TECHNICAL REPORT

DESCRIPTIVE OCEANOGRAPHY
OF KUWAIT HARBOR

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and

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ABSTRACT

A descriptive analysis of the oceanography of Kuwait Harbor and adjacent waters is presented based on observations taken between November 1948 and May 1949. Temperature, salinity, surface and subsurface currents, waves, and bottom sediment data are included plus other incidental observations and notations of water color, transparency, eddies, etc.

In winter, water temperatures show little difference with depth; salinities vary considerably through the area exceeding 41‰ in the westernmost portions and at depth, and becoming less than 38‰ near Jazirat Faylakah. Maximum currents, in excess of 2 knots, were recorded off Ras al Ardh. Choppy (short period) waves develop quickly with gusty "shamals"; waves as high as 6 feet were observed coming from the southwest. The area has a wide variety of sediments; many samples obtained were mixtures of silt, sand, or coral in varying proportions. A bathymetry chart of the area completes this presentation.

ACKNOWLEDGMENT

All the observations were made under the direction of Mr. T. J. Wehe while in the employ of the Woods Hole Oceanographic Institution, which was under contract to the Hydrographic Office for this work. Titrations also were performed by the Woods Hole Oceanographic Institution. Special acknowledgment is made of the microscopic examination and analysis of the sediment and beach samples by Dr. F. B. Phleger.

ERRATA

Abstract, line 10: for "41%", read "41%". ✓
line 11: for "38%", read "38%". ✓

Page 3, line 33: for "Figure 3", read "Figure 1". ✓

FOREWORD

The Hydrographic Office, in an effort to provide up-to-date navigational charts to the Navy and merchant marine, is constantly engaged in surveying areas of the world oceans. During these hydrographic surveys, supplemental oceanographic data are collected whenever time, ships, and personnel are available.

This procedure has on several occasions resulted in collection of timely oceanographic information which adds appreciably to the understanding of localized ocean areas.

A description of the oceanography based on data obtained during a contemporary survey of Kuwait Harbor is presented by this report.

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Rear Admiral, U. S. Navy
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I. Introduction

The Indian Ocean has two adjoining semiencllosed sea areas, the Red Sea and the Persian Gulf. These two water areas plus the Arabian Sea and eastern Mediterranean encompass the lands considered to be the birthplace of civilization. Since waters of the Tigris and Euphrates Rivers empty into the Persian Gulf, it is probable that the gulf was among the first sea areas sailed by civilized man, perhaps by citizens of the ancient city of Ur or Babylon. It is somewhat paradoxical that until recently the seas adjoining lands which were among the first in the development of learning and civilization have been among the least investigated by the modern marine scientist. Indeed, probably more is known about the Polar seas, which adjoin almost totally unpopulated land areas, than about the Persian Gulf.

In the early 1900's the German environmentalist Schultz (7) described in a brief article some general physical characteristics of Persian Gulf waters. Gerhard Schott (6) continued this work for another 10 years, compiling from widely scattered sources and observations an important treatise of almost 50 pages on the environment of the Persian Gulf. His work stood alone for more than 30 years as the most complete reference source on the environment of this area; even today, some two score years after publication, it is considered a prime reference despite the relative sparsity, heterogeneity, and varying quality of observational data used.

Because the lands bordering the Persian Gulf offered little, in the last few hundred years, in the way of natural resources or manufactured goods for sale, barter, or trade, the gulf area has remained almost isolated from maritime commerce. Even as late as 1940 ships from western countries visited the area irregularly; therefore, few marine observations were recorded annually, and these were of little aid in extending the knowledge and understanding of the area.

Planned explorations or surveys of the area were almost nonexistent prior to World War II. Only one environmental survey done before 1945 is noteworthy (a study of the biology of the area by Danish investigators in 1935-38), but it too has shortcomings since it concentrates on marine life; environmental data were collected only as incidental supplementary information. A description of related observations taken by the group is given by Blegvad (1).

With the conclusion of World War II and the simultaneous expansion in exploration and production of the oil industry along the Arabian and Iranian shores of the Persian Gulf, shipping in these waters increased

manyfold as the gulf was transited more regularly by tankers and other types of ships carrying supplies and oil drilling equipment. These ships provided some additional observational information and data; but more important, the masters of these ships demanded fuller and more detailed hydrographic information of the area.

In the summer of 1948 a considerable quantity of oceanographic data was collected throughout the gulf by Dr. K. O. Emery and his collaborators. Results of this work were published in 1956 (2). This survey, as well as the results, is not as complete as might be desired. Sediments and marine geology are probably the most comprehensively covered of all topics. However, some of the best quantitative information of the area currently available for midsummer months is supplied by Dr. Emery's work. Since observations were taken with modern oceanographic instruments and in accordance with currently accepted scientific techniques, these data represent the most accurate data collected to that time. Oceanographic observations of similar quality for the winter months are generally lacking.

With the postwar increase in shipping in the Persian Gulf, the need for a total revision of navigational charts of the area became obvious. A critical evaluation of the Hydrographic Office charts on issue in 1947-48 revealed that sounding information on existing charts was largely from nineteenth century surveys, supplemented with later incidental soundings from individual ships or limited surveys. In general few sounding data after 1935 were shown. As a result this Office arranged to conduct a series of detailed hydrographic surveys of the Persian Gulf to bring its charts up to date. This hydrographic survey requirement provided an opportunity to make oceanographic observations. This report is a descriptive compilation of the oceanographic data collected during the 1948-49 hydrographic survey. Even though this was not a systematic oceanographic survey, the data collected for these winter months provide an appreciable quantity of additional reliable information on the area.

II. Temperature

Figure 1 shows the locations of oceanographic stations and diurnal warming observations made in and near Kuwait Harbor. Figures 2 and 3, respectively, present typical midwinter surface and bottom temperatures in Kuwait Harbor, and Table I gives the observed data upon which these figures are based. The usual Nansen bottles and reversing thermometers were used for making the oceanographic stations.

In winter, water temperature in Kuwait Harbor and vicinity varies little either horizontally or vertically. The surface temperature ranges from a low of about 56°F. in the southern and western portions of the bay to nearly 60°F. just off Jazirat Faylakah. The difference between the surface and bottom is of the same order of magnitude; a maximum vertical temperature gradient of 3°F. was recorded at the mouth of the harbor in a depth of 26 feet.

This is quite in contrast to the summer conditions reported by Dr. K. O. Emery for August 1948. Observations taken by him show surface temperatures in excess of 90°F. and bottom temperatures of about 85°F. These temperatures result in a gradient of 5° to 7°F. in approximately 45 or 50 feet of water. The gradient increases markedly farther east of Fahihil where bottom temperatures reach 75° to 77°F. in a depth of about 75 feet. Development of this extremely warm surface layer probably begins in April or May when the mean maximum air temperature begins to show an appreciable increase. Also the general decrease in cloudiness with the advent of spring provides for increased solar heating (insolation) of surface waters. A reduction in frequency of frontal passages with their typical gusty "shamal" type winds is another factor contributing to the development of a strong gradient between the surface and bottom water through the spring and early summer months. Without these squally "shamal" type winds, mixing is reduced to a minimum. In autumn, beginning in October, the processes are reversed.

Even in winter, solar insolation frequently raises midafternoon air temperatures to the seventies; thus it is reasonable to expect some diurnal fluctuations in the water temperature near the surface. The two time-depth sections taken in Kuwait Harbor in January and February and one section taken off Fahihil in March illustrate well midwinter diurnal warming of the surface waters (Figs. 4, 5, and 6, respectively). These sections are based on BT observations taken at approximately half-hourly intervals while drifting along the tracks shown in the insets on Figure 1. No drift chart is available for the February observations, but the drifting boat started from approximately the same position as that for the January observations. Bathythermograph log sheets containing supplementary meteorological data for these three series of observations have been reproduced in Table II. On the cross sections all BT observations have been corrected in accordance with procedures described in H. O. Pub. No. 614, "Processing Oceanographic Data."

Diurnal temperature ranges of 1.3° and 3.1°F. were recorded at the surface for the two Kuwait Harbor series of observations; off

Fahihil the range was 2.2°F. The February series is particularly interesting in that it shows an appreciable diurnal range and the mixing effect of a strong wind in midafternoon. In this series the highest surface temperature was observed at 1300 LST (about the time of maximum air temperature and maximum solar insolation). Soon after 1300 a "shamal" type wind began; wind speeds increased to Beaufort force 4 by 1400 and remained so to the end of the observation period. Within two hours after the maximum temperature was observed, mixing had reduced the surface temperature by 3°F., and by 1600 (3 hours after the beginning of the "shamal") the entire water column was nearly isothermal.

It is possible then that diurnal heating could account entirely for the total range of temperatures shown on the surface temperature chart, Figure 2; the oceanographic station observations were taken in the same week as the BT observations for the second time-depth section. (This is the reason that local time also is given for the oceanographic stations shown in Figure 1.)

A comparison of the three diurnal warming sections illustrates well the monthly increase in water temperature, particularly that in the surface layer. It appears that as a general rule the maximum air temperature and maximum surface water temperature are within a few degrees of each other except, of course, when increased wind speeds prevent formation of or destroy the warmer surface layer by mixing.

III. Salinity

Salinity observations were taken on 23-24 February 1949 only, when the series of oceanographic stations (Fig. 1) was occupied. Water samples were collected at the surface and near the bottom, and only at the surface where depths were less than 2 meters. Of the 32 samples taken, eight were missing or the sample bottles broken in transit before reaching the laboratory. Three of these, the surface samples for Stations 2, 4, and 14, would have been helpful in adding detail to the analysis in certain areas.

Surface and bottom salinity charts, presented as Figures 7 and 8, respectively, are based on these data. Over the harbor area the total salinity range at the surface is about 3.5 ‰ (parts per thousand); maximum salinities are observed in the shoal waters near the head of the embayment. The freshest water, which incidentally exceeds the average salinity of water in the open ocean by more than 2 ‰, was observed in the very shallow water immediately west of Jazirat

Faylakah. Apparently brackish drainage water from Khawr as Sabiniyan and/or Shatt al Arab reaches the area here and reduces the gulf surface salinity from its normal value of about 40 ‰ to about 38 ‰. Even though rainfall is meager in this area (4 to 11 inches annually), most of the precipitation can be expected during the months of January and February. It is reasonable then to expect salinities in the extreme eastern portion of Kuwait Harbor (in the vicinity of Jazirat Faylakah) to be reduced slightly below the indicated surface values which were observed during a period of no rainfall. Salinities of 39 ‰ or less extending into Kuwait Harbor would be most unusual, because the tides produce strong currents between Ras al Ardh and Jazirat Faylakah that effectively mix the surface waters every few hours.

As would be expected salinity values at depth are nearly the same or slightly higher than the surface values. Even the greatest difference between the surface and bottom is hardly significant; at the harbor entrance (Station 12) a gradient of only 0.4 ‰ is observed through a 12-foot depth.

IV. Currents

The locations of current stations and nearshore current observations made in and near Kuwait Harbor are shown in Figure 9. Even though some current stations were not of sufficient duration to provide a total picture of the current regime for a particular locale, they are included in the summary of observations which appears in Table III. Other environmental items considered noteworthy have been selected from the data logs and are annotated under the station data to which they are related.

For all current stations, a Price meter was used to obtain data at the surface and an Ekman meter to obtain data at subsurface levels. All nearshore currents (off the beaches south of Ras al Ardh) were recorded with a Price meter. The results of these observations are contained in Table IV. Current observations using "current poles" and "chips" were made at several other locations, but the data were never reduced.

A few descriptive notations that offer additional information have been selected from the observation logs and are quoted here since they do not appear to apply specifically to any one current station observation series.

"During a survey along the northwest beach (Beach No. 1, Fig. 9) at Faylakah Island on 22-24 November 1948, it

was estimated that the normal current past the beach had a southwest direction, 1/2-3/4 knot. However, it was found that a 10- to 15-knot southerly wind sets up a northward inshore current of 1/2-1 knot that results mainly from the breakers angling into the beach.

"At the beginning of the flood tide (0930-1000) on February 15, 1949, at the entrance to Kuwait Harbor, a long, rather wide, tide eddy was noticed. It was found that on a calm day these eddies stir up separate clouds of mud from the bottom that give the surface of the water a brown, mottled appearance. The eddy line moves up into the harbor and dies out in the vicinity of Ras al Ajuzah as the flood becomes more pronounced. The countercurrent between Ras al Ajuzah and Ras al Ardh -- as proved by Current Station No. 10 -- flows back out into the entrance channel south of the eddy line.

"Another distinct line was observed at 1015 the same day trending generally north to south 2.6 miles due east of Ras al Ardh. The water to the west of the brown foam line that perhaps marked the boundary between waters of different densities was blue-green in color and less muddy than that water to the east of the line. This water on the west appeared to be flowing south-southeast. By 1130 the boundary line had swung on into the northern part of the harbor and at one point was 3.7 miles away from and on a bearing of 015° from Ras al Ajuzah. Later on at 1600-1612 the northern part of the boundary line extended into the harbor at 280°-100° and at 1612 was at one point 2.9 miles away from and on a bearing of 044° from Ras al Ardh.

"While there is no definite proof yet, it seems logical that this eddy line, or boundary line, is a continuation or development of the earlier one mentioned above."

Currents throughout the Kuwait area are tidal; there is little evidence of other factors appreciably influencing the current regime on a continuing basis. Of course strong southerly and easterly winds will tend to lengthen the duration and increase the speed of flood currents, and winds from the other two quadrants will tend to shorten the duration and decrease the speed. Opposite conditions hold for ebb currents. Strong winds are most frequent during the winter months and may arise quite unexpectedly, but these are normally short-lived, usually

accompanying frontal passages. Since winds over the Persian Gulf are generally weak, they contribute little to the development of the current pattern in either the gulf or Kuwait Harbor.

With almost total certainty one can say that precipitation and runoff are never of sufficient quantity to modify the tidal current patterns in Kuwait Harbor and vicinity. Only under the most exceptional circumstances would the rainfall volume over Iraq and the northern part of Kuwait produce discharges from Khawr as Sabiniyan or Shatt al Arab large enough to modify the existing current pattern in even the most eastern reaches of Kuwait Harbor. Certainly no observations taken during the 1948-49 winter season indicate that runoff or discharge from streams at the head of the Persian Gulf affect appreciably the current pattern in the Kuwait embayment.

The tidal current pattern at each station is rectilinear; at some stations significant time delays occur in the reversal of the current after high and low water. Average maximum vectors for flood and ebb at surface and depth are depicted in Figure 10 along with a generalized bathymetry configuration.

V. Bottom Sediments and Bathymetry

On this survey a total of 131 geological samples were taken; of this total, 90 were bottom samples from the Kuwait Harbor area and 35 were from the beaches east of Kuwait to Ras al Ardh and south to Fahihil. The remaining six samples were taken over Shah Allum Shoal in the southeastern part of the gulf.

The bottom sample analyses are listed in Table V and beach sample analyses in Table VI. Positions of all samples taken in Kuwait Harbor and vicinity are shown in Figures 9 and 11. Bottom sampling was done primarily from the "sound boats," sometimes in conjunction with the sounding operations, but more often on separate trips intended solely for oceanographic work. The 90 bottom samples obtained provide a close sampling grid for the Kuwait Harbor - Jazirat Faylakah - Fahihil area; however, a planned sampling network might have been more desirable instead of the random observation "system" used. An orange peel sampler or a "snapper" was used to obtain most of the bottom samples; a "scoopfish" sampler and a BT casing which was modified into an enlarged "scoopfish" were also available for sampling while underway. The latter item proved to be a particularly good instrument for obtaining sizable samples while running sounding lines and was used extensively.

For the beach areas a special effort was made to take samples at

the water line and at the berm. The location of intermediate sampling points was not standardized at specified distances from the above reference points; instead, they were taken at points where a change in the composition of the beach surface was visually apparent. The following descriptive notations concerning the beach areas are quoted from the observational logs because they are considered to contain supplementary material of interest.

"Along the shore south of Ras al Ardh, the beaches are of rather loose, unconsolidated sand that in spots has an easily breakable crust about 1/16 inch thick over the surface. A harder ridge about 50 feet wide and about 200 feet back from the waterline extends down the coast for some distance. This ridge is covered with large broken pieces of coral and marks a line of previous development of the cape. The sand of the present beach runs out along the bottom for about 500 to 600 feet before becoming overlaid with the mud with which most of the gulf bottom is covered.

"On the north side of Ras al Ardh itself, the shore is covered with approximately 2 x 2 x 1-foot blocks of shell conglomerate that uncover at low water. The beach continues back steeply to the aforementioned ridge.

"The northwest beach on Faylakah Island is rather steep and abrupt and has a well defined scarp about 2 feet high along its whole length. Directly behind this scarp and the berm, the ground slopes back gently and levels off near the center of the island. During the spring tides, the high water often washes directly against the scarp undermining and eroding it back slowly."

A bottom sediment chart prepared from the analyzed samples is presented in Figure 12. It is expected that the mud bottom shown for most of the area originates from the frequent dust storms and from the outflow of the Khawr as Sabiniyan and Shatt al Arab. However, only the finer particles in the runoff waters would remain in a state of "colloidal" suspension long enough to be deposited in the Kuwait Harbor area.

The most striking and interesting characteristic of the bottom sediment chart is the pattern of sediments off the coast southeast of Kuwait and south of Ras al Ardh. Sediments throughout this area undergo continual sorting by the relatively strong tidal currents (recorded to be in excess of 2 knots). A similar sorting of sediments

takes place along the south shore where the harbor is rather constricted and shoal. Off Jazirat Faylakah sorting is probably dependent on wave and surf action rather than on current action, the most effective agent being the relatively long waves (swell) originating in the southern part of the Persian Gulf. These swells occur with significant frequency only in the winter months; during the remainder of the year the area south of Jazirat Faylakah remains relatively quiet. The extensive shoal and the predominance of mud here seem to suggest that this area is a settling basin for fine suspended particles.

The bathymetry of the Kuwait Harbor area is presented in two charts, Figures 13 and 14, Figure 13 is of Kuwait Harbor proper; Figure 14 shows the approach area. The analysis is for 2-fathom intervals (beginning with 1 fathom) and is based on data obtained from a fine grid of sounding lines. The latest hydrographic charts for this area, H. O. Charts No. 3668, Kuwait Harbor, scale 1:50,000, and No. 3654, Ras al Buraisha to Fahihil, scale 1:100,000, provide additional detail with a dense coverage of individual soundings. The bathymetric pattern in Figure 14 shows well the advance of silt deposition into the area south of Jazirat Faylakah. Here, the mud bottom extends in a long apron south of the island terminating at about the 5-fathom isobath where the bottom slope steepens considerably to 15 fathoms. This mud shoal also extends northwest in a wide strip along the north side of Kuwait Harbor to the head of the embayment.

The deeper areas remain fairly close to the Arabian shore and form a right angle into Kuwait Harbor. The greatest depths (17 fathoms) are off Fahihil and are merely an extension of the general bottom structure of the Persian Gulf. These shoal northward to a slight sill about 9 1/2 fathoms deep just southeast of Ras al Ardh; a second depression (13 to 14 fathoms) forms an arc around Ras al Ardh. This deep water entrance to Kuwait Harbor is continuously maintained by the strong tidal currents. West of Ras al Ardh in the harbor proper, depths shoal considerably; shoaling is especially marked in the bights on either side of the town of Kuwait. Near the head of Kuwait Harbor soundings reveal a third shallow platter-shaped depression in the bottom with a maximum depth of slightly more than 6 fathoms.

VI. Tides

Tidal data are requisite to all hydrographic survey work. Accordingly, the installation of a tide gauge was undertaken immediately upon arrival of the survey ships in the Kuwait area. Following is a description of the installation and a summary of information from the reduced tide records. The original tapes and data were forwarded to the U. S.

Coast and Geodetic Survey for use in preparing pertinent tide tables.

"Kuwait Harbor (portable gage)

"The small water pier where only the Sheikh's water lighters normally moor seemed to provide the best location for a tide gage in Kuwait. Small boat traffic was negligible, the pier was of sturdy construction, and a tide staff previously had been installed on a dolphin nearby.

"About the time of low water on 14 November 1948, the installation party . . . proceeded to the pier in an LCPL boat. With the aid of a deck tackle, the 27-foot section of 4" tide well was hoisted into position, lashed temporarily with manila, and then secured with wire, the entire pipe being rigidly suspended from the pier. A new fixed tide staff was then installed about 10 feet away with the zero mark set in coincidence with the oil company's staff. A portable gage was then placed on the well (with a heavy coat of grease on the couplings) and set into operation.

"After the installation and during the survey season this portable gage required very little attention; its performance was very good. This gage later was turned over to the oil company for tending.

"Fahihil (standard gage)

"The gage at Fahihil was not set up until the middle of March because a mile-long pier was under construction in the vicinity, and location in accordance with the oil company's desires could not be considered. In March, however, it was decided to utilize a 20' x 20' steel frame dolphin situated about 50 yards south of the proposed pier outer extremity. On this structure, an oil company representative had rigidly secured a thirty-foot section of 12" steel pipe having a thickness of 1/2 inch but lacking an adapter on the bottom. This lack of an adapter was remedied to a certain extent by suspending a standard adapter under the pipe with 4 equally spaced 3/8" wires which were then secured near the top of the well and hove taut with turnbuckles.

"The installation party then constructed a house around the well and lined the interior with canvas to keep out

fine windblown sand. A fixed tide staff was erected nearby with the zero set by simultaneous readings to conform with a staff located on a small pier inshore and northward. The staff may be read with binoculars from the new pier. The gage was placed in operating condition and turned over to the oil company's engineering office.

"After departure of the survey personnel, the gage had to be tended via boat but it was planned to have a catwalk constructed in the future. Considerable wave motion was noted especially with eastern winds. . ."

Type of Tide

The type of tide in the Kuwait area is mixed; that is, two high waters and two low waters occur each tidal day, and a marked inequality exists between both successive high waters and successive low waters.

Tide Data Summary

Ranges

1. Mean range 6.59 feet.
2. Spring range 11.12 feet (age of phase inequality is about two days later).
3. Neap range 1.47 feet (age of phase inequality is about two and a half days later).
4. Greatest range observed 12.00 feet on 1 December 1948.

Datum Planes

1. Mean tide level about 9.89 feet (tide staff zero at 4.1 feet below the level of Mean Indian Low Water Springs).
2. Mean sea level about 6.95 feet.

Intervals

1. High Water Lunitidal Interval 11.92 hours.
2. Low Water Lunitidal Interval 5.92 hours.

VII. Other (Waves, Color and Transparency, Biology)

During the survey several other types of oceanographic observations were taken. These are combined in this section because only a few observations of each type were made during the entire survey period.

No attempt was made to select only observations for the Kuwait Harbor area.

Waves

In general waves in the Kuwait area are low since fetch distances are short except in the approaches. The usual low seas are interrupted most frequently during the winter months by rough seas lasting from a few hours to several days; these are induced by the gusty "shamal" type winds accompanying frontal passages. In the harbor approach areas off Fahihil long swell from the south is observed about 1/4 of the time during the winter and early spring, and rarely during other seasons. Table VII is taken from the most recent revision of H. O. Sailing Directions for the Persian Gulf (8) and contains seasonal percent frequencies of sea and swell for Kuwait Harbor and adjacent waters.

During this particular survey there was little opportunity to use a wave meter or wave pole. However, sea and swell entries were recorded regularly on the ship logs throughout the survey period. To supplement these, a series of special wave observations was made during several "shamal" periods. These wave data are contained in Table VIII.

Color and Transparency

Observations of color and transparency were extremely few and insufficient to warrant separate tabulation. These data are quoted directly from the observation logs in order to preserve the descriptive details which might be of value. The first of these repeats in part an observational note in Section IV of this report.

"At the beginning of the flood tide (0930-1000) on February 15, 1949, at the entrance to Kuwait Harbor, a long, rather wide, tide eddy was noticed. It was found that on a calm day these eddies stir up separate clouds of mud from the bottom that give the surface of the water a brown, mottled appearance. The eddy line moves up into the harbor and dies out in the vicinity of Ras al Ajuzah as the flood becomes more pronounced. The countercurrent between Ras al Ajuzah and Ras al Ardh -- as proved by Current Station No. 10 -- flows back out into the entrance channel south of the eddy line.

"Another distinct line was observed at 1015 the same day

trending generally north to south 2.6 miles due east of Ras al Ardh. The water to the west of the brown foam line that perhaps marked the boundary between waters of different densities was blue-green in color and less muddy than that water to the east of the line.

"On March 19, 1949 a very excellent line of color demarcation was noticed at the ten-fathom line 41 miles east of Fantas (located at 29°10.0'N., 48°07.5'E.). The color of the water changed from a rather muddy blue-green to a much clearer blue-green. However, without a color scale it is hard to describe the color change much more accurately. The depth beyond this point began increasing from a constant fathometer reading of 53 feet to 60 feet at a rate of one foot per minute - ship moving at about seven knots. These facts would indicate - as the charts show - that this color line and slight depth increase mark the limit of the main underwater mud delta laid down by the rivers flowing into the north end of the gulf.

"Five Secchi disk measurements were made throughout the gulf. The disk was visible for a depth of only 4.5 feet off the beach at Faylakah Island, for 10.5 feet at the western end of Kuwait Harbor (shown in Fig. 11), for 20 feet at Sitra Anchorage (Bahrein Island), for 60 feet in the vicinity of Shah Allum Shoal, and for 15 feet in the shade and 20 feet in the sun in the Strait of Hormoz. All the observations except that at Sitra Anchorage were made around 1300 LST with the one at Sitra taken at 1600 LST. The skies were partly cloudy, and the winds averaged Beaufort force 2. The colors of the water ranged from a grey, muddy green in the north, through a clear blue-green in the central parts of the gulf, to a dark murky green in the strait."

Biology

No biological observations were made in the Kuwait area, and the notes quoted below refer to the southern half of the gulf.

"It was reported to Mr. T. J. Wehe by members of the United Geophysical Company's seismic party that between Christmas and New Year's Day on the shoals 15 miles south of and 10 miles east of Bahrein Island hundreds of dead fingerlings and a few dead large fish were noted.

The deaths were attributed to a sudden change in the water temperature as no chemicals or foreign matter are pumped into that area. Actual cause of deaths not known.

"In the period of April 5-15, 1949 in the southern half of the gulf and the Strait of Hormoz, large numbers of round jellyfish up to four inches in diameter were noted. About ten miles south of the strait (April 10) the surface waters were filled with transparent jelly organisms that had single red nuclei. Shortly thereafter strings of this same organism 10 to 20 feet long with a row of red nuclei enclosed in each string also were noticed. The individual organisms may have been torn from one of these strings or they may be single fish eggs. Another type of "egg" - transparent and round, with two tendrils, one diagonally across from the other - was noted in this same area.

"In the area west of the strait and in the vicinity of Jazirat Tonb, several small patches of floating, fine-textured, red weed were noted. Also a large patch of fine green plankton or algal "spores" was seen. The observer was unable to tell how deep the layer went.

"In this southeastern area of the gulf, the water was phosphorescent enough to show plainly (when flowing by at 1 to 2 knots) the anchor chain and surface current meter when the U.S.S. JOHN BLISH was anchored overnight on a current station. This phosphorescence occurred both in an underwater "haze" and in large, bright, numerous "sparks" and also was noticed in the Gulf of Oman, the Arabian Sea, the Gulf of Aden, and to some extent in the Red Sea. The Mediterranean Sea and Atlantic Ocean waters showed only a little phosphorescence when passage of them was made in the latter part of May."

Other Observations

A total of 1,982 bathythermograph observations was made from October 1948 to June 1949. In addition to the temperature observations made in the Kuwait Harbor area, bathythermograph observations were made at approximately one-hour intervals beginning about 290 miles east of Ambrose Lightship. They continued across the Atlantic Ocean, through the Mediterranean Sea, the Red Sea, the Gulf of Aden, the Arabian Sea, the Gulf of Oman, the Persian Gulf, and back along a similar route to Norfolk, Virginia.

At least one BT profile each month from November 1948 through April 1949 was made in the northwestern quarter of the Persian Gulf; one profile was made in the southeastern half of the gulf in mid-April 1949. The monthly profiles in the northwestern quarter of the gulf generally were made during trips between Kuwait or Fahihil and Bahrein.

Table I. OCEANOGRAPHIC STATIONS - Kuwait Harbor
(Station Locations shown in Fig. 1)

Date: 23-24 February 1949

Ship: U.S.S. JOHN BLISH

Station No.	Date	Time (LST)	Depth (m.)	Temp. (°F.)	Sal. (‰)	Remarks
1	2/23	0903	Surf.	56.1*	40.21	
			12	55.29	40.28	
2	2/23	1020	Surf.	56.8*	M.**	
			11	54.45	40.93	
3	2/23	1214	Surf.	56.8*	41.20	
			2	55.86	41.17	
4	2/23	1410	Surf.	57.2*	M.**	B.S. - 66 (See Table V)
			4	55.81	M.**	
5	2/23	1635	Surf.	58.1*	40.53	B.S. - 69 (See Table V)
			3.5	55.84	40.51	
6	2/24	0824	Surf.	56.5*	40.16	
			5.5	56.33	M.**	
7	2/24	1112	Surf.	58.63	40.11	B.S. - 72 (See Table V)
			17	55.96	40.10	
8	2/24	1209	Surf.	59.23	40.29	B.S. - 73 (See Table V)
			3.5	56.60	40.22	
9	2/24	1242	Surf.	59.43	39.96	B.S. - 74 (See Table V)
			5	56.69	40.17	
10	2/24	1325	Surf.	59.59	40.06	
			8	56.53	M.**	
11	2/24	1336	Surf.	57.39	M.**	Mixing, Zone of Eddy
			8	56.22	40.06	
12	2/24	1420	Surf.	58.32	39.52	B.S. - 75 (See Table V)
			4	56.40	39.90	
13	2/24	1457	Surf.	57.73	39.32	B.S. - 76 (See Table V)
			3	55.77	39.59	
14	2/24	1531	Surf.	57.98	M.**	B.S. - 77 (See Table V)
			2.5	55.43	38.20	
15	2/24	1558	Surf.	57.86	M.**	B.S. - 78 (See Table V)
			2.5	56.69	37.89	
16	2/24	1625	Surf.	57.91	37.97	B.S. - 79 (See Table V)
17	2/24	1700	Surf.	57.50	37.77	B.S. - 80 (See Table V)

Note:

* Bucket thermometer used, read only to tenths °F.

** Sample bottles lost or broken, values missing.

23 Feb. - Wind: B. F. 2
Sea: Code 2
Weather: 00/01

24 Feb. - Wind: B. F. 1
Sea: Code 2
Weather: 02

Table II. BATHYTHERMOGRAPH LOG SHEETS (containing supplementary meteorological data) FOR THE JURNAL WARMING SECTIONS SHOWN IN FIGURES 4, 5, AND 6.

KUWAIT HARBOR

BT SERIAL NO.	TIME (LST)	DATE	LATITUDE N	LONGITUDE E	BT NO	DEPTH (ft)	SPEED (KNOTS)	SURF. TEMP. DEGREES		WIND (DIR SPEED)	R F	AIR TEMP. (°F)			APPROX. R H %	WEA- THER*	CLOUDS*		VISI- BIL- ITY*	SEA*	REMARKS
								(SURF)	(10')			(1) WET BULB	(2) DRY BULB	(3) WET BULB			TYPE	COVER			
M949	0909	1/3/49	29°23.6'	48°05.0'	1751	19	0	55.4	57.3	NNW	2	45.4	41.0	62	00	00	0/0/0	0	7	1	
M950	0930	↑	↑	↑	↑	42	↑	56.2	57.3	N	2	46.0	40.7	63	↑	↑	↑	↑	↑	↑	
M951	1000	↑	↑	↑	↑	40	↑	56.4	57.6	N	2	-	-	-	↑	↑	↑	↑	↑	↑	
M952	1030	↑	↑	↑	↑	38	↑	56.3	57.6	N	2	47.6	41.8	60	↑	↑	↑	↑	↑	↑	
M953	1100	↑	↑	↑	↑	35	↑	56.5	57.9	N	2	-	-	-	↑	↑	↑	↑	↑	↑	
M954	1130	↑	↑	↑	↑	33	↑	56.8	58.0	N	2	48.9	41.9	54	↑	↑	↑	↑	↑	↑	
M955	1200	↑	↑	↑	↑	32	↑	56.7	58.2	N	1	-	-	-	↑	↑	↑	↑	↑	↑	
M956	1230	↑	↑	↑	↑	31.5	↑	57.1	58.7	-	Calm	52.0	43.0	46	↑	↑	↑	↑	↑	↑	
M957	1300	↑	↑	↑	↑	29	↑	57.2	58.7	-	Calm	-	-	-	↑	↑	↑	↑	↑	↑	
M958	1330	↑	↑	↑	↑	29	↑	56.8	58.3	W	1	53.5	44.8	48	↑	↑	↑	↑	↑	↑	
M959	1400	↑	↑	↑	↑	26	↑	56.5	57.7	SW	1	-	-	-	↑	↑	↑	↑	↑	↑	
M960	1430	↑	↑	↑	↑	25	↑	56.3	57.7	S	1	50.8	42.0	44	↑	↑	↑	↑	↑	↑	
M961	1500	↑	29°27.1'	48°00.7'	↑	25	↑	56.3	57.5	S	1	-	-	-	↑	↑	↑	↑	↑	↑	DRIFT DIRECTION CHANGED
M962	1530	↑	↑	↑	↑	32	↑	56.9	58.4	S	1	50.3	41.5	43	↑	↑	↑	↑	↑	↑	
M963	1600	↑	↑	↑	↑	32	↑	56.7	58.3	S	1	50.3	41.5	43	↑	↑	↑	↑	↑	↑	
M964	1630	↑	↑	↑	↑	31	↑	56.3	58.1	SE	2	50.0	41.9	49	↑	↑	↑	↑	↑	↑	
M965	1655	↑	29°25.5'	48°00.5'	↑	31	↑	56.3	57.9	SE	2	-	-	-	↑	↑	↑	↑	↑	↑	

KUWAIT HARBOR

ML 1	0815	2/27/49	NO EXACT LOCATION RECORDED. PROBABLY ABOUT 29°25'N 48°02'E.		1751	56	0	57.0	57.8	-	Calm	57.0	52.0	72	01	6/0/0	4	4	1	
ML 2	0900	↑			↑	51	↑	57.6	58.2	300	1	-	-	-	01	4/0/0	4	4	1	
ML 3	0930	↑			↑	50	↑	57.8	58.3	285	2	58.8	53.5	72	01	1/0/0	3	4	1	
ML 4	1000	↑			↑	50	↑	57.8	58.8	270	2	-	-	-	01	0/0/1	3	5	1	
ML 5	1030	↑	↑	↑	↑	47	↑	57.9	58.9	270	2	56.2	52.5	77	01	9/0/1	3	5	1	
ML 6	1100	↑	↑	↑	↑	45	↑	58.3	59.1	270	2	-	-	-	01	9/0/1	3	5	1	
ML 7	1130	↑	↑	↑	↑	42	↑	58.9	59.6	255	2	57.6	53.2	78	01	9/0/1	3	5	1	
ML 8	1200	↑	↑	↑	↑	40	↑	59.1	60.1	265	2	-	-	-	02	4/0/1	5	5	1	BT TAKEN IN SHADOW
ML 9	1230	↑	↑	↑	↑	38	↑	59.6	59.7	-	Calm	60.2	54.7	70	02	4/0/0	4	5	1	
ML 10	1300	↑	↑	↑	↑	35	↑	60.2	62.0	-	Calm	-	-	-	01	1/0/0	2	5	1	BT TAKEN IN SHADOW
ML 11	1330	↑	↑	↑	↑	33	↑	60.3	61.4	100	2-3	60.2	55.0	72	01	1/0/0	2	5	1	
ML 12	1400	↑	↑	↑	↑	29	↑	59.1	60.3	110	4	-	-	-	00	0/0/0	0	5	1-2	
ML 13	1430	↑	↑	↑	↑	26	↑	58.4	59.5	110	4	58.0	55.0	83	00	0/0/0	0	5	2	
ML 14	1500	↑	↑	↑	↑	36	↑	58.0	59.0	110	4	-	-	-	00	0/0/0	0	5	2	
ML 15	1530	↑	↑	↑	↑	33	↑	57.8	59.0	110	4	57.9	55.0	83	00	0/0/0	0	5	2	
ML 16	1600	↑	↑	↑	↑	33	↑	57.8	59.0	110	4	-	-	-	00	0/0/0	0	5	2	
ML 17	1630	↑	↑	↑	↑	30	↑	57.8	59.0	110	4	57.9	55.0	83	00	0/0/0	0	5	2	

*See International Code for Radio Weather Reports from Ships (Code prior to 1 Jan. 1949).

Table II. (Cont'd) BATHYTHERMOGRAPH LOG SHEETS (containing supplementary meteorological data)
FOR THE DIURNAL WARMING SECTIONS SHOWN IN FIGURES 4, 5, AND 6.

FAHIMIL

BT SERIAL NO.	TIME (LST)	DATE	LATITUDE N.	LONGITUDE E.	BT NO.	DEPTH (F)	SPEED (KNOTS)	SURF. TEMP. DEGREES		WIND		AIR TEMP. (°F.)		APPROX. R. H. %	WEA- THEN	CLOUDS*		VISI- BIL- ITY (MI.)	SEA	REMARKS
								(°K)	(°F)	DIR (DEG.)	S.P.	DRY BULB	WET BULB			TYPE	COVER			
M1089	0730	3/21/49	1-2 MILES OFF FAHIMIL BEACH	936A	68	0		62.6	61.9	300	2	62.5	56.5	69	00	0/0/0	0	8	1	
M1090	0800				70			62.6	62.0	-	-	-	-	-	-	-	-	-	1	
M1091	0830				71			62.9	62.1	300	2	64.0	57.2	65	00	0/0/0	0	8	1	
M1092	0900				70			63.3	62.1	-	1	-	-	-	-	-	-	-	1	
M1093	0930				68			63.6	62.6	330	2	64.8	58.2	68	00	0/0/0	0	8	1	
M1094	1000				69			64.0	62.8	-	1	-	-	-	-	-	-	-	1	
M1095	1030				70			64.2	62.9	360	2	65.0	58.4	68	01	5/0/0	2	8	1	
M1096	1100				70			64.2	63.1	-	2	-	-	-	-	-	-	-	1	
M1097	1130				66			64.5	63.5	030	2	66.0	58.4	64	01	5/0/0	4	8	1	
M1098	1145				67			64.6	63.3	-	2	-	-	-	-	-	-	-	1	
M1099	1214				65			64.6	63.9	-	2	-	-	-	-	-	-	-	1	
M1100	1230		SHIFTED BOAT APPROX. 1 MILE N.		62			64.8	63.9	030	2	65.4	60.0	74	02	6/0/0	5	8	1	
M1101	1300		SHIFTED BOAT APPROX. 1 MILE E.	DRIFT	71			65.1	64.0	-	2	-	-	-	-	-	-	1		
M1102	1330				68			64.4	63.7	065	2	66.2	59.5	66	02	6/0/0	5	8	1	
M1103	1358				68			65.0	64.0	-	2	-	-	-	-	-	-	-	1	
M1104	1430				71			65.1	64.2	095	2	66.1	60.2	71	02	6/0/0	5	8	1	
M1105	1500				70			64.9	64.1	-	3	-	-	-	-	-	-	-	1	
M1106	1530				70			64.7	64.0	120	3	66.0	60.5	74	01	8/0/0	4	8	1	
M1107	1600				65			64.9	64.1	-	2	-	-	-	-	-	-	-	1	
M1108	1630				75			64.4	63.8	135	2	65.8	60.5	74	02	3,8/0/0	5	8	1	
M1109	1700				70			64.2	63.5	-	2	-	-	-	-	-	-	-	1	
M1110	1732				70			64.0	63.2	150	2	64.5	61.0	82	02	-/3,4/0	6	8	1	
M1111	1800				71			63.8	63.3	-	2	64.9	59.7	74	02	0/4/5	5	8	1	

*See International Code for Radio Weather Reports from Ships (Code prior to 1 Jan. 1949).

Table III. CURRENT STATION DATA

No. - Date Location	Depth	Flood Current			Tide	Ebb Current		
		Avg. Dir.	Avg. Speed	Max. Speed		Avg. Dir.	Avg. Max. Speed	Tide
1 Nov. 5-9, 1948 Lat. 29°25'54"N. Long. 47°57'36"E.	Surf. 30' Sfc. 30'	262° 269° 262° 269°	1.09 kn. 0.63 kn. 0.41 kn. 0.46 kn.		LLW to LHW LLW to LHW HLW to HHW HLW to HHW	083° 101° 083° 101°	0.88 kn. 0.88 kn. 0.55 kn. 0.35 kn.	HHW to LLW HHW to LLW LHW to HLW LHW to HLW
Remarks: Surface and subsurface maximum currents observed at the same time for both flood and ebb. Slack waters observed as predicted in tide tables.								
2 Nov. 9-11, 1948 Lat. 29°24'30"N. Long. 47°59'12"E.	Surf. 27'	252° 267°	0.89 kn. 0.50 kn.		To LHW To HHW	075° 071°	0.62 kn. 0.52 kn.	To LLW To HLW
Remarks: Surface and subsurface maximum currents observed at the same time for both flood and ebb. Slack waters observed as predicted in tide tables.								
3 Nov. 11-13, 1948 Lat. 29°23'12"N. Long. 47°57'54"E.	Surf. 11' Sfc. 11'	215° nil 215° nil	0.87 kn. nil 0.49 kn. nil		LLW to HHW HLW to LHW	049° nil 049° nil	0.71 kn. nil 0.71 kn. nil	HHW to LLW HLW to HLW
Remarks: Flood to HHW completed 1/2 hr. earlier than predicted, flood to slack water at LHW and to slack water at LLW and HLW observed as predicted in tide tables.								
4 Nov. 14-16, 1948 Lat. 29°26'21"N. Long. 47°51'12"E.	Surf.		1.09 kn. 0.90 kn.		HLW to HHW LLW to LHW		1.12 kn. 1.05 kn.	HHW to LLW LHW to HLW
Remarks: No directions observed. Observations limited to 27 hrs. (1130 LST 14 Nov. 1948 to 1500 LST 16 Nov. 1948. Maximum flood currents observed: 1.21 kn. to HHW, 0.93 kn. to LHW; maximum ebb currents observed: 1.32 kn. to LLW, 1.10 kn. to HLW. Surface current continues to flood about 1/2 - 1 hour after high tide at Kuwait.								
5 Nov. 16-19, 1948 Lat. 29°21'38"N. Long. 48°07'34"E.	Surf. 30' Sfc. 30'	325° 331° 325° 331°	1.34 kn. * 1.54 kn. *		HLW to HHW HLW to HHW LLW to LHW LLW to LHW	135° 143° 135° 143°	2.00 kn. * 1.34 kn. *	HHW to LLW HHW to LLW LHW to HLW LHW to HLW
Remarks: Winds NW, Force 4-5 (15-20 kn.), delays slack water from both flood and ebb for 1/2 to 1 hour past times predicted in tide tables. *Insufficient readings to determine subsurface speeds.								
6 Nov. 22-24, 1948 Lat. 29°28'54"N. Long. 48°03'06"E.	Surf. 18'	313° 310°	0.92 kn. 0.78 kn.		To LHW To HHW	136° 126°	0.83 kn. 0.72 kn.	To LLW To HLW
Remarks: Max. current recorded: Flood 1.12 kn., Ebb 1.09 kn.; Slack waters from both flood and ebb observed 1/2 to 1 hour in advance of times predicted in tide tables.								
7 Nov. 30-Dec. 2, 1948 Lat. 29°28'48"N. Long. 47°58'24"E.	Surf. 17' Sfc. 17'	265° 286° 265° 286°	0.97 kn. 0.98 kn.		HLW to HHW LLW to LHW	101° 100° 101° 100°	0.83 kn. 0.63 kn. 0.56 kn. 0.63 kn.	HHW to LLW HHW to LLW LHW to HLW LHW to HLW
Remarks: Max. current recorded: Flood 1.14 kn. with Winds NNW, Force 4 (11-16 kn.). Slack water from both flood and ebb observed to vary ±1/2 hour from times predicted in tide tables.								
8 Dec. 8-9, 1948 Lat. 29°24'36"N. Long. 47°47'48"E.	Surf. 25' *		0.74 kn. 0.36 kn.		LLW to HHW LLW to HHW		1.00 kn. 0.39 kn.	HHW to HLW HHW to HLW
Remarks: No directions observed. Observations limited to 12 hrs. (1300 LST 8 Dec. 1948 to 0100 LST 9 Dec. 1948). *Depth of observations approximate.								
9 Jan. 12-14, 1949 Lat. 29°21'42"N. Long. 47°56'55"E.	Surf. 18' Sfc. 18'	212.5° 215.5° 226° 215.5°	0.82 kn. 0.73 kn. 0.71 kn. 0.73 kn.		To LHW To LHW To HHW To HHW	027.5° (020°)* 027.5° nil	1.01 kn. 1.43 kn. 0.56 kn. nil	To LLW To LLW To HLW To HLW
Remarks: *No direction observed; value given is orientation direction of Shuwayk Channel. Maximum surface flood current observed approximately 1 hour later than subsurface maximum; maximum ebb current observed approximately 1 hour earlier than subsurface minimum.								
10 Mar. 4-6, 1949 Lat. 29°21'09"N. Long. 48°04'59"E.	Surf. 51' Sfc. 51'	245° 250° 245° 250°	0.61 kn. 0.44 kn. 0.48 kn. 0.44 kn.		HLW to LHW HLW to LHW LLW to HHW LLW to HHW	075° 124 kn. 075° 070°	0.94 kn. 1.24 kn. 0.77 kn. 1.24 kn.	HHW to HLW HHW to HLW LHW to LLW LHW to LLW
Remarks: Flood at surface begins 1/2 - 3/4 hr. earlier than slack water predicted; near bottom flood begins 1 hr. earlier than slack water predicted in tide tables. Flood observed to terminate at about 1/2 the time duration predicted, ebb then begins. Ebb current attain maximum speed shortly after ebb flow begins in other areas of Kuwait Harbor.								
11 Mar. 16, 1949 Lat. 29°14'30"N. Long. 48°09'18"E.	Surf. *	340°	1.2 kn.*			150°	1.2 kn.*	
Remarks: Observations limited to 9 hrs. (1420 - 2318 LST). Only the maximum current during observation period is shown. Maximum flood observed at HLW + 2 hrs.; maximum ebb observed at HHW + 3 hrs.								

Table IV. NEARSHORE CURRENT DATA

Beach No. Lat. (N.) Long. (E.)	Date	Time (LST)	Location Offshore Depth	Depth of Meter	Current kn./deg.	Wind kn./dir.	Stage of tide
5							
29°20'15"N.	23 Mar 49	1410	4 Fath.	Surf.	0.52/360°	14/W	Early flood from HL to HH
48°06'15"E.	23 Mar 49	1415	4 Fath.	12'	0.33	14/W	Early flood from HL to HH
	23 Mar 49	1100	4 Fath.	18'	None	14/W	HL - Stand
6							
29°16'00"N.	23 Mar 49	1140	5 Fath.	Surf.	0.14/180°	14/W	Ebb from LH to HL
48°05'45"E.	23 Mar 49	1140	5 Fath.	18'	None	14/W	Ebb from LH to HL
	23 Mar 49	1300	5 Fath.	Surf.	0.29/250°	14/W	Ebb from LH to HL
	23 Mar 49	1300	5 Fath.	18'	None	14/W	Ebb from LH to HL
7							
29°12'15"N.	9 Mar 49	0905	9 Fath.	Surf.	0.31/135°	14/W	Ebb from LH to HL
48°06'45"E.	9 Mar 49	0915	9 Fath.	45'	0.10	14/W	Ebb from LH to HL
	9 Mar 49	0920	9 Fath.	18'	None	14/W	Ebb from LH to HL
	9 Mar 49	1020	3 Fath.	Surf.	0.28/160°	14/W	Ebb from LH to HL
	9 Mar 49	1025	3 Fath.	9'	0.17	14/W	Ebb from LH to HL
	9 Mar 49	1035	5 Fath.	Surf.	0.20/120°	13/W	Ebb from LH to HL
	9 Mar 49	1040	5 Fath.	18'	0.14	13/W	Ebb from LH to HL
	9 Mar 49	1135	7 Fath.	Surf.	0.24/304°	13/W	Early flood from HL to HH
	9 Mar 49	1140	7 Fath.	18'	0.27	13/W	Early flood from HL to HH
	9 Mar 49	1145	7 Fath.	36'	0.22	13/W	Early flood from HL to HH
	10 Mar 49	0905	7 Fath.	Surf.	0.54/330°	20/S	Late flood to LH
	10 Mar 49	0910	7 Fath.	18'	0.49	20/S	Late flood to LH
	10 Mar 49	0915	7 Fath.	36'	0.36	20/S	Late flood to LH
	10 Mar 49	0945	5 Fath.	Surf.	0.39/115°	20/S	Late flood to LH
	10 Mar 49	0950	5 Fath.	18'	0.61	20/S	Late flood to LH
	10 Mar 49	1020	2 Fath.	Surf.	0.63/120°	20/S	Early ebb from LH to HL
	10 Mar 49	1020	2 Fath.	6'	0.57	20/S	Early ebb from LH to HL
	22 Mar 49	1510	3 Fath.	Surf.	0.29/337°	None	Flood from HL to HH
	22 Mar 49	1520	3 Fath.	12'	0.11	None	Flood from HL to HH
8							
29°09'30"N.	22 Mar 49	1405	3 Fath.	Surf.	0.36/326°	None	Flood from HL to HH
48°07'30"E.	22 Mar 49	1410	3 Fath.	12'	0.19	None	Flood from HL to HH
9							
29°08'15"N.	22 Mar 49	1330	3 Fath.	Surf.	0.38/320°	None	Flood from HL to HH
48°08'00"E.	22 Mar 49	1335	3 Fath.	12'	0.24	None	Flood from HL to HH
10							
29°06'45"N.	22 Mar 49	1300	5 Fath.	Surf.	0.25/324°	None	Flood from HL to HH
48°08'15"E.	22 Mar 49	1305	5 Fath.	18'	0.31	None	Flood from HL to HH
11							
29°05'30"N.	22 Mar 49	1030	4 Fath.	Surf.	None	11/W	HL - Stand
48°08'15"E.	22 Mar 49	1230	4 Fath.	12'	None	11/W	HL - Stand
12							
29°03'45"N.	22 Mar 49	0940	8 Fath.	Surf.	0.24/124°	11/W	Ebb from LH to HL
48°09'00"E.	22 Mar 49	0950	8 Fath.	18'	0.18	11/W	Ebb from LH to HL
	22 Mar 49	1000	3 Fath.	Surf.	None	11/W	Ebb from LH to HL
13							
29°01'00"N.	22 Mar 49	0810	5 Fath.	Surf.	0.34/130°	11/W	Ebb from LH to HL
48°09'30"E.	22 Mar 49	0815	5 Fath.	18'	0.12	11/W	Ebb from LH to HL

Table V. BOTTOM SEDIMENT SAMPLES

Dates: Nov. 1948 - Feb. 1949

Ship: U.S.S. JOHN BLISH

Sample No.	Date	Time (LST)	Latitude N.	Longitude E.	Depth (ft.)	Sample Description
1	11/9	1030	29°25'54"	47°57'36"	40	Gray mud with shell fragments.
2	11/9	1130	29°24'30"	47°59'12"	30	Gray mud with shell fragments and rounded sand grains.
3	11/11	1400	29°23'12"	47°57'54"	20	Gray mud.
4	11/14		29°26'21"	47°51'12"	24	Gray mud.
5	11/18		29°21'38"	48°07'34"	90	Shell, sand, and gray mud. Quartz grains rounded.
6	11/23	1800	29°28'54"	48°03'06"	30	Gray mud. A few shell fragments.
7	12/13	1130	29°24'36"	47°47'48"	35	Gray mud.
8	12/16	1400	29°24'37"	47°53'00"	9	Large shell fragments and plant debris.
9	12/18	1330	29°25'31"	47°54'01"	30	Gray mud.
10	12/20	1005	29°17'30"	48°06'47"	66	Gray mud with shell fragments.
11	12/20	1027	29°18'20"	48°05'59"	42	Shell and gray mud; mostly shell.
12	12/20	1029	29°18'23"	48°05'52"	36	Shell, sand, and larger shell fragments with some mud.
13	12/20	1031	29°18'25"	48°05'46"	30	Fine shell, sand, quartz sand, mud, and larger shell fragments.
14	12/20	1035	29°18'25"	48°05'37"	6	Fine quartz sand.
15	12/20	1052	29°19'12"	48°07'11"	69	Fine sand, shell fragments, silt, and mud.
16	12/20	1111	29°19'22"	48°09'33"	84	Mud with shell and sand.
17	12/20	1128	29°18'10"	48°08'19"	66	Mud and shell fragments.
18	12/20	1202	29°16'13"	48°08'49"	72	Mud with some shell fragments.
19	12/20	1306	29°16'07"	48°07'03"	72	Mud with some shell fragments.
20	12/20	1318	29°16'03"	48°06'13"	54	Mud with shell fragments.
21	12/20	1325	29°16'04"	48°06'04"	42	Mostly shell fragments with some mud. A few quartz sand grains.
22	12/20	1329	29°16'05"	48°05'53"	33	Shell, sand, and grit with some round and medium quartz sand grains.
23	12/20	1332	29°16'07"	48°05'44"	18	Shell fragments, medium quartz grains with some mud. Mostly shell. Sand grains rounded.
24	12/20	1338	29°16'06"	48°05'38"	6	Fine quartz sand. Numerous rounded grains.
25	12/21	1120	29°24'20"	47°46'24"	20	Gray mud.
26	12/22	1200	29°23'17"	47°45'45"	9	Medium quartz and shell, sand with gray mud.
27	12/23	1300	29°22'17"	47°57'11"	10	Gray mud with a few shell fragments.
28	12/24	1400	29°20'55"	47°54'22"	23	Medium sand with some gray mud. Sand grains well-rounded.
29	12/28	1600	29°23'33"	47°47'33"	16	Shell, sand with some quartz and mud and larger shell fragments.
30	1949 1/3	1300	29°24'07"	48°00'00"	14	Medium sand with large shell fragments and gray mud. 75% shell. Sand grains rounded.
31	1/4	1230	29°24'07"	47°48'50"	24	Gray silt and small shell fragments with some clay.
32	1/9	1040	29°26'36"	47°49'18"	41	Gray mud.
33	1/11	1605	29°26'42"	47°51'00"	24	Gray mud.
34	1/13	1149	29°23'32"	47°43'54"	8	Medium sand (rounded and polished grains) with shell fragments and gray mud.
35	1/13	1452	29°22'39"	47°42'08"	36	Poorly sorted quartz and shell, sand (fine sand to coarse sand) with larger shell fragments and a little mud.
36	1/14		29°21'42"	47°56'55"	29	Gray mud.
37	1/28	0812	29°24'24"	48°01'21"	37	Gray mud with some medium sand and numerous large shell fragments.
38	1/28	0841	29°23'01"	48°02'00"	10	Gray mud and large shell fragments with some quartz sand. Shell fragments large and 90% of samples. Few quartz sand grains and well-rounded.
39	1/28	0845	29°24'22"	47°51'14"	7	Medium to coarse quartz and shell, sand with larger shell fragments and a little mud.
40	1/28	0900	29°22'00"	48°02'06"	7	Fine to medium sand, mostly black rounded grains, with some mud and shell fragments.
41	1/28	0905	29°25'23"	47°50'42"	39	Gray mud.
42	1/28	0914	29°22'35"	48°03'02"	14	Gray mud with occasional shell fragments.

Table V. (Cont'd). BOTTOM SEDIMENT SAMPLES

Dates: Nov. 1948 - Feb. 1949

Ship: U.S.S. JOHN BLISH

Sample No.	Date 1949	Time (LST)	Latitude N.	Longitude E.	Depth (ft.)	Sample Description
43	1/28	0930	29°21'36"	48°04'03"	14	Gray mud with abundance of shell fragments.
44	1/28	0942	29°21'08"	48°05'16"	74	Fine sand and mud with a few shell fragments. Most of sand grains are rounded. A large percent of sand grains are black.
45	1/28	1000	29°21'26"	48°06'03"	68	Medium quartz sand with some shell. Large percent of sand grains perfectly rounded and highly-polished.
46	1/28	1012	29°21'19"	48°05'49"	61	Sand with considerable mud. Very little shell. Most of quartz grains rounded and polished.
47	1/28	1014	29°21'16"	48°05'36"	68	Medium-rounded quartz sand with some mud and considerable shell.
48	1/28	1058	29°19'56"	48°06'07"	36	Shell fragments and some mud. Occasional rounded medium sand grains.
49	1/28	1105	29°20'02"	48°06'03"	30	Medium sand with abundant small shell fragments. Numerous rounded sand grains.
50	1/28	1113	29°20'01"	48°06'24"	55	Sand, shell, and mud. Large shell fragments. Rounded quartz grains.
51	1/28	1120	29°20'03"	48°06'52"	72	Indication of coral and sand. (No quantity obtained).
52	1/28	1125	29°20'07"	48°07'14"	72	Indication of coral and sand. (No quantity obtained).
53	1/28	1131	29°19'58"	48°07'58"	81	Mostly shell with some sand and considerable mud.
54	1/28	1334	29°24'34"	48°07'32"	78	Gray mud.
55	1/28	1348	29°24'51"	48°06'18"	84	Gray mud and shell. Shell mostly broken echinoids.
56	1/28	1405	29°24'00"	48°05'00"	69	Gray mud and shell with occasional quartz sand grains.
57	1/28	1420	29°22'54"	48°05'55"	92	Mainly large shell fragments with some gray mud. Mostly oyster shell.
58	1/28	1430	29°23'13"	47°43'58"	34	Medium sand and mud with some shell fragments.
59	1/28	1442	29°23'04"	48°03'59"	33	Gray mud and shell with some medium sand.
60	1/28	1455	29°23'56"	48°03'04"	48	Gray mud with shell. Some sand grains.
61	1/28	1508	29°25'00"	48°04'00"	72	Gray mud.
62	2/15	1135	29°10'30"	48°15'24"	76	Mud.
63	2/15	1300	29°10'48"	48°08'54"	68	Mud.
64	2/15	1340	29°10'18"	48°08'48"	64	Mud.
65	2/15	1504	29°10'12"	48°15'24"	78	Mud.
66	2/23	1410	29°28'09"	47°52'43"	13	Gray mud.
67	2/23	1425	29°27'24"	47°55'27"	18	Gray mud.
68	2/23	1546	29°30'44"	48°02'30"	14	Silt and clay with some shell fragments.
69	2/23	1635	29°30'22"	48°01'30"	11	Gray mud.
70	2/24	0920	29°23'27"	48°07'24"	79	Gray mud.
71	2/24	1000	29°21'07"	48°10'15"	43	Gray mud.
72	2/24	1130	29°25'17"	48°05'47"	62	Gray mud.
73	2/24	1205	29°28'14"	48°07'01"	15	Gray mud.
74	2/24	1255	29°25'52"	48°07'52"	23	Gray mud.
75	2/24	1430	29°21'18"	48°14'10"	16	Gray mud.
76	2/24	1500	29°23'01"	48°17'19"	15	Fine-grained silt and clay with some shell fragments.
77	2/24	1535	29°24'22"	48°16'27"	13	Gray silt and clay with abundant shell fragments.
78	2/24	1600	29°25'00" ?	48°14'07" ?	11	Gray silt and clay.
79	2/24	1625	29°25'23"	48°12'05"	8	Gray silt with a little clay.
80	2/24	1700	29°27'33"	48°14'08"	10	Gray silt with a little clay.
81	2/25	0800	29°28'04"	47°58'15"	30	Gray mud.
82	2/25	0835	29°29'12"	47°58'47"	24	Gray mud.
83	2/25	0910	29°28'06"	48°01'02"	36	Gray mud.
84	2/25	1100	29°22'15"	48°09'19"	52	Gray mud.
85	2/25	1130	29°19'39"	48°14'34"	26	Gray mud.
86	2/25	1200	29°17'08"	48°16'35"	23	Gray mud.
87	2/25	1325	29°16'41"	48°14'43"	69	Gray mud.
88	2/25	1340	29°16'06"	48°12'12"	70	Gray mud.
89	2/25	1415	29°15'12"	48°08'29"	72	Fine silt and clay.
90	2/25	1440	29°18'24"	48°09'36"	69	Gray mud and shell fragments.

Table VI. BEACH SAMPLES

Beach No. Lat. (N.) Long. (E.)	Date	Time (LST)	Distance from Water Line	Remarks	
	1948				
1					
29°26'02"N.	11/22	1242	240'S*	Water depth 6.3'	Gray mud.
48°16'08"E.	11/22	1255	140'S	Water depth 3.0'	Coral and shell of sand to stone sizes.
(South Limit	11/22	1302	90'S	Water depth 3.0'	Coral and shell of sand to stone sizes.
of Beach)	11/22	1304	40'S	Water depth 2.0'	Coarse quartz sand and shell fragments. Sand rounded and polished.
	11/22	1310	0	Water depth 0	Medium to coarse quartz and shell sand. Quartz grains rounded and polished.
	1949				
1					
29°26'02"N.	11/23	1015	350'S	Water depth 4'	Shell fragments and gray silt and clay.
48°16'08"E.	11/23	1020	150'S	Water depth 3'	Quartz sand, shell fragments and gray silt and clay. Quartz grains rounded and polished.
(300 yds. North	11/23	1025	0	Water depth 0	Very coarse quartz and shell fragment sand.
of above	11/23	1030	50'L*		Coarse quartz sand with shell fragments.
location)	11/23	1035	150'L		Medium quartz sand with abundant shell fragments and some silt. Quartz grains rounded and polished.
	1949				
3					
29°23'30"N.	3/24	1445	0		Medium quartz sand; large % rounded and polished.
48°00'30"E.	3/24	1445	100-200'L		Medium quartz sand; large % rounded and polished with occasional shell fragments.
(North Limit	3/24	1445	-	At Berm	Medium to coarse quartz sand with some shell fragments.
of Beach)					
3					
29°23'30"N.	3/24	1420	0		Medium and medium fine sand. Very high % rounded grains.
48°00'30"E.	3/24	1420	30'L	At Berm	Medium and medium fine sand. Very high % rounded grains.
(South Limit	3/24	1420	60'L		Medium to very coarse sand with numerous shell fragments.
of Beach)					
4					
29°20'30"N.	3/24	1345	0		Medium to very coarse quartz sand and numerous shell fragments.
48°04'15"E.	3/24	1345	45'L		Medium sand over half well rounded and polished. Occasional shell fragments.
(West Limit	3/24	1345	95'L	At Berm	Medium quartz sand, mostly rounded and polished with abundant shell fragments. Some very coarse quartz grains.
of Beach)					
4					
29°20'30"N.	3/24	1320	0		Medium quartz sand, mostly rounded and polished. Numerous larger quartz grains some rather small shell fragments.
48°04'15"E.	3/24	1320	30'L		Medium and coarse quartz sand and shell fragments. High % of medium quartz grains rounded and polished.
(East Limit	3/24	1320	55'L		Medium to coarse quartz sand and shell fragments. Medium grains mostly rounded and polished.
of Beach)	3/24	1320	100'L	At Berm	Coarse quartz sand and shell fragments with numerous rounded and polished grains of medium size.
10					
29°06'45"N.	3/24	1100	0		Medium to fine sand with a few shell fragments. 10-15% rounded and polished grains.
48°08'15"E.	3/24	1100	45'L	At Berm	Medium to fine quartz sand. 40% rounded.
	3/24	1100	120'L		Fine to coarse quartz sand with occasional small stones.
11					
29°05'30"N.	3/24	1030	0		Medium quartz sand with a few shell fragments.
48°08'15"E.	3/24	1030	45'L	At Berm	Medium quartz sand.
	3/24	1030	90'L		Medium to coarse quartz sand with a few shell fragments.
12					
29°03'45"N.	3/24	0900	0		Medium quartz sand.
48°09'00"E.	3/24	0900	38'L	At Berm	Medium quartz sand.
	3/24	0900	140'L		Medium and coarse quartz sand with quartz granules and a few shell fragments.
13					
29°01'00"N.	3/24	0945	0		Medium sand with several sand grains of coarse sizes and a few shell fragments.
48°09'30"E.	3/24	0945	80'L	At Berm	Medium sand with numerous coarse particles.
	3/24	0945	150'L		Fine to coarse sand and shell stones. Large shell fragments.

*Note:

S = Indicates samples taken seaward of waterline.

L = Indicates samples taken landward of waterline.

Table VII. FREQUENCY OF SEA AND SWELL (PERCENT) FOR KUWAIT HARBOR AND ADJACENT WATERS

SEA

WINTER

(JANUARY, FEBRUARY, MARCH)

	<3'	3'-5'	5'-8'	8'-12'	>12'	TOTAL
N	13	2	1	*		17
NE	5	1				6
E	6	*				6
SE	12	4	1			17
S	4					4
SW	5					5
W	9					9
NW	16	3	1	*		20
TOTAL	71	10	3	*		84

CALM 16

NO. OBS. 457

SPRING

(APRIL, MAY, JUNE)

	<3'	3'-5'	5'-8'	8'-12'	>12'	TOTAL
N	5	1				6
NE	4					4
E	6	*				6
SE	11	2	*	*		13
S	3					3
SW	5					5
W	13					13
NW	18	10	2	*		30
TOTAL	65	13	2	*		80

CALM 20

NO. OBS. 307

SUMMER

(JULY, AUGUST, SEPTEMBER)

	<3'	3'-5'	5'-8'	8'-12'	>12'	TOTAL
N	5	*				5
NE	1					1
E	1					1
SE	6	*	*			7
S	5					5
SW	4					4
W	21					21
NW	30	7	5	1		43
TOTAL	73	8	5	1		87

CALM 13

NO. OBS. 306

AUTUMN

(OCTOBER, NOVEMBER, DECEMBER)

	<3'	3'-5'	5'-8'	8'-12'	>12'	TOTAL
N	13	5	1			19
NE	2	1				3
E	3	*				3
SE	4	2	*			6
S	5					5
SW	4					4
W	5					5
NW	24	9	5	*	*	39
TOTAL	60	17	6	*	*	84

CALM 16

NO. OBS. 288

SWELL

WINTER

(JANUARY, FEBRUARY, MARCH)

	1'-6'	6'-12'	>12'	TOTAL
N				
NE				
E	4	1		5
SE	16	3		19
S				
SW				
W				
NW				
TOTAL	20	4		24

CALM 76

NO. OBS. 310

SPRING

(APRIL, MAY, JUNE)

	1'-6'	6'-12'	>12'	TOTAL
N				
NE				
E	3			3
SE	6	2		8
S				
SW				
W				
NW				
TOTAL	9	2		11

CALM 89

NO. OBS. 264

SUMMER

(JULY, AUGUST, SEPTEMBER)

	1'-6'	6'-12'	>12'	TOTAL
N				
NE				
E				
SE	2			2
S				
SW				
W				
NW				
TOTAL	2			2

CALM 98

NO. OBS. 137

AUTUMN

(OCTOBER, NOVEMBER, DECEMBER)

	1'-6'	6'-12'	>12'	TOTAL
N				
NE				
E	1			1
SE	3			3
S				
SW				
W				
NW				
TOTAL	4			4

CALM 96

NO. OBS. 148

* LESS THAN 0.5 PERCENT

Table VIII. SPECIAL WAVE OBSERVATIONS

Date	Time (LST)	Ship Heading	Wind dir./kn.	Dir. (°)	Waves		Fetch (miles)	Wave Length		Wave Vel. Calc. (kn.)
					Ht. (ft.)	Per. (sec.)		Est. (ft.)	Calc. (ft.)	
*11/16/48	0830	012°-015°	330°/20	330°	3	4.26	6.5	50	92.7	12.8
*11/16/48	1200	359°-003°	330°/20	330°	3	3.37	6.5	30	58.0	10.1
*11/16/48	1530	325°	340°/14	330°	2	3.08	6.5	30	48.4	9.2
*11/17/48	0845	348°-358°	320°/25	315°	3-4	3.44	6.5	35	60.3	10.3
* 2/16/49	0930	110°-160°	145°/40+	140°	3-4	3.76	2.5	40-50	72.1	11.3
			Remarks: Shamal sprang up at 0630							
* 2/16/49	1030	128°-135°	145°/35+	140°	3-5	3.57	2.5	60	65.0	10.7
* 2/16/49	1130	132°-141°	140°/40	140°	2-4	3.43	2.5	60	60.0	10.3
* 2/16/49	1400	260°-280°	300°/28	290°	2-3	3.78	10-15	50	72.9	11.3
			Remarks: By 1600 sea had become choppy with little semblance of swell. Wind variable Beaufort Force 4-5							
** 3/17/49	0630	050°-060°	140°/25+	140°	3-6	4.75		50	12.8	15.0
			Remarks: Wind variable Beaufort Force 5-7							

Note:

*Denotes observations taken while ship at anchor in Kuwait Harbor Roadstead at approximately 29°25'N., 47°58'E. Water depth 5-6 fathoms.

**Denotes observation taken at 29°13'N., 48°09'E. Water depth 12 fathoms.

FIGURE 1. LOCATIONS OF OCEANOGRAPHIC STATIONS AND DIURNAL WARMING OBSERVATIONS

FIGURE 2. TYPICAL MIDWINTER SURFACE TEMPERATURE (°F), KUWAIT HARBOR

FIGURE 3. TYPICAL MIDWINTER BOTTOM TEMPERATURE (°F), KUWAIT HARBOR

FIGURE 4. DIURNAL WARMING OBSERVATIONS, (°F) KUWAIT HARBOR (3 JANUARY 1949)

FIGURE 5. DIURNAL WARMING OBSERVATIONS (°F.), KUWAIT HARBOR (27 FEBRUARY 1949)

FIGURE 6. DIURNAL WARMING OBSERVATIONS (°F), FAHIL (21 MARCH 1949)

FIGURE 7. TYPICAL MIDWINTER SURFACE SALINITY (‰), KUWAIT HARBOR

FIGURE 8. TYPICAL MIDWINTER BOTTOM SALINITY (‰), KUWAIT HARBOR

FIGURE 9. LOCATIONS OF CURRENT STATIONS, NEARSHORE CURRENT OBSERVATIONS, AND BEACHES

FIGURE 10. TIDAL CURRENTS (INCLUDING GENERAL BATHYMETRY, WATER COLOR, AND TRANSPARENCY DATA)

FIGURE 11. LOCATION OF BOTTOM SEDIMENT SAMPLES

FIGURE 12. BOTTOM SEDIMENTS

FIGURE 13. BATHYMETRY, KUWAIT HARBOR

FIGURE 14. BATHYMETRY, KUWAIT HARBOR APPROACHES

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3. Oceanography -
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