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PRELIMINARY STUDIES OF THE TIDAL CURRENTS NEAR DOHA

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ABSTRACT

A systematic program for current observations was planned by the Department of Marine Sciences, University of Qatar to cover the Qatari waters. The tidal currents were studied by analysing the data obtained from mooring of Aanderaa current–meters in different places in the Doha area, the preliminary results from the first moored experiments in the study area showed that the predominant current directions were: north, south, south–east and north–east respectively. The residual current and the tidal constitunuents were calculated, and the maximum possible current in the area was also obtained.

INTRODUCTION

Currents in the Gulf have many causes and observed currents in a particular place and at a certain time are the resultant. They result from the superposition of currents caused by different factors. In addition to tidal currents, meteorologically – induced currents and those due to thermo–haline causes play an important role in the total picture. Excessive evaporation in the Gulf results in a two – layered flow with Indian Ocean water entering through the Strait of Hormuz on top of outgoing more saline – warmer water. Meteorologically induced currents have periods ranging from the short period storm induced currents to the annual period currents resulting from the monsoon and the seasonal variation in water level in the Gulf. All this motion is affected by the earth's rotation with the attendant variation between the eastern and the western sides. Moreover, the bottom topography and the coastal configuration influence the currents because of the shollow depths in the Gulf.

Description of the Area

The present area under investigation (Fig. 1) is part of the Qatari waters, in the middle of the western part of the Gulf. It lies to the east of Qatar Peninsula between 25° 15′ N and 25° 21′ N latitude and between 51° 31′ E and 51° 42′ E longitude. It is relatively shallow with gentle slopes towards the east with depths varying between 10 and 40 meters.

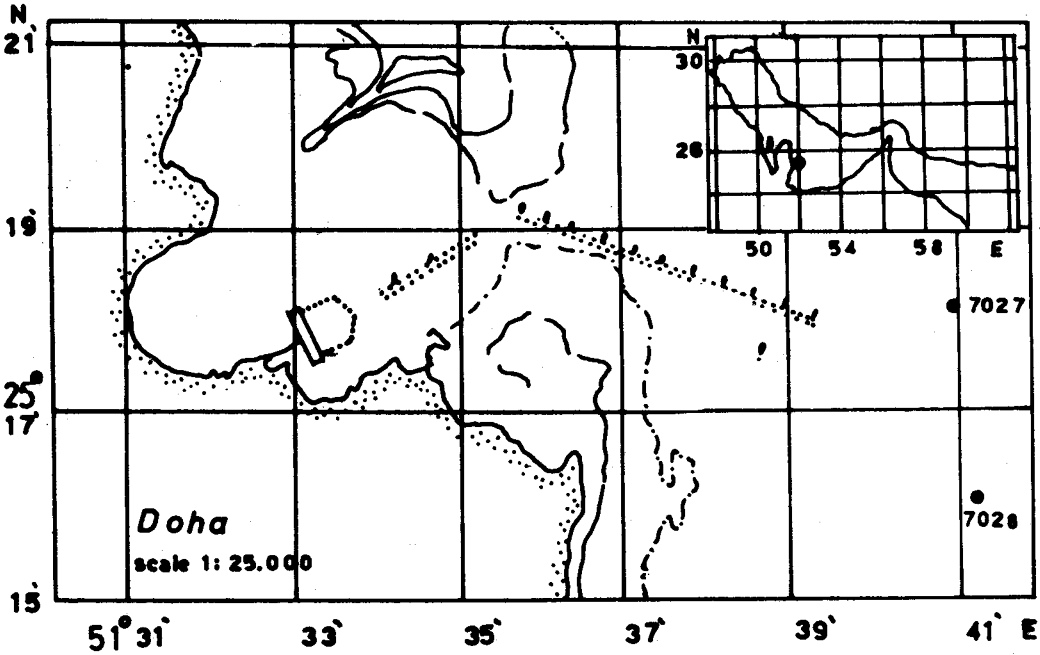


Fig. 1 : Area of investigation.

MATERIALS AND METHODS

R/V Mukhtabar Albihar of the University of Qatar was used to moor and retrieve two Aanderaa current meters at 5 – 6 m. above the bottom. The current meters were located near the Doha Harbour pilot buoy at 25° 16′.8 N lat. and 51° 41′.2 E longitude (Fig. 1), where the water depth was 18 to 22 m. The mooring was the usual, being U shaped, the current meter branch be totally submerged, and a surface float ending the other branch. The current meters recorded speed and direction, in addition to the water temperature and salinity for periods and frequencies listed in Table I.

The record of the tidal height inside Doha habour was obtained and digitized to read the water level every two hours for the same period as the current measurements. The record was then subjected to the same analysis as the current meter record to obtain the different components (Fig. 9 & Fig. 10 and Table VI).

A computer software was written to analyse the current meter data as well as the observed tidal heights utilising the computer facilities available at the University of Qatar. The tidal heights data were read every two hours, for a period to coincide with the dates and times of recording of the currents. Harmonic analysis was done for periods selected from Table II.

The reason of the selection is the closeness of some of the periods to each other, e.g. S2(12.00 h) and T2(12.01 h). Such periods could not be properly resolved from each other except by using a very long record. Using a record containing n periods would allow one component to affect the next by an amount proportionate to its magnitude with the factor of proportionality being approximately equal to:

$$\frac{T}{2\pi\epsilon n} \sin\left(\frac{2\pi n\epsilon}{T}\right)$$

Where:

T is the period of one of the coefficients (assumed to be very near to each other), and taken as 12 hours for the semidiurnal components and 24 hours for the diurnal ones.

n is the number of periods in the record, taken as 60 for the semidiurnal components and 30 for the diurnal ones.

ϵ – is the time difference between the two periods considered.

As the sine has a maximum value of one, it can be seen that the contamination of one period to an adjacent one has an upper limit that diminishes with the length of the record (increasing n) or increasing the time difference between periods (increasing ϵ). To ensure that no coefficient affects any adjacent one by more than 10%. Coefficients were selected that were at least $.20^h$ apart in the semidiurnal group, and were 0.80^h apart in the diurnal group. This put an upper limit on the contamination of one component by another of $1/2\pi$, and the selected components become:

S2 [Selected from K2 (11.79 h), S2 (12.00 h), T2 (12.01 h]

λ 2 [Selected from L2 (12.19 h), λ 2 (12.22 h)]

γ 2 [Selected from γ2 (12.63 h), N2 (12.66 h)]

μ 2 [Selected from μ 2 (12.87 h), 2N2 (12.91 h)]

K1 [Selected from K1 (23.93 h), P1 (24.07 h)]

and M2(12.42 h), J1(23.10 h), M1(24.86), O1(25.82) and Q1(26.87 h).

The last five components were sufficiently far from the others to be considered resolvable.

Assuming that there are one half hourly recordings in the records of V_i, the mean current magnitude in the i_{th} interval, and of the D_i, the instantaneous direction of the current setting (000 being current going north, 090 going east)

$v_i = V_i \cos D_i \leftarrow$ the component of the current north

and

$u_i = V_i \sin D_i \leftarrow$ the component of the current towards east

As the total current components v_i and u_i are made up from various categories of currents, it is possible to present them in the form.

v_i , u_i = the steady current + Periodic currents with tidal periods + Periodic currents with other periods + noise.

Again :

Periodic currrent with tidal period = Periodic currents with semidiurnal tidal periods + Periodic currents with diurnal tidal periods + Periodic currents with other tidal periods.

The present paper is concerned with extracting from the current records, the steady currents and the currents with semidiurnal and diurmal tidal periods.

Thus, assume that:

$v_i = A_o + \Sigma_j A_j \cos(2\pi i\ t/T_j) + B_j \sin(2\pi i\ t/T_j)$

+ Tidal component other than diurnal and semidiurnal

+ Components other than tidal

+ Noise

and $u_i = A'_o + \Sigma_j A'_j \cos(2\pi i\ t/T_j) + B'_j (\sin 2\pi i\ t/T_j)$

+ Tidal component other than diurnal and semidiurnal

+ Components other than tidal

+ Noise

Where,

$A_o = 1/I\ \Sigma_i v_i$

$A'_o = 1/I\ \Sigma_i u_i$

$A_j = 2/I\ \Sigma_i v_i \cos(2\pi j\ t/T_j)$,

$B_j = 2/I\ \Sigma_i v_i \sin(2\pi j\ t/T_j)$,

$A'_j = 2/I\ \Sigma_i u_i \cos(2\pi j\ t/T_j)$,

$B'_j = 2/I\ \Sigma_i u_i \sin(2\pi j\ t/T_j)$, and $\sqrt{A^2_j + B^2_j}$ = the magnitude of the j^{th} tidal component in the north direction,

and $\sqrt{A'^2_j + B'^2_j}$ = the magnitude of the j^{th} tidal component in the east direction,

B'_j / A_j, B'_j / A'_j = tan (the phase of the components with respect to the time of starting the observation)

RESULTS

The stick diagram (Fig. 2) shows the changes in the direction and magnitude of the analysed current. It is clear that the predominant direction is the northerly though the current tend to posses equal magnitude in the southerly direction also.

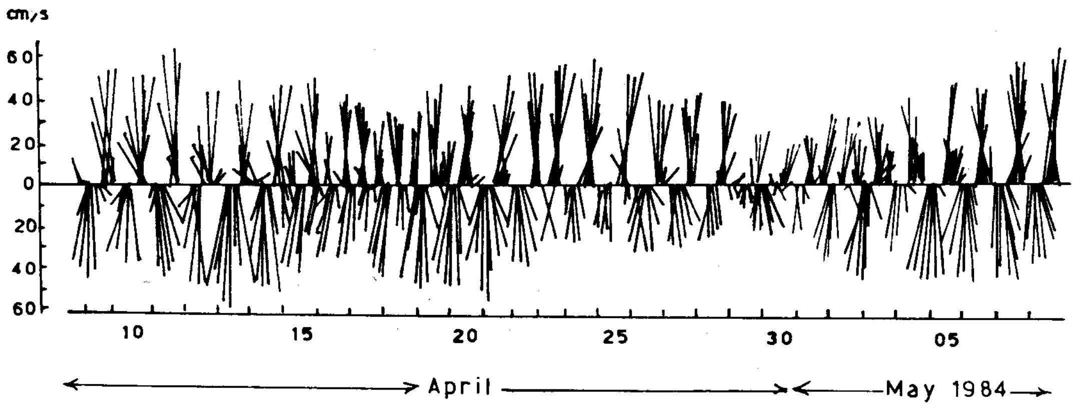


Fig. 2 : The changes in the direction and magnitude of the observed currents with time.

The statistical analysis for the values of the predominant directions in addition to the number of observation is presented in Tables III & IV. The constituents obtained for the different tidal components and the corresponding time periods are shown in Table V. The results show that the principal lunar constituent has the highest magnitude (20.68 cm/s) in the semidiurnal group while the Luni Solar diurnal constituent is the largest (26.99 cm/s) in the diurnal group. In addition the maximum possible tidal current from alll components is 92.78cm/s in the direction 005, while the residual current Fig. 8 reaches 1.43 cm/s in the direction 028. Fig. 3 shows the changes of the calculated semidiurnal north-south components with length of record and Fig. 4 shows the east-west ones.

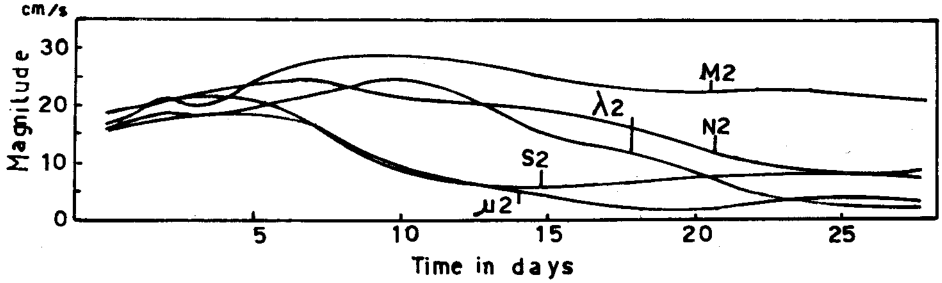


Fig. 3 : N-S Semidiurnal Constituents

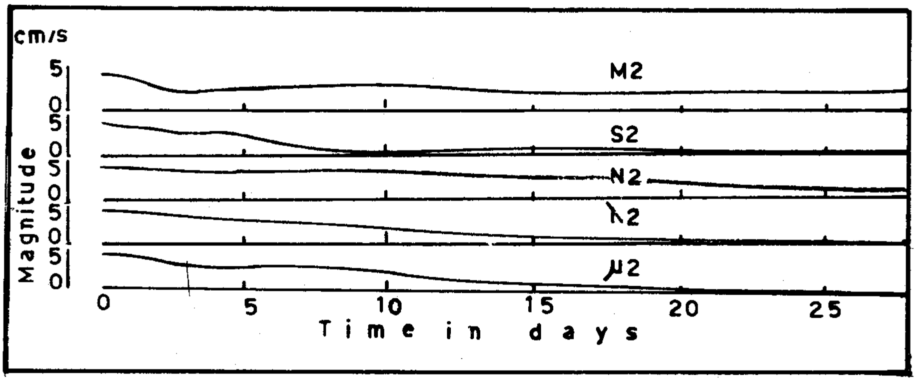


Fig. 4 : E-W Semidiurnal Contstituents

Figs. 5&6 show the corresponding changes in the diurnal component. Fig. 7 shows the computed tidal current constituent in the north–south and in the east–west direction as well as the observed constituents for the same period. It can be seen that the two records are similar but for the larger magnitudes of change in the observed record. This departure could be due to the presence of other components of the current.

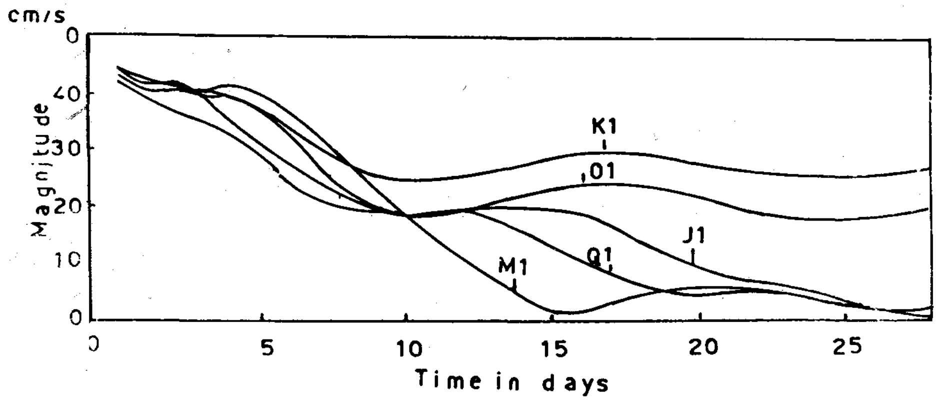


Fig. 5 : N–S Diurnal Constituents.

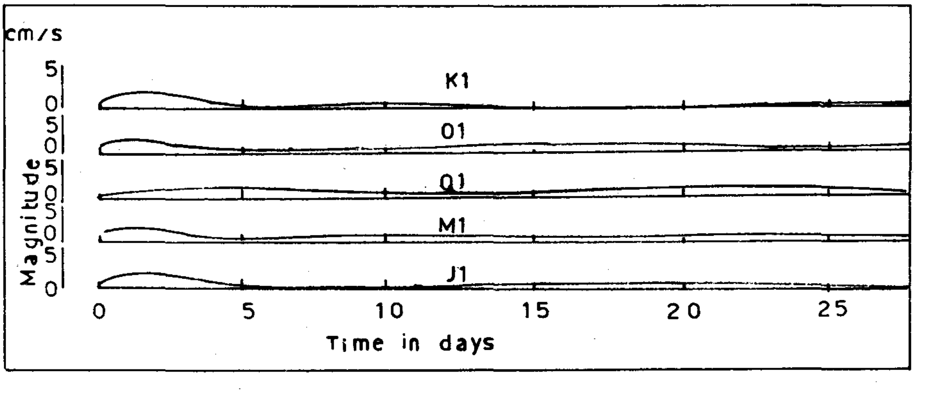
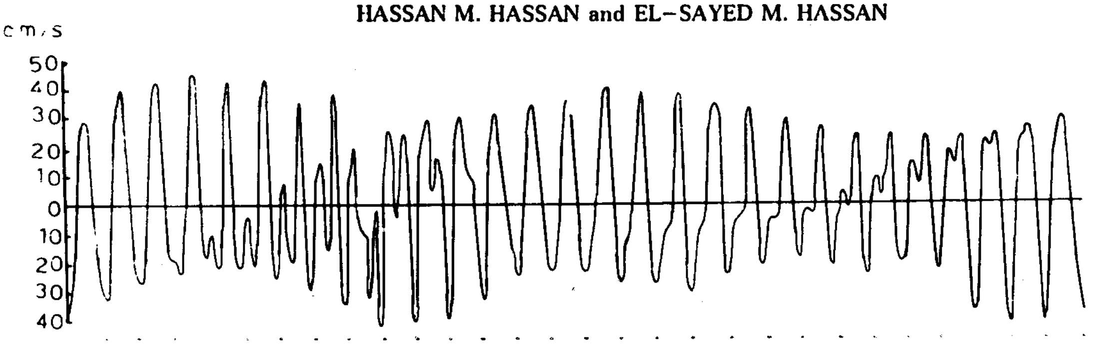
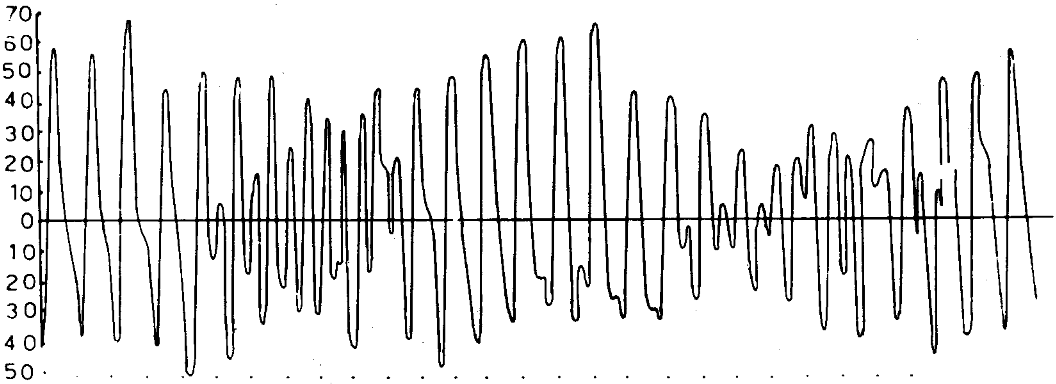


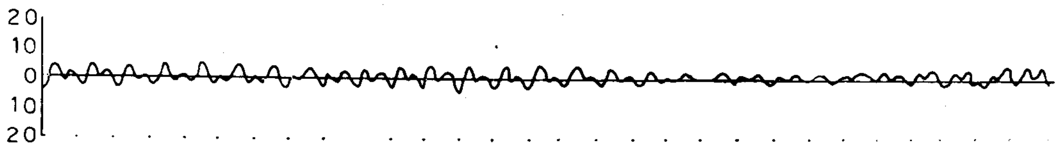
Fig. 6 : E–W Diurnal Constituents.



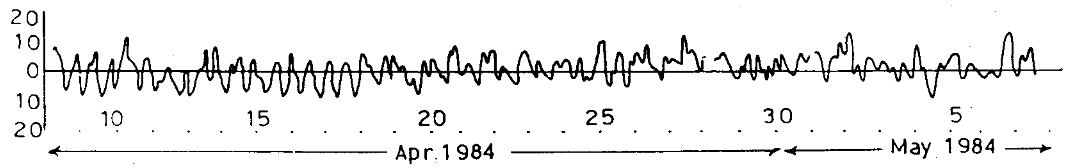
Computed North South Tidal Current Component.



Observed North South Tidal Current Component.



Computed West East Tidal Current Component.



Observed West East Tidal Current Component.

Fig. 7 : Computed and Observed Current Components.

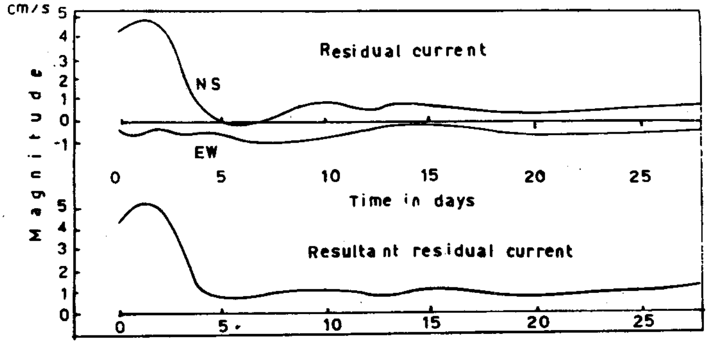


Fig. 8 : Residual Current Component and the Resultant.

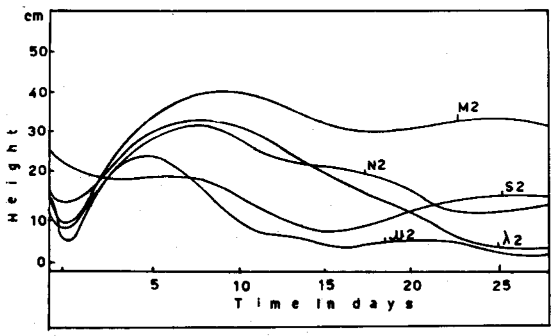


Fig. 9 : Semidiurnal Tidal Constituents.

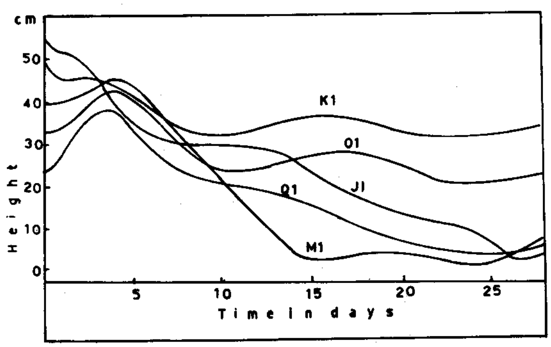


Fig. 10 : Diurnal Tidal Constituents.

Table I : Details of Current-meter Moorings.

Current Meter No.	Location Lat. Long		From	To	Total Duration (Days)	Sampling Interval (Hours)	Sampling Depth Of ct (m)
	N	E					
7027	25/08/2	51/04/9	08/04/84	08/05/84	30	1/2	15
7028	25/16/8	51/41/2	08/03/84	15/03/84	7	1	12

Table II : After Neumann and Pierson (1966), Major Tidal Potential Constituents.

Symbol	Name	Period
	SEMI – DIURNAL COMPONENTS	
M2	Principal lunar	12.42
S 2	Pricipal solar	12.00
N2	Lrge lunar eliptic	12.66
M2	Smaller lunar evectional	12.22
M2	Variational	12.87
	DIURNAL COMPONENTS	
K1	Luni solar diurnal	23.93
O1	Principal lunar diurnal	25.82
Q1	Larger lunar elliptical	26.87
M1	Smaller lunar elliptic	24.86
J 1	Small lunar elliptic	23.10

Table III : Frequency distribution (expressed in percetage) of Current Speed and Direction for Station 1.

Current speed (cm/s) From To	Direction									
	N	NE	E	SE	S	SW	W	SW	Sum	%
00.0 – 05.0	3	1	1	9	3	0	0	3	20	12.3
05.0 – 10.0	3	3	0	0	5	1	0	1	13	08.0
10.0 – 15.0	6	1	1	0	2	2	0	0	12	07.5
15.0 – 20.0	3	1	1	2	7	1	1	1	17	10.5
20.0 – 25.0	6	2	4	1	7	2	1	3	26	16.0
25.0 – 30.0	2	4	1	2	5	4	1	2	21	13.0
30.0 – 35.0	7	2	1	1	6	3	0	1	21	13.0
35.0 – 40.0	6	3	0	1	3	3	0	1	17	10.5
More than 45.0	4	2	0	0	5	1	1	2	15	09.2
Sum	40	19	9	16	43	17	4	14	162	
	24.7	11.7	5.6	9.9	26.4	10.5	2.5	8.7		100

Table IV : Frequency distribution (expressed in percentage) of Current Speed and Direction for Station 2.

Current Speed (cm/s) From To	Direction									
	N	NE	E	SE	S	SW	W	NW	Sum	%
00.0 – 5.0	8	6	8	16	10	6	2	0	56	03.8
05.0 – 10.0	45	40	23	32	39	11	3	15	208	13.4
10.0 – 15.0	58	14	6	38	48	8	1	12	185	12.7
15.0 – 20.0	96	3	0	8	70	5	0	3	185	12.7
20.0 – 25.0	80	0	0	4	77	2	0	3	166	11.5
25.0 – 30.0	54	1	0	2	83	1	0	1	142	09.7
30.0 – 35.0	52	1	0	0	79	0	0	0	132	09.1
35.0 – 40.0	53	0	0	0	41	0	0	0	94	06.5
40.0 – 45.0	44	0	0	0	47	0	0	0	91	06.3
45.0 – 50.0	40	0	0	0	33	0	0	0	73	05.0
50.0 – 55.0	33	0	0	0	22	0	0	0	55	03.8
55.0 – 60.0	27	0	0	0	6	0	0	0	33	02.3
60.0 – 65.0	15	0	0	0	3	0	0	0	18	01.2
65.0 – 70.0	11	0	0	0	3	0	0	0	14	00.9
More than 70.0	0	0	0	0	2	0	0	0	2	00.1
Sum	616	65	37	100	563	33	66	34	1454	
%	42.4	4.5	2.5	6.9	38.7	2.3	0.4	2.3		100

Table V : Computed Constant of Different Tidal Component.

Constant	A_n (cm/s)	B_n (cm/s)	$\sqrt{A^2+B^2}$ (cm/s)	A'_n (cm/s)	B'_n (cm/s)	$\sqrt{A'^2+B'^2}$ (cm/s)	Magnitude (cm/s)	Period (Hours)
Semidiurnal Group:								
M2	15.07	−13.75	20.41	−01.50	−03.04	03.39	20.68	12.42
S2	−4.91	05.01	07.02	−00.31	00.04	00.31	07.02	12.00
N2	−4.98	−05.41	07.35	−01.02	00.29	01.06	07.43	12.66
γM2	−0.19	02.56	02.57	00.33	00.33	00.47	02.61	12.22
M2	0.40	02.48	02.51	−00.36	−00.09	00.37	02.54	12.87
Diurnal Group:								
K1	−22.60	−14.68	26.95	−01.47	−00.05	01.47	26.99	23.93
O1	−19.40	00.55	19.44	−00.87	00.41	00.96	19.43	25.82
Q1	−02.24	01.45	02.67	−00.52	−00.28	00.59	02.72	26.87
M1	−02.14	−01.88	02.85	−00.14	00.12	00.18	03.03	24.86
J1	−00.27	−00.56	02.62	−00.02	−00.34	00.34	00.71	23.10

AO (Residual NS Current Component) = 1.27 cm/s
AO′ (Residual WE Current Component) = 0.65 cm/s

Table VI: The Height of the Different Components.

Constant	An (cm)	Bn (cm)	$\sqrt{A_n 2+B_n 2}$ (cm)	Period (Hours)
Semidiurnal Group:				
M2	27.71	−12.77	30.51	12.42
S2	−12.36	00.13	12.36	12.00
N2	−03.65	−09.48	10.16	12.66
M2	−02.95	−01.09	03.15	12.22
M2	−00.51	02.01	02.07	12.87
Diurnal Group:				
K1	31.95	10.03	33.48	23.93
O1	23.71	−04.68	24.17	25.82
Q1	01.20	04.90	05.04	26.87
M1	05.85	−01.68	06.09	24.86
J1	01.31	02.42	02.75	23.10
Mean Sea Level (Observed harbour datum) = 87.97 cm.				

The results of sea level analysis were consistent with those of the current. The tidal components of the current (Table V) arranged in the order of decreasing amplitude are K1, M2 and O1 all being 19.4 cm/s and greater. No other component reaches 8 cm/s. The major components in the height analysis (Table VI) arranged in the same order have amplitudes in excess of 20 cm. S2 and N2 however, have amplitudes between 10 & 20 cm. the phase difference between the current and the heights are also consistent with each other.

CONCLUSION

Currents near Doha have a large tidal component that accounts for most of the observed currents. The dominant components are diurnal to the extent that K1 (Luniosolar diurnal) exceeds M2 (the principal lunar semidiurnal) and far exceed S2 (the principal solar semidiurnal). The dominance of the diurnal components can be seen from the visual inspection of the record where most of the time one tide occurs per day and a great inequality exists when two tides exist per day. This is consistent with the classical picture of the tides (1), (Admiralty Co−tidal Chart, 1976). From an inspection of the variation of the component amplitudes with length of record, it can be seen that a 15 day record would be sufficient to give good results for the semidiurnal and diurnal currents.

Analysis of the tidal heights showed good agreement with the currents. The ranking of the tidal component was identical with the exception of $\mu 2$ and J1 which occupied the last position in the ranking, but in the reverse order in the current in the heights. The semidiurnal components in the heights were relatively more important than in the case of the currents, the sum of their amplitudes being 0.82 of the sum of the diurnal components in the case of heights and 0.76 in the case of the currents.

This could be an indication of the tidal gauge in the port registering more short period components because of its location, and that needs further study. The height record seems more noisy than that of the current, and thus, a longer record is needed for analysis of the height.

ACKNOWLEDGEMENT

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دراسات مبدئية عن تيارات المد والجزر بالقرب من الدوحة

حسن مصطفى حسن و السيد محمد حسن

خطط قسم علوم البحار في جامعة قطر لعمل برنامج منتظم لقياس التيارات يغطي المياه القطرية ودرست تيارات المد والجزر بتحليل بيانات جمعت بواسطة أجهزة قياس تيار من طراز أندرا من مواقع مختلفة في منطقة الدوحة وإتضح من التجارب الأولى لتثبيت الأجهزة أن الاتجاهات السائدة للتيار هي : الشمال - الجنوب ، الجنوب الشرقي والشمال الشرقي على الترتيب ، وحُسب التيار المتبقي وأقصى تيار ممكن بناء على النتائج .