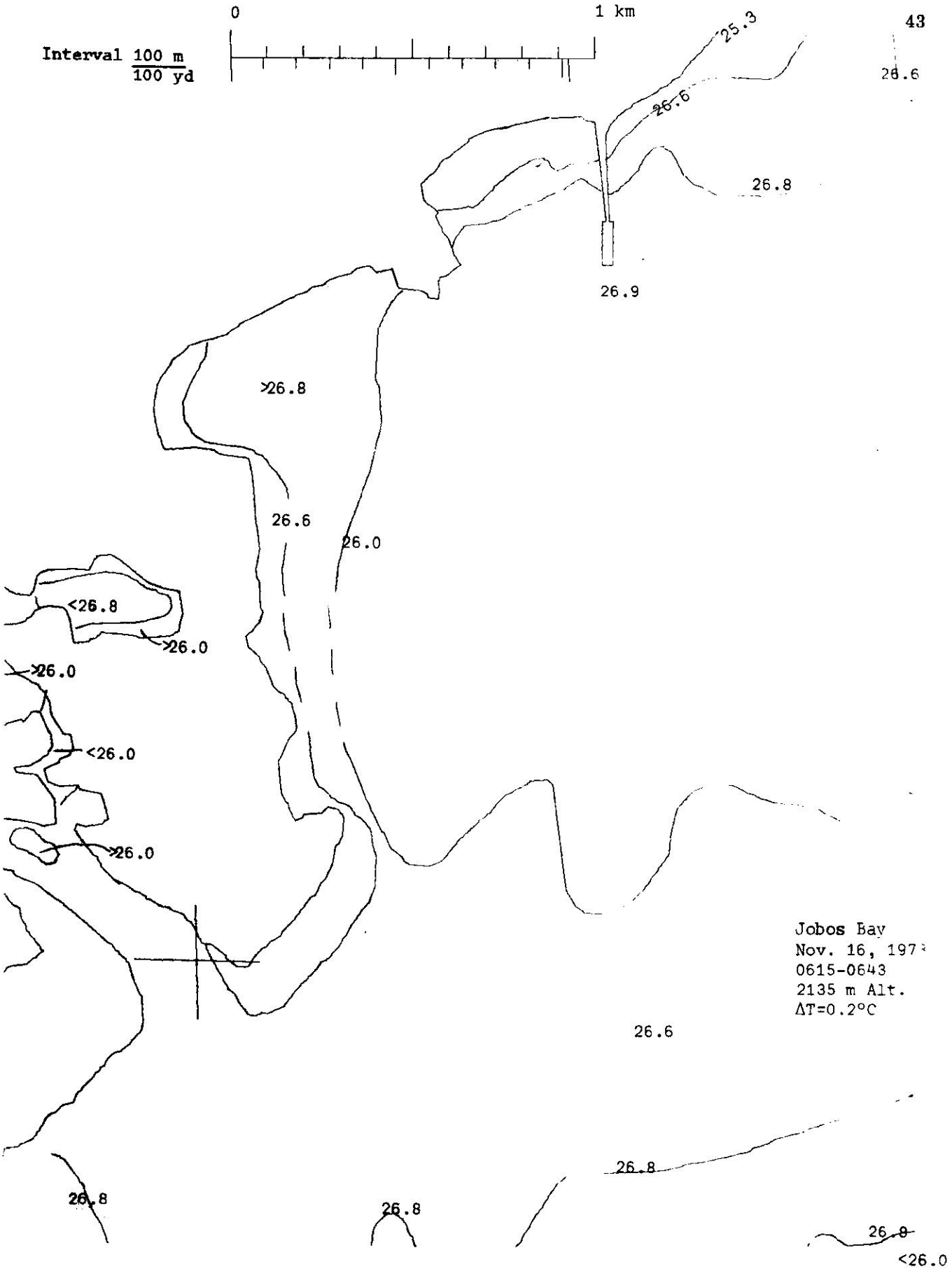


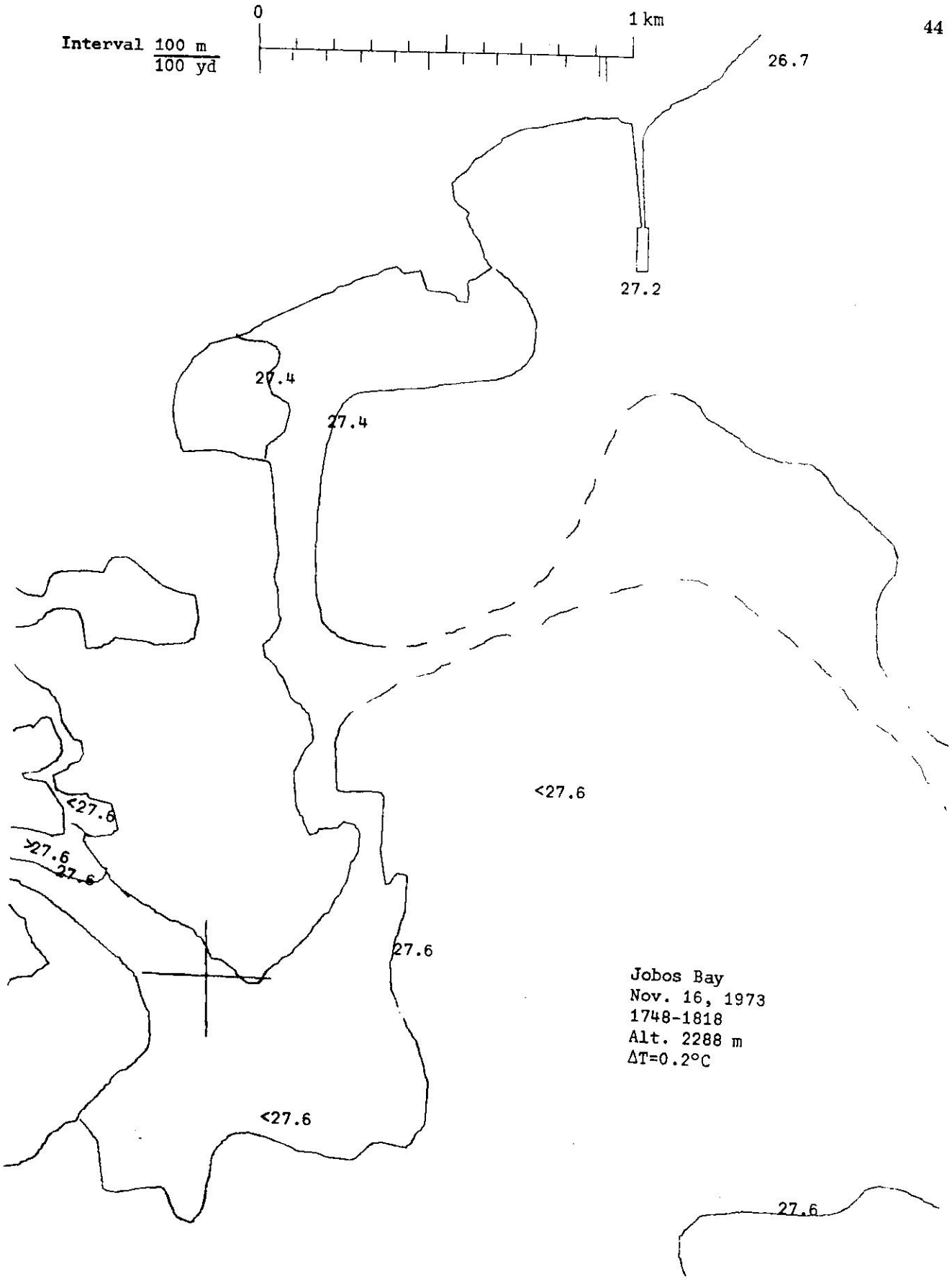
Jobos Bay
Oct. 2, 1973
0615-0647
Alt. 1830 m
ΔT=0.2°C

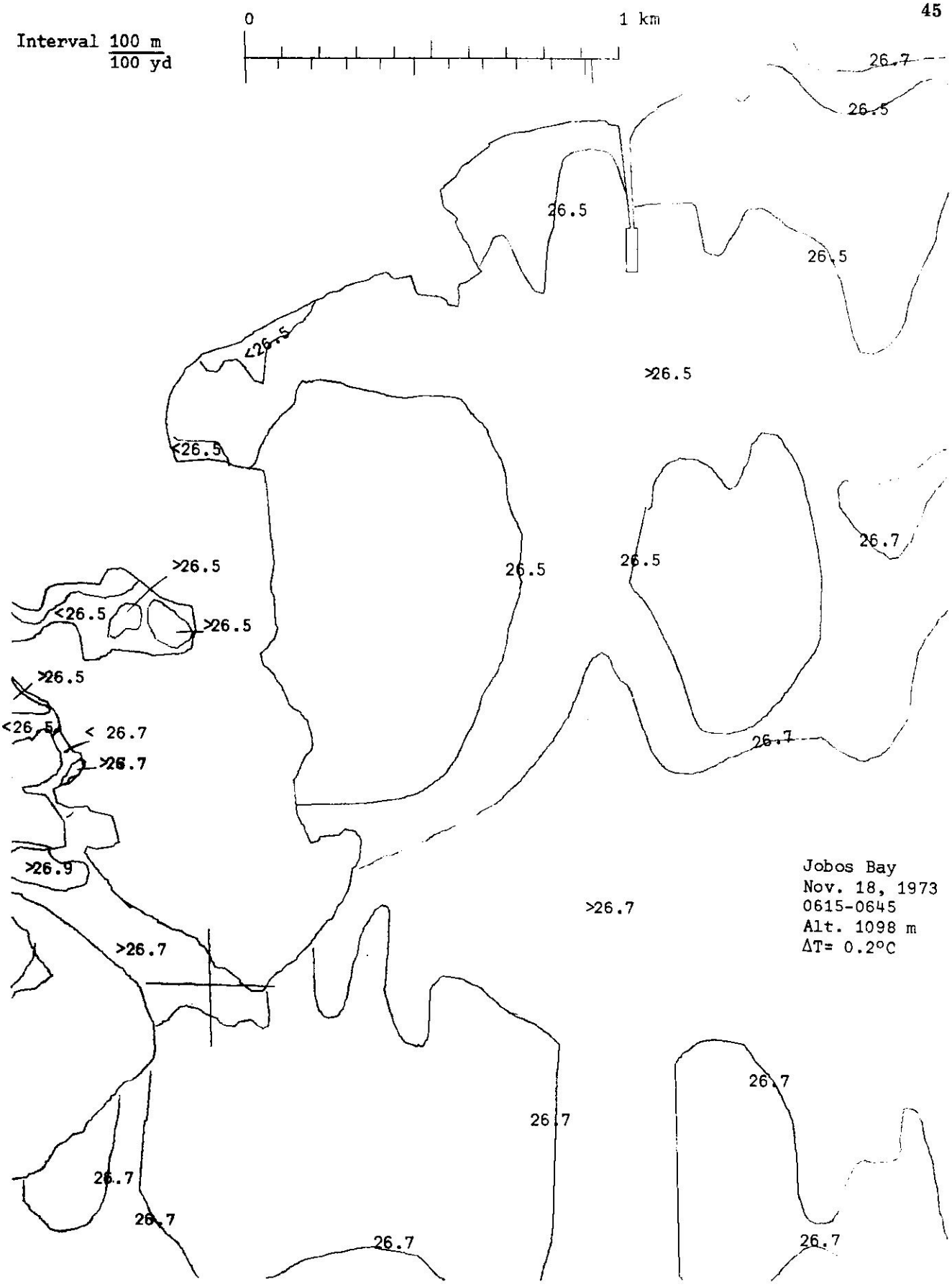

Interval 100 m
100 yd
0
1 km
27.9
27.9
27.9
<28.1
<28.1
27.9
27.9
27.9
Jobos Bay
Nov. 12, 1973
0630- 0700
Alt. 1830 m
ΔT=0.2°C

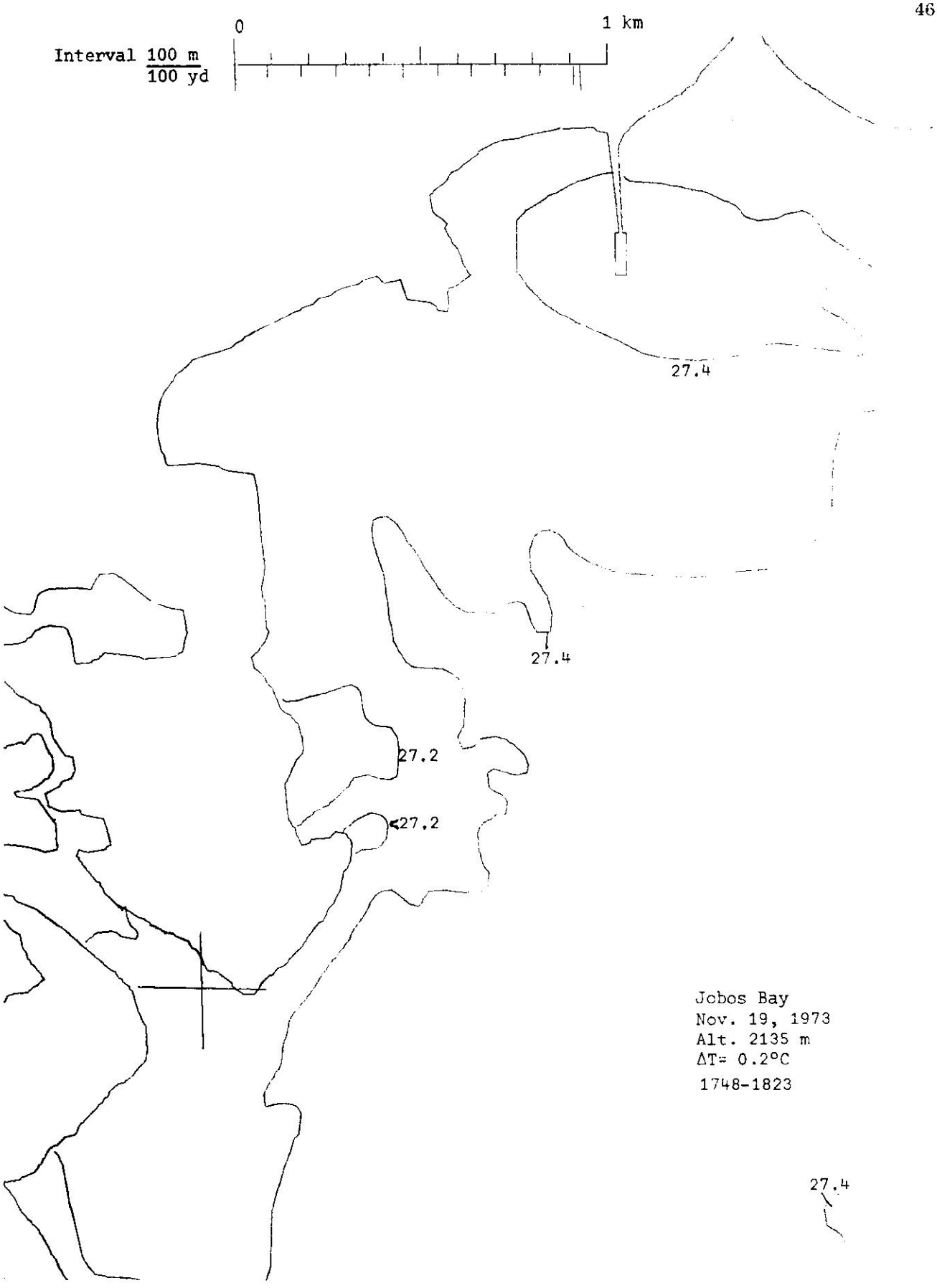

Interval 100 m
100 yd
0
1 km
27.4
27.6
27.7
27.4
27.4
>27.6
27.4
27.6
27.6
27.4
27.6
27.6
27.4
Jobos Bay
Nov. 14, 1973
0605-0640
Alt. 915 m
ΔT= 0.2°C

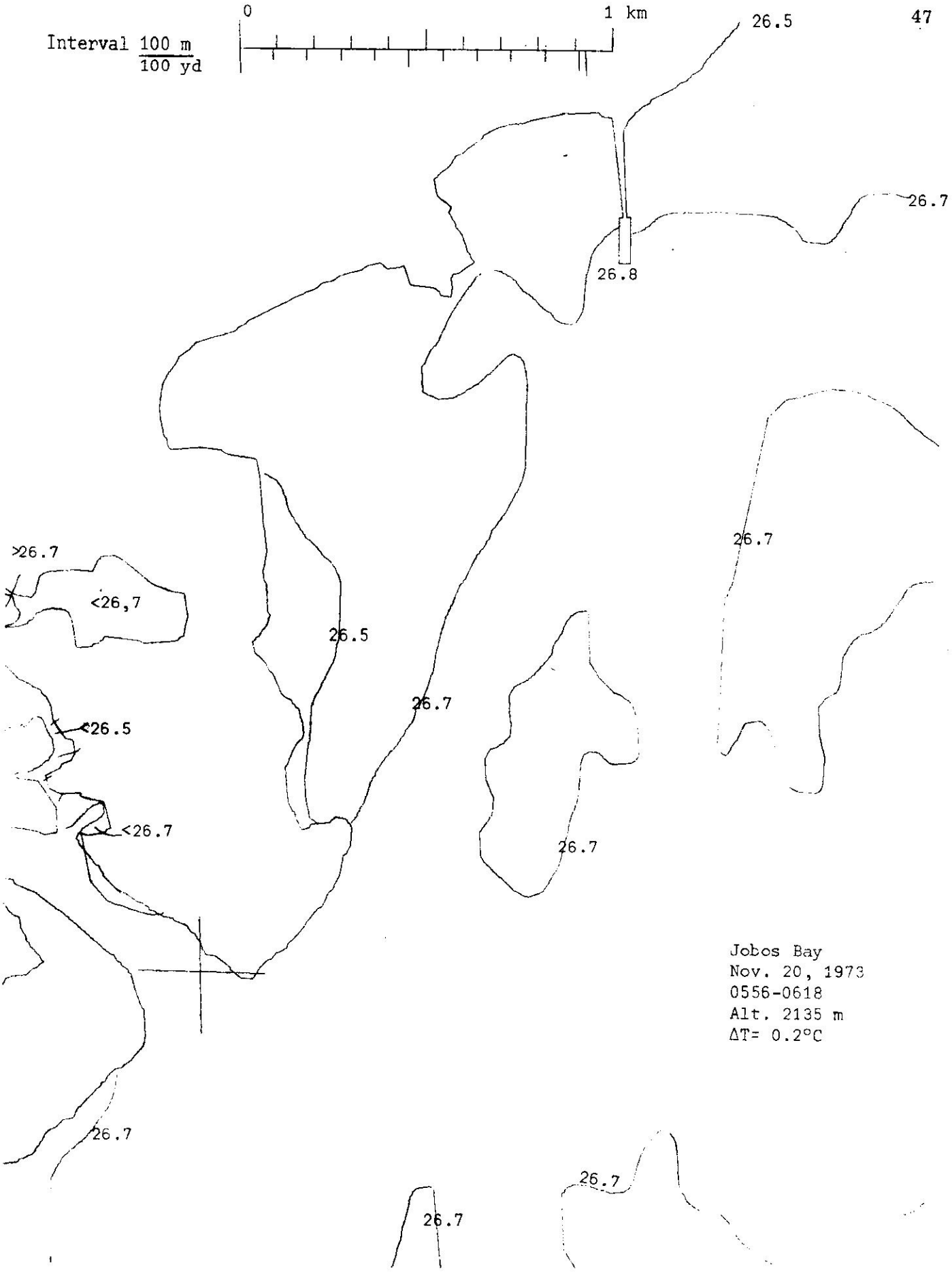

0
1 km
Interval 100 m
100 yd
27.0
27.1
27.0
27.0
>27.0
<27.0
>27.0
27.0
27.0
27.0
Jobos Bay
Nov. 15, 1973
1745-1810
Alt. 2135 m
ΔT=0.2°C

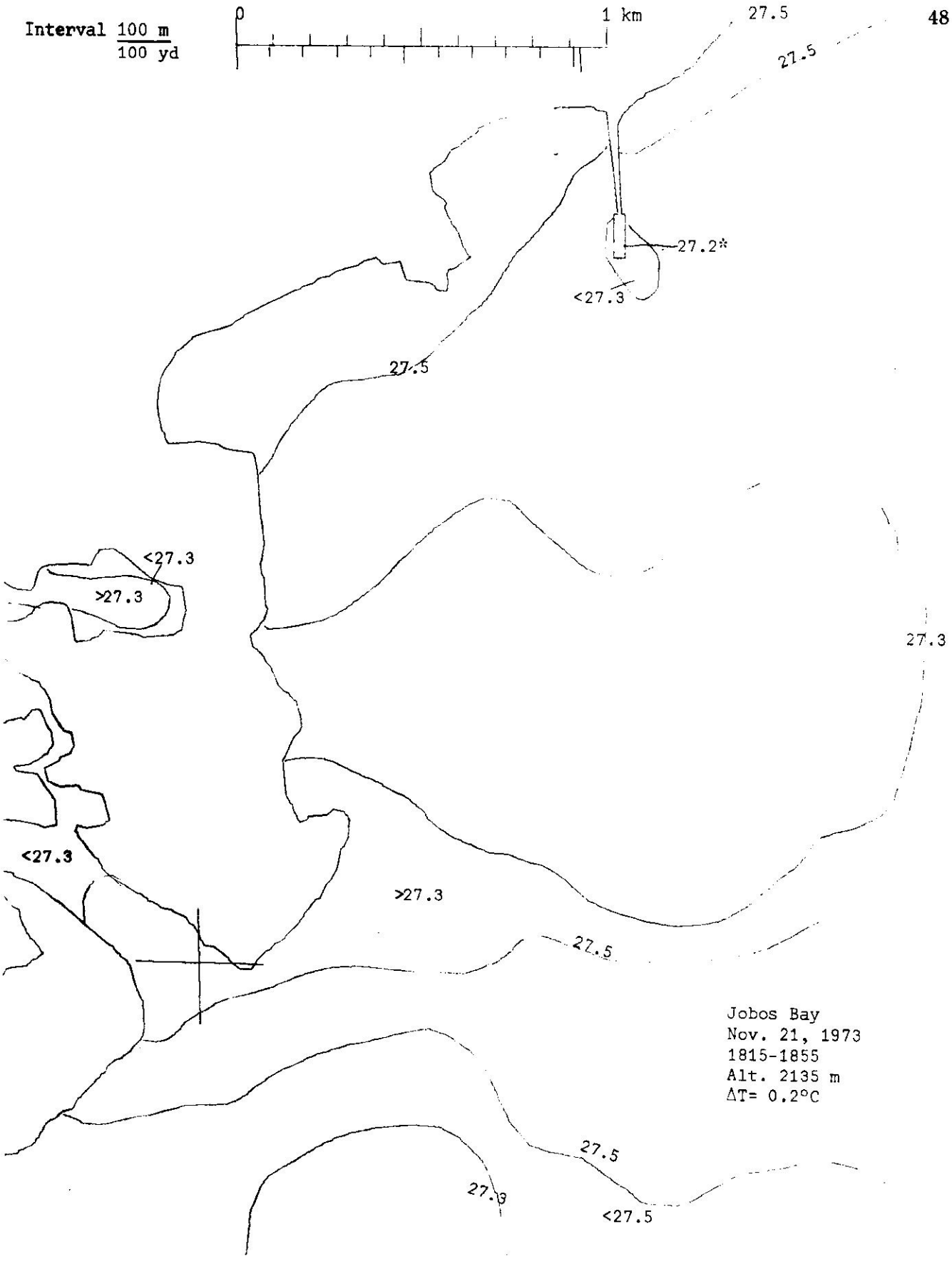

0
1 km
Interval 100 m
100 yd
25.3
26.6
26.8
26.9
>26.8
26.6
26.0
<26.8
>26.0
>26.0
<26.0
>26.0
26.6
26.8
26.8
26.8
<26.0
Jobos Bay
Nov. 16, 197
0615-0643
2135 m Alt.
ΔT=0.2°C

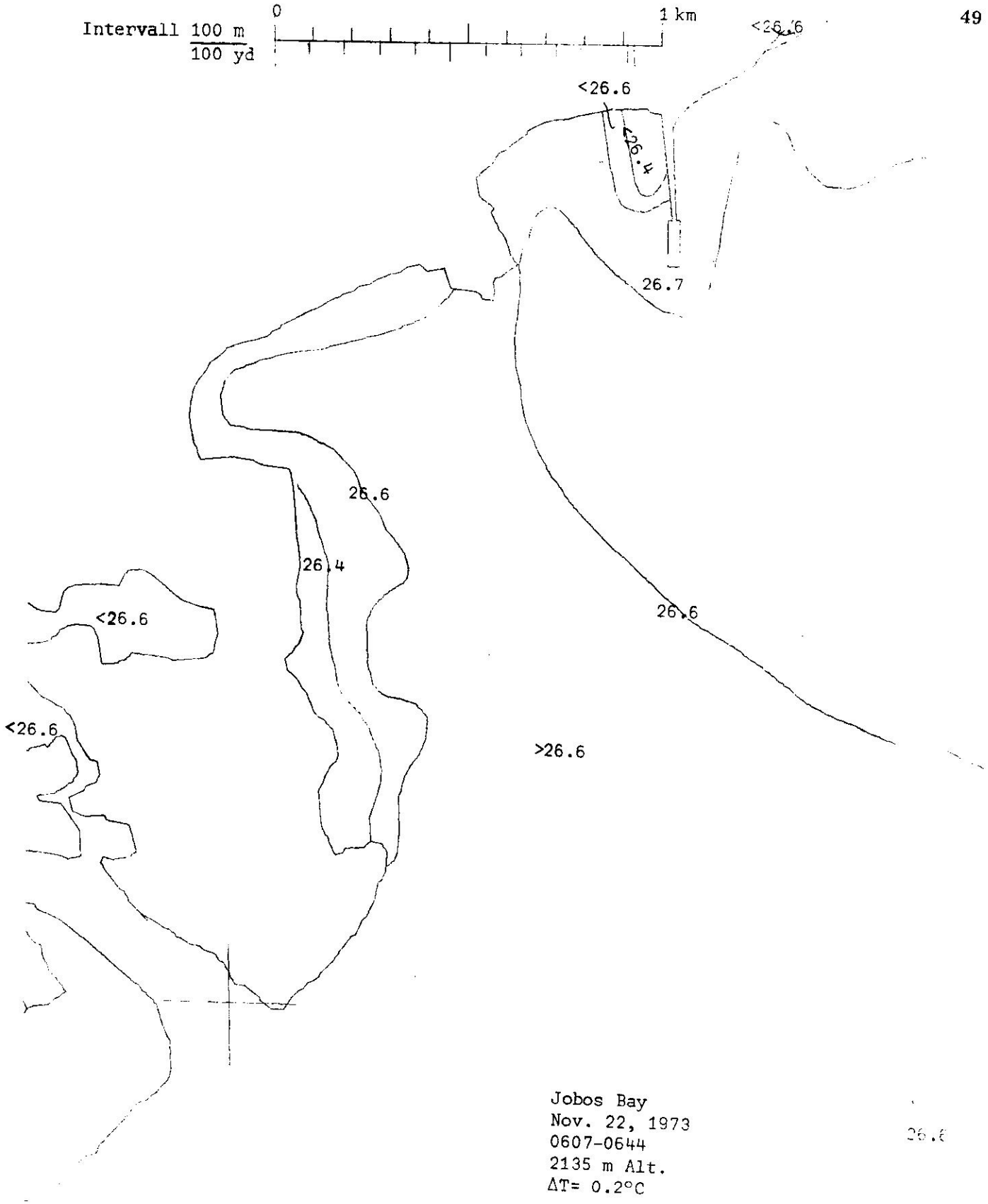

Interval 100 m
100 yd
0
1 km
26.7
27.2
27.4
27.4
<27.6
<27.6
>27.6
27.6
27.6
<27.6
27.6
Jobos Bay
Nov. 16, 1973
1748-1818
Alt. 2288 m
ΔT=0.2°C


Interval 100 m
100 yd
0
1 km
26.7
26.5
26.5
26.5
<26.5
>26.5
<26.5
26.5
26.5
26.7
>26.5
<26.5
>26.5
>26.5
<26.5
< 26.7
>26.7
>26.9
>26.7
>26.7
26.7
26.7
26.7
26.7
26.7
Jobos Bay
Nov. 18, 1973
0615-0645
Alt. 1098 m
ΔT= 0.2°C

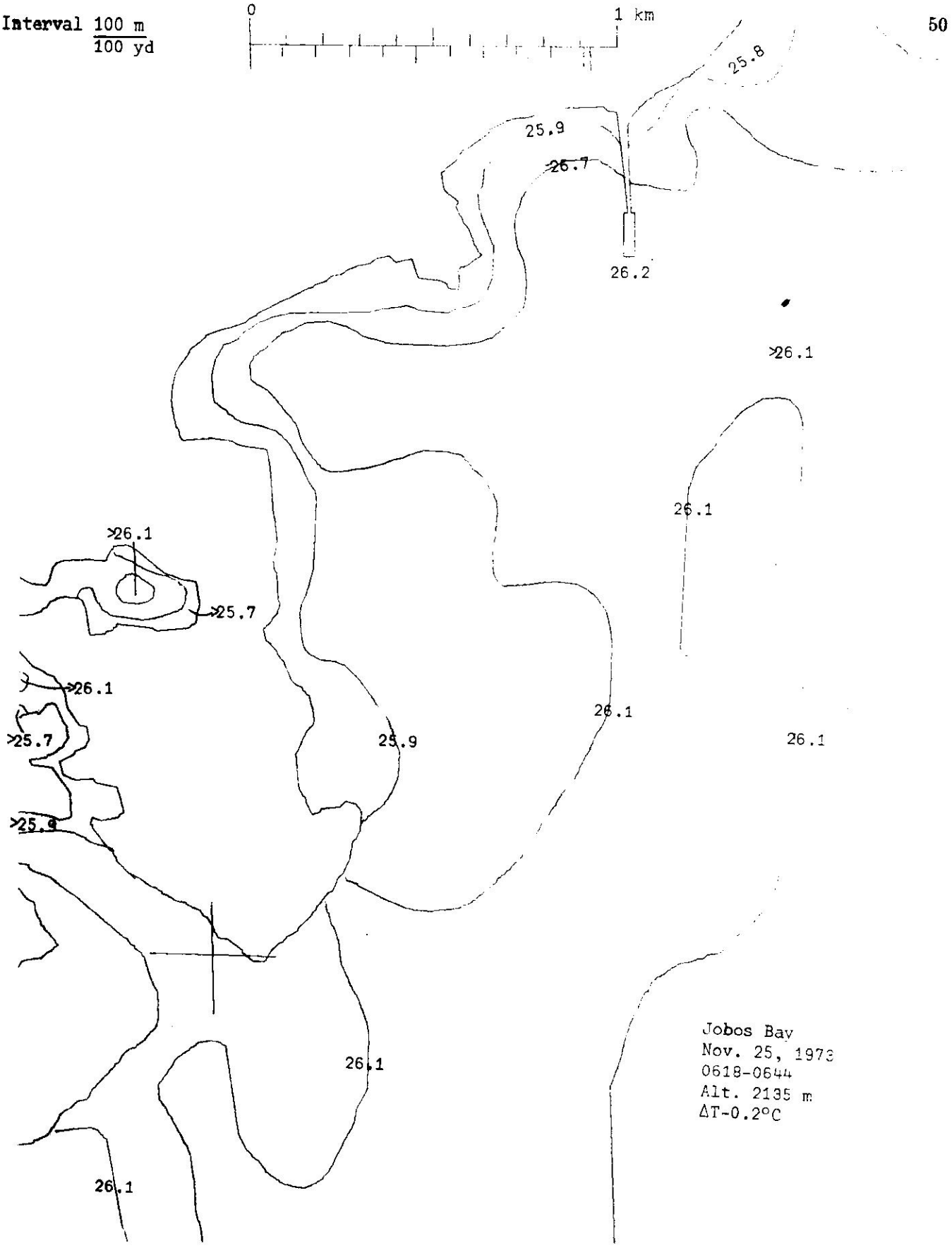

0
1 km
Interval 100 m
100 yd
27.4
27.4
27.2
27.2
Jobos Bay
Nov. 19, 1973
Alt. 2135 m
ΔT= 0.2°C
1748-1823
27.4

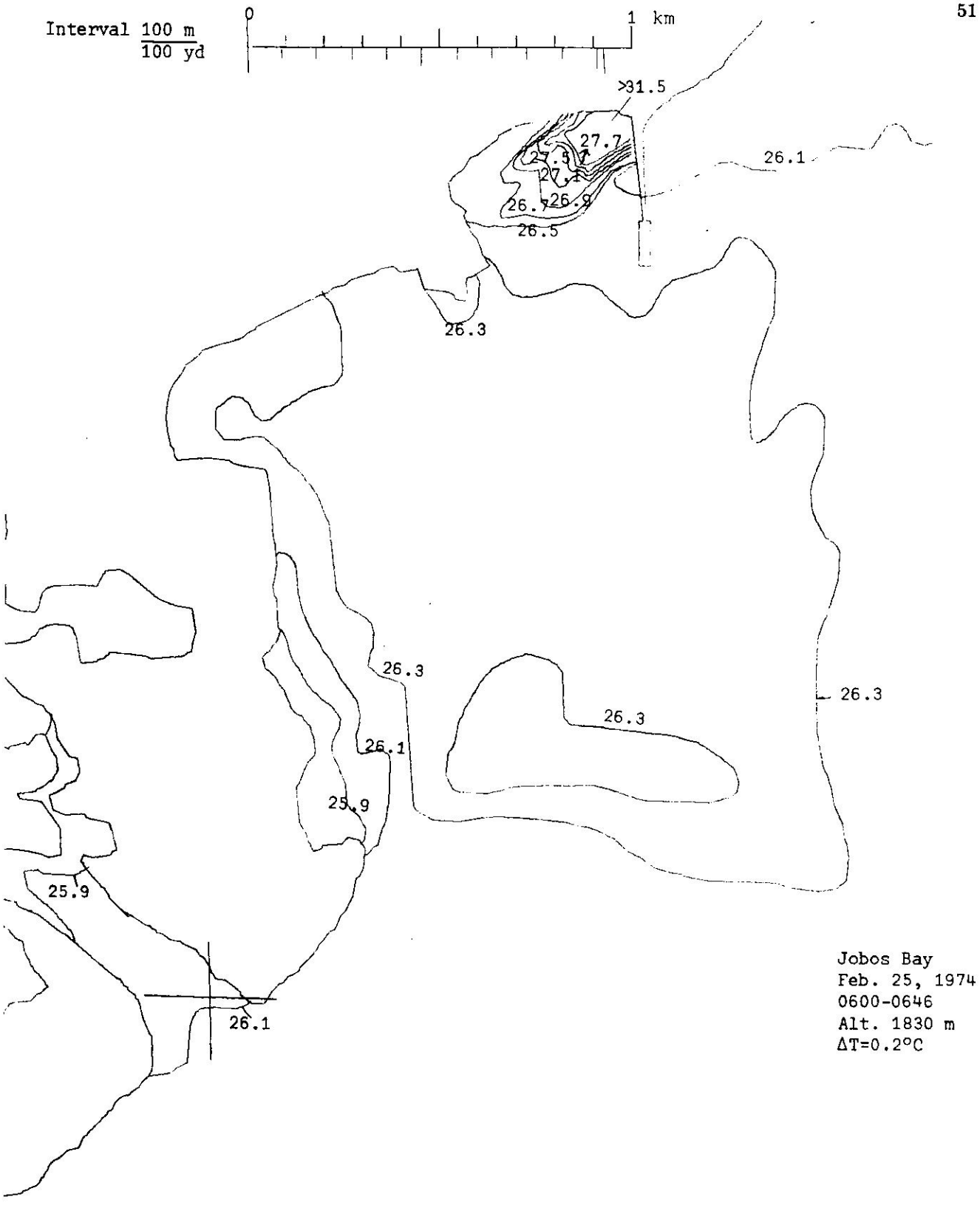

Interval 100 m
100 yd
0
1 km
26.5
26.7
26.8
>26.7
<26,7
26.5
26.7
<26.5
<26.7
26.7
26.7
26.7
26.7
26.7
Jobos Bay
Nov. 20, 1973
0556-0618
Alt. 2135 m
ΔT= 0.2°C


Interval 100 m
100 yd
0
1 km
27.5
27.5
27.2*
<27.3
27.5
<27.3
>27.3
27.3
<27.3
>27.3
27.5
Jobos Bay
Nov. 21, 1973
1815-1855
Alt. 2135 m
ΔT= 0.2°C
27.5
27.3
<27.5

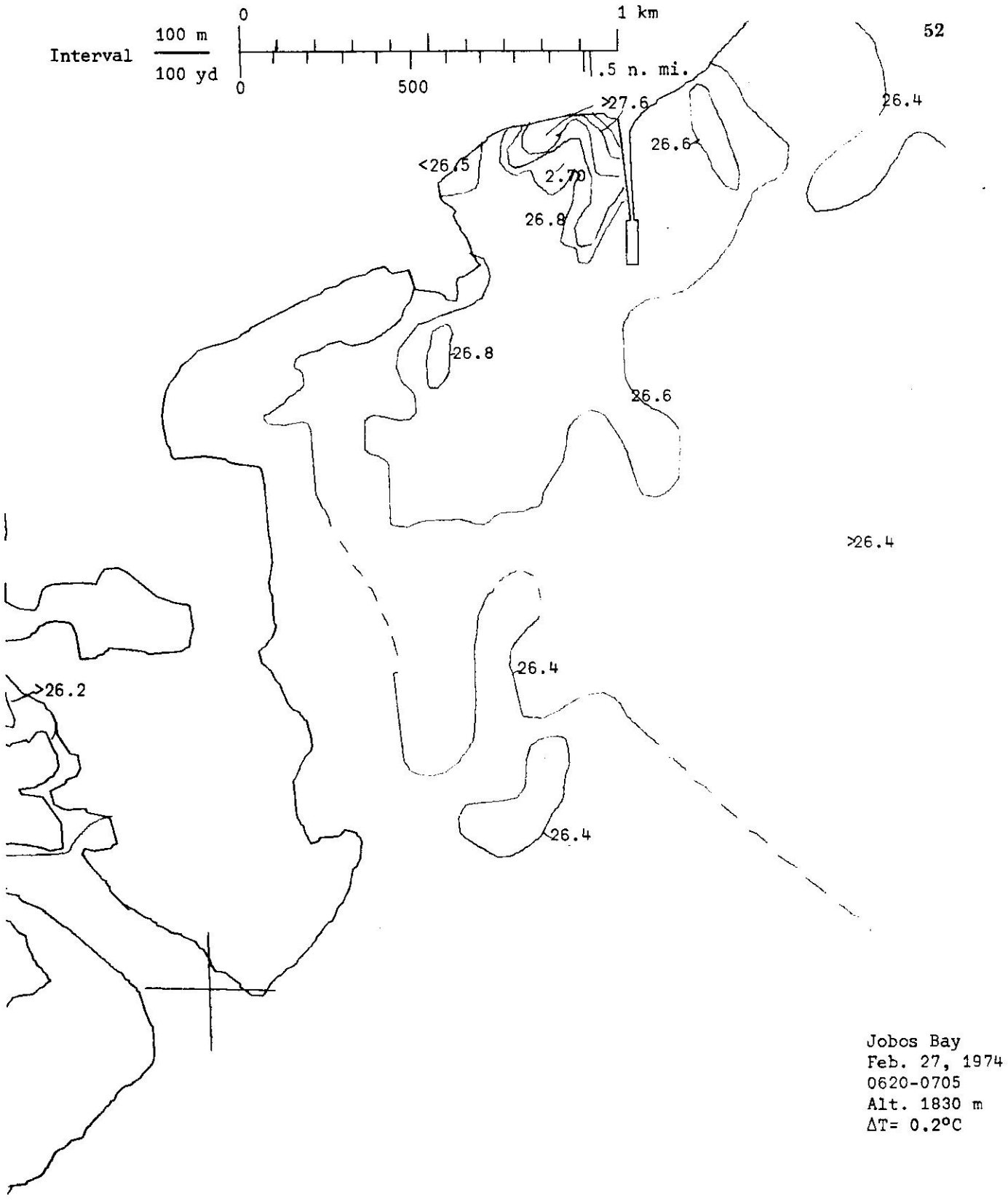


Jobos Bay
Nov. 22, 1973
0607-0644
2135 m Alt.
ΔT= 0.2°C

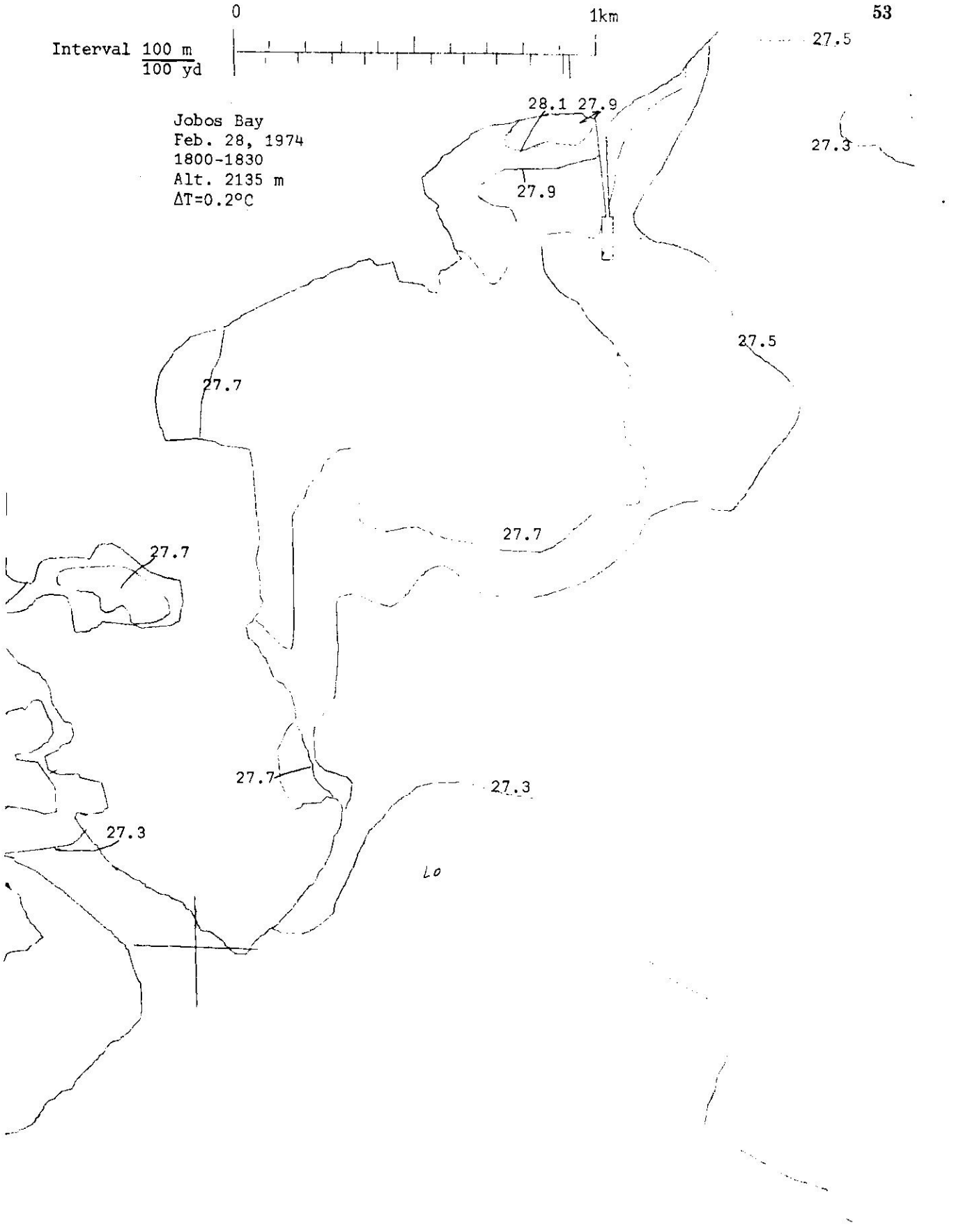

Interval 100 m
100 yd
0
1 km
25.8
25.9
25.7
26.2
>26.1
26.1
>26.1
>25.7
>26.1
26.1
>25.7
25.9
26.1
>25.9
26.1
26.1
Jobos Bay
Nov. 25, 1973
0618-0644
Alt. 2135 m
ΔT-0.2°C

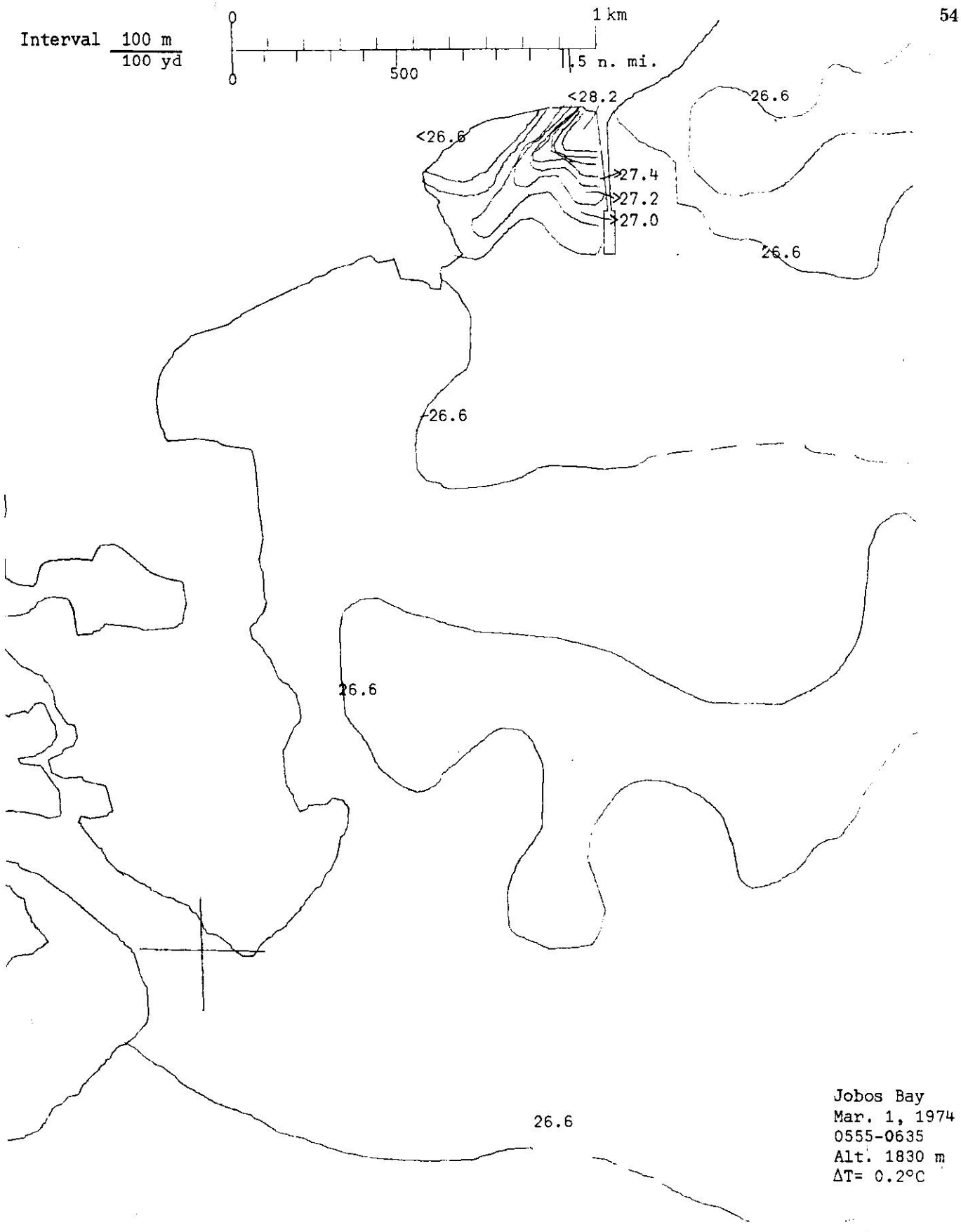


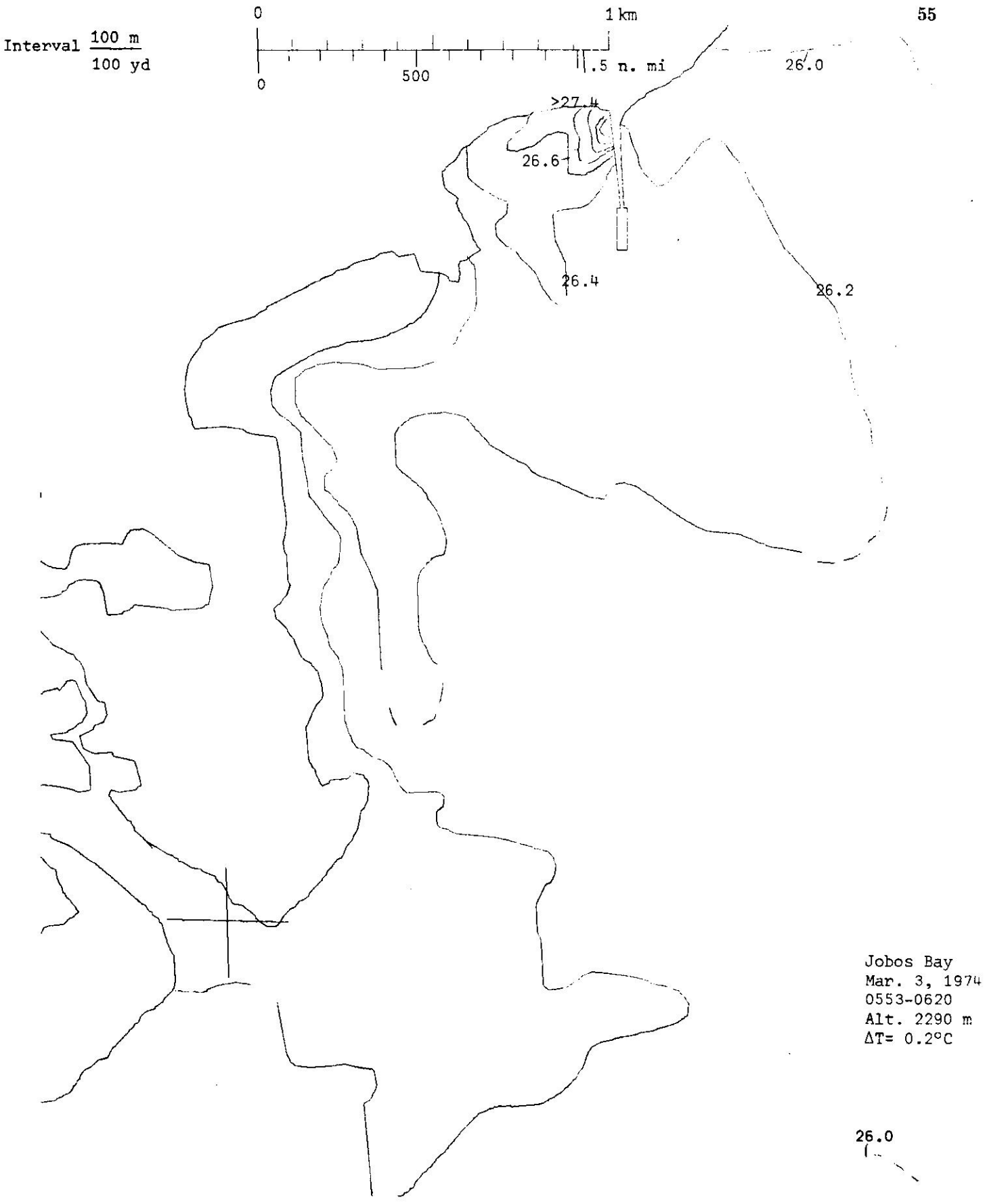
Jobos Bay
Feb. 25, 1974
0600-0646
Alt. 1830 m
ΔT=0.2°C



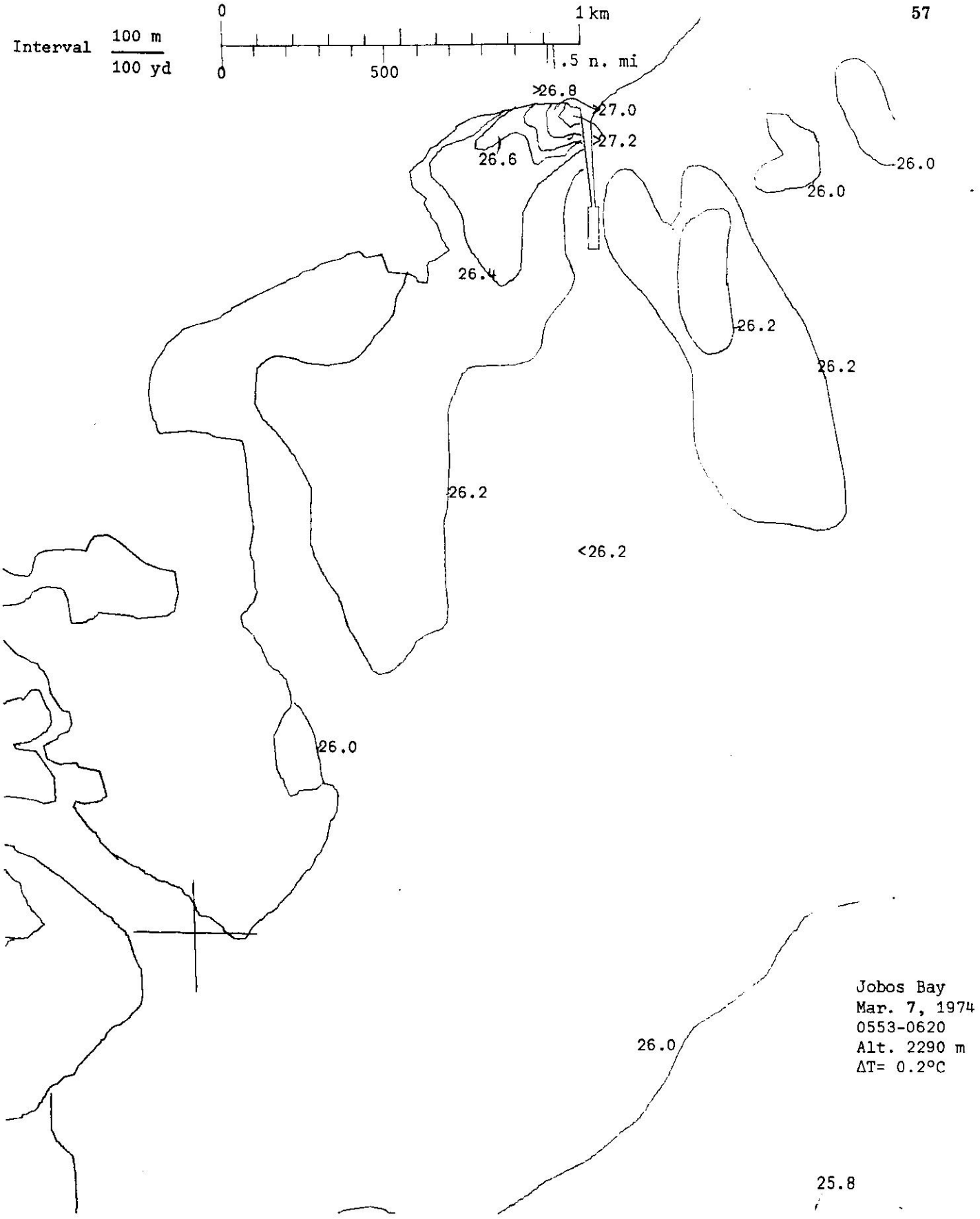
Jobos Bay
Feb. 27, 1974
0620-0705
Alt. 1830 m
ΔT= 0.2°C

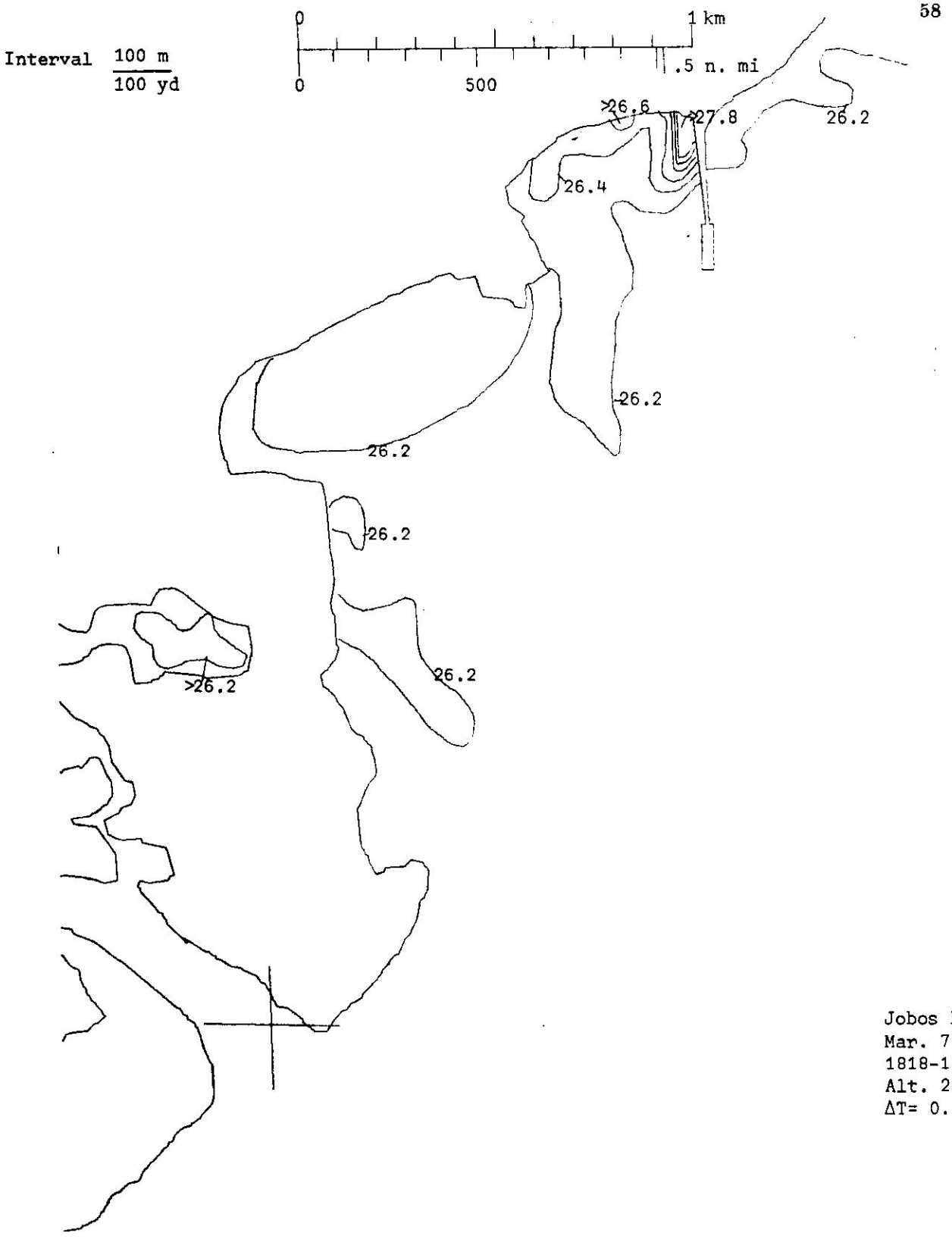

0
1km
Interval 100 m
100 yd
Jobos Bay
Feb. 28, 1974
1800-1830
Alt. 2135 m
ΔT=0.2°C
28.1 27.9
27.9
27.5
27.3
27.5
27.7
27.7
27.7
27.7
27.3
27.3
Lo


Interval 100 m / 100 yd
0
1 km
500
.5 n. mi.
<28.2
26.6
<26.6
>27.4
>27.2
>27.0
26.6
26.6
26.6
26.6
Jobos Bay
Mar. 1, 1974
0555-0635
Alt. 1830 m
ΔT= 0.2°C

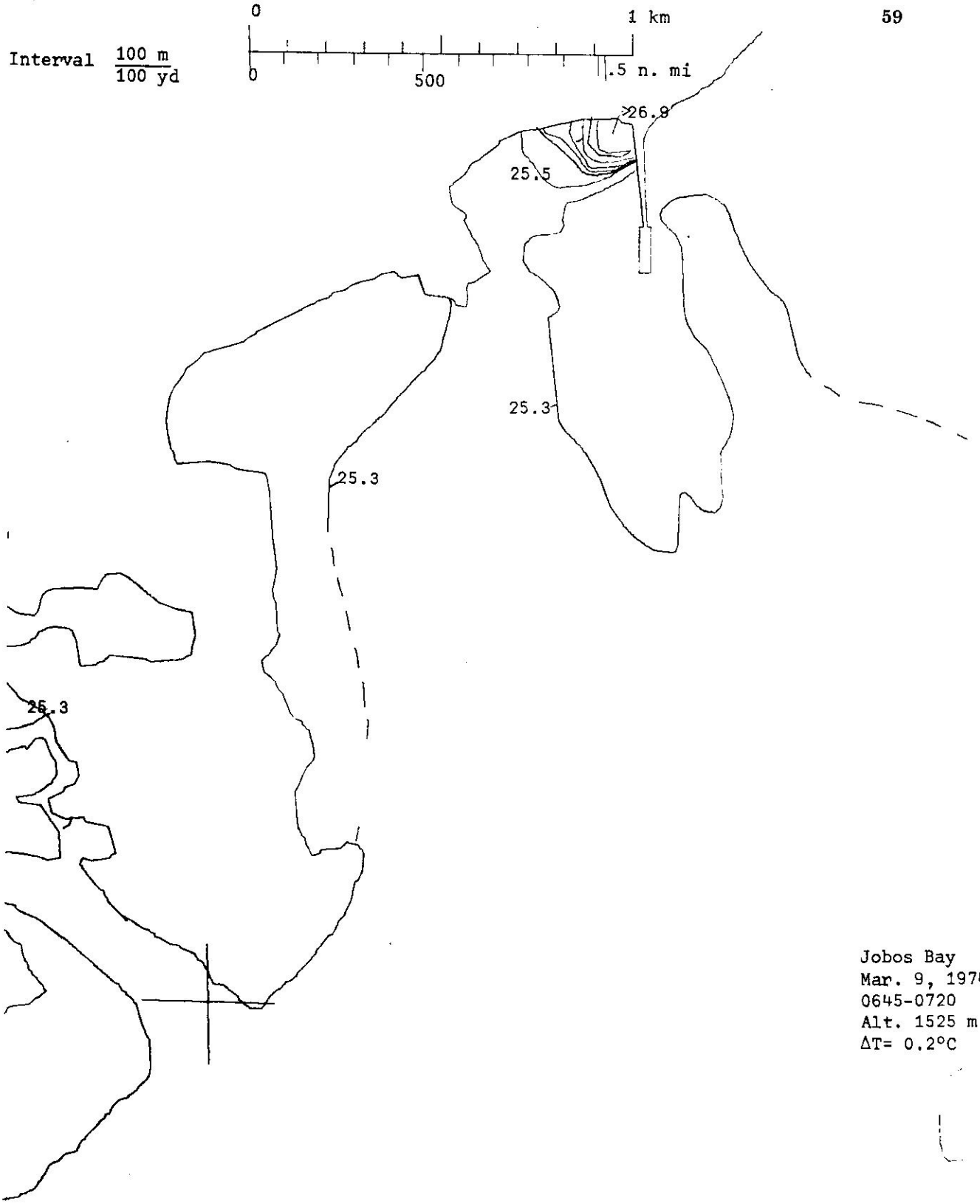

Interval 100 m
100 yd
0
1 km
0
500
.5 n. mi
26.0
>27.4
26.6
26.4
26.2
Jobos Bay
Mar. 3, 1974
0553-0620
Alt. 2290 m
ΔT= 0.2°C
26.0


Interval 100 m / 100 yd
0
1 km
0
500
.5 n. mi
>27.2
>26.2
26.4
26.2
26.2
26.4
26.2
Jobos Bay
Mar. 5, 1974
0545-0720
Alt. 2440 m
ΔT= 0.2°C

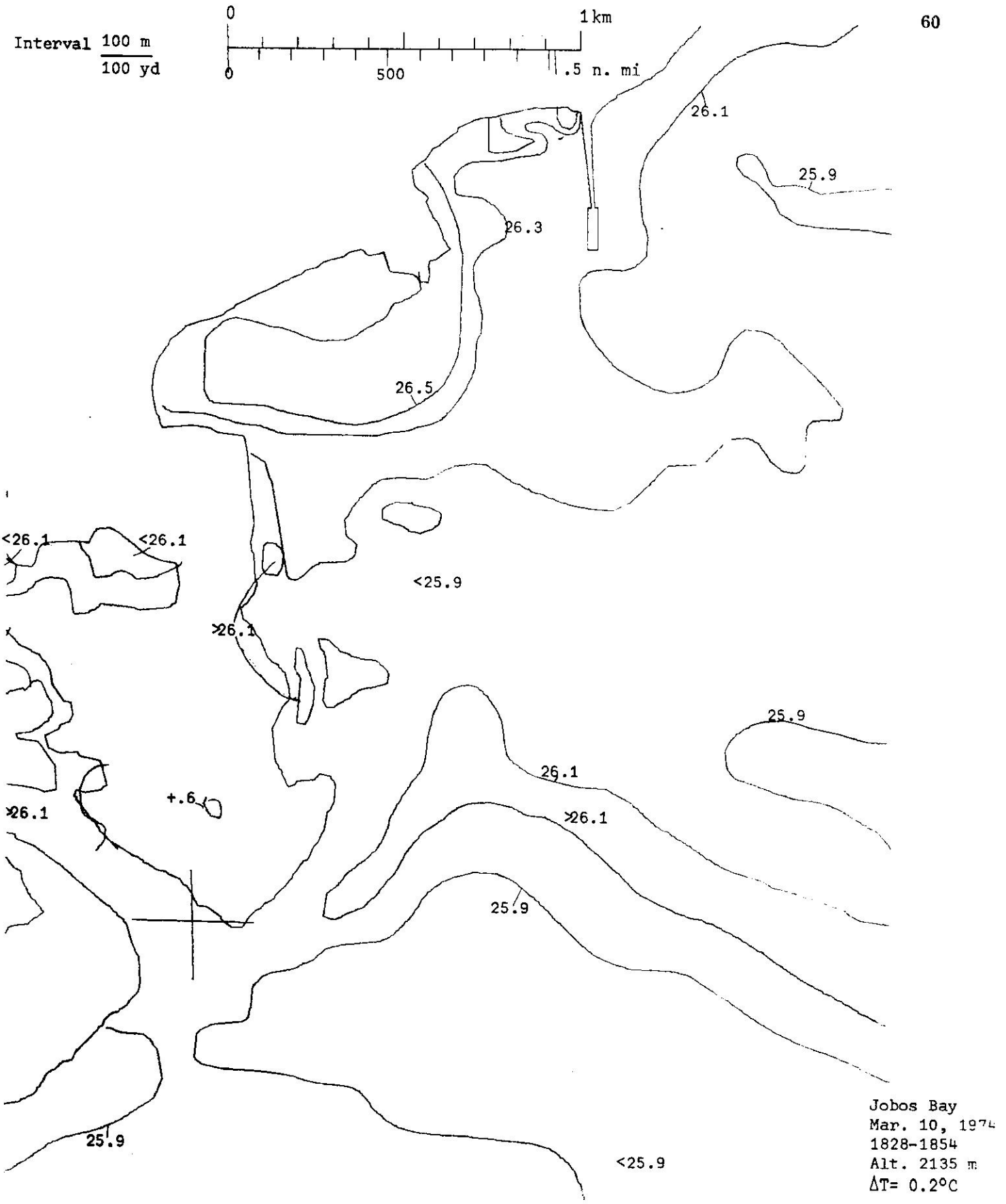

Interval 100 m / 100 yd
0
1 km
0
500
.5 n. mi
>26.8
>27.0
>27.2
26.6
26.0
26.0
26.4
26.2
26.2
26.2
<26.2
26.0
26.0
25.8
Jobos Bay
Mar. 7, 1974
0553-0620
Alt. 2290 m
ΔT= 0.2°C

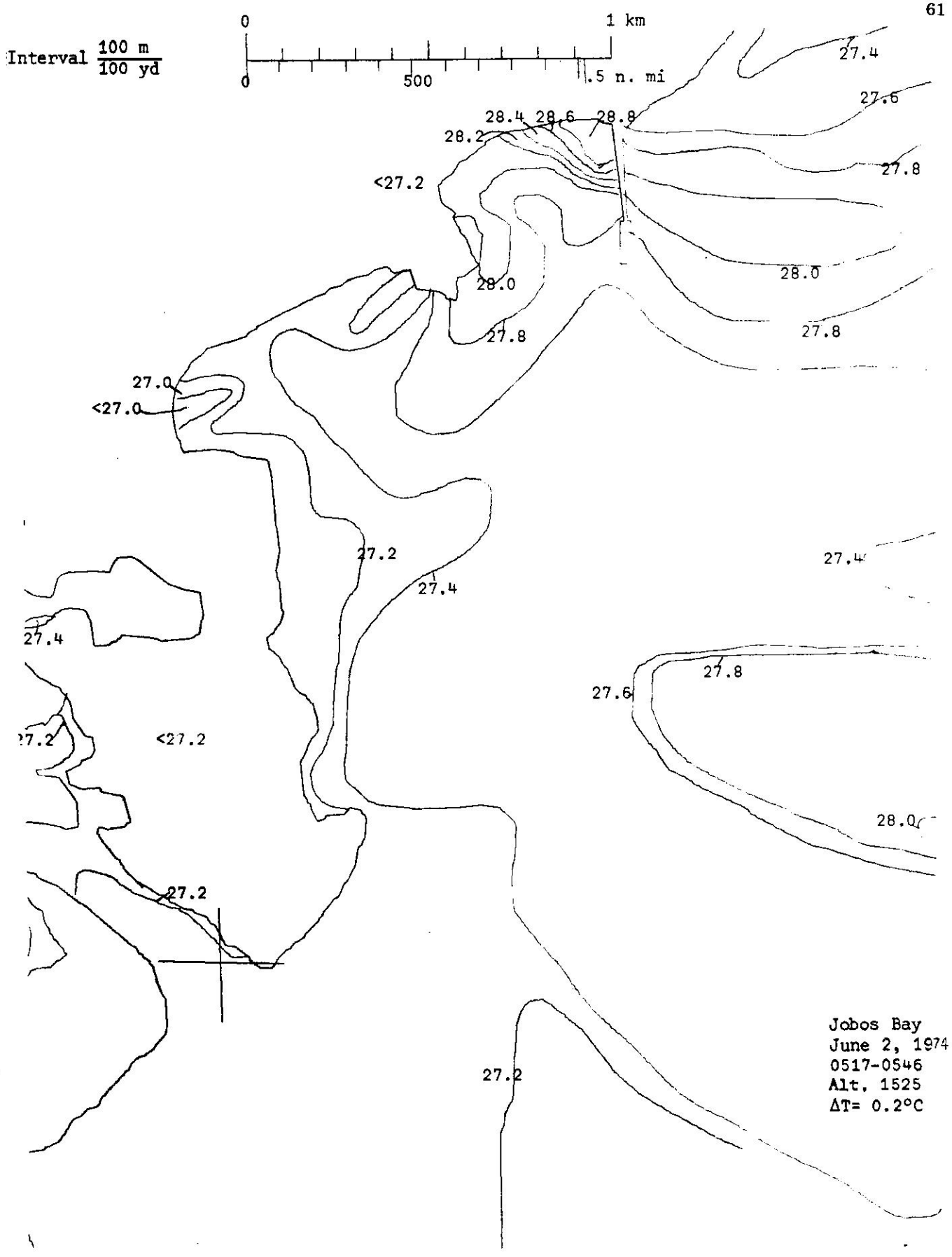


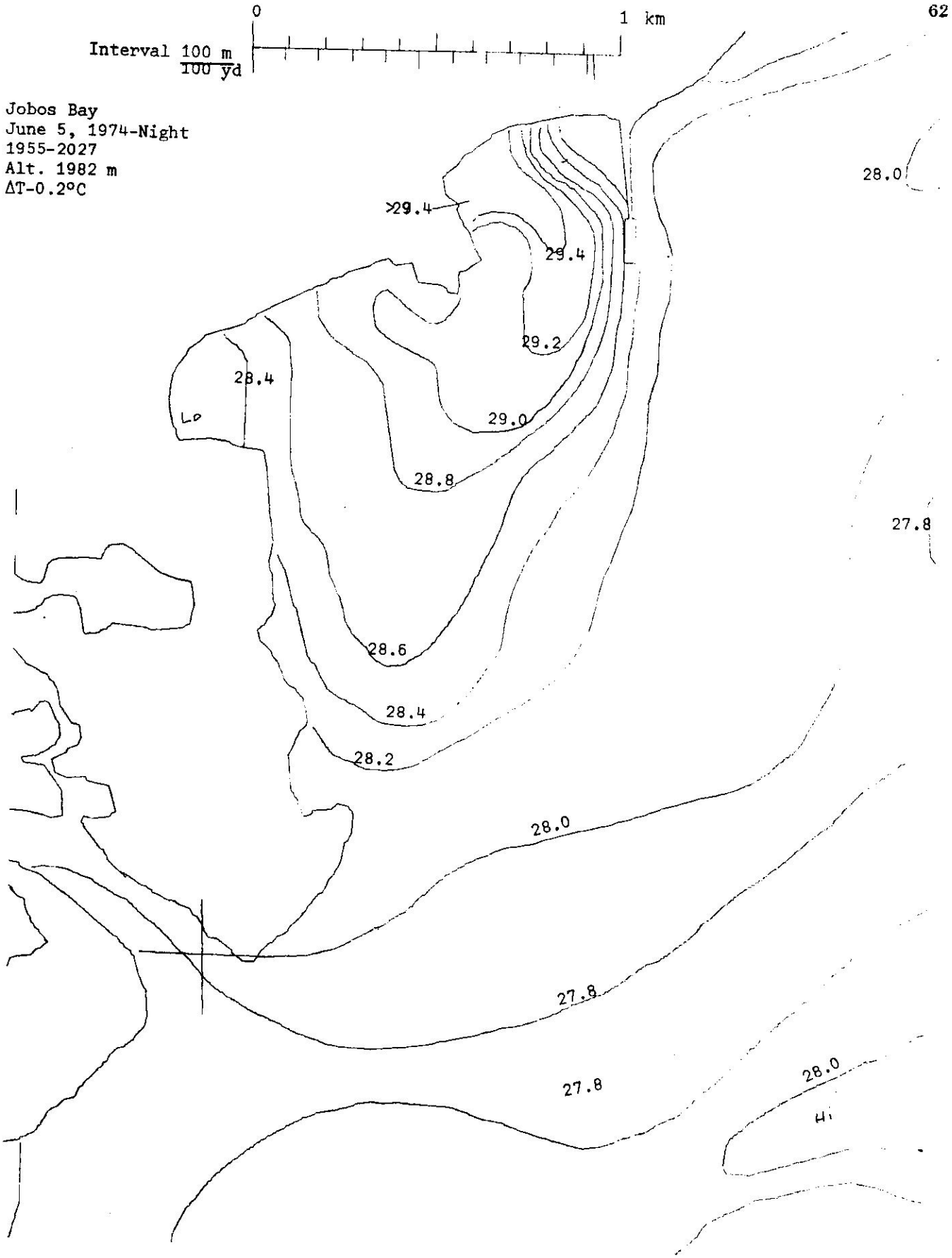
Jobos Bay
Mar. 7, 1974
1818-1852
Alt. 2135 m
ΔT= 0.2°C

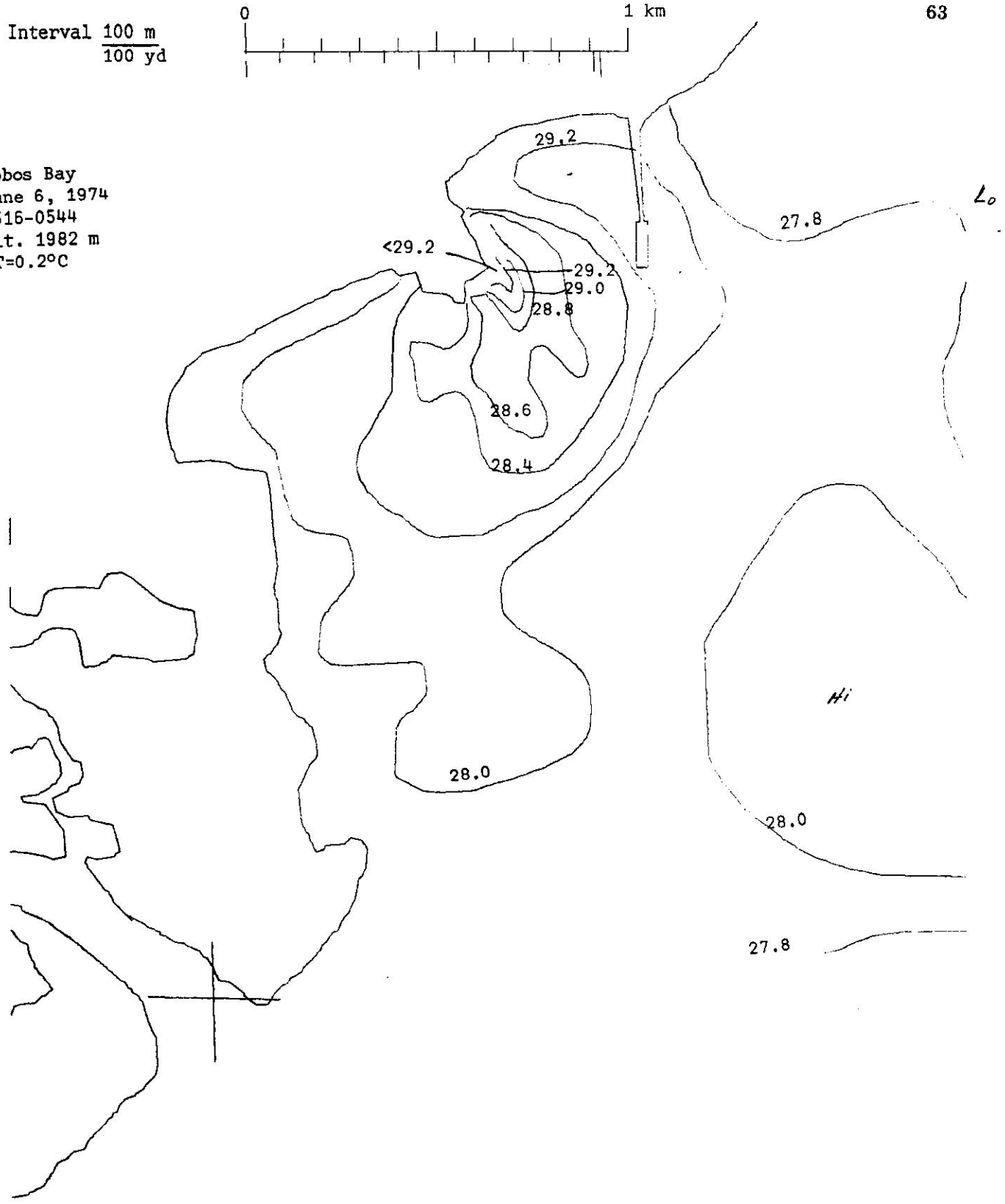


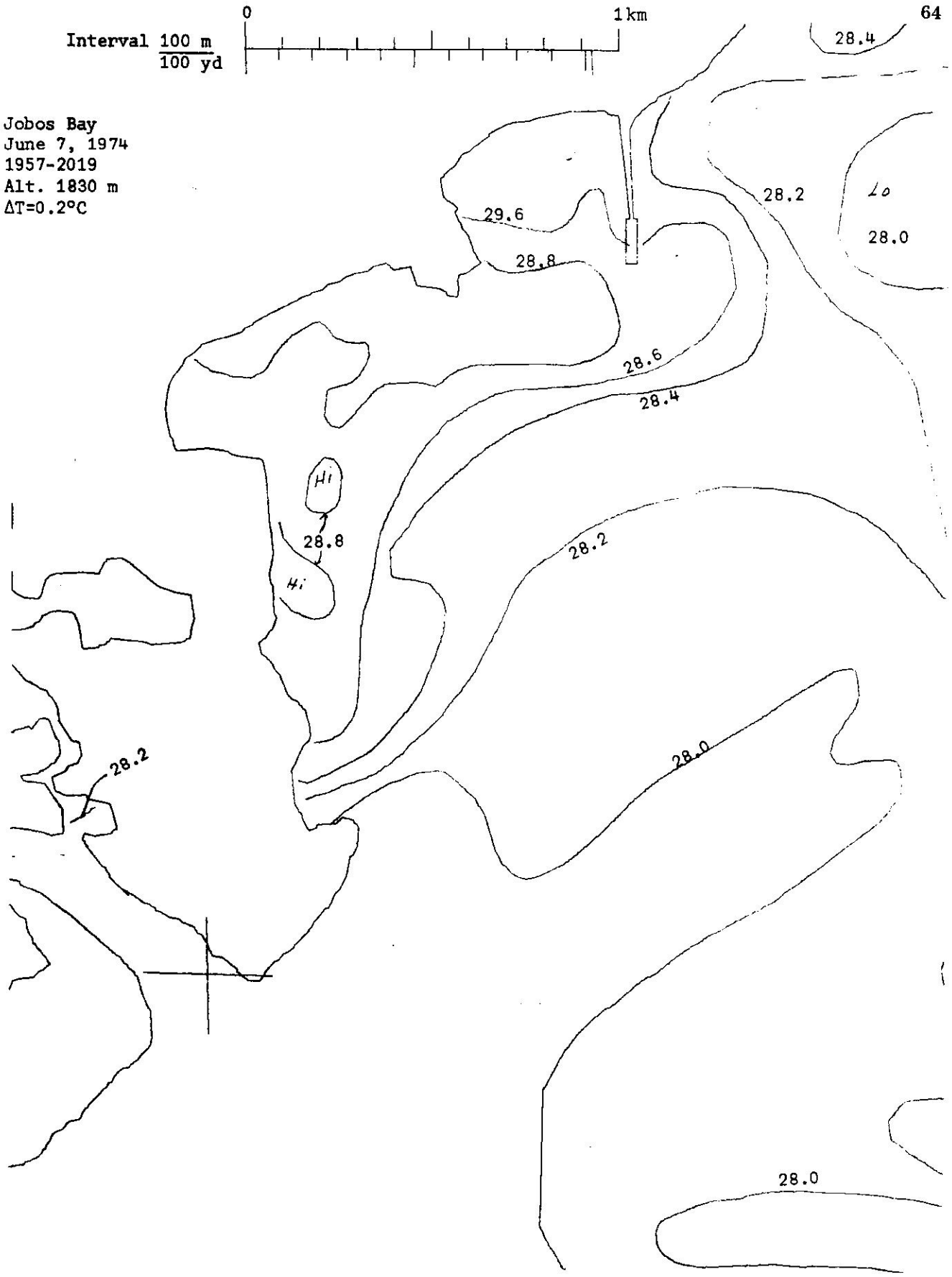
Jobos Bay
Mar. 9, 1974
0645-0720
Alt. 1525 m
ΔT= 0.2°C

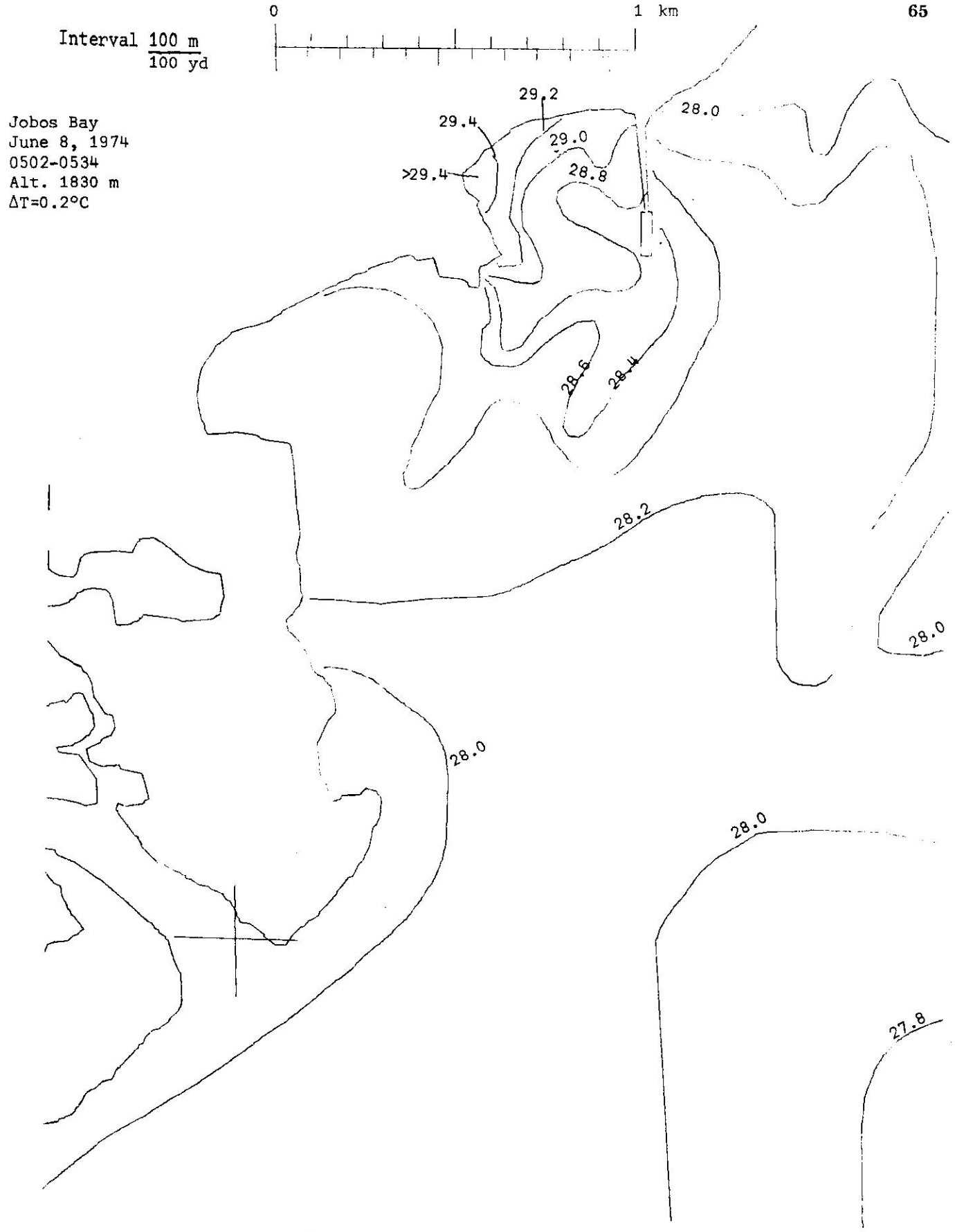

Interval 100 m
100 yd
0
1 km
0
500
.5 n. mi
26.1
25.9
26.3
26.5
<26.1
<26.1
<25.9
>26.1
25.9
26.1
+.6
>26.1
>26.1
25.9
25.9
<25.9
Jobos Bay
Mar. 10, 1974
1828-1854
Alt. 2135 m
ΔT= 0.2°C

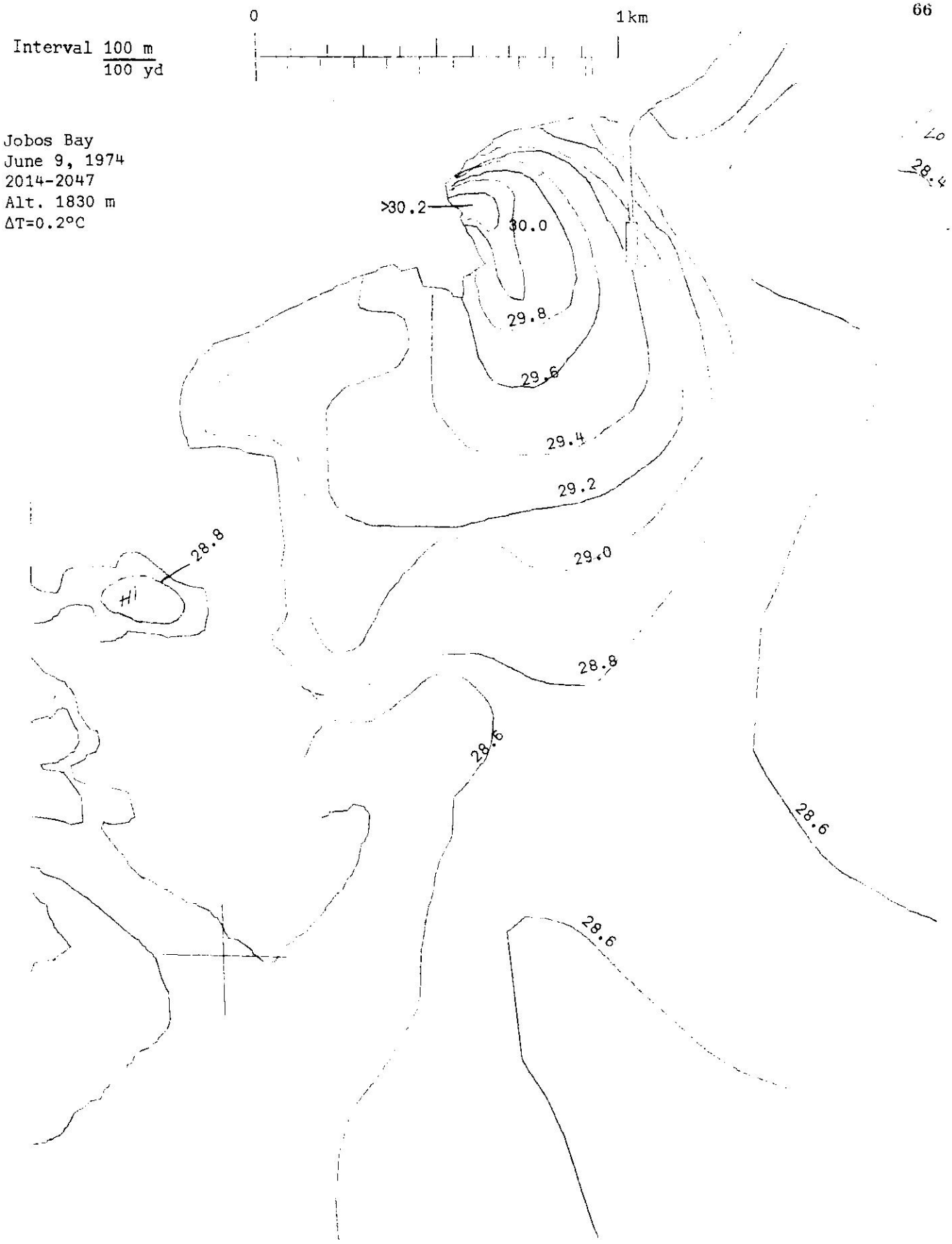

Interval 100 m / 100 yd
0
1 km
0
500
.5 n. mi
27.4
27.6
28.4
28.6
28.8
28.2
27.8
<27.2
28.0
27.8
27.0
<27.0
27.2
27.4
27.4
27.8
27.6
<27.2
28.0
27.2
27.2
Jobos Bay
June 2, 1974
0517-0546
Alt. 1525
ΔT= 0.2°C

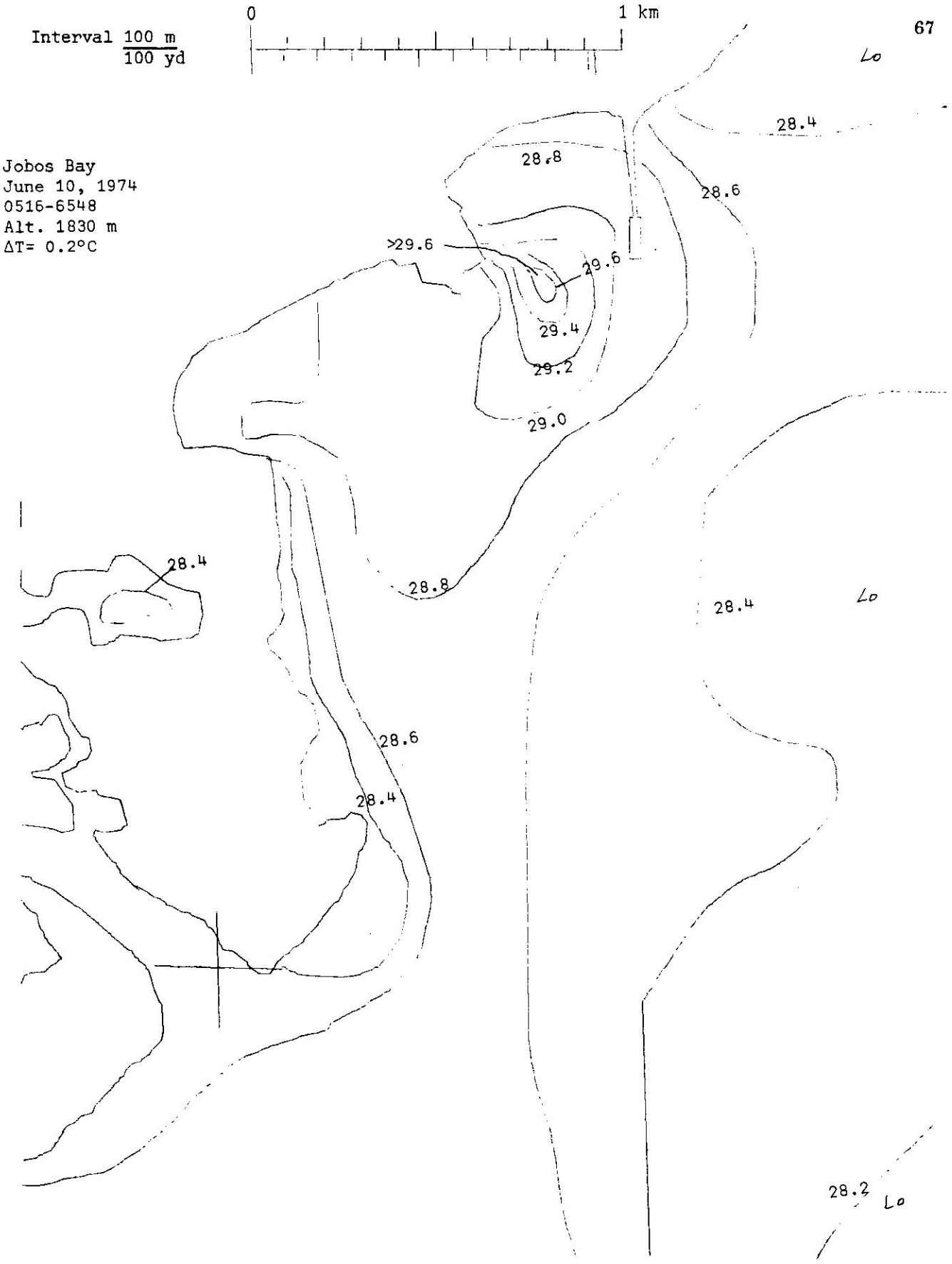

0
1 km
Interval 100 m
100 yd
Jobos Bay
June 5, 1974-Night
1955-2027
Alt. 1982 m
ΔT-0.2°C
>29.4
29.4
29.2
29.0
28.8
28.6
28.4
28.2
28.4
28.0
28.0
27.8
27.8
27.8
28.0
Lo
Hi

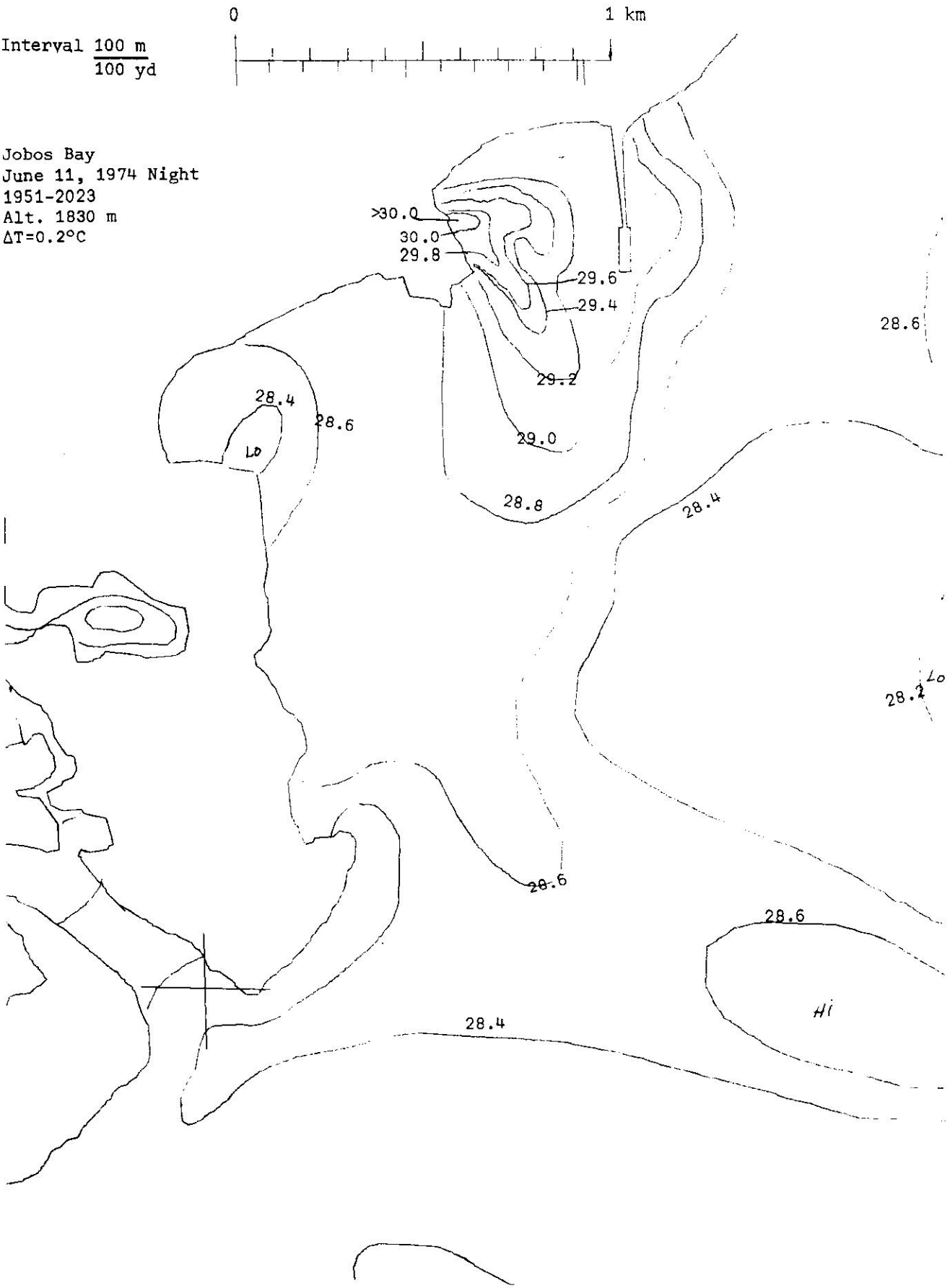

Interval 100 m
100 yd
0
1 km
Jobos Bay
June 6, 1974
0516-0544
Alt. 1982 m
ΔT=0.2°C
29.2
27.8
Lo
<29.2
29.2
29.0
28.8
28.6
28.4
Hi
28.0
28.0
27.8

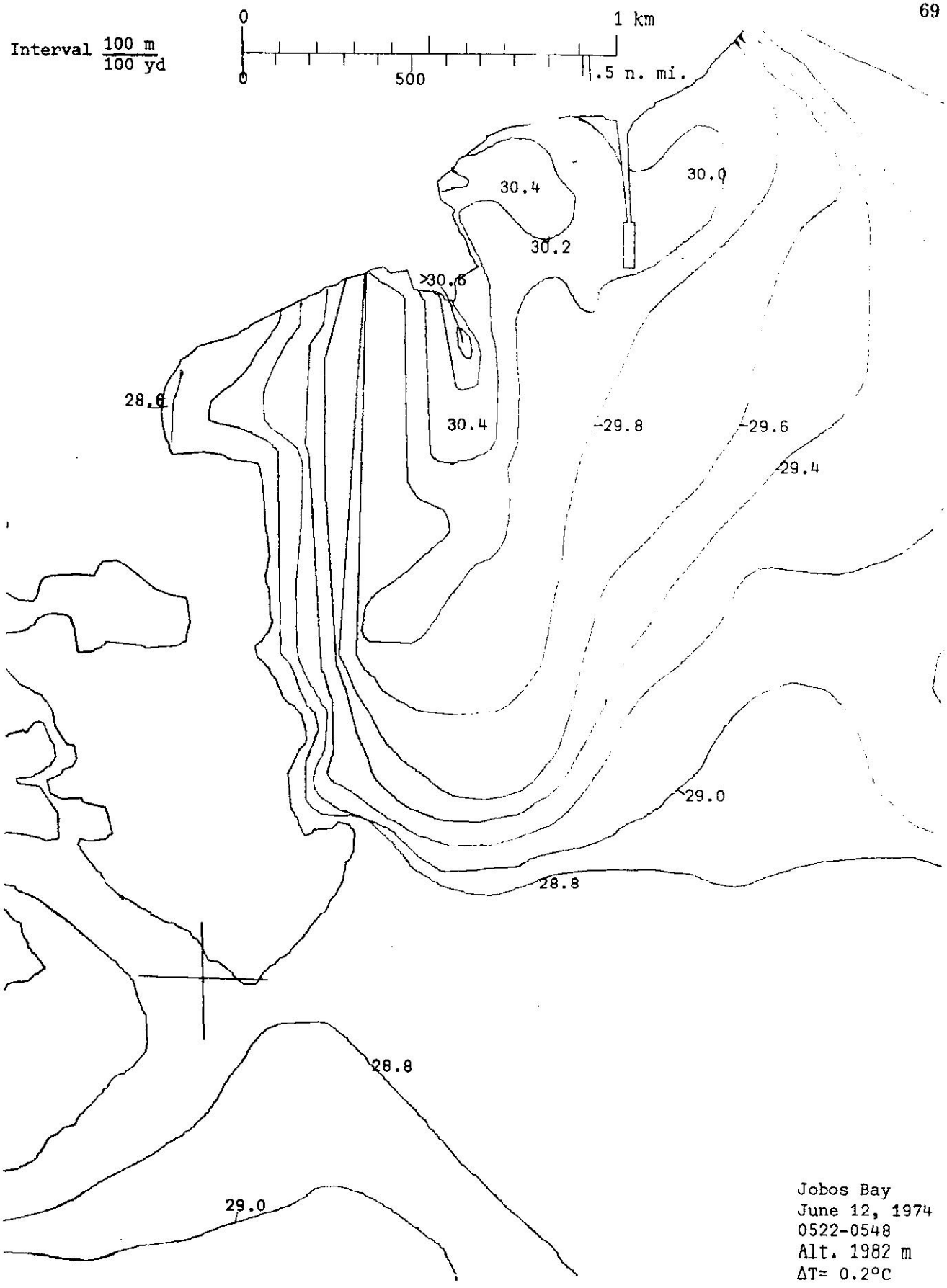

Interval 100 m
100 yd
0
1 km
Jobos Bay
June 7, 1974
1957-2019
Alt. 1830 m
ΔT=0.2°C
28.4
28.2
Lo
28.0
29.6
28.8
28.6
28.4
Hi
28.8
Hi
28.2
28.2
28.0
28.0


0
1 km
Interval 100 m
100 yd
Jobos Bay
June 8, 1974
0502-0534
Alt. 1830 m
ΔT=0.2°C
29.2
29.4
29.0
>29.4
28.8
28.0
28.6
28.4
28.2
28.0
28.0
28.0
27.8

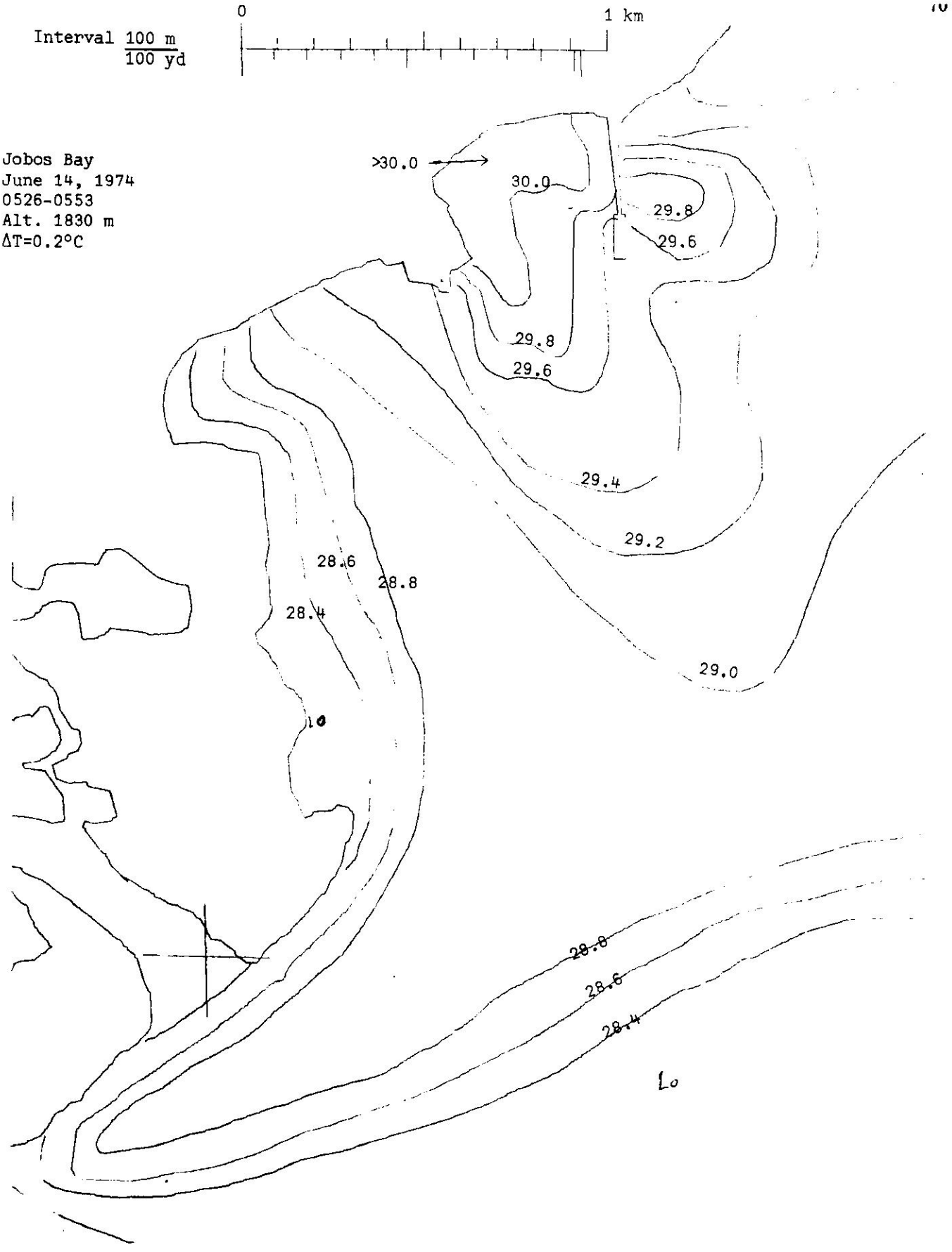

Interval 100 m
100 yd
0
1 km
Jobos Bay
June 9, 1974
2014-2047
Alt. 1830 m
ΔT=0.2°C
>30.2
30.0
29.8
29.6
29.4
29.2
29.0
28.8
28.6
28.4
Hi

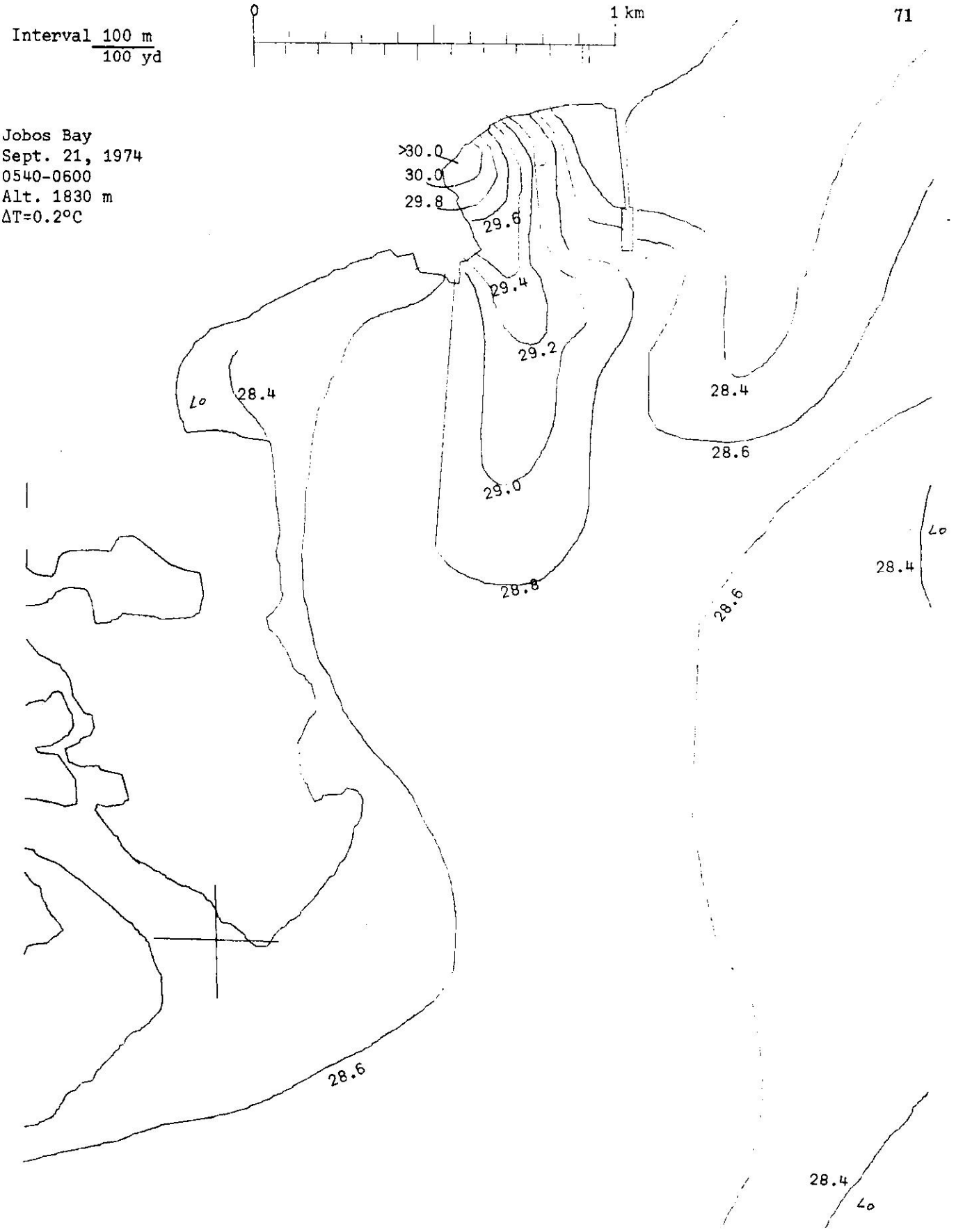

Interval 100 m
100 yd
0
1 km
Jobos Bay
June 10, 1974
0516-6548
Alt. 1830 m
ΔT= 0.2°C
28.4
28.8
28.6
>29.6
29.6
29.4
29.2
29.0
28.8
28.4
28.4
28.6
28.4
Lo
Lo
28.2
Lo

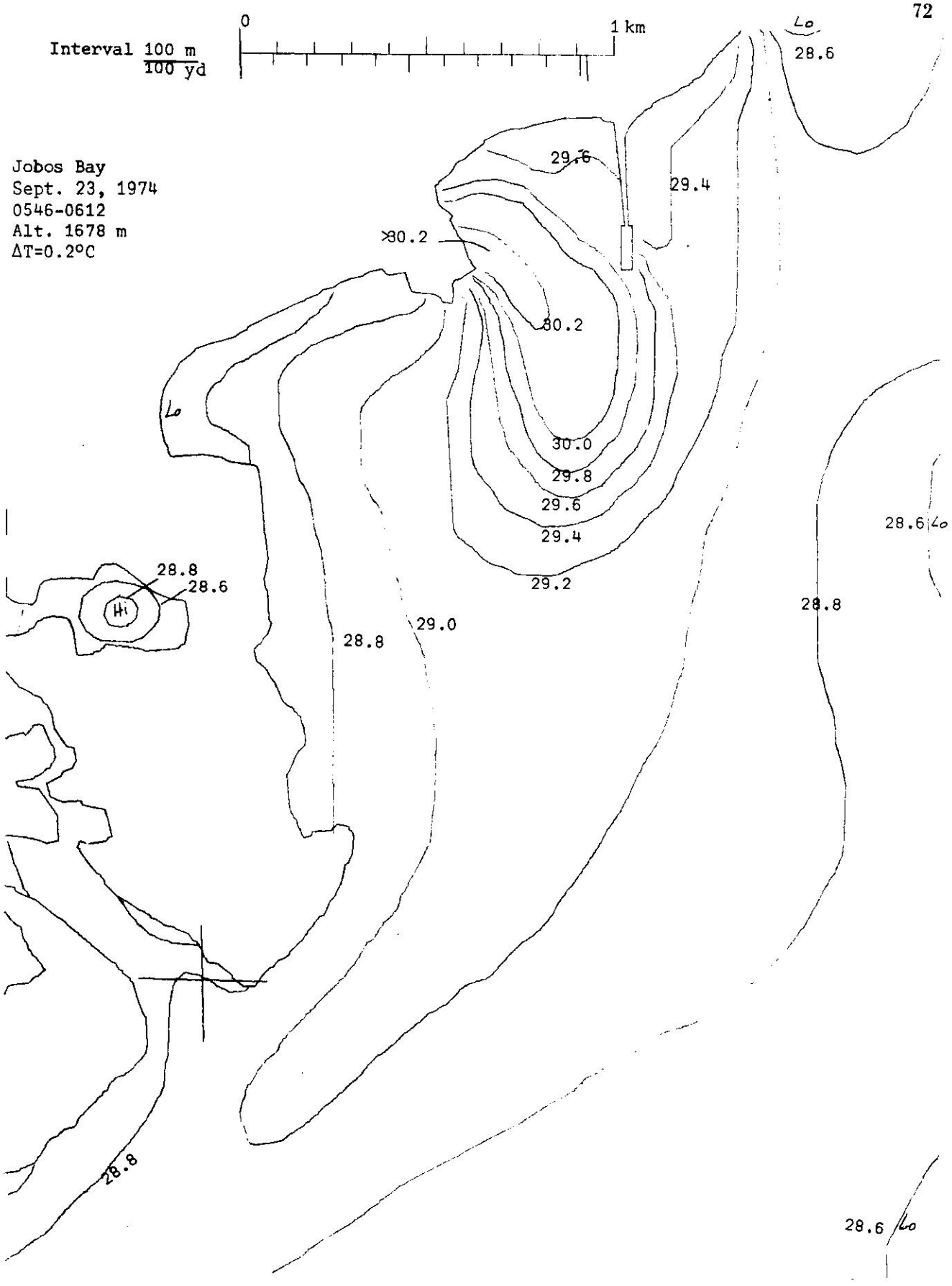

0
1 km
Interval 100 m
100 yd
Jobos Bay
June 11, 1974 Night
1951-2023
Alt. 1830 m
ΔT=0.2°C
>30.0
30.0
29.8
29.6
29.4
29.2
29.0
28.8
28.6
28.4
28.2
Lo
Hi

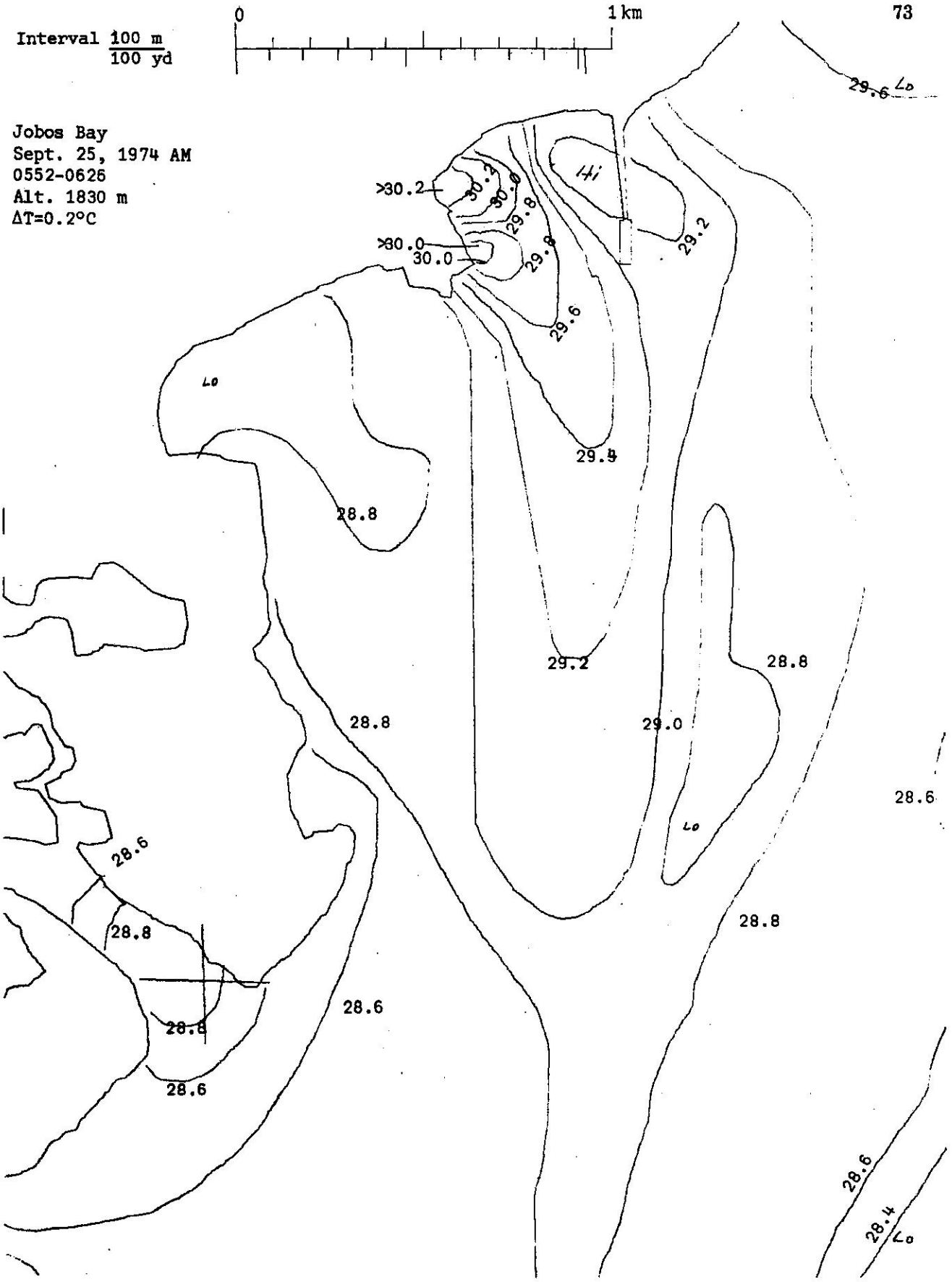


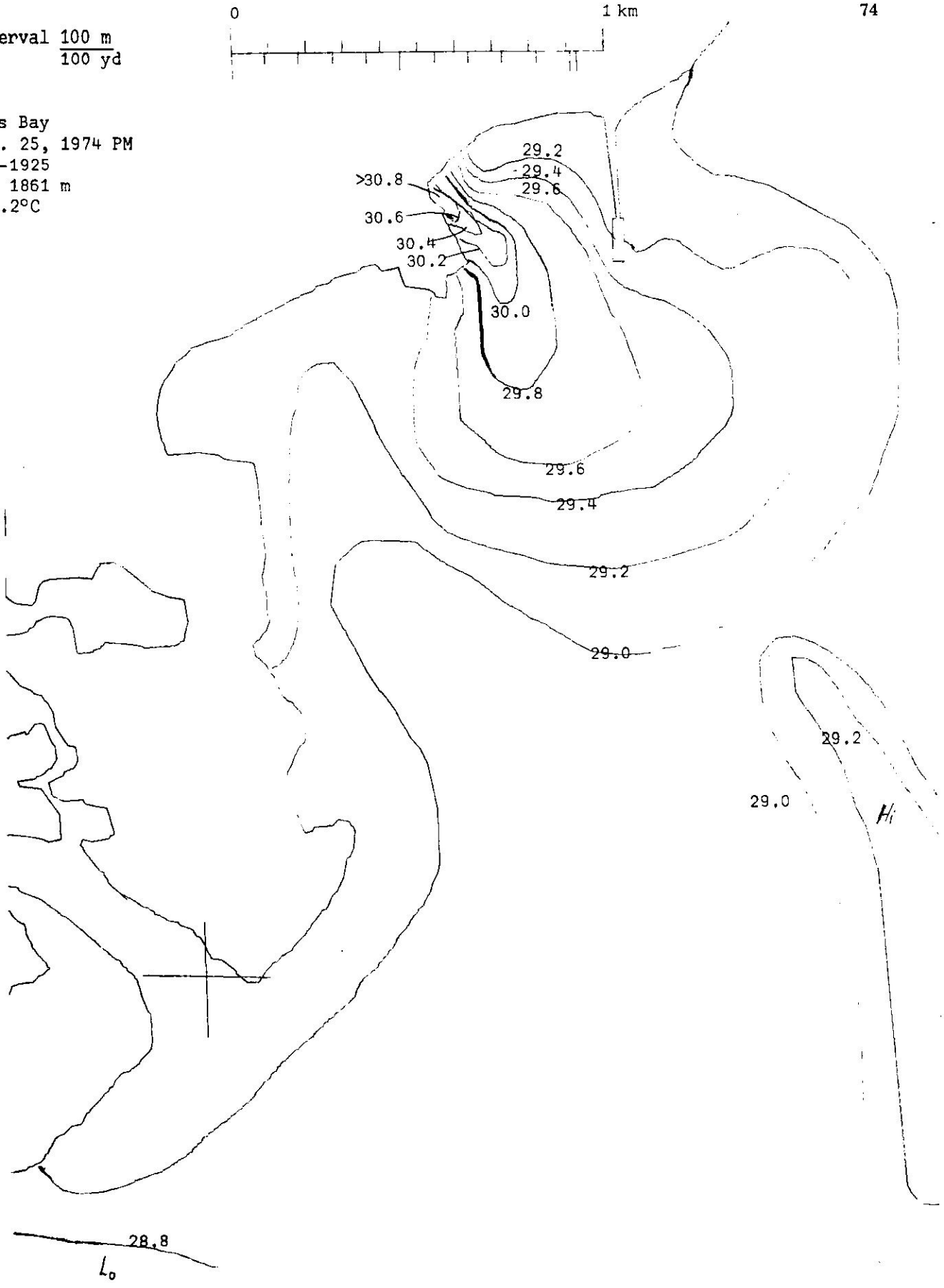
Jobos Bay
June 12, 1974
0522-0548
Alt. 1982 m
ΔT= 0.2°C

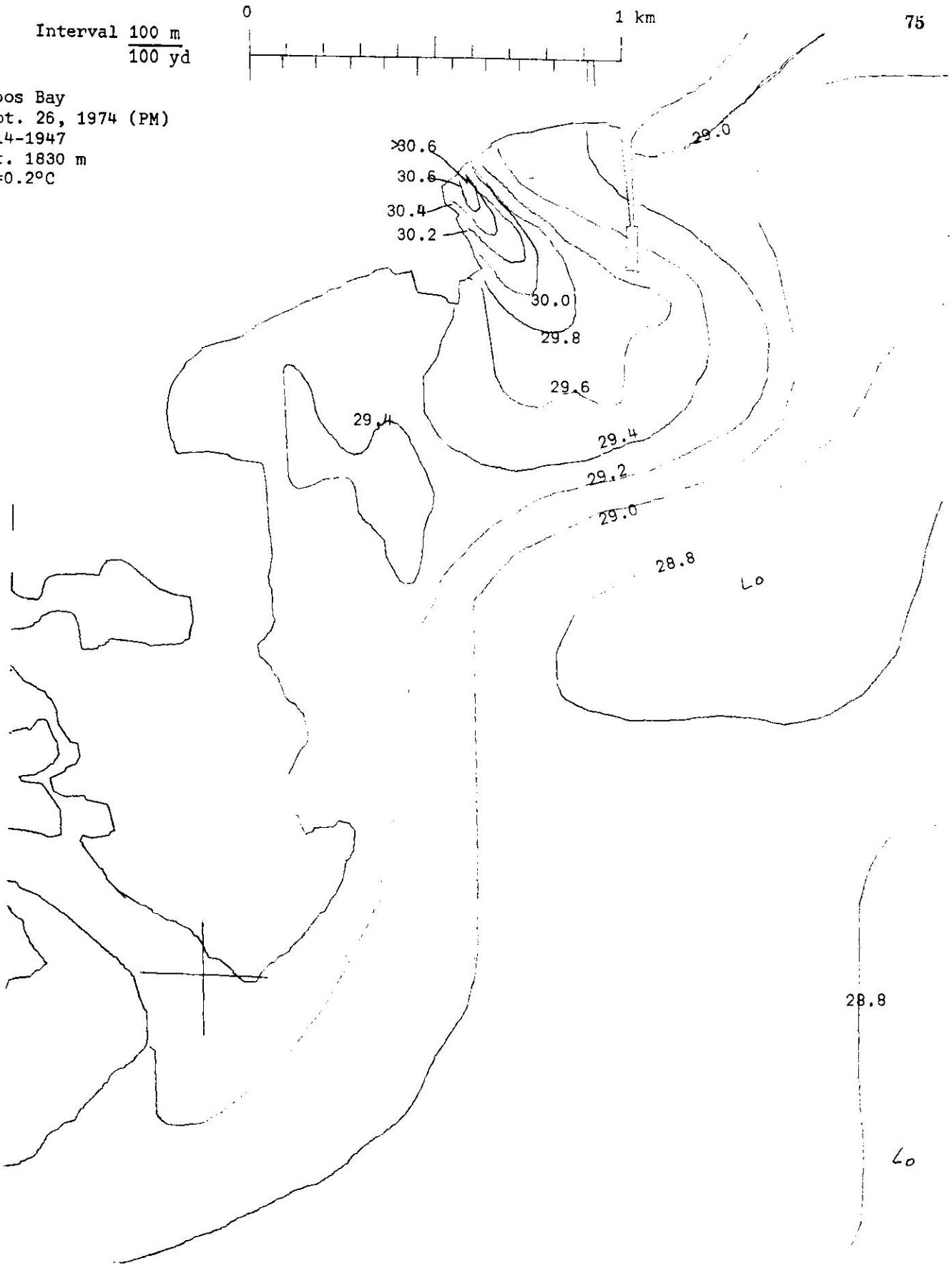

Interval 100 m
100 yd
0
1 km
Jobos Bay
June 14, 1974
0526-0553
Alt. 1830 m
ΔT=0.2°C
>30.0
30.0
29.8
29.6
29.8
29.6
29.4
29.2
28.6
28.8
28.4
29.0
10
29.8
28.6
28.4
Lo

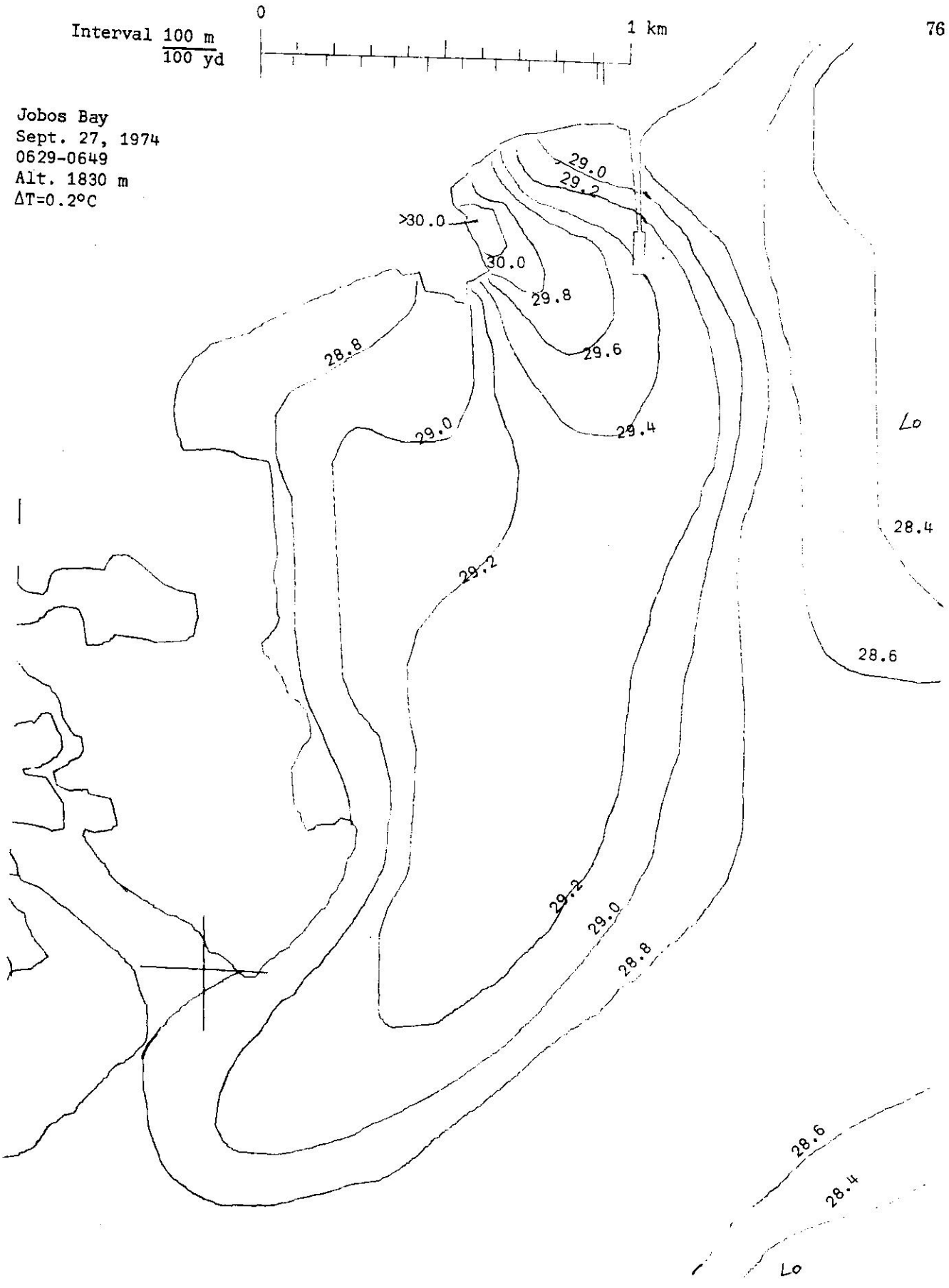

Interval 100 m
100 yd
0
1 km
Jobos Bay
Sept. 21, 1974
0540-0600
Alt. 1830 m
ΔT=0.2°C
>30.0
30.0
29.8
29.6
29.4
29.2
29.0
28.8
28.6
28.4
28.4
28.6
28.4
28.6
28.4
28.6

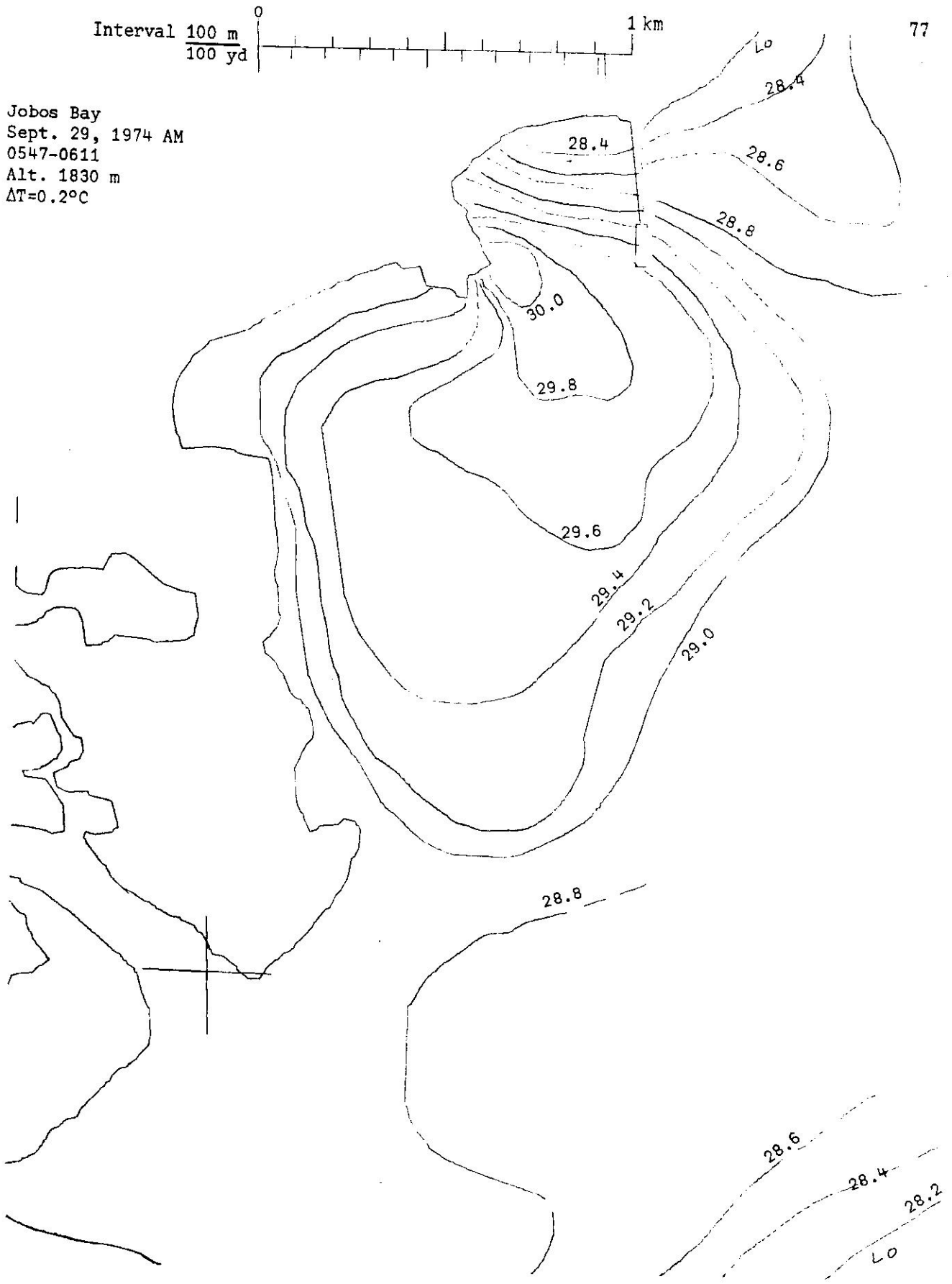

Interval 100 m
100 yd
0
1 km
Jobos Bay
Sept. 23, 1974
0546-0612
Alt. 1678 m
ΔT=0.2°C
Lo
28.6
29.6
29.4
30.2
30.2
30.0
29.8
29.6
29.4
29.2
28.6 Lo
28.8
28.6
Hi
28.8
29.0
28.8
28.8
28.6 Lo

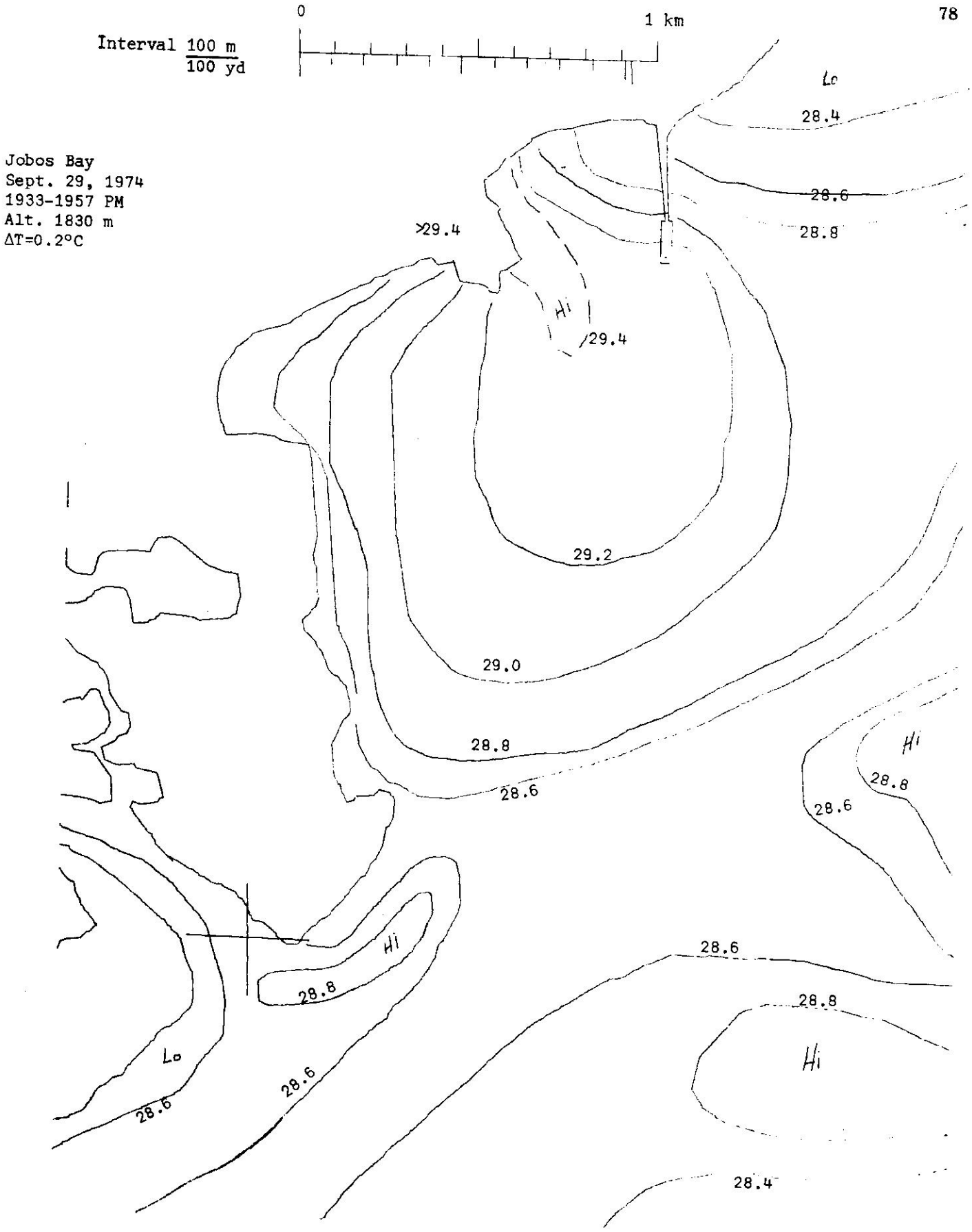

Interval 100 m
100 yd
0
1 km
Jobos Bay
Sept. 25, 1974 AM
0552-0626
Alt. 1830 m
ΔT=0.2°C
>30.2
30.2
30.0
29.8
>30.0
30.0
29.8
29.6
29.2
29.6
Hi
Lo
29.4
28.8
29.2
28.8
28.8
29.0
28.6
Lo
28.6
28.8
28.8
28.6
28.6
28.6
28.4
Lo

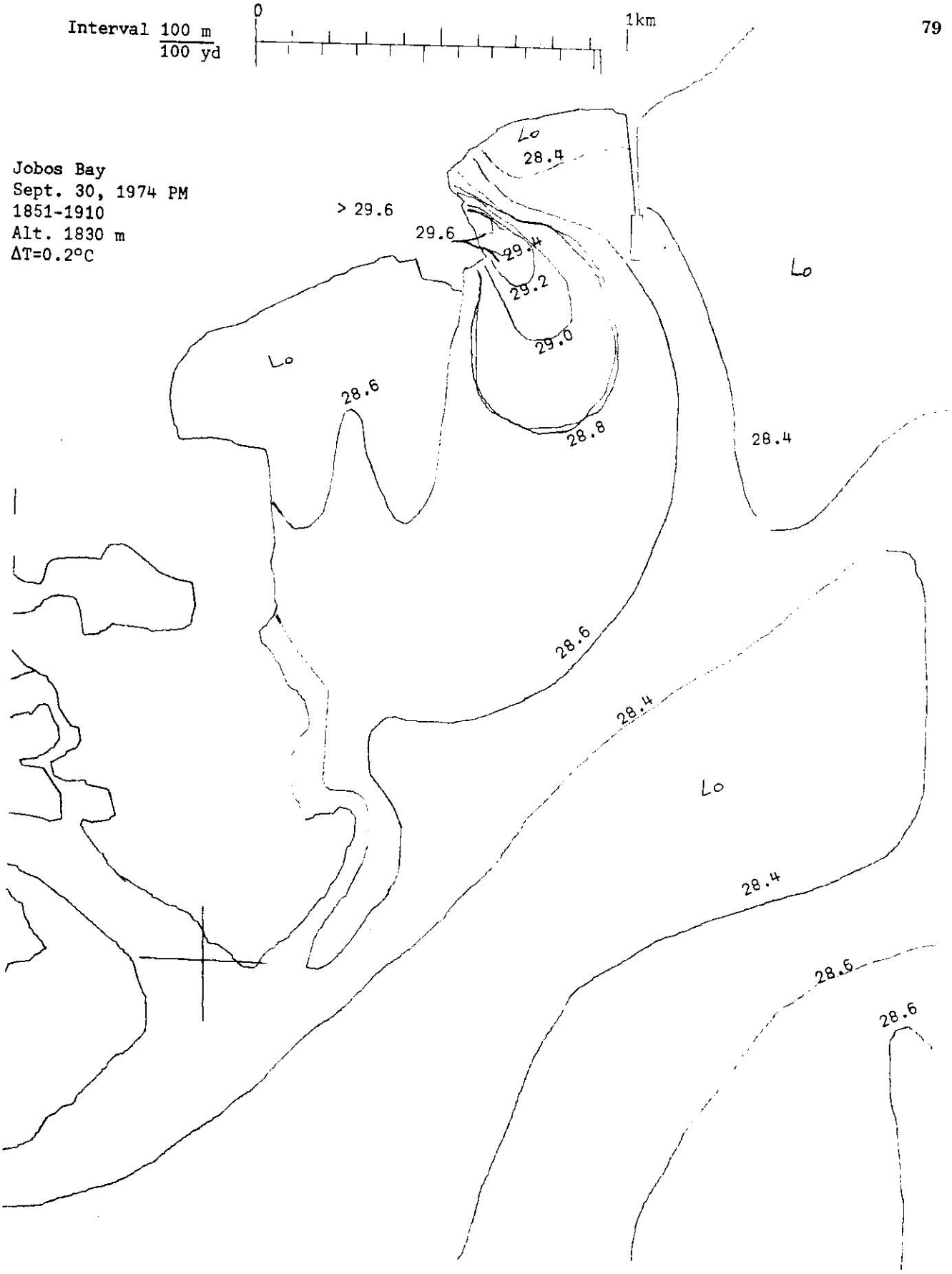

Interval 100 m
100 yd
0
1 km
Jobos Bay
Sept. 25, 1974 PM
1845-1925
Alt. 1861 m
ΔT=0.2°C
>30.8
30.6
30.4
30.2
30.0
29.8
29.6
29.4
29.2
29.0
29.2
29.4
29.6
29.2
29.0
Hi
28.8
Lo

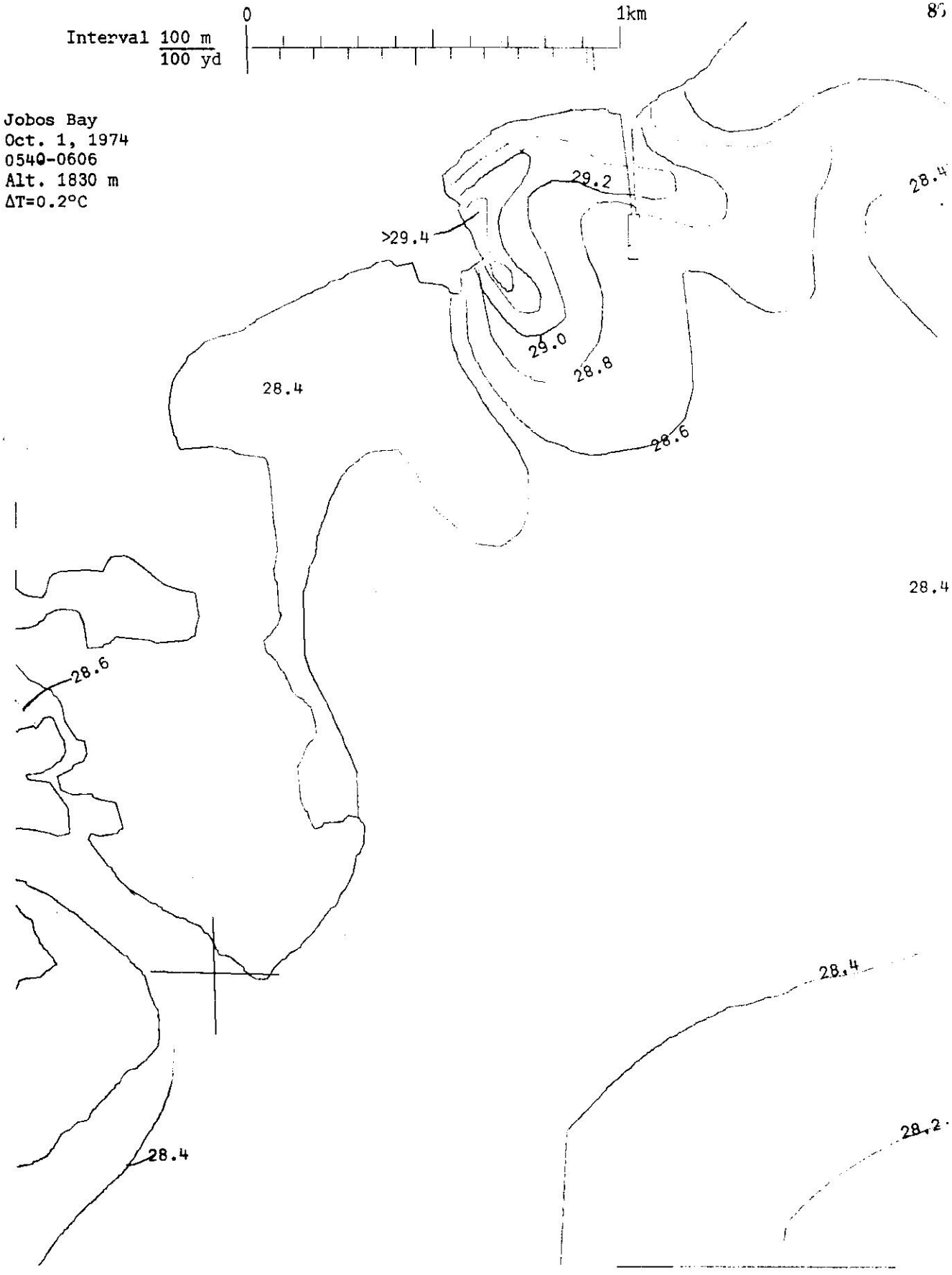

Interval 100 m
100 yd
0
1 km
Jobos Bay
Sept. 26, 1974 (PM)
1914-1947
Alt. 1830 m
ΔT=0.2°C
>30.6
30.6
30.4
30.2
30.0
29.8
29.6
29.4
29.4
29.2
29.0
29.0
28.8
Lo
28.8
Lo

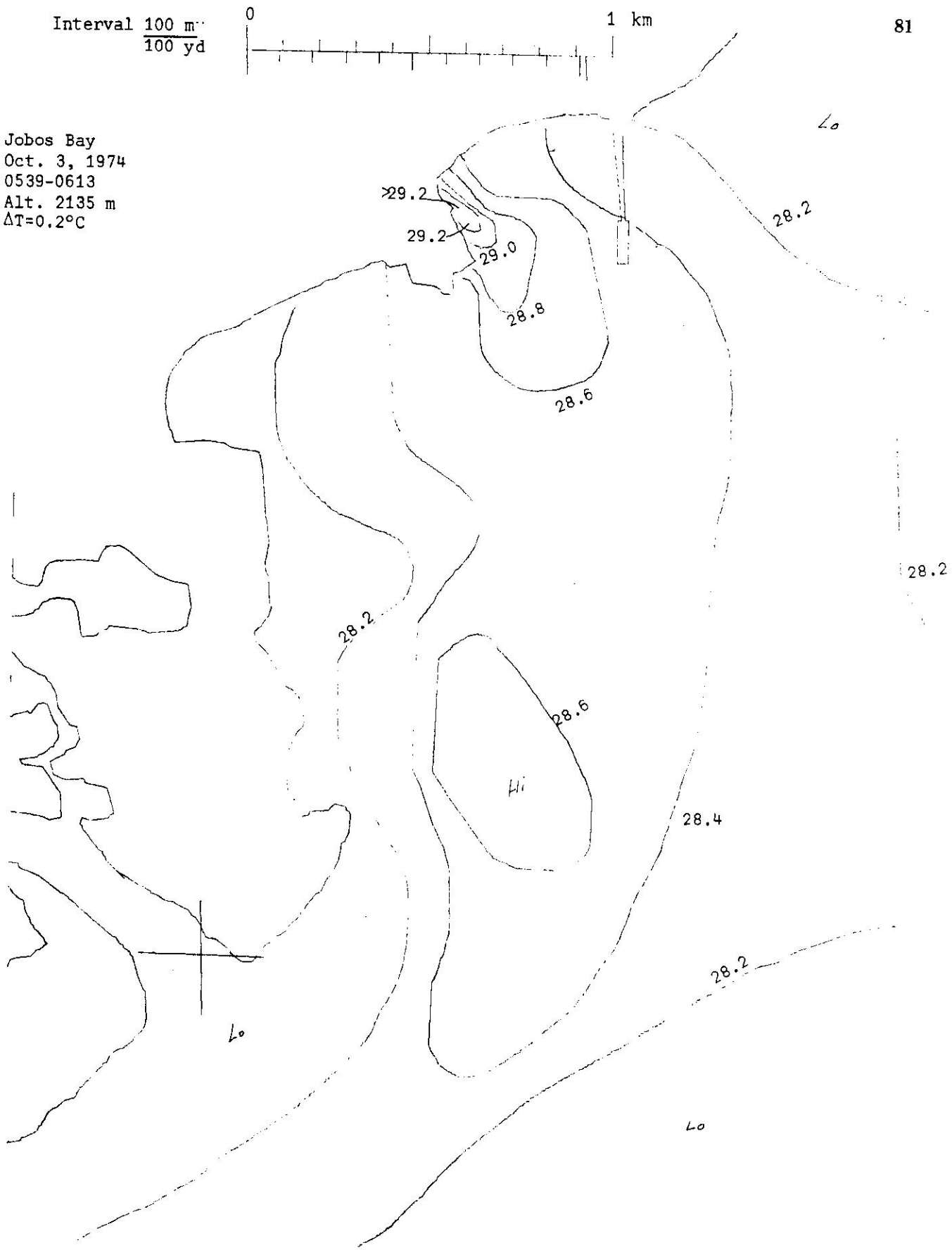

Interval 100 m
100 yd
0
1 km
Jobos Bay
Sept. 27, 1974
0629-0649
Alt. 1830 m
ΔT=0.2°C
>30.0
30.0
29.8
29.6
29.4
29.2
29.0
28.8
28.6
28.4
Lo

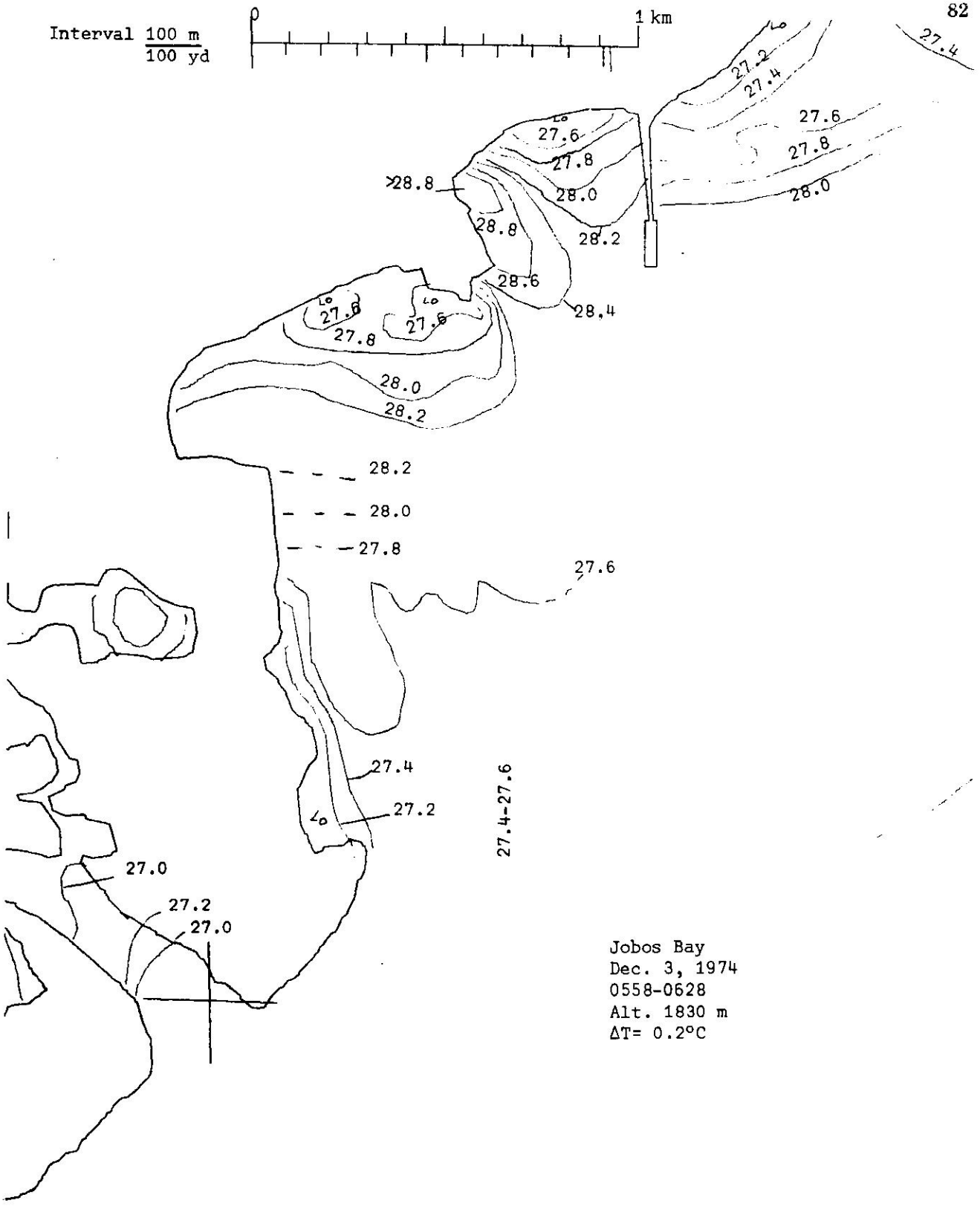

Interval 100 m / 100 yd
0
1 km
Jobos Bay
Sept. 29, 1974 AM
0547-0611
Alt. 1830 m
ΔT=0.2°C
LO
28.4
28.4
28.6
28.8
30.0
29.8
29.6
29.4
29.2
29.0
28.8
28.6
28.4
28.2
LO

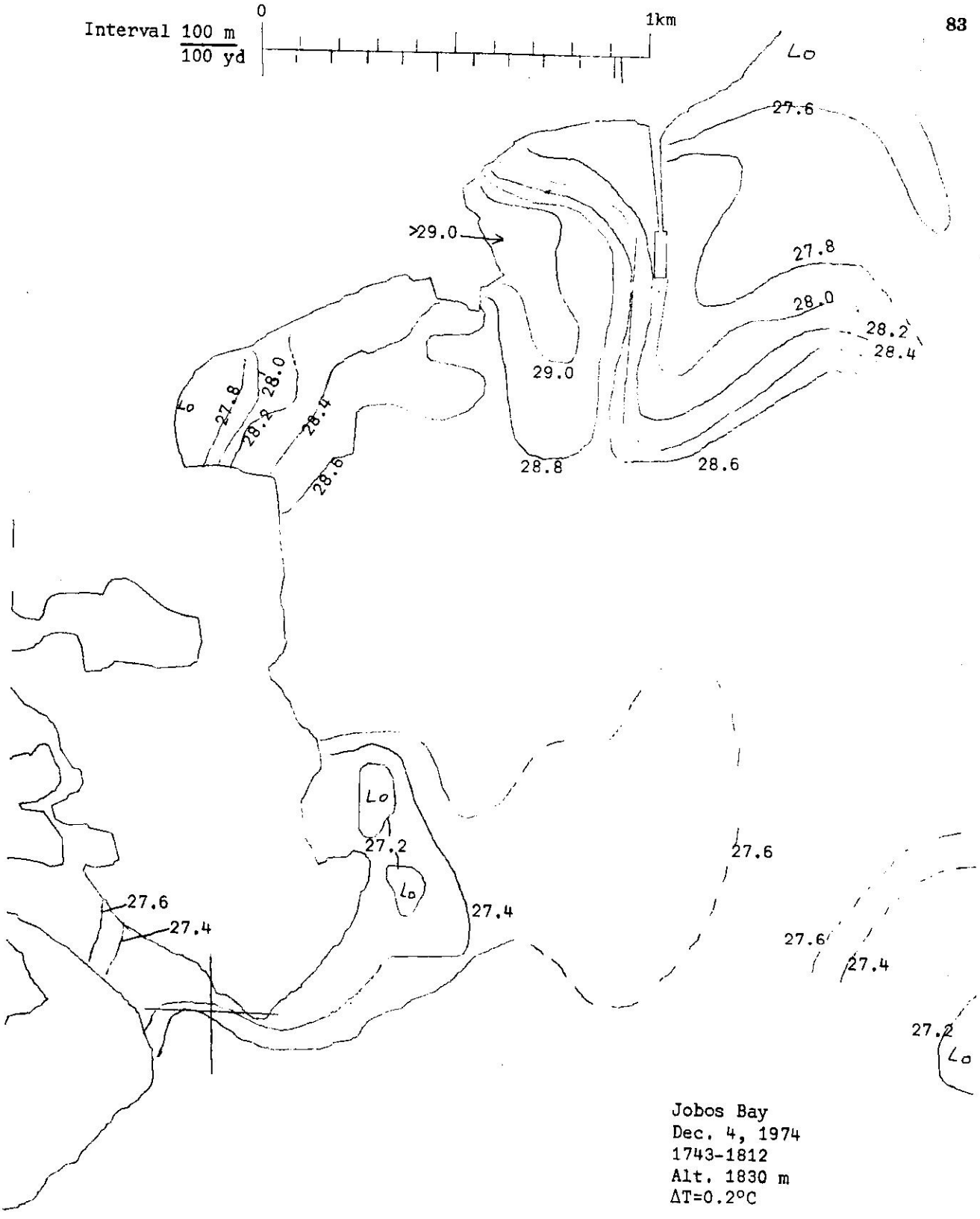

Interval 100 m / 100 yd
0
1 km
Jobos Bay
Sept. 29, 1974
1933-1957 PM
Alt. 1830 m
ΔT=0.2°C
Lo
28.4
28.6
28.8
>29.4
Hi
29.4
29.2
29.0
28.8
28.6
Hi
28.8
28.6
Hi
28.8
Lo
28.6
28.6
28.6
28.8
Hi
28.4


Interval 100 m
100 yd
0
1km
Jobos Bay
Sept. 30, 1974 PM
1851-1910
Alt. 1830 m
ΔT=0.2°C
Lo
28.4
> 29.6
29.6
29.4
29.2
29.0
Lo
Lo
28.6
28.8
28.4
28.6
28.4
Lo
28.4
28.6
28.6

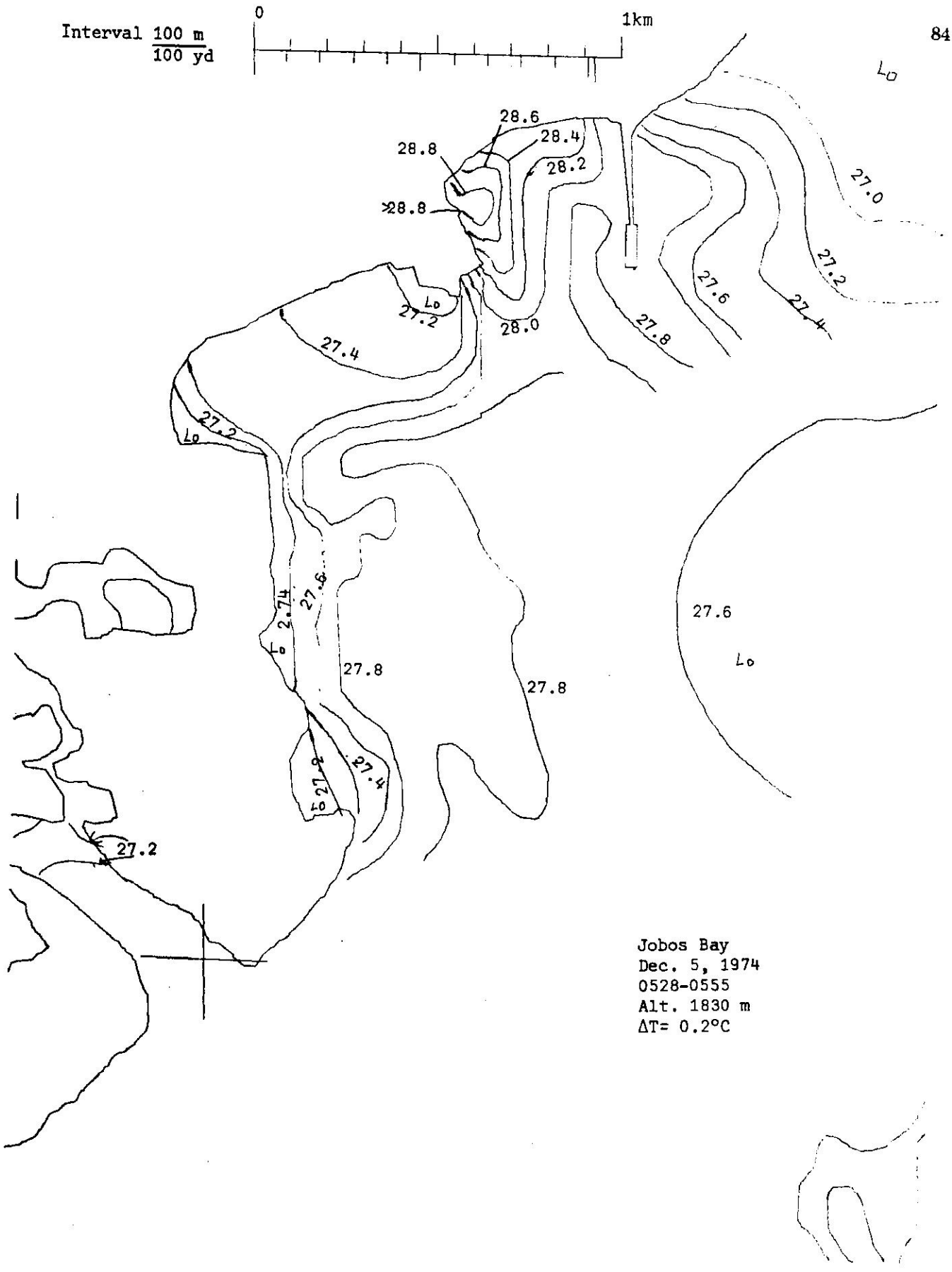

Interval 100 m
100 yd
0
1km
Jobos Bay
Oct. 1, 1974
0540-0606
Alt. 1830 m
ΔT=0.2°C
>29.4
29.2
29.0
28.8
28.6
28.4
28.4
28.6
28.4
28.4
28.2

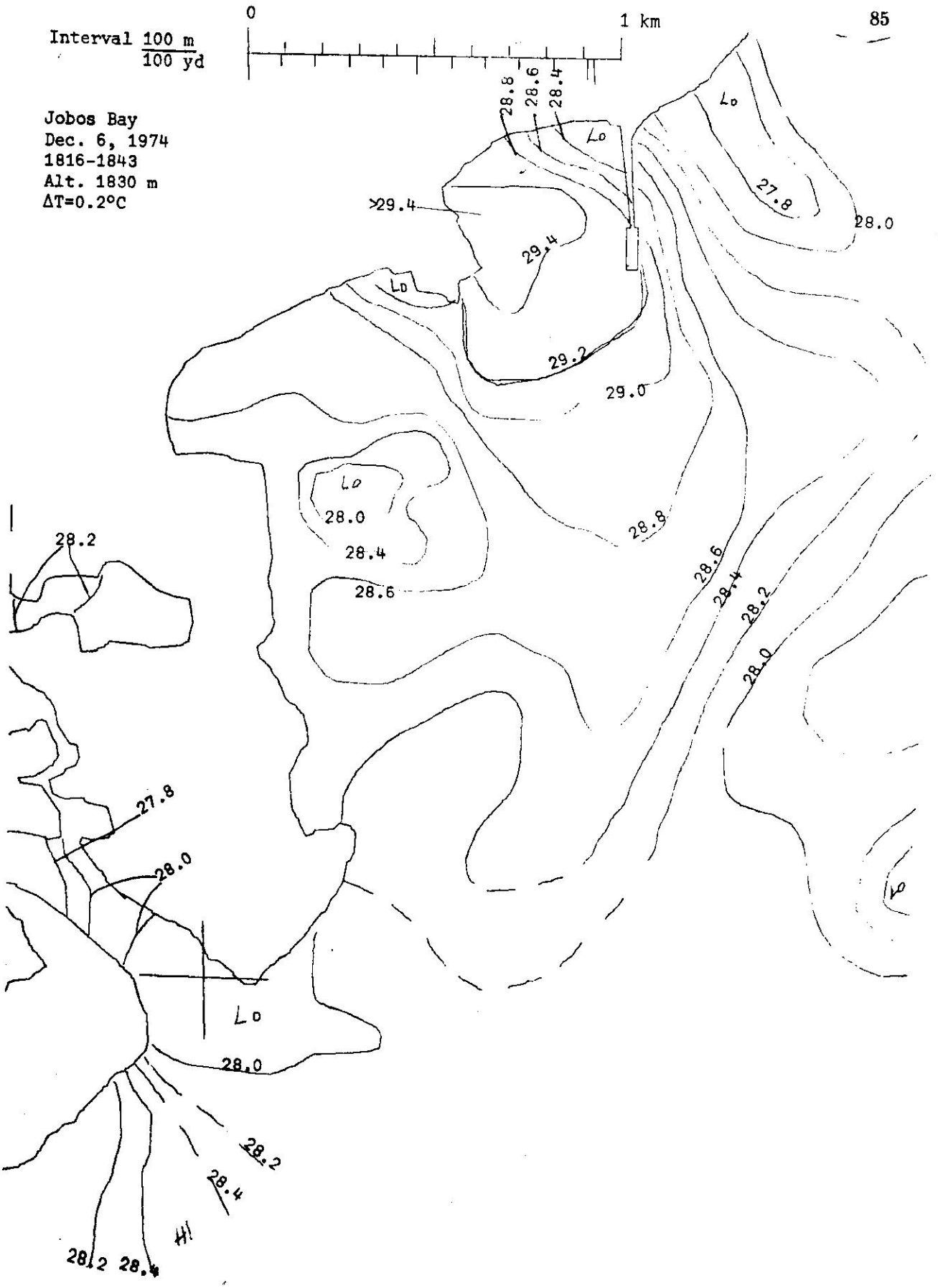

Interval 100 m
100 yd
0
1 km
Jobos Bay
Oct. 3, 1974
0539-0613
Alt. 2135 m
ΔT=0.2°C
>29.2
29.2
29.0
28.8
28.6
28.2
28.2
28.2
28.6
Hi
28.4
28.2
Lo
Lo
Lo


Interval 100 m
100 yd
0
1 km
27.4
27.2
27.4
27.6
27.8
28.0
27.6
27.8
28.8
28.0
28.8
28.2
28.6
28.4
27.6
27.8
27.6
28.0
28.2
28.2
28.0
27.8
27.6
27.4
27.2
27.4-27.6
27.0
27.2
27.0
Jobos Bay
Dec. 3, 1974
0558-0628
Alt. 1830 m
ΔT= 0.2°C



Jobos Bay
Dec. 4, 1974
1743-1812
Alt. 1830 m
ΔT=0.2°C

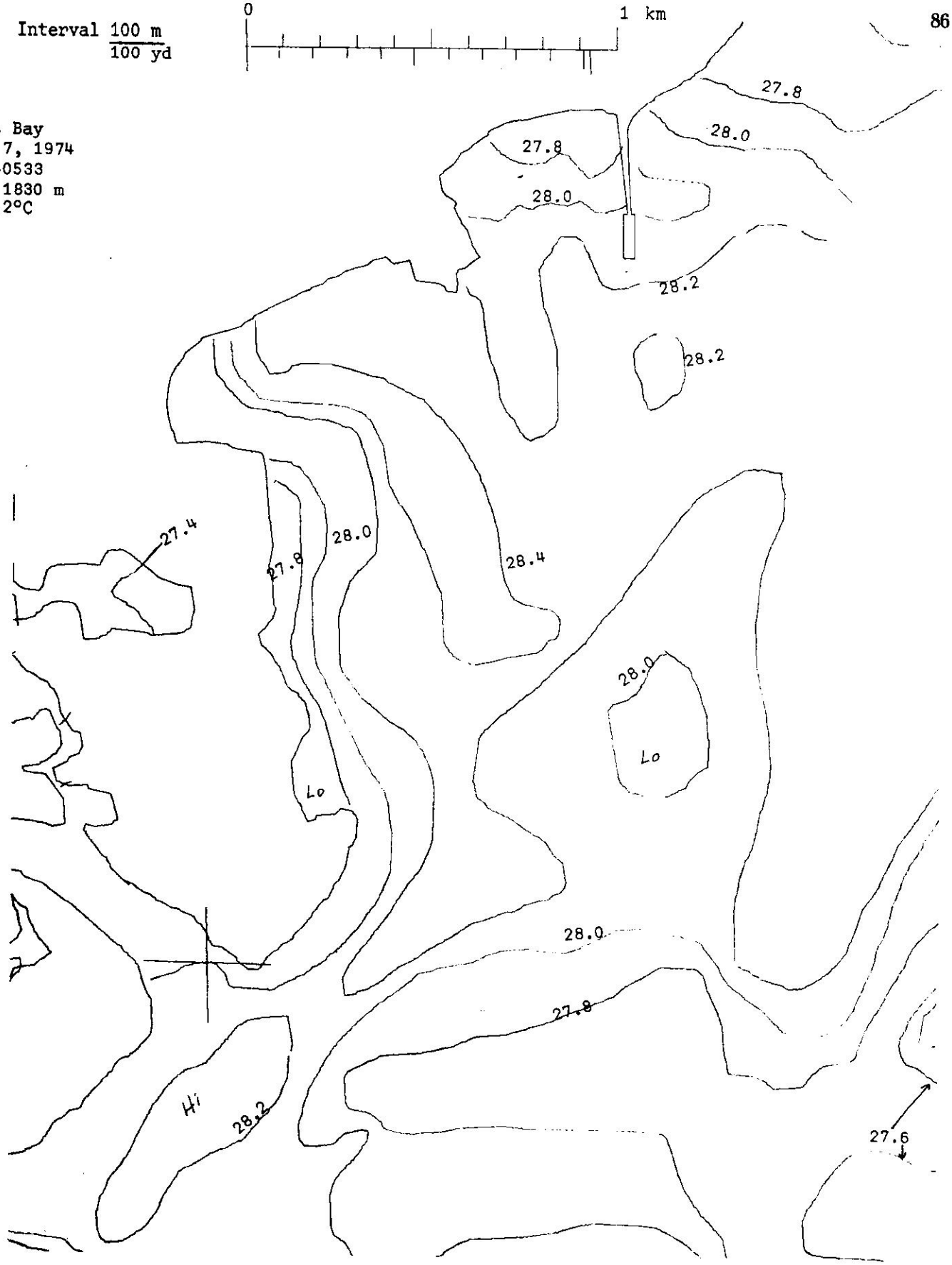

Interval 100 m
100 yd
0
1km
28.6
28.4
28.8
28.2
28.8
27.0
27.2
27.6
27.4
27.2
28.0
27.8
27.4
27.2
27.6
27.4
27.8
27.8
27.6
27.2
Jobos Bay
Dec. 5, 1974
0528-0555
Alt. 1830 m
ΔT= 0.2°C

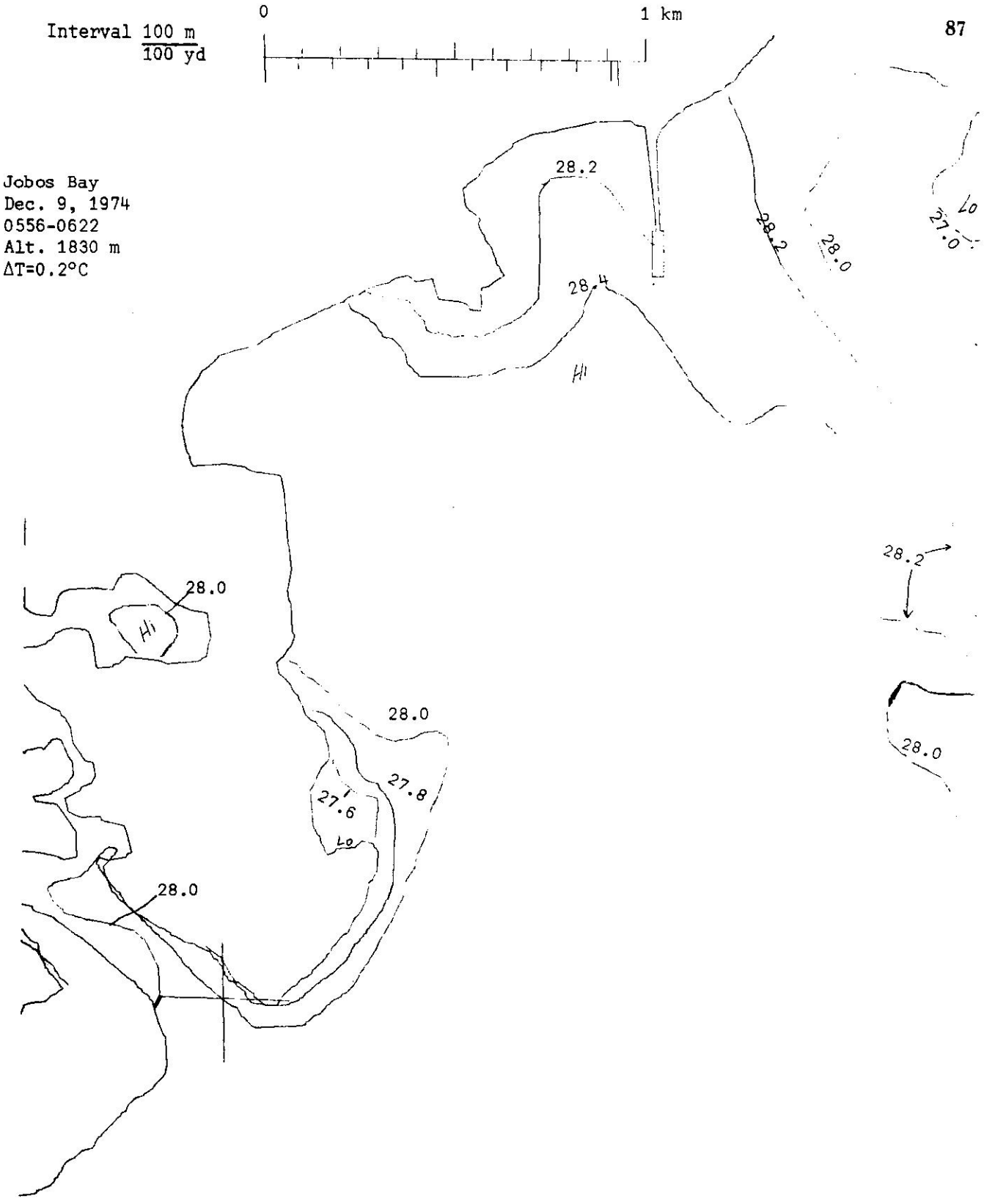

Interval 100 m
100 yd
0
1 km
Jobos Bay
Dec. 6, 1974
1816-1843
Alt. 1830 m
ΔT=0.2°C
28.8
28.6
28.4
Lo
27.8
28.0
>29.4
29.4
29.2
29.0
28.8
28.6
28.4
28.2
28.0
28.2
28.4
28.6
Lo
28.0
28.4
28.2
27.8
28.0
Lo
28.0
28.2
28.4
Hi
28.2
28.4

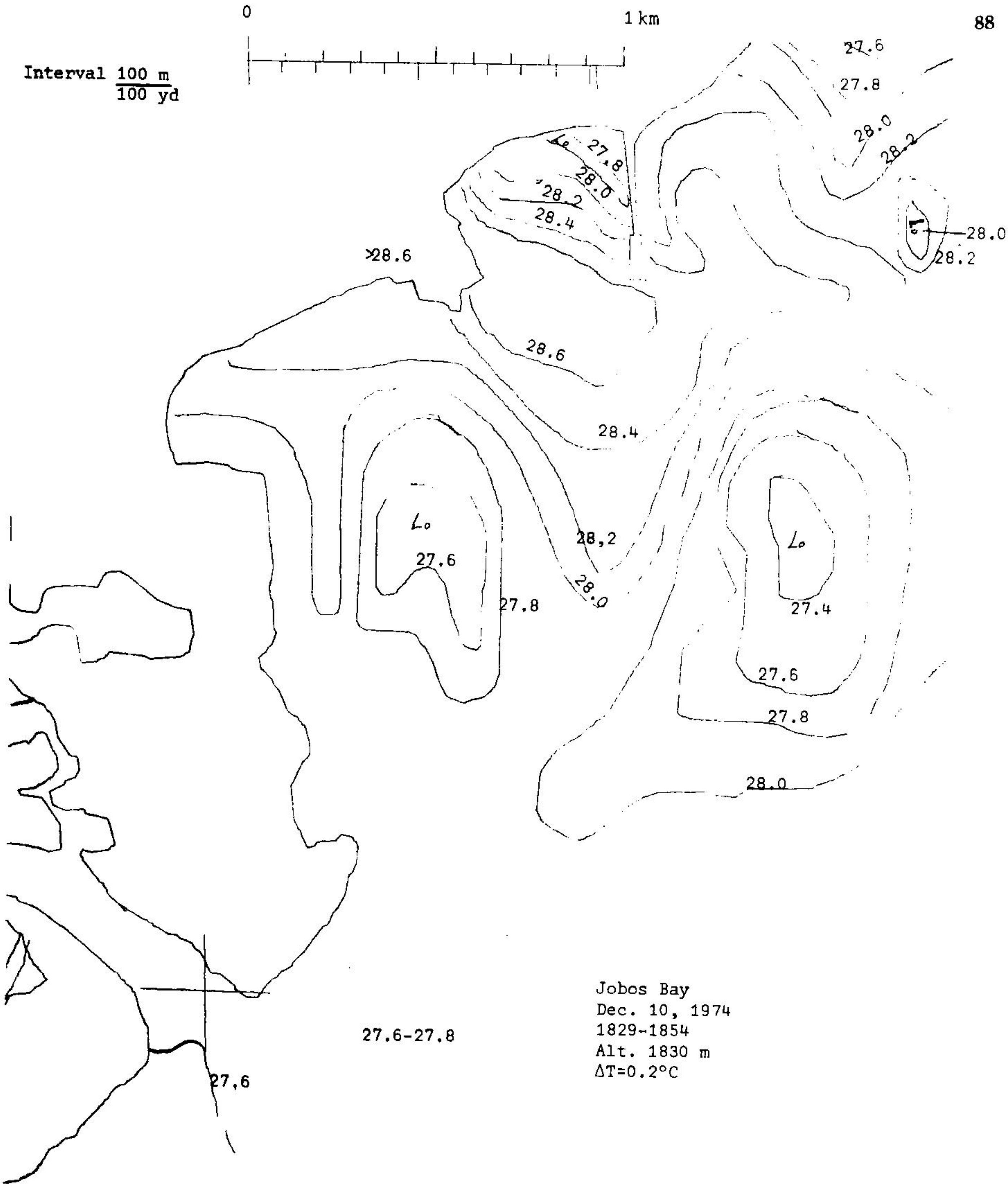
Interval 100 m / 100 yd

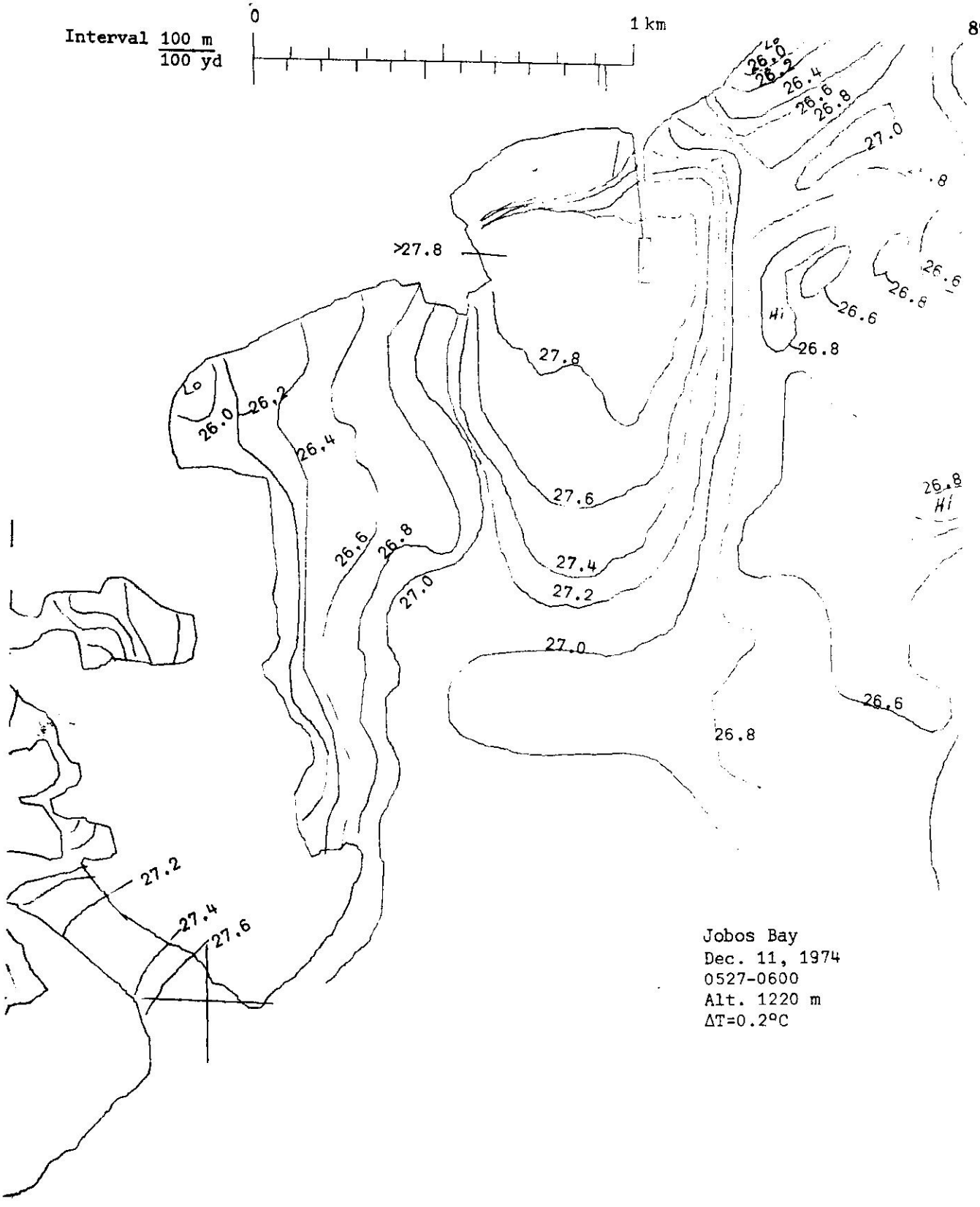
0 1 km

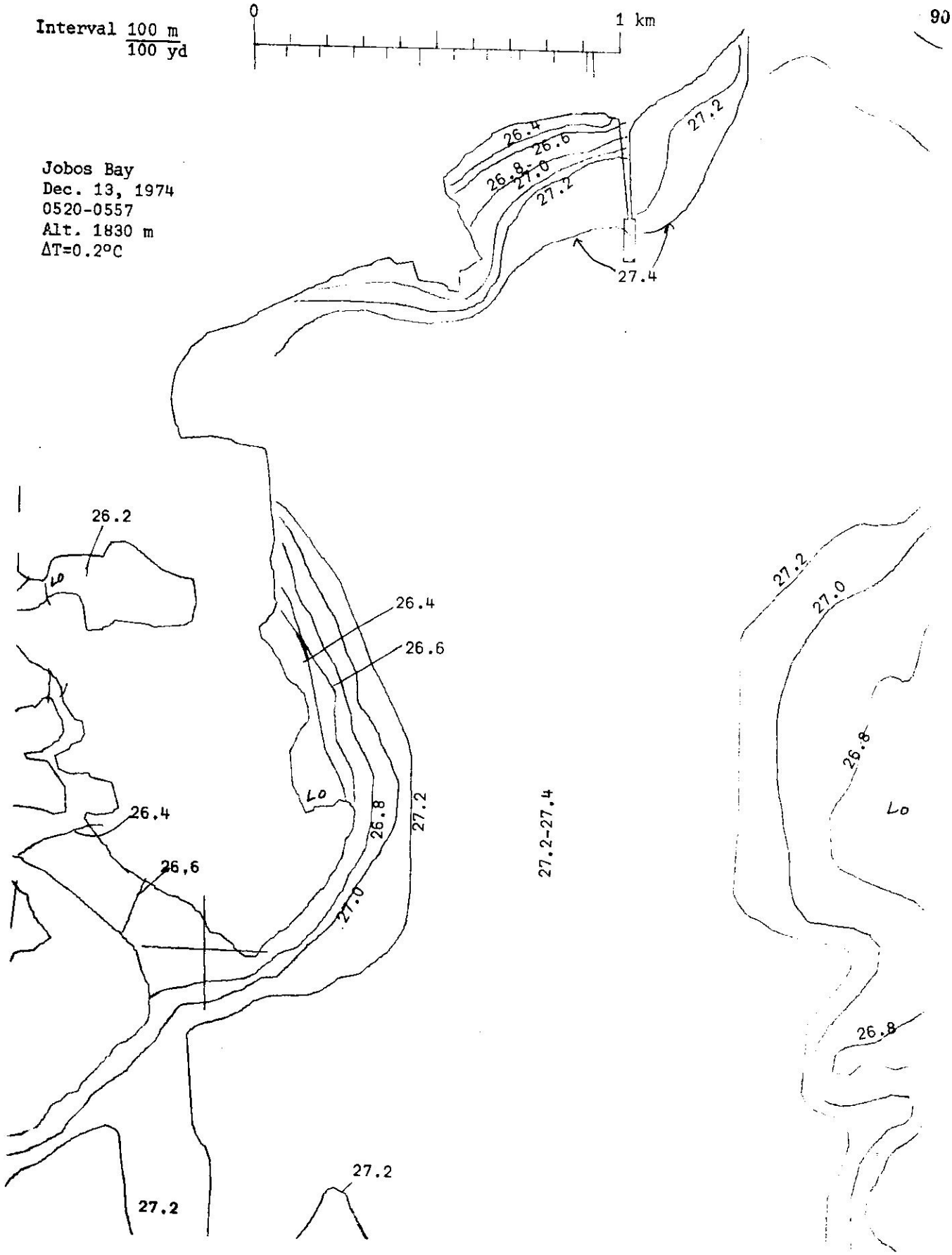
Jobos Bay
Dec. 7, 1974
0513-0533
Alt. 1830 m
ΔT=0.2°C

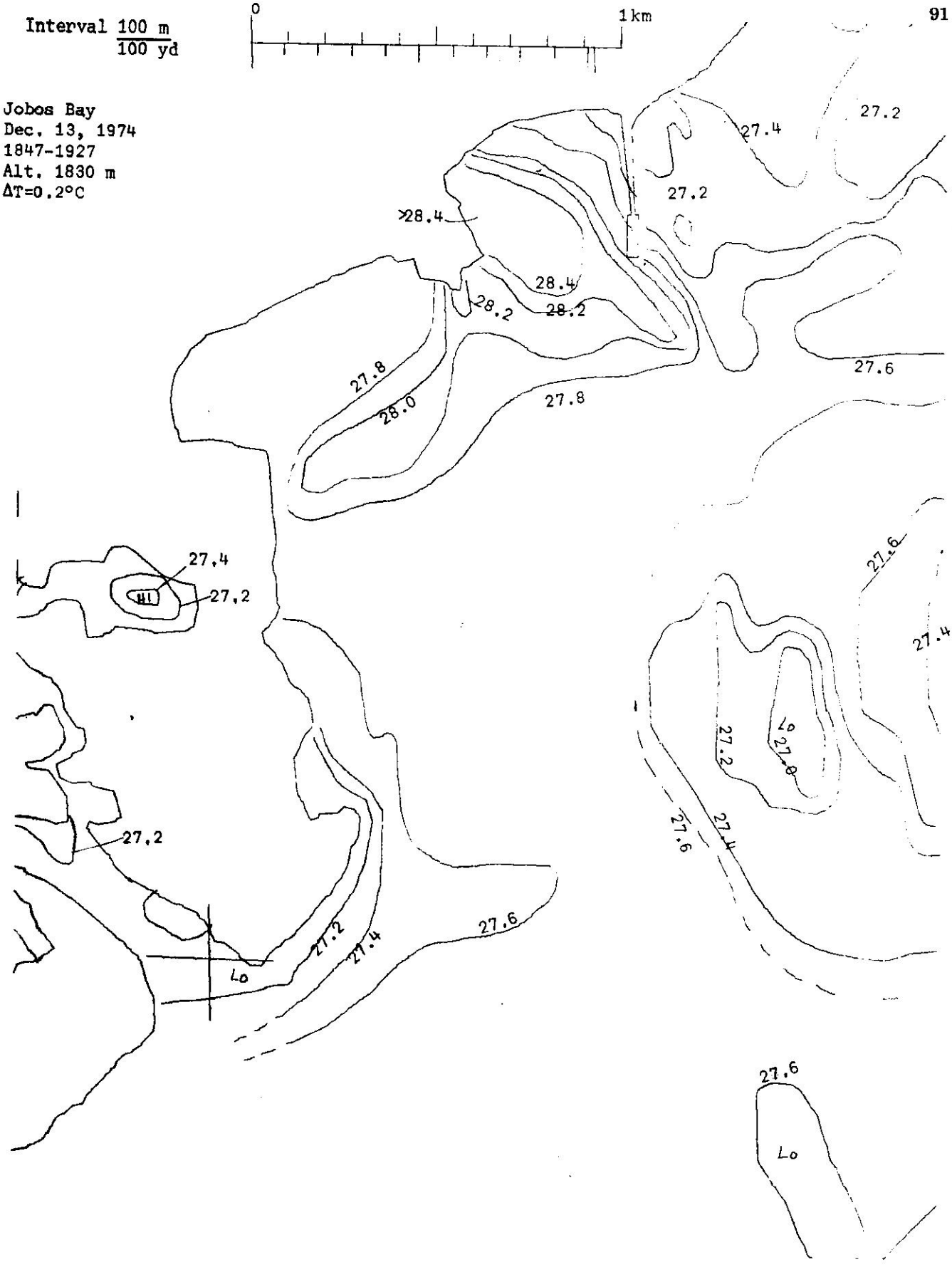


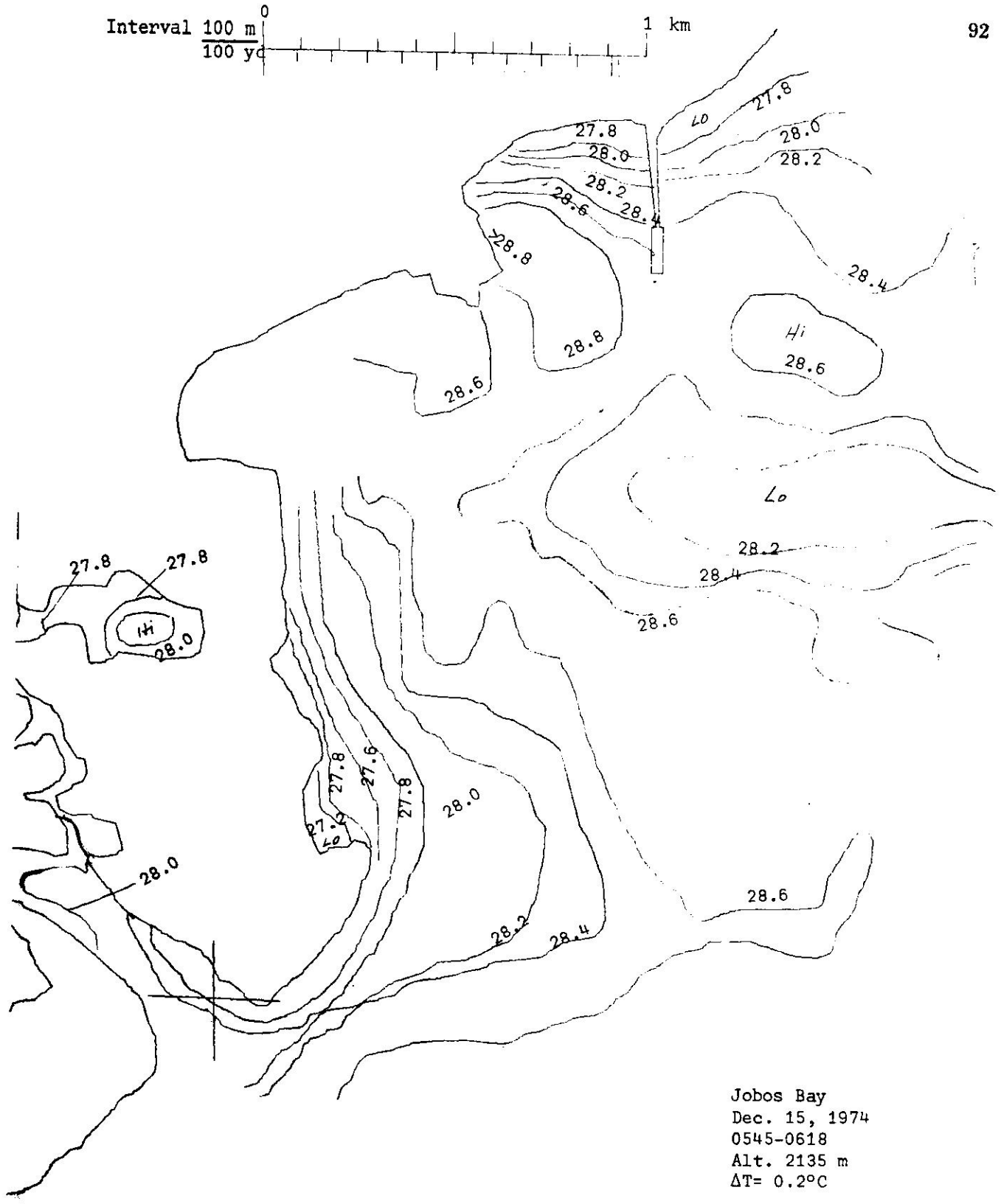

Interval 100 m
100 yd
0
1 km
Jobos Bay
Dec. 9, 1974
0556-0622
Alt. 1830 m
ΔT=0.2°C
28.2
28.4
Hi
28.0
Hi
28.0
27.8
27.6
Lo
28.0
28.2
28.0


0
1 km
Interval 100 m
100 yd
27.6
27.8
28.0
28.2
Lo
27.8
28.0
28.2
28.4
Lo
28.0
28.2
>28.6
28.6
28.4
Lo
27.6
28,2
27.8
28.0
Lo
27.4
27.6
27.8
28.0
27.6-27.8
27,6
Jobos Bay
Dec. 10, 1974
1829-1854
Alt. 1830 m
ΔT=0.2°C

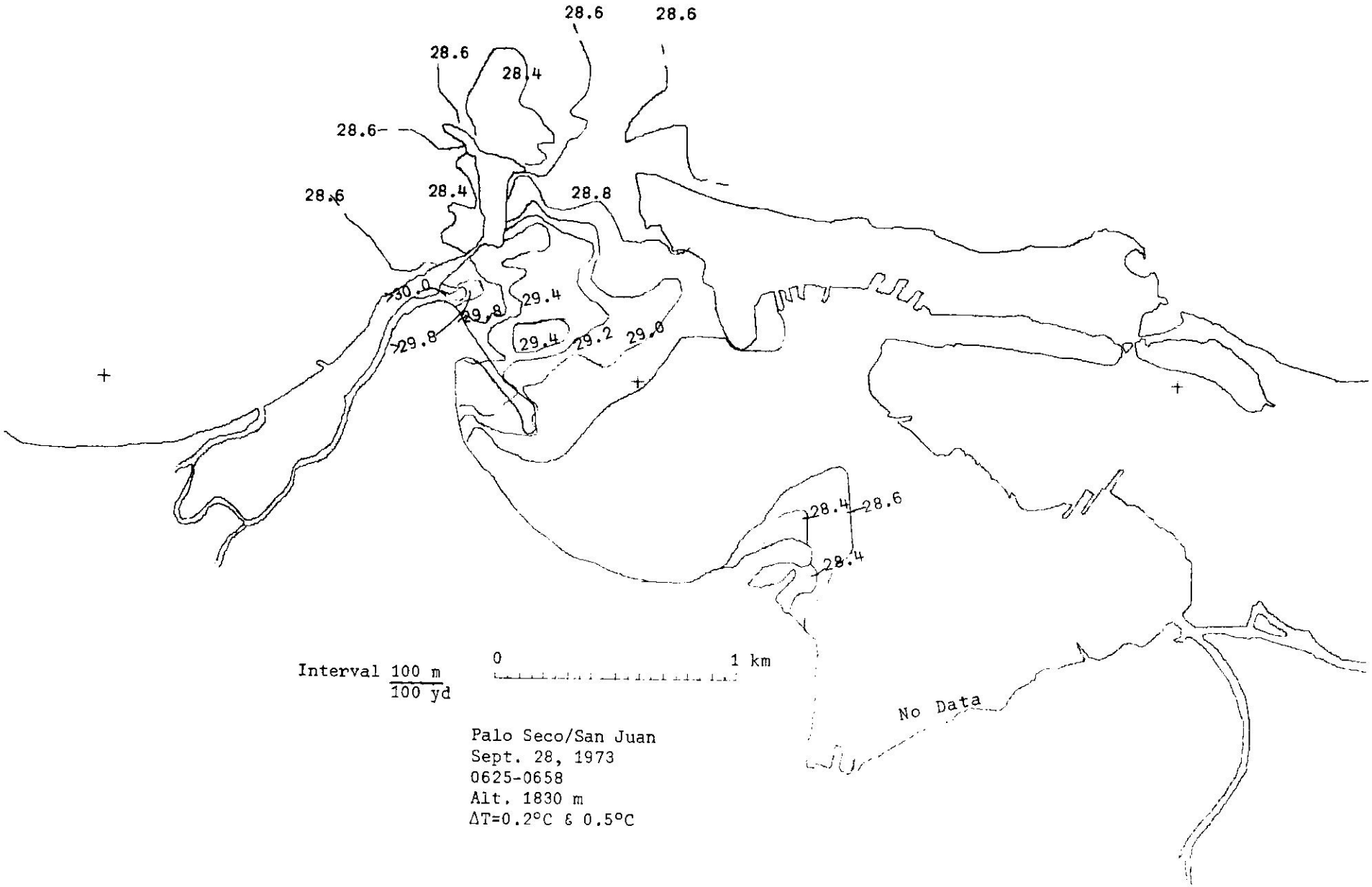

Interval 100 m
100 yd
0
1 km
>27.8
27.8
27.6
27.4
27.2
27.0
26.8
26.6
26.4
26.2
26.0
Lo
Hi
Jobos Bay
Dec. 11, 1974
0527-0600
Alt. 1220 m
ΔT=0.2°C

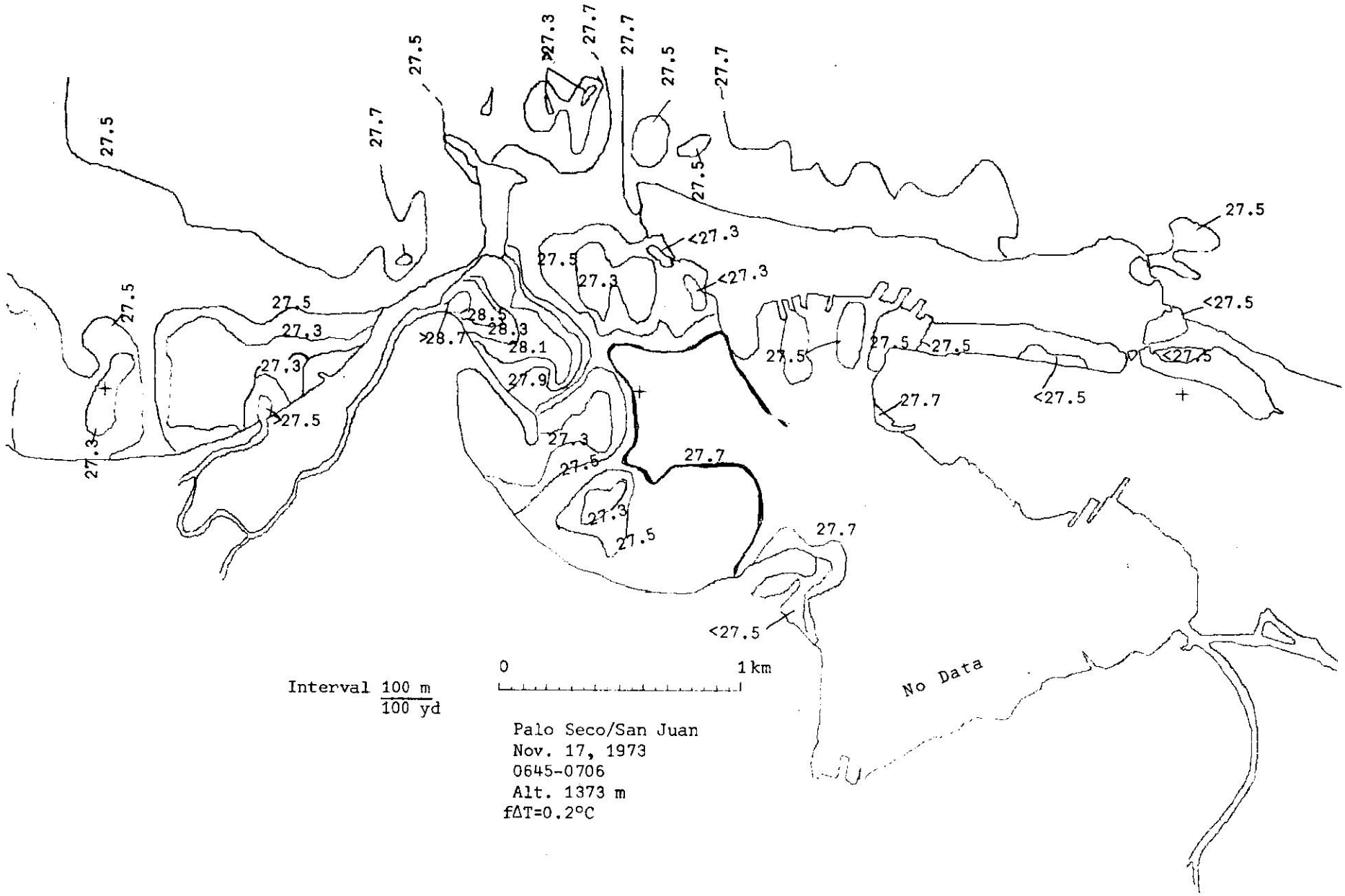

Interval 100 m
100 yd
0
1 km
Jobos Bay
Dec. 13, 1974
0520-0557
Alt. 1830 m
ΔT=0.2°C
26.4
26.6
26.8
27.0
27.2
27.4
26.2
Lo
26.4
26.6
Lo
26.8
27.2
26.4
26.6
27.0
27.2-27.4
27.2
27.0
26.8
Lo
26.8
27.2
27.2

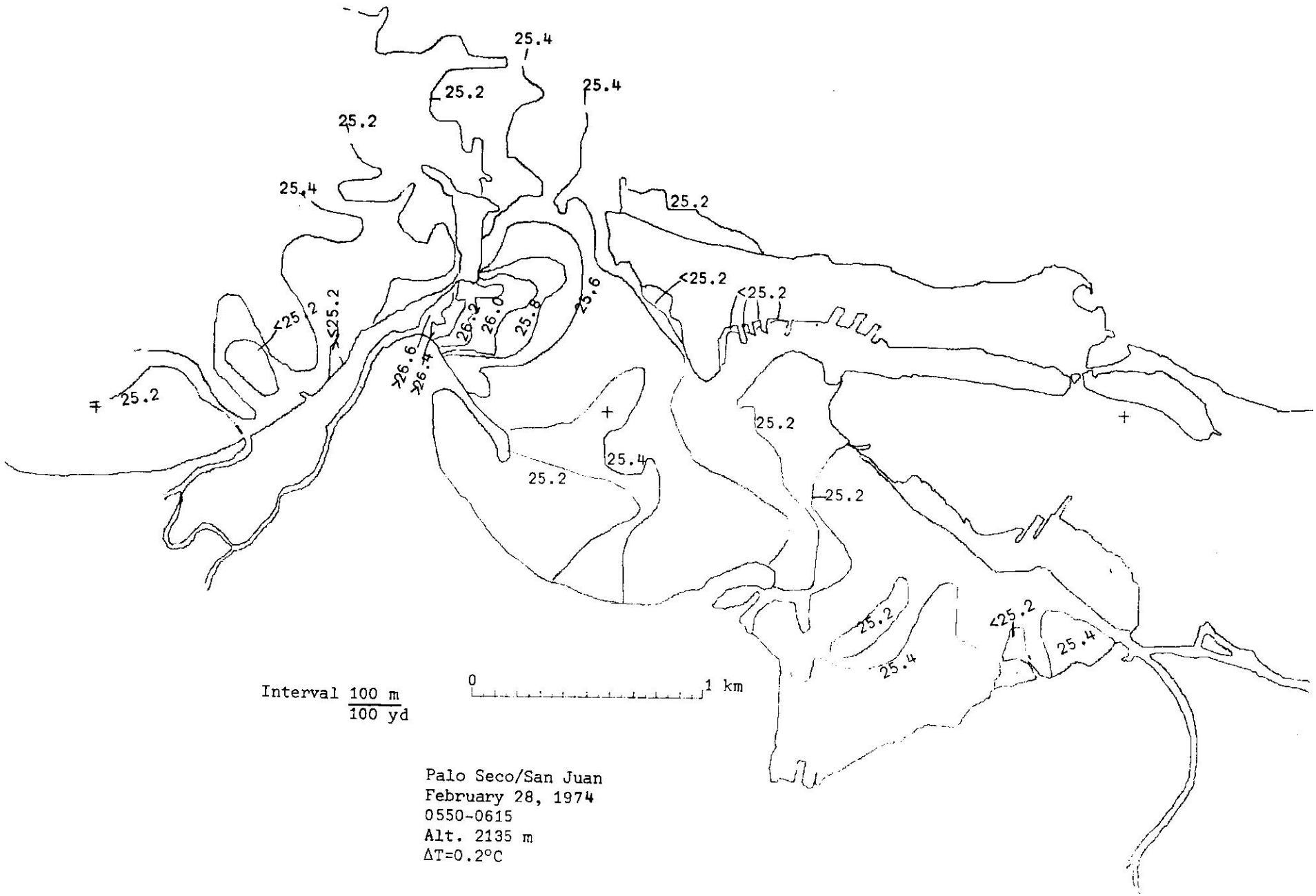

Interval 100 m
100 yd
0
1 km
Jobos Bay
Dec. 13, 1974
1847-1927
Alt. 1830 m
ΔT=0.2°C
>28.4
28.4
28.2
28.2
27.8
28.0
27.8
27.6
27.4
27.2
27.2
27.4
Hi
27.2
27.6
27.4
Lo
27.8
27.2
27.6
27.4
27.2
27.4
27.6
Lo
27.6



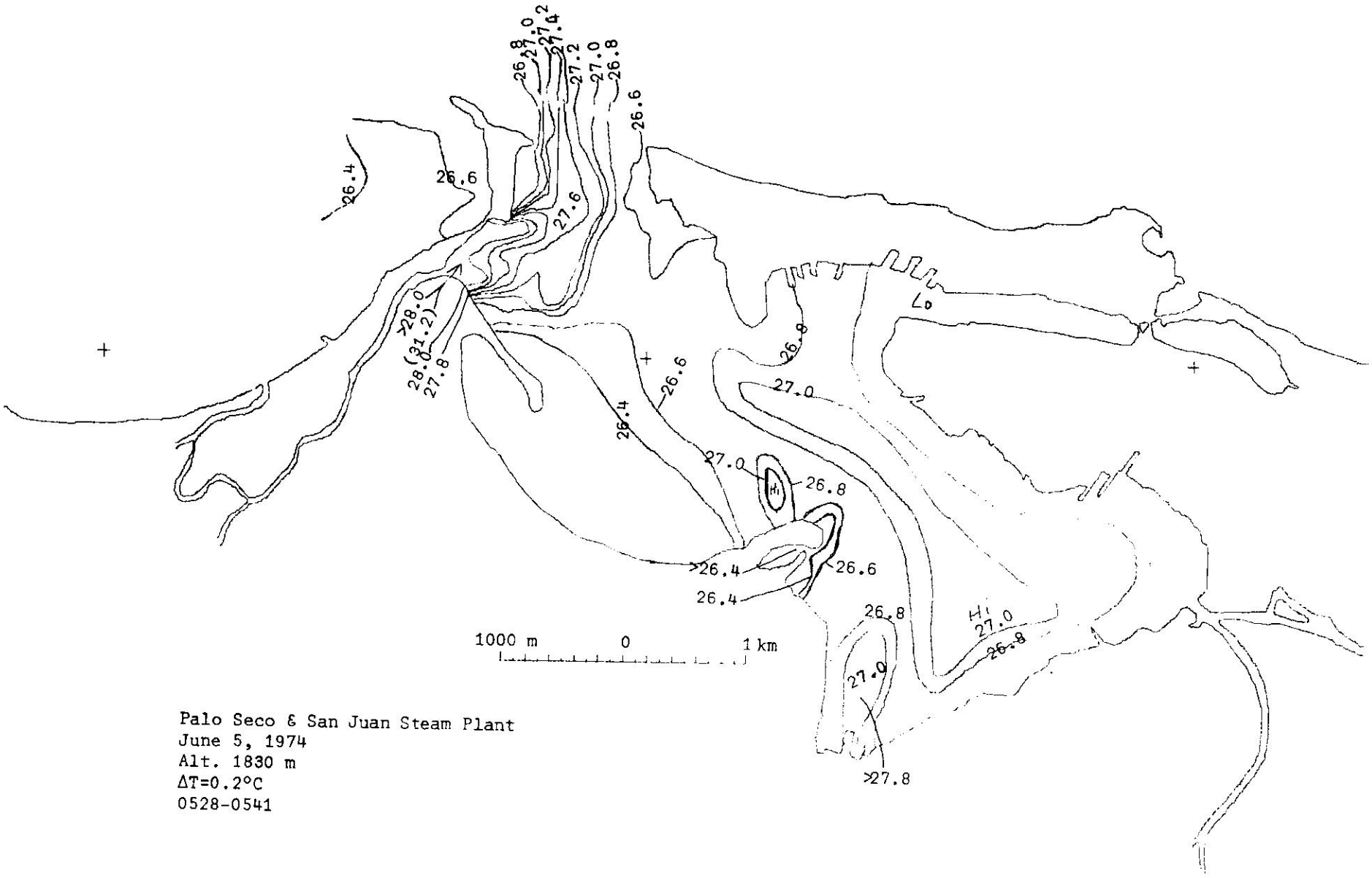
Jobos Bay
Dec. 15, 1974
0545-0618
Alt. 2135 m
ΔT= 0.2°C


28.6
28.6
28.6
28.4
28.6
28.6
28.4
28.8
>30.0
29.8
29.4
29.8
29.4
29.2
29.0
28.4
28.6
28.4
Interval 100 m
100 yd
0
1 km
No Data
Palo Seco/San Juan
Sept. 28, 1973
0625-0658
Alt. 1830 m
ΔT=0.2°C & 0.5°C

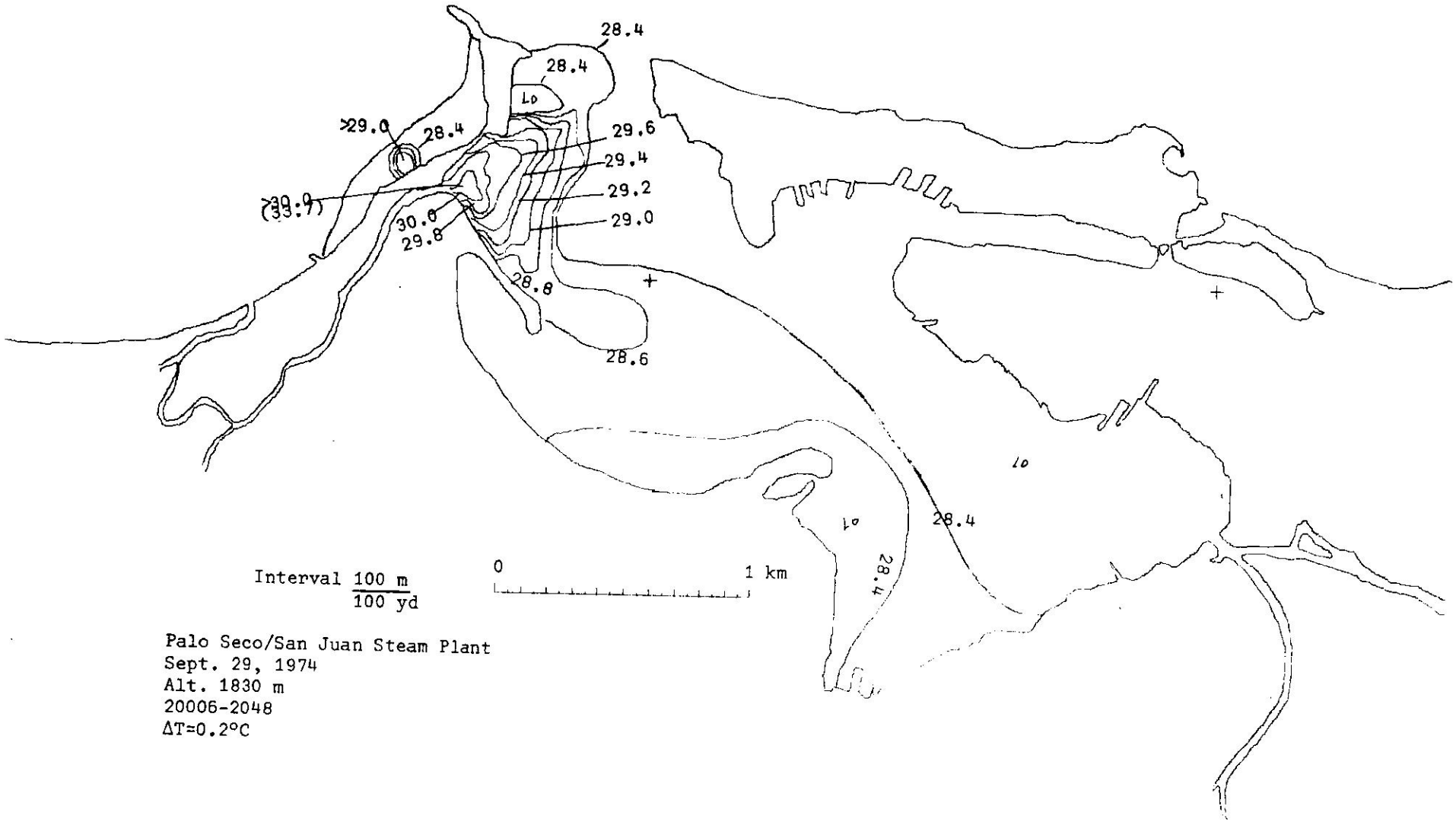

27.5
27.7
27.5
>27.3
27.7
27.7
27.5
27.7
27.5
27.5
<27.3
27.5
27.3
<27.3
27.5
<27.5
27.5
27.3
28.3
28.3
>28.7
28.1
27.3
27.9
>27.5
27.5
27.5
27.5
<27.5
27.3
27.7
<27.5
27.3
27.7
27.5
27.3
27.5
27.7
<27.5
0
1 km
Interval 100 m
100 yd
No Data
Palo Seco/San Juan
Nov. 17, 1973
0645-0706
Alt. 1373 m
fΔT=0.2°C

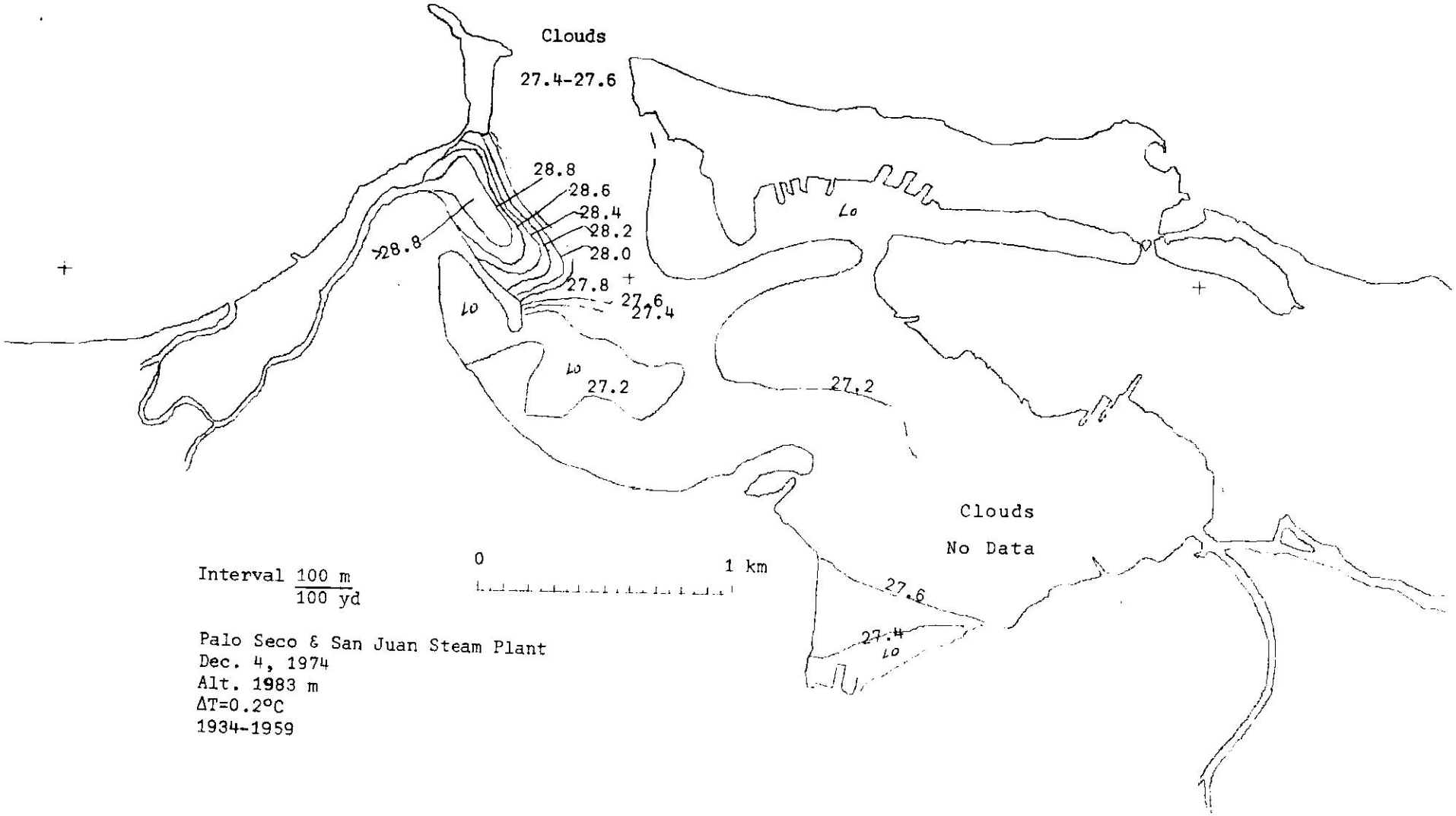


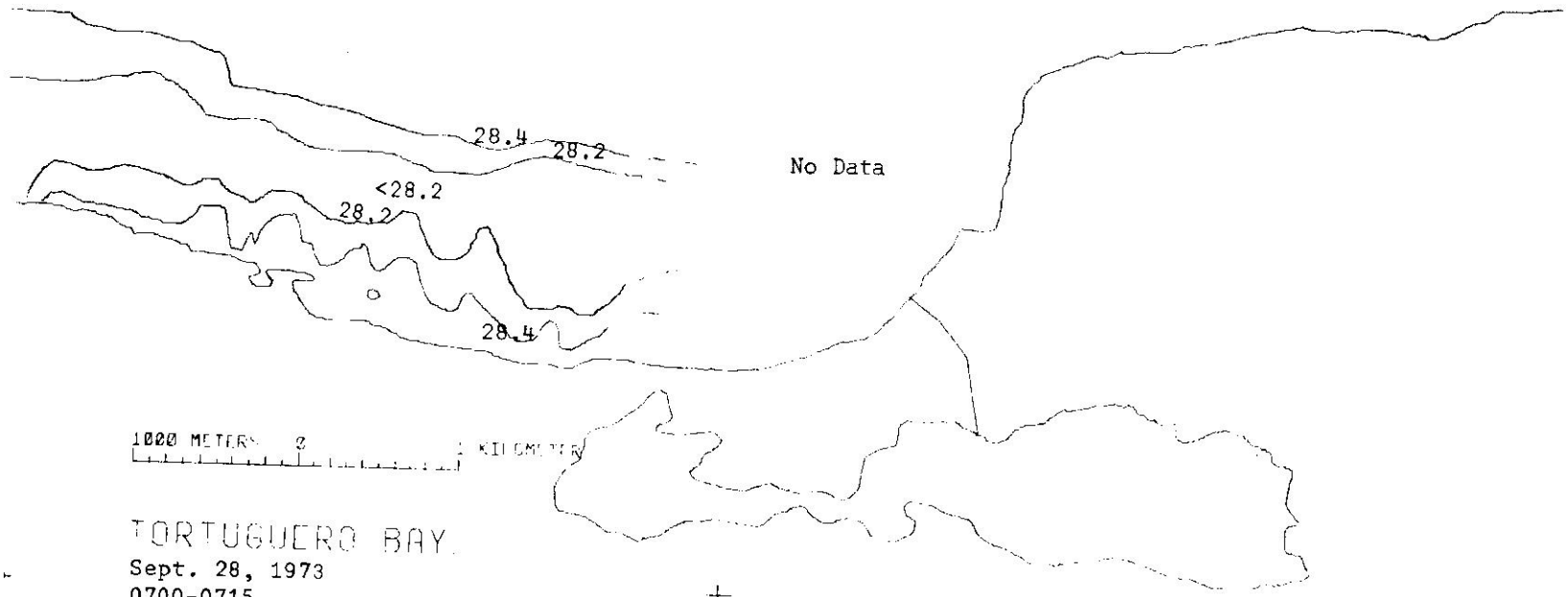
Palo Seco/San Juan
February 28, 1974
0550-0615
Alt. 2135 m
ΔT=0.2°C



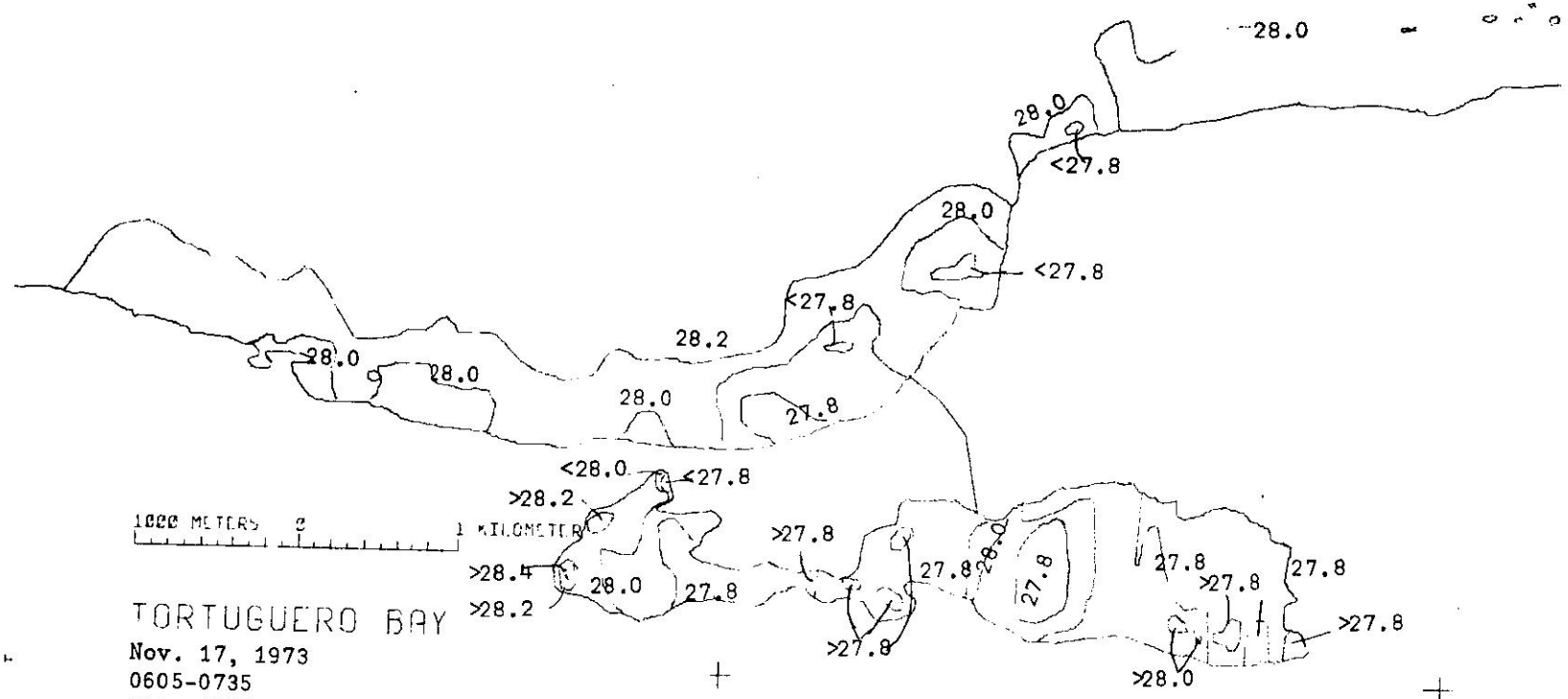
Palo Seco & San Juan Steam Plant
June 5, 1974
Alt. 1830 m
ΔT=0.2°C
0528-0541


28.4
28.4
>29.0
28.4
29.6
29.4
29.2
29.0
(33.7)
30.0
29.8
28.8
28.6
28.4
28.4
Interval 100 m
100 yd
0
1 km
Palo Seco/San Juan Steam Plant
Sept. 29, 1974
Alt. 1830 m
20006-2048
ΔT=0.2°C

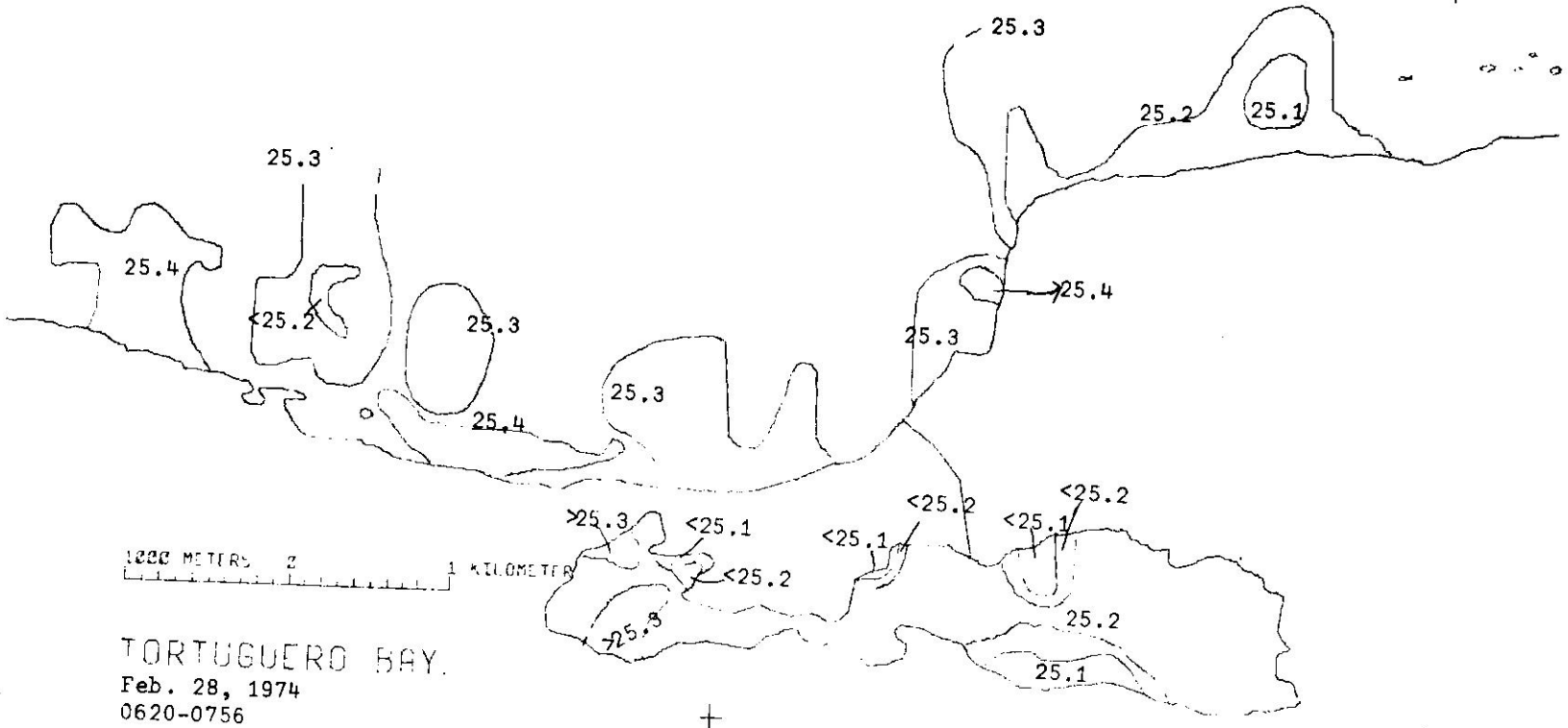

Clouds
27.4-27.6
28.8
28.6
28.4
28.2
28.0
27.8
27.6
27.4
28.8
Lo
Lo
27.2
27.2
Clouds
No Data
27.6
27.4
Lo
0
1 km
Interval 100 m / 100 yd
Palo Seco & San Juan Steam Plant
Dec. 4, 1974
Alt. 1983 m
ΔT=0.2°C
1934-1959



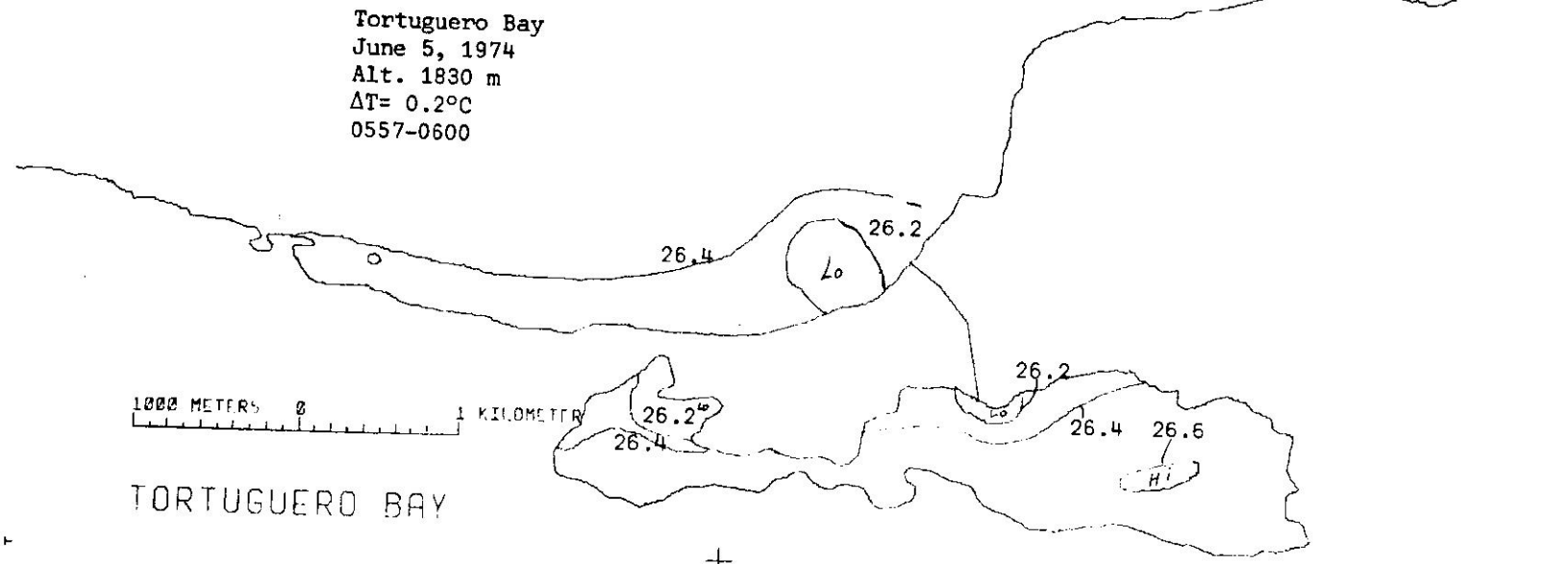
TORTUGUERO BAY
Sept. 28, 1973
0700-0715
Alt. 1830 m
ΔT=0.2°C

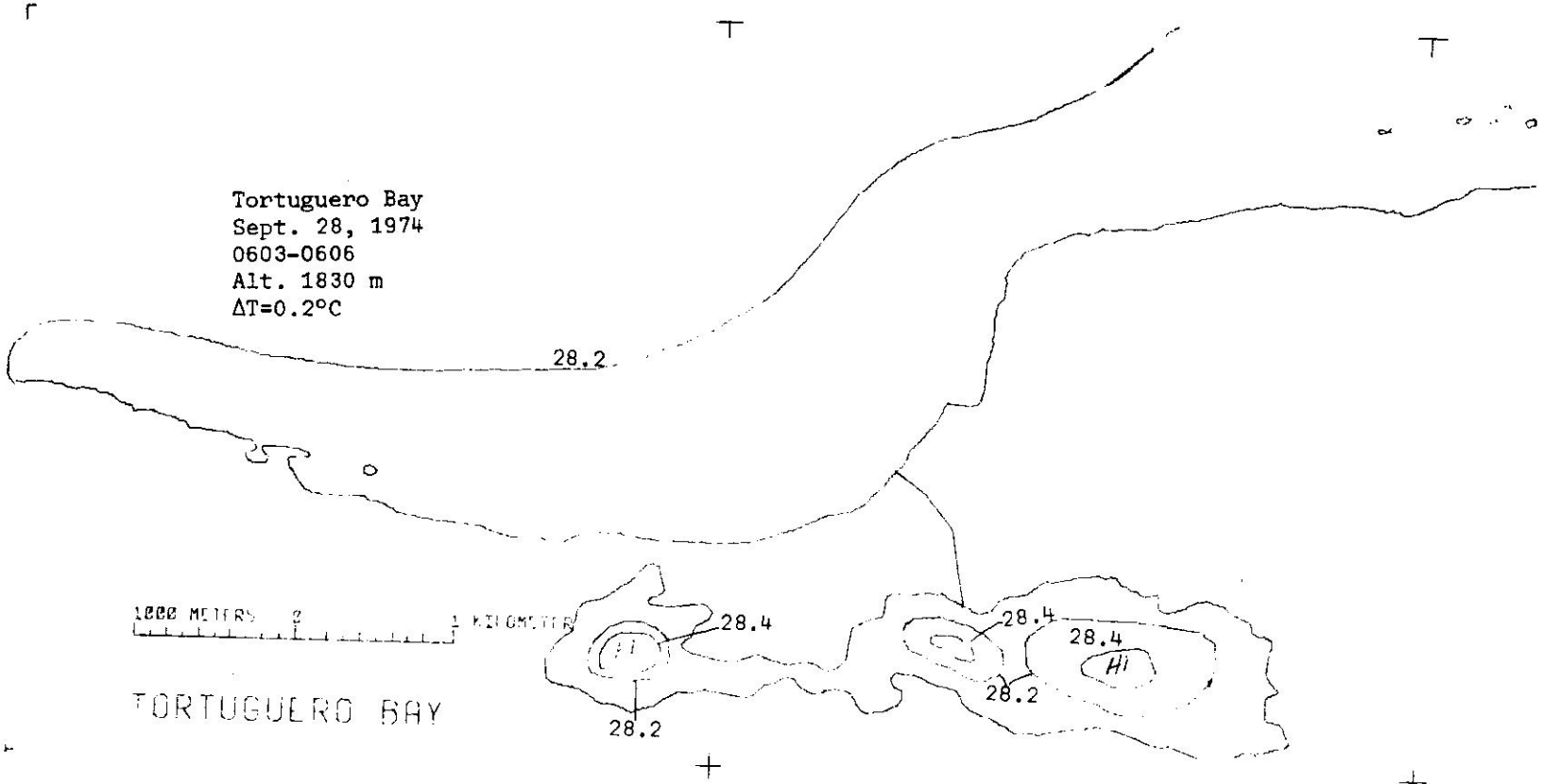


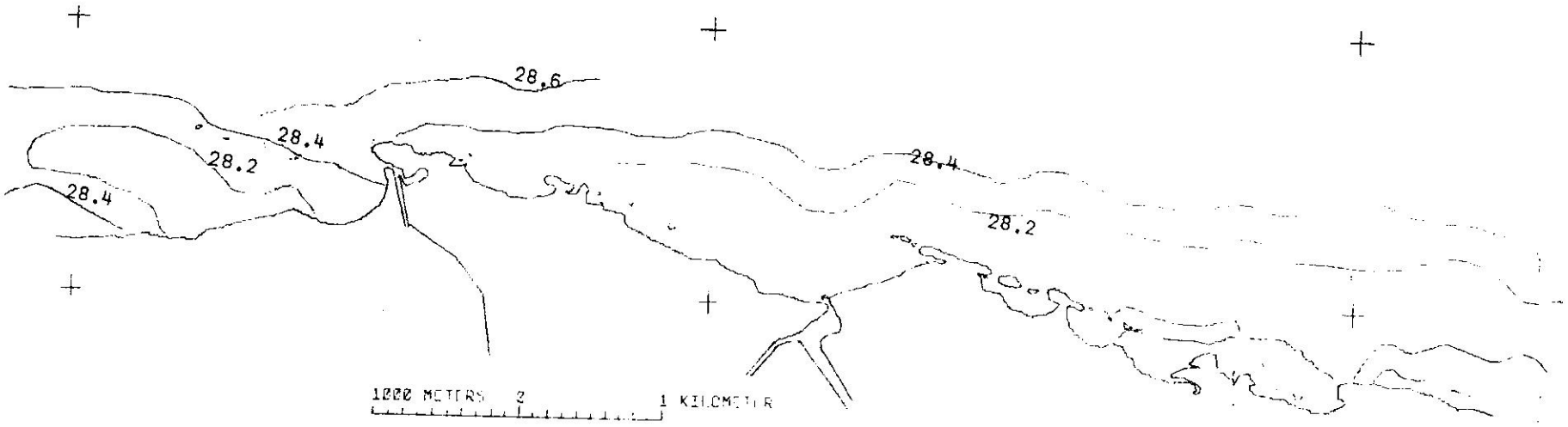
TORTUGUERO BAY
Nov. 17, 1973
0605-0735
Alt. 1373 m
ΔT=0.2°C



TORTUGUERO BAY.
Feb. 28, 1974
0620-0756
Alt. 2135 m
ΔT=0.1°C


Tortuguero Bay
June 5, 1974
Alt. 1830 m
ΔT= 0.2°C
0557-0600
26.4
26.2
Lo
26.2
1000 METERS 0 1 KILOMETER
26.2
26.4
26.4
26.6
Lo
Hi
TORTUGUERO BAY

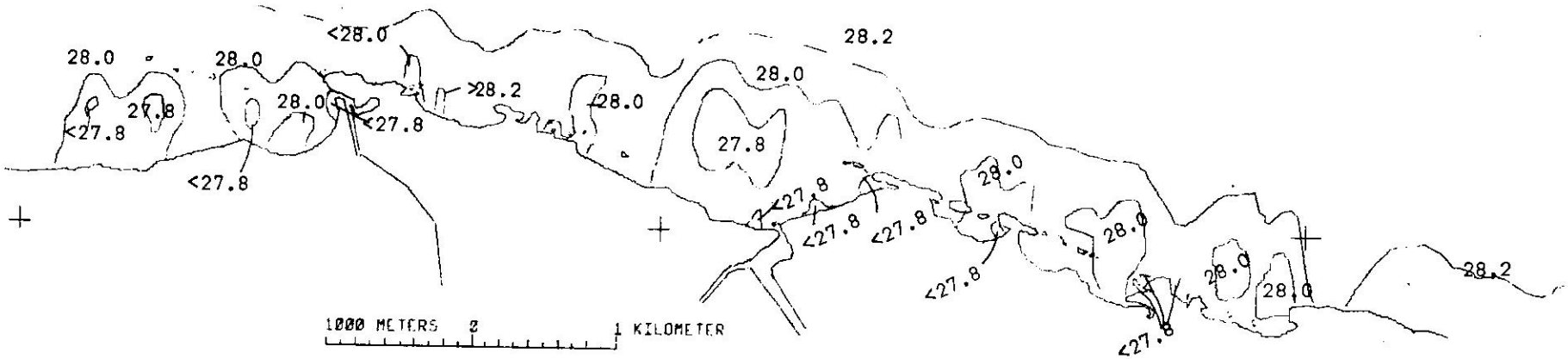

Tortuguero Bay
Sept. 28, 1974
0603-0606
Alt. 1830 m
ΔT=0.2°C
28.2
1000 METERS
1 KILOMETER
28.4
28.4
28.4
28.2
28.2
TORTUGUERO BAY



PT. MANATI

Sept. 28, 1973
0700-0715

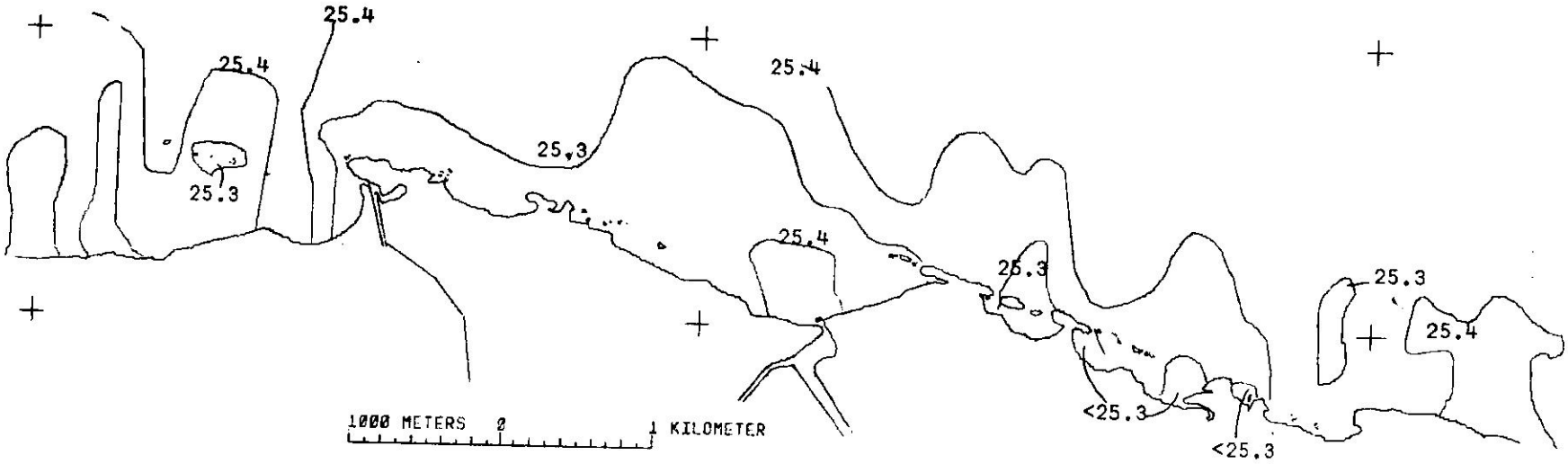
Alt. 1830 m
ΔT= 0.2°C



PT. MANATI

Nov. 17, 1973
0605-0735

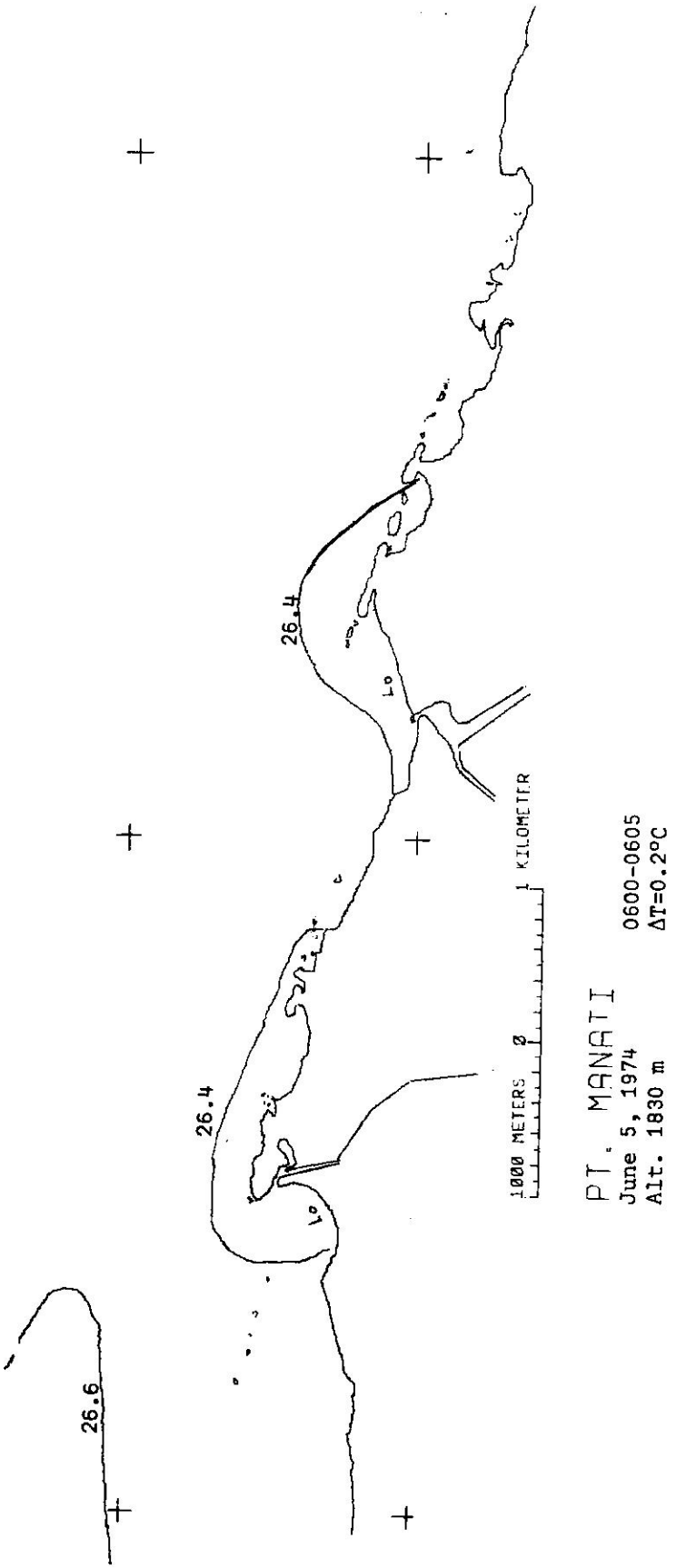
Alt. 1373 m
ΔT= 0.2°C

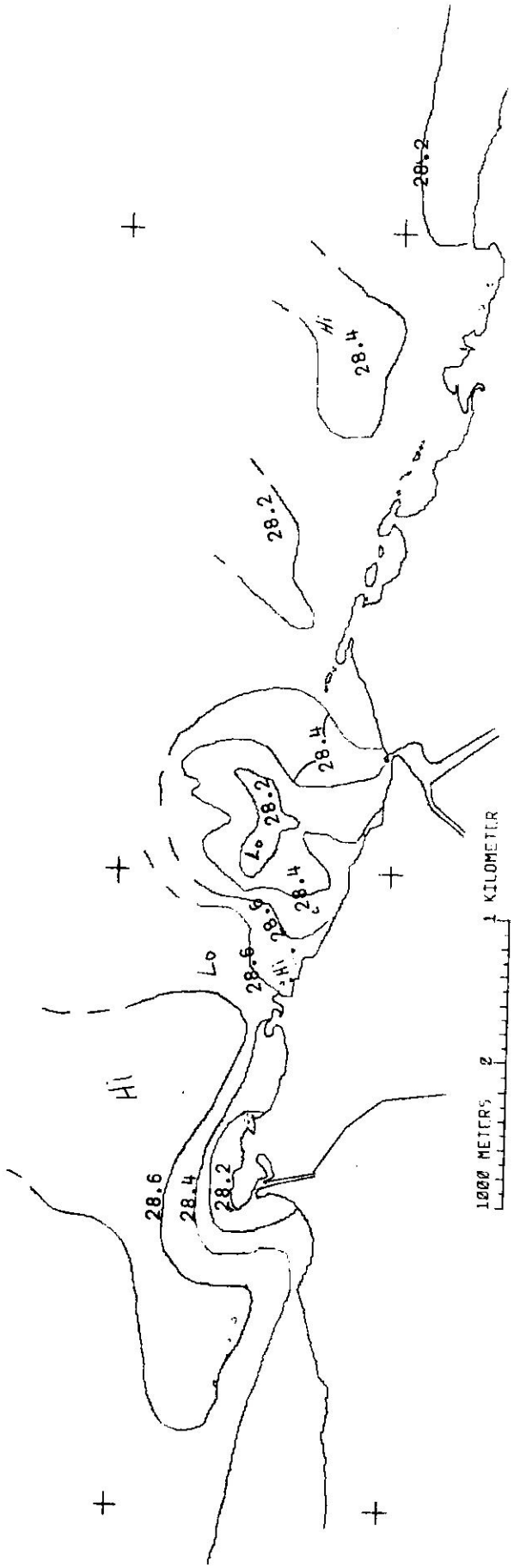


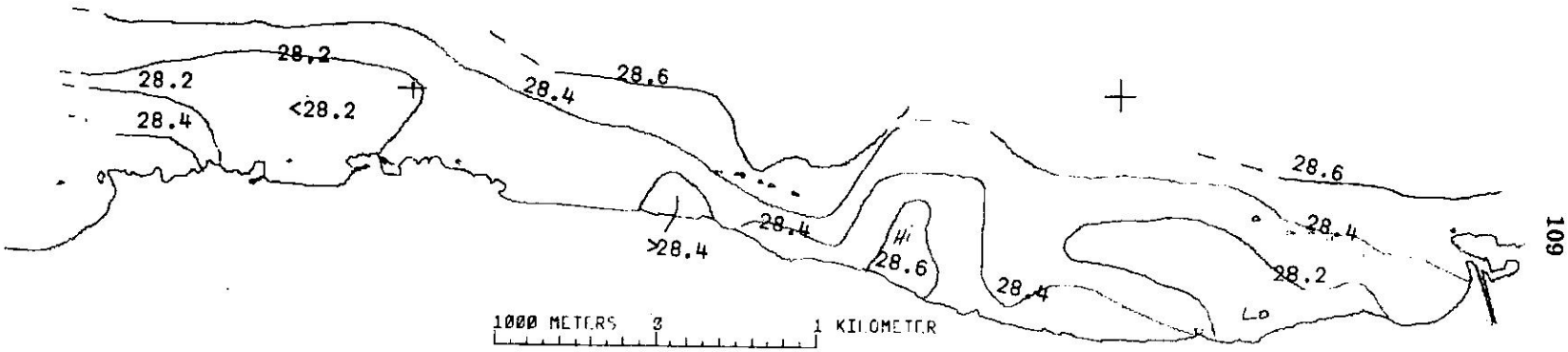
PT. MANATI

Feb. 28, 1974
0620-0756

Alt. 2135 m
ΔT= 0.1°C

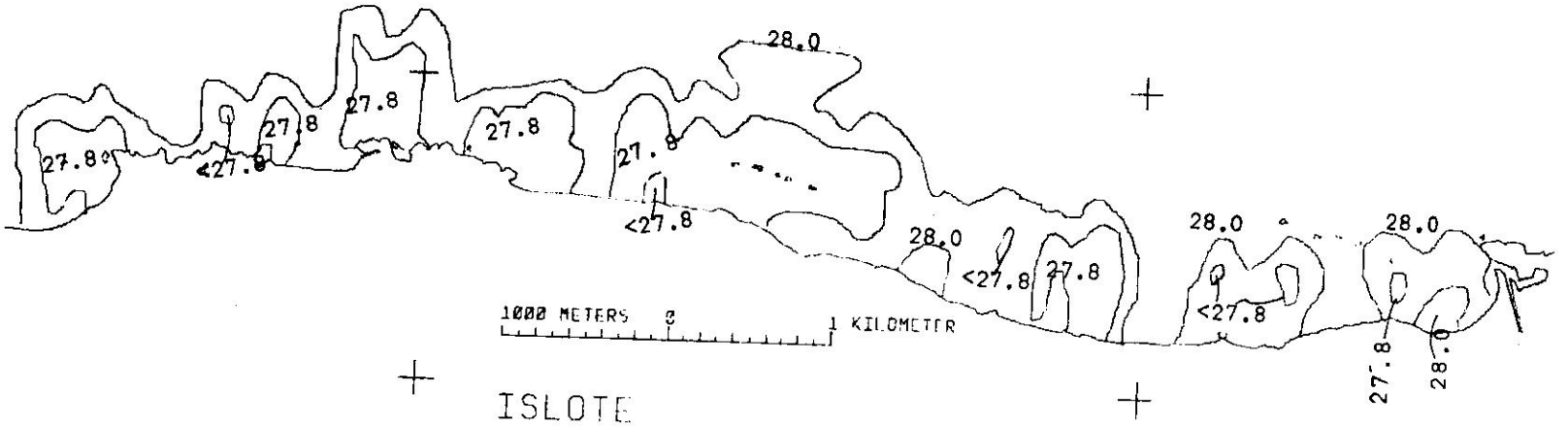

26.4
26.4
26.6
1000 METERS 0 1 KILOMETER
PT. MANATI
June 5, 1974
Alt. 1830 m
0600-0605
ΔT=0.2°C


28.2
Hi
28.4
28.2
28.4
28.4
Lo
28.2
28.6
28.6
Hi
Hi
28.6
28.4
28.2
1000 METERS 2
1 KILOMETER
PT. MANATI
Sept. 28, 1974
0605-0610
Alt. 1830 m
ΔT=0.2°C



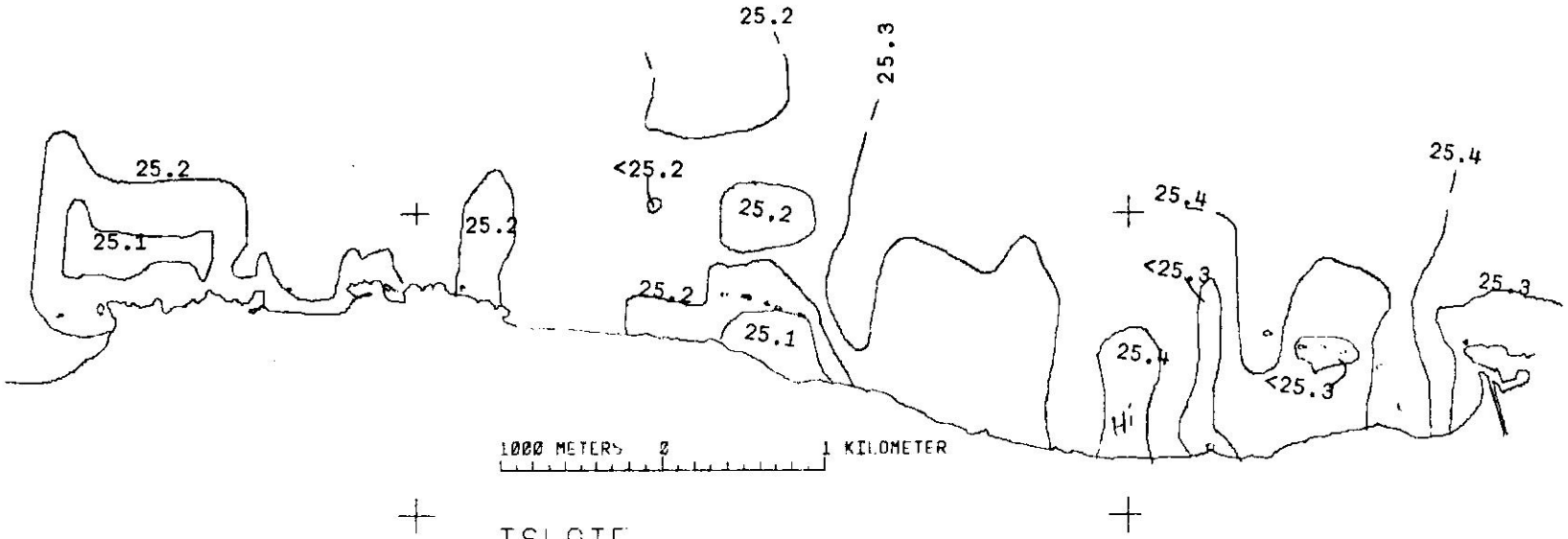
ISLOTE

Sept. 28, 1973
0700-0715
Alt. 1830 m
ΔT=0.2°C



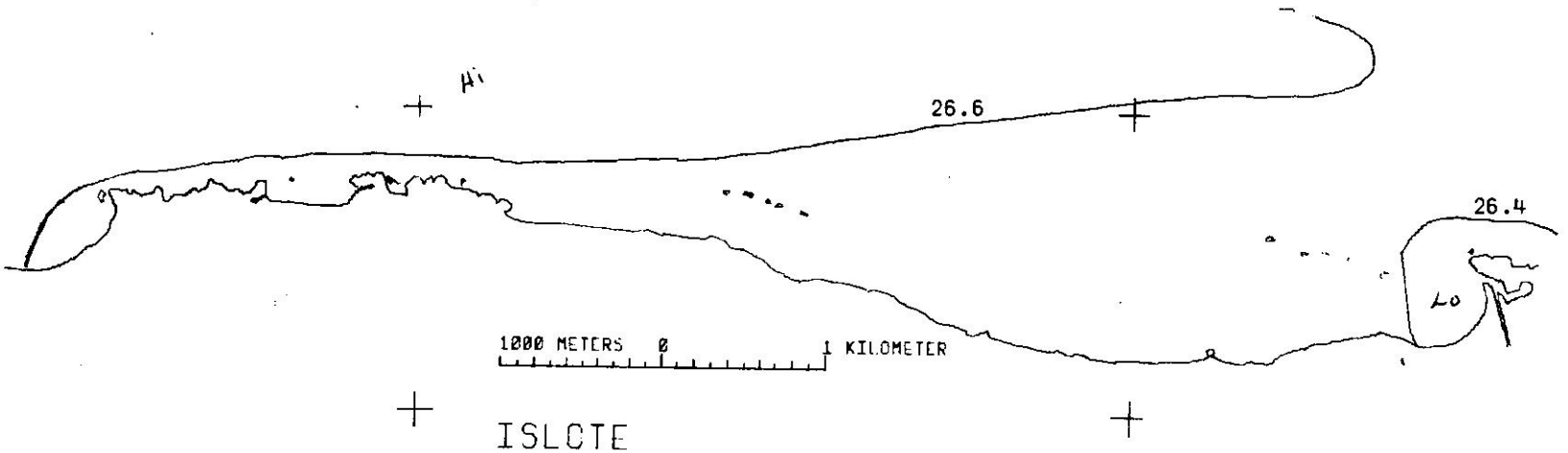
ISLOTE

Nov. 17, 1973
0605-0735
Alt. 1373 m
ΔT=0.2°C

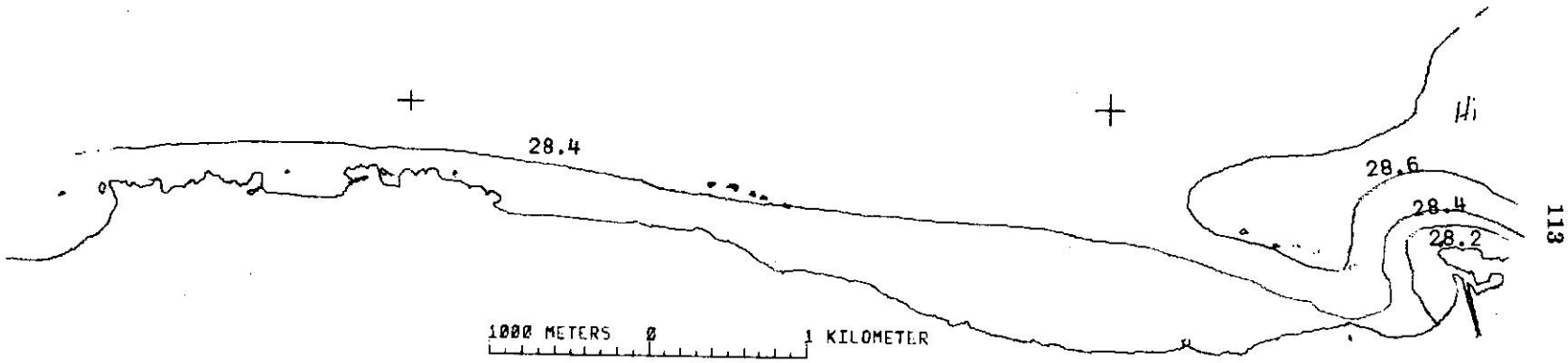


ISLOTE

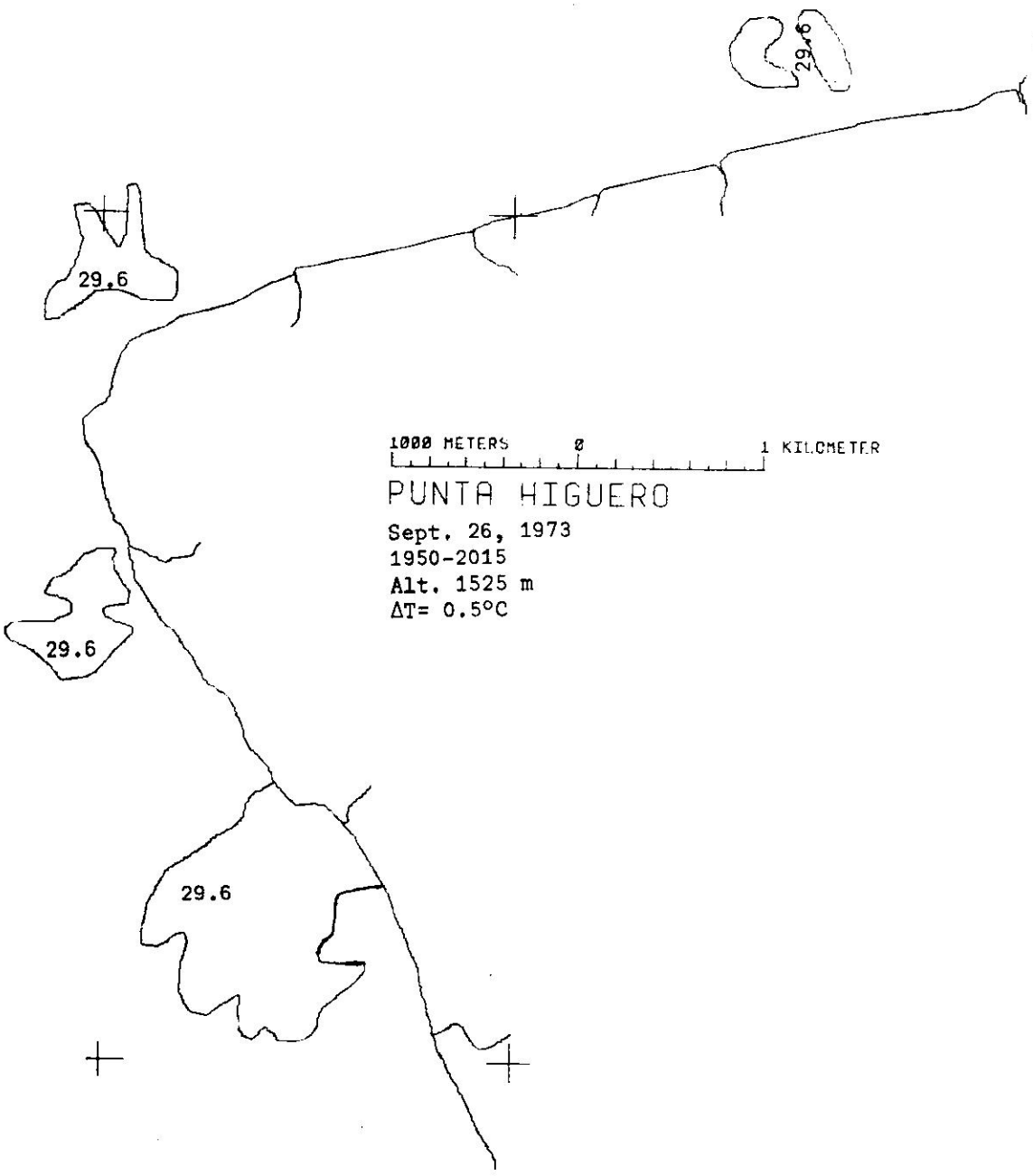
Feb. 28, 1974
0620-0756
Alt. 2135 m
ΔT=0.1°C

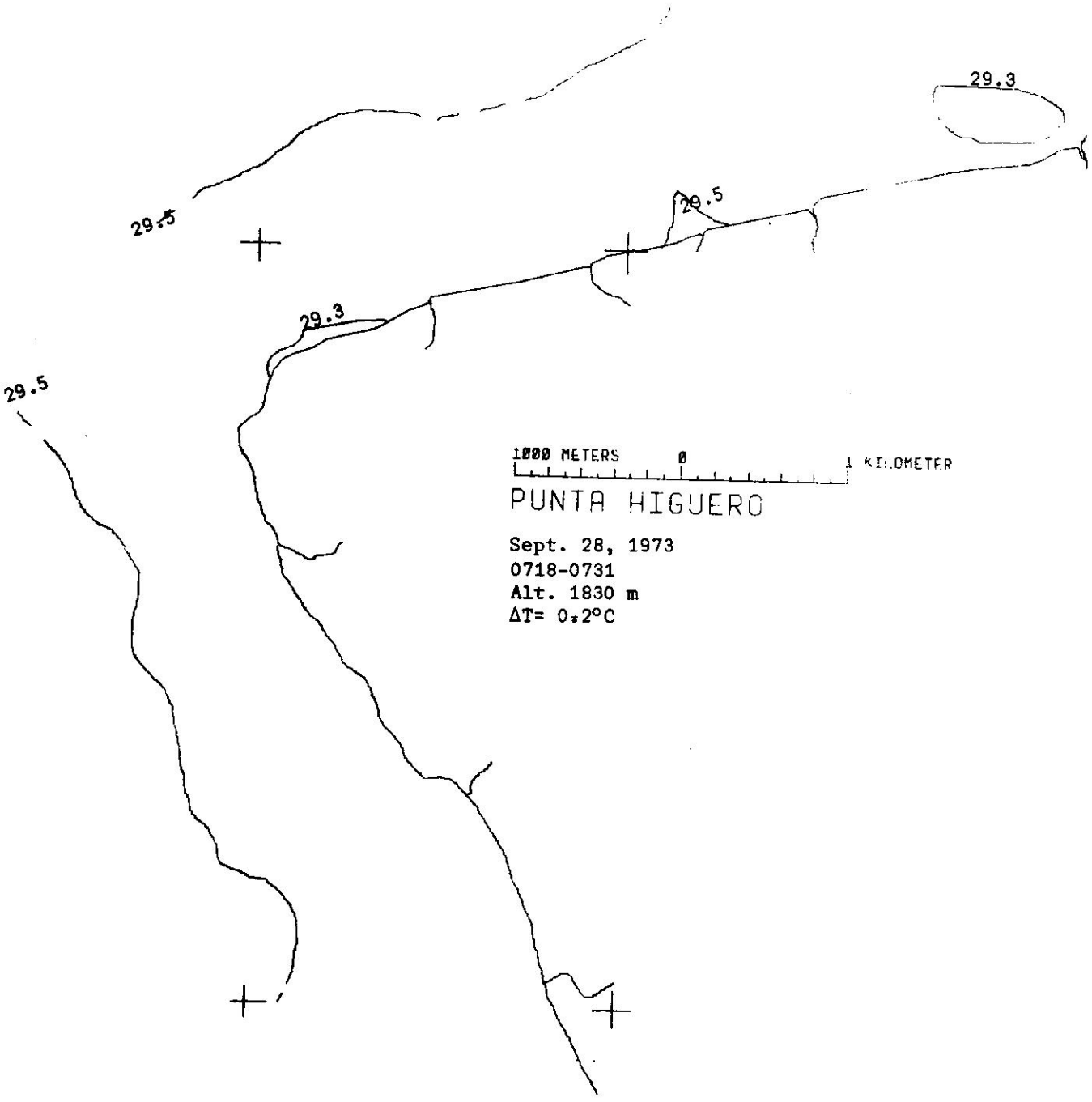


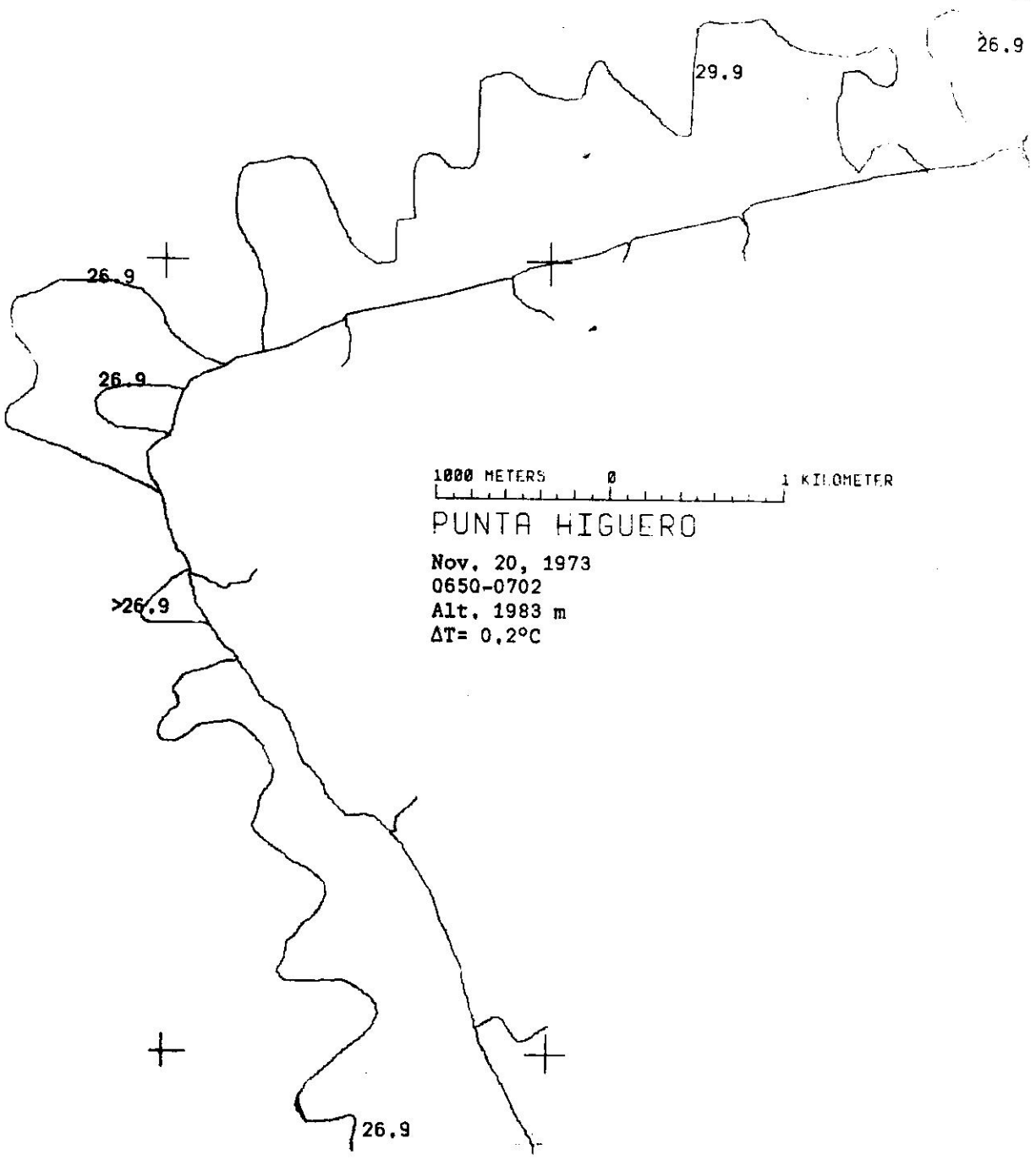
ISLOTE
June 5, 1974
Alt. 1830 m
ΔT= 0.2°C
0604-0628

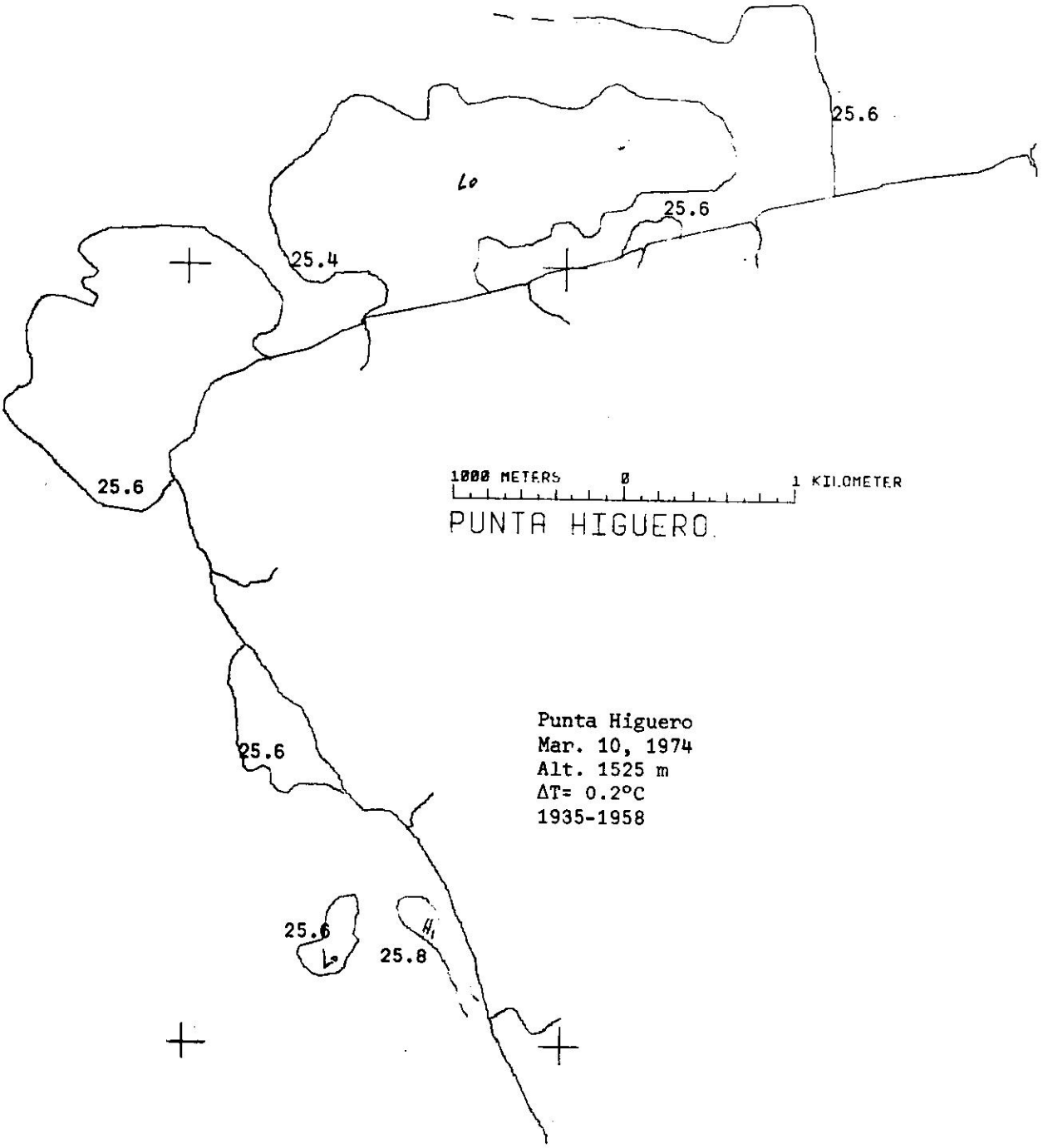


ISLOTE.
Sept. 28, 1974
0609-0633
Alt. 1830 m
ΔT=0.2°C

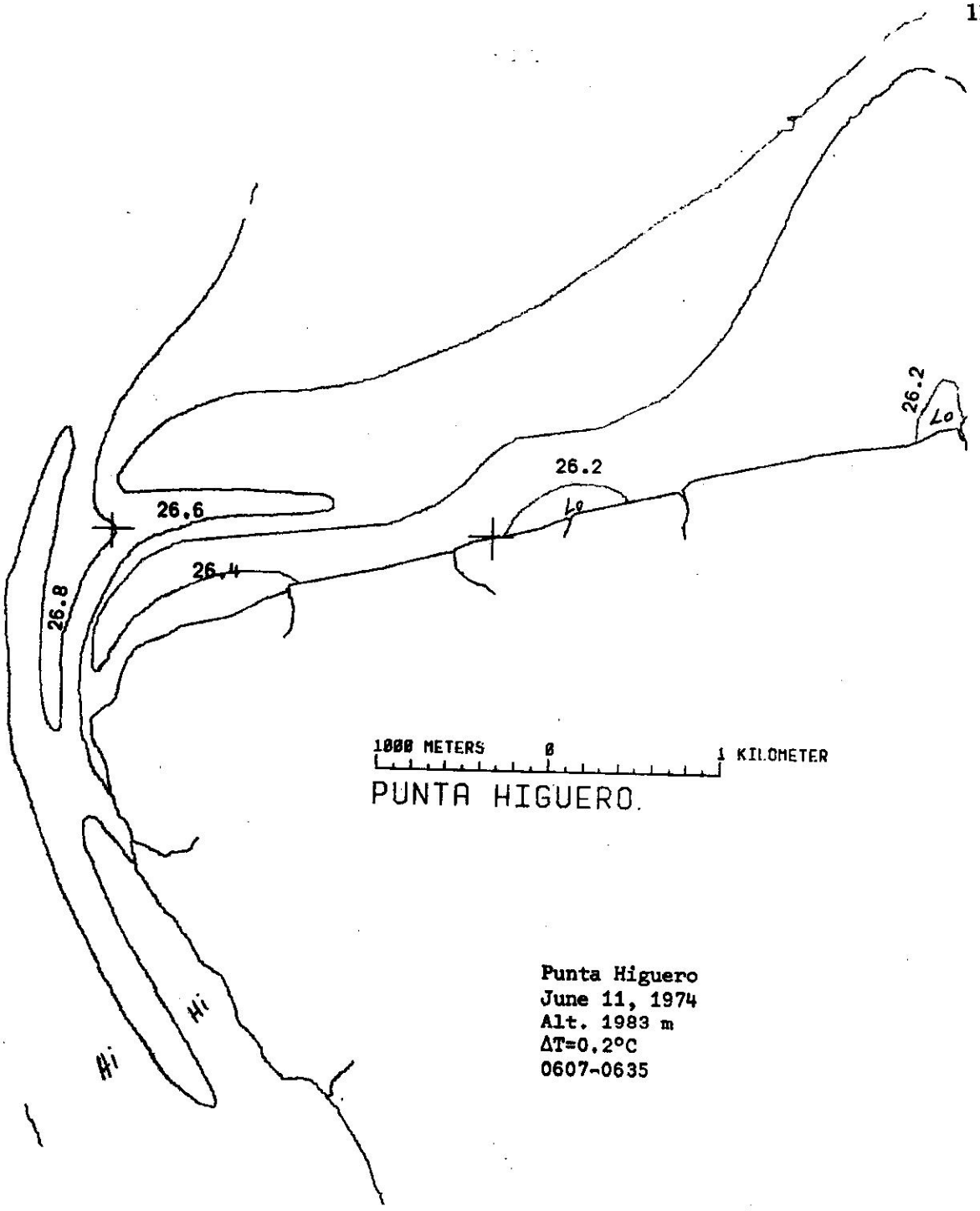

29.6
29.6
29.6
29.6
1000 METERS 0 1 KILOMETER
PUNTA HIGUERO
Sept. 26, 1973
1950-2015
Alt. 1525 m
ΔT= 0.5°C


29.3
29.5
29.5
29.3
29.5
1000 METERS
0
1 KILOMETER
PUNTA HIGUERO
Sept. 28, 1973
0718-0731
Alt. 1830 m
ΔT= 0,2°C

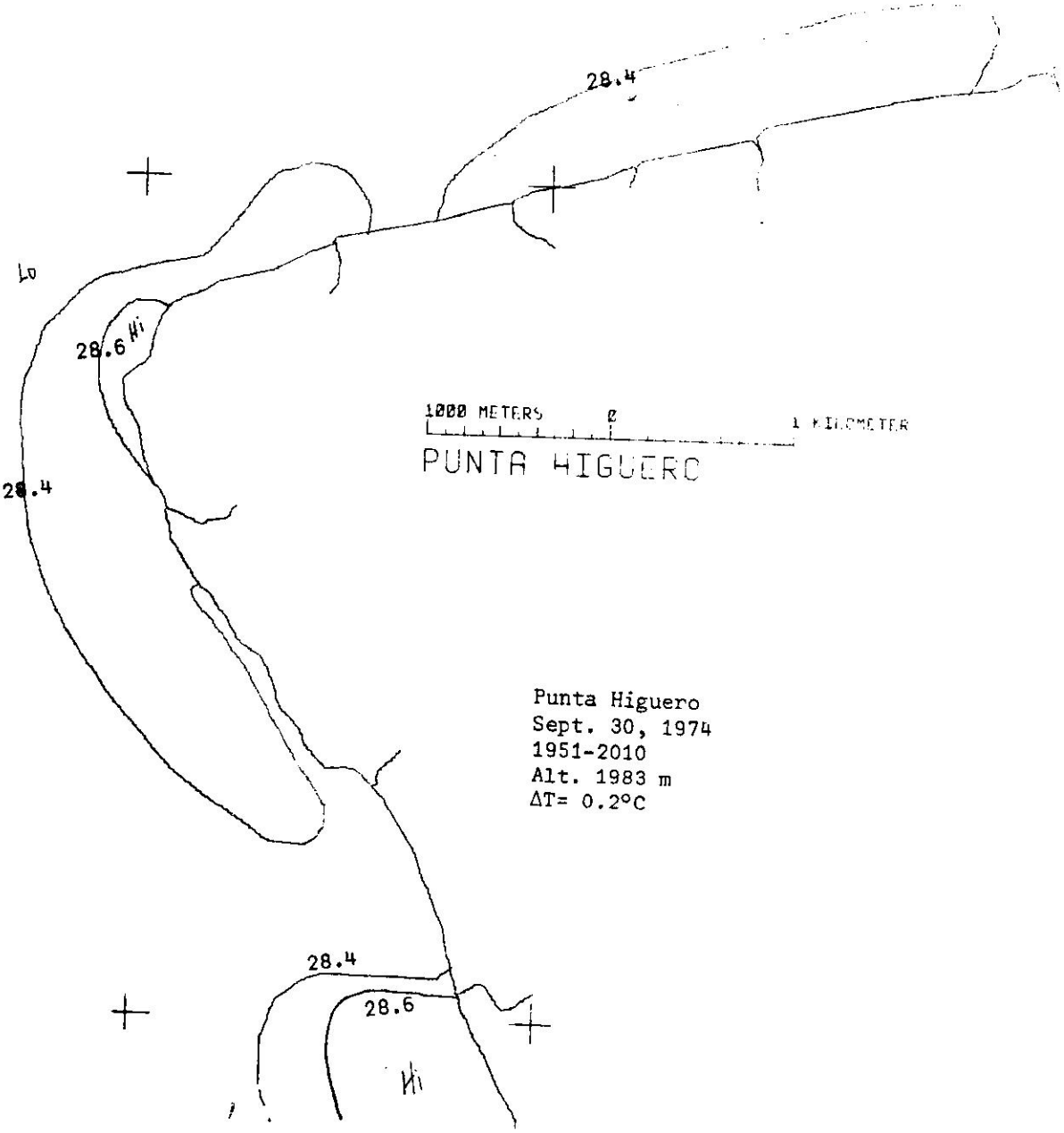

26.9
29.9
26.9
26.9
1000 METERS
0
1 KILOMETER
PUNTA HIGUERO
Nov. 20, 1973
0650-0702
Alt. 1983 m
ΔT= 0.2°C
>26.9
26.9



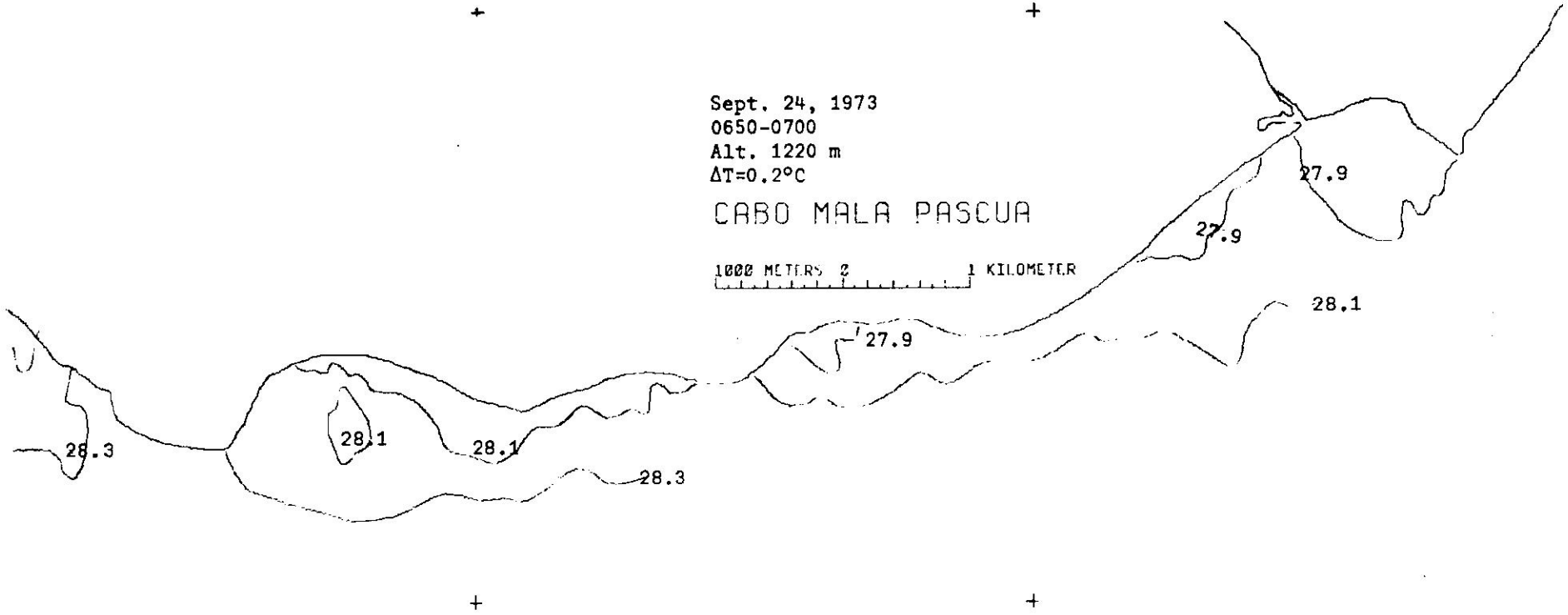
Punta Higuero
Mar. 10, 1974
Alt. 1525 m
ΔT= 0.2°C
1935-1958



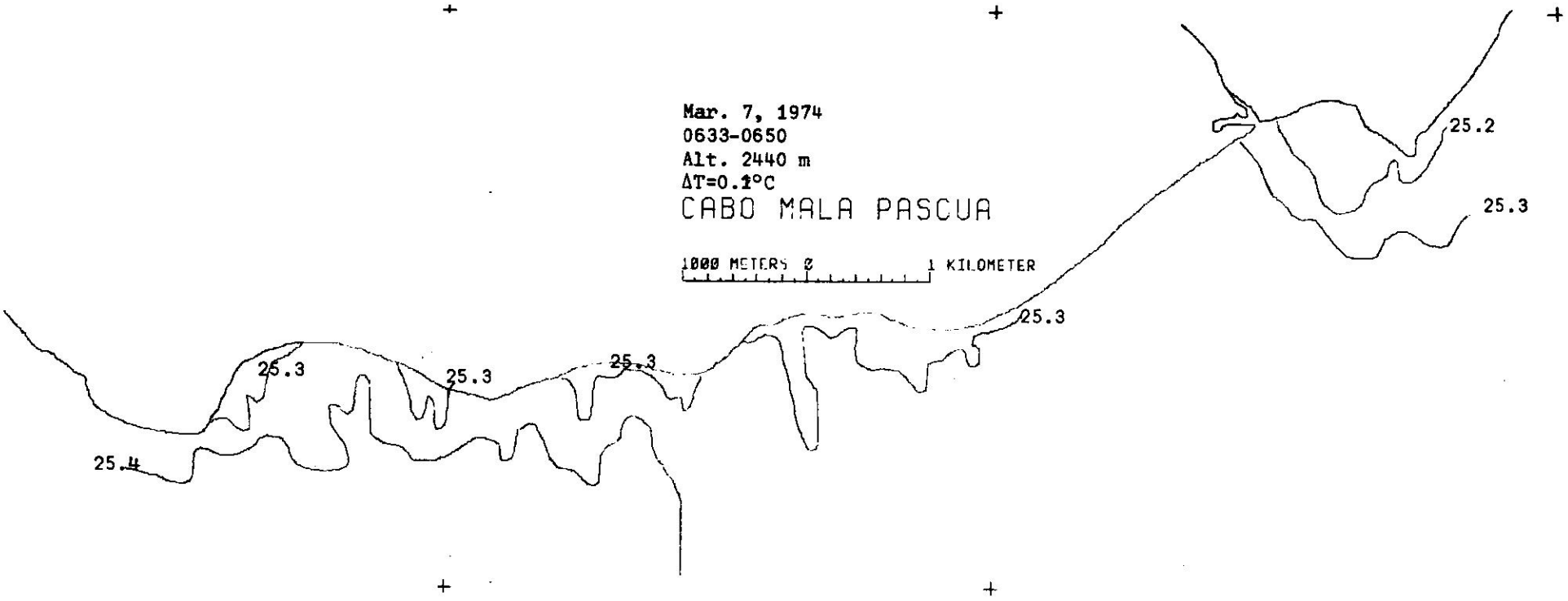
Punta Higuero
June 11, 1974
Alt. 1983 m
ΔT=0.2°C
0607-0635



Punta Higuero
Sept. 30, 1974
1951-2010
Alt. 1983 m
ΔT= 0.2°C


Sept. 24, 1973
0650-0700
Alt. 1220 m
ΔT=0.2°C
CABO MALA PASCUA
1000 METERS 0 1 KILOMETER
27.9
27.9
28.1
27.9
28.3
28.1
28.1
28.3


Nov. 19, 1973
0630-0700
Alt. 1068 m
ΔT=0.2°C
CABO MALA PASCUA
1000 METERS 0
1 KILOMETER
26.7
26.9
26.9
26.7
26.7


Mar. 7, 1974
0633-0650
Alt. 2440 m
ΔT=0.1°C
CABO MALA PASCUA
1000 METERS 0 1 KILOMETER
25.2
25.3
25.3
25.3
25.3
25.3
25.4

Cabo Mala Pascua
Sept. 29, 1974
Alt. 1830 m
ΔT=0.2°C
0623-0649