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COASTAL GEOMORPHOLOGY AND RESOURCES IN TERMS OF SENSITIVITY TO OIL SPILL IN KUWAIT

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ABSTRACT

An oil spill environmental sensitivity index (ESI) was developed for the coastal environments of Kuwait as an aid to oil spill contingency planning and response efforts. A total of 11 maps were developed which (a) characterize and rank the shoreline into 10 categories based on sensitivity to oil, (b) denote the ranges of oil-sensitive and commercially important wildlife species, (c) denote the location of important coastal socioeconomic features, and (d) provide a preliminary protection strategy for combating an oil spill.

Field studies were undertaken in April 1983 and January 1984 and encompassed both aerial and ground surveys of the entire coast of Kuwait including Bubyan and Failaka Islands. Based on these surveys, the shoreline of Kuwait was classified as follows (listed in order of increasing sensitivity to spilled oil):

(1) Concrete seawalls and harbor structures (18 km)
(2) Beach-rock outcrops (16 km)
(3) Fine-sand beaches (47 km)
(4) Medium- to coarse-sand beaches (346 km)
(5) Hard sand or mud tidal flats with low productivity (261 km)
(6) Riprap (boulder) structures (73 km)
(7) Cobble/boulder beaches (3 km)
(8) Exposed bedrock platforms (52 km)
(9) Hard sand or mud tidal flats with high productivity (73 km)
(10) Soft mud tidal flats with high productivity (339 km)

The wildlife groups included in the ESI for Kuwait were fish, birds and marine turtles. Fish were categorized in terms of nearshore food species (31 species or species groups), offshore food species (10 species or species groups), and mudskippers (four species of Gobiidae). Birds were categorized as wading birds (23 species), shorebirds (45 species), coastal birds (18 species), migratory waterfowl (15 species), and pelagic birds (10 species). The marine turtle designation included three species, although the green turtle (*Chelonia mydas*) is most commonly sighted in Kuwait's nearshore waters. Seasonality data were also presented for each species.

Sites of determined socioeconomic or human-use value were desalination/power plants, marinas, and public recreational areas.

To assist the spill-response effort, cleanup and protection guidelines were devised for each shoreline type and were also presented in terms of a priority strategy for combating a spill within each of the 11 oil-spill sensitivity maps.

INTRODUCTION

The Arabian Gulf is the largest oil export region in the world and yet supports a varied and abundant ecological community, provides numerous recreation amenities, and is a major source of fresh water through desalination. A major oil spill, particularly along the southern side of the Gulf, could have a major impact on each of these functions. The purpose of this project was to delineate the most sensitive shoreline and wildlife habitats in Kuwait, in order to assist oil-spill planning and response activities. Factors that entered into this analysis were shoreline geology and coastal processes, fish and wildlife occurrence, and socioeconomic factors such as recreational beaches, marinas, and desalination plants. As part of the evaluation, primary response strategies were developed based on shoreline characteristics and the delineation of sensitive areas.

PREVIOUS STUDIES AND ENVIRONMENTAL SETTING

SHORELINE GEOLOGY

The subsurface and surficial geology of Kuwait are major influences on the geomorphology and sediment types present along the shoreline (Al-Sarawi 1980). Major subsurface stratigraphic studies include Fuchs *et al.* (1968), Humphreys (1965), and publications of the Kuwait Oil Company. The surface geology of Kuwait has received the attention of Fox (1959) and Milton (1967), among others. Other studies have dealt with the sedimentation of carbonate along the southern coast of Kuwait (Saleh 1975) and general sedimentation patterns in the Arabian Gulf (Purser & Evans 1973; Purser & Seibold 1973). Particularly relevant to understanding the geology of the shoreline have been the studies by Al-Asfour (1975) on the sea level changes along Kuwait Bay, Hayes *et al.* (1977) and RPI (1979) on coastal processes at Kuwait City, Khalaf (1969) on the geology and mineralogy of beach sediments along northern Kuwait Bay, and Al-Ghadban (1980) on recent shallow-water sediments along the southern Kuwait coast.

Beach sediments along the Kuwait coast vary in grain size from silt and clay to large boulders (as found at the base of eroding cliffs). The Pleistocene and Holocene oolitic carbonate sediments along the southern Kuwait coast belong to the northernmost marginal sector of the carbonate province of the shallow Arabian shelf, which extends from the Strait of Hormuz to the Tigris–Euphrates delta (Picha 1978). Several oolitic ridges, desposited during Quaternary fluctuations in the sea level, are present in the south of Kuwait (Saleh 1975). The clastic deposits in the north, originating from the Shatt Al-Arab, were deposited by an anticlockwise current in the Arabian Gulf. The hard and well-cemented beach rock along the southern coast of Kuwait is related to deposition during eustatic changes in sea level during the Quaternary.

Coastal mapping projects of this nature have not been undertaken previously in Kuwait or in the Arabian Gulf region. In the United States, similar sensitivity mapping has been completed for most of the coastal areas, and sponsored by U.S. National Oceanic and Atmospheric Administration (NOAA), Seattle. Canada has embarked on joint sensitivity mapping projects with the United States and is completing the Great Lakes areas, which is sponsored by Environment Canada, Toronto. Other areas of application include South Africa (Jackson & Lipshitz 1985), Panama (Gundlach *et al.* 1985), Hamburg Harbor, West Germany (Leo & Nil 1983), and the outer coast of Nigeria (Gundlach 1985). The basis of the sensitivity analysis, referred to as the oil spill Environmental Sensitivity Index (ESI), is presented in Gundlach & Hayes (1978). Previous oil-spill-related work in Kuwait has focussed on determining the level of coastal shorline tar pollution (Osstdam & Anderlini 1978; Anderlini & Al-Harmi 1979).

CLIMATOLOGY

Climate controls the overall wind patterns and can greatly influence the currents and tides of the Arabian Gulf. Data available from the Kuwait Civil Aviation Meteorological Department (DGCAMD 1983) and in Al-Kulaib (1975) indicate that the climate along the shoreline of Kuwait can vary considerably during the course of any given year, but is generally characterized as hot and arid with moderate winds. The maximum high temperature was 50.8°C, recorded at Shuwaikh, while the record low was –4.0°C at Kuwait International Airport. Approximate annual rainfall is 120 mm, although it may vary greatly. The winter months are the wettest, while little to no rainfall occurs during July through September.

TIDES

Tides in Kuwait have a mean range of approximately 3 m and contain important semidiurnal and diurnal components. Spring tidal range, excluding the influence of wind setup, is approximately 4.3 m (USDOC 1984). Wind setup, causing much higher than normal tides, is a particularly important process along the north shore of Kuwait Bay where raised water levels can cause inundation several kilometres inland.

CURRENTS

Galt et al. (1983) summarized the currents of the Arabian Gulf, particularly in regard to oil-slick movement. The principal driving forces for currents in the Gulf and Kuwait Bay are the tides which enter through the Strait of Hormuz. However, on the whole, there is little net motion occurring because of the tides since there is a balance between oscillatory ebb and flood currents. Therefore other factors, primarily winds, become very important. Other secondary factors are caused by a sea-water inflow through the Strait of Hormuz to replace water evaporated in the Gulf and by fresh-water inflow at the Shatt Al-Arab. For the predominant northwesterly winds, Galt *et al.* (1983) predict a weak (0.25 m/s) southerly current along the coast. Southeasterly winds would generate an even weaker current flowing to the north.

COASTAL AND NEARSHORE BIOLOGY

Scientific information concerning the natural history of the Arabian Gulf has been steadily increasing. The publications of Basson *et al.* (1977), Relyea

(1981), Harrison (1981), Arnold (1981), and Smythe (1981) provide an overview of the biotopes, fishes, mammals, birds, seashells, and wildflowers, respectively, of the Arabian Gulf. Specific to Kuwait is Clayton (1981), describing many coastal and marine organisms, and Halwagy & Halwagy (1977), delineating coastal vegetative types and zonation.

FISHERIES

Over the past five years, commercial fisheries have provided an annual yield of 5,000–6,000 metric tons. Offshore fishes once led in yields, but recently the importance of nearshore species has increased. Fish are caught by four methods: (1) fish traps (*hadras*) on the tidal flats, (2) nearshore haul nets and cast nets, (3) hook and line, and (4) trawls or other large nets used from boats. Hadras selectively capture fish which use the tidal flats during high tides and which move offshore as the tide recedes. Nearshore nets are hand-hauled or thrown from small boats in shallow areas and the mouths of channels. Hook and line is used by recreational as well as commercial fishermen. Trawls drag the bottoms for most of the fish and shrimp seen in the marketplace.

METHODS

Methods utilized for this study include a combination of literature evaluation, ground surveys, aerial overflights, and laboratory analysis. The field methods utilized were originally developed to rapidly assess large sections of coastline in Alaska (Hayes *et al.* 1973), updated through experience gained during oil spill investigations (Gundlach *et al.* 1978). Biological and geological field studies were completed concurrently to ensure compatibility between results.

LITERATURE COLLECTION

During all stages of the study, pertinent information was collected and evaluated pertaining to Kuwait's ecological setting, climate, geology, and socioeconomic features. Detailed 1:25,000- and 1:50,000-scale topographic maps of Kuwait were obtained from the Kuwait University (KU) Geology Department and were used as project base maps. Locations of important socioeconomic features, primarily marinas and desalination plants, were obtained from the 1:25,000-scale maps, updated by field observations.

GROUND SURVEYS

To determine the distribution of shoreline types and coastal ecological communities, two types of ground survey stations were established: (a) detailed profile stations, and (b) rapid-survey stations.

Detailed profile stations were positioned approximately every 10 km along the coastline to enable analysis of a variety of shoreline types throughout Kuwait. In all, a total of 25 stations were analyzed during April 1983 and January 1984 using the following methods:

(1) A topographic profile of the beach was measured at low tide using the Emery (1961) method. The profile was most commonly run from a fixed datum point (e.g. a corner of a building, fence or seawall) to enable repetition of the same profile. Descriptions of the geomorphic features, sediment types, and resident biology (relative species abundance, location along the profile, etc.) were made concurrently with the measurement of the profile.
(2) The biological characteristics of each survey station were marked along the measured topographic profile and noted during a careful walk across the entire site during January 1984. When possible, all dominant organisms and algae were classified in the field; otherwise, specimens were brought back to the laboratory for classification using published field guides (particularly, Bosch & Bosch 1982; Basson *et al.* 1977; Jennings 1981; Relyea 1981; Sharabati 1981). Surface as well as infaunal organisms were collected and noted.
(3) A sketch was made to illustrate all aspects of the study site. Sample locations, as well as geological, biological, and geomorphic features, were indicated on the sketch. A sketch served to reinforce observations of key details more clearly than a photograph alone.
(4) 35-mm photographs were taken of all aspects of the site. All photographs from the field surveys were classified by date, roll number, and station number, and served as a data source to classify the coastline.

Rapid survey stations, over 40 in total, were positioned along the coast during February 1984 to enable the detailed analysis of areas not clearly observed during the other ground surveys or the aerial overflight. The biological and geomorphic characteristics of each site were noted during a walking survey across the area. Information was recorded photographically and in a field notebook. Specimens not identified in the field were taken back to the laboratory for further study. In most cases, the site was described and classified in less than one hour.

AERIAL SURVEYS

Overflights of the Kuwait coastline (except most of Bubyan Island) were undertaken in April 1983 and January 1984, using a Kuwait military helicopter. From an altitude of 150 m, the coastline was classified as to shoreline type directly onto 1:50,000-scale topographic maps. Video and 35-mm photography were used to check aerial observations. The shoreline environments of Bubyan Island were classified from 1:10,000-scale aerial photographs available at the KU Geology Department. After classification, shoreline types were ranked in order of increasing sensitivity to spilled oil based on observations at numerous oil spills. Table 1 contains the list of spills which serve as a basis for this ranking.

Table 1. Principal oil spills and references which serve as a basis for the Environmental Sensitivity Index

Oil spill	Date	Type and amount	Studies
WW II Tankers, U.S. East Coast	Jan–Jun 1942	Various: 533,740 tons	Campbell *et al.* (1977)
Torrey Canyon, Scilly Isles, U.K.	Mar 1967	Arabian Gulf crude; 117,000 tons total; 18,000 tons on shore	Smith (1968); Southward & Southward (1978)
Santa Barbara Blowout	Jan 1969	California crude; 11,290 to 112,900 tons total; 4,509 tons on shore	Foster *et al.* (1971); Kolpack (1971)
Arrow, Chedabucto Bay, Nova Scotia	Feb 1970	Bunker C; 18,220 tons total	Owens (1978); Vandermeulen & Gordon (1976)
Metula, Strait of Magellan, Chile	Aug 1974	Saudi Arabian crude; 53,000 tons total; 40,000 tons onshore	Hann (1974)
Amoco Cadiz, Brittany, France	Mar 1978	Arabian Gulf crude; 223,000 tons total	Hess (1978); Gundlach *et al.* (1983)
Urquiola, La Coruña, Spain	May 1978	Arabian Gulf crude; 110,000 tons total; 25,000–30,000 onshore	Gundlach *et al.* (1978)
Peck Slip, Eastern Puerto Rico	Dec 1978	Number 6 oils; 1,500 tons	Gundlach *et al.* (1979)
Ixtoc I, Gulf of Mexico	Jun 1979–Apr 1980	Crude oil; several hundred thousand tons	Hooper (1981)
Burmah Agate, Texas	Nov 1979	Crude and refined product; 8,800 tons	Thebeau & Kana (1981); Thompson *et al.* (1981)

BIOLOGICAL EVALUATION

Species or biological communities were selected for inclusion on the map series based on recreational, commercial or ecological value. The major species groups included were fish, marine turtles, and birds. Information concerning habitat usage and species present was derived from the literature (as discussed previously) and from field observations. Species sensitivity to oil is derived from the petroleum-related literature including the 1973–1985 Oil Spill Conferences (API 1973–1985), and several summary publications (e.g. Card *et al.* 1984; Starr *et al.* 1981).

SOCIOECONOMIC EVALUATION AND SPILL-RESPONSE STRATEGIES

Coastal sites noted for their recreational or human-welfare importance were noted and mapped during the field survey. Primary response strategies and guidelines for oil spill were derived from spill observations (Gundlach *et al.* 1978), working directly with oil cleanup contractors, and from the literature (e.g. Kanter 1983; ITOPF 1984/85).

RESULTS

A total of 11 maps were prepared as part of this study (Fig. 1). Each contains a ranking of shoreline types, a delineation of wildlife and socioeconomic resources, and primary response strategies. Each of these topics is discussed in the following sections, after which examples of four maps are presented.

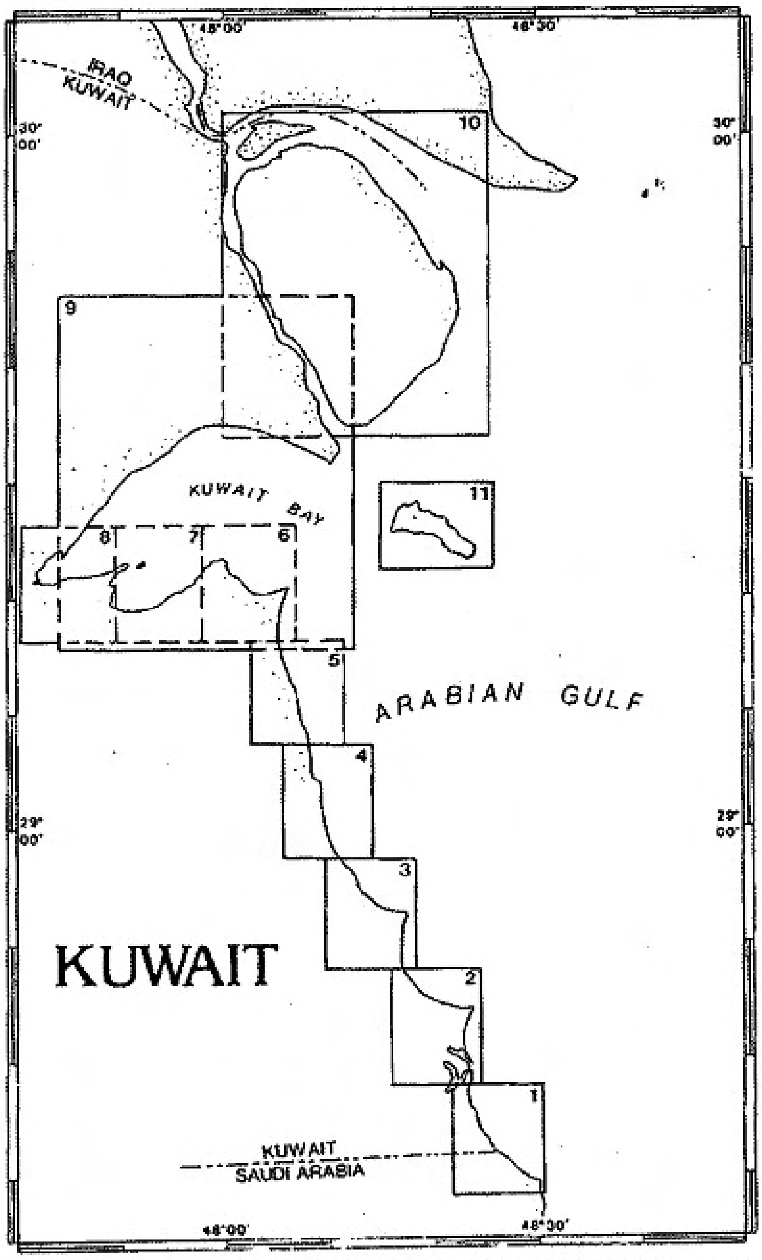

Fig. 1. Location of II maps generated as part of this project. Al-Sarawi *et al.* (1985) contains all maps. Figs 24–27 are coloured reproductions of maps 1, 9, 10, and 11.

SHORELINE CLASSIFICATION

The coastal environments of Kuwait were classified and ranked into the categories illustrated in Table 2. They are listed in order of increasing sensitivity to spilled oil as determined during studies of several oil spills. Environments 9 and 10 are particularly sensitive and warrant special protection during a spill. Sensitivity includes the persistence of oil, the effects of oil on resident biota, the abundance and diversity of the species present, and the ability of the biological community to recover.

Table 3 presents a summary of the distance covered by each shoreline type in Kuwait. Since several types may be present along a particular section of shore (e.g. an exposed bedrock platform fronting a sand beach fronting a seawall), the total length of shoreline in Kuwait is overstated.

A characterization of each shoreline type in terms of geological and biological description, predicted oil effects and applicable spill-response measures follows. The distribution and photographs of each shoreline are illustrated in Figs 2–21. Shorelines are listed in order of increasing sensitivity.

Table 2. The ESI shoreline classification for Kuwait, ranked in order of increasing sensitivity to spilled oil

Ranking	Shoreline type
1.	Concrete seawalls and harbor structures
2.	Beach-rock outcrops
3.	Fine-sand beaches
4.	Medium-to-coarse-sand beaches
5.	Hard sand or mud tidal flats with low productivity
6.	Riprap (boulder structures)
7.	Cobble/boulder beaches
8.	Exposed bedrock platforms
9.	Hard sand or mud tidal flats with high productivity
10.	Soft mud tidal flats with high productivity

Table 3. Distance of each shoreline type along the coast of Kuwait. Map locations are presented in Fig. 1. Since map 9 overlaps several others, shorelines from the overlapped sections (maps 5—8 and 10) are excluded from the distances measured under map 9

	Shoreline type (distance, km)									
Map Number	1	2	3	4	5	6	7	8	9	10
1.	1·0	1·5	4·9	6·8	14·0	1·3	0·6	0·0	0·6	0·0
2.	0·3	2·0	31·3	7·1	4·0	1·0	0·0	0·5	0·0	0·0
3.	1·5	0·6	8·0	12·9	3·5	1·1	0·2	0·3	0·0	0·0
4.	4·5	0·4	0·0	11·5	1·9	5·2	0·0	0·3	0·0	0·0
5.	1·9	0·5	0·0	14·9	1·4	1·5	0·2	9·2	0·0	0·0
6.	2·6	0·3	0·2	6·7	1·1	15·6	0·0	4·0	0·0	0·0
7.	3·4	1·4	0·3	14·8	11·3	15·6	0·0	10·2	0·0	15·2
8.	1·8	0·0	0·0	22·9	16·8	3·4	0·0	9·2	14·3	15·5
9.	0·0	0·0	0·0	70·0	76·2	0·0	0·0	0·0	54·7	55·0
10.	0·9	0·0	2·1	158·0	119·2	0·0	0·0	0·0	3·0	253·0
11.	0·3	8·9	0·0	21·0	15·2	2·4	2·1	18·4	0·0	0·0
Total	18·2	15·6	46·8	346·6	264·6	47·1	3·1	52·1	72·6	338·7

Type 1: Concrete seawalls and harbor structures

DESCRIPTION

* The distribution and photograph of these structures are presented in Figs 2 and 3
* Most common around industrial ports and fronting coastal property
* In many cases, seawalls protecting coastal property are located along the upper intertidal zone, backing sand beaches
* Biological productivity is low Species abundance and diversity are low
* Resident plant species include blue-green algae and green algae
* Algae are present although not abundant on structures in the middle and upper intertidal zones
* Most common organisms include top shells (*Trochus erythraeus* and *Clanculus pharaonius*) and cluster winkles (*Planaxis sulcatus*)

PREDICTED OIL IMPACT

* Oil will coat the seawall or harbor structure to a maximum width equal to the intertidal and splash zones
* Oil persistence will be long-term in sheltered areas
* Along exposed structures, the extent of oiling and oil persistence is much less
* A heavy oil coating on these structures will kill many of the attached resident organisms

RESPONSE ACTIVITIES

Preferred:

* Booms, skimmers, and sorbents—to divert and collect oil before it comes ashore; avoid trampling biota during placement
* Natural cleansing—useful in exposed areas

Viable:

* Low-pressure flushing—valid on fresh, unweathered oil; avoid hot or fresh water; avoid trampling; recover flushed oil
* Sorption—recover oiled sorbents; less effective on large spills
* Manual removal—labor intensive; avoid slopping recovered oil
* Vacuum pumping—avoid sucking up biota

Not advisable:

* Burning—avoid population centres; less effective on weathered oil
* Dispersant—spray offshore; must have adequate dilution

Avoid:

* High-pressure spraying—use when contamination is severe
* Sand blasting—may assist recolonization
* Steam cleaning—avoid trampling or dragging equipment over unoiled areas

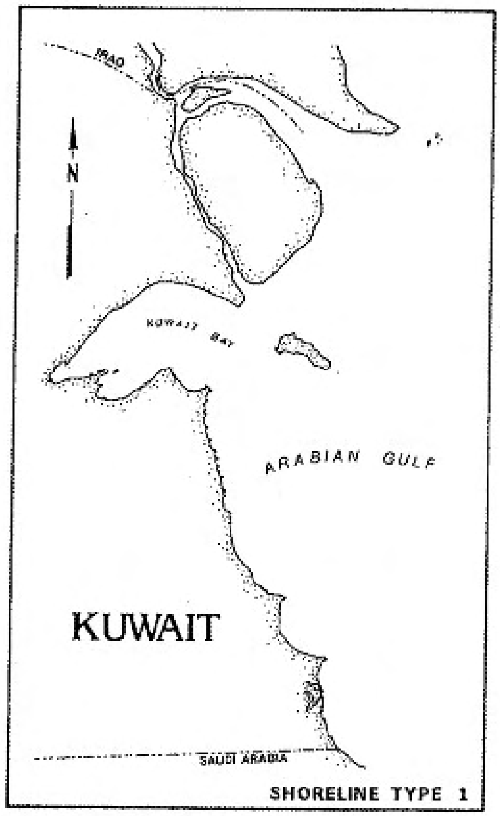

Fig. 2. Distribution of shoreline type I, concrete seawalls and harbor structures.


Fig. 3. Photograph of shoreline type 1, concrete seawalls and harbor structures.

Type 2: Beach-rock outcrops

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 4 and 5
* Generally low-lying (less than 2 m high)
* Commonly found in back of sand beaches, although in some cases they dip vertically throughout the intertidal zone
* Exposed to moderate-to-high wave energies
* Relatively unproductive with a low number of species
* Plants include blue-green algae and green algae
* Barnacles are common; oysters and serpulid worms are less common
* Top shells (*Trochus erythraeus* and *Clanculus pharaonius*), turbans (*Turbo coronatus*), drills (*Thais savignyi*), and cluster winkles (*Planaxis sulcatus*) are common

PREDICTED OIL IMPACT

* Many of these units are located above the normal intertidal zone and will be oiled only during exceptionally high (storm or wind-driven) tides
* Units within the intertidal zone may become covered with oil during large spills and relatively calm conditions
* If oil-covered, most resident biota will be killed
* Under moderate-to-high wave conditions, oil coverage will be limited
* Oil may persist for several months, especially if allowed to asphaltize on the rock surface
* Recolonization of biota will be relatively rapid because of the open nature of this habitat

RESPONSE ACTIVITIES -

Preferred:

* Booms, skimmers, and sorbents—to divert and collect oil before it comes ashore; avoid trampling biota during placement
* Natural cleansing—useful in exposed areas

Viable:

* Low-pressure flushing—valid on fresh, unweathered oil; avoid hot or fresh water; avoid trampling; recover flushed oil
* Sorption—recover oiled sorbents; less effective on large spills
* Manual removal—labor intensive; avoid slopping recovered oil
* Vacuum pumping—avoid sucking up biota

Not advisable:

* Burning—avoid population centres; less effective on weathered oil
* Dispersant—spray offshore; must have adequate dilution

Avoid:

* High-pressure spraying—use when contamination is severe
* Sand blasting—may assist recolonization
* Steam cleaning—avoid trampling or dragging equipment over unoiled areas

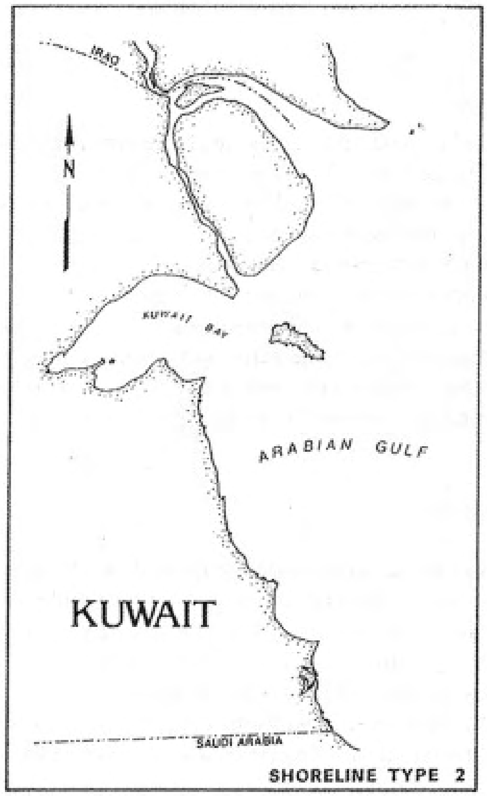

Fig. 4. Distribution of shoreline type 2, beach-rock outcrops.

Fig. 5. Photograph of shoreline type 2, beach-rock outcrops.

Type 3: Fine-sand beaches

DESCRIPTION

* The distribution and photograph of fine-sand beaches are presented in Figs 6 and 7
* Not particularly common in Kuwait
* Generally have a flat topographic profile
* Contain few organisms; crustaceans dominate
* Mole crabs (Hippa sp.) are found in the lower intertidal zone and are buried in the substrate at low tide
* Ghost crabs (Ocypode saratan) are occasionally found along the upper shoreline in undisturbed areas

PREDICTED OIL IMPACT

* Oil will commonly penetrate 3 to 5 cm into beach sediments
* Oiled-sediment layers may become buried up to 15 cm into the beach depending on changes in the beach profile
* Oil will be primarily deposited along the high-tide swash lines in the upper intertidal zone
* Oil persistence will likely be short-term (days to weeks) before being reworked by wave action
* Some biota will likely be killed, especially under heavy oil concentrations

RESPONSE ACTIVITIES

Preferred:
* Booms, skimmers, and sorbents—to divert and collect oil before it comes ashore
* Manual labor—useful to limit sediment removal; labor intensive, avoid contaminating clean, back-beach areas by sloppy handling techniques
* Mechanical cleanup—useful on hard, flat beaches; if possible, wait until all oil has come ashore; avoid excessive sand removal; avoid contaminating clean, back-beach areas
* Natural cleansing—particularly appropriate if wave energies are moderate to high
* Vacuum pumping—useful only for thick layers of low viscosity oil; line collection pits with plastic to limit penetration into the sediment

Viable:
* Dispersants—spray ahead of the advancing tide; avoid contaminating adjacent areas; do not use with sorbents
* Low-pressure flushing—viable only for low viscosity oils; only for limited areas; recover flushed oil using booms or sorbents pads; recover all sorbent material after use
* Mixing—only for low concentrations of oil not feasible to be removed physically

Avoid:
* Burial, burning, and substrate removal

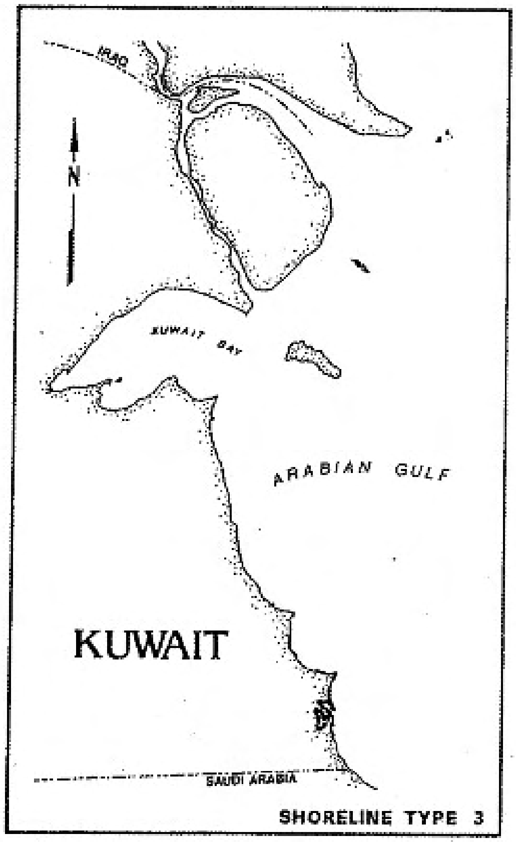

Fig. 6. Distribution of shoreline type 3, fine-sand beaches.

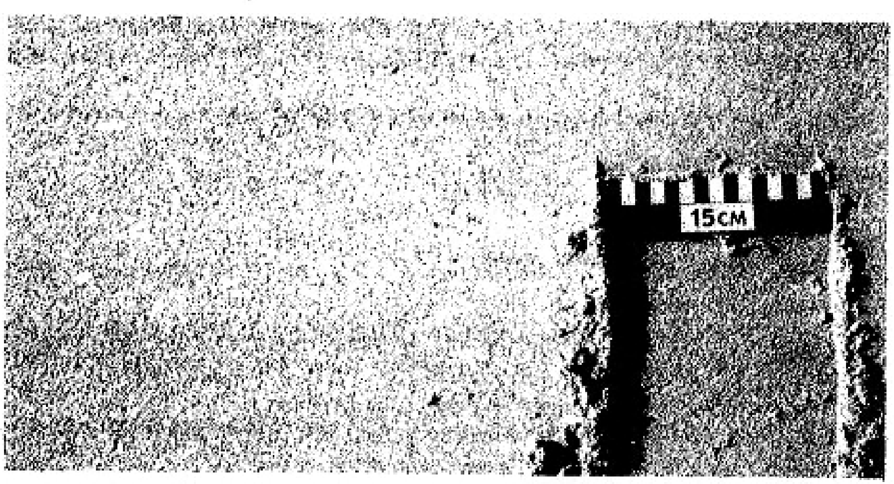

Fig. 7. Photograph of shoreline type 3, fine-sand beaches.

Type 4; Medium- to coarse-sand beaches

DESCRIPTION

* The distribution and photograph of this shoreline are presented in Figs S and 9
* The most common beach type in Kuwait
* Contain a moderately to steeply sloping beach profile
* May be clastic or oolitic, and commonly mixed with shell fragments
* Most commonly exposed to moderate wave action
* Supports few organisms and low populations
* Along the lower intertidal zone, mole crabs (*Hippa* sp.) are common on medium-sand beaches
* Ocypodid crabs are occasionally found along the upper shore

PREDICTED OIL IMPACT

* Large accumulation will initially cover the entire beach face, after which oil on the lower intertidal will be removed and transported offshore, along the shore, or higher up the beach face
* Under light accumulations, oil will be deposited along the high-tide swash lines
* Oil may penetrate 20—30 cm into the sediments along the upper beach face

RESPONSE ACTIVITIES

Preferred:

* Booms, skimmers, and sorbents—to divert and collect oil before it comes ashore; avoid trampling biota during placement

Viable:

* Manual labor—useful to limit sediment removal; labor intensive; especially appropriate for recreational beaches in Kuwait City; avoid contaminating clean, back-beach areas by sloppy handling techniques
* Mechanical cleanup—useful on hard, flat beaches; usually inappropriate for softer, coarse-sand beaches; if possible, wait until all oil has come ashore; avoid excessive sand removal; avoid contaminating clean, back-beach areas
* Natural cleansing—particularly appropriate if wave energies are moderate to high, especially for beaches not extensively used by the public
* Vacuum pumping—useful only for thick layers of low-viscosity oil; line collection pits with plastic to limit penetration into the sediment
* Mixing—only for low concentrations of oil not feasible to be removed physically

Avoid:

* Burial, burning, and substrate removal

Fig. 8. Distribution of shoreline type 4, medium-to-coarse-sand beaches.

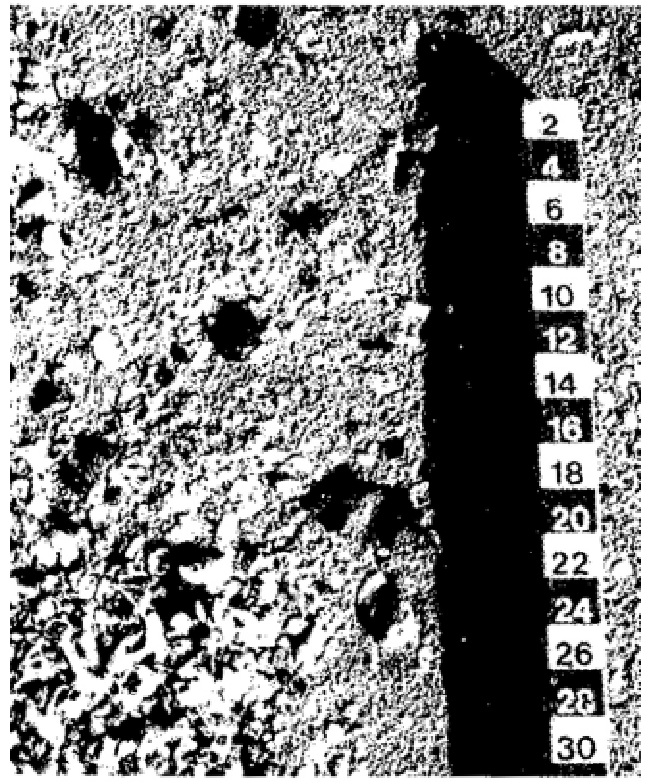

Fig. 9. Photograph of shoreline type 4, medium-to-coarse-sand beaches.

Type 5: Hard sand or mud tidal flats with low productivity

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 10 and 11
* Most common along Kuwait Bay above the soft mud zone, around Failaka Island and in the southern Khiran area
* Sediment may be only a thin veneer over a bedrock platform
* Contain relatively low productivity and few species
* Halophytes (*Halocnemum* and *Salicornia*) are occasionally found along the upper fingers of the Kuwait Bay area
* Green algae (*Enteromorpha* sp.) and brown algae (*Ectocarpus* sp.) are common and occasionally dense
* Gastropods are the dominant fauna
* Typical gastropod species include button top (*Umbonium vestiarium*) and dove (*Mitrella blanda*) shells
* Sabellid polychaete worms are commonly present

* Fish traps (*hadras*) are most often found on the surface of this beach type

PREDICTED OIL IMPACT

* Most oil will rapidly be pushed across the surface of the flat and onto the adjacent beach as the tide rises
* Oil will remain on the upper fringes of the flat along northern Kuwait Bay where the supratidal zone contains sabkha
* Deposition of oil on the flat may temporarily occur under large oil accumulations and on a falling tide
* Oil incorporation into the flat sediments will be limited especially along the edge of northern Kuwait Bay
* In sandy flats around Failaka Island and in southern Kuwait, oil incorporation may occur depending on the duration of oil lying on the flat surface
* Organisms within the flat surface, especially in sandy areas, may be killed by smothering or oil incorporation in the water column

RESPONSE ACTIVITIES

Preferred:

* Booms and skimmers—used to divert or control incoming oil
* Natural cleansing—most effective on active sandy flats; will probably occur over a few tidal cycles; not likely to occur along the upper flats of northern Kuwait Bay
* Manual removal—most effective on very hard, compacted flats

Viable:

* Mechanical cleanup—most effective for large oil quantities; avoid grinding the oil into the sediments
* Vacuum pumping—effective on the upper flats of northern Kuwait Bay; limited effectiveness on weathered or highly viscous oils; trenches may be necessary to concentrate oil

Not advisable:

* Dispersant—spray ahead of advancing tide; avoid overdosing; do not use with sorbents
* Substrate removal—remove oiled sediments only to depth of oiling; avoid damage to backshore vegetation, as along northern Kuwait Bay.

Avoid:

* Burial, mixing, and high-pressure flushing

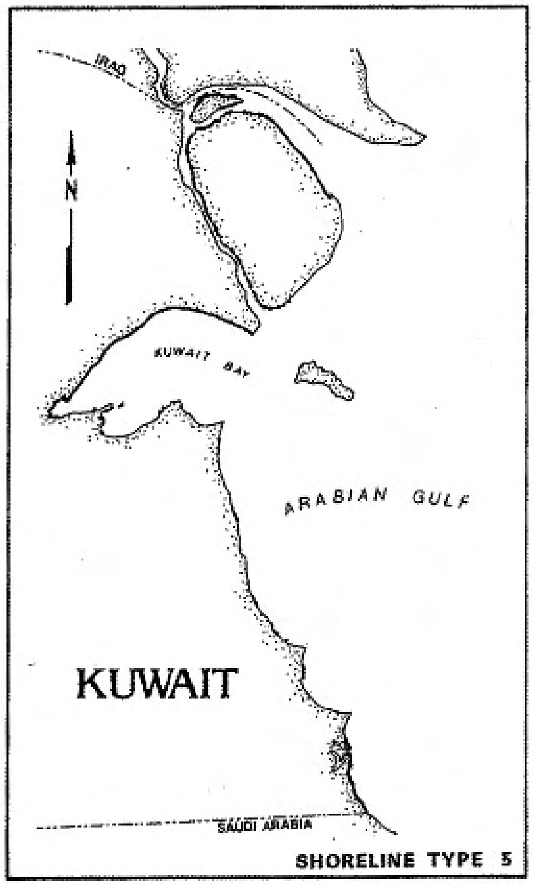

Fig. 10. Distribution of shoreline type 5, hard sand or mud tidal flat with low productivity.

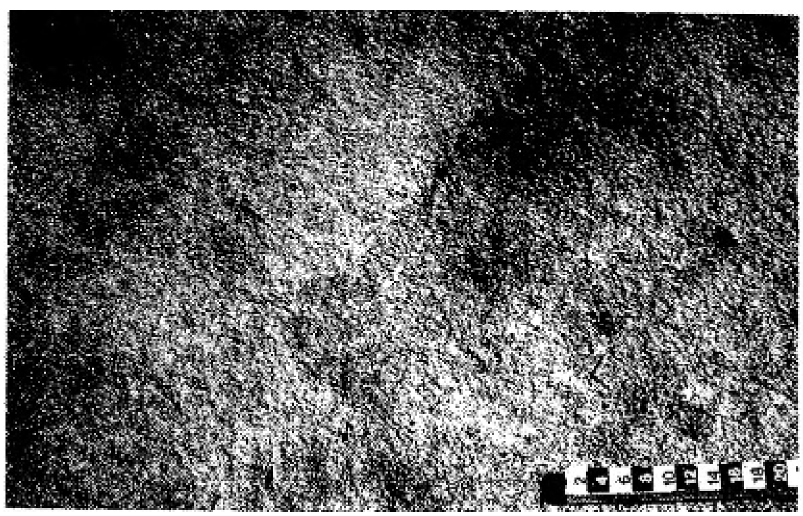

Fig. 11. Photograph or shoreline type 5, hard sand or mud tidal flat with low productivity.

Type 6: Riprap (boulder) structures

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 12 and 13
* Consist of boulder seawalls and groins used to protect marinas and shoreline property
* Occasionally composed of construction debris (as around Kuwait City)
* The cracked and sheltered openings in the structures support a moderate-to-high abundance of species
* Species diversity is also high
* Green algae (*Enteromorpha* sp.) and brown algae (*Ectocarpus* sp.) are common
* Encrusting fauna include serpulid worms, oysters (*Saccostrea cucullata*), barnacles (*Balanus* sp.) and limpets (*Diadora funiculata*)
* Snails are common and rich in species
* Typical snails include top shells (*Trochus coronatus* and *Clanculus pharaonius*), turbans (*Turbo coronatus*), drills (*Thais savignyi* and *T mutabilis*), cerithids (*Cerithium caeruleum*) and cluster winkles (*Planaxis sulcatus*)
* Crabs are common; species dominant on and under the rocks include the rock crab (*Metapograpsus messor*) and a variety of xanthid species

PREDICTED OIL IMPACT

* Oil will penetrate deep into the cavities between the boulders
* Primary oil deposition and rock coating will occur along the upper intertidal zone
* The extent of oil deposition will increase in the lower intertidal zone as the quantity of incoming oil increases
* Oil persistence will be relatively short-lived in exposed areas, and long-term in sheltered sites
* Biota present may be killed by smothering or by lethal oil concentrations within the water column
* Biological damage will be relatively short-term due to rapid recruitment from adjacent habitats and the exposed nature of most sites

RESPONSE ACTIVITIES

Preferred:

* Booms, skimmers, and sorbents—use to divert or collect incoming oil
* Natural cleansing—appropriate for outer structures exposed to moderate-to-high wave energies
* Manual collection—use sorbent material; avoid trampling biota; avoid sloppy handling of oily debris; collect all used sorbent material
* Low-pressure flushing—collect flushed oil; do not use hot or fresh water

Viable:

* Dispersant—preferred only for low-viscosity oils on moderate-energy structures; avoid contaminating adjacent areas; use in conjunction with low-pressure flushing
* High-pressure flushing—only for use in the upper intertidal zone with few or no resident biota

Not advisable:

* Sand blasting—only for areas with few or no biota; will destroy resident biota but may aid future recolonization

Avoid:
* Steam cleaning, substrate displacement, and substrate removal.

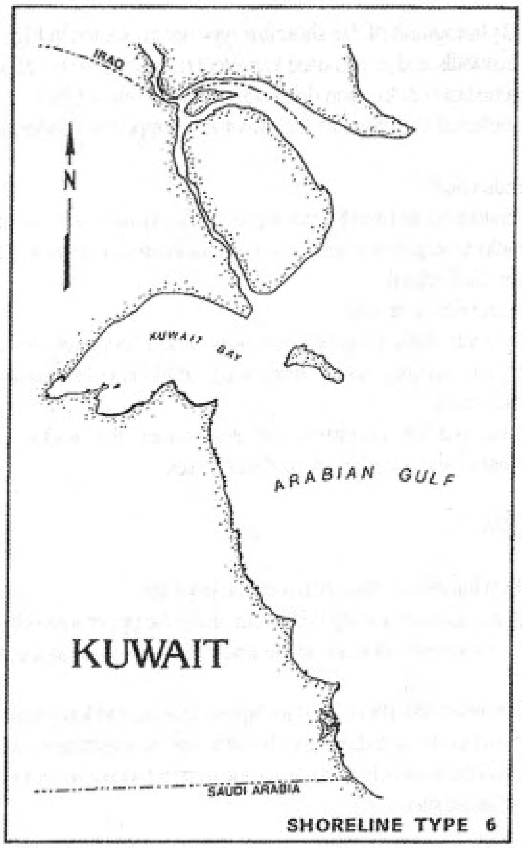

Fig. 12. Distribution of shoreline type 6, riprap (boulder) structures.

Fig. 13. Photograph of shoreline type 6, riprap (boulder) structures.

Type 7: Cobble/boulder beaches

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 14 and 15
* Common along the base of cliffs and by eroding bedrock
* Size varies from small cobbles to large boulders
* Sand may be present under or at the base of the rocks
* Productivity is relatively high, with high species abundance and diversity
* Green algae (*Enteromorpha* sp.) and brown algae (*Ectocarpus* sp.) are common
* Encrusting fauna include serpulid worms, oysters (*Saccostrea cucullata*), barnacles (*Balanus* sp.), and limpets (*Diadora funiculata*)
* Snails are common and rich in species
* Typical snails include top shells (*Trochus coronatus* and *Clanculus pharaonius*), turbans (*Turbo coronatus*), drills (*Thais savignyi* and *T. mutabilis*), cerithids (*Cerithium caeruleum*) and cluster winkles (*Planaxis sulcatus*)
* Crabs are common; species dominant on and under the rocks include the rock crab (*Metapograpsus messor*) and a variety of xanthid species
* Where a sandy substrate is also present, organisms typical of the hard sand tidal flat are common, particularly cerithids, button top shells, dove shells, and sabellid polychaete worms

PREDICTED IMPACT

* Oil tends to coat the boulders and cobbles especially along the upper intertidal zone
* As the oil quantity increases, boulders and cobbles along the lower intertidal zone will become increasingly oiled
* Where boulders and cobbles are found massed together, oil will penetrate deeply into the porous structure found between rocks
* Resident biota may be killed, wither by smothering or by lethal concentrations of oil in the water column
* Biological damage will probably be short-term due to relatively rapid recruitment from adjacent communities

RESPONSE ACTIVITIES

Preferred:
* Booms, skimmers, and sorbents—use to divert .or collect incoming oil
* Natural cleansing—appropriate in most cases since these environments are exposed to moderate-to-high wave energies
* Manual collection—use sorbent material; avoid trampling biota; avoid sloppy handling of oily debris; collect all used sorbent material
* Low-pressure flushing—collect flushed oil; do not use hot or fresh water

Viable:
* Dispersant—preferred only for low-viscosity oils on moderate-to-high energy structures; avoid contaminating adjacent areas; use in conjunction with low-pressure flushing
* High-pressure flushing—only for use in the upper intertidal zone with few or no resident biota

Not advisable:

* Sand blasting—only for areas with few or no biota; will destroy resident biota but may aid future recolonization

Avoid:

* Steam cleaning, substrate displacement, and substrate removal

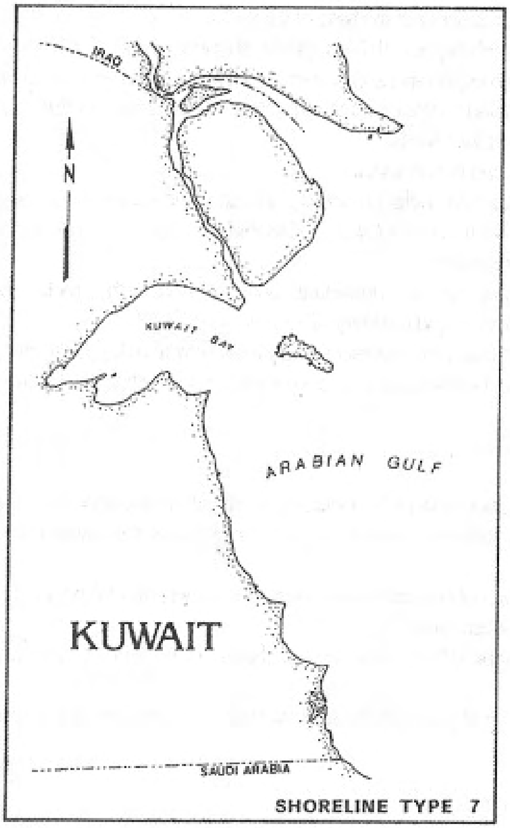

Fig. 14. Distribution of shoreline type 7, cobble/boulder beaches.

Fig. 15. Photograph of shoreline type 7, cobble/boulder beaches.

Type 8: Exposed bedrock platforms

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 16 and 17
* Most common on Failaka Island and Doha Peninsula
* Exposed only at low tide
* Exposed to moderate-to-high wave energy or tidal currents
* Contain the highest productivity with the greatest number of intertidal species in Kuwait
* In places, diversity is reduced by overlying mud or sand
* Common flora are green algae (*Enteromorpha* sp.), red and brown algae (*Sargassum* sp.), and tiny seagrasses (*Halophila* sp. and *Halodule* sp.)
* Exposed rocks are encrusted with oysters (*Saccostrea cucullata*), serpulid and sabellid worms, various sponges, bryozoans, barnacles and other invertebrates
* Corals are present but not common
* Common snails include communities of cerithids (*Cerithidea cingulata*), top shells (*Trochus erythraeus*, *Clanculus pharaonius*, and *Umbonium vestiarium*), turbans (*Turbo coronatus*), drills (*Thais mutabilis* and *T. savignyi*), and murex (*Hexaplex kuesterianus*)
* Within the superficial sand on the platform, attached and burrowing organisms are common, including pearl oysters (*Pinctada margaritifera*), mussels (*Brachidontes* sp.), arks (*Anadara ehrenbergi*), scallops (*Chlamys ruschenbergerii*) and many others
* Tidal pools and the underside of rocks contain other molluscs as well as crustaceans such as crabs (*Metapograpsus messor*), pistol shrimp (*Alpheus* sp.), starfish (*Asterina cephea*), sea urchins (*Diadema* sp.) and fish such as gobies (*Gobiidae*) and stonefish (*Synanceja verrucosa* and *Pseudosynanceja melanostigma*)
* Fish nets (*hadras*) are occasionally found on this shoreline type

PREDICTED OIL REACTION

* Most of the incoming oil will be carried across the bedrock platform and onto the adjacent shoreline
* On a falling tide, and particularly under heavy accumulations, oil will be deposited on the platform
* Biota may be killed by smothering or by lethal concentrations in the water column
* Biological recovery will be fairly rapid because of limited oil persistence and rapid biological recruitment

RESPONSE ACTIVITIES

Preferred:
* Booms and skimmers—to divert and collect oil before it comes ashore; avoid trampling biota during placement
* Natural cleansing—useful in most platform areas

Viable:
* Low-pressure flushing—valid on fresh, unweathered oil; avoid hot or fresh water; avoid trampling; recover flushed oil
* Sorption—recover oiled sorbents; less effective on large spills
* Manual removal—labor intensive; avoid slopping recovered oil
* Vacuum pumping—avoid sucking up biota

Not advisable:

* Burning—avoid population centres; less effective on weathered oil
* Dispersant—spray offshore; must have adequate flushing and dilution

Avoid:

* High-pressure spraying—will destroy attached biota
* Sand blasting—may assist recolonization
* Steam cleaning—avoid trampling or dragging equipment over unoiled areas

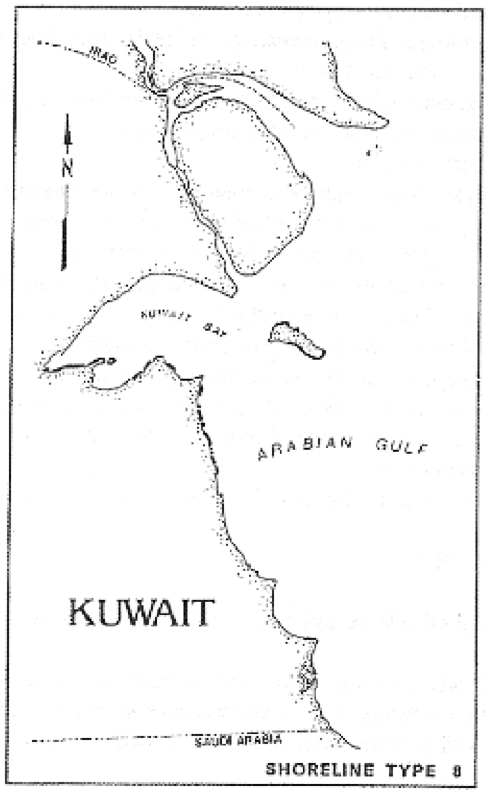

Fig. 16. Distribution of shoreline type 8, exposed bedrock platforms.

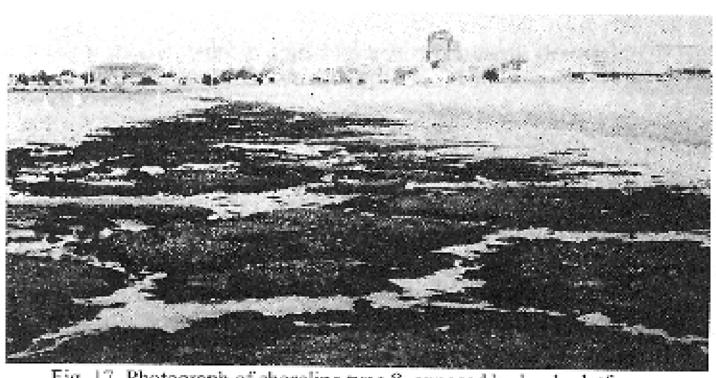

Fig. 17. Photograph of shoreline type 8, exposed bedrock platforms.

Type 9: Hard sand or mud tidal flats with high productivity

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 18 and 19
* Most commonly associated with the tidal flats of Kuwait Bay and around Bubyan Island
* Composed of muds and silts
* Generally located between very soft, outer mud flats (ranking = 10) and hard, nonproductive flats (ranking = 5)
* Contain a very productive habitat with an abundance of species and individuals
* Common flora are green algae *(Enteromorpha* sp.), red and brown algae (*Sargassum* sp.); tiny seagrasses (*Halophila* sp.) are occasionally found
* Fauna are dominated by large cerithid communities (*Cerithidea cingulata*) and other snails including top shells, turbans, and miters, depending on the presence of rocks
* Common bivalves include venus clams (*Circentita callipyga f. arabica*), cockles (*Trachycardium lacunosum*), razors (*Solen brevis*), other burrowers, and various sabellid polychaete worms

PREDICTED OIL IMPACT

* Most oil will be pushed rapidly across the surface of the flat and onto the adjacent beach as the tide rises
* Oil will remain on the upper fringes of the flat along the northern Kuwait Bay where the supratidal zone contains sabkha
* Deposition of oil on the flat may temporarily occur under large oil accumulations and a falling tide
* Oil incorporation into flat sediments will be limited due to the hard, compacted nature of the substrate
* Organisms on the surface and within the flat sediments may be killed by smothering or oil incorporation into the water column
* Recovery of this habitat will be slow due to moderate oil incorporation within the sediment and slow recruitment abilities by the resident biological community

RESPONSE ACTIVITIES

Preferred:

* Booms and skimmers—used to divert or control incoming oil
* Natural cleansing- —most effective on active sandy flats; will probably occur over a few tidal cycles
* Manual removal—most effective on very hard, compacted flats; avoid grinding in the oil by human or vehicular activities

Viable:

* Mechanical cleanup—most effective for large oil quantities; avoid grinding the oil into the sediments

Not advisable:

* Dispersant—spray ahead of advancing tide; avoid overdosing; do not use with Sorbents
* Substrate removal—remove oiled sediments only to depth of oiling; avoid damage to backshore vegetation, along the northern Kuwait Bay
* Vacuum pumping—limited effectiveness on weathered or highly viscous oils and in water-saturated flats; trenches would rapidly infill with interstitial water

Avoid:
* Burial, mixing, and high-pressure flushing

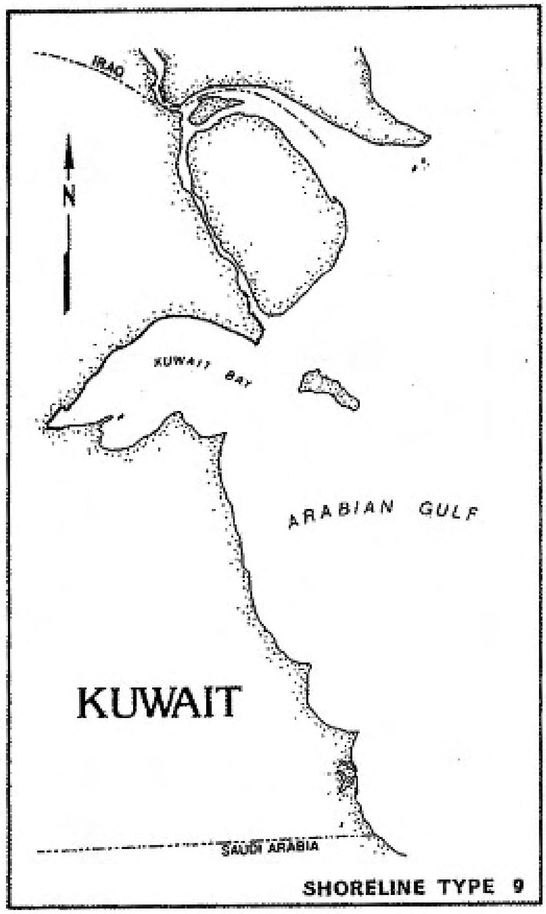

Fig. 18. Distribution of shoreline type 9, hard sand or mud tidal flats with high productivity.

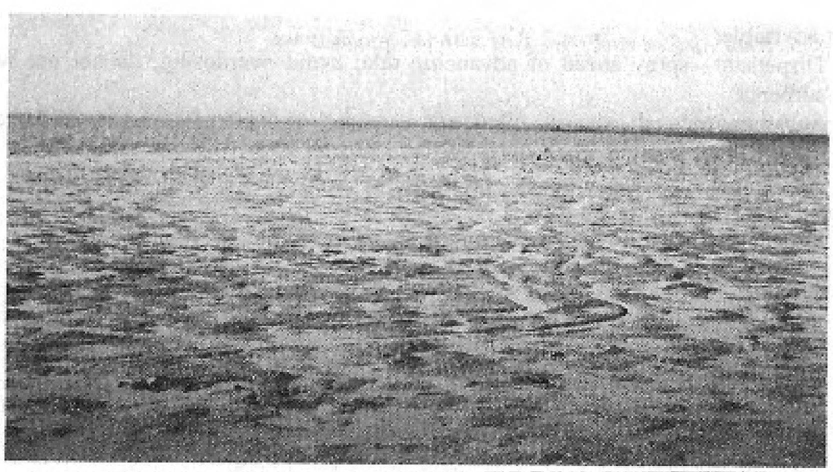

Fig. 19. Photograph of shoreline type 9, hard sand or mud tidal flats with high productivity.

Type 10: Soft mud tidal flats with high productivity

DESCRIPTION

* The distribution and photograph of this shoreline type are presented in Figs 20 and 21
* Found in Kuwait Bay, Sulaibikhat Bay, Khor As-Subiyah, and around Bubyan Island
* Composed of extremely soft mud, unable to support men or machinery
* Support high biological productivity including large numbers of species and individuals
* Commonly composed of four zones which can be dominated by any combination of cerithids, worms, crabs and mudskippers
* The cerithid community contains dense concentrations of *Cerithidea cingulata* and lesser numbers of other mud-dwelling snails (top shells and dove shells)
* The worm community is dominated by various polychaetes and nematodes. One species (*Ikeda taenoides*), in particular, is found in patches throughout this shoreline type
* The crab community is commonly dominated by mud crabs (*Macrophthalmus depressus and M. pectinipes*), and other ocypods (*Cleistostoma* sp.) and xanthids (*Eurycarcinus* sp.)
* The mudskipper community is found integrated with crabs and worms
* Fish nets (*hadras*) are seldom found on this shoreline type due to the difficulty of access

PREDICTED OIL IMPACT

* On a rising tide, much of the incoming oil will be carried across the flat and onto the adjacent shoreline
* Oil may be deposited on the flat during heavy accumulations, and on falling tide areas about 5—15 percent of the incoming oils will settle out and sink
* Oil may bind with surface sediments and become incorporated into the interstitial waters of the flat
* Persistence of oil, especially along the upper edges of this habitat may become long-term once incorporated into the muds
* Biota are likely to be destroyed by oil incorporation into the water column and, in some instances, by oil smothering

RESPONSE ACTIVITIES

Preferred:
* Skimmers, booms, and sorbents—primarily important in controlling or diverting the spill before it enters this habitat
* Dispersants—to be applied offshore
* Natural cleansing—applicable only along flats of outer Kuwait Bay where waves are present, and along the tidally dominated Khor As-Sabiyah

Viable:
* The soft muds of this habitat make access and cleanup extremely difficult. Most operations involving men and machinery will only grind oil deeper into flat sediments, thereby increasing oil persistence and biological damage. Because of this it is particularly important to have an effective offshore response

Not advisable:
* Manual removal—extremely difficult due to the very soft substrate
* Sorption—difficult to apply and collect after use; most effectively done using shallow-draft boats

* Low-pressure flushing -difficult to gain access; flushing may resuspend the oil which can be collected using sorbents

Avoid:

* Substrate removal—sediments are noncohesive and will destroy biota
* Burial, mixing, high-pressure flushing, and sediment displacement

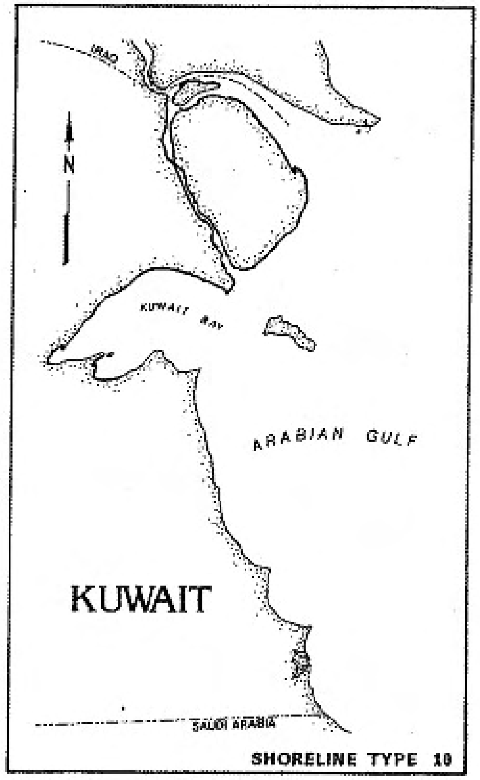

Fig. 20. Distribution of shoreline type 10, soft mud tidal flats with high productivity.

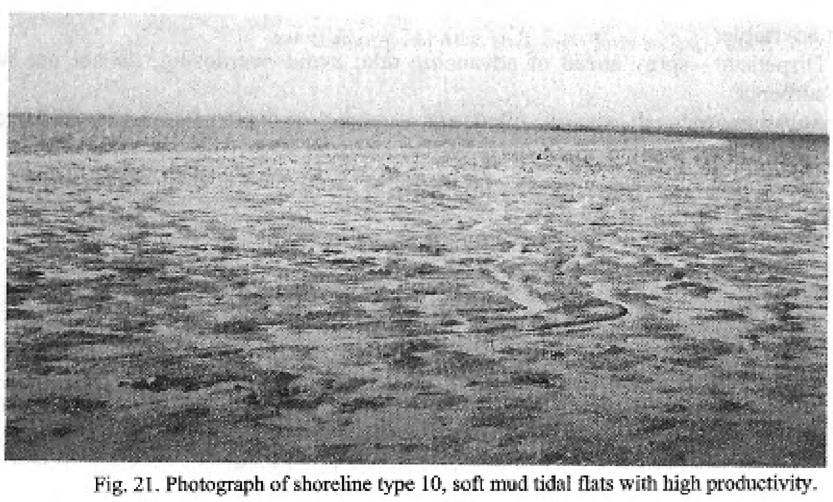

Fig. 21. Photograph of shoreline type 10, soft mud tidal flats with high productivity.

BIOLOGICAL RESOURCES

Biological resource information was incorporated into the analysis in two manners:

(1) Shorelines having a biological community that is sensitive to oil has a higher value than shorelines supporting no biota or having less sensitive species
(2) The locations or habitats of key species are indicated using a special symbol

The shoreline ranking system has been discussed previously. A summary of the locations of important fish, turtle, and bird species is presented in Table 4. The legend used to indicate species type and seasonality is presented in Fig. 22. The common and scientific names of each species represented by these figures is included in Al-Sarawi *et al.* (1985).

Fishes are subdivided into three groups depending on habitat usage. The first group (A) consists of nearshore or coastal food fishes having local commercial and/or recreational importance. These fish, caught in fish nets (*hadras*), hand-held nets, or by hook and line, are frequently used for personal consumption but are also common in Kuwait fish markets. The second group (B) may enter nearshore areas, but are most often captured away from shore by shrimp boats and dhows; they are commonly seen and sold in Kuwait fish markets. The third group (C) are the mudskippers (Gobiidae) which inhabit the very soft tidal flats of Sulaibikhat Bay, northern Kuwait Bay, and around Bubyan Island. These species are of ecological importance to these areas of Kuwait and are unique to the Arabian Gulf. Their ability to create pools and maintain a suitable living environment during low tides enables other organisms to survive and flourish in this habitat.

Marine turtles are ecologically important species found in the Arabian Gulf off the coast of Kuwait. Common species are green turtle (Chelonia mydas), hawksbill (*Eretmochelys imbricata*), and leatherback (*Dermochelys coriacea*). Of these, the green turtle is most commonly observed since it feeds on shallow seagrasses. Although the beaches of mainland Kuwait are not used as nesting areas, nesting may occur on Kuwait's offshore islands from April to November.

Coastal and aquatic birds are the most obvious victims of an oil spill, often causing great public concern. Birds may be affected by direct oiling or ingestion. Oiling of a nesting bird may also spread oil onto its eggs or young. Ingested oil can be toxic to both adult birds and their young. Bird cleaning using gentle detergents is the primary means of aiding bird survival and includes public participation.

The five major bird groups and their preferred habitats in Kuwait are:

(1) Wading birds—long-legged birds which wade across shallow water and tidal flats while feeding; includes herons, egrets, cranes, and allies.
(2) Shorebirds—mostly smaller species which feed on beaches, shoreline, and exposed tidal flats; include sandpipers, plovers, and allies.
(3) Coastal birds—gulls and terns which fly along the coast, feeding on water or shore.
(4) Migratory waterfowl—ducks and allies which are mostly winter visitors.
(5) Pelagic birds—a mixture of fish-eating and diving species from various groups of birds, most of which rarely fly inland and spend most of their time offshore.

Table 4. Summary of the habitats utilized by fishes, turtles and birds in Kuwait

(1) Groups found nearshore and over mud flats:
* Food fishes—typically shads, minnows, whiting, porgies, bream, mullets, flounders, and sole
* Mudskippers
* Wading birds—typically herons, egrets, cranes, and flamingos
* Coastal birds—mainly gulls and terns
* Migratory waterfowl—ducks and related species

(2) Groups found offshore:
* Food fishes—typically sharks, hamoor, groupers, snappers, and drums
* Sea turtles
* Pelagic birds—shearwater, petrel, cormorant, and certain terns

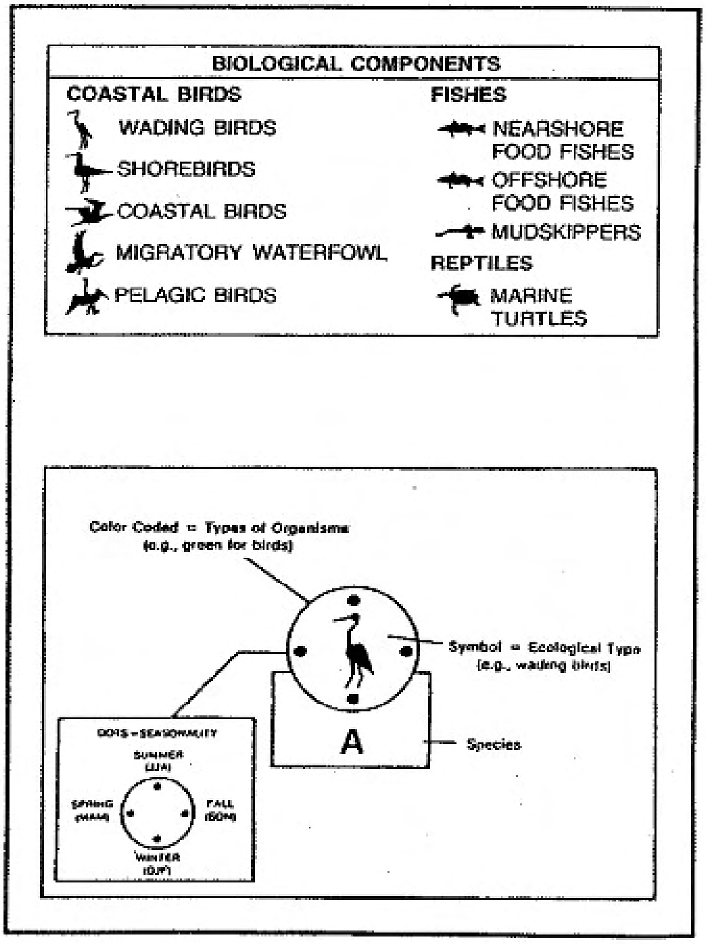

Fig. 22. Legend used to indicate species type, distribution, and seasonality of organisms having commercial, recreational and/or ecological importance.

SOCIOECONOMIC COMPONENTS

The major socioeconomic features were considered particularly important in Kuwait and would deserve priority protection during an oil spill: desalination/power plants, public recreational areas, and marinas. The symbols used to illustrate these features and a summary map showing the locations of each are presented in Fig. 23.

The desalination plants are one of the most important and sensitive socioeconomic resources since most of Kuwait's freshwater supply is derived from these facilities. Oil concentrations in the parts per million range are enough to force closure. Marinas and recreational areas are included to highlight localities that are extensively used by the public.

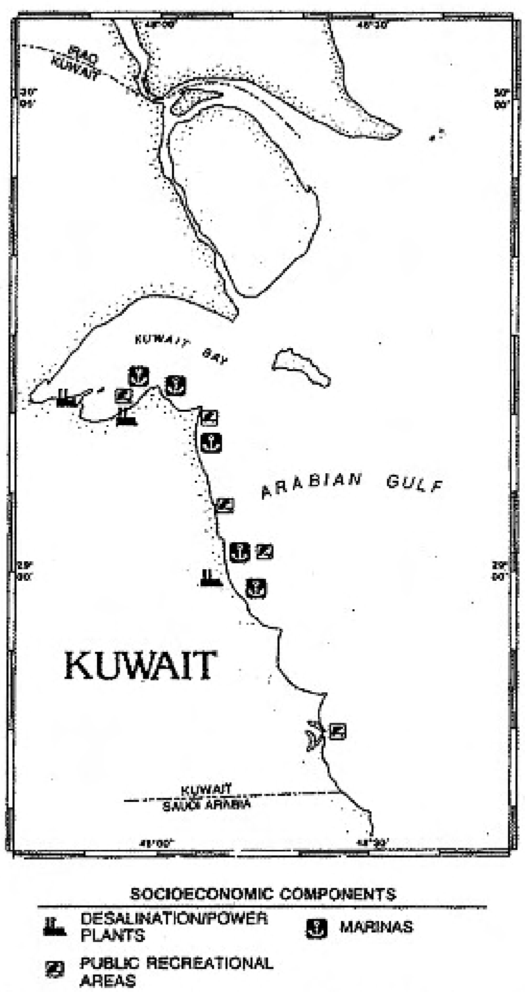

Fig. 23. Symbols used and locations of major socioeconomic features in Kuwait that could be affected by an oil spill.

SPILL-RESPONSE COMPONENTS

Primary response guidelines were included within the description of each shoreline type and as a separate feature on each map. The recommended response activities included on each map were based on the scenario of a large offshore spill and commonly encompassed the following points:

(1) If at all possible, the spill should be contained at its source using open-water skimmers and booms.
(2) Areas having desalination plants should receive priority nearshore protection using primarily open-water booms and sorbent booms.
(3) Natural resource areas to be especially protected by an offshore response are the most sensitive soft mud tidal flats.
(4) Artificial jetties and harbors serve as natural collecting places for the oil and should be utilized during cleanup.
(5) Priority sites to be cleaned once the oil has come onshore are most commonly the public recreational beaches.
(6) Natural wave action will greatly assist the cleansing of many of Kuwait's beaches since the Arabian Gulf shoreline is relatively exposed.

EXAMPLES OF MAPS

Four sensitivity maps are discussed in this paper: (1) adjacent to the border with Saudi Arabia, (2) Kuwait Bay, (3) Bubyan Island, and (4) Failaka Island.

BORDER WITH SAUDI ARABIA

The southern area of Kuwait is primarily composed of sand beaches (fine- and coarse-grained), fronted by hard sandy tidal flats having relatively low productivity (Fig. 24). There are also minor amounts of low-sensitivity seawalls, harbor structures and beach-rock outcrops. The tidal flat at An-Naq has the most sensitive shoreline type, a hard sand tidal flat with high productivity having a ranking of 9.

Within the Khor Al-Mamiahah, wading birds and shorebirds are common while along the outer coast three bird-species groups, wading birds, shorebirds, and coastal birds, are present. All species are found year round. Nearshore and offshore food fishes are found in the nearby Gulf waters. This is one of the few areas where marine turtles have been sighted.

The response strategy for the area is to protect the sheltered flats behind the spits at Khor An-Nhaim and An-Naq. The rest of the area is difficult to protect and would rely primarily upon removing oil from the beaches. It is important to keep the removal of sand from the beaches to a minimum lest shoreline erosion be increased.

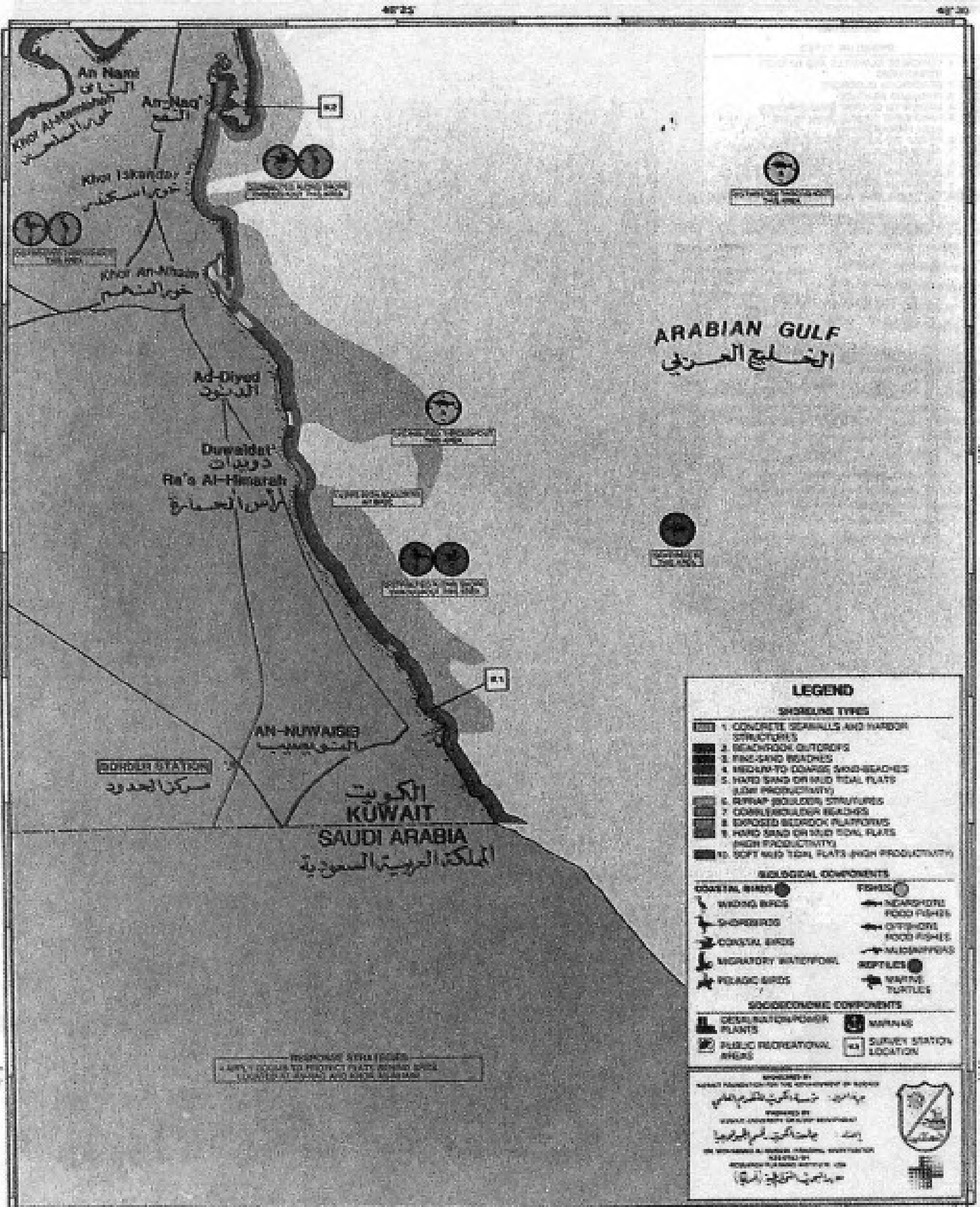

Fig. 24. Sensitivity index map of Kuwait southern coast line adjacent to the border with Saudi Arabia.

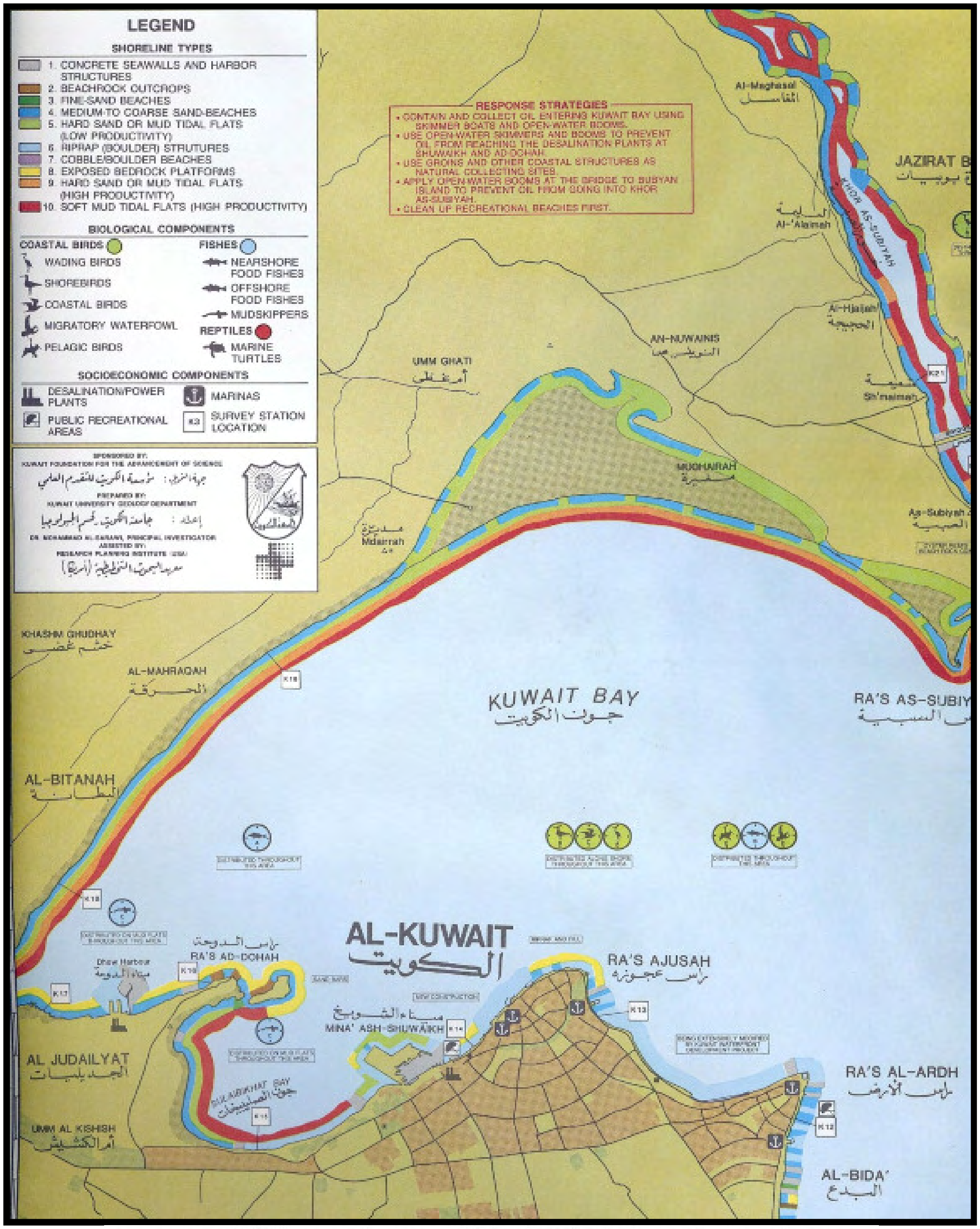

Fig. 25. Sensitivity index of Kuwait Bay.

KUWAIT BAY

Kuwait Bay contains a variety of oil sensitive habitats. The entire north shore contains four principal shoreline types: sand beaches (4); fronted by hard, low productivity tidal flats (5); fronted by highly productive, hard mud flats (9); fronted by soft, high productive mud flats (10). Sulaibikhat Bay has much the same sequence although the southern portion of the bay has been infilled with construction debris. The Ras Ad-Dohah area and Ras Ajusah, both contain highly productive bedrock platforms that are exposed during low tide. Much of the shoreline adjacent to Kuwait City is dominated by seawalls and harbor structures, although several recreational sand beaches are present. Similarly, the waterfront between Ras Ajusah and Ras Al-Ardh is undergoing extensive redevelopment during which time the shorefront will be changing dramatically from infilled construction debris to recreational beaches and walking areas.

Although not documented in the oil spill literature, probably the most sensitive species of the area is the mudskipper which inhabits the extensive soft mud flats surrounding much of Kuwait Bay. Other species present include wading birds, shorebirds and coastal birds along the shoreline, and migratory waterfowl and pelagic birds offshore. All birds are found year round except the migratory species which are only present during fall, winter, and spring. Nearshore and offshore food fishes are also present within the bay. Fish traps or *hadras* are common along most sections of Kuwait Bay.

Numerous sites of socioeconomic and human-use value are present along the southern portion of the bay. Of greatest importance is the presence of two desalination/power plants which supply water and power to Kuwait City and environs. Of recreational importance are the numerous small-craft marinas and several bathing beaches, also along the south shore and extending into the Arabian Gulf.

The oil-spill response strategy for the area first involves containment of a spill within the bay using skimmer boats and open-water booms (and possibly dispersants) to prevent the oil from impacting the sensitive tidal flats and desalination plants. The onshore strategy involves the use of booms to protect the desalination plants and to prevent the alongshore movement of oil. The numerous groins present along the shoreline act as natural collecting basins from which oil can be skimmed. In terms of shoreline cleanup, the recreational beaches should receive priority.

BUBYAN ISLAND

Bubyan Island is a low-lying island formed by the sedimentary deposits of the Tigris— Euphrates River system. Along the low-tide zone, it is dominated by very sensitive and highly productive, soft mud flats (ranked as 10). Along the more exposed coast facing the Arabian Gulf, the flats are consistently backed by medium-to-coarse-sand beaches, while in the more sheltered regions elsewhere along the island, the flats gently grade up to similar sand beaches or into harder flats. River flow and tidal currents control the exact location of harder, sand-dominated flats versus soft, mud-dominated areas. Scattered beach rock outcrops, some covered with oysters, are present along the lower Khor As-Subiyah on the mainland side.

The pattern of wildlife is consistent around the island. Wading birds, shorebirds, and coastal birds are found along the shore, and mudskippers are found throughout the soft, lower intertidal mud flats. Nearshore food fishes are common

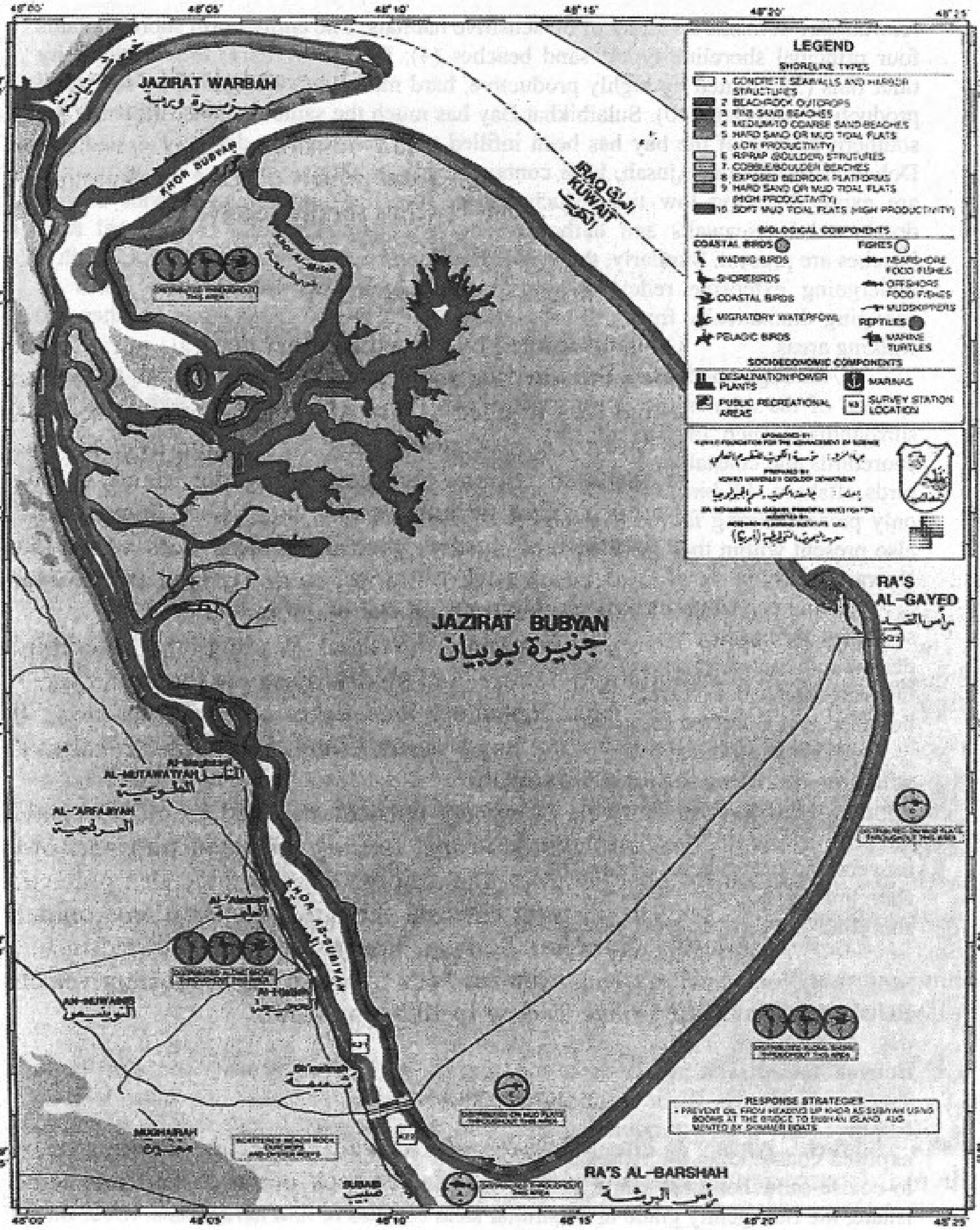

Fig. 26. Sensitivity index map of Bubyan Island.

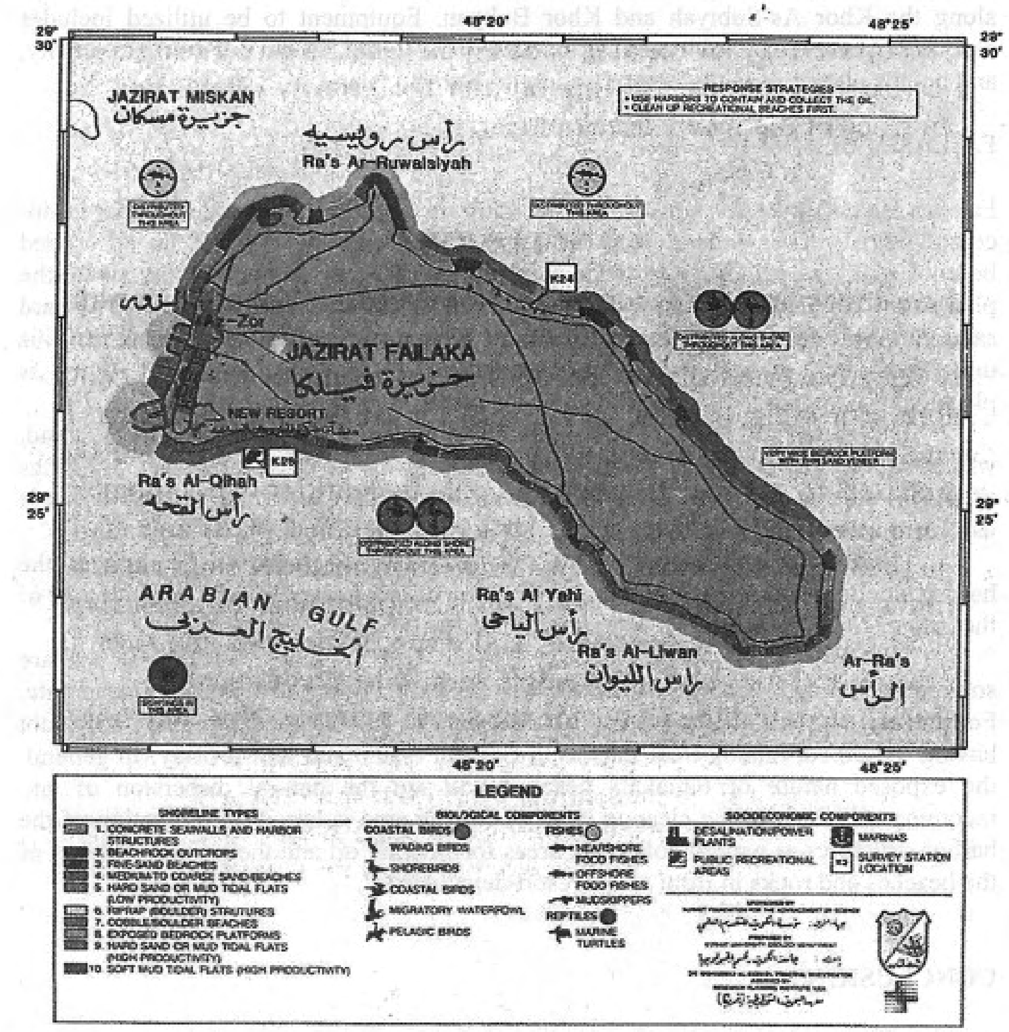

Fig. 27. Sensitivity index map of Failaka Island.

along the southern sections of the waters surrounding Bubyan Island. Fish traps or hadras are common along the lower Khor As-Subiyah.

The coastal habitats of Bubyan Island are particularly hard to protect against oil spills. Tidal currents are particularly strong, causing the rapid transport of oil and oil entrainment under most boom configurations. The recommended protection strategy is designed to prevent oil from entering the more sheltered environments along the Khor As-Subiyah and Khor Bubyan. Equipment to be utilized includes mobile skimmer boats with moving skimmer belts to lessen the net current velocity, and booms placed from the bridge leading to Bubyan Island.

FAILAKA ISLAND

Failaka Island, lying 35 km offshore of Kuwait City, is dominated by medium-to-coarse-sand beaches separated by beach-rock outcrops and perched on an eroded bedrock platform. Along most of the northern and western sections of the island, the platform is covered with a thin sedimentary veneer causing it to be classified as hard sand flats, while along the eastern and southern parts of the island, the veneer remains uncovered and has a generally more productive biological community. Riprap is placed to protect the harbor facilities along the western edge of the island.

Shorebirds and coastal birds are common along the shoreline of Failaka Island, while nearshore food species are distributed throughout the adjacent waters. Sightings of marine turtles have also been made around the island although the island is not used for turtle nesting.

Human-use of the coastal zone is limited to small-craft utilization of the harbor facility, development of a large recreational resort area in the southwest part of the island, and commercial fishing using fish traps (*hadras*).

Because of its position in the Arabian Gulf, response actions at sea are somewhat limited although dispersant application may be quite appropriate. Fortunately, the sensitivity of the island's coastal habitats are relatively low, not having the broad, muddy tidal flats as at Bubyan Island and Kuwait Bay. In general, the exposed nature of Failaka's beaches will aid the natural dispersion of any incoming oil. A shoreline cleanup strategy for the area is based on utilization of the harbor structures as natural collecting areas for floating oil and the priority cleanup of the beaches and rocks in front of the resort development.

CONCLUSIONS

An oil spill sensitivity analysis as formulated for the coastal areas of Kuwait provides a preliminary basis for oil spill contingency planning and response. Knowledge of particularly sensitive zones or site-localities serves to direct the spill-control effort and, therefore, can mitigate some of the spill's most detrimental effects. However, the preparation of broad-scale sensitivity maps is only the first step in the process of being prepared to combat a large oil spill. In addition to equipment and an organized (and practised) spill-response structure, detailed plans and analysis must be made for each sensitive locality. This evaluation includes such aspects of exact boom locations and anchoring methods (with emplacement of anchoring bolts or heavy weights), equipment access points, and disposal methods and sites. Biological assessment teams and bird-cleaning centres should be predesignated.

In all of this, a controlling factor for success is practice. Not only must the men and equipment be ready for deployment, but the governmental, industrial, and scientific communities must be incorporated into the response activities so that each fully understands his role and responsibilities before a major incident occurs. If this is left undecided until a spill occurs, the response effort may receive conflicting signals resulting in greatly reduced efficiency.

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