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OTEC Thermal Resource Report for Dampier Land, Australia

May 1979

MASTER

Prepared for
U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Central Solar Technology

Under Contract No. ET-78-C-01-2898

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Washington, D.C. 20585

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Under Contract No. ET-78-C-01-2898

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INTRODUCTION

One of the basic environmental considerations in site selection for an Ocean Thermal Energy Conversion (OTEC) power plant is the availability of an adequate temperature difference resource. OTEC plants are designed to convert the potential energy in the temperature difference between the warm ocean surface water and the cold water existing at deeper depths into electricity. The turbines which produce the electricity must run on temperature differentials which are extremely small by the standards of conventional energy plants. Therefore, a definition of the most probable temperature structure for a site is most important.

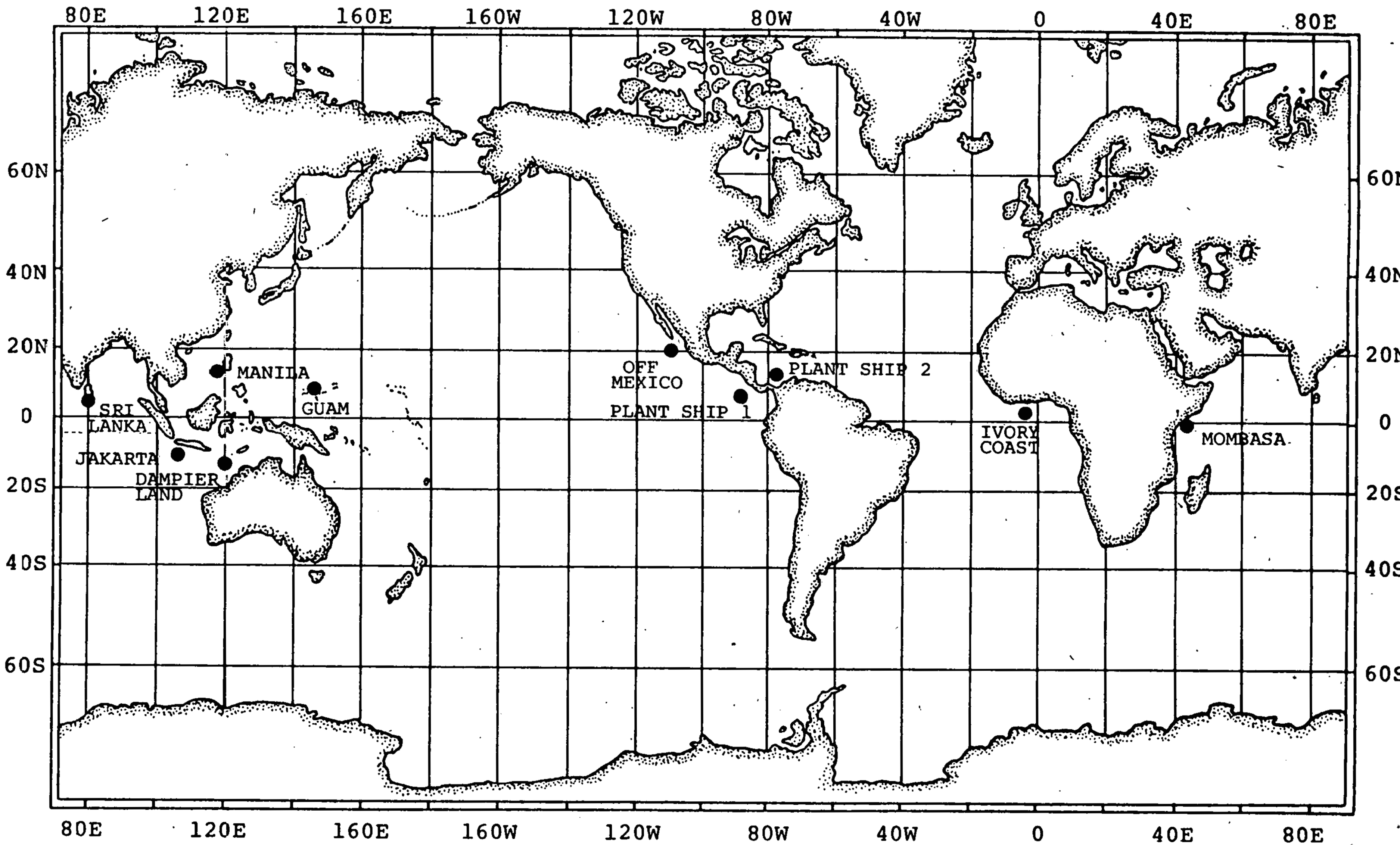
In order to define temperature structures for OTEC areas of interest, Ocean Data Systems, Inc. (ODSI) has developed computer data files of all unclassified soundings available. The primary sources for the data were NOAA's National Oceanographic Data Center, and the U.S. Navy's Fleet Numerical Weather Central. The files were updated in September 1978. Included in the data base were mechanical bathythermographs (MBT), expendable bathythermographs (XBT), salinity temperature depth systems (STD), and Nansen casts.

Under U.S. Department of Energy, Division of Solar Energy Contract No. EY-78-C-2989, ODSI has analyzed the monthly temperature structure for ten different geographical areas. The ten sites selected for study by the Department of Energy are:

		Latitude	Longitude
Bottom Mounted or Shore Plants:	Dampier Land	13-18°S	118-121°E
	Manila	14-16°N	118-120°E
	Guam	12-15°N	142-146°E
	Ivory Coast	3-6°N	3-8°W
	Jakarta	6-9°S	104-109°E
	Mexico	20-23°N	105-110°W
	Sri Lanka	5-10°N	78-83°E
	Mombasa	5°S-3°N	40-45°E
Ship Plants:	No. 1	5-10°N	90-95°W
	No. 2	13-15°N	75-80°W

The location of these sites is shown on the following map; a separate report was produced for each site.

For each area, the most probable temperature structures were determined. When the most probable temperature soundings were plotted, some month to month variability was present which was caused by the non-uniform data sample rather than by real changes in the ocean. These short-period time variations were removed by a filtering process described by Wolff, et al (1977), [44]. Availability of cold and warm water was examined at each site. In addition to warm and cold water availability, there are other requirements for the continuous operation of an OTEC plant. An adequate temperature differential (ΔT) is the primary need. A ΔT greater than 16.7°C (30°F) for the coldest month of the year would enable year round operation. The annual mean ΔT for



LOCATION OF THE TEN SELECTED SITES

a site should equal or exceed 20°C (36°F). Besides the thermal resource, there are other operational requirements. Bottom depth should be less than 1500 meters for mooring. Minimum distances offshore to 1000-meter depth is another important consideration for shore plants. Currents should be sufficient to guarantee good cold/warm water sources and to provide for dispersion of modified water. Desirable sites also have light winds, minimum sea and swell, and the lack of severe storms. These parameters have been examined for each site. The following tables summarize some of the key site parameters for each location.

SUMMARY OF SITE PARAMETERS

Site	Monthly Mean Temperature (°C) Surface Range	Monthly Mean Temperature (°C) 1000M	Annual Mean ΔT(°C) 500M	Annual Mean ΔT(°C) 1000M	Coldest Monthly Mean ΔT (°C) 500M	Coldest Monthly Mean ΔT (°C) 1000M
Sri Lanka	27.5-28.6	6.5-6.7	18.0	21.3	17.5	20.8
Mombasa N	25.4-28.7	7.2-7.5	17.0	19.5	15.6	18.2
Mombasa S	25.5-28.4	6.3-7.0	18.0	20.2	15.9	18.5
Jakarta	27.2-29.0	5.1-5.6	19.1	22.8	17.9	21.9
Dampier Land	25.6-28.2	4.9-5.0	19.1	22.6	17.4	20.7
Manila	27.1-29.5	4.4-4.6	20.0	24.0	18.6	22.6
Guam	27.7-29.2	4.3-4.4	21.1	24.1	20.4	23.4
Off Mexico	22.5-28.0	4.4-4.5	17.6	20.9	14.9	18.0
Plant Ship Pacific	27.1-28.5	4.6-4.8	19.4	22.8	18.1	21.7
Ivory Coast	24.3-28.1	4.5	19.2	22.1	16.8	19.7
Plant Ship Caribbean	26.4-28.4	5.0-5.3	18.1	22.4	17.2	21.3

SUMMARY OF SITE PARAMETERS

SITE	RANGE DISTANCE (IN KILOMETERS) TO SHORE FROM 1000 METERS	MONTHLY MEAN MIXED LAYER DEPTH METERS	MONTHLY MEAN SURFACE CURRENTS (CM/SEC)	SEA STATE MAX % OF TIME >3 METERS	NUMBER TROPICAL CYCLONES PER YEAR
SRI LANKA	22-55	30-80	25-62	3	0.2-1.2
MOMBASA	33-130	30-90	30-62	2	0.0-0.1
JAKARTA	18-60	55-80	25-52	2	0.0-0.1
DAMPIER LAND	265-417	30-80	25-47	4	0.4-1.2
MANILA	6-82	20-80	30-52	5	4.0-6.0
GUAM	7-18	60-120	30-47	5	2.0-3.0
OFF MEXICO	5-104	10-30	25-31	2	0.6-4.0
PLANT SHIP PACIFIC	-	0-30	30-52	2	0.0-2.0
IVORY COAST	33-52	0-30	25-31	2	0.0-0.1
PLANT SHIP CARIBBEAN	-	40-110	30-62	3	0.6-1.2

I. EXECUTIVE SUMMARY

The region off Dampier Land, Australia was selected for study as a potential OTEC site. The region examined was between 13-18° South latitude and 118-121° East longitude. Data coverage was sparse, but the existing data demonstrated a fine potential for Ocean Thermal Energy Conversion (OTEC) use. The maximum temperature gradient remains relatively stable throughout the year. The annual average ΔT at 1000 meters is 22.6°C. At 600 meters, an annual average ΔT greater than 20°C is obtainable.

The continental shelf off Dampier Land is very wide; thus, the distance to water 1500 meters deep may be as much as 480 kilometers (260 nautical miles). Water 1000 meters deep lies at least 265 kilometers (143 nautical miles) offshore. This distance is a major problem, perhaps necessitating the use of a plant ship. Tropical storms can be a problem between December and April. The ocean off Dampier Land has an upper mixed layer throughout the year. Currents are generally moderate, although the surface circulation pattern changes during the year.

II. BATHYMETRY

The location of the area off Dampier Land is shown on Figure II-1. Figure II-2 shows the rough bathymetry off the Dampier Land coast taken from Defense Mapping Agency Hydrographic Center (1974), [10]. The continental shelf in this area is relatively wide with long distances from acceptable depths to an installation on shore. Table II-1 summarizes distances to selected depths off Dampier Land.

TABLE II-1: DISTANCES TO SELECTED DEPTHS OFF DAMPIER LAND. From Defense Mapping Agency (1974), [10].

DEPTH (Meters)	CLOSEST DISTANCE (Kilometers)	FARTHEST DISTANCE (Kilometers)
100	98	283
500	218	408
1000	265	417
1500	293	482

Because of the long distances to shore, a floating OTEC plant should be considered for this area.

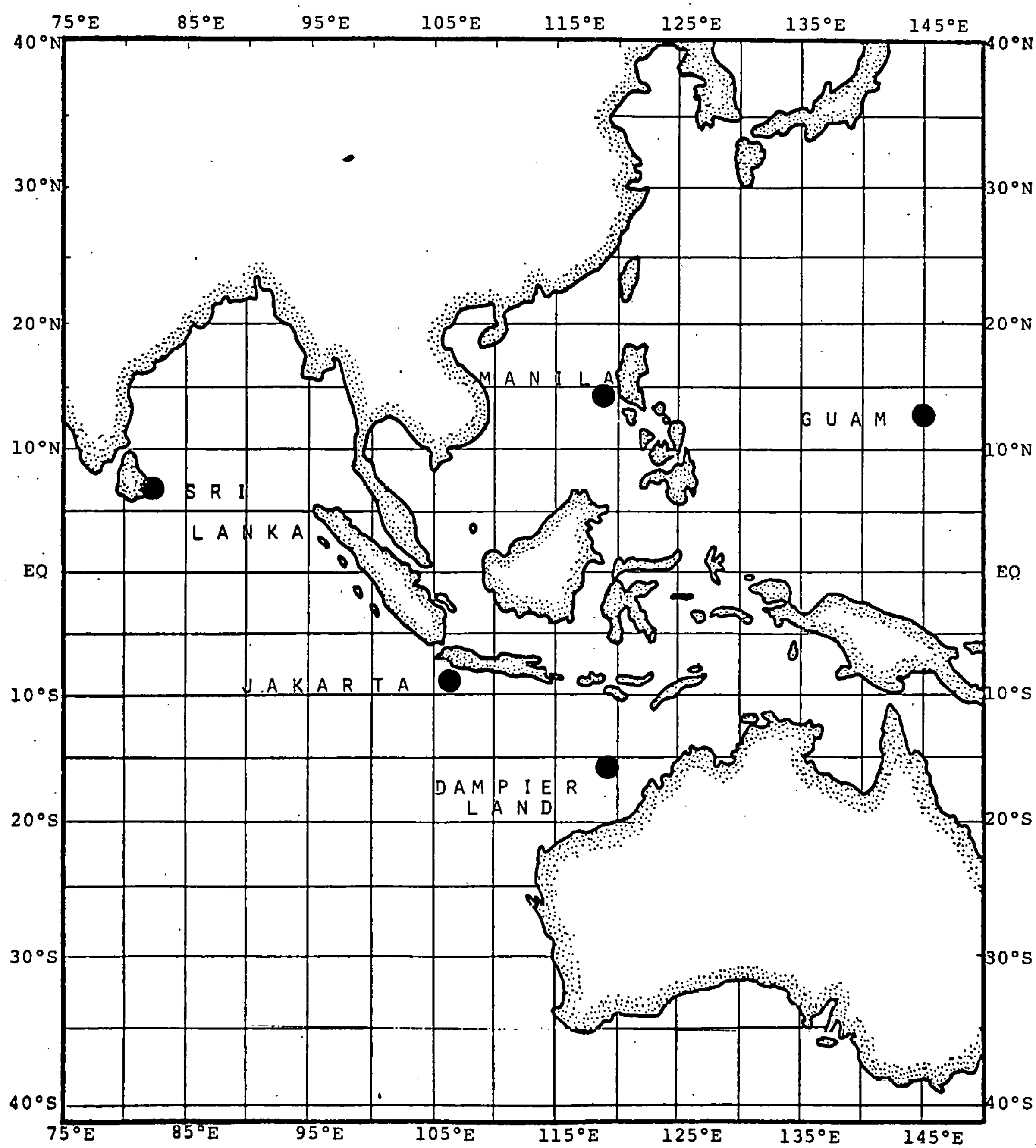


FIGURE II-1: LOCATOR CHART SHOWING AREA OF INTEREST OFF DAMPIER LAND.

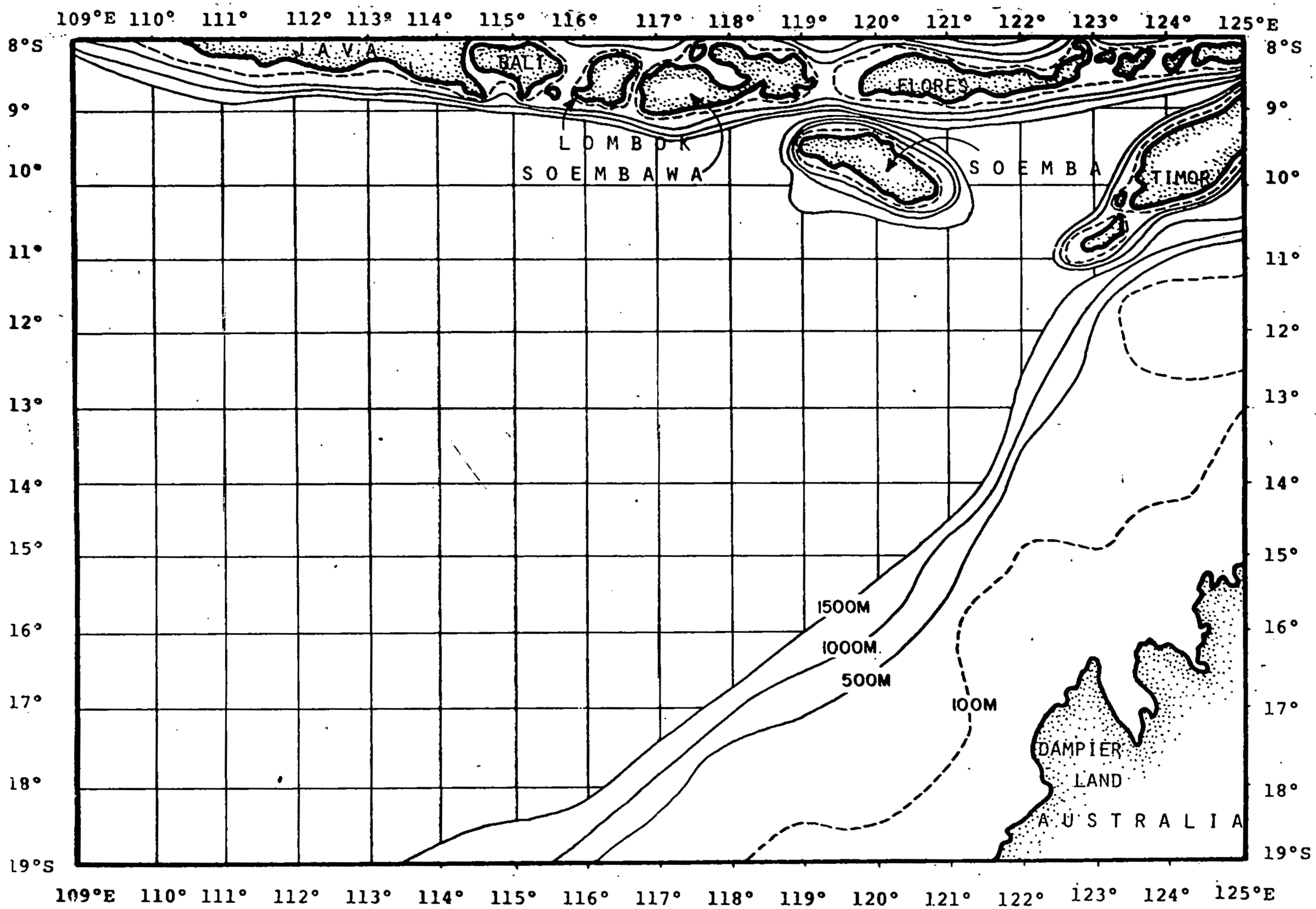


FIGURE II-2: CHART SHOWING ROUGH BATHYMETRY OFF DAMPIER LAND. From Defense Mapping Agency (1974) [10].

III. THERMAL RESOURCE

Even through a large area was selected for study, there was a paucity of sounding data during some months and at some depths. The ODSI master subsurface file was the main source for evaluation of the thermal resource; however, Colburn (1974) [6] and Wyrtki (1971) [47] were used as additional references.

The data available indicate a thermal structure with good potential for OTEC operations. An annual average ΔT of greater than 20°C is available at a depth of 600 meters. The area has a permanent, broad thermocline during all months. There is also an ample supply of warm surface water with mean temperatures ranging from 25.6 to 28.2°C. Open access to Antarctic source regions assures a good cold water supply.

Table III-1 shows the monthly most probably temperature structure off Dampier Land as a function of depth. Table III-2 shows the same data presented as ΔT (surface temperature minus temperature at depth) while Figure III-1 shows monthly ΔT contours for the area off Dampier Land. Short period fluctuations due to the sparse data sample were removed using a filtering process described by Wolff, et al (1977), [44].

TABLE III-1: MONTHLY MOST PROBABLE TEMPERATURE (°C) PROFILE

DAMPIER LAND 13-18°S/118-121°E

Depth	Month 1	2	3	4	5	6	7	8	9	10	11	12	Annual Mean
0	28.1	27.5	27.3	27.8	27.5	26.8	25.6	25.6	26.1	27.4	28.2	28.2	27.2
50	26.5	26.9	26.3	27.0	27.1	26.6	25.2	25.2	25.3	25.9	26.2	26.7	26.2
100	23.4	22.9	22.8	23.5	24.5	25.0	24.2	24.1	24.1	24.1	23.9	23.5	23.8
150	19.8	19.6	19.9	20.3	20.8	21.7	21.3	21.4	20.9	21.1	20.7	20.0	20.6
200	15.6	15.6	15.6	16.2	16.7	17.5	17.3	17.2	16.9	17.1	17.0	16.5	16.6
250	13.2	12.9	12.8	13.0	13.3	14.1	14.1	14.3	14.3	13.9	14.1	13.7	13.6
300	11.3	10.9	10.8	11.1	11.5	11.9	12.0	12.0	11.8	11.8	11.8	11.6	11.5
350	10.1	10.0	10.2	10.3	10.4	10.5	10.6	10.6	10.6	10.4	10.5	10.3	10.4
400	9.4	9.3	9.3	9.5	9.5	9.6	9.6	9.6	9.6	9.5	9.5	9.4	9.5
450	8.6	8.6	8.6	8.7	8.8	8.9	8.9	8.8	8.8	8.7	8.7	8.6	8.7
500	8.1	8.1	8.1	8.2	8.3	8.3	8.2	8.1	8.1	8.0	8.0	8.0	8.1
550	7.6	7.6	7.6	7.7	7.8	7.8	7.7	7.5	7.5	7.4	7.5	7.5	7.6
600	7.1	7.1	7.2	7.3	7.3	7.3	7.2	7.1	7.0	6.9	7.0	7.0	7.2
650	6.7	6.7	6.8	6.9	6.9	6.9	6.8	6.7	6.6	6.6	6.6	6.6	6.7
700	6.4	6.4	6.4	6.5	6.5	6.4	6.3	6.3	6.3	6.2	6.3	6.3	6.4
750	6.1	6.0	6.0	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	6.0	6.0
800	5.8	5.8	5.8	5.8	5.9	5.8	5.8	5.8	5.8	5.7	5.7	5.8	5.8
850	5.6	5.5	5.5	5.5	5.6	5.5	5.5	5.5	5.5	5.4	5.5	5.6	5.5
900	5.4	5.4	5.3	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.4	5.3
950	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
1000	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	5.0	4.9
1050	4.8	4.8	4.7	4.8	4.8	4.8	4.7	4.6	4.7	4.7	4.7	4.8	4.7
1100	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.6	4.6	4.6	4.6
1150	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.5	4.5	4.4
1200	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.3	4.3	4.3
1250	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.1
1300	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	4.0	4.1	4.0
1350	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.9	3.9	3.8
1400	3.7	3.7	3.7	3.7	3.6	3.6	3.7	3.7	3.7	3.7	3.7	3.7	3.7
1450	3.5	3.5	3.6	3.6	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.5	3.6
1500	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.4	3.4	3.4

TABLE III-2: SURFACE TEMPERATURE - TEMPERATURE AT DEPTH DIFFERENTIAL (°C) BY MONTHS DAMPIER LAND 13-18°S/118-121°E

Depth	Month												Annual
	1	2	3	4	5	6	7	8	9	10	11	12	Mean
50	1.6	0.6	1.0	0.8	0.4	0.2	0.4	0.4	0.8	1.5	2.0	1.5	0.9
100	4.7	4.6	4.5	4.3	3.0	1.8	1.4	1.5	2.0	3.3	4.3	4.7	3.3
150	8.3	7.9	7.4	7.5	6.7	5.1	4.3	4.2	5.2	6.3	7.5	8.2	6.6
200	12.5	11.9	11.7	11.6	10.8	9.3	8.3	8.4	9.2	10.3	11.2	11.7	10.6
250	14.9	14.6	14.5	14.8	14.2	12.7	11.5	11.3	11.8	13.5	14.1	14.5	13.5
300	16.8	16.6	16.5	16.7	16.0	14.9	13.6	13.6	14.3	15.6	16.4	16.6	15.6
350	18.0	17.5	17.1	17.5	17.1	16.3	15.0	15.0	15.5	17.0	17.7	17.9	16.8
400	18.7	18.2	18.0	18.3	18.0	17.2	16.0	16.0	16.5	17.9	18.7	18.8	17.7
450	19.5	18.9	18.7	19.1	18.7	17.9	16.7	16.8	17.3	18.7	19.5	19.6	18.5
500	20.0	19.4	19.2	19.6	19.2	18.5	17.4	17.5	18.0	19.4	20.2	20.2	19.1
550	20.5	19.9	19.7	20.1	19.7	19.0	17.9	18.1	18.6	20.0	20.7	20.2	19.6
600	21.0	20.4	20.1	20.5	20.2	19.5	18.4	18.5	19.1	20.5	21.2	21.2	20.1
650	21.4	20.8	20.5	20.9	20.6	19.9	18.8	18.9	19.5	20.8	21.6	21.6	20.4
700	21.7	21.1	20.9	21.3	21.0	20.4	19.3	19.3	19.8	21.2	21.9	21.9	20.8
750	22.0	21.5	21.3	21.7	21.4	20.7	19.6	19.6	20.1	21.4	22.2	22.2	21.1
800	22.3	21.7	21.5	22.0	21.6	21.0	19.8	19.8	20.3	21.7	22.5	22.4	21.4
850	22.5	22.0	21.8	22.3	21.9	21.3	20.1	20.1	20.6	22.0	22.7	22.6	21.7
900	22.7	22.1	22.0	22.4	22.1	21.4	20.3	20.3	20.8	22.1	22.9	22.8	21.8
950	22.9	22.4	22.2	22.7	22.4	21.7	20.5	20.5	21.0	22.3	23.1	23.1	22.1
1000	23.1	22.5	22.4	22.9	22.6	21.9	20.7	20.7	21.2	22.5	23.3	23.2	22.6
1050	23.3	22.7	22.6	23.0	22.7	22.0	20.9	21.0	21.4	22.7	23.5	23.4	22.4
1100	23.5	22.9	22.7	23.2	22.9	22.3	21.1	21.1	21.6	22.8	23.6	23.6	22.6
1150	23.6	23.1	22.9	23.4	23.1	22.4	21.2	21.2	21.7	23.0	23.7	23.7	22.8
1200	23.8	23.2	23.0	23.5	23.2	22.6	21.4	21.4	21.9	23.2	23.9	23.9	22.9
1250	23.9	23.3	23.2	23.7	23.4	22.7	21.5	21.5	22.0	23.3	24.0	24.0	23.0
1300	24.0	23.5	23.3	23.8	23.5	22.8	21.6	21.7	22.2	23.5	24.2	24.1	23.2
1350	24.2	23.7	23.5	24.0	23.7	23.0	21.8	21.8	22.3	23.6	24.3	24.3	23.3
1400	24.4	23.8	23.6	24.1	23.9	23.2	21.9	21.9	22.4	23.7	24.5	24.5	23.5
1450	24.6	24.0	23.7	24.2	24.0	23.3	22.1	22.0	22.5	23.8	24.6	24.7	23.6
1500	24.7	24.1	23.9	24.4	24.1	23.4	22.2	22.2	22.6	23.9	24.8	24.8	23.8

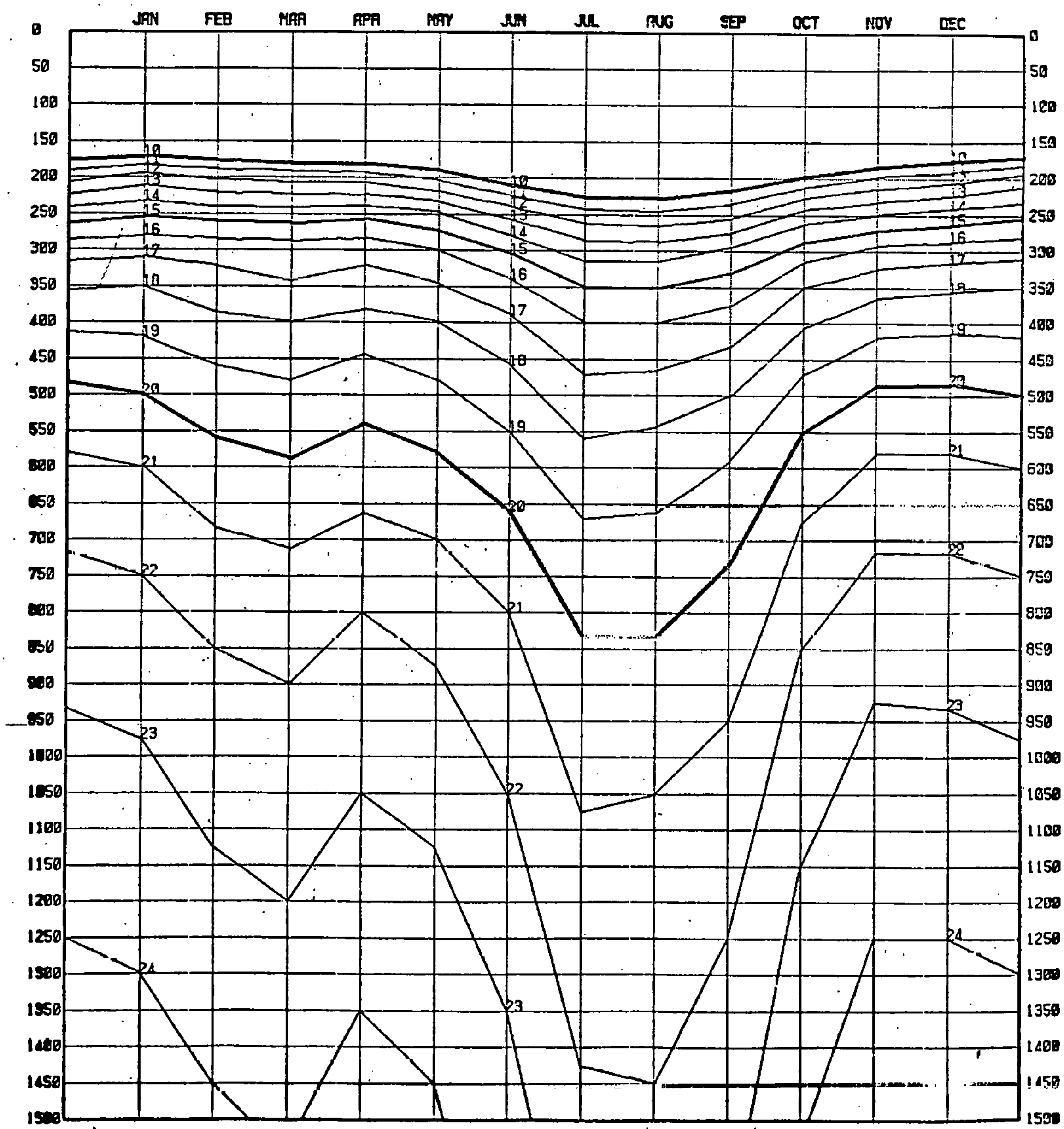


FIGURE III-1: CHART SHOWING MONTHLY ΔT CONTOURS (°C) AT 50-METER DEPTH INTERVALS FOR THE AREA OFF DAMPIER LAND, AUSTRALIA (13-18S, 118-121E).

IV. MIXED LAYER DEPTH

An adequate mixed layer depth (MLD) exists the year round. The MLD is deep enough to assure an intake of uniformly warm water, and shallow enough so that the mixed exhaust water can be discharged below the MLD in order to minimize the possibility of recirculation. Because of the distance offshore, a floating OTEC plant was recommended for consideration in this area; this would further enhance the safe dispersion of modified waters.

Mixed layer depths in this area were determined from the profiles used in the thermal resource assessment (Section III) and the investigations of Colburn (1974), [6]. Typical monthly MLD values are shown in Table IV-1.

TABLE IV-1: TYPICAL MIXED LAYER DEPTHS (METERS) OFF DAMPIER LAND, AUSTRALIA.

JAN	FEB	MAR	APR	MAY	JUN
40	30	30	40	50	70
JUL	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
80	80	70	60	40	40

V. WINDS AND STORMS

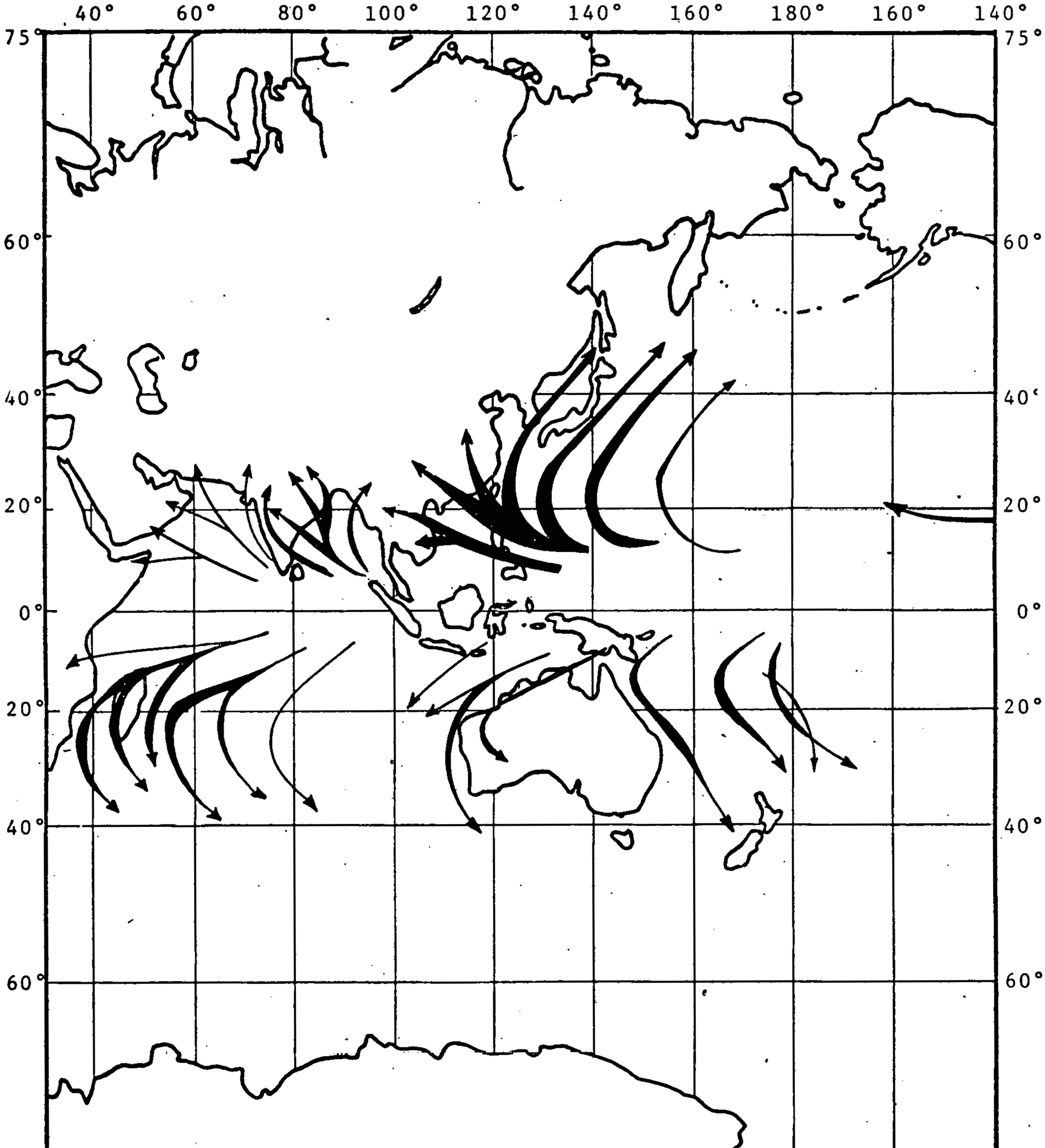
The proposed site lies within the climatological region of the Southeast Trade Winds, and storms are a potential problem for OTEC operations off Dampier Land. The main season for storms is from December to April, with significant occurrences in May, June, and November. The monthly average tropical storms per year are as follows:

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Tropical Storms	3	4	5	1	0	0	0	0	0	0	0	2

This data was derived from H.L. Crutcher and R.G. Quayle (1974), [7]. Figure V-1 and V-2 are adapted from the same source. Figure V-1 shows the preferred annual storm tracks for the region. Figure V-2 from the same source provides the average number of tropical cyclones per 5° square per year. There is a wide range of numbers of tropical storms per year depending upon where in the site region the plant was located. In the northern part, plants would be less affected by tropical storms.

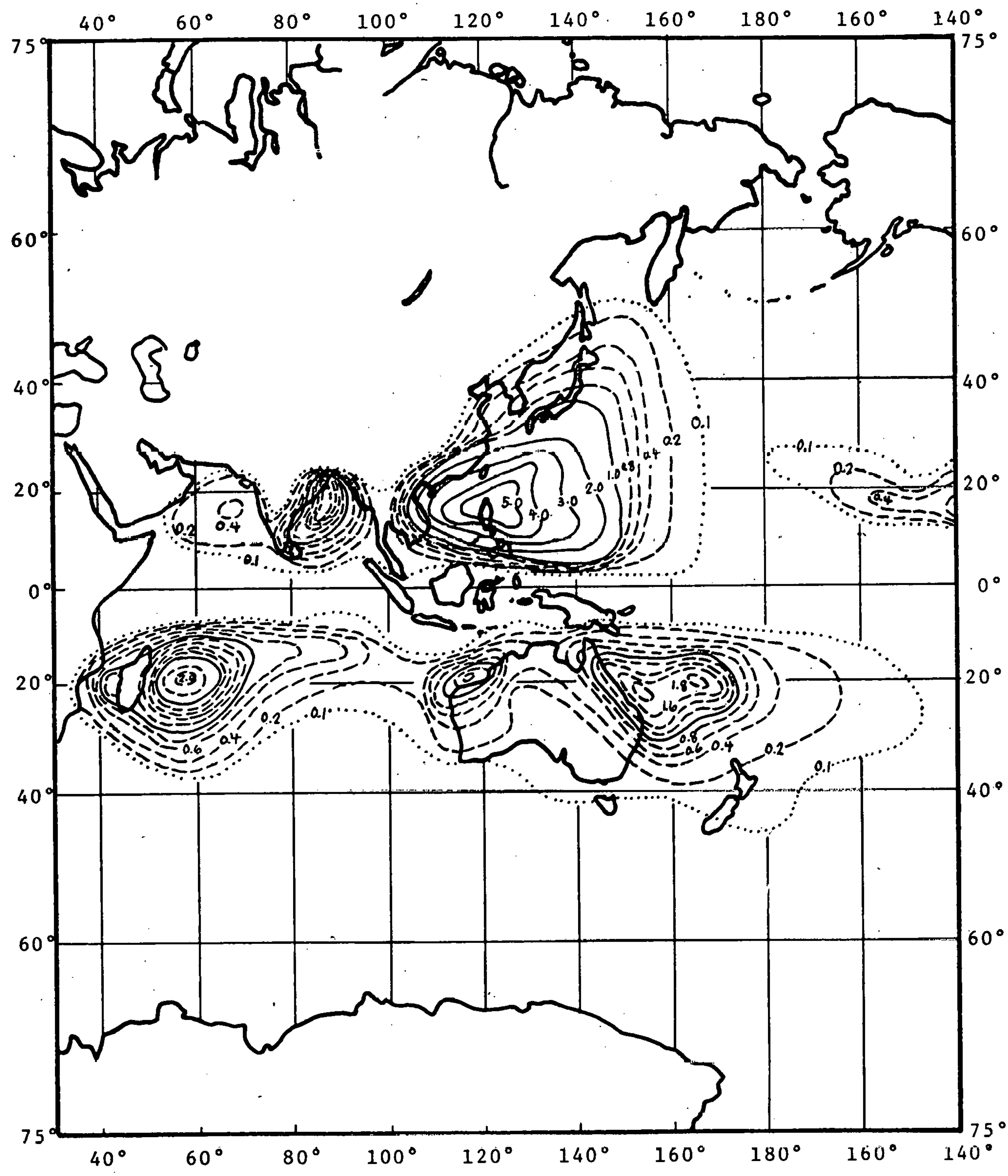
Johnson and Denwick in an NDBO study (1978), [20], shows that a hurricane can cause a temperature anomaly of -3°C for about a four day period. While this result was measured in the Gulf of Mexico, the resulting temperature difference and the recovery process is uniform throughout the tropics. Currents will be formed. Mountainous wave heights of 10 to 15 meters have been reported on numerous occasions in hurricanes, according to Gentry, (1970), [18]. Sustained wind speeds may approach 50 meters per second.

Tables V-1 through V-4, taken from the U.S. Naval Weather Service (1938), [31], shows basic information on the winds for each of the ten sites examined under this contract.



ANNUAL PERFERRED STORM TRACKS FOR TROPICAL STORMS

FIGURE V-1



AVERAGE NUMBER OF
TROPICAL CYCLONES PER 5°
SQUARE PER YEAR

FIGURE V-2

TABLE V-1

RESULTANT WINDS

Average Wind Velocity in Meters per Second

Location	Dec-Jan-Feb	Mar-Apr-May	Jun-Jul-Aug	Sep-Oct-Nov
Ivory Coast	3.1-4.1	3.1-4.1	4.1-5.1	4.1-5.1
Mombasa	5.1-6.2	4.1-5.1	6.2-7.2	4.1-5.1
Sri Lanka	4.1-5.1W 5.1-6.2E	4.1-5.1	6.2-7.2W 7.2-8.2E	5.1-6.2
Jakarta	4.1	3.1-4.1	5.1-6.2	5.1-6.2
Dampier Land	4.1-5.1	4.1-6.2	5.1-6.2	4.1-5.1
Philippines	5.1-6.2	3.1-4.1	4.1	6.2-7.2
Guam	5.1-6.2	4.1-5.1	4.1-5.1	4.1-5.1
Off Mexico	3.1-4.1	2.1-4.1	2.1-4.1	4.1-5.1
Plant Ship Pacific	3.1-4.1	3.1-4.1	4.1-5.1	4.1-6.2
Plant Ship Caribbean	6.2-7.2	5.1-6.2	6.2-8.2	4.1-5.1

TABLE V-2

FREQUENCY AND PERCENTAGE OF MODERATE GALES AND STRONGER WINDS,

BEAUFORT FORCE 7 AND HIGHER

(≥ 14.4 meters per second)

MONTH	IVORY COAST	MOMBASA	SRI LANKA	JAKARTA	DAMPIER LAND	PHILLIPINES	GUAM	OFF MEXICO	PLANT SHIP (PACIFIC)	PLANT SHIP (CARIBN)
JAN	0*	0-1	0	0	0	1-5	1-5	1-5	0	5
FEB	0	0	1	1-5	1-5	5	1-2	1-2	0	5
MAR	1-2	0	0	1-2	1-2	1	0	1-2	0	1-5
APR	0	0	0	1-2	0	1	1-5	1	0	1-5
MAY	0	1	1-5	1	0	1-5	0	0	0	1
JUN	0	5-10	5-10	1-5	0	1-5	0	1	0	1-5
JUL	0	5-10N 10-20S	1-5	1-5	1-5	5	0	0	0	1-5
AUG	0	1-5S 5-15N	1-5	0	0	1-5	1-5	1-5	0	1-5
SEP	0	0	1-5	1-5	0	5	1-5	0	0	1
OCT	0	0	0W 1-5E	1-5	0	1-5	1-2	1	1	1-5
NOV	0	0	1-5	1-5	0	10-15N 1-10S	5-15	1-5	0-5	1-5
DEC	0	1-2	0W 1-5E	1-5	0	10-15N 5-10S	1-5	1-5	0	1-5

* 0 = few or none.

TABLE V-3

PERCENTAGE OF WINDS WITH BEAUFORT FORCE 8 AND HIGHER

(≥ 17.5 meters per second)

LOCATION	Dec-Jan-Feb	Mar-Apr-May	Jun-Jul-Aug	Sep-Oct-Nov
Ivory Coast	0	1	0	0
Mombasa	N 1 S 0	0	0	0
Sri Lanka	0	0	1	0
Jakarta	1	1	0	1
Dampier Land	1	1	0	0
Philippines	5	0	1	1-5
Guam	0	1	1	1-5
Off Mexico	1	1	0	1
Plant Ship Pacific	0	1	0	0
Plant Ship Caribbean	1	0	1	0

TABLE V-4

PREDOMINANT SURFACE WIND DIRECTION

MONTH	MOMBASA	SRI LANKA	DAMPIER LAND	JAKARTA	MANILA	GUAM	OFF MEXICO	PLANT SHIP (PACIFIC)	PLANT SHIP (CARIBN)	IVORY COAST
JAN	↓ ↓	↙	↗ ↗	↘	↙	↙	↘	↙	↙	↑ ↗
FEB	↓	↙	↗	→	↙	↙	↓	↙	↙	↑
MAR	↙	↓ O ↙ ↓	↘ ↗	→	↓	↙	↘	↙	←	↑
APR	O° ↙ / ↖	O ↗ ↗	↖ ↖	↖	↓	↙	↘	↙	←	↑
MAY	↑ ↑	↗	↖	↖	↙ ↖	↙	↘	↖	←	↑
JUN	↑	↗	↖	↖	↗	←	↘	↘ ↙ ↑	←	↑
JUL	↑	↗	↖	↖	↗	↑ ↑ ←	↘	↑	←	↑
AUG	↑	↗	↖	↖	↗	← ↖	↓	→ → ↑	←	↗
SEP	↑	→ O ↗	↖	↖	↙ ↗	←	↘	↗	←	↑
OCT	↖	→	↖	↖	↙	↙	↓	↑	←	↑
NOV	↙ / ↖	→ O ↙	↖ ↗	↘ ↖	↙	↙	↓	↙ ↓ ↖ ↖	←	↑
DEC	↙	↙	↗	↗	↓	↙	↓	←	↙	↗

VI. SEA AND SWELL CHARACTERISTICS

High sea and swell conditions present some problems to continuous OTEC operations for the area off Dampier Land. The area is within the main axis of the Southeast Trade Winds. High seas and swell are more common during the southern winter in July and August. Average frequencies (in percent) for the high and low seas and swells are presented in Table VI-1.

TABLE VI-1: SEA AND SWELL FREQUENCIES OFF DAMPIER LAND

	Low Seas (0.3-0.9 meters)	High Seas (2.4 meters and higher)
JAN-FEB	42%	8%
JUL-AUG	29%	16%

	Low Swell (0.3-1.8 meters)	High Swell (3.0 meters and higher)
JAN-FEB	47%	18%
JUL-AUG	32%	31%

The source of this information is the U.S. Hydrographic Office's Wind Waves at Sea, (1947) [5].

Table VI-2 provides wave statistics for the Dampier Land site taken from Ocean Wave Statistics, (1967), [19]. This statistical breakdown shows the number of observations in various height verses period catagories. The summary is

TABLE VI-2: STATISTICAL BREAKDOWN SHOWING NUMBER OF SHIPS OBSERVATIONS OFF DAMPIER LAND, AUSTRALIA REPORTING HEIGHT/PERIOD COMBINATIONS (ALL SEASONS). From Ocean Wave Statistics (1967), [19].

Wave Height (meters)	Wave Period (Seconds) Calm	<5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	over 21	Total	Percent of Grand Total
0.25	171	281	17	3	1	2	1			2	1	479	2
0.5	28	1030	106	30	13	7	2	1	1	1	26	1245	5
1.0	50	2508	1435	375	135	49	12	6		14	22	4606	17
1.5	101	1747	3502	1408	403	160	53	11	2	2	2	7391	27
2.0	64	500	2140	1951	764	259	76	22	7	1	1	5785	21
2.5	38	174	998	1324	752	265	88	26	6			3671	13
3.0	28	59	388	710	544	213	88	15	2			2047	7
3.5	7	23	135	352	312	164	52	16	2			1063	4
4.0	6	11	91	182	191	113	56	20	5			675	2
4.5	1	8	49	84	84	86	36	17	2	1		368	1
5.0	4		2	10	14	18	6	3	1			58	<1
5.5	4		10	13	11	13	11					62	<1
6.0	4	4	8	6	9	5	8	2	1			47	<1
6.5		3	6	5	7	9	3	3	1			37	<1
7.0				5	4	2	2					13	<1
7.5				8	1	1	2	3	1			16	<1
8.0	1				2	1		1	1	3		9	<1
8.5		1		2	1	3	2					9	<1
Total	507	6349	8887	6468	3248	1370	497	146	32	25	52	27581	
Percent of Grand Total	2	23	32	23	12	5	2	<1	<1	<1	<1		

based upon actual ship's observations from a somewhat larger region than that for which the thermal resource was examined; however, they are generally representative of the site region. Figure VI-1 provides a graph of the relative frequency of various wave heights for this site.

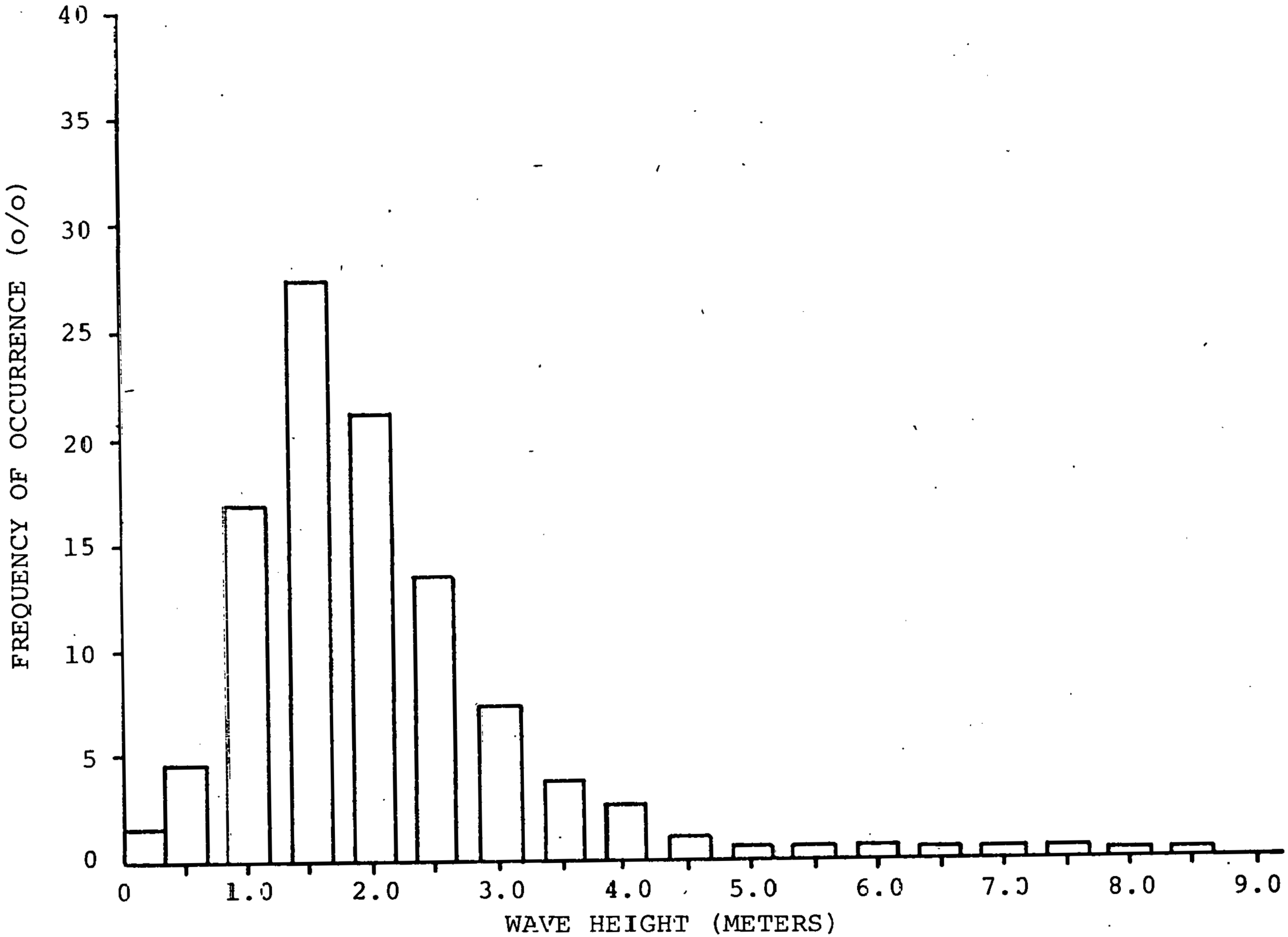


FIGURE VI-1

WAVE HEIGHT FREQUENCIES (DAMPIER LAND)

VII. CURRENTS

Düing (1970, [14]) in the Monsoon Regime of the Currents in the Indian Ocean states the monsoon affected currents winds are generally limited to the area north of 10°S. While the Dampier Land site is south of 10°S, the surface currents have the characteristic of a monsoon area in that the mean resultant surface current changes by more than 90° through the year.

The circulation pattern of this region shows variation during the year. During the summer, the northward flowing cooler West Australia Current enters the area. The influence of the West Australia Current decreases in early winter. Subsequently, the South Equatorial Current penetrates the area with westward flowing waters, including some of Pacific origin. The monsoonal effects exist within the upper 200-300 meters off Dampier Land (Düing, 1970, [14]). Surface current speeds are weak to moderate throughout the year with speeds generally less than 51 cm/sec. Düing (1970, [14]) felt there was insufficient data for monthly charts of the currents in the Indian Ocean. Most of the knowledge of surface currents for this area is based on ship logs derived from calculations of ship's drift.

Hurricanes occasionally effect this region and can cause changes in the current regime. Leipper's (1967, [21]) study of Hurricane Hilda showed that a current had developed in the area transversed by the storm. Analysis of temperature-depth data showed a current of approximately 50 cm/sec.

A theoretical study by O'Brien and Reid (1967, [27]) states that hurricanes will cause currents with a speed of approximately one meter per second.

The passage of hurricanes will induce upwellings of sub-surface waters for a temporary period of up to a week. This upwelling will cause anomalous vertical current shears. Additionally, Colburn and others have noted regions of upwelling off northwest Australia that may cause similar vertical current shears. The region between Java and the northwest coast of Australia is the source of the South Equatorial Current of the Indian Ocean. Off the northwest coast of Australia the flow is generally offshore. An article by K. Wyrtki (1972, [45]) indicates that while there is fairly low temperature at 200 meters and the area is very rich in zooplankton, characteristics of upwelling, the strongest upwelling, is not along the Northwestern Australian shelf but along the coast of Java. Part of the reason for the rich zooplankton may be the strong tidal currents which effect the area. Still there is upwelling in this site region, which may cause strong current shears.

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