Chapter 3

Marine Field Survey

by
Shigeru Suizu
Hiroshi Kuboki
Akira Watanabe

Chapter 3 Marine Field Survey

3.1 Outline of Field Survey

Umm Al Nar Station is located in the lagoon, about 25 km south east of Abu Dhabi City. Sea water from Arabian Gulf is supplied to the sea water intake facilities of the station through several channels in the lagoon.

The sea water is used as cooling water in power plants and as raw sea water in desalination plants in Umm Al Nar.

It is necessary to install a system to protect against oil contamination and a monitoring system to forecast and reduce the influence of pollution on the station. That is to say, it is necessary to adequately understand the characteristics of the marine area near the station and around the Abu Dhabi Island in order to properly install these systems and to establish a suitable institute for oil contamination.

This field survey will clarify the following items:

(a) Obtaining information and data necessary for carrying out numerical *calculation of oil dispersion in the marine area around the Abu Dhabi* Island;

(b) Oil contamination conditions near Umm Al Nar Station;

(c) Characteristics of the marine area around the Abu Dhabi Island in order to plan a periodical monitoring against oil pollution;

(d) Tidal current conditions near Umm Al Nar Station in order to design a new sea water intake facilities for the purpose of protecting Umm Al Nar Station from oil contamination..

The field survey covered a period of the two seasons, summer and winter, as the conditions of the marine area are subject to seasonal variation.

The distributions of tidal currents and water temperature-salinity were observed in the predetermined marine sites in March 1988 in order to effectively conduct the second and third field surveys.

Outlines of each field survey are as follows:

(a) First Field Survey

The distributions of tidal currents and water temperature and salinity were observed in the marine area around the Abu Dhabi Island on March 20, 1988.

(b) Second Field Survey

The second field survey was conducted during the period of September to November, 1988 according to the time schedule shown in Table 3.1.1 in order to clarify the summer characteristics of the marine area.

(c) Third Field Survey

The third field survey was conducted during the period of January to March, 1989 according to the time schedule shown in Table 3.1.2 in order to clarify the winter characteristics of the marine area.

The observation records and a part of analysis results are shown in the supplements (Data Book).

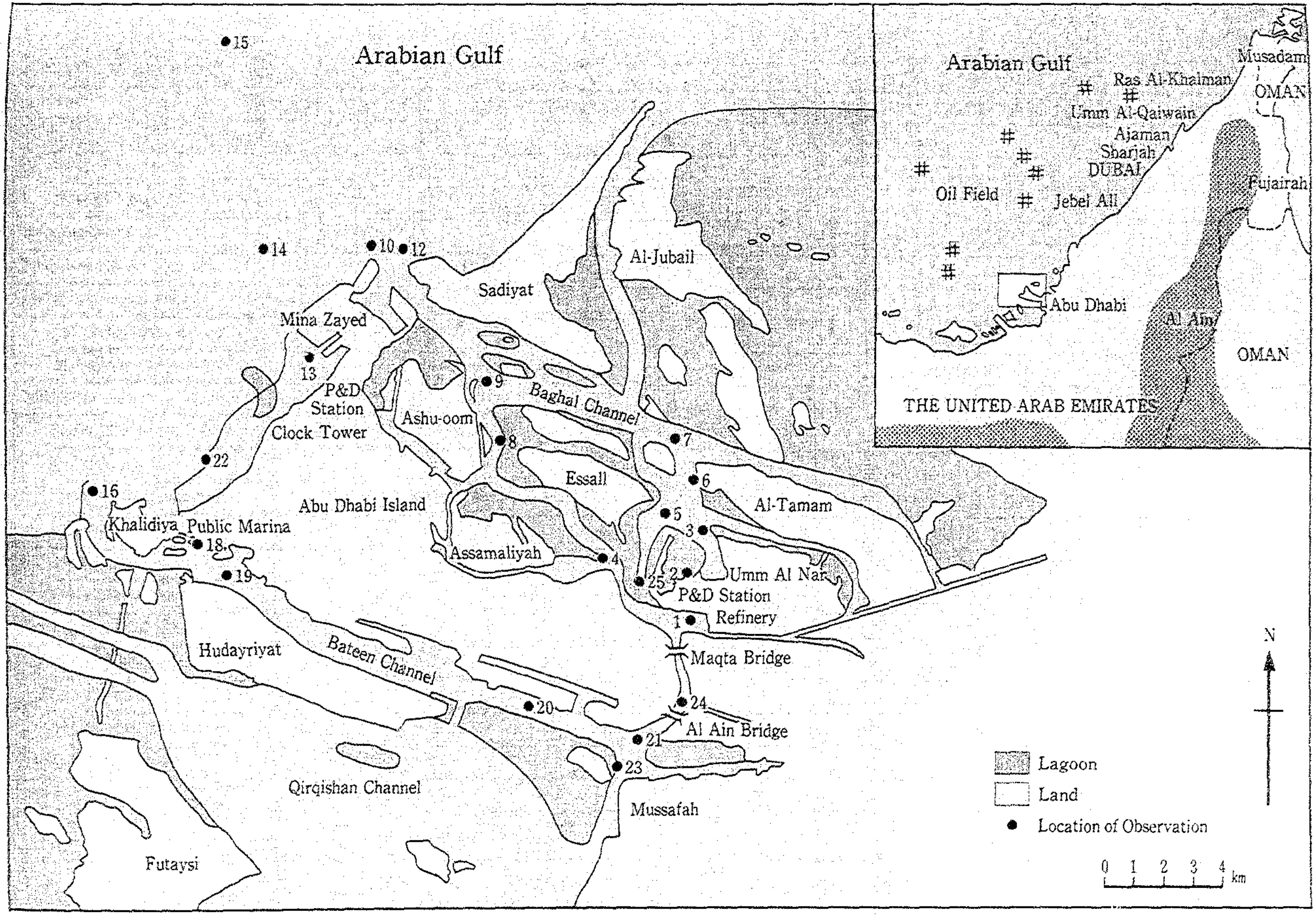


Fig. 3.1.1: Topographical Map around Abu Dhabi Island and Observation Sites

Table 3.1.1: Time Schedule of Second Field Survey

Month: September 1988 (Day 14 15 20 25 30) — October (Day 1 5 10 15 20 25 30) — November (Day 1 5 10)

Age of the Moon: ◐ ○ ◑ ● ◐ ○ ◑ ●

Survey Item	Site
Tidal Currents	
Consecutive Observation	1 7 9 15 20 21 23
Current Drag	Baghal Channel Bateen Channel
Vertical Profile	1 3 4 5 6 7 9 12 16 19 20 24 25
Tidal Elevation	
Continuous Observation	1 10 18
Leveling	
Water Temperature	
Consecutive Observation	1 7 9 15 19 20 21 23
Vertical Profile	1 2 3 4 5 6 7 9 12 15 16 19 20 24 25
Long-term Observation	1
Salinity	
Consecutive Observation	1 7 9 19 20 21 23
Vertical Profile	1 2 3 4 5 6 7 9 12 15 16 19 20 24 25
Sampling of Water Quality	1 2 3 7 9 12 13 15 16 19 20
Sampling of Bottom Sediment	1 4 5 7 8 9 12 13 14 15 16 19 20
Marine Organism	
Sampling of Plankton	1 2 9 13 15
Sampling of Benthos	1 4 5 7 8 9 12 13 14 15 16 19 20
Observation of Coastal Organism	1 2 13 22
Climate	

Notes : ● New Moon ○ Very Fine
◐ Waxing Moon ⦶ Fine
○ Full Moon ◎ Cloudy
◑ Waning Moon ● Rainy

Table 3.1.2: Time Schedule of Third Field Survey

Survey Item (Month: January 1989 – February – March; Day; Age of the Moon)	Site
Tidal Currents	
Consecutive Observation	1 7 9 15 20 21 23
Current Drag	Baghal Channel Bateen Channel
Vertical Profile	1 3 4 5 6 7 9 12 18 19 20 24 25
Tidal Elevation	
Continuous Observation	1 10 18
Leveling	
Water Temperature	
Consecutive Observation	1 7 9 15 19 20 21 23
Vertical Profile	1 2 3 4 5 6 7 9 12 15 16 19 20 24 25
Long-term Observation	1
Salinity	
Consecutive Observation	1 7 9 19 20 21 23
Vertical Profile	1 2 3 4 5 6 7 9 12 15 16 19 20 24 25
Sampling of Water Quality	1 2 3 7 8 9 12 13 15 16 19 20
Sampling of Bottom Sediment	1 4 5 7 8 9 12 13 15 16 19 20
Marine Organism	
Sampling of Plankton	1 2 9 13 15
Sampling of Benthos	1 4 5 7 8 9 12 13 14 15 16 19 20
Observation of Coastal Organism	1 2 13 22
Climate	

Notes : ● New Moon ◐ Waxing Moon ○ Full Moon ◑ Waning Moon; ○ Very Fine ⦶ Fine ◎ Cloudy ● Rainy

3.2 Tidal Currents

3.2.1 Consecutive Anchored Observation of Tidal Currents

(1) Purpose

The purpose of consecutive anchored observation of tidal current is to clarify the statistical characteristics of tidal currents around the Abu Dhabi Island and also to obtain the fundamental information necessary for the numerical calculation of oil dispersion.

(2) Observation Location

The locations for the consecutive observation of tidal currents are shown in Fig. 3.2.1. The eight locations were selected as observation sites so that the general features of the tidal currents in the sea around the Abu Dhabi Island could be ascertained.

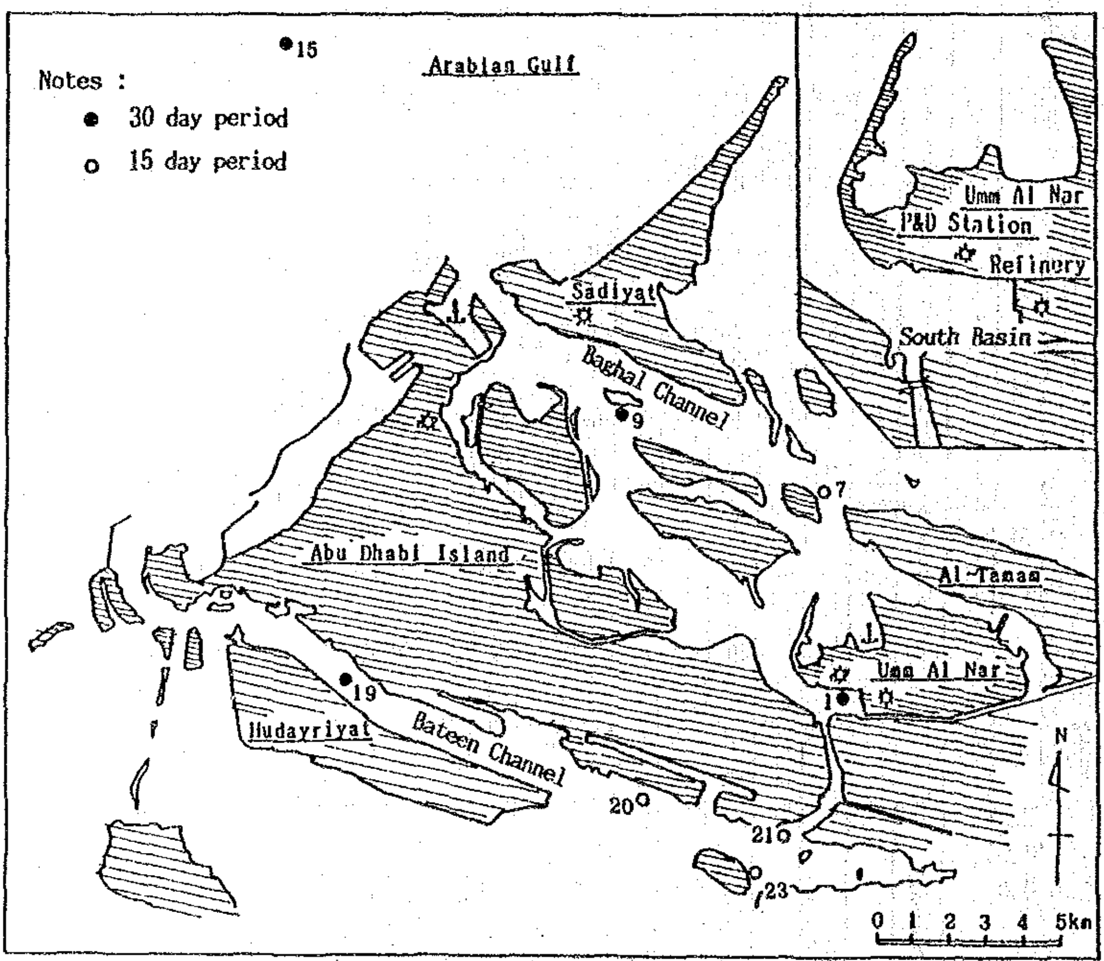


Fig. 3.2.1: Location of Consecutive Observation of Tidal Currents

(3) Duration of Observation

The durations of observation at each site were as follows :

1) Second Field Survey

Site 1	September 26 to November 1, 1988	(36 days)
Site 7	October 15 to October 31, 1988	(16 days)
Site 9	September 27 to October 31, 1988	(34 days)
Site 15	October 8 to November 8, 1988	(31 days)
Site 19	September 27 to November 1, 1988	(35 days)
Site 20	September 26 to October 15, 1988	(19 days)
Site 21	September 26 to October 15, 1988	(19 days)
Site 23	October 15 to November 1, 1988	(17 days)

2) Third Field Survey

Site 1	January 23 to February 25, 1989	(33 days)
Site 7	January 24 to February 11, 1989	(18 days)
Site 9	January 24 to February 26, 1989	(33 days)
Site 15	January 28 to February 28, 1989	(31 days)
Site 19	January 23 to February 25, 1989	(33 days)
Site 20	February 11 to February 26, 1989	(15 days)
Site 21	February 11 to February 26, 1989	(15 days)
Site 23	January 23 to February 25, 1989	(33 days)

(4) Method of Observation

The observation of tidal currents was carried out with the self-recording current meter of RCM-4S type. According to the magnitude of tidal currents at each site, the current meter was installed at the site of a small current speed (Sites 1 and 15) by way of Case-1 and at the site of a large current speed (Sites 7, 9, 19, 20, 21 and 23) by way of Case-2.

A sketch of the installation of the current meter is shown in Fig. 3.2.2.

Case I

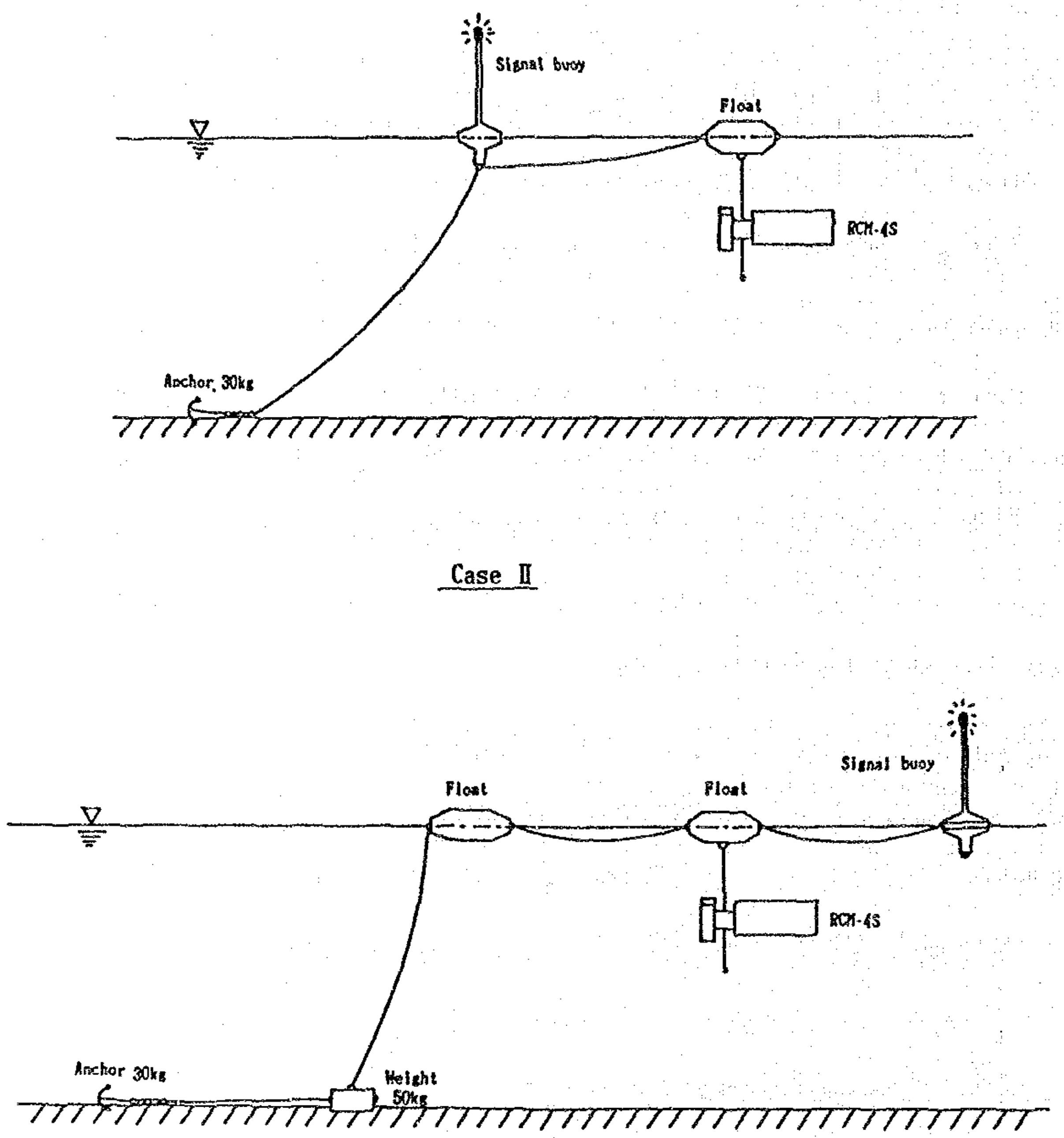


Fig. 3.2.2: Sketch of Installation of Current Meter

(5) Arrangement and Analysis of Tidal Current Observation

Using the results of tidal current observations, the following arrangement and analysis were conducted:

1) Outlines of Current Conditions

* Scattering plot
* Component current curve
* Frequency distribution of current direction
* Frequency distribution of current speed

2) Analysis of Tidal Current Characteristics by Harmonic Analysis

* Harmonic constants
* Main current direction
* Average current over observation period
* Disharmonic constants

3) Prediction of Current Conditions during Spring Tide Period

* Hodograph
* Chart of current conditions

4) Analysis of Periodic Characteristics

* Short-term periodicity
  - Correlation curve
  - Power spectrum chart
* Long-term periodicity
  - Average movement vector of tidal currents over a 25 hour period
  - Advance vector

5) Analysis on Diffusion Field of Tidal Currents

* Diffusion coefficient

(6) Observation Results of Tidal Currents

1) Second Field Survey

(a) Outlines of Current Conditions

Using the whole observation results of current directions and speeds which were recorded in the field survey, a scattering plot at each site is drawn up. The scattering plot, in which the current directions and speeds of each 10 minutes period is plotted on rectangular coordinates, shows roughly the current conditions at each site during the whole observation period.

The scattering plots are shown in Fig. 3.2.3.

According to the scattering plots, it is clear that returning currents parallel to the respective channel were dominated at Site 7, Site 9, Site 19, Site 20, Site 21 and Site 23 which are located in Baghal Channel or Bateen Channel. The inshore stream towards the interior of the lagoon and the offshore stream are distributed to the same degree at Site 9 and Site 19.

On the other hand, the current speed of the south east (SE) direction towards the interior of Bateen Channel at Site 20 and that of north (N) direction at Site 23 was larger than that of the opposite direction respectively. Current speed at Site 1 near the sea water intake facilities of Umm Al Nar Station was generally low, and eastward stream from the inlet of Umm Al Nar Station south basin to the interior was high to a certain degree.

On the other hand, the extent of south (S) or N direction was relatively higher than that of east (E) or west (W) direction at offshore Site 15 but the current speed was lower compared to that of the observation sites in the channels. Regarding periodicity of tidal currents, semi-diurnal or diurnal variation of tidal currents was distinctly shown at the sites in both the channels. These periodic variations corresponded well to the variations of tidal level as shown in Fig. 3.2.4.

That is to say, semi-diurnal currents dominating during the spring tide period when semi-diurnal tidal level variation was dominant, and diurnal currents dominating during the neap tide period when diurnal inequality became remarkable. Both east component speed and north component speed were low at Site 1 and semi-diurnal variation was observed in the east component speed during the spring tide period.

On the other hand, current speed at Site 15 was not so high as that at the sites in both the channels, but semi-diurnal variation during the spring tide period and diurnal variation during the neap tide period were observed, similarly to the other sites.

Direction and frequency distributions of current are shown in Fig. 3.2.5, and speed and frequency distributions of current are shown in Fig. 3.2.6.

Outlines of current direction at each site are shown in Table 3.2.1. According to this table, returning currents parallel to the respective channel were dominant at Site 7, Site 9, Site 19, Site 20, Site 21 and Site 23 in Baghal Channel or Bateen Channel and the appearance of the frequency of the reciprocating currents was 60 to 90%.

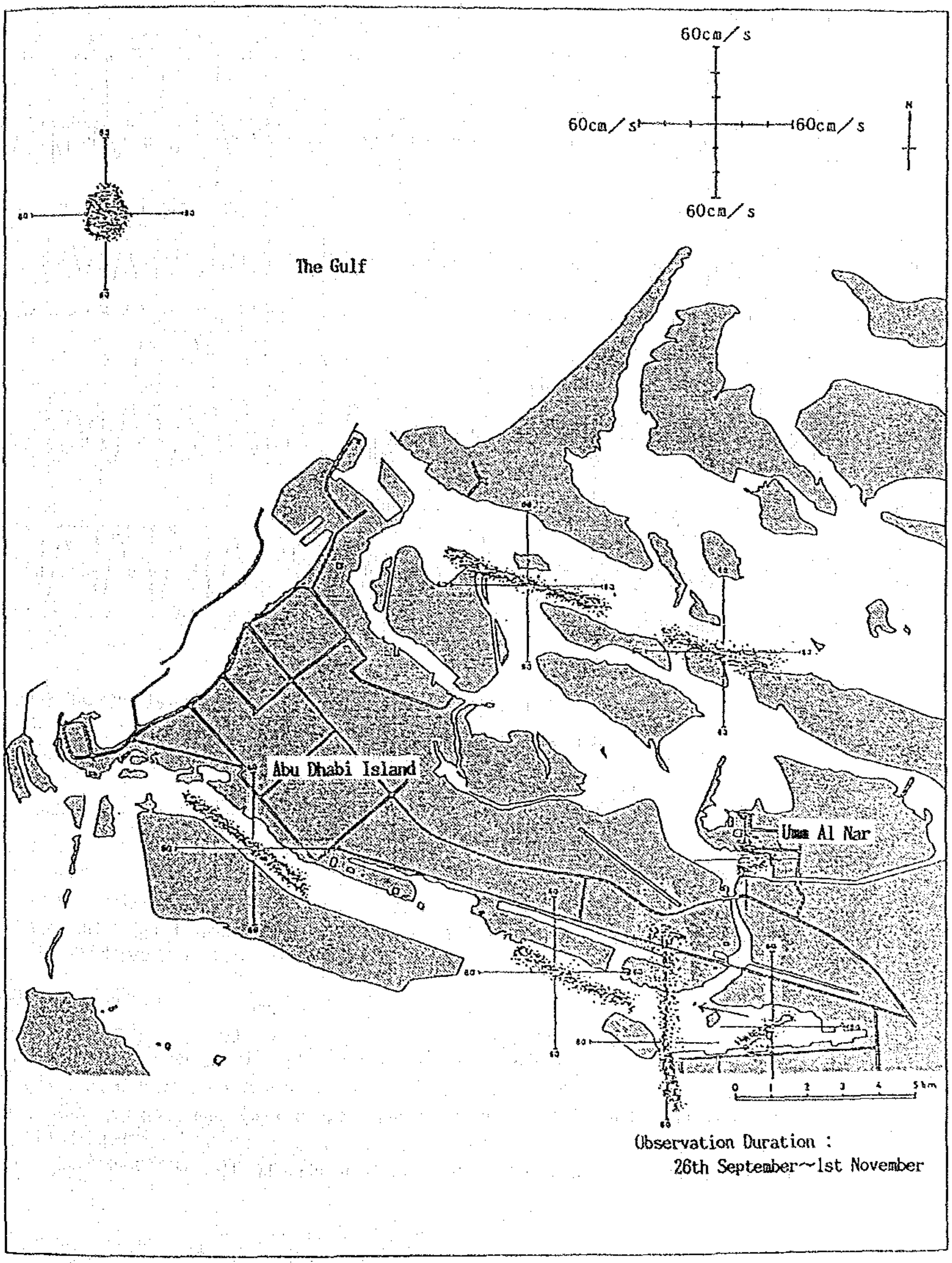
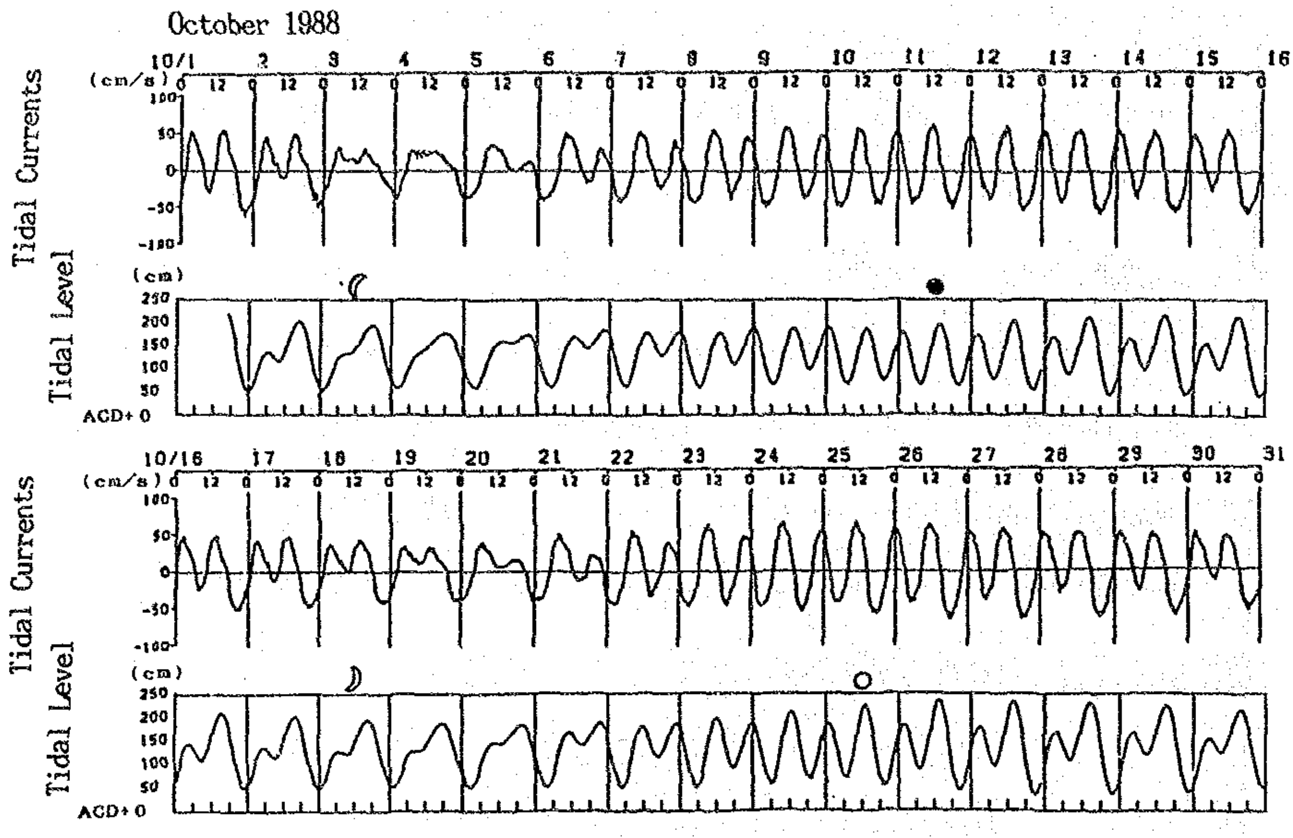


Fig. 3.2.3: Scattering Plots of Tidal Current Observations Records in Second Field Survey



Remarks :

Tidal Currents---East Component of Observations at Site 9

Tidal Level---Observations at Mina Zayed

Fig. 3.2.4: Typical Relations between Tidal Level and Tidal Currents

There was not a dominant direction at Site 1 near the sea water intake facilities of Umm Al Nar Station and at offshore Site 15, but the frequency of E or SW direction, was to some extent in excess respectively.

Outlines of current speed at each site are shown in Table 3.2.2. According to this table, current speed at Site 1 near the intake was the lowest speed at all sites, and next at offshore Site 15 and at Site 21 in Bateen Channel and appearance frequency of lower speed classes was high. On the other hand, the highest speed was recorded at Site 23 and frequency of each class in 0 to 50 cm/s at 10 cm/s interval respectively tended to distribute at the appearance frequency of 10 to 20% at the other sites.

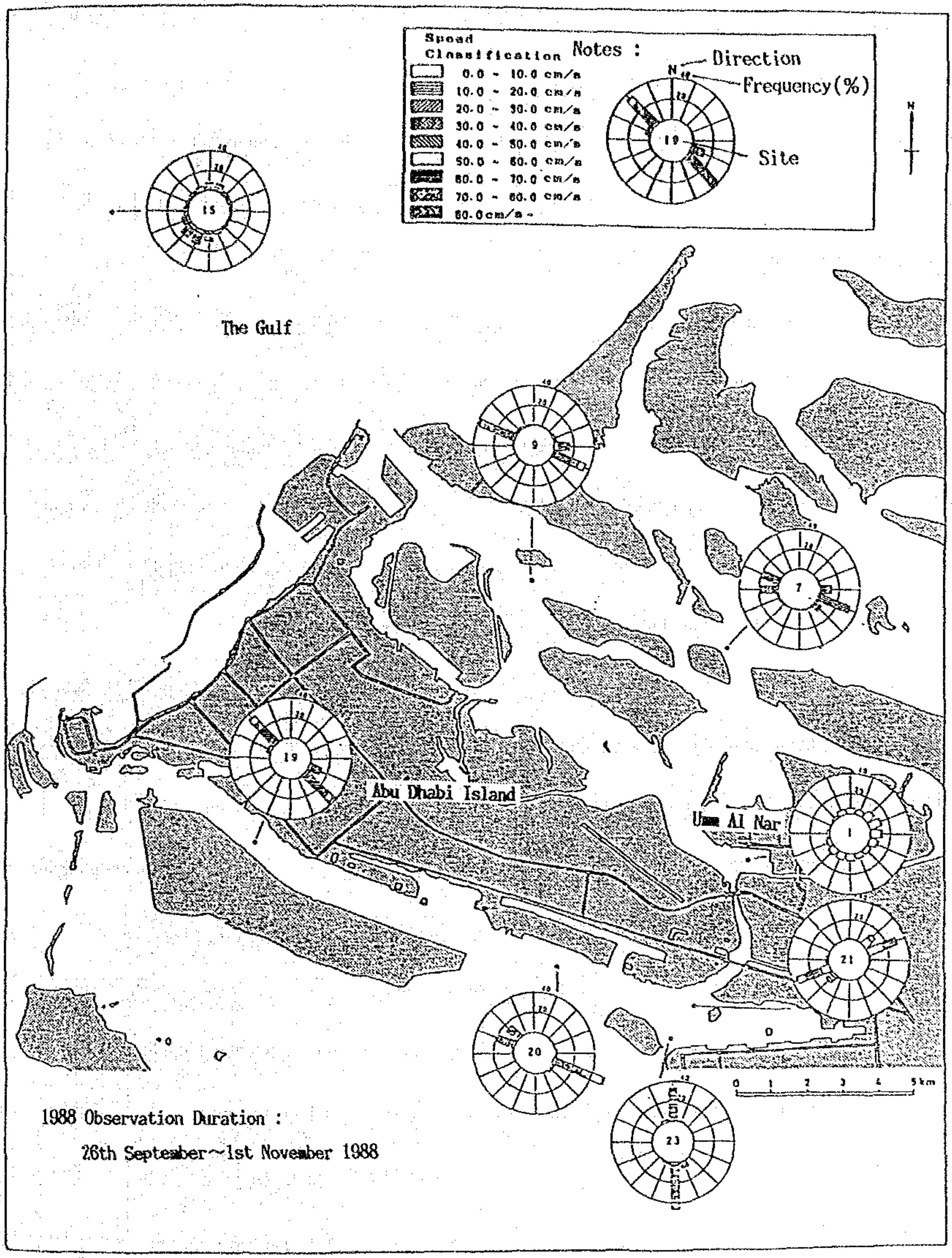


Fig. 3.2.5: Direction and Frequency Distributions of Current in Second Field Survey

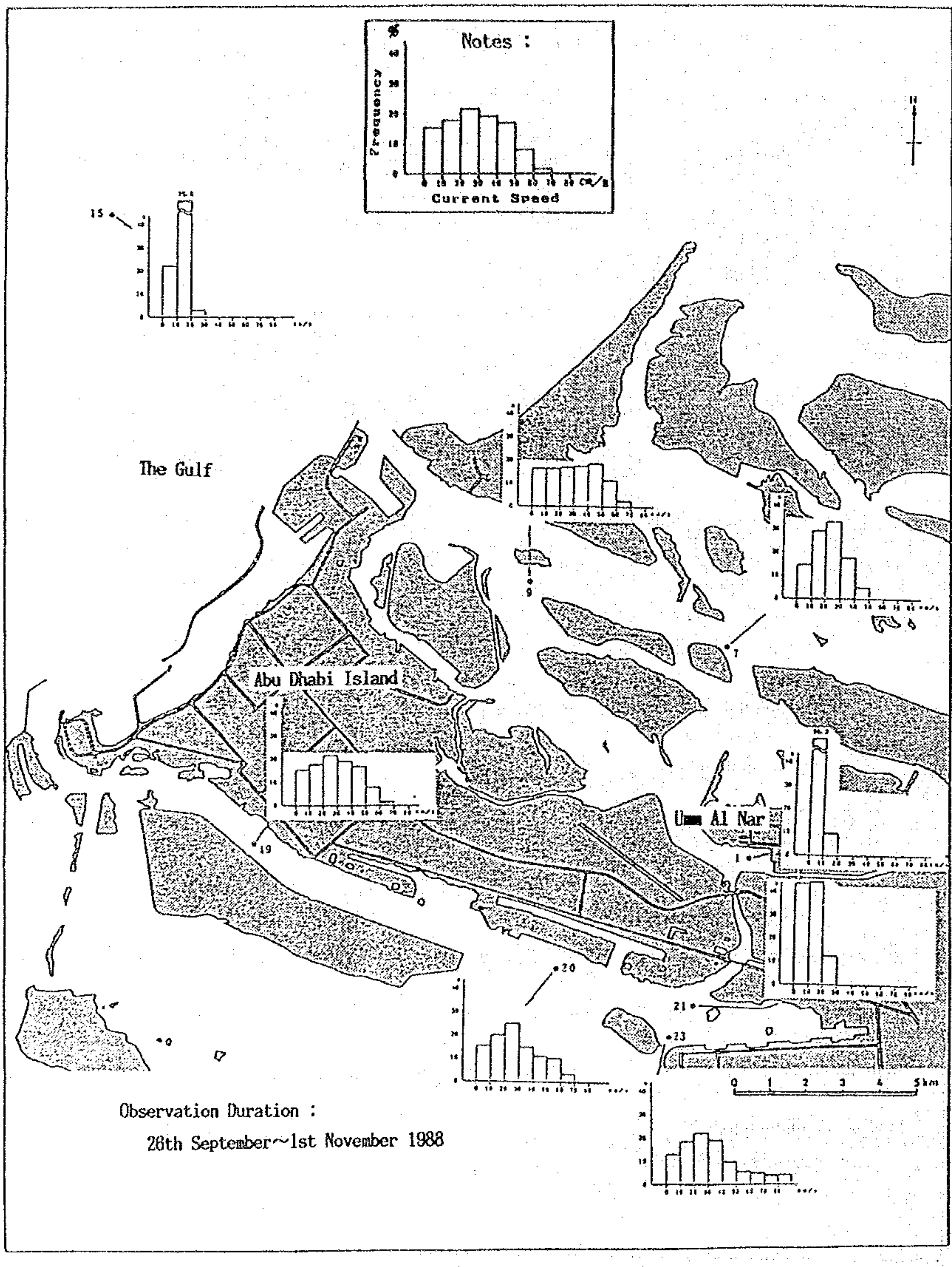


Fig. 3.2.6: Speed and Frequency Distribution of Current in Second Field Survey

Table 3.2.1: Outlines of Current Direction in Second Field Survey

Site	Hydrographic Conditions
1	Dominant direction wasn't shown. Frequency of E direction was rather in excess.
7	Frequency of ESE and W-WNW directions was very much.
9	Dominant direction was ESE or WNW and its frequency was more than 70 %.
15	Dominant direction wasn't shown. Frequency of SW directin was rather in excess.
19	Dominant direction was SE or NW . Its frequency was more than 70%.
20	Dominant direction was ESE, WNW, or NW. Its frequency was more than 80%.
21	Dominant direction was ENE or WSW direction. Its frquency was more than 60 %.
23	Dominant direction was N or S direction. Its frequency was more than 80%.

Table 3.2.2: Outlines of Current Speed in Second Field Survey

Site	Hydrographic Conditions
1	The range of 0-10cm/s was occupied more than 90%.
7	The range of 0-60cm/s was occupied very much. The class of 20-30cm/s showed the most frequency.
9	The range of 0-80cm/s was occupied very much. Frequency of each class in 0-50cm/s was more than 15%.
15	The range of 0-30cm/s was occupied very much. Frequency of 10-20cm/s class was about 75%.
19	The range of 0-70cm/s was occupied very much. Frequency of each class in 0-50cm/s was 15-20%.
20	The range of 0-70cm/s was occuoied very much. Frequency of 20-30cm/s class was about 25 %.
21	The range of 0-40cm/s was occupied very much. Frequency of 0-20cm/s values was about 90 %.
23	The range of 0-100cm/s was occupied vgery much. Frequency of more than 50cm/s was about 20%.

Table 3.2.3: Outlines of Harmonic Analysis Results of Tidal Currents in Second Field Survey

Site	Main Direction (deg)	M_2 (cm/s)	S_2 (cm/s)	K_1 (cm/s)	O_1 (cm/s)	U_0 (cm/s)
1	74	3.1	1.6	2.4	1.6	1.9
7	285	22.9	10.2	17.3	8.5	1.9
9	287	34.5	16.0	28.1	13.0	3.1
15	18	7.9	4.0	12.6	6.2	2.3
19	308	32.0	13.7	28.9	14.6	1.8
20	297	30.6	14.4	21.4	8.7	13.2
21	61	11.6	5.6	9.5	4.4	2.7
23	357	37.5	15.3	30.2	14.5	3.2

b) Analysis on Characteristics of Tidal Currents by Harmonic Analysis

Outlines of harmonic analysis results of tidal currents are shown in Table 3.2.3. According to this table, the amplitude of the M_2 component current was the highest value (3.1 to 37.5 cm/s) of all component currents at Site 1, Site 7, Site 9, Site 19, Site 20, Site 21 and Site 23 except Site 15 and next that of K_1 component current was high at 2.4 to 30.2 cm/s. On the other hand, that of K_1 component current is the highest value of all component currents at offshore Site 15, next M_2 component is high and the distribution tendency of component at Site 15 was different from those at the other sites.

The average current speed over the whole observation period (U_0) was in the range of 1.8 to 13.2 cm/s and the maximum current was observed at Site 20.

The nonharmonic constants were calculated from the amplitudes in main current direction and U_0 as shown in Table 3.2.4.

Table 3.2.4: Nonharmonic Constants Table of Tidal Currents in Second Field Survey

Site	M_2+S_2 (cm/s)	K_1+O_1 (cm/s)	$M_2+S_2+K_1+O_1$ (cm/s)	$\frac{K_1+O_1}{M_2+S_2}$ (−)	$\frac{U_0}{M_2+S_2+K_1+O_1}$ (−)
1	4.7	4.0	8.7	0.85	0.22
7	33.1	25.8	58.9	0.78	0.03
9	50.5	41.1	91.6	0.81	0.03
15	11.9	18.8	30.7	1.58	0.07
19	45.7	43.5	89.2	0.95	0.02
20	45.0	30.1	75.1	0.67	0.18
21	17.2	13.9	31.1	0.81	0.09
23	52.8	44.7	97.5	0.85	0.03

Where,

$M_2 + S_2$: Semi-diurnal component current sum
$K_1 + O_1$: Diurnal component current sum
$M_2 + S_2 + K_1 + O_1$: Four principal component current sum
$(K_1 + O_1)/(M_2 + S_2)$: Classification function of tidal current types

According to this table, the minimum of 4 principal component currents sums was 8.7 cm/s at Site 1 nearby the sea water intake facilities of Umm Al Nar Station and the range of the sums at the other sites except Site 1 was 30.7 to 97.5 cm/s. The semi-diurnal component current sum was respectively larger than the diurnal component current sum at each site except offshore Site 15.

The tidal type, which is evaluated from the value of French type classification function shown in 2.3, was the mixed type at each site except Site 15 and the diurnal type at only Site 15 respectively. Regarding the

ratio of Uo to 4 principal component currents, the ratio was very small at less than 0.1 at each site except Site 1 and Site 20.
Therefore, it seems that the average current has little influence on current conditions at these sites.

c) Prediction of Current Conditions during Spring Tide Period

According to the harmonic analysis results of tidal currents, it was clear that among the tidal current components around the Abu Dhabi Island, the semidiurnal M_2 and S_2 component currents were to some extent larger than the diurnal K_1 and O_1 component currents except at Site 15, but both the component currents were large to the same extent.

Current conditions for the maximum spring tide period were accordingly predicted. Mina Zayed was designated as the standard point of tidal time which was based on the observations of tidal level in this study.

The predicted current conditions at the sites in the channels are shown in Fig. 3.2.7 and the hodographs of Site 1 and Site 15 are shown in 3.2.8 and 3.2.9 respectively.

According to these figures, the time when offshore ebb current, namely from the interior of the lagoon to the Gulf, becomes strongest is 5 to 7 hours after the time of higher high water level (H.H.W.L.) at Mina Zayed. It is likely that the time is relatively early in the offing and Baghal Channel and that the time is later in the interior of the lagoon and Bateen Channel. At Site 1 and Site 21, the time is latest of 7 hours after the time of H.H.W.L.

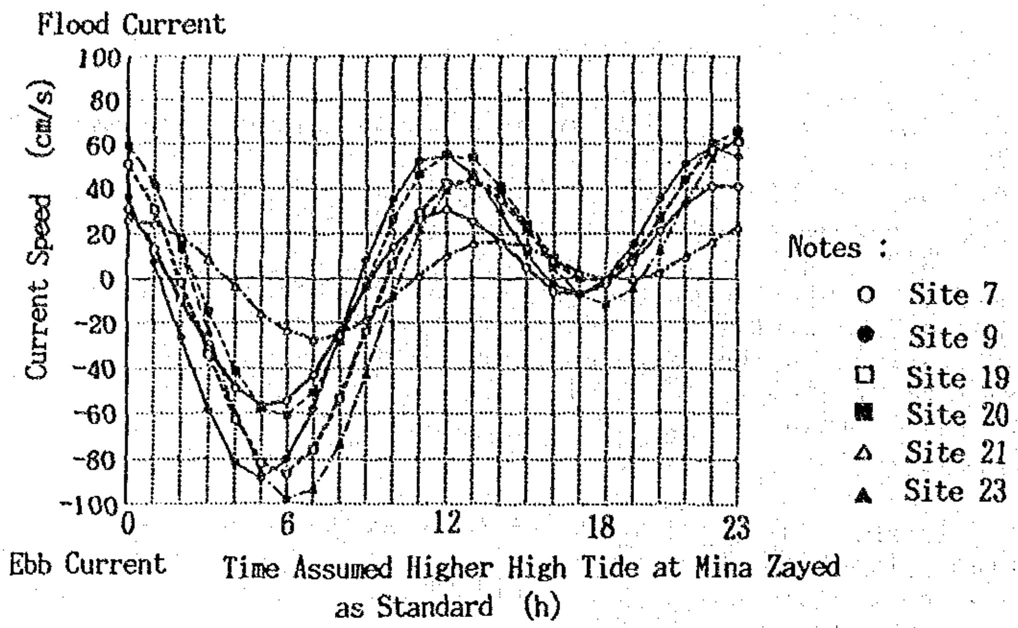
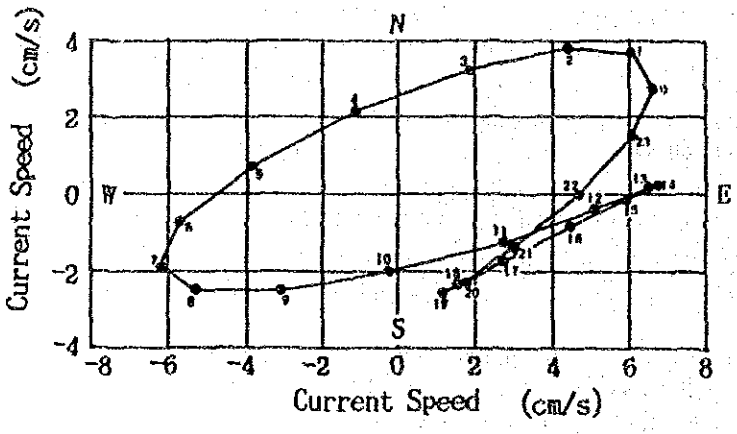
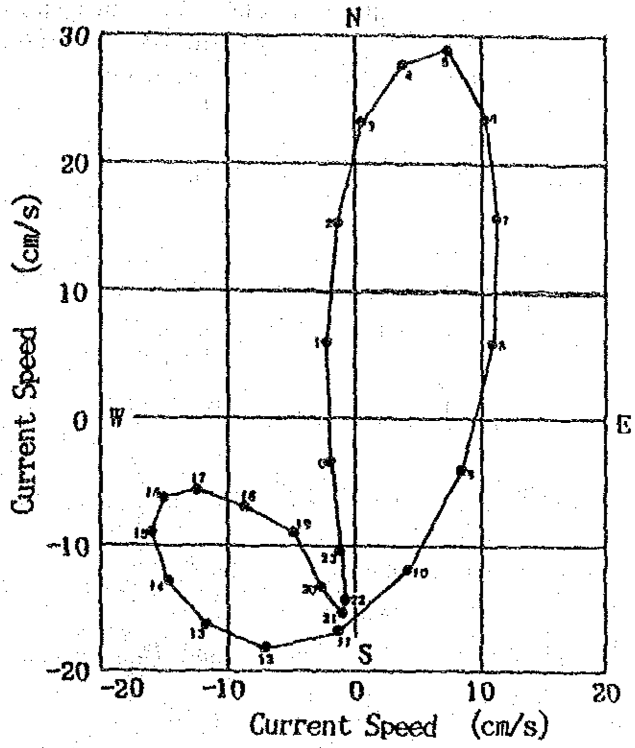


Fig. 3.2.7: Predicted Current Conditions in Channel at Maximum Spring Tide Period in Second Field Survey



Remarks : Figure is time assumed higher high tide at Mina Zayed as standard. (h)

Fig. 3.2.8: Predicted Hodograph of Site 1 at Maximum Spring Tide Period in Second Field Survey



Remarks : Figure is time assumed higher high tide at Mina Zayed as standard. (h)

Fig. 3.2.9: Predicted Hodograph of Site 15 at Maximum Spring Tide Period in Second Field Survey

On the other hand, the time when inshore flood current, namely from the Gulf to the interior of the lagoon becomes strongest is 2 hours before H.H.W.L. to 0 hours after H.H.W.L. and it is likely that the time is early in Baghal Channel and that the time is late in Bateen Channel.

Similarly to the ebb current, the time is latest at Site 1 and Site 21.

The maximum current speed at each site is in the range of 6 to 99 cm/s (the average is 57 cm/s) in the ebb current and is in the range of 7 to 63 cm/s (the average is 41 cm/s). Regarding the average of the maximum current speed at each site, the ebb current speed is to some degree larger than the flood current speed.

d) Periodic Characteristics of Tidal Currents

To ascertain periodic characteristics of tidal currents around the Abu Dhabi Island, correlation curve and power spectrum density on main current directions were calculated from the observations of current directions and speeds of tidal currents were calculated. An example of correlation curve and power spectrum density is shown in Fig. 3.2.10 and Fig. 3.2.11 respectively.

The vertical axis shows power spectrum density and the horizontal axis shows period in Fig. 3.2.11. The periodic variation of dominant tidal current speed is shown from peak's position in this figure.

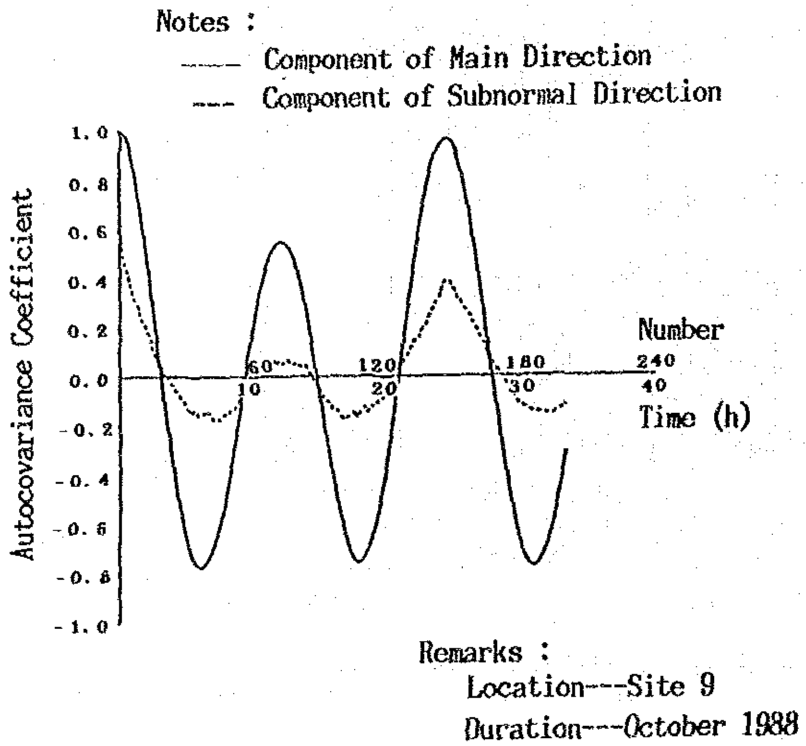
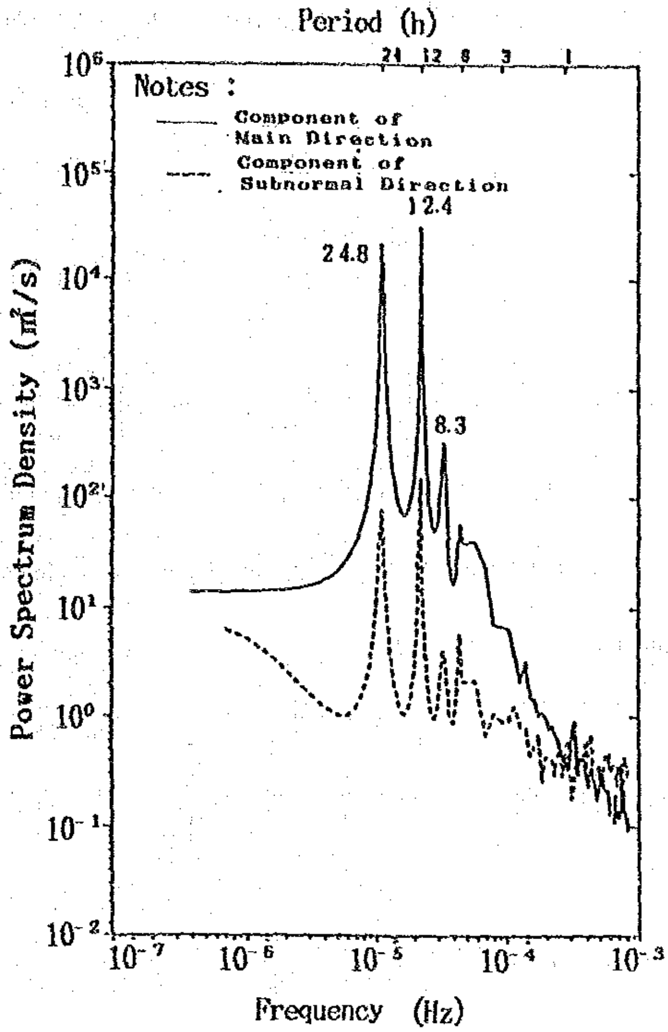


Fig. 3.2.10: Example of Correlation Curve



Remarks :
Location---Site 9
Duration---October 1988

Fig. 3.2.11: Example of Power Spectrum Density Curve

The dominant cycle periods at each site are as shown in Table 3.2.5. According to this table, there were peaks of power spectrum density at the period of about half a day and of about a day in the variation of tidal currents at each site. Also, there were no peaks in the long periodic side of more than a day at each site, but it is likely that the power spectrum density in the long periodic side became higher at only Site 15.

Table 3.2.5: Dominant Cycle Periods of Tidal Currents in Second Field Survey

Site	1	7	9	15	19	20	21	23
Period (h)	12.4	12.4	12.4	12.4	12.4	12.2	12.2	12.4
	24.8	24.8	24.8	23.9	24.8	24.8	27.3	24.8

The long-term periodicity of tidal currents was analyzed using average movement of tidal currents over a 25 hour period. An example of average movement is shown in Fig. 3.2.12. The analysis results are shown in Table 3.2.6. According to this table, it is very likely that the frequency of the current direction was more in the direction from the offing to the interior of the lagoon in both the channels and the eastward stream at Site 1 and the southward stream at site 15 were well observed.

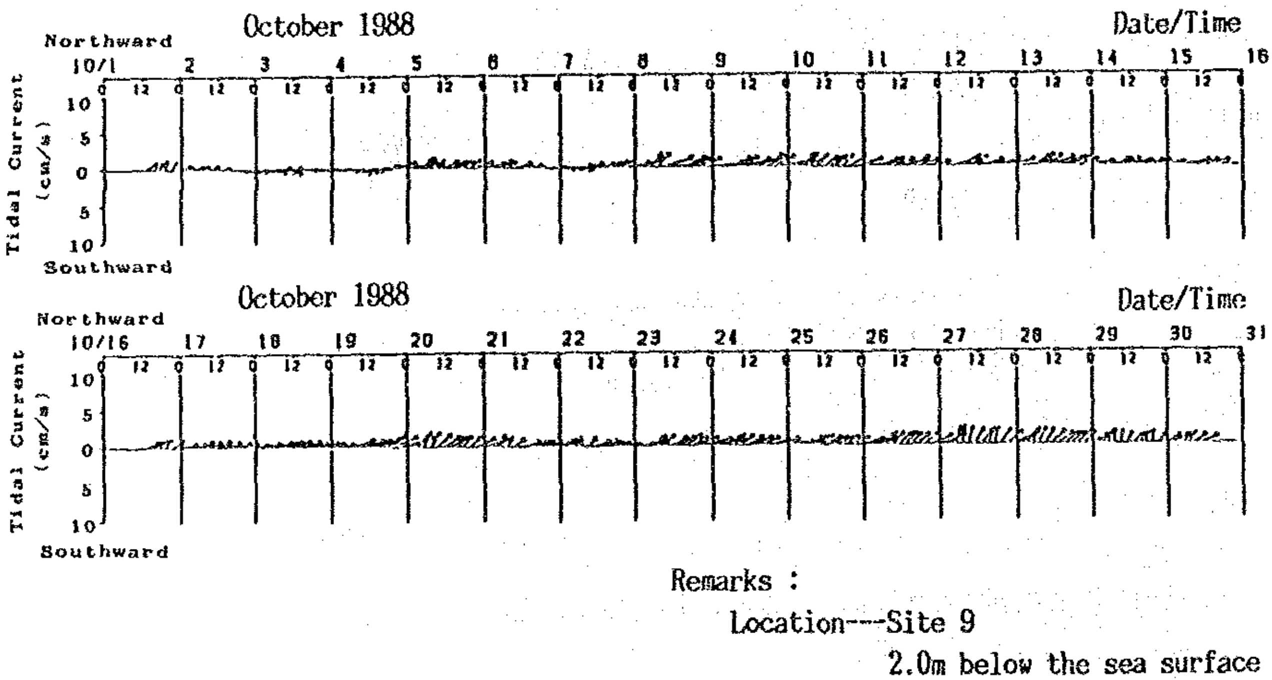


Fig. 3.2.12: Example of Average Movement of Tidal Currents

Table 3.2.6: Outlines of Analysis Results by Average Movement of Tidal Currents in Second Field Survey

Site	Hydrographic Conditions
1	Frequency of NE-SE currents was rather in excess and the current speed was slow during the whole period.
7	Frequency of E currents was very much during the whole period. The current speed of about 5cm/s was very numerous.
9	Frequency of N-E currents was very much during the whole period. The current speed was slow level of a few cm/s.
15	Frequency of S-SW currents was rather in excess. The current speed was varied within the range of 0-10cdm/s.
19	Frequency of SE direction from the open sea to the interior of channel was very much during the whole period. The nearly diurnal period in current speed was found.
20	The ESE direction from the open sea to the interior of channel was dominant during the whole period. The current speed was almost more than 10cm/s and was the highest values of all sites.
21	Frequency of SW direction from the interior of channel to the open sea was more during the whole period. The current speed was slow generally.
23	The N-NNE directions were almost most during the whole period. The current speed was about 5cm/s generally.

The average movement at the whole sites was generally small in the range of zero to 10 cm/s. Furthermore, the above mentioned long-term periodic tidal currents were confirmed using advance vector. The advance vector was figured by the way that the moving distance and direction each 10 minutes is calculated from the observations of tidal currents and that the distance and the direction are consecutively plotted on rectangular coordinates and the plotted points are sequentially connected with lines.

A stream path in this figure does not express an actual path of water movement, but it is available for getting an understanding of the features of tidal currents.

Advance vector was figured from average movement over a 25 hour period in order to see the constant current of a long-term period longer than one day. An example of advance vector is shown in Fig. 3.2.13. According to this advance vector, the stream path at each site had a similar tendency to the results of analysis with the average movement vector.

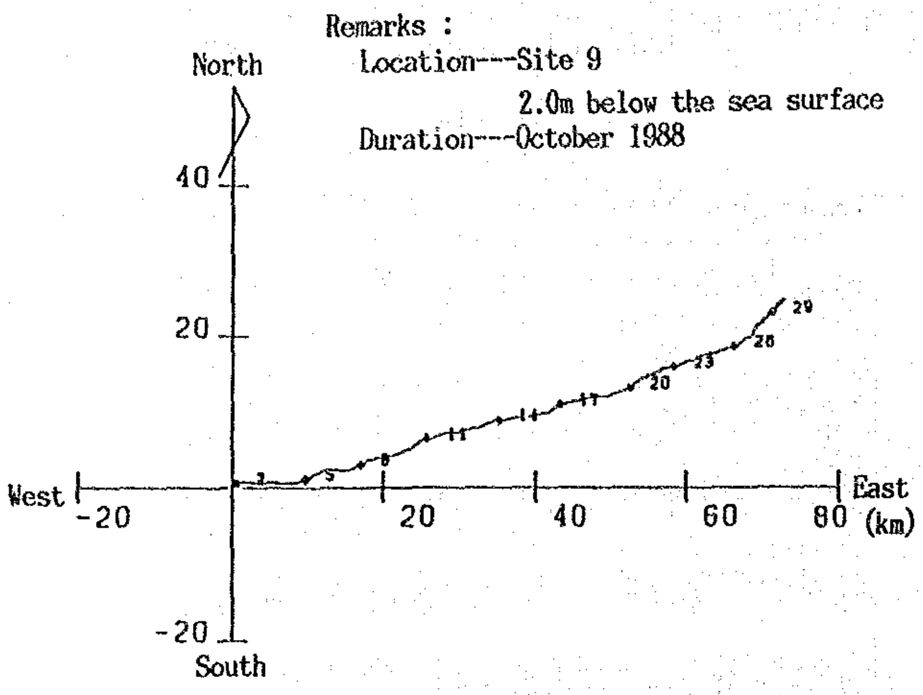


Fig. 3.2.13: Example of Advance Vector of Tidal Currents

e) Analysis on Tidal Currents Distribution

Diffusion coefficients were calculated from the observed data which were obtained through excluding the current components of longer period than 12 hours. The calculation results are as shown in Table 3.2.7.

According to this table, the diffusion coefficient in main direction is in the range of 1.6 x 10^4 to 3.7 x 10^5 cm^2/s and the minimum and the maximum is respectively shown at Site 1 near the sea water intake facilities of Umm Al Nar Station and at Site 23. The diffusion coefficient in perpendicular direction is to the level of 10^3 to 10^4 cm^2/s.

Table 3.2.7: Diffusion Coefficient of Tidal Currents in Second Field Survey

Site	Main Direction (deg)	Component of Main Direction (cm^2/s)	Component of Subnormal Direction (cm^2/s)
1	65	1.6×10^4	1.7×10^4
7	285	1.5×10^5	1.1×10^4
9	285	1.5×10^5	2.7×10^3
15	20	2.7×10^4	1.1×10^4
19	310	9.4×10^4	4.1×10^3
20	295	1.1×10^5	6.7×10^3
21	65	8.9×10^4	4.2×10^3
23	0	3.7×10^5	8.0×10^3

2) Third Field Survey

a) Outlines of Current Conditions

The scattering plots of tidal current observation records are shown in Fig. 3.2.14. According to this figure, it is clear that reciprocating currents parallel to the respective channel were dominant at the sites in Baghal Channel and Bateen Channel.

At Site 1 near the sea water intake facilities of Umm Al Nar Station, the current speed was generally slow and the current direction was uniformly distributed in almost all directions, but the extent of the east direction was slightly higher. On the other hand, at offshore Site 15, the current direction was uniformly distributed in almost all directions, except the current speed of the SW direction which was high to some extent.

Regarding periodicity of tidal currents, semi-diurnal or diurnal variation of tidal currents was distinctly shown at the sites in both the channels. This periodic variation corresponded very well to the variation of tidal level. Both east component speed and north component speed were slow at Site 1 and the apparent periodicity of tidal current was not observed. On the other hand, the variation of the semi-diurnal or diurnal periodicity was observed at Site 15.

Direction and frequency distributions, and speed and frequency distributions of current are shown in Figs. 3.2.15 and 3.2.16, respectively.

Outlines of current direction at each site are shown in Table 3.2.8. According to this table, reciprocating currents parallel to the respective channel were dominant at Site 7, Site 9, Site 19, Site 20, Site 21 and Site 23 in Baghal Channel and Bateen Channel and the frequency of the reciprocating currents was more than 90%.

There was not the dominant direction at Site 1 near the sea water intake facilities of Umm Al Nar Station and at offshore Site 15, but the frequency of SW direction was slightly large at Site 15.

Outlines of current speed at each site are shown in Table 3.2.9. According to this table, the lowest current speed was recorded at Site 1 among the observation sites and then at Site 15, then at Site 21. On the other hand, the highest current speed was recorded at Site 23, and the current speed at each site, except Site 23, was widely distributed between 0 to 80 cm/s.

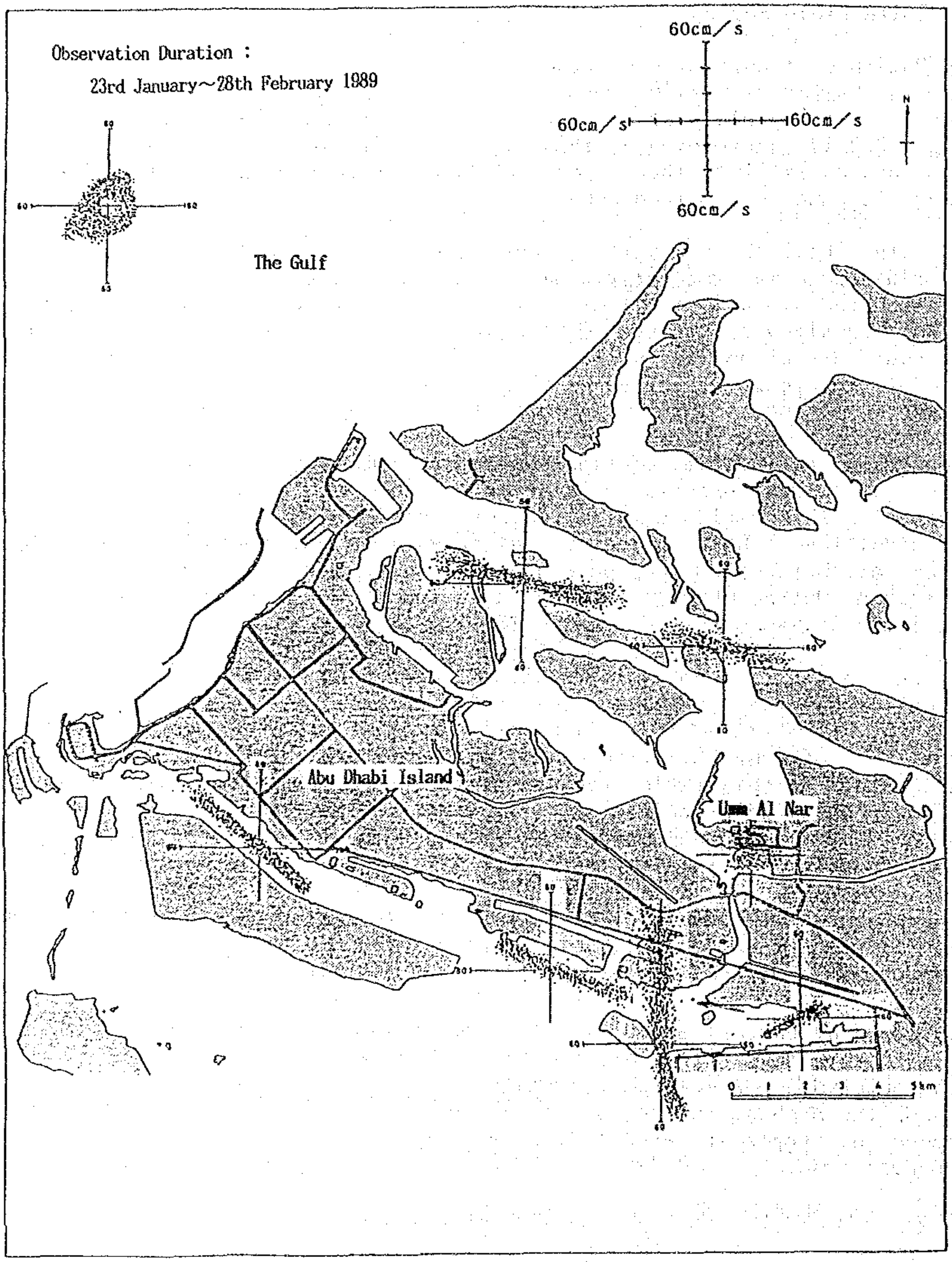


Fig. 3.2.14: Scattering Plots of Tidal Current Observation Records in Third Field Survey

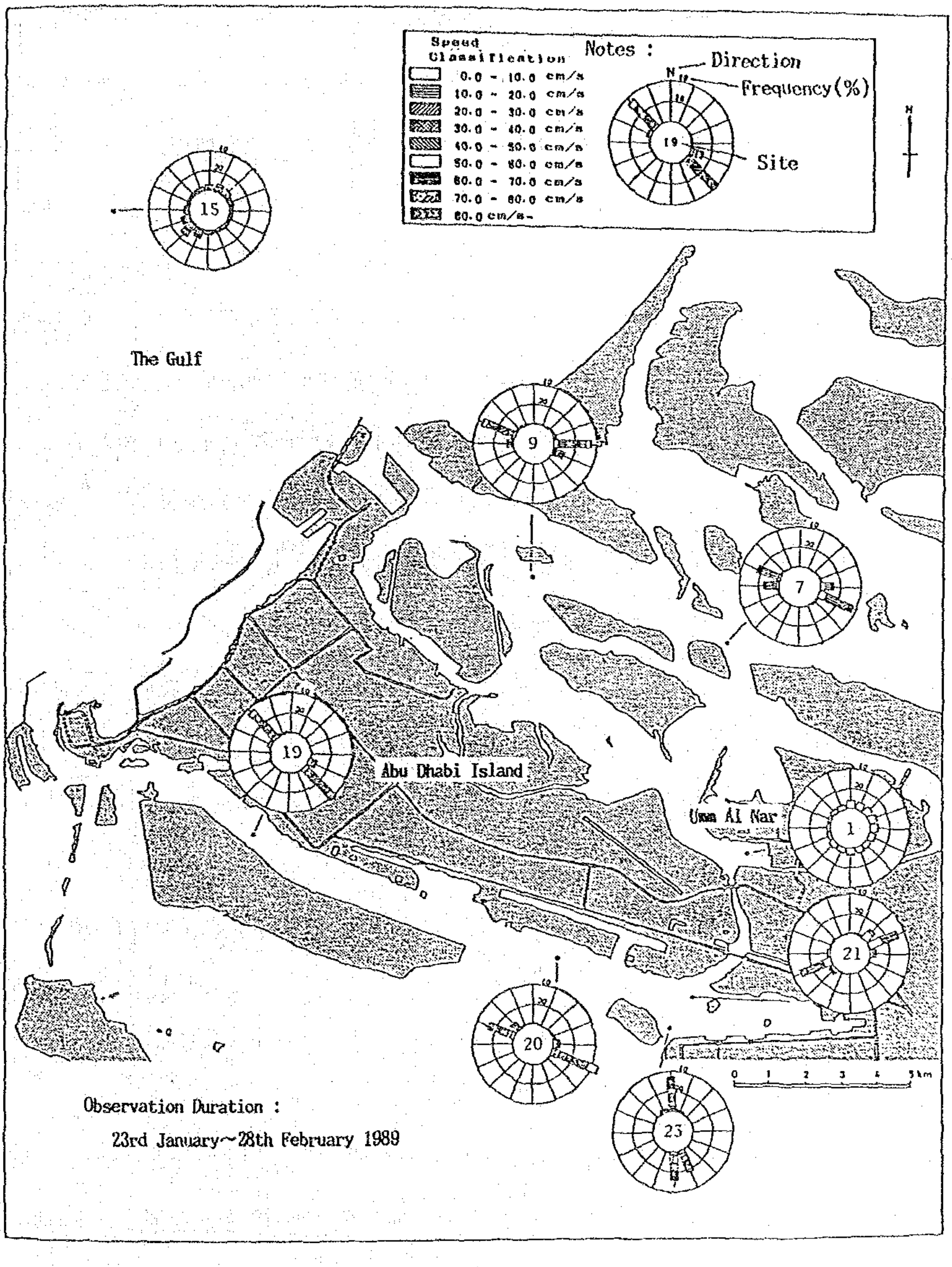


Fig. 3.2.15: Direction and Frequency Distributions of Current in Third Field Survey

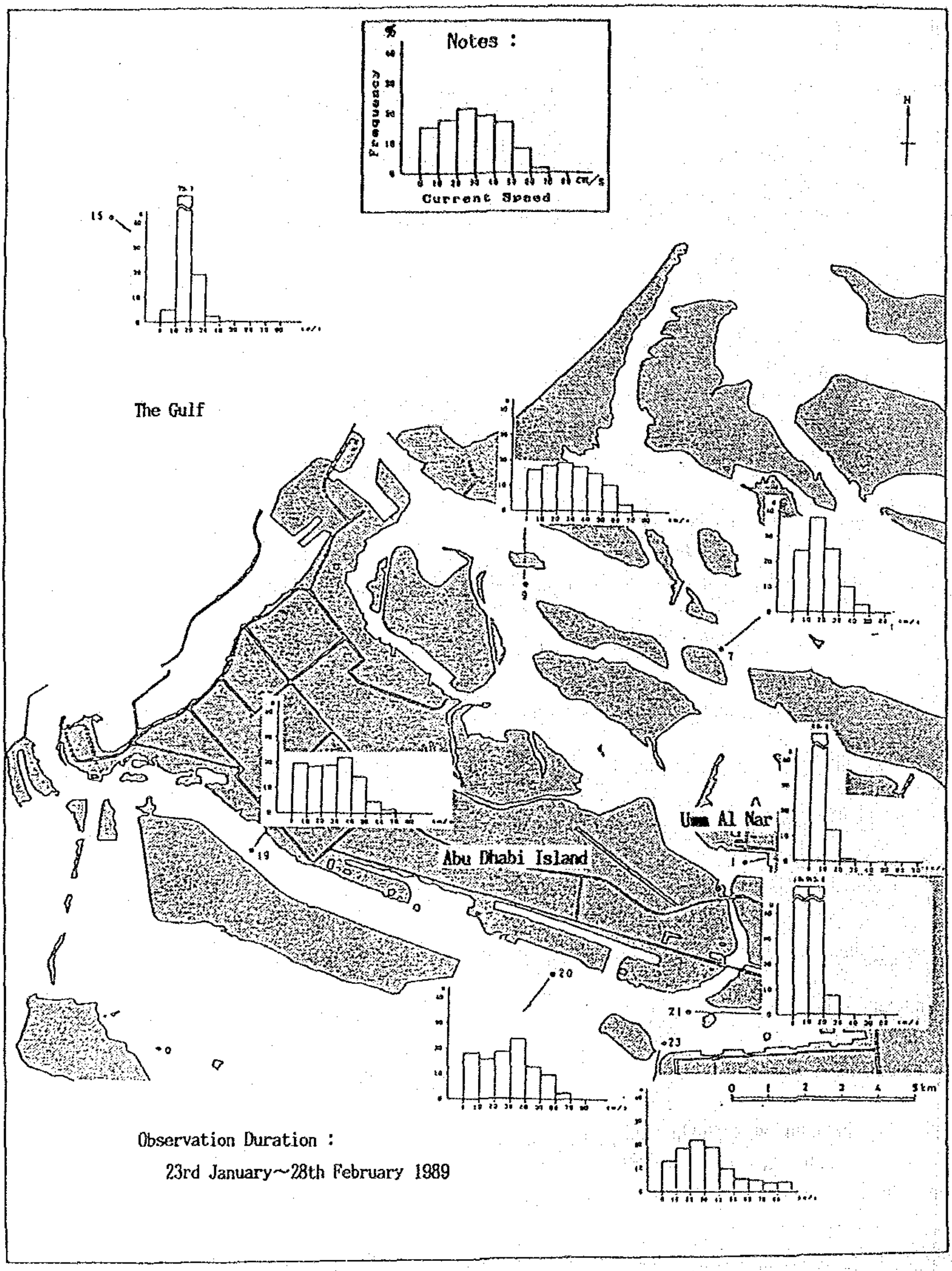


Fig. 3.2.16: Speed and Frequency Distributions of Current in Third Field Survey

Table 3.2.8: Outlines of Current Direction in Third Field Survey

Site	Hydrographic Conditions
1	Dominant direction wasn't shown.
7	Dominant direction was ESE or WNW and its frequency was more than 60%.
9	Dominant direction was E or WNW. Its frequency was more than 70%.
15	Dominant direction wasn't shown. Frequency of SW direction was rather in excess.
19	SE or NW direction was extremely dominant. Its frequency was more than 80%.
20	Dominant direction was ESE or WNW. Its frequency was more than 70%.
21	Dominant direction was ENE or WSW. Its frequency was more than 60%.
23	Dominant direction was N or SSE-S. Its frequency was more than 80%.

Table 3.2.9: Outline of Current Speed in Third Field Survey

Site	Hydrographic Conditions
1	The range of 0~10cm/s was occupied more than 80 %.
7	The range of 0~60cm/s was occupied very much. The class of 10-20cm/s showed the most frequency.
9	The range of 0~80cm/s was occupied very much. Frequency of each class in 0-50cm/s was more than 15%.
15	The range of 0~50cm/s was occupied very much. Frequency of 10-20cm/s class was more than 70 %.
19	The range of 0~80cm/s was occupied very much. Frequency of each class in 0-40cm/s was more than 15%.
20	The range of 0~70cm/s was occupied very much. Frequency of each class in 0~40cm/s was more than 15%.
21	The range of 0~40cm/s was occupied very much. Frequency of 0-20cm/s values was more than 90 %.
23	The range of 0-90cm/s wwas occupied very much. Frequency of more than 50cm/s was about 20%.

b) Analysis on Characteristics of Tidal Currents by Harmonic Analysis

Outlines of harmonic analysis results of tidal currents are shown in Table 3.2.10. According to this table, the amplitude of K_1 component current was the highest value (12.5 cm/s) of all component currents at offshore Site 15 and that of M_2 component current was the highest value (2.7 to 38.4 cm/s) at other sites. Also, Uo was in the range of 0.4 to 9.9 cm/s and the maximum current was observed at Site 20 in Bateen Channel.

The nonharmonic constants are shown in Table 3.2.11. According to this table, the minimum of four principal component currents sum was 7.1 cm/s at Site 1 near the sea water intake facilities of Umm Al Nar Station and the range of the sums at the other sites, except Site 1, was 26.6 to 93.1 cm/s. The semi-diurnal component current sum was higher than the diurnal component current sum at each site except offshore Site 15.

The tidal type was the mixed type at all the sites (F = 0.47 to 1.24). Regarding the ratio of average current over the whole observation period to four principal component currents, the ratio was very small at less than 0.1 at each site, except Site 1 and Site 20. Therefore, the average current has little influence on current conditions at those sites.

Table 3.2.10: Outlines of Harmonic Analysis Results of Tidal Currents in Third Field Survey

Site	Main Direction (deg)	M_2 (cm/s)	S_2 (cm/s)	K_1 (cm/s)	O_1 (cm/s)	U_0 (cm/s)
1	62	2.7	1.0	1.8	1.6	1.3
7	285	20.1	8.6	11.4	6.2	0.5
9	282	34.6	21.4	17.0	9.8	2.5
15	17	9.1	5.8	12.5	6.0	2.4
19	310	31.7	15.8	17.3	11.2	0.8
20	293	33.0	15.5	15.6	7.3	9.9
21	65	11.4	5.0	4.7	5.5	0.4
23	356	38.4	20.1	21.0	13.6	5.4

Table 3.2.11: Nonharmonic Constants Table of Tidal Currents in Third Field Survey

Site	$M_2 + S_2$ (cm/s)	$K_1 + O_1$ (cm/s)	$M_2 + S_2 + K_1 + O_1$ (cm/s)	$\frac{K_1 + O_1}{M_2 + S_2}$ (–)	$\frac{U_0}{M_2 + S_2 + K_1 + O_1}$ (–)
1	3.7	3.4	7.1	0.92	0.18
7	28.7	17.6	46.3	0.61	0.01
9	56.0	26.8	82.8	0.48	0.03
15	14.9	18.5	33.4	1.24	0.07
19	47.5	28.5	76.0	0.60	0.01
20	48.5	22.9	71.4	0.47	0.14
21	16.4	10.2	26.6	0.62	0.02
23	58.5	34.6	93.1	0.59	0.06

c) Prediction of Current Conditions during Spring Tide Period

According to the harmonic analysis results of tidal currents, it was clear that on the tidal current components around the the Abu Dhabi Island, the semi-diurnal M_2 and S_2 component currents are to some degree larger than the diurnal K_1 and O_1 component currents except at Site 15, but both the component currents exist to the same degree. Accordingly, current conditions during the maximum spring tide period ($M_2 + S_2 + K_1 + O_1$) were predicted. Mina Zayed was designated as the standard point of tidal time which is based on observations of tidal level.

The predicted current conditions at the sites in the channels, the hodograph of Site 1 and the hodograph of Site 15 are shown in Figs. 3.2.17, 3.2.18 and 3.2.19 respectively.

According to these figures, the time when the offshore ebb current, namely from the interior of the lagoon to the offing, becomes strongest is 5 to 7 hours after the time of H.H.W.L. at Mina Zayed and it is likely that the time of strongest ebb current is relatively early in the offshore area and in Baghal Channel and that the time of strongest ebb current is late in the interior of the lagoon and in Bateen Channel.

On the other hand, the time when inshore flood current, namely from the offshore area to the interior of the lagoon, becomes strongest in 2 hours before H.H.W.L. to 1 hour after H.H.W.L. at the site, except Site 15 where flood current becomes strongest at 12 hours after H.H.W.L. The time of the strongest flood current is early in Baghal Channel, late in Bateen Channel and latest at Site 1 and Site 21.

Regarding the maximum current speed at each site, the ebb current speed is to some degree higher than the flood current speed.

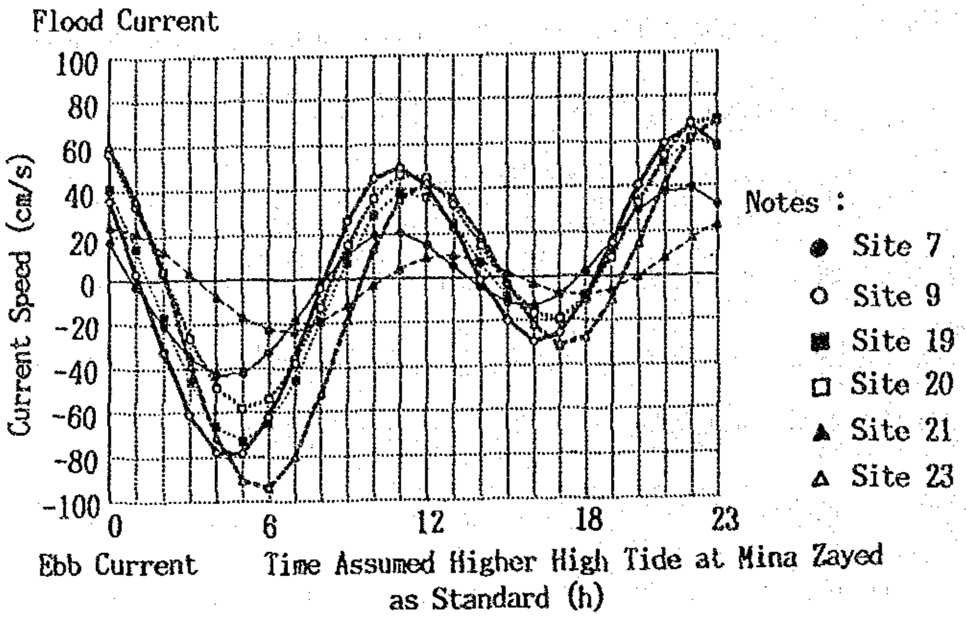
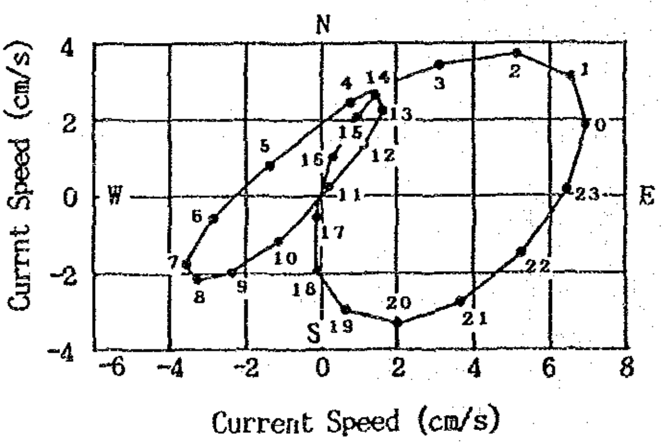
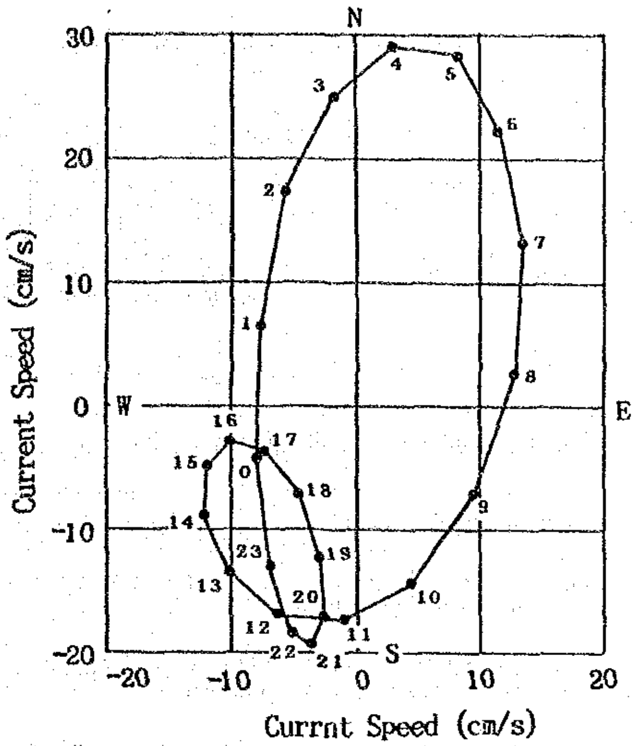


Fig. 3.2.17: Predicted Current Conditions in Channel at Maximum Spring Tide Period in Third Field Survey



Remarks : Figure is time assumed higher high tide at Mina Zayed as standard.(h)

Fig. 3.2.18: Predicted Hodograph of Site 1 at Maximum Spring Tide Period in Third Field Survey



Remarks : Figure is time assumed higher high tide at Mina Zayed as standard.(h)

Fig. 3.2.19: Predicted Hodograph of Site 15 at Maximum Spring Tide Period in Third Field Survey

d) Periodic Characteristics of Tidal Currents

The dominant cycle periods at each site are shown in Table 3.2.12. According to this table, there are the apparent peaks in power spectrum curve at the period of about half a day and of about one day in the variation of tidal currents at each site.

The long-term periodicity of tidal currents was analyzed using average movement of tidal currents over a 25-hour period. The summary of the analysis results are shown in Table 3.2.13.

Furthermore, advance vector charts were drawn using the average movement over a 25 hour period. According to the stream path on these charts, the above mentioned long-term periodic tidal currents were reconfirmed.

Table 3.2.12: Dominant Cycle Period of Tidal Currents in Third Field Survey

Site	1	7	9	15	19	20	21	23
Period (h)	12.2	12.2	12.4	12.2	12.4	12.0	12.4	12.4
	23.9	25.8	24.8	23.9	24.8	27.3	28.1	24.8

Table 3.2.13: Analysis Results by Average Movement of Tidal Currents in Third Field Survey

Site	Hydrographic Conditions
1	Frequency of NE-SE currents was rather in excess and the current speed was slow during the whole period.
7	Frequency of E currents was very much during the whole period. The current speed of less than 5cm/s was very much.
9	Frequency of N-E currents was so much during the whole period. The current speed was slow level of a few cm/s.
15	Frequency of S-SW currents was rather in excess. The current speed was varied within the range of 0-10cdm/s.
19	Frequency of SE direction from the open sea to the interior of channel or NW direction was very much during the whole period.
20	The ESE direction parallel to the channel was dominant during the whole period. The current speed was almost more than 10cm/s.
21	Frequency of SW direction from the interior of channel to the open sea was more during the whole period.
23	The N direction was almost most during the whole period. The current speed was about 20cm/s during most rapid stream period.

e) Analysis on Tidal Currents Distribution

Diffusion coefficients were calculated from the observed data which were obtained through excluding the current components of longer periods than 12 hours. These calculation results are shown in Table 3.2.14.

According to this table, the diffusion coefficient in the main direction is in the range of 2.2×10^4 to 3.6×10^5 cm^2/s and the minimum and the maximum is respectively shown at Site 1 near the sea water intake facilities of Umm Al Nar Station and at Site 23. The diffusion coefficient in subnormal direction is at a level of 10^3 to 10^4 cm^2/s.

Table 3.2.14: Diffusion Coefficient of Tidal Currents in Third Field Survey

Site	Main Direction (deg)	Component of Main Direction (cm^2/s)	Component of Subnormal Direction (cm^2/s)
1	62	2.2×10^4	2.7×10^4
7	285	1.5×10^5	4.9×10^3
9	282	1.0×10^5	3.8×10^3
15	17	3.3×10^4	2.2×10^4
19	310	1.1×10^5	3.1×10^3
20	293	1.9×10^5	5.0×10^3
21	65	9.4×10^4	5.1×10^3
23	356	3.6×10^5	1.4×10^4

(7) Summary

1) The marine field around the Abu Dhabi Island can be classified into the following 3 zones from the aspect of tidal current:

Strong Current Zone

Because of the geographical factor that Baghal Channel and Bateen Channel have the features of shallow water depth and narrow channel width respectively, tidal current speed was high in both channels and it reached 90 to 100 cm/s at the strongest current time. Tidal current direction was parallel to the channel.

Middle Current Zone

About 8 km offshore of the Abu Dhabi Island, there was no dominant current direction. However, it is likely that its tidal currents were reciprocating parallel to the seashore, namely, NE-ward or SW-ward. The frequency of a current speed of 10 to 20 cm/s were more than 70%.

Weak Current Zone

At Site 1 near the sea water intake facilities of Umm Al Nar Station, the current speed was very low and the frequency of zero to 10 cm/s was more than 80% . There was no dominant currents direction.

2) Regarding the current component, the semi-diurnal periodicity and the diurnal periodicity were apparently observed at each site and their variation corresponded well to variation of tidal level.

3) According to the harmonic analysis results, the tidal types were mixed type at all sites except offshore Site 15 of which tidal type was diurnal type almost similar to the mixed type observed in the summer survey.

4) According to the prediction results of current, it takes 5 to 7 hours to become the strongest ebb current which streams offshore after the tidal level of Mina Zayed reaches H.H.W.L. It is likely that it was early at Site 15 and at the sites in Baghal Channel, and that it was late at the sites in Bateen Channel and at Site 1 in the interior of the lagoon.

On the other hand, the time of the strongest flood current which streams inshore was 2 hours before to 1 hour after H.H.W.L. at all sites, except offshore Site 15, where it was 12 to 13 hours after H.H.W.L. at Mina Zayed. It is likely that it was early in Baghal Channel and that it was late in Bateen Channel and in the interior of the lagoon.

5) The observations of the third field survey in winter were almost similar to those of the second field survey in summer.

Currents of observation area were subject to rise and fall force of tidal level. In the channels around the Abu Dhabi Island, rapid reciprocating currents parallel to the channels were dominant. Around the intake of Umm Al Nar Station, current speed was rather slow according to the geographical characteristics that location of the intake was far from main strong currents.

3.2.2 Horizontal Observation by Current Drag

(1) Purpose

The purpose of horizontal observation by current drag is to clarify the horizontal characteristics of tidal currents around the Abu Dhabi Island.

(2) Observation Location

The observation by current drag was conducted in Baghal Channel, Bateen channel and the south basin near the sea water intake facilities of Umm Al Nar Station during the flood and ebb tide periods so that the Lagrange stream around the Abu Dhabi Island could be ascertained generally.

(3) Date of Observation

1) Second Field Survey

* Flood tide period on October 10, 1988
* Ebb tide period on October 11, 1988

2) Third Field Survey

* Ebb tide period on February 1, 1989
* Flood tide period on February 7, 1989

(4) Method of Observation

The current drag as shown in Fig. 3.2.20 was traced by observation boat and the distance moved and direction were determined sometimes. Observation layers were the 2 layers of 2 m and 7 m below the sea surface.

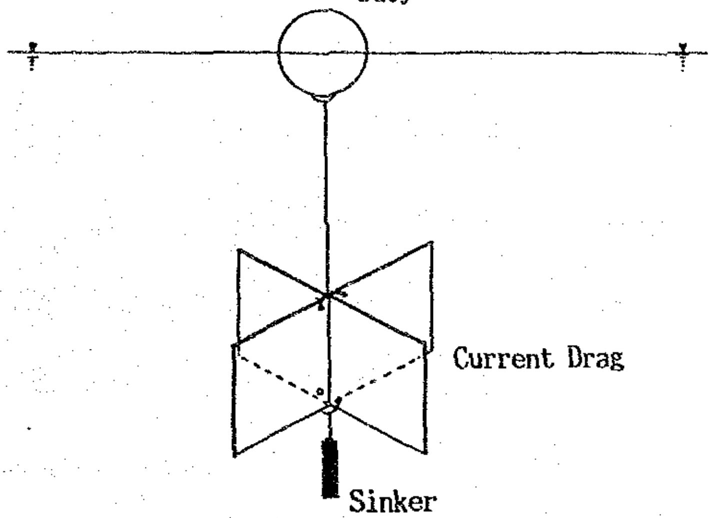


Fig. 3.2.20: Sketch of Current Drag

(5) Results of Observations

The observation results of current drag are shown in Figs. 3.2.21(1) to 3.2.21(4).

1) Flood Tide Period on October 10, 1988 in Second Field Survey

According to the results, the current drag moved inshore along the channel toward the interior of the lagoon with a speed of 25 to 68 cm/s at Sites 1, 2 and 3 in Baghal Channel, with a speed of 49 cm/s at Site 7 and with the speed of 27 cm/s at Site 8 in Bateen Channel respectively.

It moved SW-ward with a speed of 29 cm/s at Site 5 in the interior of the lagoon and moved S-ward with a speed of 45 to 65 cm/s at Site 6. It moved E-ward along the protection shore of Umm Al Nar Station with the low speed of about 10 cm/s at Site 4 near the sea water intake of Umm Al Nar Station.

2) Ebb Tide Period on October 11, 1988 in Second Field Survey

The current drag moved offshore at Site 1 in Baghal Channel and at Site 10 in Bateen Channel, but it still moved inshore in a similar direction to the flood tide period.

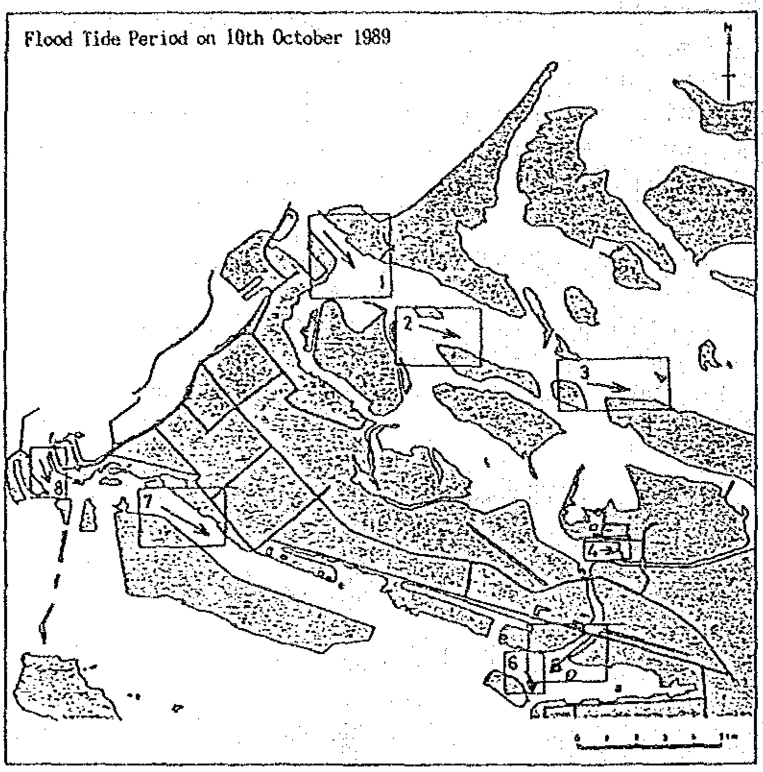


Fig. 3.2.21(1): Tracing Results of Current Drag Movement in Second Field Survey (Flood Tide Period)

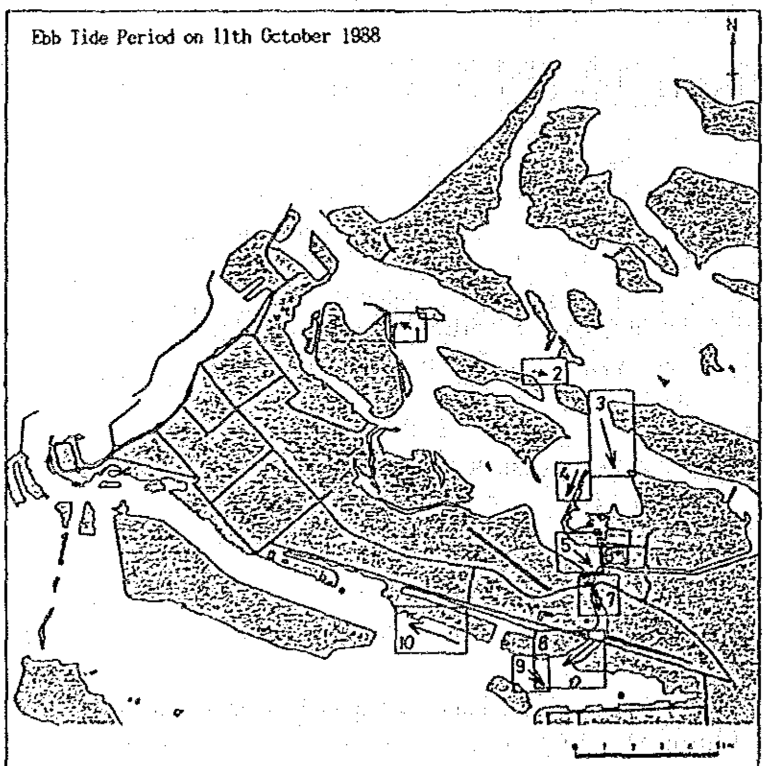


Fig. 3.2.21(2): Tracing Results of Current Drag Movement in Second Field Survey (Ebb Tide Period)

3) Ebb Tide Period on February 1, 1989 in Third Field Survey

The current drag moved offshore respectively at a speed of 32 to 63 cm/s at Site 1 and at Site 2 in Baghal Channel and at a speed of 23 to 56 cm/s at Site 9 and at Site 10 in Bateen Channel. Also it moved N-ward at a speed of 10 to 42 cm/s at Site 4 in the interior of the lagoon and S-ward at a speed of 29 cm/s at Site 6. It moved W-ward along the protection shore at a speed of 11 to 20 cm/s at Site 5 near the sea water intake of Umm Al Nar Station.

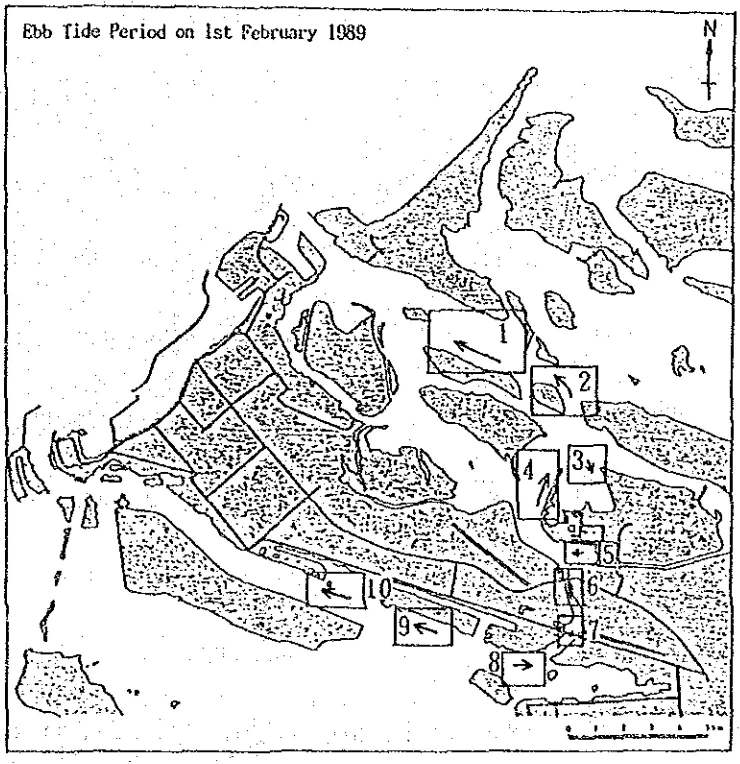


Fig. 3.2.21(3): Tracing Results of Current Drag Movement in Third Field Survey (Ebb Tide Period)

4) Flood Tide Period on February 7, 1989 in Third Field Survey

The current drag moved inshore toward the interior of the lagoon at a speed of 35 to 67 cm/s at Site 1, Site 2 and Site 3 in Baghal Channel and at Site 11 in Bateen Channel, and also it moved toward the brine discharge facilities of Umm Al Nar Station at a speed of 44 to 58 cm/s at Site 4 and Site 5 in the interior of the lagoon and moved S-ward at a speed of 42 to 46 cm/s at Site 6 and Site 7.

It moved SW-ward and SE-ward at Site 9 and Site 10 on the south side of the lagoon respectively. It moved E-ward along the protection shore at a speed of 17 cm/s at Site 8 near the sea water intake of Umm Al Nar Station.

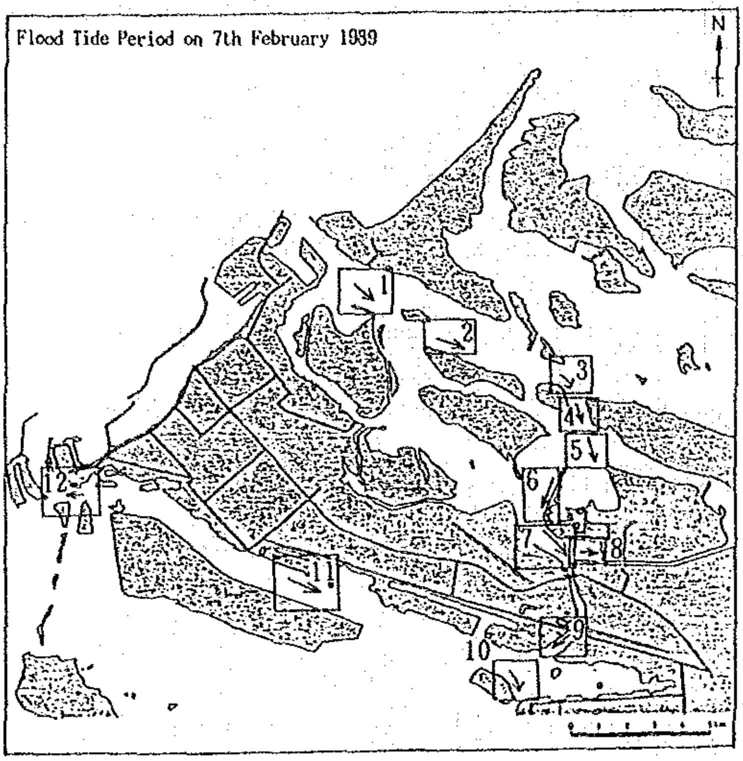


Fig. 3.2.21(4): Tracing Results of Current Drag Movement in Third Field Survey (Flood Tide Period)

(6) Summary

1) The current drag moved inshore toward the interior of the lagoon at a speed of 20 to 70 cm/s in Baghal Channel and Bateen Channel during the flood tide period, and also moved offshore during the ebb tide period.

2) Near the sea water intake of Umm Al Nar Station, the current drag moved E-ward and W-ward respectively along the protection shore of Umm Al Nar Station at the low speed of about 10 cm/s during the flood tide period and during the ebb tide period.

3) The current drag observation results of Lagrange's measurement were similar to the consecutive anchored tidal current observations of Euler's measurement.

4) The observations of the third field survey in winter were similar to those of the second field survey in summer.

3.2.3 Results of Vertical Profile Observation of Tidal Currents

(1) Purpose

The purpose of vertical profile observation of tidal currents is to clarify the vertical distribution characteristics of tidal currents around the Abu Dhabi Island and near the sea water intake of Umm Al Nar Station.

(2) Observation Location

The observation locations are shown in Fig. 3.2.22. 9 locations were selected as sites so that the tidal current conditions near the sea water intake could be clarified in detail.

13 locations were selected so that the conditions in the sea around the Abu Dhabi Island could be generally understood.

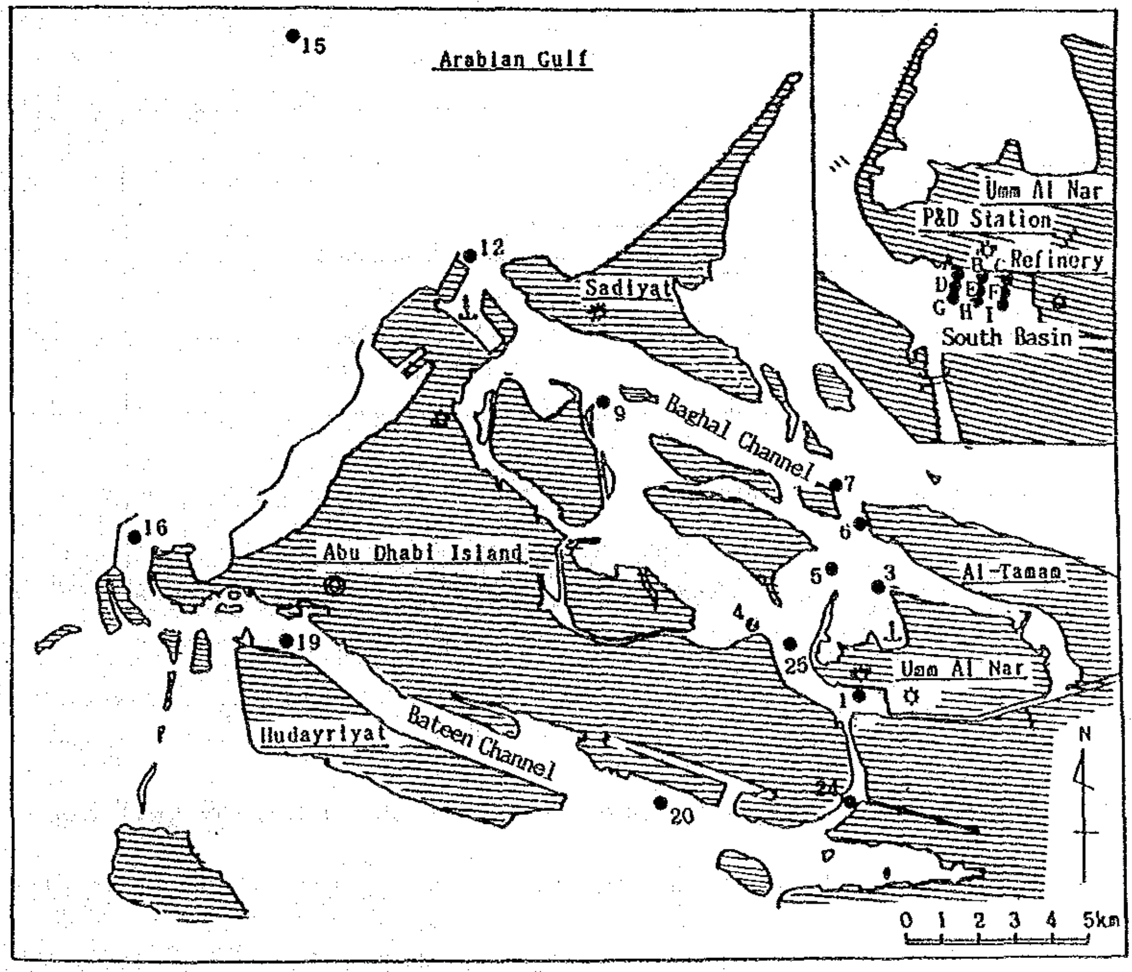


Fig. 3.2.22: Location of Vertical Profile Observation of Tidal Currents

(3) Date of Observation

1) Second Field Survey

* Ebb tide period on October 25, 1988
* Flood tide period on October 26, 1988

2) Third Field Survey

* Ebb tide period on February 2, 1989
* Flood tide period on February 8, 1989

(4) Method of Observation

The tidal current observation was conducted simultaneously with those of water temperature and salinity. Three layers of upper (0.3 below sea surface), middle (3.0 m below sea surface) and lower (1.0 m above sea bottom) were studied using the direct-reading electric current meter of a CM-2 type as shown in Fig. 3.2.23.

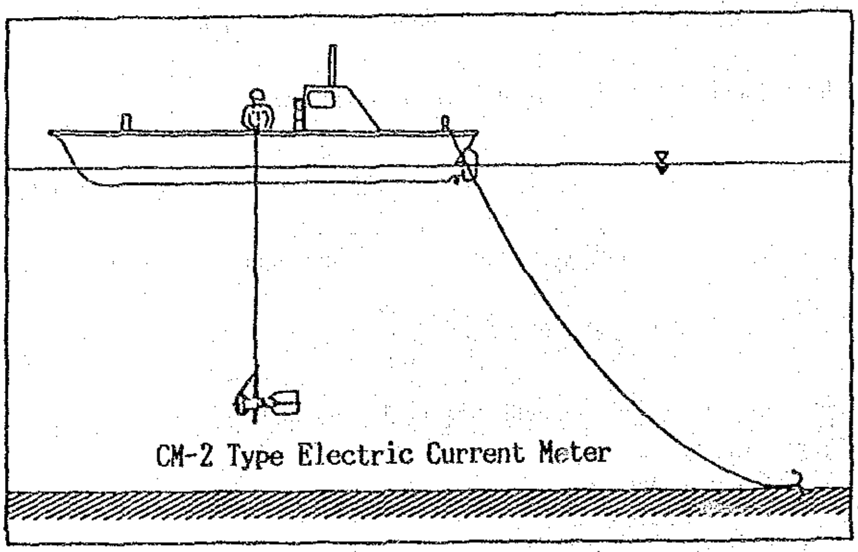


Fig. 3.2.23: Sketch of Vertical Profile Observation of Tidal Currents

(5) Results of Observations

The site classification according to the range among all layers in current direction and speed is shown in Table 3.2.15(1).

1) Ebb Tide Period on October 25, 1988 in Second Field Survey

According to Table 3.2.15 (1), ranges greater than 90 degrees in the current direction were shown respectively at Site 1-I, Site 3, Site 16, and Site 25. In addition to the large direction range, the range in current speed was higher than 20 cm/s, in particular, at Site 1-I and Site 25 and so it seems that the stream of the upper layer was different from those of the middle and lower layers at both the sites. At the other sites, the streams advanced almost offshore from the interior of the lagoon and parallel to the channel at all the layers.

Regarding the neighborhood of the sea water intake facilities of Umm Al Nar Station, the dominant streams were those toward the intakes at Site 1-A, Site 1-B and Site 1-C, and those W-ward along the protection shore of Umm Al Nar Station at the other sites. The streams of the lower layer were faster than those of the upper layer at Site 1-B.

At offshore Site 15, the streams were NW-ward to N-ward in the upper layer, but the current speed was zero cm/s in the lower layer.

Table 3.2.15 (1): Site Classification According to Range among Layers in Current Direction and Speed (Ebb Tide Period on October 25, 1988)

		Range of Current Speed	
		<20cm/s	≧20cm/s
Range of Direction	<90deg.	1-A,1-C,1-E,1-G,1-H,4,9,12,15,19,20,24	1-B,1-D,1-F,5,6,7
	≧90deg.	3,16	1-I,25

2) Flood Tide Period on October 26, 1988 in Second Field Survey

According to Table 3.2.15(2), ranges greater than 90 degrees in the current direction were shown at Site 1-I and Site 3 and the current directions of the upper layer and the lower layer were mutually in opposite directions at the sites. At the sites in both the channels, the tidal currents were almost uniform in all the layers and the current direction was in the opposite direction to that during the ebb tide period, that is to say, it was inshore current and almost parallel to the channel.

Regarding the neighborhood of the sea water intake facilities of Umm Al Nar Station, the dominant streams were similar to those during the ebb tide period, namely those toward the intakes, at Site 1-A, Site 1-B and Site 1-C near the intakes, and were opposite to those during the ebb tide period, namely those E-ward along the protection shore of Umm Al Nar Station, at the other sites.

At offshore Site 15, the S-ward streams were dominant in all the layers and the current speed was 12 to 18 cm/s.

Table 3.2.15(2): Site Classification According to Range among Layers in Current Direction and Speed (Flood Tide Period on October 26, 1988)

		Range of Current Speed	
		<20cm/s	≧20cm/s
Range of Direction	<90deg.	1-C,1-D,1-E,1-F,1-G,1-H, 4,5,6,15,16,24	1-A,1-B,7,9,12,19,20,25
	≧90deg.	1-I	3

3) Ebb Tide Period on February 2, 1989 in Third Field Survey

According to Table 3.2.15(3), the sites in which the range was greater than 90 degrees in current direction, and more than 20 cm/s in current speed, were Site 6, Site 20, and Site 25. The streams in the channels were parallel to the channels and their directions were inshore toward the interior of the lagoon at Site 16, Site 19 and Site 20 in Bateen Channel, and offshore from the interior at Site 7 and Site 9 in Baghal Channel respectively.

Regarding the neighborhood of the sea water intake facilities of Umm Al Nar Station, the dominant streams were those toward the intakes at Site 1-A, Site 1-B and Site 1-C, and those W-ward along the protection shore of Umm Al Nar Station at the other sites. The streams of the lower layer were faster than those of the upper layer at Site 1-B.

Table 3.2.15(3): Site Classification According to Range among Layers in Current Direction and Speed (Ebb Tide Period on February 2, 1989)

		Range of Current Speed	
		<20cm/s	≧20cm/s
Range of Direction	<90deg.	1-A,1-B,1-C,1-D,1-E,1-G, 1-H,1-I,9,12,16	1-F,3,5,7,15,19,
	≧90deg.	24	6,20,25

4) Flood Tide Period on February 8, 1989 in Third Field Survey

According to Table 3.2.15(4), the sites in which the range was greater than 90 degrees in current direction were Site 3 and Site 19. At the other sites in the channels, the tidal currents were almost uniform in all the layers at each site, and the current direction in the channels was inshore toward the interior of the lagoon from offing and almost parallel to the channel.

Regarding the neighborhood of the sea water intake facilities of Umm Al Nar Station, the dominant streams were those toward the intakes at Site 1-A, Site 1-B and Site 1-C and were opposite to those during the ebb tide period, namely E-ward and almost parallel to the shore protecting embankment of Umm Al Nar Station, at the other sites. At offshore Site 15, the streams were S-ward in all the layers and the current speed was 6 to 18 cm/s.

Table 3.2.15(4): Site Classification According to Range among Layers in Current Direction and Speed (Flood Tide Period on February 9, 1989)

		Range of Current Speed	
		<20cm/s	≧20cm/s
Range of Direction	<90deg.	1-A,1-B,1-C,1-D,1-E,1-F, 1-G,1-H,4,5,12,15,16,24	1-I,6,7,9,20,25
	≧90deg.	19	3

(6) Summary

1) In Baghal Channel and Bateen Channel, the streams were almost uniform in all the layers at each site during both the flood tide period and the ebb tide period. The very strong current speed of 50 to 100 cm/s were observed sometimes.

2) Near the sea water intake of Umm Al Nar Station, the dominant streams were those toward the intakes at Site 1-A, Site 1-B and Site 1-C and the current speed (20 to 40 cm/s) of the lower layer was higher compared with the upper layer.

   At the other sites a little away from the sea water intake facilities of Umm Al Nar Station, the stream conditions in all the layers were similar to the consecutive observations where the streams along the shore protecting embankment of Umm Al Nar Station were respectively E-ward during the flood tide period and W-ward during the ebb tide period.

3) Near the north of the outfall of Umm Al Nar Station, the range of the current in all the layers was relatively large, and during the flood tide period, the stream at upper layer was toward the outfall, and the streams in middle and lower layers were opposite to that, namely NW-ward. During the ebb tide period, the streams in all of the layers were N-ward streams.

4) The observations of the third field survey in winter were similar to those of the second field survey in summer.

3.3 Tidal Level

(1) Purpose

The statistical characteristics of tides will be clarified by the continuous observations of tidal level at typical locations around the Abu Dhabi Island and also will be used as boundary parameters in the numerical calculation of oil dispersion.

(2) Observation Location

The observation locations are shown in Fig. 3.3.1. One location inside the lagoon (Umm Al Nar) and two locations near the entrance of the channels (Mina Zayed and Public Marina) were selected as observation sites so that the characteristics of tides in the sea around the Abu Dhabi Island could be ascertained generally.

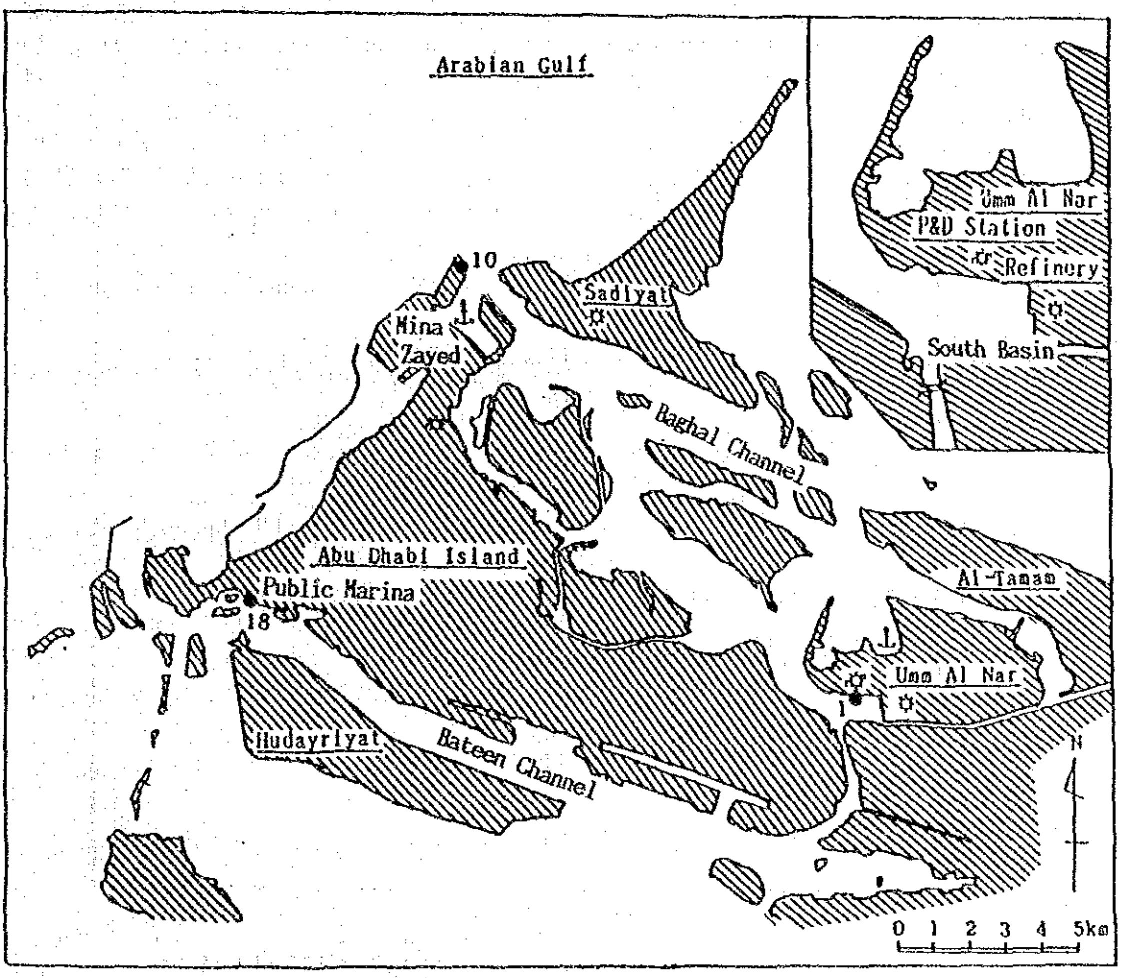


Fig. 3.3.1: Observation Location of Tidal Level

(3) Duration of Observations

The durations of observation at each site were as follows:

1) Second Field Survey

* Site 1 (Umm Al Nar) October 3, 1988 to November 8, 1988
* Site 10 (Mina Zayed) October 1, 1988 to November 8, 1988
* Site 18 (Public Marina) September 28, 1988 to November 8, 1988

2) Third Field Survey

* Site 1 (Umm Al Nar) November 8, 1988 to February 28, 1989
* Site 10 (Mina Zayed) November 8, 1988 to February 27, 1989
* Site 18 (Public Marina) November 8, 1988 to February 27, 1989

(4) Method of Observation

The observations of tidal level were conducted using the long-term self-recording tide gauges of a water pressure type. A sketch of the tide gauge installed is shown in Fig. 3.3.2.

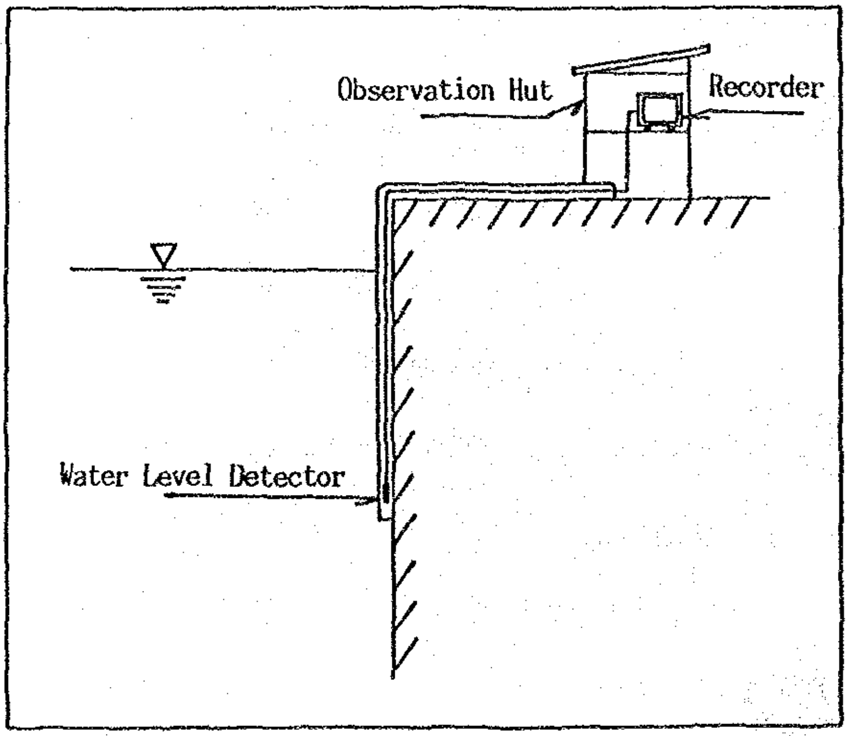


Fig. 3.3.2: Sketch of Tide Gauge Installation

(5) Arrangement and Analysis of Observation Results

The harmonic constants of each site were calculated from the hourly tidal level (cm) given with value over ACD (Admiralty Chart Datum) by harmonic analysis. Method of harmonic analysis is described in 2.3.

(6) Observation Results

The variation of tidal level is shown in Figs. 3.3.3(1) to 3.3.3(3) as tidal curve. The symbols in this figure express respectively the following items:

● : New Moon
◐ : First Quarter
○ : Full Moon
◑ : Last Quarter

The time of new moon or full moon is the spring tide period, and the time of first quarter or last quarter is the neap tide period.

According to Figs. 3.3.3(1) to 3.3.3(3), the tidal levels of 3 sites showed a very similar tendency to one another. That is to say, the variation of tidal level showed principally the semi-diurnal periodicity, but the diurnal inequality, which expresses the phenomena that the tidal levels of successive high or successive low tide and the time interval of successive high or successive low tide are not stable, was frequently recorded.

Because both the sun and the moon were located on the same side of equator at the time of the new moon and of the full moon in October, the diurnal inequality was especially small and the range of semi-diurnal tides were almost equal in a day during the spring tide period in October. On the other hand, because the moon was located near the tropics, the diurnal inequality was large at the time of first quarter and last quarter in October.
Because both the sun and the moon were located near the tropics, the diurnal inequality was large at the time of new moon and full moon in December. On the other hand, because the moon was located near the equator, the diurnal inequality was small at the time of first quarter and last quarter in December.

Location : Site I

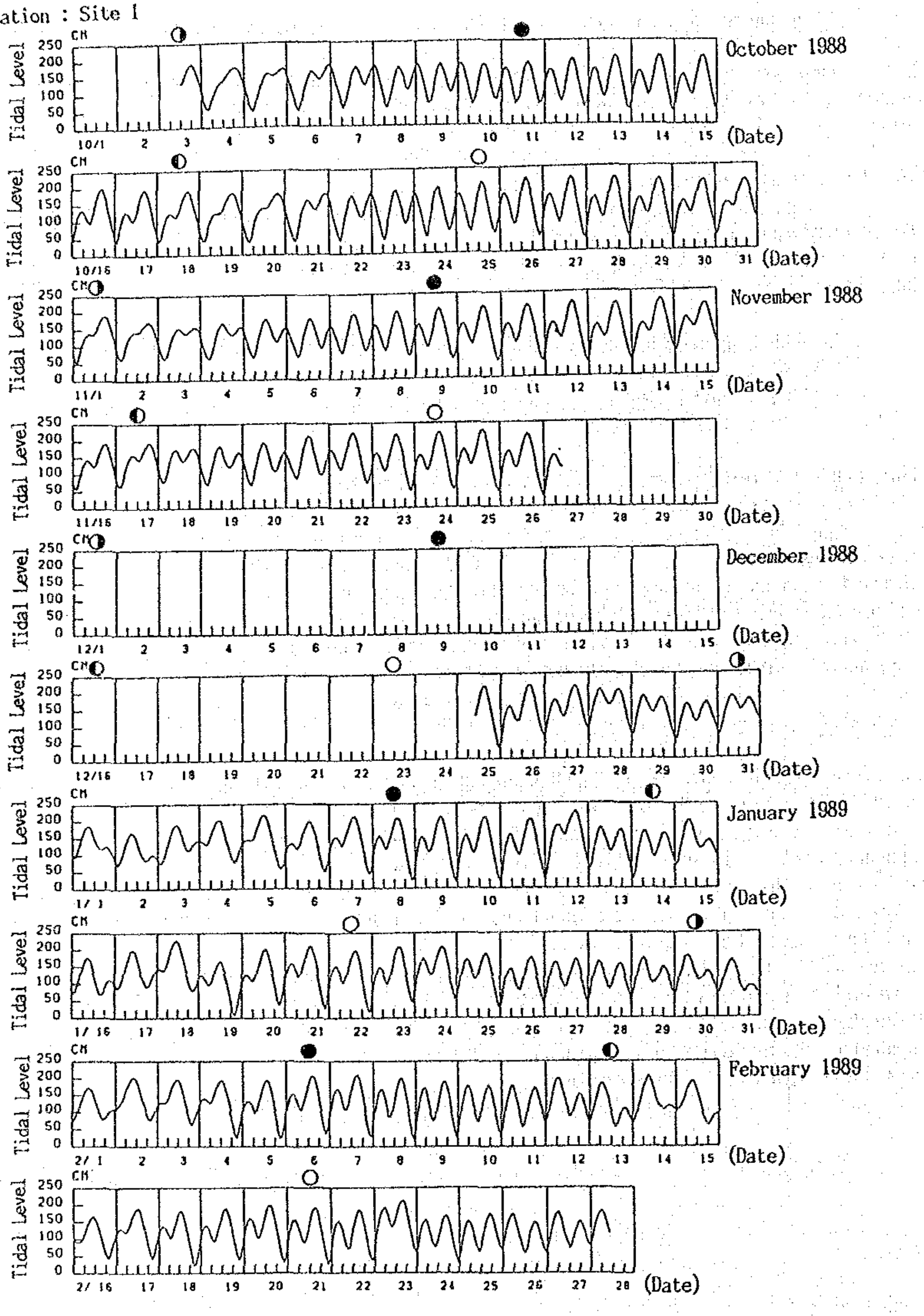


Fig. 3.3.3(1): Variation of Tidal Level during Whole Observation Period

Location : Site 10

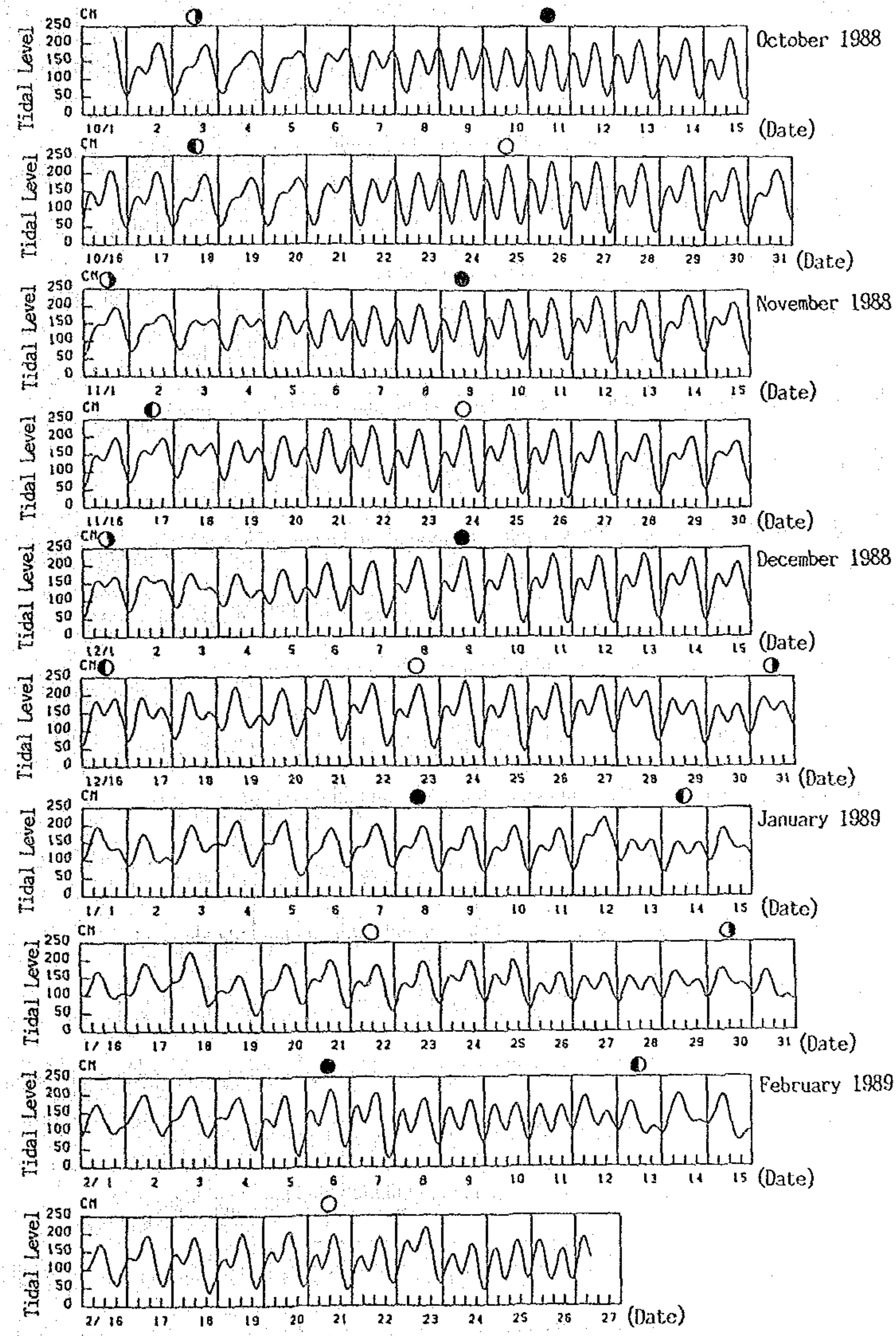


Fig. 3.3.3(2) : Variation of Tidal Level during Whole Observation Period

Location : 18

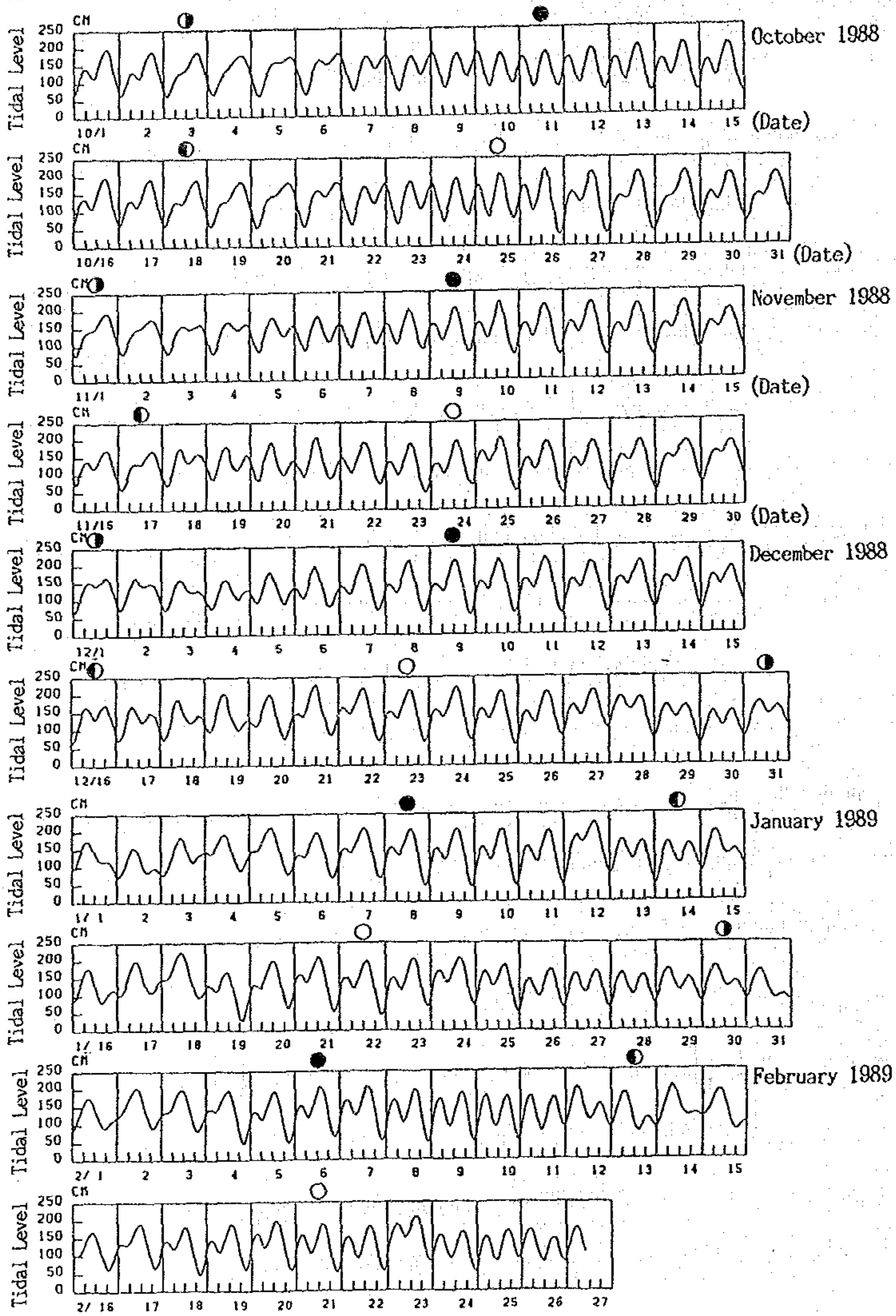


Fig. 3.3.3(3) : Variation of Tidal Level during Whole Observation Period

The harmonic analysis results are as shown in Table 3.3.1. According to this table, the 4 main component tides of M_2, S_2, K_1 and O_1 as described in 2.3 occupied the larger part of all amplitudes at the 3 sites.

The semi-diurnal component tide sum (M_2 + S_2) was respectively 53.4 cm at Site 1-1, 55.0 cm at Site 1-2, 45.7 cm at Site 10 and 43.0 cm at Site 18. The diurnal component tide sum was respectively 60.0 cm at Site 1-1, 58.3 cm at Site 1-2, 60.2 cm at Site 10 and 55.8 cm at Site 18.

Table 3.3.1: Harmonic Constants Table of Tides

Site	1-1		1-2		10		18	
Component Tide	Amp. (cm)	Ph. (deg)	Amp. (cm)	Ph. (deg)	Amp. (cm)	Ph. (deg)	Amp. (cm)	Ph. (deg)
Q_1	2.1	159	3.8	194	2.6	161	2.5	167
O_1	21.8	151	20.6	168	22.7	146	19.8	153
K_1	38.2	168	37.7	192	37.5	166	36.0	170
MU_2	3.0	176	2.5	191	2.2	141	1.8	184
N_2	6.4	63	7.1	76	5.8	57	5.4	56
M_2	37.7	74	36.1	75	33.6	54	30.8	61
L_2	2.1	118	1.5	41	1.9	58	1.4	81
S_2	15.7	79	18.9	120	12.1	73	12.2	87
M_4	1.4	6	0.7	16	0.6	160	0.3	31
MS_4	0.6	23	1.9	43	0.5	228	0.5	38
P_1	12.7	168	12.5	192	12.5	166	12.0	170
NU_2	1.2	63	1.4	76	1.1	57	1.1	56
K_2	4.3	79	5.2	120	3.3	73	3.3	87
V_0	132cm		127cm		135cm		135cm	

Remarks : Duration of Analysis
Site 1-1 3rd October 1988 ~ 27th November 1988
Site 1-2 25th December 1988 ~ 28th February 1989
Site 10 1st October 1988 ~ 27th February 1989
Site 18 1st October 1988 ~ 27th February 1989

The F values which were calculated by the following equation are shown in Table 3.3.2.

F: Classification function of tidal types

$$F = (K_1 + O_1)/(M_2 + S_2)$$

According to this table, the range of F is 1.06 to 1.32. Therefore, the tidal types are the mixed tidal type (Site 1) and the diurnal type (Site 10 and Site 18).

The time of higher high water level at Site 1 and Site 18 delayed as compares with that at Site 10 as shown in Figs. 3.3.4 and 3.3.5.

Table 3.3.2: Value of Classification Function of Tidal Types

Site	Nonharmonic Constants		F Value
	M_2 + S_2 (cm/s)	K_1 + O_1 (cm/s)	
1-1	53.4	60.0	1.12
1-2	55.0	58.3	1.06
10	45.7	60.2	1.32
18	43.0	55.8	1.30

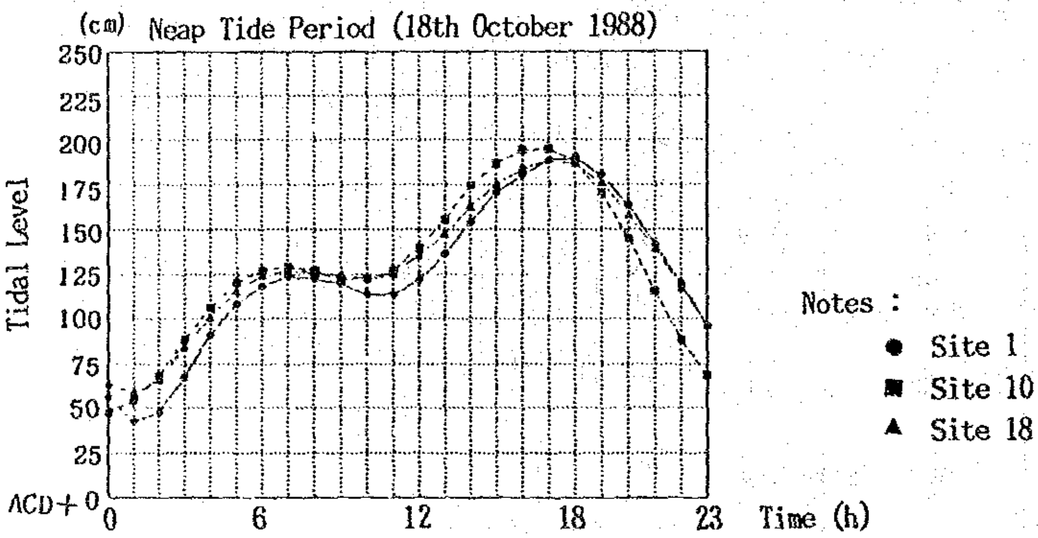


Fig. 3.3.4: Typical Daily Profile of Tidal Level during Neap Tide Period

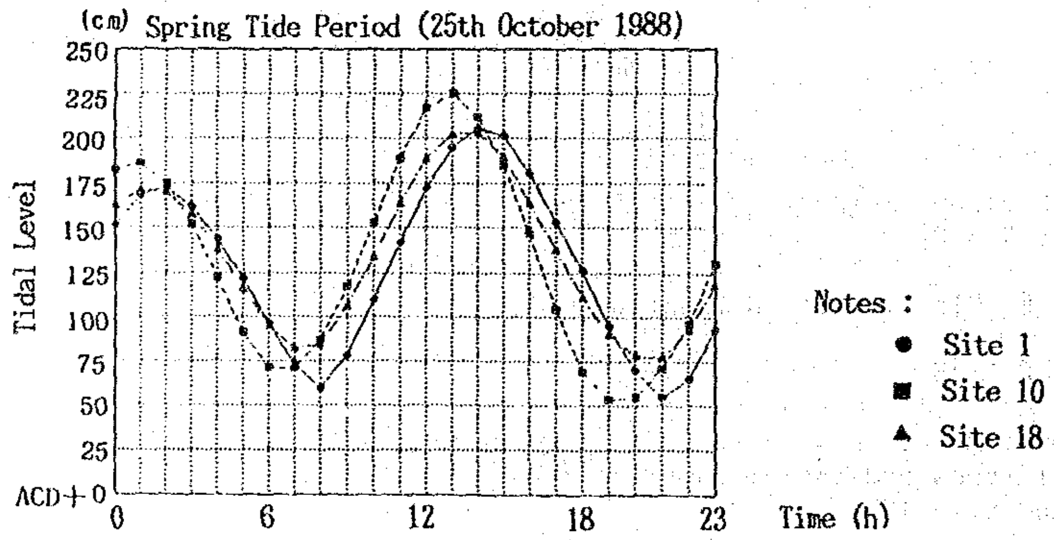


Fig. 3.3.5: Typical Daily Profile of Tidal Level during Spring Tide Period

(6) Summary

1) The tidal levels of the three sites showed a very similar tendency to one another. That is to say, the variation of the tidal level showed principally the semi-diurnal periodicity. But not only the diurnal inequality but also the apparent diurnal periodicity was recorded.

2) According to the harmonic analysis results, the four main component tides of M_2, S_2, K_1 and O_1 occupied the larger part of all amplitudes at the three sites and the sum of the four main component tides was about 100 cm/s.

3) The value of classification function of tidal types was respectively 1.09 at Umm Al Nar, 1.33 at Mina Zayed and 1.30 at Public Marina and therefore, the tidal types are the mixed tidal type.

4) The average high water interval was respectively 15 h 33 min at Mina Zayed, 15 h 44 min at Umm Al Nar, and 15 hour 14 min at Public Marina. Accordingly the time of higher high water level at Umm Al Nar and at Public Marina were respectively delayed 32 min or 14 min as compared with that at Mina Zayed.

5) According to the observations during the five month period, the average water level at Mina Zayed was higher than that at Umm Al Nar by about 5 cm.

3.4 Water Temperature

3.4.1 Long-Term Observation

(1) Purpose

The purpose of long-term observation of water temperature is to clarify the vertical distribution and the long-term tendency of water temperature nearby the sea water intake facilities of Umm Al Nar Station.

(2) Observation Location

The observation location is shown in Fig. 3.4.1.

(3) Duration of Observation

September 28, 1988 to February 25, 1989

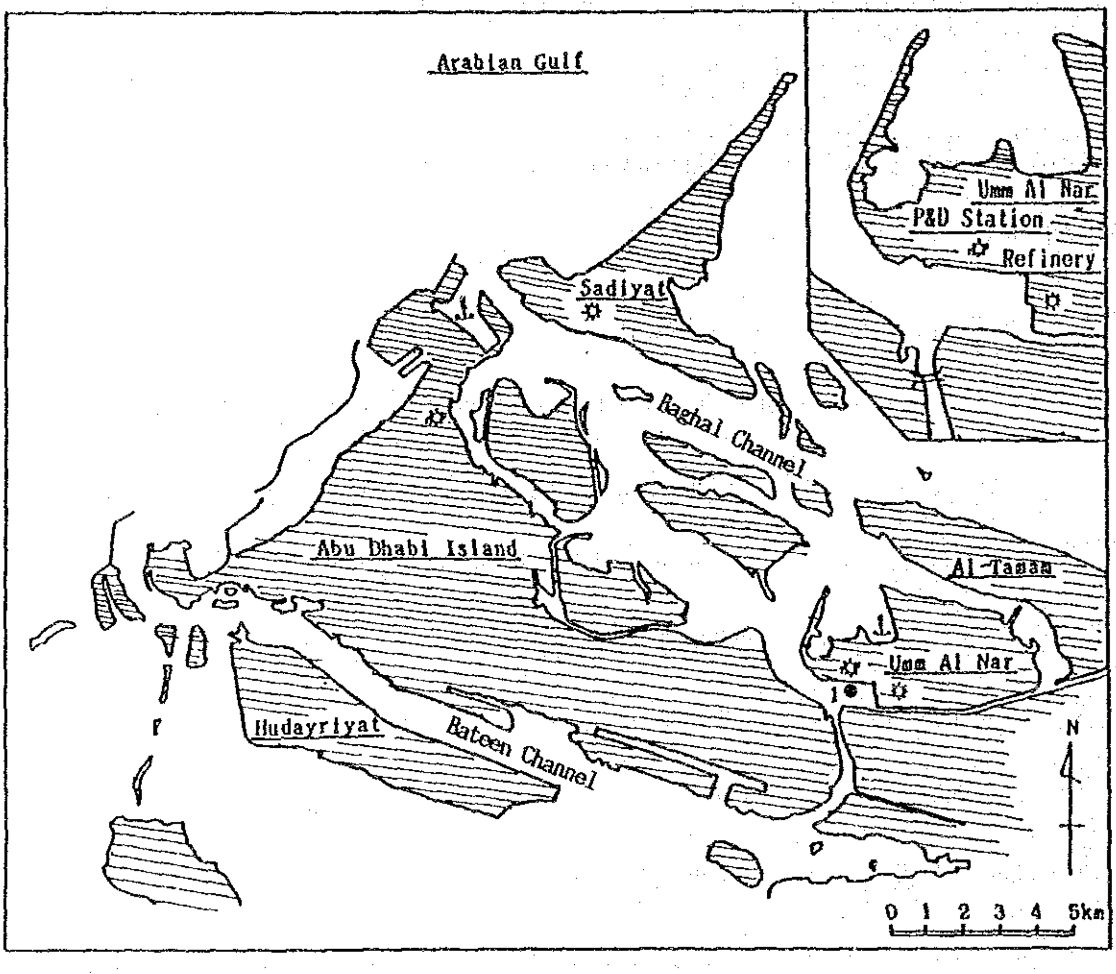


Fig. 3.4.1: Location of Long-term Observation of Water Temperature

(4) Method of Observation

The long-term observation of water temperature was conducted using a self-recording water thermometer of the PR-2 type. The observed layers were ten layers each 0.5 m from 0.5 m to 5.0 m below the sea surface. A sketch of the self-recording water thermometer installed is shown in Fig. 3.4.2.

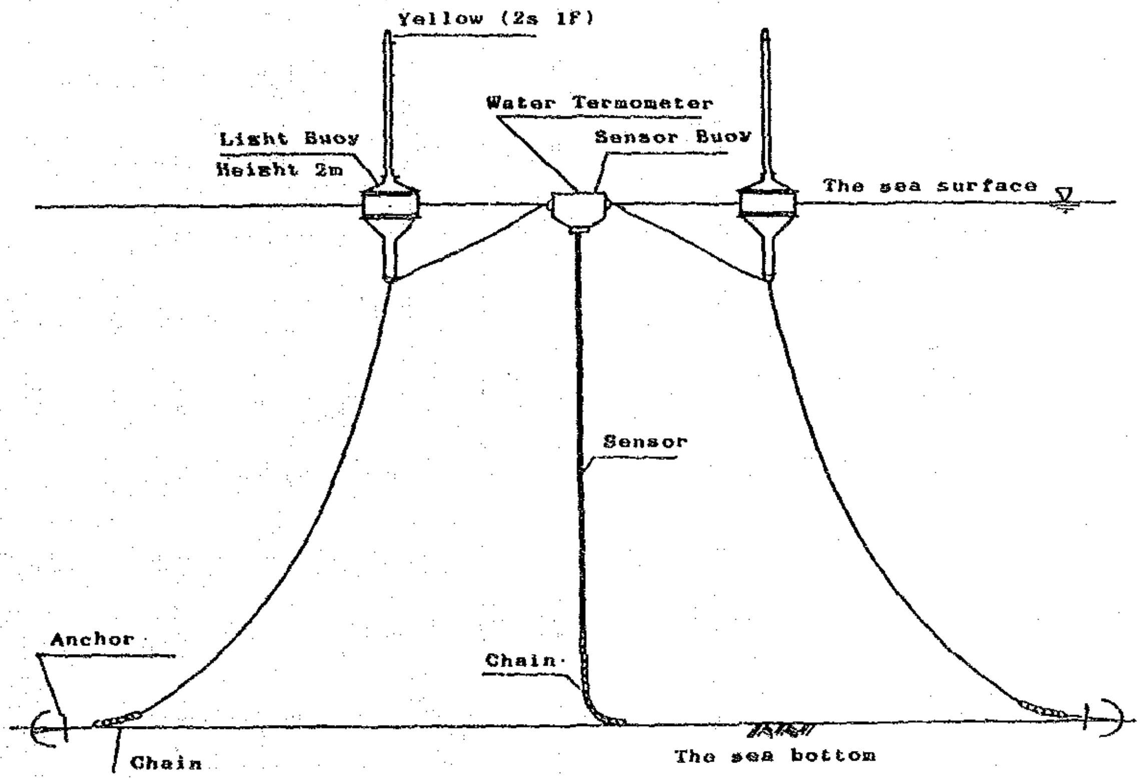
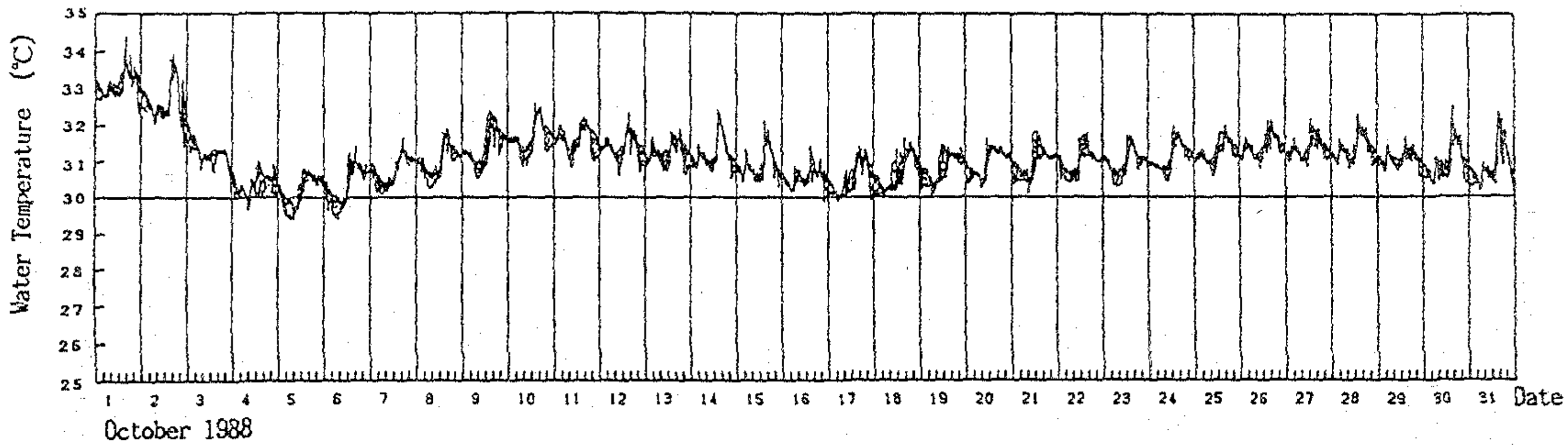


Fig. 3.4.2: Sketch of Installation of Water Thermometer

(5) Results of Observations

The variation of water temperature is shown in Figs. 3.4.3(1) to 3.4.3(3). According to these figures, the variation of water temperature showed almost the same trend in all the layers, and the vertical range of water temperature was very small during the whole observation period.

The monthly water temperature are shown in Table 3.4.1. According to this table, the monthly average water temperature showed a maximum of 31.1 °C in October, 1988 and then continued gradually dropping. The temperature showed a minimum of 18.8 °C in January, 1989 and then started rising in February, 1989.



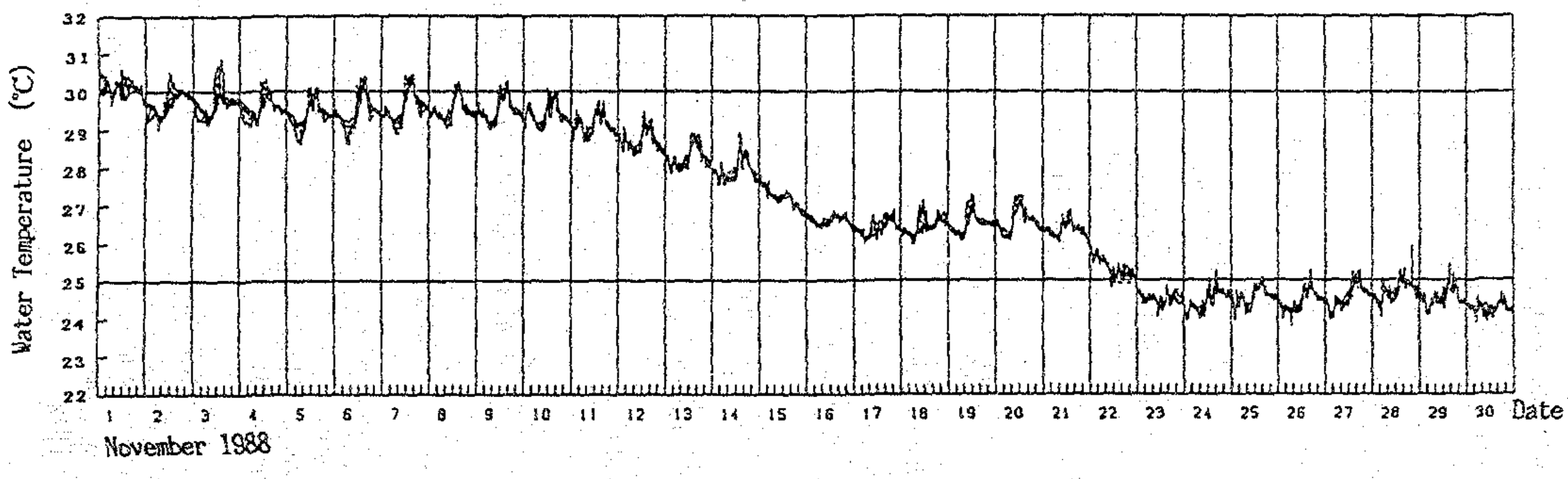


Fig. 3.4.3(1): Variation of Water Temperature near Umm Al Nar Station
Intake during Whole Observation Period

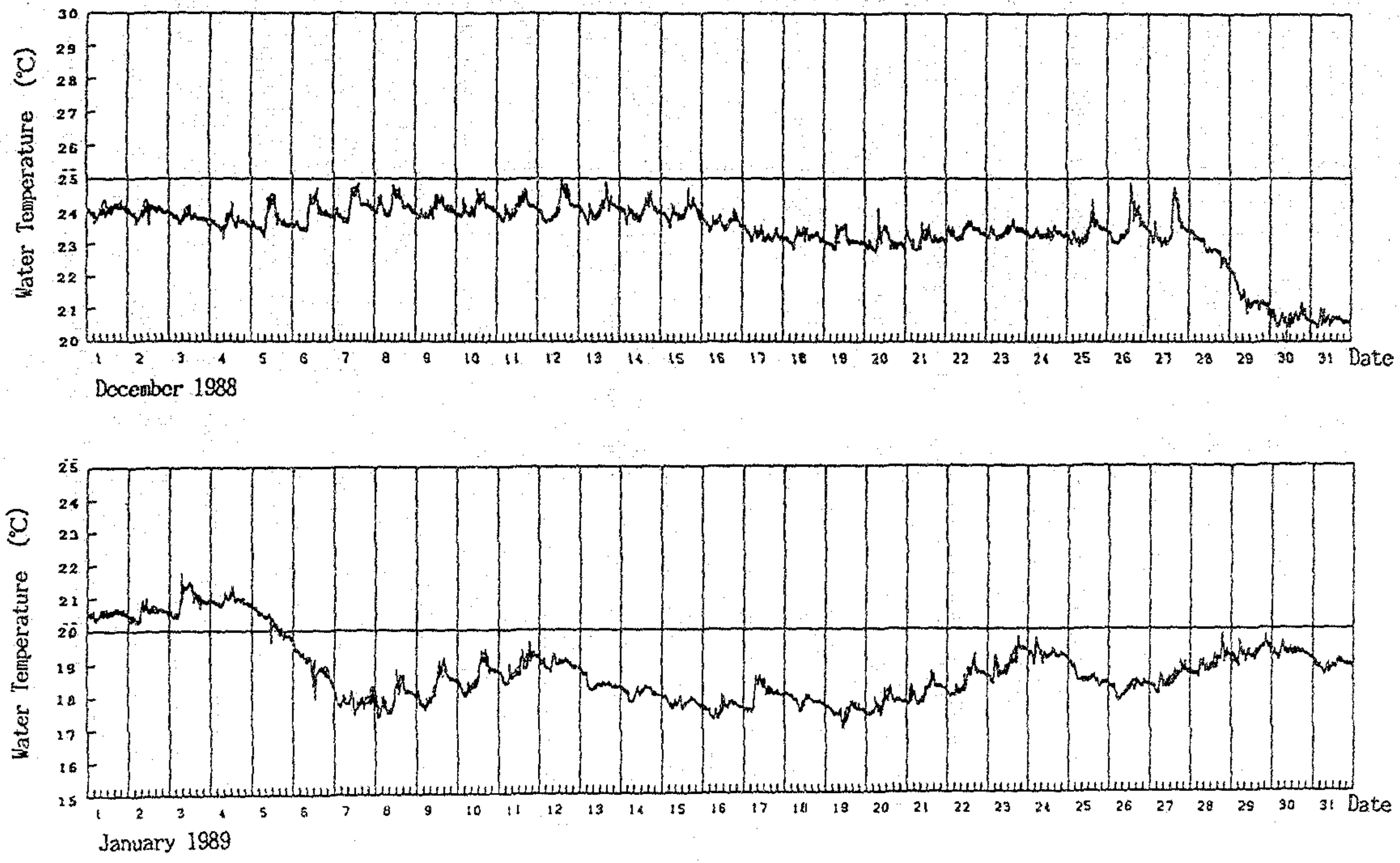


Fig. 3.4.3(2): Variation of Water Temperature near Umm Al Nar Station Intake during Whole Observation Period

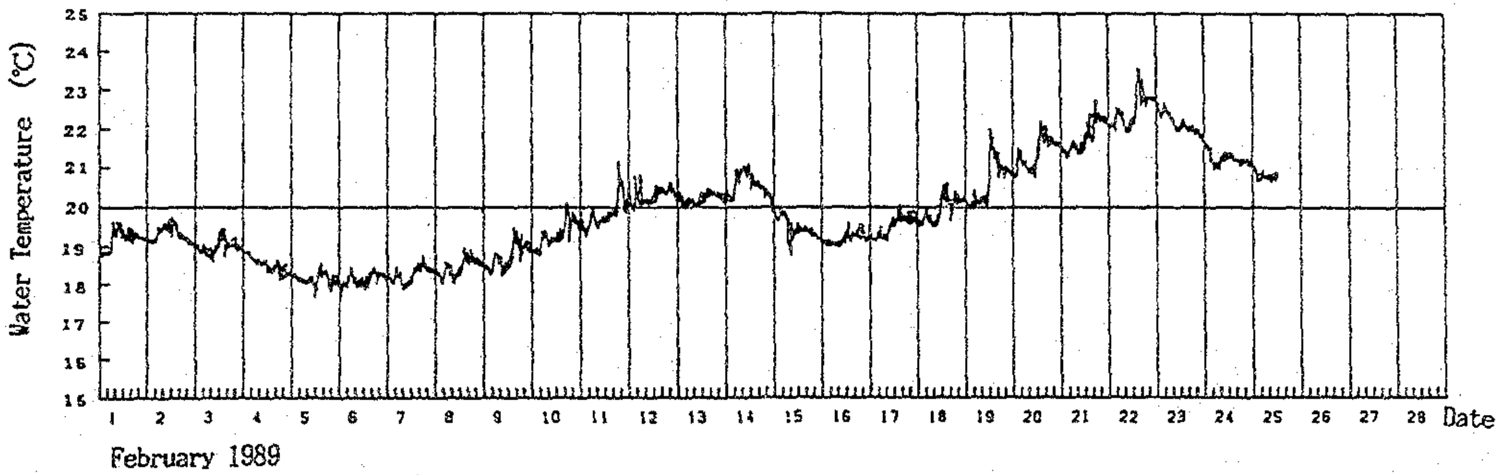


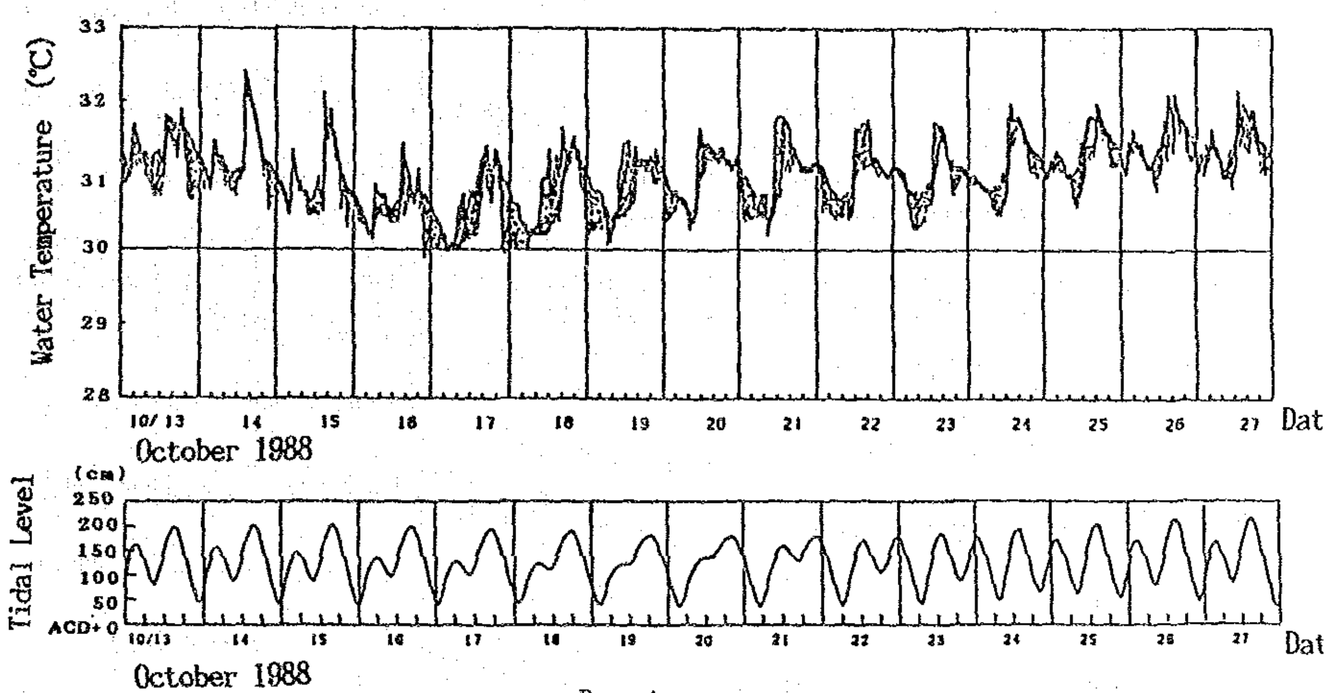
Fig. 3.4.3(3): Variation of Water Temperature near Umm Al Nar Station Intake during Whole Observation Period

Table 3.4.1: Monthly Water Temperature near Umm Al Nar Station Intake

Year / Month / Parameter	1988			1989	
	October	November	December	January	February
Max. Temp. (℃)	34.4	30.9	25.0	21.8	23.6
Min. Temp. (℃)	29.4	23.8	20.0	16.9	17.6
Ave. Temp. (℃)	31.1	27.3	23.4	18.8	19.9

The relations between water temperature and tidal level are as shown in Fig. 3.4.4. According to this figure, diurnal or semi-diurnal variation was shown distinctly in the variation of the temperature, and the variation of the temperature corresponded relatively well to the tidal level.

That is to say, it is likely that the temperature was high from the flood tide period to the high tide period, and was low from the ebb tide period to the low tide period.



Remarks :

Location--- Site 1 Near Umm Al Nar Station

Fig. 3.4.4: Relations between Tidal Level and Water Temperature at Site 1

Furthermore, the periodicity of water temperature variation was studied by the time series analysis method.

Leading series : Average movement over a one hour period
T_{LEAD} added to data of water temperature each 30 minute
Seasonal series: Average movement over a month period
T_{SEASON} added to T_{LEAD}
Middle series: Average movement over a 25 hour period
T_{MIDDLE} added to $T_{LEAD}-T_{SEASON}$
Daily series: $T_{LEAD}-T_{SEASON}-T_{MIDDLE}$
T_{DAY}

The above mentioned T_{LEAD}, T_{SEASON}, T_{MIDDLE} and T_{DAY} are shown in Figs. 3.4.5 (1) to 3.4.5 (3). According to this figure, the feature of each series is as follows :

1) T_{SEASON} (Variation component of a period more than a month)

Because of the short observation period, the seasonal variation was not grasped. Nevertheless, it is thought that the vertical range of temperature was very small and that the seasonal variation of temperature occurred simultaneously in all the layers. T_{SEASON} showed the maximum of about 30 °C in October, 1988 and the minimum of about 19 °C in January, 1989.

2) T_{MIDDLE} (Variation component of a period between a day and a month)

T_{MIDDLE} component showed a periodic variation of several days.

3) T_{DAY} (variation component of a period less than a day)

According to the variation of T_{DAY} component, the water temperature varied in the range of 1 to 2 °C in about a one day period.

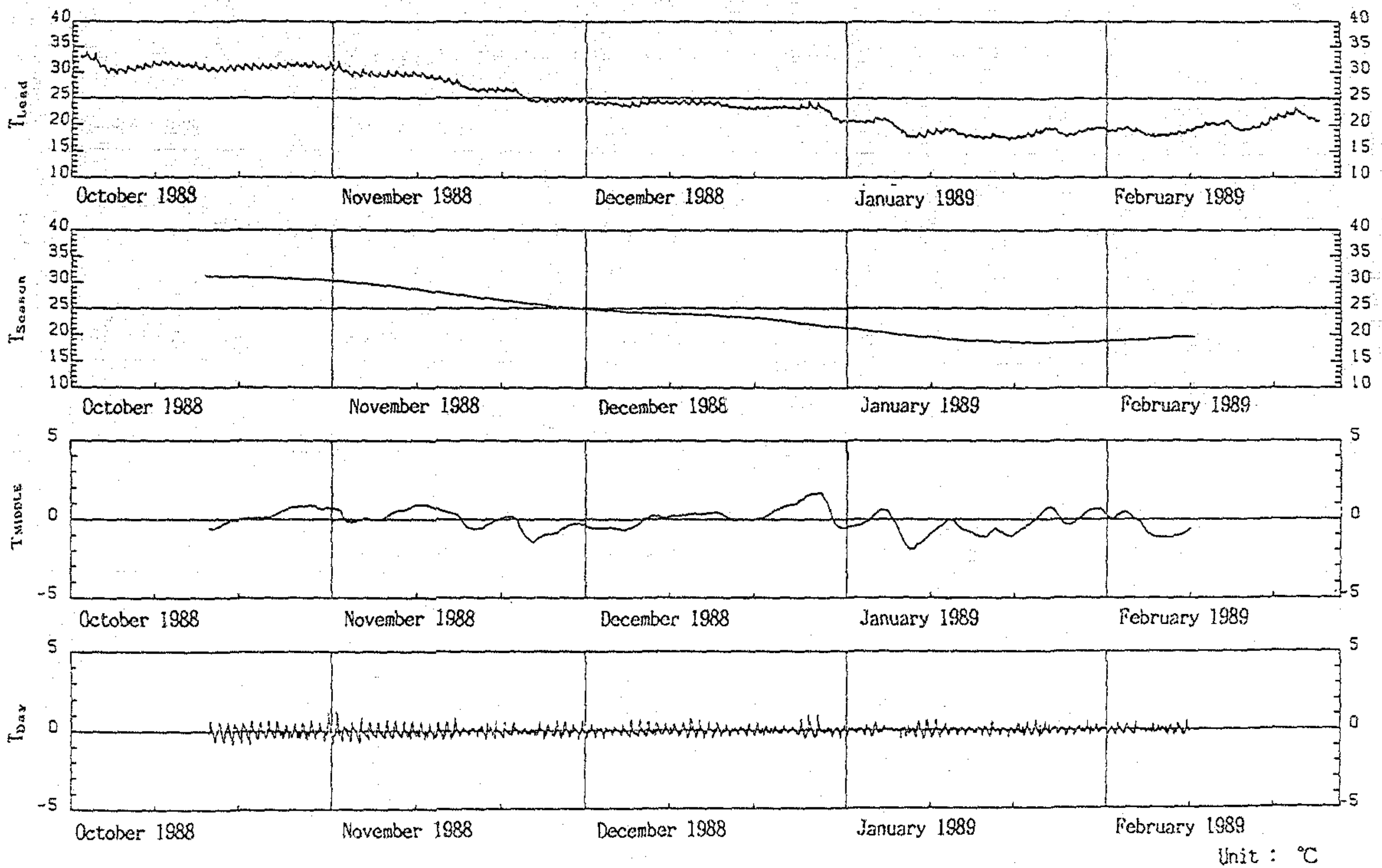


Fig. 3.4.5(1): Periodicity in Variation of Water Temperature
(0.5 m below sea surface)

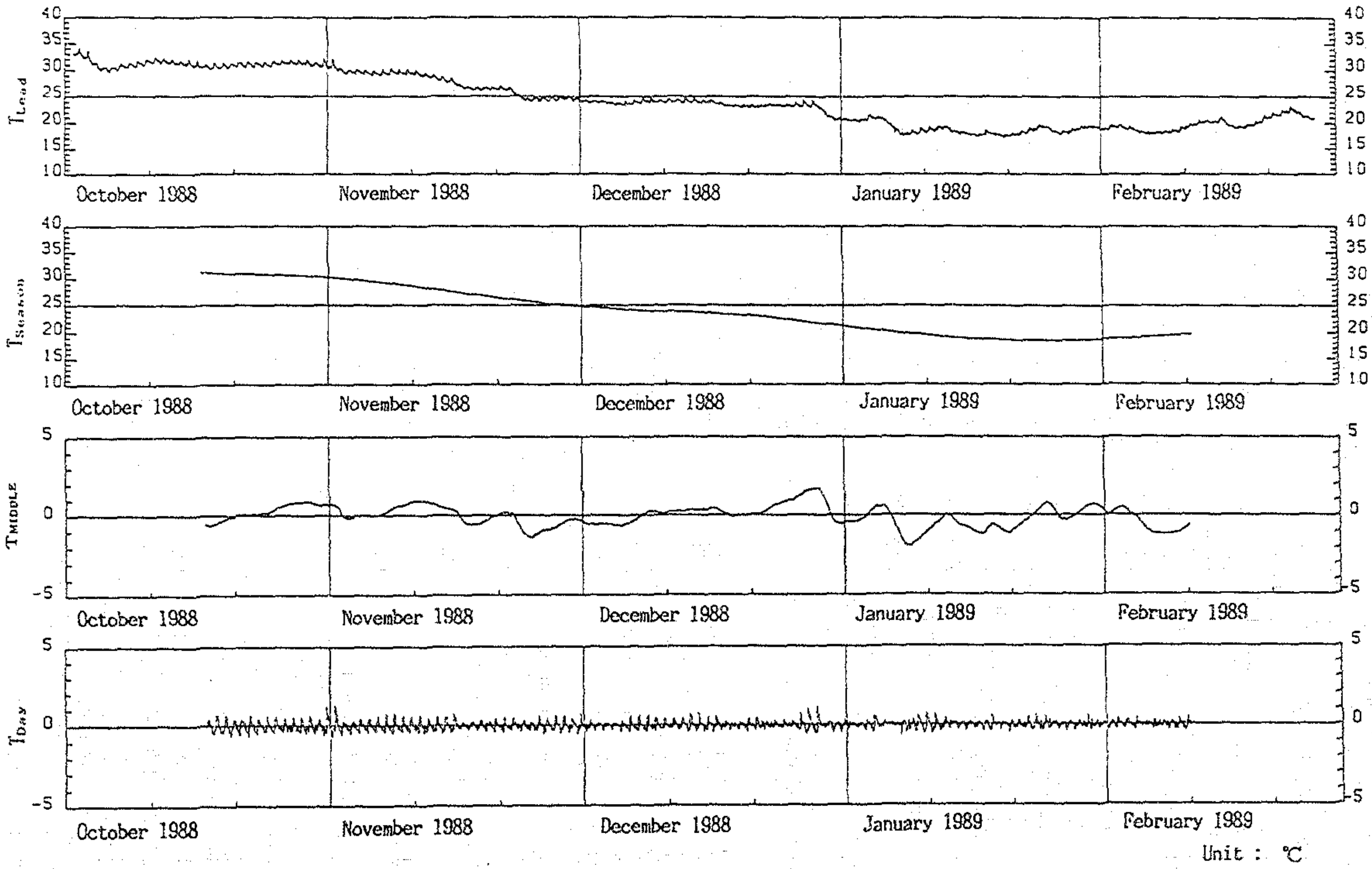
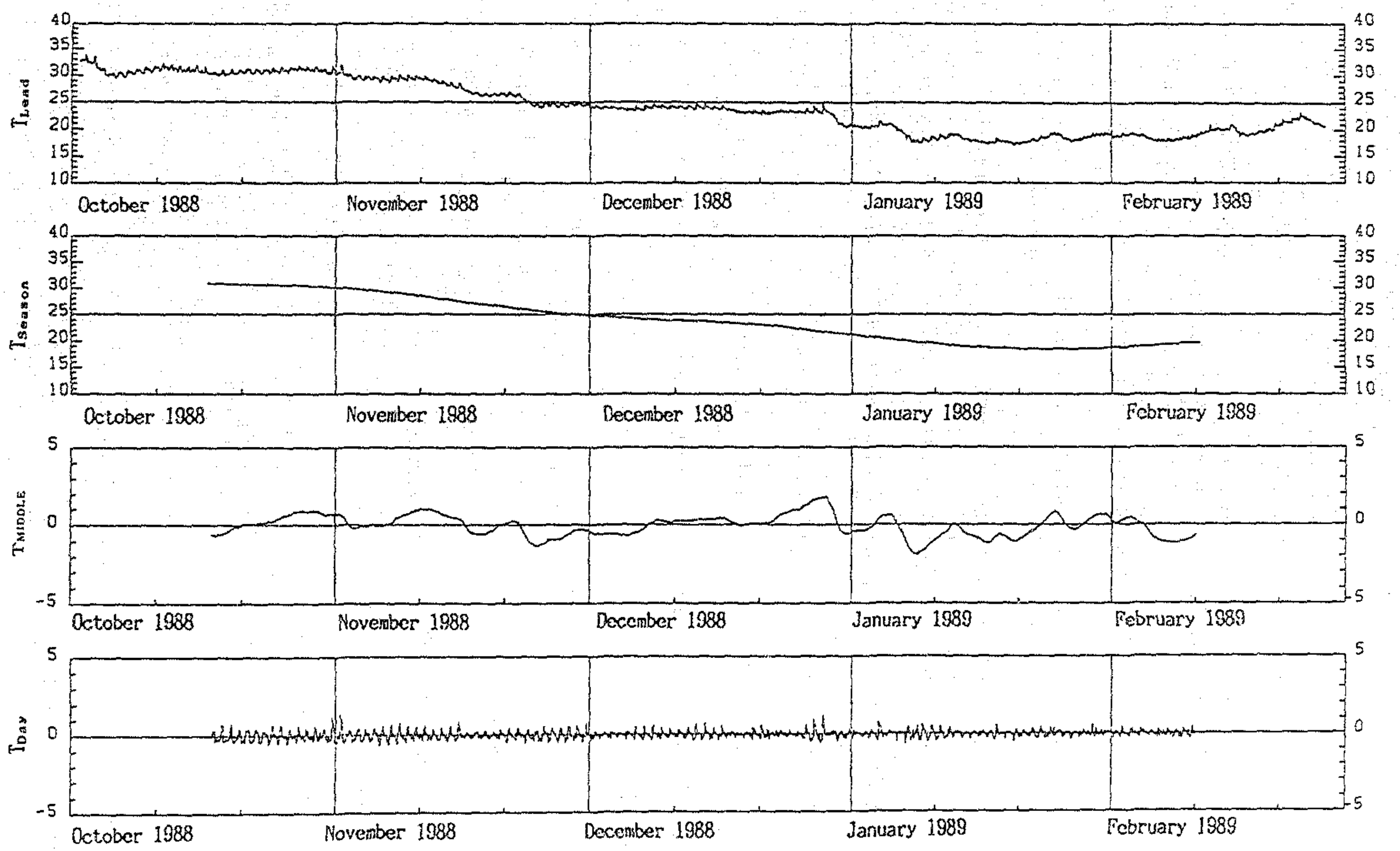


Fig. 3.4.5(2): Periodicity in Variation of Water Temperature
(3.0 m below sea surface)
(0.5 m below sea surface)



Unit : ℃

Fig. 3.4.5(3) Periodicity in Variation of Water Temperature
(0.5 m below sea surface)

(6) Summary

1) The vertical range of water temperature was very small during the whole observation period and the variation of the temperature showed almost the same trend in all the whole layers.

2) The maximum during the whole observation period the monthly average of 31.1 °C and the monthly maximum of 34.4 °C was recorded in October 1988 and the minimum the monthly average of 18.8 °C and the monthly minimum of 16.9 °C was recorded in January 1989. Then the temperature started rising in February 1989.

3) The diurnal variation was distinctly shown in the temperature and the temperature varied in the range of 1 to 2 °C in a one day period.

As mentioned above, the variation of the water temperature nearby the sea water intake facilities of Umm Al Nar Station had the characteristics of long-term variation, in that the temperature continued gradually dropping since October and showed the minimum in January, intermediate variation of a period of several days, and furthermore of distinctly short-term variation of the diurnal period.

3.4.2 Consecutive Anchored Observation of Water Temperature

(1) Purpose

The purpose of consecutive observation of water temperature is to clarify the conditions of the water temperature in typical locations around Abu Dhabi.

(2) Observation Location

The locations of consecutive observation of water temperature are shown in Fig. 3.2.1.

(3) Duration of Observation

The duration of observation at each site is as follows:

1) Second Field Survey

* Site 1 September 26 to November 1, 1988
* Site 7 October 15 to October 31, 1988
* Site 9 September 27 to 31st October 31, 1988
* Site 15 October 8 to November 8, 1988
* Site 19 September 27 to November 1, 1988
* Site 20 September 26 to October 15, 1988
* Site 21 September 26 to October 15, 1988
* Site 23 October 15 to November 1, 1988

2) Third Field Survey

* Site 1 January 23 to February 25, 1989
* Site 7 January 24 to February 11, 1989
* Site 9 January 24 to February 26, 1989
* Site 15 January 28 to February 28, 1989
* Site 19 January 23 to February 25, 1989
* Site 20 February 11 to February 26, 1989
* Site 21 February 11 to February 26, 1989
* Site 23 January 23 to February 25, 1989

(4) Method of Observation

The consecutive observations of water temperature were conducted simultaneously with those of tidal currents and salinity using the self-recording water thermometer.

(5) Observations

1) Second Field Survey

The variation of the daily average water temperature at the typical sites is shown in Fig. 3.4.6. The observations of water temperature are tabulated in Table 3.4.2. According to this table, the temperature at Site 1 was always high compared with the other sites, and the average over the whole observation period was more than 31 °C.

The water temperature was respectively 30 to 32 °C at Site 9, 29 to 31 °C at Site 7, 29 to 31 °C at Site 19 and 29 to 31 °C at Site 20. The water temperature at Site 23 was low compared with the other sites, and the average over the whole observation period was less than 30 °C.

The water temperature at offshore Site 15 continued gradually dropping from about 31.5 °C and approached 29.5 °C on November 7, 1988. The water temperature dropped by about 2 °C over a monthly period. The diurnal or semi-diurnal variation at each site was observed as shown in Fig. 3.4.7.

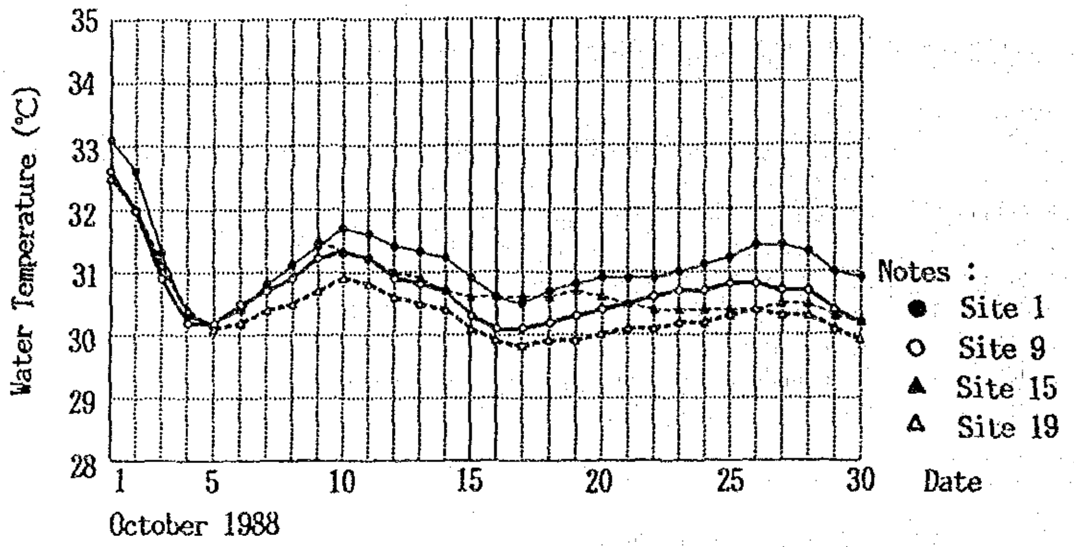


Fig. 3.4.6: Daily Average Water Temperature at Typical Sites in Second Field Survey

Table 3.4.2: Water Temperature at Each Sites in Second Field Survey

Site	Max. (℃)	Min. (℃)	Ave. (℃)	Duration of Observation
1	34.1	29.3	31.1	1st Oct. ~ 30th Oct. 1988
7	32.0	29.2	30.4	16th Oct. ~ 30th Oct. 1988
9	32.9	29.8	30.7	1st Oct. ~ 30th Oct. 1988
15	31.8	29.2	30.4	9th Oct. ~ 7th Nov. 1988
19	32.9	29.5	30.4	1st Oct. ~ 30th Oct. 1988
20	32.6	27.6	30.3	30th Sep. ~ 14th Oct. 1988
21	33.6	28.2	30.3	30th Sep. ~ 14th Oct. 1988
23	30.8	28.5	29.6	16th Oct. ~ 30th Oct. 1988

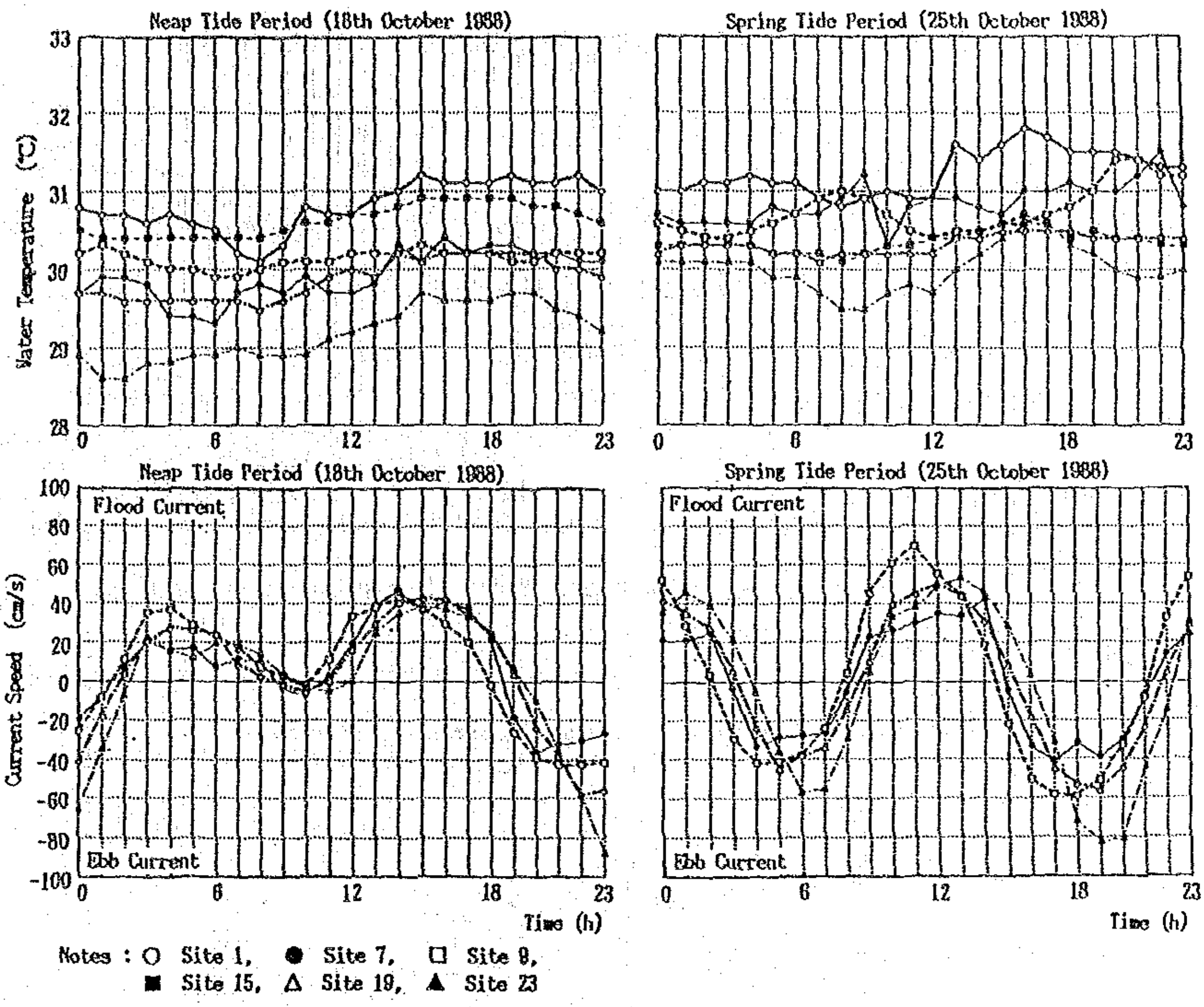


Fig. 3.4.7: Typical Profile of Water Temperature and Current Conditions in Second Field Survey

2) Third Field Survey

The variation of the daily average water temperature at typical sites is shown in Fig. 3.4.8. The water temperature is tabulated in Table 3.4.3. According to this table, the water temperature at all of the sites was in the range of 16.9 to 23.6 °C, and the average water temperature at all of the sites was in the range of 18.7 to 20.1 °C.

The diurnal and semi-diurnal variation of the water temperature were observed at each site.

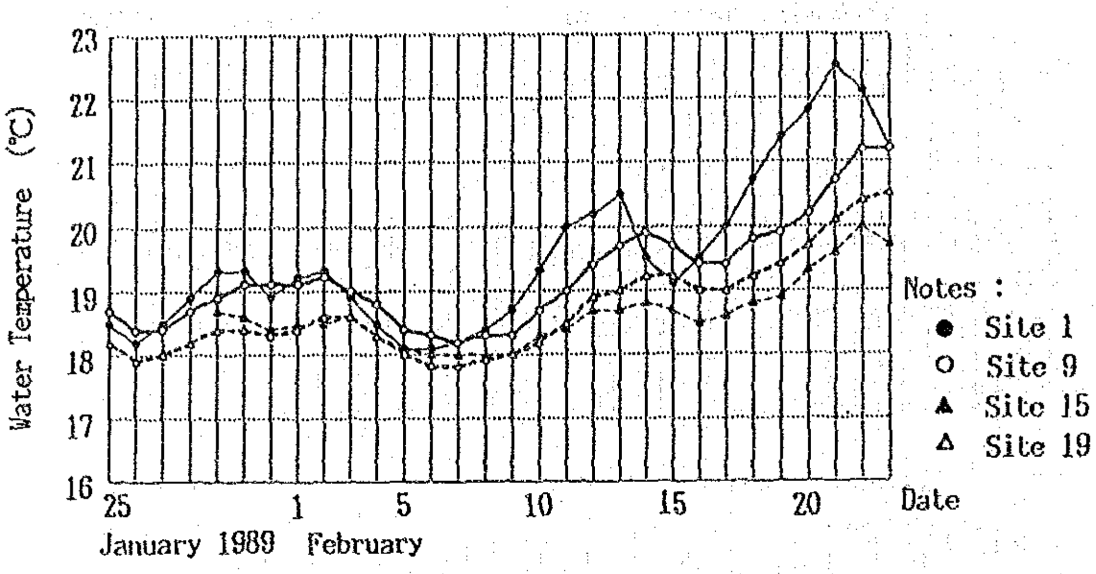


Fig. 3.4.8: Daily Average Water Temperature at Typical Sites in Third Field Survey

Table 3.4.3: Water Temperature at Each Site in Third Field Survey

Site	Max. (°C)	Min. (°C)	Ave. (°C)	Duration of Observation
1	23.6	17.7	19.6	Jan. 1 to Feb. 23, 1989
7	20.1	17.5	18.7	Jan. 25 to Feb. 8, 1989
9	22.4	17.8	19.7	Jan. 25 to Feb. 23, 1989
15	20.5	17.7	18.8	Jan. 29 to Feb. 27, 1989
19	20.8	17.6	18.7	Jan. 25 to Feb. 23, 1989
20	22.3	18.1	20.1	Feb. 11 to Feb. 26, 1989
21	22.8	18.3	20.1	Feb. 11 tl Feb. 26, 1989
23	22.6	16.9	19.4	Jan. 25 tp Feb. 23, 1989

(6) Summary

1) The water temperature in the summer survey was in the range of 27.6 to 34.1 °C and it tended to be higher near the Umm Al Nar Station intakes. Also, the temperature in the winter survey was in the range of 16.9 to 23.6 °C and it tended to be higher near the Umm Al Nar Station intakes and in the interior of Bateen Channel. Regarding the average water temperature, that in the winter survey was to a degree of 10 °C lower than that in the summer survey.

2) The diurnal and semi-diurnal variation was shown in the water temperature and the range of the variation was 1 to 2 °C in both the channels and near the Umm Al Nar Station intakes.

3.4.3 Vertical Profile Observation of Water Temperature

(1) Purpose

The purpose of vertical profile observation of water temperature is to clarify the vertical distribution of water temperature around the Abu Dhabi Island and near the sea water intake facilities of Umm Al Nar Station.

(2) Observation Location

The observation locations are shown in Fig. 3.4.9. 9 locations were selected as observation sites so that the vertical distribution of water temperature near the sea water intake facilities of Umm Al Nar Station could be ascertained in detail. 14 locations were selected so that the distribution around the Abu Dhabi Island could be ascertained generally.

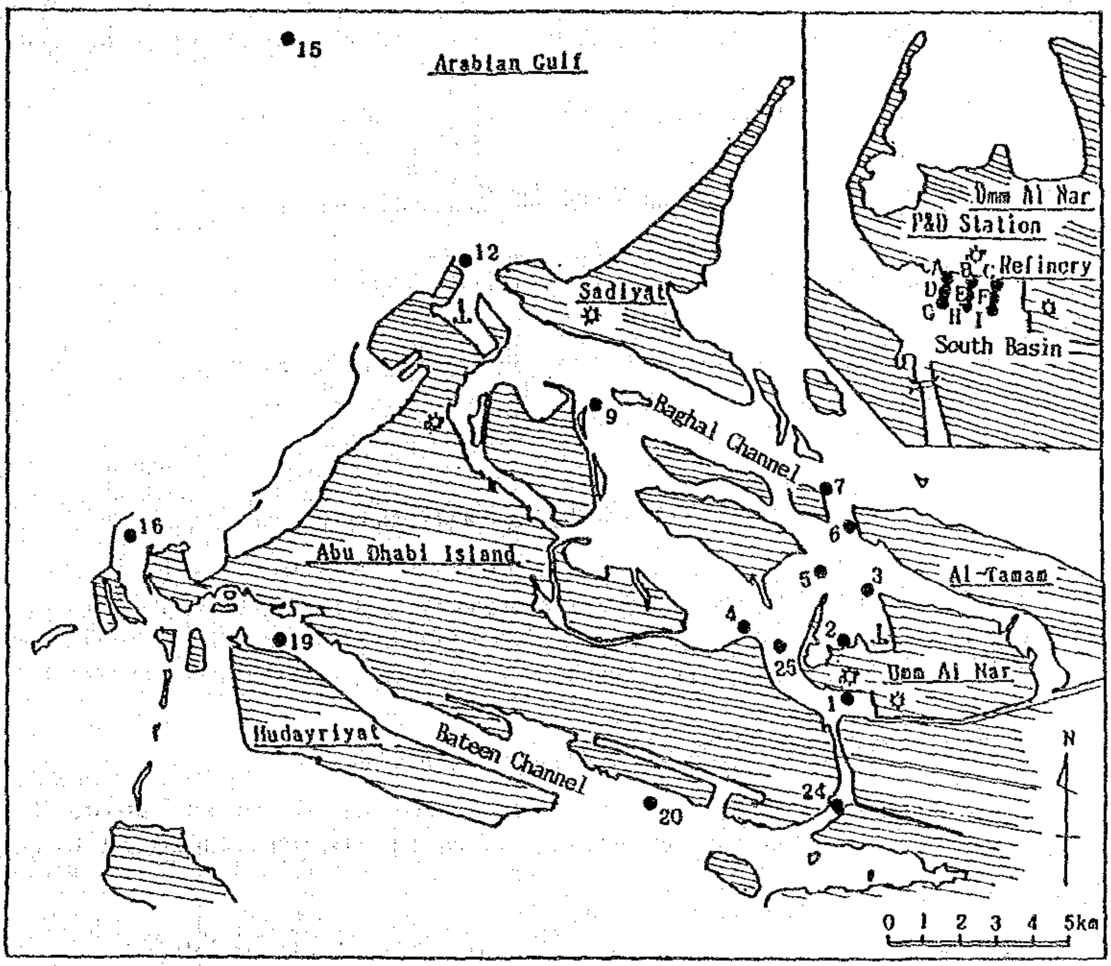


Fig. 3.4.9: Location of Vertical Profile Observation of Water Temperature and Salinity

(3) Date of Observation

The date of observation is as follows:

1) Second Field Survey

* Ebb tide period on October 25, 1988
* Flood tide period on October 26, 1988

2) Third Field Survey

* Ebb tide period on February 2, 1989
* Flood tide period on February 8, 1989

(4) Method of Observation

The vertical observation of water temperature was conducted simultaneously with those of tidal currents and salinity. Three layers (upper, middle and lower) were observed with a direct-reading electric water thermometer of the ET-5 type. A sketch of water temperature observation is shown in Fig. 3.4.10.

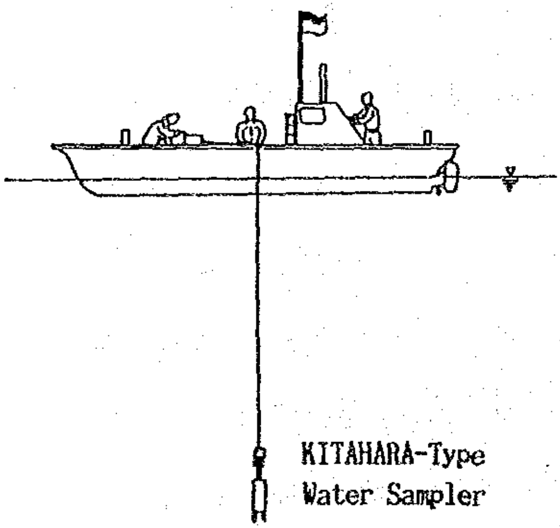


Fig. 3.4.10: Sketch of Vertical Profile Observation of Water Temperature

(5) Results of Observations

The vertical profile of water temperature are as shown in Tables 3.4.4(1) to 3.4.4(4). The site classification according to the range in all layers is shown in Tables 3.4.5(1) to 3.4.5(4).

1) Ebb Tide Period on October 25, 1988 in Second Field Survey

According to these tables, the water temperature was in the range of 30.2 to 36.9 °C over the whole observation period and the average temperature was 31.2 °C.

The vertical temperature range at each site was generally small. However, the temperature in the middle or lower layers was respectively higher than that in the upper layer at Site 3 about 2 km north of the brine discharge facilities of Umm Al Nar Station, and also, relatively large vertical ranges were seen in the temperature at the sites in Umm Al Nar Station South Basin and at the offshore site. The vertical distribution of the water temperature was almost uniform at each site except at these two sites.

Table 3.4.4(1): Vertical Profile of Water Temperature
(Ebb Tide Period on October 25, 1988)

Item / Layer	Maximum Value (℃)		Minimum Value (℃)		Average Value (℃)
0.3m	36.9	(Site 2)	30.4	(Site 19)	31.6
3.0m	32.1	(Site 1-I)	30.3	(Site 20)	31.3
B+1m	33.2	(Site 3)	30.2	(Site 16)	31.2
Whole	36.9		30.2		31.2

Table 3.4.5(1): Site Classification According to Range among Layers in Water Temperature (Ebb Tide Period on October 25, 1988)

	Range of Temperature< 0.5℃	Range of Temperature≧ 0.5℃
Site	1-A,1-B,1-C,1-F,1-I,4,5,7,9,12, 19,20,24	1-D,1-E,1-G,1-H,3,6,15,16,25

2) Flood Tide Period on October 26, 1988 in Second Field Survey

The water temperature was in the range of 29.9 to 36.8 ℃ over the whole observation period and the average temperature was 31.0 ℃.

The vertical temperature range at each site was generally small and a range of more than 0.5 ℃ was observed only at Site 3 north of the brine discharge facilities of Umm Al Nar Station. The vertical distribution of the temperature was almost uniform at each site except Site 3.

Table 3.4.4(2): Vertical Profile of Water Temperature
(Flood Tide Period on October 26, 1988)

Layer	Maximum Value (℃)		Minimum Value (℃)		Average Value (℃)
0.3m	36.8	(Site 2)	30.2	(Site 20)	31.3
3.0m	31.7	(Site 25)	30.0	(Site 20)	30.9
B+1m	31.7	(Site 25)	29.9	(Site 20)	30.9
Whole	36.8		29.9		31.0

Table 3.4.5(2): Site Classification According to Range among Layers in Water Temperature
(Flood Tide Period on October 26, 1988)

	Range of Temperature< 0.5℃	Range of Temperature≧ 0.5℃
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-H,1-I.4,5,6,7,9,12,15,16,19,20,24,25	3

3) Ebb Tide Period on February 2, 1989 in Third Field Survey

The water temperature was in the range of 18.4 to 23.6 °C over the whole observation period and the average temperature was 19.5 °C.

The vertical temperature range at each site was generally small and a range of more than 0.5 °C was observed at four sites, and among them the temperature in the lower layer was higher than that in the upper layer respectively at Site 3, Site 6 and Site 7, north of the brine discharge facilities of Umm Al Nar Station.

Table 3.4.4(3): Vertical Profile of Water Temperature
(Ebb Tide Period on February 2, 1989)

Layer	Maximum Value (℃)		Minimum Value (℃)		Average Value (℃)
0.3m	23.6	(Site 2)	18.4	(Site 15)	19.5
3.0m	23.5	(Site 2)	18.4	(Site 15)	19.4
B+1m	21.7	(Site 7)	18.4	(Site 15)	19.5
Whole	23.6		18.4		19.5

Table 3.4.5(3): Site Classification According to Range among Layers in Water Temperature
(Ebb Tide Period on February 2, 1989)

	Range of Temperature< 0.5℃	Range of Temperature≧ 0.5℃
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-H 2,4,5,9,12,15,16,19,20,24,25	1-I,3,6,7

4) Flood Tide Period on February 8, 1989 in Third Field Survey

The water temperature was in the range of 17.3 to 20.7 °C over the whole observation period and the average temperature was 18.2 °C.

The vertical water temperature range at each site was generally small and a range of more than 0.5 °C was observed at only two sites, and among them the temperature in the lower layer was higher than that in the upper layer at Site 3.

Table 3.4.4(4): Vertical Profile of Water Temperature (Flood Tide Period on February 8, 1989)

Layer	Maximum Value (°C)		Minimum Value (°C)		Average Value (°C)
0.3m	20.7	(Site 2)	17.3	(Site 16)	18.3
3.0m	20.6	(Site 2)	17.3	(Site 16)	18.3
B+1m	18.9	(Site 25)	17.4	(Site 16)	18.2
Whole	20.7		17.3		18.2

Table 3.4.5(4): Site Classification According to Range among Layers in Water Temperature (Flood Tide Period on February 8, 1989)

	Range of Temperature< 0.5℃	Range of Temperature≧ 0.5℃
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-I, 2,4,5,6,7,9,12,15,16,19,20,24,25	1-H,3

(6) Summary

1) The water temperature range was generally small both in the summer survey and in the winter survey. That is to say, the formation of a thermocline is assumed to be very difficult in the marine area around the Abu Dhabi Island both due to the shallow water depth and due to the relatively large current speed at each site.

2) The water temperature in the middle and the lower layer was likely to be higher than that in the upper layer north of the brine discharge facilities of Umm Al Nar Station.

3) The water temperature difference in the upper and lower layers was small at all sites in general. However, there was the tendency for the water temperature in the middle and lower layers to be 1 to 2 higher than that of the upper layer, to the north of the brine discharge facilities of Umm Al Nar Station.

3.5 Salinity

3.5.1 Consecutive Anchored Observation of Salinity

(1) Purpose

The purpose of consecutive observation of salinity is to clarify the conditions of salinity variation in typical locations around the Abu Dhabi Island.

(2) Observation Location

The locations of consecutive observation of salinity are as shown in Fig. 3.2.1.

(3) Duration of Observation

The duration of observation at each site is as follows:

1) Second Field Survey

* Site 1 September 26 to November 1, 1988
* Site 7 October 15 to October 31, 1988
* Site 9 September 27 to October 31, 1988
* Site 15 October 8 to November 8, 1988
* Site 19 September 27 to November 1, 1988
* Site 20 September 26 to October 15, 1988
* Site 21 September 26 to October 15, 1988

2) Third Field Survey

* Site 1 January 23 to February 25, 1989
* Site 7 January 24 to February 11, 1989
* Site 9 January 24 to February 26, 1989
* Site 15 January 28 to February 28, 1989
* Site 19 January 23 to February 25, 1989
* Site 20 February 11 to February 26, 1989
* Site 21 February 11 to February 26, 1989
* Site 23 January 23 to February 25, 1989

(4) Method of Observation

The consecutive observation of salinity was conducted simultaneously with those of tidal currents and water temperature using the self-recording electric conductivity meter.

(5) Results of Observations

1) Second Field Survey

The variations of the daily average salinity in the typical sites are shown in Fig. 3.5.1. The consecutive anchored observations of the salinity are tabulated in Table 3.5.1.

According to this table, the salinity was in the range of 41.42 to 47.22 and the maximum, and minimum were respectively recorded at Site 1 and at Site 15.

Regarding the average value at each site, the minimum was recorded at offshore Site 15, next at Site 9 and Site 19 near entrance in Baghal Channel and Bateen Channel, then next at Site 7, Site 20, Site 21 and Site 23 near the interior of the lagoon, and lastly at Site 1 nearby the sea water intake facilities of Umm Al Nar Station. That is, the salinity was likely to become higher as one approaches the interior of the lagoon.

The salinity was always very high, in particular, at Site 1 near the sea water intake facilities of Umm Al Nar Station. The long-term variation of salinity was relatively small at each site, but the short-term variation of salinity was characteristically large at each site except Site 1 and Site 15 as shown in Fig. 3.5.2. That is to say, the diurnal or semi-diurnal variation within a range of 1 to 2 was recorded.

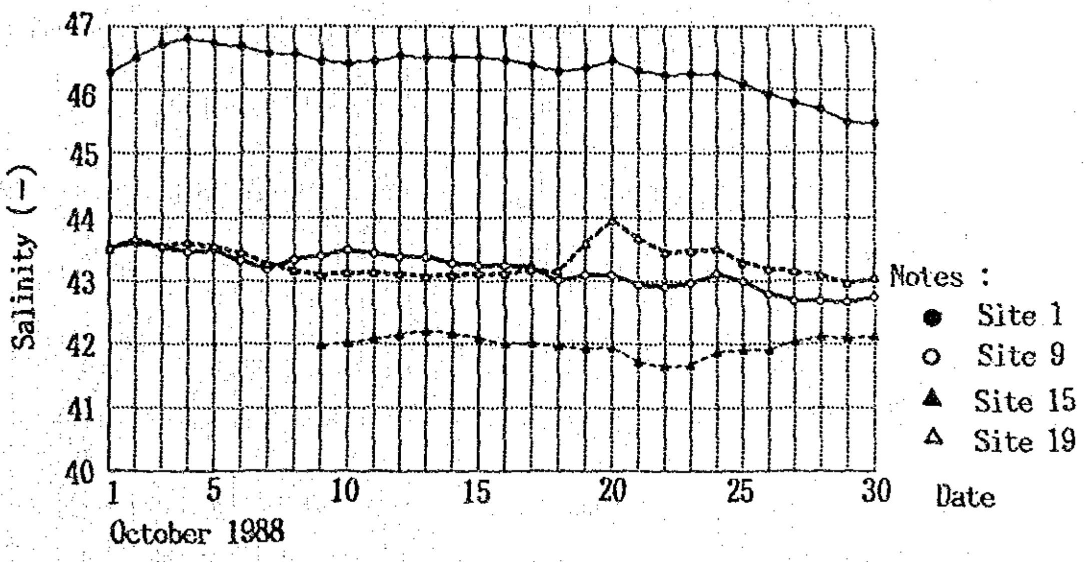


Fig. 3.5.1: Variations of Daily Average Salinity at Typical Sites around Abu Dhabi Island in Second Field Survey

Table 3.5.1: Tabulation of Salinity at Each Site in Second Field Survey

Site	Max. (−)	Min. (−)	Ave. (−)	Duration of Observation
1	47.22	45.13	46.29	1st Oct. ~ 30th Oct.1988
7	46.50	41.91	44.43	16th Oct. ~ 30th Oct.1988
9	45.42	41.47	43.14	1st Oct. ~ 30th Oct.1988
15	42.51	41.42	42.02	9th Oct. ~ 7th Nov.1988
19	44.84	42.09	43.28	1st Oct. ~ 30th Oct.1988
20	45.77	43.45	44.73	30th Sep. ~ 14th Oct.1988
21	46.37	45.00	45.71	30th Sep. ~ 14th Oct.1988
23	46.20	44.52	45.33	16th Oct. ~ 30th Oct.1988

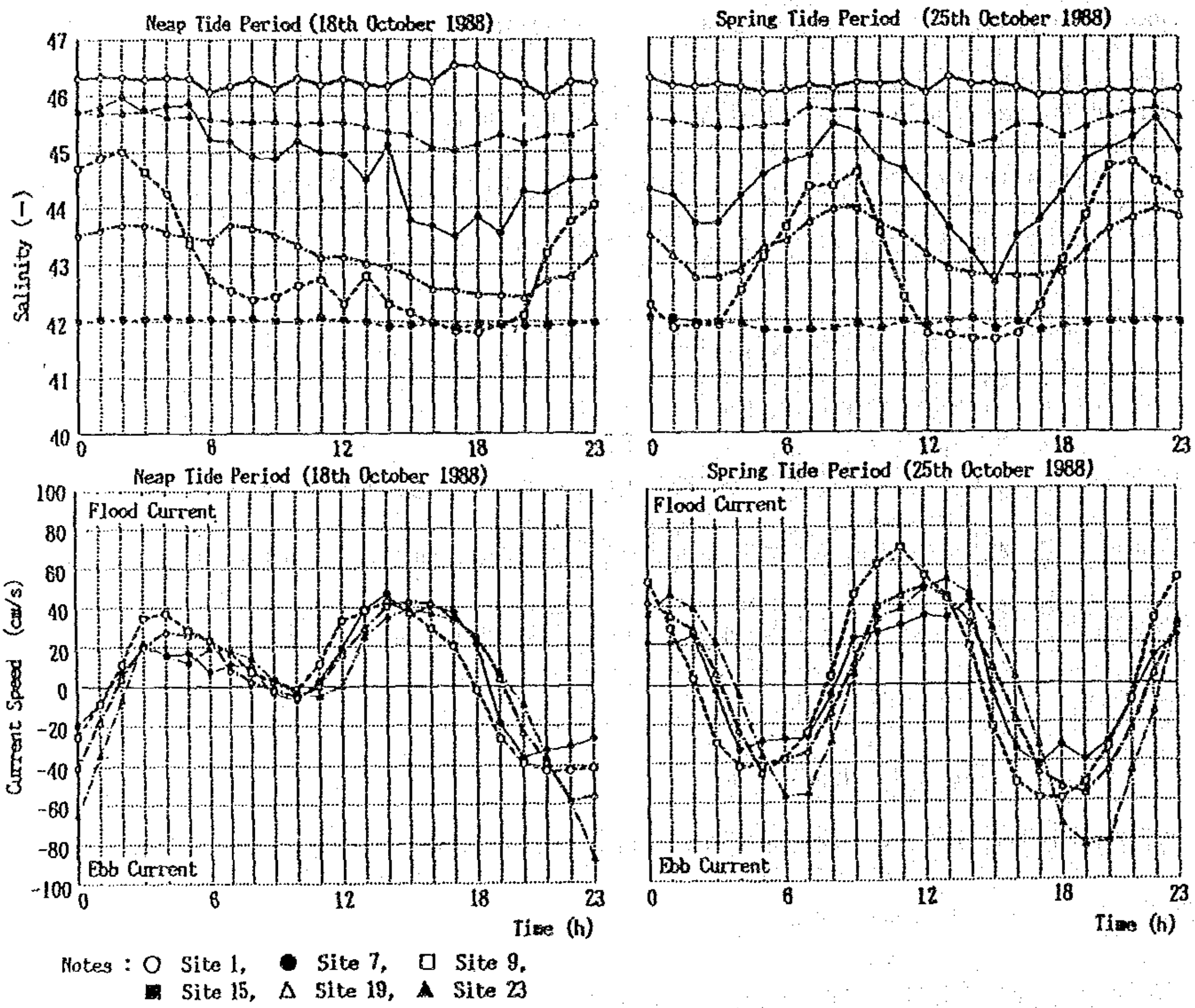


Fig. 3.5.2: Relations between Salinity and Current Conditions around Abu Dhabi Island

2) Third Field Survey

The variation of the daily average salinity at typical sites is shown in Fig. 3.5.3. The observations of salinity are tabulated in Table 3.5.2. According to this table, the salinity was in the range of 41.38 to 47.21 and the maximum and minimum were recorded at Site 1 nearby the sea water intake facilities of Umm Al Nar Station and at offshore Site 15 respectively.

Regarding the average value at each site, the minimum was observed at Site 15 and the maximum was observed at Site 1 near the sea water intake facilities of Umm Al Nar Station.

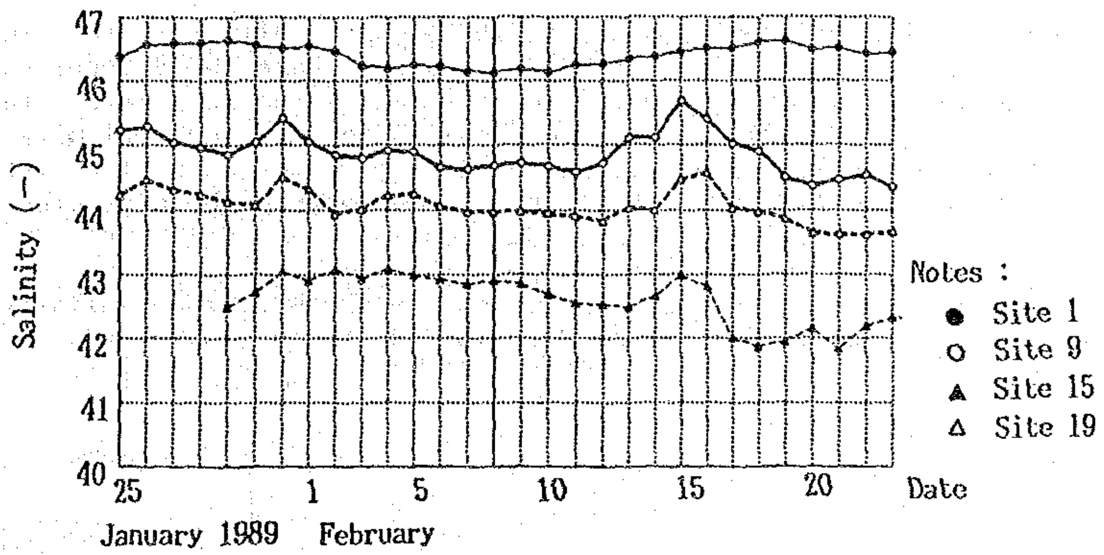


Fig. 3.5.3: Variations of Daily Average Salinity at Typical Sites around Abu Dhabi Island in Third Field Survey

Table 3.5.2: Salinity at Each Site in Third Field Survey

Site	Max. (-)	Min. (-)	Ave. (-)	Duration of Observation
1	47.21	45.82	46.37	25th Jan. ~ 23th Feb.1989
7	46.68	43.85	45.58	25th Jan. ~ 8th Feb.1989
9	46.72	42.87	44.85	25th Jan. ~ 23th Feb.1989
15	43.44	41.38	42.62	29th Jan. ~ 27th Feb.1989
19	45.64	43.20	44.03	25th Jan. ~ 23th Feb.1989
20	46.23	44.20	45.34	11th Feb. ~ 26th Feb.1989
21	46.63	45.41	46.06	11th Feb. ~ 26th Feb.1989
23	47.13	44.78	45.82	25th Jan. ~ 23th Feb.1989

Similarly to the observations in the second field survey, the long-term variation of salinity was relatively small at each site, but the short-term variation of salinity was characteristically large at each site except Site 1 and Site 15. That is to say, the diurnal or semi-diurnal variation within a range of 1 to 3 was recorded.

(6) Summary

1) The salinity in each survey was respectively in the range of 41.42 to 47.22 in the summer survey, and in the range of 41.38 to 47.21 in the winter survey and a salinity of more than 40 was observed during both surveys. Regarding the average at each site, that of the winter survey was higher to some degree than that of the summer survey.

2) Regarding the horizontal distribution of the salinity, the lowest value was recorded at the offshore site, next came the sites in both the channels, continuing up to the site nearby the sea water intake facilities of Umm Al Nar Station. That is to say, the salinity was likely to become higher as one approached the interior of the lagoon, and in particular, the salinity was always very high near the sea water intake facilities of Umm Al Nar Station

3) The diurnal and semi-diurnal variation was shown in the salinity at the sites except at Site 1 and Site 15, and the variation was in the range of 1 to 3.

3.5.2 Vertical Profile Observation of Salinity

(1) Purpose

The purpose of vertical observation of salinity is to clarify the conditions of the vertical distribution of salinity around the Abu Dhabi Island and near the sea water intake facilities of Umm Al Nar Station.

(2) Observation Location

The observation locations are shown in Fig. 3.4.7. 9 locations were selected as observation sites so that the vertical distribution of salinity near the sea water intake facilities could be ascertained in detail. 14 locations were selected so that the distribution around the Abu Dhabi Island could be ascertained generally.

(3) Date of Observation

The date of observation is as follows:

1) Second Field Survey

* Ebb tide period on October 25, 1988
* Flood tide period on October 26, 1988

2) Third Field Survey

* Ebb tide period on February 2, 1989
* Flood tide period on February 8, 1989

(4) Method of Observation

The vertical observation of salinity was conducted simultaneously with those of tidal currents and water temperature. The sea water from three layers (upper, middle and lower) was sampled with a water sampler of the Kitahara type and the salinity of the sea water was determined with a salinometer. A sketch of salinity observation is shown in Fig. 3.5.4.

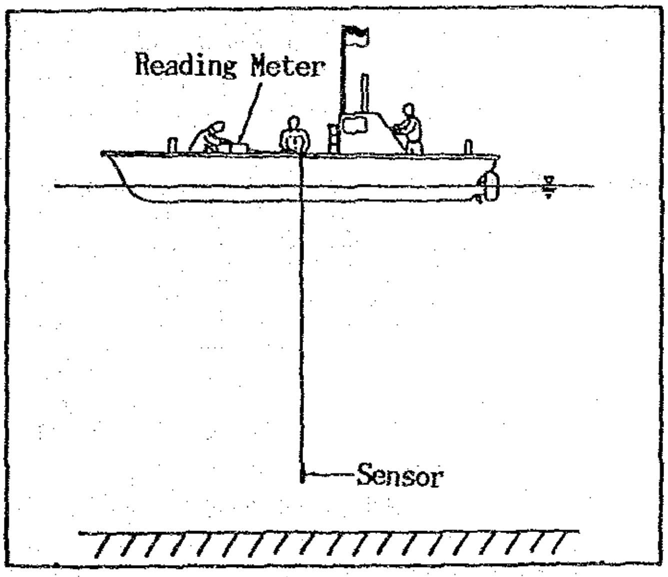


Fig. 3.5.4: Sketch of Vertical Profile Observation of Salinity

(5) Observations

The observations of salinity are tabulated in Tables 3.5.3(1) to (4). The site classification according to the range in all the layers is shown in Tables 3.5.4(1) to (4).

1) Ebb Tide Period on October 25, 1988 in Second Field Survey

The salinity was in the range of 41.68 to 48.76 in the whole observations and the average salinity was 44.60. The vertical salinity range at each site was generally small and the vertical distribution of the salinity was almost uniform at each site except Site 7. But the salinity in the lower layer was higher than that in the upper layer at Site 7, 2 km north of the brine discharge facilities of Umm Al Nar Station.

Table 3.5.3(1): Vertical Tabulation of Salinity
(Ebb Tide Period on October 25, 1988)

Layer	Maximum Value (−)		Minimum Value (−)		Average Value (−)
0.3m	48.76	(Site 2)	41.72	(Site 12)	44.70
3.0m	45.93	(Site 1-E)	41.68	(Site 12)	44.55
B+1m	46.54	(Site 3)	41.74	(Site 12)	44.80
Whole	48.76		41.68		44.60

Table 3.5.4(1): Site Classification According to Range among Layers in Salinity (Ebb Tide Period on October 25, 1988)

	Range of Salinity < 0.5	Range of Salinity ≧ 0.5
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-H, 1-I,4,5,7,9,12,16,19,20,24	3,6,15,25

2) Flood Tide Period on October 26, 1988 in Second Field Survey

The salinity was in the range of 41.59 to 48.31 over the whole observation period and the average salinity was 44.52. The vertical salinity range at each site was generally small and the vertical distribution of the salinity was almost uniform at each site, similar to that of the ebb tide period.

Table 3.5.3(2): Vertical Tabulation of Salinity
(Flood Tide Period on October 26, 1988)

Layer	Maximum Value (−)		Minimum Value (−)		Average Value (−)
0.3m	48.31	(Site 2)	41.59	(Site 12)	44.65
3.0m	45.89	(Site 25)	41.59	(Site 12)	44.54
B+1m	45.89	(Site 25)	41.61	(Site 12)	44.61
Whole	48.31		41.59		44.52

Table 3.5.4(2): Site Classification According to Range among Layers in Salinity (Flood Tide Period on October 26, 1988)

	Range of Salinity < 0.5	Range of Salinity ≧ 0.5
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-H, 1-I,4,5,6,7,9,12,15,16,19,20,24,25	3

3) Ebb Tide Period on February 2, 1989 in Third Field Survey

The salinity was in the range of 42.97 to 48.91 in the whole observations and the average salinity was 45.46. The vertical salinity range at each site was generally small and the vertical distribution of the salinity was almost uniform at each site except at Site 3, Site 5, Site 6 and Site 7, north of the brine discharge facilities of Umm Al Nar Station.

Table 3.5.3(3): Vertical Tabulation of Salinity (Ebb Tide Period on February 2, 1989)

Layer	Maximum Value (−)		Minimum Value (−)		Average Value (−)
0.3m	48.91	(Site 2)	43.03	(Site 15)	45.49
3.0m	46.50	(Site 1-D)	42.97	(Site 15)	45.39
B+1m	47.56	(Site 7)	43.20	(Site 15)	45.76
Whole	48.91		42.97		45.54

Table 3.5.4(3): Site Classification According to Range among Layers in Salinity (Ebb Tide Period on February 2, 1989)

	Range of Salinity < 0.5	Range of Salinity ≧ 0.5
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-H, 1-I,4,9,12,15,16,19,20,24,25	3,5,6,7

4) Flood Tide Period on February 8, 1989 in Third Field Survey

The salinity was the range of 42.99 to 48.67 over the whole observation period and the average salinity was 45.66. The vertical salinity range at each site was generally small, and the vertical distribution of the salinity was almost uniform at each site similar to that of the ebb tide period.

Table 3.5.3(4): Vertical Tabulation of Salinity (Flood Tide Period on February 8, 1989)

Layer	Maximum Value (-)		Minimum Value (-)		Average Value (-)
0.3m	48.67	(Site 2)	43.03	(Site 15)	45.71
3.0m	46.31	(Site 25)	42.99	(Site 15)	45.59
B+1m	47.06	(Site 3)	43.06	(Site 15)	45.69
Whole	48.67		42.99		45.66

Table 3.5.4(4): Site Classification According to Range among Layers in Salinity (Flood Tide Period on February 8, 1989)

	Range of Salinity < 0.5	Range of Salinity ≧ 0.5
Site	1-A,1-B,1-C,1-D,1-E,1-F,1-G,1-H, 1-I,4,5,6,7,12,15,16,19,20,24,25	3,9

(6) Summary

1) The minimum salinity was recorded at the offshore site and the salinity became higher as one approached the interior of the lagoon. The maximum salinity was recorded at Site 2 near the brine discharge facilities of Umm Al Nar Station.

2) The vertical salinity range at each site was generally small both in the summer survey and in the winter survey.

3) To the north of the brine discharge facilities of Umm Al Nar Station, the salinity in the middle and lower layers was likely to be higher than that in the upper layer. Also, as shown in 3.4 on water temperature, of the brine discharge facilities of Umm Al Nar Station, the water temperature in the middle and lower layer was higher by 1 to 2 °C compared to that of the upper layer.

   The sea water specific gravity calculated from the water temperature and salinity was 1.028 to 1.034 in the upper layer, 1.028 to 1.034 in the middle layer and 1.029 to 1.034 in the lower layer, respectively. The specific gravity in the lower layer was to some degree large compared with that in upper and middle layers, but the vertical distribution of the specific gravity was generally uniform from the upper layer to the lower layer.

Accordingly, during the flood tide period, the sea water in the upper layer streamed toward the brine discharge facilities of Umm Al Nar Station and the sea water in the middle and lower layers streamed northward opposite to the upper stream, due to the formation of a down stream in the neighborhood of the brine discharge facilities of Umm Al Nar Station. That is to say, this phenomenon indicates that the high temperature and high salinity discharge from Umm Al Nar Station streams north while submerging down to the lower layer.

3.6 Water Quality

(1) Purpose

The purpose of water quality observation is to clarify the horizontal and vertical distribution of water quality in the sea around the Abu Dhabi Island.

(2) Observation Location

The observation locations are shown in Fig. 3.6.1. 9 locations in the sea around the Abu Dhabi Island, 2 locations near the sea water intake facilities of Umm Al Nar Station, and one location near the brine discharge facilities of Umm Al Nar Station, were selected as observation sites so that the water quality in the sea around the Abu Dhabi Island could be ascertained generally.

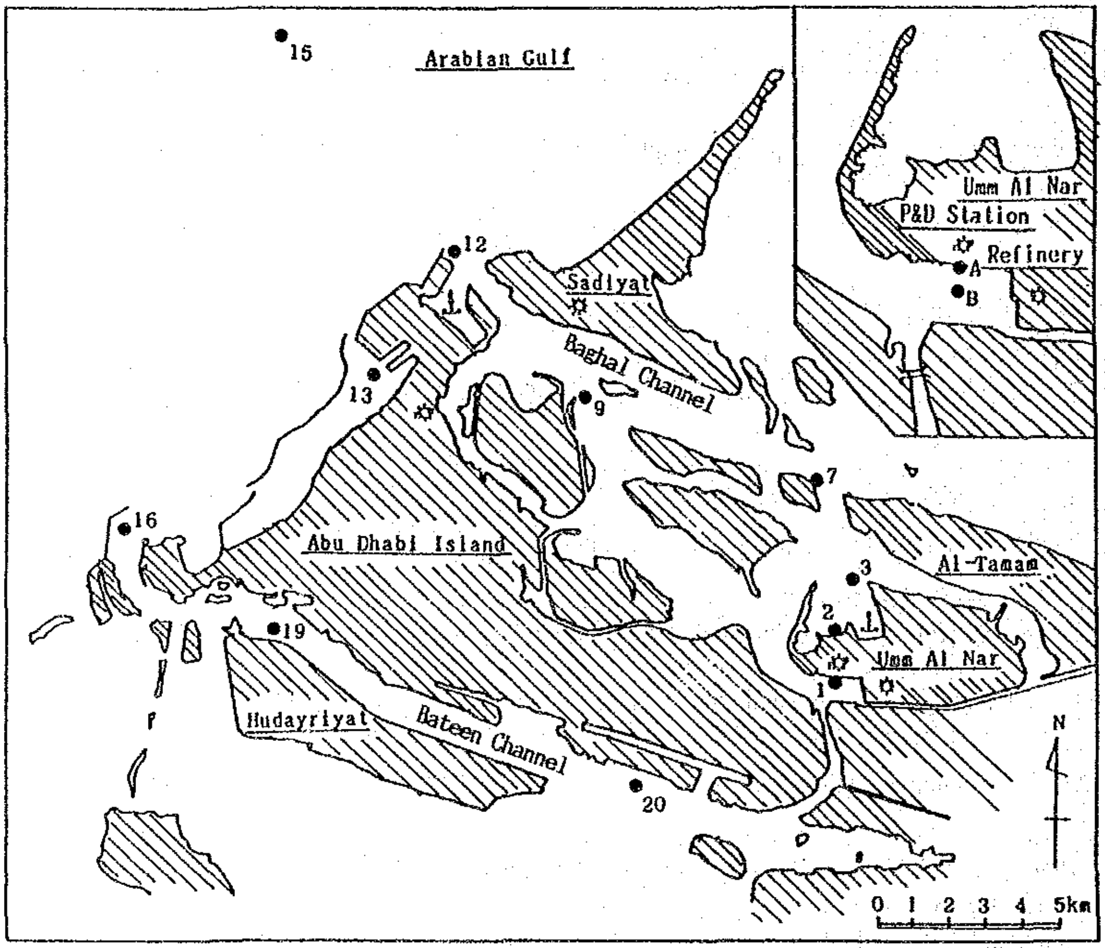


Fig. 3.6.1: Observation Location of Water Quality

(3) Date of Observation

The date of observation is as follows:

1) The Second Field Survey

* Low tide period on October 2, 1988
* High tide period on October 2, 1988

2) Third Field Survey

* Low tide period on January 31, 1989
* High tide period on February 6, 1989

(4) Method of Observation

Three layers (upper, middle and lower) were observed at each site and sea water was sampled on an observation boat with a water sampler of the Van Dorn type as shown in Fig. 3.6.2.

The methods of measurement and chemical analysis are shown in Table 3.6.1.

Water temperature, water color and dissolved oxygen were determined at each and salinity, pH, turbidity, TOC, NH_4-N, and oil content were examined at Material Testing Laboratory in Umm Al Nar Station, after the sea water was sampled at each site.

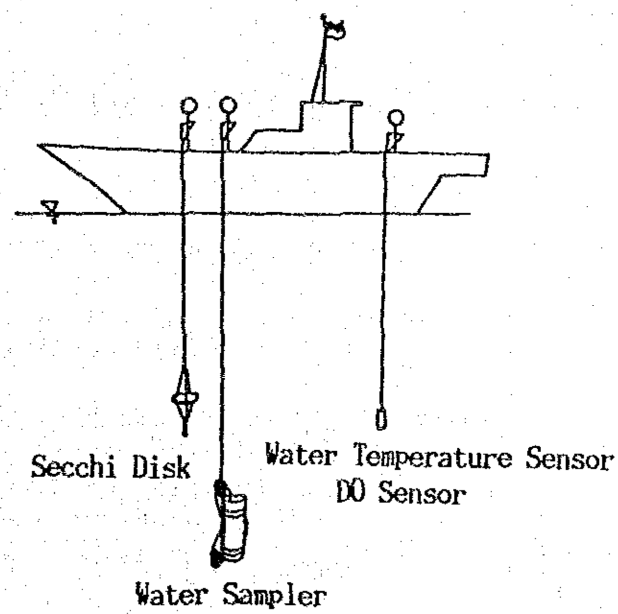


Fig. 3.6.2: Sketch of Observation of Water Quality

Table 3.6.1: Method of Measurement and Chemical Analysis

Parameter	Method	Reference
Water Temperature	Measurement with thermister thermometer	1)
Transparency	Visual inspection with Secchi disk	2)
Water Color	Comparison with color of standard solution	2)
Salinity	Electric conductivity method with salinometer	3)
Hydrogen ion concentration	Measurement with glass electrode pH-meter	1)
Dissolved Oxygen	Diaphragm electrode method	1)
Turbidity	Permeability turbidity	4)
Total Organic Carbon	Infra-red method	1)
Ammonia-N	Indophenol method	2)
Oil Content	Infra-red method	1)

(5) Results

The results of the water quality tests will be studied at first, and then the marine characteristics around the Abu Dhabi Island will be considered.

1) Second Field Survey

The results of water quality are tabulated in Table 3.6.2. The basic stable on water quality is shown in Table 3.6.3.

(a) Water color

The water color is determined by comparing a reference solution (available in blue to brown colors) with the color of the water of the sea surface. The reference solution consists of types No.1 to No.24. The smaller the number the more blue-based the color presented is.

At offshore Site 15, the water color was No.8 or No.7 both during the low tide period and the high tide period. The value of water color increased as one approached deeper into the interior of the lagoon. In particular, in the neighborhood of the sea water intake facilities of Umm Al Nar Station, the water color was No.11, which is of a more turbid color than those at the other sites.

Table 3.6.2(1): Analysis Results of Water Quality in Second Field Survey
(Low Tide Period on October 2, 1988)

Site	Time	Water Depth (m)	Layer (m)	Water Color (No)	Trans (m)	Temp. (℃)	Sal. (-)	pH (-)	DO Amount (mg/ℓ)	DO Satur (%)	Turb (deg)	TOC (mgC/ℓ)	NH_4-N (mg/ℓ)	Oil (mg/ℓ)
1-A	09:30 ～ 09:50	8.0	0.3	11	2.0	32.1	46.10	8.0	6.3	111	2.5	2.4	0.016	<0.1
			4.0	—	—	32.1	46.14	8.1	6.3	111	2.4	2.4	0.004	<0.1
			7.0	—	—	32.1	46.18	8.0	6.4	113	2.6	2.2	0.007	<0.1
1-B	10:04 ～ 10:22	7.0	0.3	11	1.6	32.4	46.26	8.0	5.8	103	1.6	2.4	0.017	<0.1
			3.0	—	—	32.4	46.26	8.0	5.9	105	3.4	2.4	0.007	<0.1
			6.0	—	—	32.3	46.25	8.1	6.3	111	2.3	2.4	0.006	<0.1
2	8:55 ～ 9:08	3.2	0.3	11	2.0	35.9	47.18	8.0	6.1	114	2.3	2.4	0.005	<0.1
			—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—
3	09:12 ～ 09:40	2.0	0.3	9	Bottom	33.6	46.61	8.1	5.9	107	1.9	2.7	0.002	<0.1
				—	—	—	—	—	—	—	—	—	—	—
			1.0	—	—	33.7	46.69	8.1	5.9	107	1.1	2.5	0.008	<0.1
7	10:02 ～ 10:17	8.5	0.3	9	6.0	31.7	45.23	8.1	5.5	96	0.7	2.1	0.009	<0.1
			3.0	—	—	31.6	45.27	8.1	5.5	96	0.8	2.3	0.011	<0.1
			7.5	—	—	31.5	45.31	8.1	5.5	96	0.9	2.1	0.008	<0.1
9	10:40 ～ 11:12	5.0	0.3	10	Bottom	32.0	43.39	8.1	5.7	99	1.4	2.1	0.004	<0.1
			2.0	—	—	32.0	43.42	8.1	5.7	99	<0.5	1.9	0.011	<0.1
			4.0	—	—	31.7	43.46	8.1	5.6	97	1.0	1.9	0.009	<0.1
12	11:33 ～ 11:52	14	0.3	8	8.5	31.8	42.49	8.1	5.6	96	<0.5	2.0	0.003	<0.1
			7.0	—	—	31.8	42.48	8.1	5.7	98	<0.5	1.8	0.005	<0.1
			13	—	—	31.7	42.52	8.1	5.7	98	<0.5	1.9	0.006	<0.1
13	13:52 ～ 14:10	6.0	0.3	9	3.0	32.6	42.77	8.1	6.0	105	0.6	2.0	0.003	<0.1
			3.0	—	—	32.6	42.76	8.1	6.0	105	0.6	1.8	<0.001	<0.1
			5.0	—	—	32.6	42.76	8.1	6.1	106	1.0	2.0	0.004	<0.1
15	12:33 ～ 13:00	14	0.3	8	Bottom	32.6	42.39	8.1	5.8	101	<0.5	2.1	0.005	<0.1
			7.0	—	—	32.5	42.37	8.1	5.9	103	<0.5	1.9	0.004	<0.1
			13	—	—	32.5	42.38	8.1	5.9	103	<0.5	1.9	0.002	<0.1
16	13:37 ～ 13:57	9.0	0.3	8	Bottom	32.4	42.78	8.1	5.7	99	<0.5	2.0	0.002	<0.1
			4.0	—	—	32.4	42.84	8.1	5.7	99	<0.5	2.0	0.003	<0.1
			8.0	—	—	32.3	42.92	8.1	5.9	103	<0.5	1.8	0.006	<0.1
19	12:46 ～ 12:54	7.0	0.3	10	6.5	32.1	43.38	8.1	5.6	97	<0.5	2.0	0.004	<0.1
			3.0	—	—	32.1	43.57	8.1	5.6	97	<0.5	2.0	0.003	<0.1
			6.0	—	—	31.9	43.62	8.1	5.8	101	<0.5	2.0	0.007	<0.1
20	11:11 ～ 11:28	7.5	0.3	9	4.0	31.2	45.30	8.0	5.6	97	0.8	2.3	0.014	<0.1
			3.0	—	—	31.2	45.29	8.0	5.8	100	0.7	2.3	0.016	<0.1
			6.5	—	—	31.0	45.30	8.0	6.1	105	1.4	2.3	0.015	<0.1

Table 3.6.2(2): Analysis Results of Water Quality in Second Field Survey
(High Tide Period on October 2, 1988)

Site	Time	Water Depth (m)	Layer (m)	Water Color (No)	Trans (m)	Temp. (℃)	Sal. (‰)	pH (−)	DO Amount (mg/ℓ)	DO Satur (%)	Turb (deg)	TOC (mgC/ℓ)	NH_4-N (mg/ℓ)	Oil (mg/ℓ)
1-A	16:58 ~ 17:18	8.0	0.3	11	1.8	33.6	46.78	8.1	6.3	114	2.7	2.5	0.016	<0.1
			3.0	—	—	33.4	46.79	8.1	6.1	110	3.2	2.5	0.013	<0.1
			7.0	—	—	33.4	46.83	8.1	6.2	112	1.3	2.4	0.005	<0.1
1-B	16:36 ~ 16:48	7.0	0.3	11	1.8	33.2	46.65	8.1	6.4	115	2.5	2.6	0.003	<0.1
			3.0	—	—	33.2	46.65	8.1	6.4	115	2.2	2.6	0.008	<0.1
			6.0	—	—	33.2	46.64	8.1	6.4	115	3.3	2.6	0.010	<0.1
2	18:14 ~ 18:20	3.5	0.3	11	2.0	37.1	47.68	8.0	6.0	115	2.2	2.7	0.003	<0.1
			—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—
3	17:27 ~ 17:33	2.5	0.3	9	Bottom	31.9	44.93	8.1	5.8	101	1.3	2.4	0.003	<0.1
				—	—	—	—	—	—	—	—	—	—	—
			1.5	—	—	31.8	44.91	8.1	5.8	101	2.0	2.2	0.006	<0.1
7	17:03 ~ 17:12	10	0.3	8	6.0	31.9	43.24	8.1	5.8	100	<0.5	1.9	0.002	<0.1
			5.0	—	—	32.0	43.58	8.1	5.9	102	0.7	2.0	0.005	<0.1
			9.0	—	—	32.0	44.03	8.1	5.9	103	1.0	2.0	0.005	<0.1
9	16:20 ~ 16:37	5.0	0.3	8	Bottom	31.8	42.54	8.1	5.8	100	<0.5	1.8	0.002	<0.1
			2.0	—	—	31.8	42.52	8.1	5.9	102	<0.5	1.9	0.006	<0.1
			4.0	—	—	31.8	42.59	8.1	5.9	102	<0.5	1.9	0.009	<0.1
12	13:00 ~ 13:28	15	0.3	6	6.5	30.6	42.74	8.0	6.1	103	1.2	2.2	0.023	<0.1
			7.0	—	—	30.7	42.73	8.1	6.0	102	1.8	2.0	0.075	<0.1
			14	—	—	30.7	42.73	8.1	6.1	103	1.2	2.2	0.030	<0.1
13	14:05 ~ 14:37	7.0	0.3	7	3.0	32.5	43.59	8.1	6.0	105	1.3	2.0	0.015	<0.1
			3.0	—	—	32.3	43.55	8.1	6.0	105	2.1	2.2	0.027	<0.1
			6.0	—	—	32.0	43.48	8.1	6.0	104	1.3	2.1	0.020	<0.1
15	14:55 ~ 15:20	14	0.3	7	12	32.8	42.18	8.2	5.8	101	<0.5	2.0	0.005	<0.1
			7.0	—	—	32.6	42.30	8.1	5.8	101	<0.5	1.9	0.003	<0.1
			13	—	—	32.6	42.27	8.1	5.8	101	<0.5	1.8	0.002	<0.1
16	14:00 ~ 14:20	9.5	0.3	8	Bottom	32.4	42.72	8.1	5.8	101	<0.5	1.9	0.011	<0.1
			4.0	—	—	32.4	42.85	8.1	5.8	101	<0.5	1.8	0.014	<0.1
			8.5	—	—	32.4	42.92	8.1	6.0	104	<0.5	1.9	0.012	<0.1
19	14:43 ~ 15:00	7.0	0.3	9	6.5	32.2	42.91	8.1	5.7	99	<0.5	1.9	0.008	<0.1
			3.0	—	—	32.4	42.93	8.1	5.7	99	<0.5	1.9	0.012	<0.1
			6.0	—	—	32.4	43.03	8.1	5.8	101	<0.5	1.9	0.003	<0.1
20	15:45 ~ 16:05	8.0	0.3	10	5.0	31.6	44.69	8.1	5.7	99	1.0	2.2	0.012	<0.1
			3.0	—	—	31.6	44.68	8.0	5.7	99	0.8	2.2	0.011	<0.1
			7.0	—	—	31.6	44.67	8.0	5.9	102	1.0	2.3	0.014	<0.1

Table 3.6.3(1): Basic Statistical Table of Water Quality
(Low Tide Period on October 2, 1988)

Parameter / Item Unit		Sample Number	Max.	Min.	Ave.	S.D.
Water Color	No.	12	11	8	9.4	1.2
Trans	m	12	8.5	1.6	2.8	2.9
Temp.	℃	33	35.9	31.0	32.3	0.9
Salinity	—	33	47.18	42.37	44.19	1.63
pH	—	33	8.1	8.0	8.1	0.0
DO						
Amount	mg/l	33	6.4	5.5	5.8	0.2
Saturation	%	33	114	96	102	5
Turb	deg	33	3.4	<0.5	0.9	1.0
TOC	mgC/l	33	2.7	1.8	2.1	0.2
NH_4-N	mg/l	33	0.017	<0.001	0.007	0.005
Oil	mg/l	33	<0.1	<0.1	<0.1	0.0

Table 3.6.3(2): Basic Statistical Table of Water Quality
(High Tide Period on October 2, 1988)

Parameter / Item Unit		Sample Number	Max.	Min.	Ave.	S.D.
Water Color	No.	12	11	6	8.8	1.7
Trans	m	12	12.0	1.8	3.7	3.6
Temp.	℃	33	37.1	30.6	32.4	1.1
Salinity	—	33	47.68	42.18	44.04	1.68
pH	—	33	8.2	8.0	8.1	0.0
DO						
Amount	mg/l	33	6.4	5.7	5.9	0.2
Saturation	%	33	115	99	104	5
Turb	deg	33	3.3	<0.5	1.0	1.0
TOC	mgC/l	33	2.7	1.8	2.1	0.3
NH_4-N	mg/l	33	0.075	0.002	0.012	0.013
Oil	mg/l	33	<0.1	<0.1	<0.1	0.0

(b) Transparency

Transparency is one of the indices to show the degree of purity-impurity of sea water. A white disk, the so-called Secchi disk, which has a diameter of 30 cm is dropped into the sea, and the depth at which it just goes out of sight, when viewed from above, is referred to as the transparency.

At offshore Site 15, the maximum transparency was observed at 14 m (landing on the bottom) during the low tide period, and 12 m during the high tide period. The transparency decreased as one approached deeper into both Baghal Channel and Bateen Channel. In the neighborhood of the sea water intake facilities of Umm Al Nar Station, the minimum transparency was observed, namely 1.6 m at Site 1-B during the low tide period and 1.8 m at Site 1-A during the high tide period.

(c) Water Temperature

The highest water temperature was observed at Site 2 nearby the brine discharge facilities of Umm Al Nar Station, namely 35.9 °C during the low tide period and 37.1 °C at the high tide period. Vertically, almost uniform values were recorded at each site.

(d) Salinity

At present, the salinity of the sea water is measured in accordance with practical salinity as defined by UNESCO in 1978. This salinity is determined by the electric conductivity ratio and is expressed nondimensionally.

At offshore Site 15, the lowest salinity level was recorded, namely 42.37 (middle layer) during the low tide period and 42.18 (upper layer) during the high tide period. The salinity increased as one advanced further into Baghal Channel and Bateen Channel, showing the highest value (a level of 47) near the brine discharge facilities of Umm Al Nar Station.

The vertical distribution was almost uniform.

(e) Hydrogen Ion Concentration (pH)

The variation of the pH value in sea water was small as compared with that in fresh water, owing to the buffer action of dissolved salts. The pH value presented weak alkalinity, depending on the concentration of dissolved carbon dioxide, bicarbonate ion, carbonate ion, etc. Normally, pH is in the range of 8.0 to 8.3.

The pH was in the range of 8.0 to 8.2, and uniform values were exhibited during each tide period and at each layer.

(f) Dissolved Oxygen (DO)

The dissolved oxygen in the sea water depends on water temperature and salinity under an equilibrium condition with the atmosphere. The solubility of oxygen into the sea water decreases as water temperature increases and also as salinity increases. The percentage of the amount of oxygen which is actually dissolved in the sea water to the amount of saturated oxygen is called the degree of oxygen saturation. The amount of saturated oxygen is calculated by Weiss's formula.

The DO was in the range of 5.5 to 6.4 mg/l during the low tide period and 5.7 to 6.4 mg/l during the high tide period. Uniform values were measured during each tide period and at each layer. The degree of DO saturation showed a value of about 100% at all the sites.

(g) Turbidity

Turbidity is the value to indicate to what extent the water is turbid. Formazine is used as reference solution for testing. At offshore Site 15, the turbidity was low (0.5 degrees or less) during both the low tide period and the high tide period. In the neighborhood of Umm Al Nar Station, however, the turbidity was high, in particular at Site 1-B located near the sea water intake facilities of Umm Al Nar Station, and the maximum value was recorded, namely 3.4 degrees in the middle layer during the low tide period and 3.3 degrees in the lower layer during the high tide period.

(h) Total Organic Carbon (TOC)

TOC refers to carbon in organic matter present in the water. The value of TOC, therefore, increases owing to oil contamination of the sea water.

TOC was high in the neighborhood of Umm Al Nar Station, indicating the maximum value 2.7 mgC/l in the upper layer of Site 3 during the low tide period and 2.7 mgC/l in the lower layer of Site 2 during the high tide period.

(i) Ammoniac Nitrogen (NH_4-N)

NH_4-N is produced when organic matter containing nitrogen decomposes. NH_4-N is contained in factory effluent, sewage, etc., and is referred to as an index of pollution caused by human activity.

NH_4-N was high in the neighborhood of the sea water intake facilities of Umm Al Nar Station during the low tide period, indicating 0.017 mg/l in the upper layer of Site 1-B. During the high tide period, NH_4-N was high at Site 23, indicating the maximum value 0.075 mg/l in the middle layer.

(j) Oil Content (Oil)

Oil content was not detected at all the sites (less than 0.1 mg/l). However, according to the visual observation carried out on October 28, 1988, the drifting of tar balls was observed on the sandy beach and in the harbor in front of Abu Dhabi City. Also, near the embankment in the neighborhood of Site 13, the presence of an oil film was recognized on the sea surface.

2) Third Field Survey

The results of water quality are tabulated in Tables 3.6.4(1) and (2) and the basic statistical table on water quality is shown in Tables 3.6.5(1) and (2).

Table 3.6.4(1) : Analysis Results of Water Quality in Third Field Survey (Low Tide Period on February 6, 1989)

Site	Time	Water Depth (m)	Layer (m)	Water Color (No)	Trans (m)	Temp. (℃)	Sal. (−)	pH (−)	DO Amount (mg/ℓ)	DO Satur (%)	Turb (deg)	TOC (mgC/ℓ)	NH_4-N (mg/ℓ)	Oil (mg/ℓ)
1-A	11:45 ~ 12:05	7.0	0.3	10	2.8	17.9	46.30	8.1	7.0	98	2.2	2.0	0.011	<0.1
			3.0	—	—	17.9	46.30	8.1	7.0	98	2.5	2.0	0.015	<0.1
			6.0	—	—	17.8	46.31	8.1	6.9	96	2.5	2.0	0.026	<0.1
1-B	12:10 ~ 12:25	6.5	0.3	11	3.0	18.0	46.22	8.1	6.8	95	1.4	2.0	0.018	<0.1
			3.0	—	—	18.0	46.21	8.1	6.6	92	1.8	1.9	0.011	<0.1
			5.5	—	—	18.0	46.22	8.1	6.8	95	2.3	1.9	0.016	<0.1
2	12:47 ~ 12:50	3.0	0.3	10	1.8	21.0	48.98	8.2	6.8	102	2.8	2.2	0.009	<0.1
			—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—
3	12:35 ~ 12:52	12	0.3	7	3.0	18.8	45.68	8.1	6.9	97	1.3	2.0	0.011	<0.1
			6.0	—	—	19.5	46.46	8.1	6.7	96	1.8	2.1	0.009	<0.1
			11	—	—	20.4	46.55	8.1	6.8	99	2.1	2.0	0.010	<0.1
7	12:11 ~ 12:25	12	0.3	7	3.0	18.3	44.45	8.1	6.8	94	2.6	2.0	0.010	<0.1
			6.0	—	—	18.3	44.48	8.1	6.8	94	3.1	2.1	0.014	<0.1
			11	—	—	18.3	44.65	8.1	7.0	97	2.2	1.9	0.015	<0.1
9	11:40 ~ 11:53	13	0.3	6	4.0	18.1	43.85	8.1	6.9	95	1.4	2.0	0.013	<0.1
			6.0	—	—	18.1	43.84	8.1	7.0	96	1.4	1.9	0.012	<0.1
			12	—	—	18.1	43.84	8.1	7.0	96	1.5	1.8	0.011	<0.1
12	11:07 ~ 11:23	14	0.3	6	4.5	18.0	43.88	8.1	6.9	95	0.9	1.9	0.015	<0.1
			7.0	—	—	18.0	43.90	8.1	7.1	98	1.1	1.8	0.014	<0.1
			13	—	—	18.0	43.93	8.1	7.1	98	1.5	1.9	0.019	<0.1
13	10:30 ~ 10:50	4.0	0.3	7	3.0	17.9	43.87	8.1	7.1	97	1.2	1.8	0.013	<0.1
			2.0	—	—	17.9	43.89	8.1	6.9	95	1.7	1.8	0.013	<0.1
			3.0	—	—	17.9	43.90	8.1	6.9	95	1.1	1.9	0.018	<0.1
15	09:30 ~ 09:52	14	0.3	5	6.0	17.9	43.01	8.1	6.9	94	<0.5	1.8	0.009	<0.1
			7.0	—	—	17.9	43.01	8.1	6.9	94	<0.5	1.8	0.017	<0.1
			13	—	—	18.0	43.11	8.1	6.9	94	<0.5	1.9	0.008	<0.1
16	09:07 ~ 09:22	7.5	0.3	6	5.5	17.5	43.69	8.1	7.0	95	<0.5	1.8	0.021	<0.1
			3.0	—	—	17.6	43.70	8.1	7.1	97	0.9	1.8	0.013	<0.1
			6.5	—	—	17.6	43.71	8.1	7.0	95	0.8	1.9	0.018	<0.1
19	09:44 ~ 09:58	8.0	0.3	7	6.0	17.3	43.88	8.1	6.9	94	0.6	1.8	0.014	<0.1
			4.0	—	—	17.3	43.85	8.1	6.9	94	0.6	1.9	0.007	<0.1
			7.0	—	—	17.3	43.85	8.1	6.9	94	<0.5	1.8	0.010	<0.1
20	10:45 ~ 11:05	8.0	0.3	9	4.5	17.6	45.60	8.1	7.1	98	1.0	2.1	0.014	<0.1
			4.0	—	—	17.6	45.60	8.1	7.0	97	1.6	2.1	0.017	<0.1
			7.0	—	—	17.6	45.60	8.1	7.0	97	1.0	2.1	0.017	<0.1

Table 3.6.4(2): Analysis Results of Water Quality in Third Field Survey (High Tide Period on January 31, 1989)

Site	Time	Water Depth	Layer	Water Color	Trans	Temp.	Sal.	pH	DO		Turb	TOC	NH_4-N	Oil
									Amount	Satur				
		(m)	(m)	(No)	(m)	(℃)	(-)	(-)	(mg/ℓ)	(%)	(deg)	(mgC/ℓ)	(mg/ℓ)	(mg/ℓ)
1-A	12:05 ～ 12:25	7.5	0.3	11	2.4	18.6	46.45	8.1	6.7	95	2.8	2.3	0.017	<0.1
			3.0	—	—	18.6	46.43	8.1	6.7	95	1.9	2.0	0.014	<0.1
			6.5	—	—	18.7	46.47	8.1	6.6	93	2.2	2.2	0.017	<0.1
1-B	12:27 ～ 12:40	7.0	0.3	11	2.2	18.7	46.48	8.1	6.8	96	1.8	2.1	0.016	<0.1
			3.0	—	—	18.6	46.44	8.1	6.6	93	1.9	2.0	0.017	<0.1
			6.0	—	—	18.7	46.46	8.1	6.7	95	1.7	2.1	0.022	<0.1
2	13:18 ～ 13:30	4.0	0.3	10	2.0	21.2	48.85	8.2	7.1	107	2.1	2.3	0.014	<0.1
			—	—	—	—	—	—	—	—	—	—	—	—
			—	—	—	—	—	—	—	—	—	—	—	—
3	13:25 ～ 13:50	13	0.3	7	3.0	20.0	46.55	8.1	6.8	99	1.4	1.9	0.016	<0.1
			6.0	—	—	20.1	46.86	8.1	6.8	99	1.9	2.0	0.010	<0.1
			12	—	—	21.3	47.42	8.1	6.7	100	1.7	2.1	0.016	<0.1
7	12:59 ～ 13:17	14	0.3	7	3.3	19.5	46.09	8.1	6.8	97	0.9	1.9	0.019	<0.1
			6.0	—	—	19.5	46.26	8.1	6.8	98	1.6	1.8	0.021	<0.1
			13	—	—	19.5	46.47	8.1	6.8	98	2.0	1.9	0.021	<0.1
9	12:10 ～ 12:28	13	0.3	6	5.5	18.9	44.16	8.1	7.1	99	0.7	1.8	0.014	<0.1
			6.0	—	—	18.9	44.98	8.1	6.7	94	0.8	1.9	0.016	<0.1
			12	—	—	18.9	44.93	8.1	6.9	97	0.6	1.7	0.016	<0.1
12	11:25 ～ 11:46	15	0.3	5	4.5	18.5	43.62	8.1	6.8	94	0.7	1.7	0.013	<0.1
			7.0	—	—	18.5	43.61	8.1	6.9	96	<0.5	1.7	0.017	<0.1
			14	—	—	18.4	43.61	8.1	6.8	94	0.7	1.6	0.009	<0.1
13	10:43 ～ 11:02	5.0	0.3	7	3.7	18.9	43.97	8.1	7.1	99	0.7	1.7	0.011	<0.1
			2.0	—	—	18.9	43.97	8.1	7.0	98	0.7	1.7	0.011	<0.1
			4.0	—	—	19.1	44.07	8.1	7.1	100	0.6	1.7	0.014	<0.1
15	09:40 ～ 10:10	15	0.3	4	6.0	18.3	43.06	8.1	7.0	96	1.1	2.0	0.020	<0.1
			7.0	—	—	18.3	43.06	8.1	7.1	98	1.4	1.7	0.011	<0.1
			14	—	—	18.3	43.12	8.1	7.2	99	1.7	1.8	0.018	<0.1
16	09:15 ～ 09:32	9.0	0.3	6	4.0	18.0	43.65	8.1	7.0	96	1.2	1.7	0.011	<0.1
			4.0	—	—	18.0	43.65	8.1	7.0	96	1.5	1.7	0.015	<0.1
			8.0	—	—	18.2	43.76	8.1	6.9	95	0.7	1.7	0.011	<0.1
19	10:03 ～ 10:16	8.5	0.3	7	6.0	18.3	43.86	8.1	7.0	97	<0.5	1.7	0.016	<0.1
			4.0	—	—	18.1	43.88	8.1	7.0	96	<0.5	1.7	0.011	<0.1
			7.5	—	—	18.0	43.91	8.1	6.8	94	0.5	1.7	0.017	<0.1
20	11:10 ～ 11:25	9.5	0.3	9	6.0	18.2	45.52	8.1	7.0	98	<0.5	1.9	0.010	<0.1
			4.0	—	—	18.4	45.64	8.1	6.8	95	0.6	1.9	0.008	<0.1
			8.5	—	—	18.2	45.99	8.1	6.9	96	<0.5	1.9	0.020	<0.1

Table 3.6.5(1): Basic Statistical Table of Water Quality
(Low Tide Period on February 6, 1989)

Parameter	Item Unit	Sample Number	Max.	Min.	Ave.	S.D.
Water Color	No.	12	11	5	7.6	1.9
Trans	m	12	6.0	1.8	4.0	1.4
Temp.	℃	34	21.0	17.3	18.1	0.8
Salinity	—	34	48.98	43.01	44.77	1.37
pH	—	34	8.2	8.1	8.1	0.0
DO						
Amount	mg/l	34	7.1	6.6	6.9	0.1
Saturation	%	34	102	92	96	2
Turb	deg	34	3.1	<0.5	1.5	0.7
TOC	mgC/l	34	2.2	1.8	1.9	0.1
NH_4-N	mg/l	34	0.026	0.007	0.014	0.004
Oil	mg/l	34	<0.1	<0.1	<0.1	0.0

Table 3.6.5(2): Basic Statistical Table of Water Quality
(High Tide Period on January 31, 1988)

Parameter	Item Unit	Sample Number	Max.	Min.	Ave.	S.D.
Water Color	No.	12	11	4	7.5	2.3
Trans	m	12	6.0	1.8	4.2	1.5
Temp.	℃	34	21.3	18.0	18.8	0.8
Salinity	—	34	48.85	43.06	45.10	1.51
pH	—	34	8.2	8.1	8.1	0.0
DO						
Amount	mg/l	34	7.2	6.6	6.9	0.2
Saturation	%	34	107	93	97	3
Turb	deg	34	2.8	<0.5	1.2	0.6
TOC	mgC/l	34	2.3	1.6	1.9	0.2
NH_4-N	mg/l	34	0.022	0.008	0.015	0.004
Oil	mg/l	34	<0.1	<0.1	<0.1	0.0

(a) Water Color

At offshore Site 15, the water color was No. 5 during the low tide period and No. 4 during high tide period, thus exhibiting a bluish color. In both Baghal Channel and Bateen Channel, the value increased as one advanced further into the channels, exhibiting No. 11 (brown color) in the neighborhood of the the sea water intake facilities of Umm Al Nar Station.

In both the second and third surveys, a more brownish and cloudy color was observed as one advanced further into both the channels. In the third field survey, however, the water color number was small in the offshore area and channel part as compared with the second field survey, which exhibited a more bluish color.

(b) Transparency

The transparency at the sites in Baghal Channel was 3.0 to 5.5 m during both the low tide period and the high tide period which was smaller compared with the offshore sites and the sites in Bateen Channel (transparency was 4.0 to 6.0 m). In the neighborhood of Umm Al Nar Station, the transparency was small at 1.8 to 3.0 m.

The transparency in the third field survey was generally small compared with that of the second field survey. Particularly, at offshore Site 15, the transparency in the third field survey (6.0 m during both the low tide and the high tide) was less than a half of that in the second field survey (14 m on the bottom during the low tide period and 12 m during the high tide period).

(c) Water Temperature

As for water temperature, the maximum value was observed at Site 2, namely 21.0 °C during the low tide period and 21.2 °C during the high tide period. In the lower layer of Site 3, assuming the thermal effluent is present, the water temperature was found to be high. At the other sites, almost uniform distribution was observed in vertically.

The average value in the third field survey (18.1 °C during the low tide period and 18.8 °C during the high tide period) was about 14 °C lower than that in the second field survey (32.3 °C during the low tide period and 32.4 °C during the high tide period).

(d) Salinity

The minimum salinity was observed at offshore Site 15, that is, 43.01 in the upper layer and middle layer during the low tide period and 43.06 in the upper layer and middle layer during the high tide period.

The salinity increased as one advanced further into both Baghal Channel and Bateen Channel, indicating the maximum value (a level of 48) near the brine discharge facilities of Umm Al Nar Station.

Vertically, the salinity was found to be high in the lower layer of Site 3, where the thermal effluent is assumed to be present.

The average value in the third field survey (44.77 during the low tide period and 45.10 during the high tide period) was higher than that in the second field survey (44.29 during the low tide period and 44.04 during the high tide period).

(e) Hydrogen Ion Concentration (pH)

The pH was 8.1 at all the sites except at Site 2 nearby the brine discharge facilities of Umm Al Nar Station where pH was 8.2 during both the low tide period and the flood tide period. No remarkable difference was observed owing to the time of survey between the second field survey and the third field survey.

(f) Dissolved oxygen (DO)

The DO was in the range of 6.6 to 7.1 mg/l during the low tide period and 6.6 to 7.2 mg/l during the high tide period. Uniform values were indicated during each tide period and in each layer as well.

The DO saturation degree was about 100 at all the sites.

The solubility of oxygen into the sea water increased as water temperature decreased. The average DO value was about 1 mg/l higher in the third field survey (6.9 mg/l during the low tide period and 6.1 mg/l during the high tide period) than that in the second field survey (5.8 mg/l during the low tide period and 5.9 mg/l during the high tide period).

(g) Turbidity

The turbidity was found to be a little higher in the neighborhood of Umm Al Nar Station (the maximum value was 3.6 degrees during the low tide period in the middle layer of Site 7 and 2.8 degrees during the high tide period in the upper layer of Site 1-A). No other particular distribution tendency was recognized.

The average value in the third field survey (1.9 degrees during the low tide period and 1.9 degrees during the high tide period) was 1.0 degrees higher than that in the second field survey (0.9 degrees during the low tide period and 1.0 degrees during the high tide period).

(h) Total Organic Carbon (TOC)

The TOC was found to be high in the neighborhood of Umm Al Nar Station, showing the maximum value of 2.2 mgC/l in the upper layer of Site 2 nearby the brine discharge facilities of Umm Al Nar Station during the low tide period and 2.3 mgC/l in the upper layer of Site 2 and Site 1-A during the high tide period.

The average value in the third field survey (1.9 mgC/l during both the low tide period and the high tide period) was 0.2 mgC/l lower than that in the second field survey (2.1 mgC/l during both the low tide period and the high tide period).

i) Ammonic nitrogen (NH_4-N)

The NH_4-N exhibited the maximum value of 0.026 mg/l in the lower layer of Site 1-A during the low tide period, and 0.022 mg/l in the lower layer of Site 1-B during the high tide period.

The average value in the third field survey (0.014 mg/l during the low tide period and 0.015 mg/l during the high tide period) was a little higher than that in the second field survey (0.007 mg/l during the low tide period and 0.012 mg/l during the high tide period).

(j) Oil Content (Oil)

No oil content was detected (less than 0.1 mg/l at all the sites).

(7) Summary

1) Features in the Marine Area around Abu Dhabi Island

The distribution tendency in the marine area around the Abu Dhabi Island during the second and third field survey are described as follows:

In horizontal distribution, the sea water in the inner part of both Baghal Channel and Bateen Channel, especially in the neighborhood of Umm Al Nar Station, showed higher salinity, water color, transparency and TOC values than those in the offshore area of the Abu Dhabi Island and in the neighborhood of the entrance of both channels.

In vertical distribution, it was found in the third field survey that at Site 3 the effluent from Umm Al Nar Station was present in the lower layer, resulting in increased water temperature and salinity. At the other sites, however, the vertical distribution of water quality was almost uniform.

2) Expression of Water Quality and Classification of Water Mass by Principal Component Analysis

To determine the general water quality in the marine area around the Abu Dhabi Island, an analysis was carried out by classifying information, in which the measured values of each water quality parameter are contained, into a small number of general characteristic values, namely the principal components. The two-dimensional scatter diagram based on the first principal component (COMP1) and second principal component (COMP2) is as shown in Fig. 3.6.3.

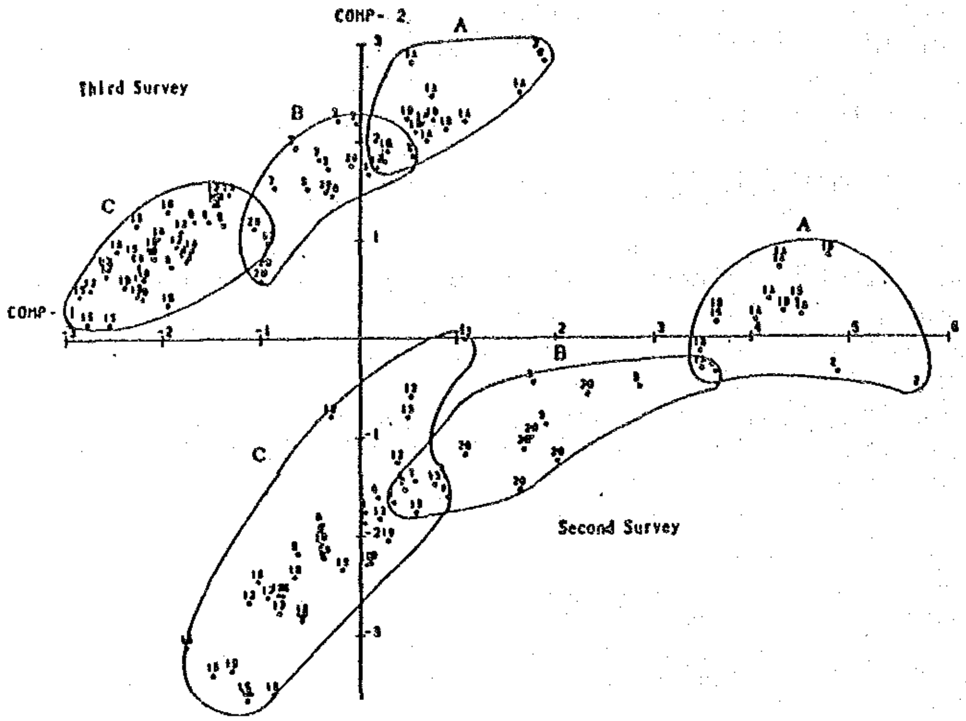


Fig. 3.6.3: Two-Dimensional Scattering Plot According to Principal Component Analysis

Table 3.6.6: Classification of Water Mass According to Principal Component Analysis

Water Mass	Site	Characteristic
A	1-A 1-B 2	There is this water mass around UAN intake and out-fall. The characteristics of the water mass are high water temperature and salinity in particular, low transparency, and relatively high turbidity and TOC.
B	3 7 20	There is this water mass in the interior of both Baghal Channel and Bateen Channel around Abu Dhabi Island. The characteristics of the water mass are not so aparent as A water mass, but are high salinity, turbidity, and TOC and low transparency.
C	9,12 13,15 16,19	There is this water mass near the inlet of Baghal Channel and Bateen Channel and offshore Abu Dhabi Island. The characteristics of the water mass are high transparency and low salinity, turbidity, and TOC.

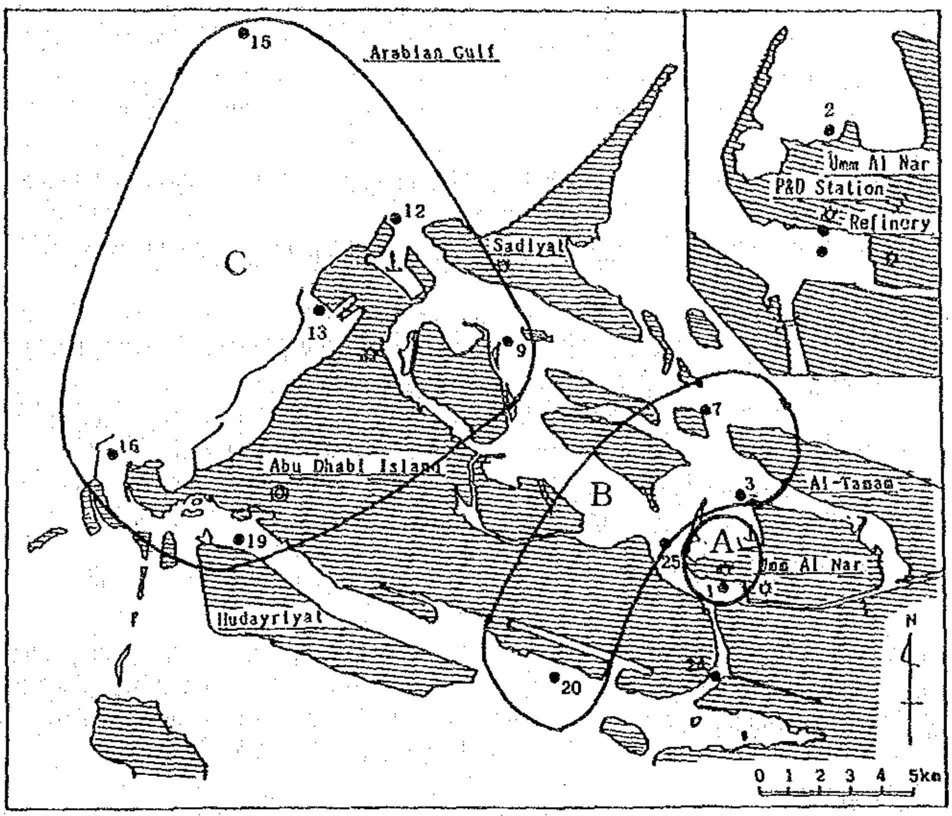


Fig. 3.6.4: Classification of Water Mass According to Principal Component Analysis

To calculate the principal components, data in the second field survey and the third field survey were analyzed collectively with respect to the following 10 parameters : water color, transparency, water temperature, salinity, pH, DO, DO saturation degree, turbidity, TOC and NH_4-N. The data can be broadly divided into two categories, by the time of the survey and its effect on water temperature and other factors.

Next, in the data classified by the time of the survey, if attention is paid to the sites, this data can further be divided into three water masses.

3) Sea Water Intake of Umm Al Nar Station

In the neighborhood of Umm Al Nar Station, the salinity is high and the sea is turbid. It can be considered that the presence of high salinity in the inner part of the channels on both sides of the Abu Dhabi Island is attributable to the fact that the high salinity effluent from Umm Al Nar Station cannot be easily replaced with sea water in the open sea.

It is also possible that the presence of high turbidity and increased facilities. In the present survey, however, its cause could not be identified.

According to the classification of water masses, the sea water near the sea water intake facilities of Umm Al Nar Station has high salinity similar to that found at the brine discharge facilities of Umm Al Nar Station, which may be attributed to the following reasons:

* On the eastern side of the sea water intake facilities of Umm Al Nar Station, there is the channel which comes from the interior of the lagoon and sea water of high salinity is supplied through this channel.

* In the neighborhood of the sea water intake facilities of Umm Al Nar Station, there is a brine discharge outlet, and high salinity is caused by the discharge of brine.

It will be necessary to carry out a continuous survey on the water quality near Umm Al Nar Station, particularly in the marine area near the sea water intake facilities of Umm Al Nar Station.

4) Oil Contamination

In the present survey, no oil content in the sea water was detected in the two surveys. However, in the survey conducted in the coastal area, there were some locations where oil balls and films were observed, thus it does not mean that there is no oil contamination.

The Fig. 3.6.5 shows the seaside where oil balls were observed. The seaside is part of the seaside in front of Abu Dhabi City, and oil from ships is considered attributable to the presence of these oil balls. In this neighborhood, there is the sea water intake facilities of Umm Al Nar Station, and the influence of pollution owing to oil balls is feared.

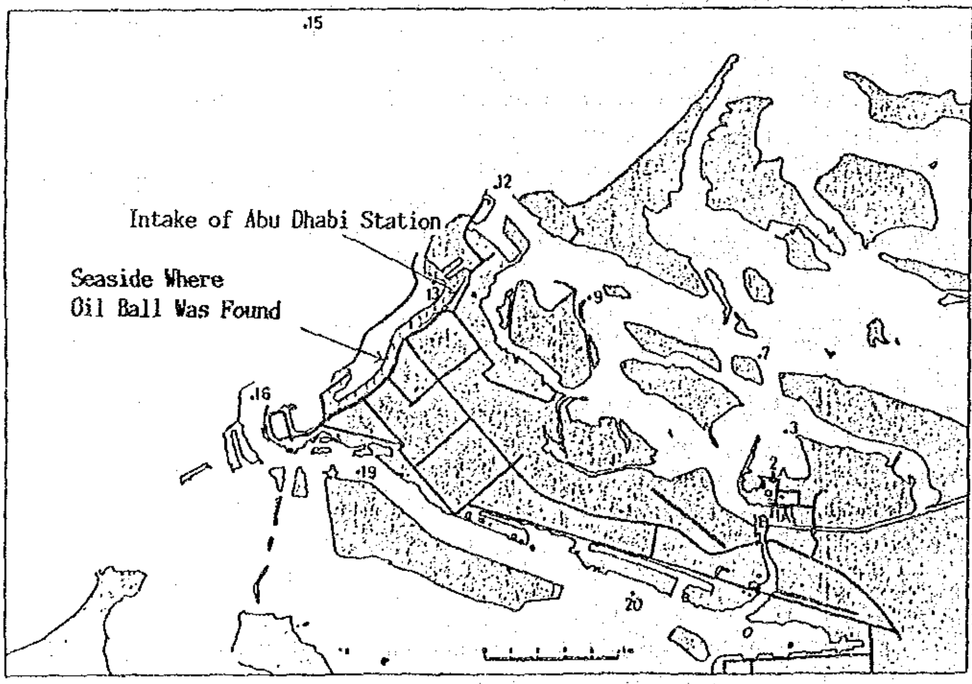


Fig. 3.6.5: Seaside Where Oil Ball was Found