Sustainable Management of Scarce Resources  
In the Coastal Zone

D06.2: Case Study Report (Egypt)  
Abu Qir Bay, Egypt  
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Resource Table

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Executive Summary

Abu Qir Bay region of the Mediterranean coast of Egypt includes Abu Qir Bay, Rosetta branch of the River Nile, Lake Edku and adjacent region bounded from the south by Mahmoudia Canal. Mahmoudia Canal supplies the region and Alexandria City with fresh water through the Rosetta branch of the River Nile. The region hosts an important resource of high biodiversities of palm trees of national recognition. A number of highly populated historic cities and large areas fertile agricultural land are included and are undergoing large changes. The region is considered an important underutilized resource of agriculture, tourism and industrial production in Egypt.

The extensive industrial, agricultural and domestic pollution in the area is an important factor contributing to deterioration of environmental conditions in general and water quality in particular. The shortage of institutional capabilities for planning, monitoring, assessment and pollution control in addition to lack of awareness among stakeholders, have rendered this region into a highly degraded and continuously deteriorating environment.

It has been realized that the region is not short of water resources as the Rosetta branch of the River Nile passes through it, but it is prone to impacts of low water quality as many industrial, agricultural and domestic wastewater sources dump their waste in the region. In addition, the impact of large scale salt water intrusion is dominating various impacts in the region.

The objective of this work is to use modern technologies of remote sensing, GIS, modeling, indicators and surveys to properly identify inherent problems and to present an integrated plan for sustainable development that takes into account the severe limitation of water quality, shortage of awareness and shortages of institutional capabilities.

This case study of the consortium represents work for sustainable development of a coastal region under the severe limitation of the low quality of water resources which could be taken as a pilot experiment that could be replicated at many other similar areas in the region. In this context, the plan of the project involved:

1. Collection, analysis and interpretation of available data and indicators on various spatial and administration sectors of the region.
2. Building, verifying and analyzing a detailed GIS for various indicators in the region including land use models based on recent satellites images of the region. Change detection analysis and sensitivity analysis have been carried out and are considered main tools for identifying hidden conflicts.
3. Surveying socioeconomic conditions and carrying out questionnaire analysis of stakeholders identifying options for development, inherent awareness problems and suggesting proper plans of development
4. Advancing an IZCM plan for development of the region based on suitability analysis and sensitivity analysis and carrying out a questionnaire survey involving stakeholders.
5. Recommending proper management policies and monitoring indicators for guarantee of sustainable development of the region

This report represents results of the final collection and analysis of data as well as building and verifying of GIS database and carrying out sensitivity analysis. The report also includes a compilation of some important monitoring parameters of water quality indicators of the region and an assessment of changes in the region based on CORINE classification of satellite imagery over a period of 15 years (1990-2004), the results of which have been verified through ground based observations. The results of satellite imagery analysis has revealed important changes and conflicts in the region including severe losses of biodiversity, drastic changes of land use and excessive rates of unplanned urbanization despite regulations.

A questionnaire directed towards identifying and assessing conflicts in the region and options for solutions has been carried out. Dissemination and analysis of the questionnaire has been carried out by a NGO in collaboration with SMART team. The objective of the questionnaire was to upgrade awareness of stakeholders through person to person communication involving members of nongovernmental organization in addition to other objectives of collection of data. Results have revealed many important aspects of changes, needs and interests of stakeholders.

A comprehensive integrated and iterative plan for development of the region based on sensitivity analysis maps and stakeholder’s participation has been carried out. A final plan for development of the region has been reached and presented.

The following specific results have been obtained:

1. A detailed GIS has been established of the following layers:
   a. Baseline data and maps of the region has been collected, verified and encoded for more than forty layers
   b. Sensitivity analysis has been carried out to identify high sensitivity areas
   c. Low land areas vulnerable to sea level rise and salt water intrusion were identified
   d. GIS has helped to develop plans for development of the area

2. Analysis of marine environmental indicators over hot spots including Abu Qir bay area showed:
   a. Continuous control of marine pollution over the years 1998-2002
   b. Loss of control over the years 2002-2004, most probably due to changes of control policy
   c. Time series of incidents of waterborne diseases in the region would be a good indicator for cross correlations to be explored. Time series data is required in this direction

3. Change detection analysis of satellite images for each 5 years has been carried out and revealed:
   a. Loss of over 17% of palm trees between 1990-1995 and over 60% between the years 1995-2000 indicating serious problems. This has been located and verified by ground based observations.
   b. Excessive rates of unplanned urbanization exceeding 23% and excessive rates of loss of fertile land
   c. Third level Corine classification has been carried out for the year 2004 and compared to results of earlier Corine classifications
4. *Telemac model has been worked out to assess expected pollution levels in the lake and bay based on levels of input drains. The following results are obtained:*
   a. The model has been capable of predicting levels in harmony of results of verification measurements
   b. It is recommended that the model be a part of any management system for the lake and future development of the bay

5. *A questionnaire addressing stakeholders was carried out to collect and disseminate information based on personal communications in cooperation with a non-governmental organization. Results have revealed that:*
   a. Main interest of most stakeholders is in industrial development in the region since it provides the best available employment opportunities for jobless populations
   b. Severe need for infrastructure including wastewater plants, transportation systems and medical care
   c. Strong need for tourism education among stakeholders
   d. Severe need for marketing facilities of products, transportation and/or preservation methods
   e. Private investments opportunities are very high, yet investment is very low.

6. *A final integrative iterative plan of development has been worked out. Zones of specific land uses are identified on detailed maps of the region with the following main features:*
   a. Precautionary development of coastal tourism in some specific sites
   b. Strong need for wastewater treatment plants at several sites
   c. Strong need for sanitation infrastructure
1- Introduction:

The coastal zone of Egypt on the Mediterranean extends from Rafah to the east to Sallum to the west for over 1200 km. It hosts five large lakes; namely Bardawil, Manzala, Burullus, Edku and Maryut which represent about 25% in area of the total wetland of the Mediterranean. It also hosts a number of important residential and economic centers of the country including the cities of Alexandria, Port Said, Damietta, Rosetta and Matruh. Activities on the coastal zone include fishing, industrial activities, tourism, trading and agricultural activities in the delta region.

Abu Qir Bay coastal zone, located between Abu Qir city and Rosetta city, near the western side of the Rosetta branch of the River Nile, is of unique character of mixed environmental components that give this zone its importance and priority for further studies for environmental and urban development. It is believed that the promotion of this coastal, agricultural, touristic and historic spots would result an equivalent promotion of the whole economy of the country. The objective of this work is to carry out in depth studies for further development of this coastal zone taking into consideration the water quality limitation of the region.

The region under study is a coastal region of Abu Qir bay extending between “10 and 30” km inland. The Rosetta promontory lies east of Rosetta Nile branch and extends seaward for about 7 km long. The Rosetta Nile branch is one of the two major distributaries of the River Nile. This branch has developed the triangular Rosetta headland promontory trending. Also, the regional attraction potential is expected to increase after the construction of an international coastal highway connecting Matruh and Alexandria cities to Sinai and Arish City to the east. Recently, a large-scale harbor to export natural gas is being constructed at Edku south west of Rosetta.

Several ecological systems are hosted by environment of this region. The coastal ecosystem includes: the agricultural land, clusters of palm trees, sand dunes residues scattered in the middle of the area, wide sandy beaches, the Rosetta Nile branch, River Nile basin, different classes of Lake Idku land cover, the urban environment expressed in a of a hierarchy of urban clusters varying in size starting from a vast number of villages and farms and towns to large urban conglomeration resembling the main cities of the governorate of the region. This is besides the interfering transportation network of roads, water system expressed in canals and drains, and various components of the infrastructure of the region.

Even though the region hosts many natural and economic resources such as the scenic tourist views and moderate weather, historic and archeological sites, ecotourism sites, extended beaches and high ecological and species biodiversity, it has suffered from important environmental problems. These problems include lack of institutional capabilities and infrastructure, pollution, salt-water intrusion and shortages of awareness, which made sustainable development of the region under prevailing conditions practically impossible. The main objective of this project is to develop policies, tools and management practices, which could help support sustainable development of the region under prevailing conditions of scarce water of high quality.
General policy of the coastal zone in Egypt

There has been no officially endorsed National Policy and national coastal zone management strategy for Egypt; however, considerable efforts by stakeholders have led to an agreement on the general principals of Coastal Zone Management. A National ICZM Committee involving governmental stakeholders has been formulated and has endorsed the definition of the coastal zone. It has contributed to processes, policies, guidelines and regulatory mechanisms that contribute to management of coastal resources:

1. The Shore Protection Authority (SPA) has prepared draft guidelines for the Shoreline Impact Assessment and is in the processes of preparing a monitoring strategy and shoreline Monitoring System.
2. The Egyptian Environmental Affairs Agency has prepared Environmental Guidelines for Development in the Coastal Areas (1966).
3. The Tourism Development Authority (TDA) has developed guidelines for tourism related activities on the Red Sea and Gulf of Aqaba.
4. The ICZM committee (EEAA) has introduced a framework for an action plan for ICZM, 1996
5. Other stakeholders such as the Ministry of Planning, the Ministry of Housing, the Ministry of Transportation, the Ministry of Agriculture, the Ministry of Defense and the Suez Canal Authority all have activities that directly affect the integrity and value of the coastal zone.

A- Rosetta Study Region

The study region includes a variety of environmental habitats: Abu Qir Bay, Lake Edku, Rosetta branch of the River Nile and the adjacent agricultural, industrial, urban and coastal area. Abu Qir Bay is a shallow semicircular basin, with a total area of about 400 km². Abu Qir Bay is located east of Alexandria with average depth about 16 m. At the eastern side of Abu Qir Bay is the Rosetta branch of the River Nile. The eastern boundary of our study area is taken as the western side of Lake Brullus, while the southern boundary is taken as Mahmoudia Canal. Lake Edku is a coastal lagoon covers an area of about 126 km² with a mean depth of 1 m located to the south of the bay and connected with it through Maadia outlet which is about 3m in depth, 100m wide and 200m in length. Midway between Abu Qir residential area and Maadia outlet the outfall of El Tabia Pumping station is located. Figure (1) shows a satellite image of the Abu Qir Bay, Lake Edku and Rosetta branch estuary.
B-Hydrology of the Study Region

The Rosetta branch of the River Nile is about 220 km in length with an average width of 180 m and depth varying between 2 and 4 m. The Rosetta estuary is delimited by a barrage for controlling water discharge at Edfina City, 30 km before its connection with the sea. It was estimated that this branch receives more than 0.5 million m$^3$ daily of untreated or partially treated domestic and industrial wastes and huge amount of agricultural drain water (Awad and Yousef, 2002)

Deterioration of the nearby marine environment in Abu Qir Bay is a result of substantial load of pollution from the various land-based activities surrounding it and through River Nile drainage and Lake Edku. The two main sources of pollution inputs are El Tabia Pumping Station, in the south-east part of the bay with a flow rate of about 2.0 Million m$^3$/day and Lake Edku, in addition to the agricultural activities in the area. Figure (2) shows the drainage and canal networks in the study region.

The estimated current water supplies for the study area are as follows: surface 890 mm, treated water 149 mm and rainfall 150 mm. The current water demands of the study area are: Agriculture 900 mm, industry 110 mm, domestic 80 mm and tourism 10 mm.
C-Morphodynamic Changes of the Rosetta Promontory

The Nile delta coast including Abu Qir bay forms a unique depositional environment, in which sedimentation is controlled by a combination of environmental factors such as waves, currents, tides and river discharge. Similar to other worldwide deltas, the Nile delta is presently subjected to significant coastal changes due to a combination of several factors. The main factor is the reduction in the Nile discharge and sediment load to the Nile promontory mouths due to the construction of water control structures and dams along the Nile (UNESCO/UNDP, 1978). In the meantime, and since building of the High Aswan Dam in 1964, sediment discharge at the Nile promontories has reduced to near zero. In the absence of sediment supply to the coast, the continued action of waves and currents act to induce beach erosion. Presently, all sediments are being trapped and deposited in Lake Nasser (south of Aswan High Dam) instead of being delivered to the sea through the two promontories. However, waves and currents continue to move sediments alongshore, resulting in a major reorientation of the coastline as some beaches erode while other accretes. This erosion is mitigated by the construction of a series of coastal engineering structures at the rapidly eroding promontories. Protective measures, which started during the last decade, are in progress and others are planned for the future (Frihy et al. 2003). As a consequence, the original erosion/accretion patterns along the Nile delta promontories have been reshaped as a result of these protective structures.

The study area of Rosetta promontory lies on the northwestern Nile delta coast and extends seaward for about 7 km long (Naffaa, 1995). The Rosetta Nile branch is one of the two major distributaries of the River Nile. This branch has developed the
triangular Rosetta headland promontory trending. Also, the regional attraction potential is expected to increase after the construction of an international coastal highway connecting Matruh and Alexandria cities to Sinai and Arish City to the east. Recently, a large-scale harbor to export natural gas is being constructed at Edku south west of Rosetta.

The Rosetta promontory on the western coast of the Nile delta has been subject to the most severe erosion of the delta coastline (e.g. UNESCO/ UNDP, 1978; Frihy et al., 1991; Fanos et al., 1991; Chen et al., 1992; El Raey et al., 1995).

In this section, we analyze the morphodynamic behavior of the coastline of the Nile delta Rosetta promontories prior to and after protection by engineering seawall implemented in the last decade, and determine whether the general erosion/ accretion pattern along the delta has been reshaped. Beach profile measurements between 1971 and 1990 (pre- construction) and between 1990 and 2000 (post- construction) supplemented by wave data are used to interpret processes reshaping the coastline of these dynamically active promontories (Frihy et al, 2002).

Coastal Processes

Along the Rosetta promontory, waves approach the coastline from N-W and N-E quadrants (Naffaa, 1995). Prevailing littoral current, current driven by the momentum of wave breaking in the surf zone, flow to southeast along the eastern side and to the southwest along the western side (Fanos et al., 1991). Under the effect of this littoral current, sand eroded from the promontory margin is transported to the southeast and southwest, resulting in a shoreline accretion along Abu Qir bay and Abu Khashaba shore. The net littoral sand transport is to the southwest along the western flank of the promontory and to the southeast along the eastern side. The pattern of longshore transport corresponds to the predominant wave direction from N-W and N- N-W (Naffa et al, 1991). The predominant N-W wave approach is responsible for the eastward flowing longshore current. A smaller component of waves from the N-N-E produces the seasonal long shore currents towards the southwest.

Methodology

The Coastal Research Institute of Egypt initiated a beach profile survey program early in 1971. The program covers the entire Nile delta coast from Abu Qir headland at Alexandria on the west to Port Said at the east. The profile lines are perpendicular to the coastline, and extend to about 6 m water depth or up to about 1200 m distance from the fixed baseline. Beach leveling and water soundings are adjusted to the mean sea level (MSL) datum using local fixed benchmarks of known elevation. The survey was carried out during the calm conditions of September and October. The beach survey including the positions of the coastline and protective structures was done using a Differential Global Positioning System (DGPS) type GBX-Pro, Theodolite and an Electronic Total Station (POWER Set 3010).

A total of 24 profiles that cover the entire coastlines of Rosetta promontory have been chosen for the analysis of shoreline position. Profile survey dated prior to (1971-1990) and after protection of the study promontories (1990-2000). The measured shoreline displacement from the fixed baseline (Y) provides a database for monitoring the shoreline changes over the time of profile collection. The data from each profile
are arranged in a 2-D graph, where Y is the shoreline position relative to the fixed baseline, and X is the date of survey. This permits the determination of the mean annual rate of shoreline displacement (meters per year) employing a least squares techniques. In addition, data obtained from beach survey taken in 1990 and 2000 were utilized to detect changes in platform configuration resulting from protection of the study promontories.

The longshore sediment transport rate at 200m intervals along the shoreline of the study promontories was estimated using the RCPWAVE model (Ebersole et al., 1986). The input data include wave characteristics (height (Hs), period (T), angle (α)) and seabed bathymetry including the shoreline surveyed in 2000. The wave data measured at Abu Qir bay were used in calculating sediment transport rate along the Rosetta

**Discussion**

Superposition of the 1990 and 2000 shorelines shows pronounced erosion along the tip of this promontory, Figure (3-A). Analysis of incident waves versus shoreline orientation revealed that the N, NNW, NW, WNW and NNE (totaling 90°) waves are jointly acting to transport sediment toward the southwest and east along the western and eastern flanks of the Rosetta promontory, respectively, Figure (3-A). Conversely, small wave components approaching from W (20°) and NE (30°) move sediment to the NNE and west directions, respectively, along these coastal stretches.

The variations of long shore sediment transport along the length of the Rosetta promontory show wide variability in the intensity and directions due to the pronounced angle between shoreline orientations versus incident waves. As expected, increasing gradient of sediment transport rates corresponds to areas of shoreline erosion while decreasing gradient alongshore towards areas where there has been shoreline accretion, Figure (3-B). The net long shore sediment transport (heading southwest) along the west coast is relatively higher than that along the east coast (heading east), being 1292 x 10^3 m^3 and 549 x 10^3 m^3 year, respectively, Figure (3-B). These higher rates result from the higher obliquity of the wave approach compared with that experienced along the east side. The decreasing in long shore sediment transport along the western and eastern down drifts of the promontory coast indicates an accretionary pattern. A major transport reversal occurs in front of the Rosetta mouth creating a divergence of long shore sediment transport nodal points; i.e. a place where sand moves alongshore to both the east and southwest away from the mouth Figure (3-A and 3-B).

The annual rates of shoreline change prior to 1990 demonstrate that higher erosion centered on both sides of the promontory tip, but with accretion to either side along the promontory flanks, Figure (3-C). Maximum erosion revealed on the east and west sides adjacent to the River mouth are 52 and 88 m/yr, respectively. This erosion decreases systematically alongshore both to the west and east, and then reverses to accretion at nodal points. Nodal points denote at the change of areas of sediment transport from erosion to deposition or vice versa that result from the orientation changes of the shoreline. These points are located 6.2 km southwest of Abu Qir Bay and 7 km of the Rosetta saddle of Abu Khashaba measured from the Rosetta mouth. This presents a simple pattern of erosion from the tip of the promontory near the mouth of the river,
with eroded sand moving alongshore as it is transported by long shore currents to the southwest along the shoreline of Abu Qir Bay and to the east along the eastern flank of the promontory. The western and eastern parts adjacent to the Rosetta mouth are parts of the Abu Qir and Rosetta sub-cells, respectively, identified by Frihy et al. (1991).

To reduce the erosion impacts at the Rosetta promontory, two seawalls (4 and 7 tons) were constructed between 1989 and 1991 on both sides of the Rosetta Nile branch mouth, Figure (3-A). The western and eastern seawalls were constructed inland and extend alongshore to a length of 1.5 km and 3.35 km, respectively. The seawalls stand 6.75 m above MSL, and vary in width from 48 to 70 m. The rate of shoreline changes after protection reveals that the two seawalls have succeeded in stopping the shoreline erosion along the tip of the promontory. However, they have shifted the erosion to down drift areas at the east and west wall ends, being 3 and 13 m/yr, respectively, Figure (3-C). The post construction erosion rates are lower than being experienced prior to building the seawalls, which originally was 106 m/yr. Consequently, five groins were built to combat the local erosion that resulted at the eastern end of the seawall, Figure (3-A). The lengths of these groins vary between “400 and 500” meters seaward and are spaced 800 to 900 m apart.
Figure (3): (A) The Rosetta promontory showing the positions of 1990 and 2000 shorelines, location of the examined 24 beach profiles. Wave-induced littoral currents are schematically denoted. (B) Alongshore pattern of estimated littoral transport rate. (C) The effect of protection system on the behavior of the coastline based on comparison between shoreline change rates before (1971-1990) and after protection (1990-2000). R1 to R24 denote Rosetta beach profile numbers.
**d- Water quality Problems**

*Fresh Water Availability and Quality*

Fresh water is available through the Rosetta branch of the River Nile. The annual discharge in the Mediterranean Sea has reached as much as 48.03 km$^3$ during the period 1956-1964 with a peak during September and October, but it has been controlled and decreased to as low as 2.51 km$^3$ during the period 1966-1989 with a peak in winter. After erection of Aswan High Dam, the discharge has been fully controlled and changed in amount and time. About 70% of the total annual input is currently discharged during December, January and February. This riverine input expectedly adds more stress on the bay through the high load of pollutants it carries with; e.g. pesticides. Table (1) presents annual fresh water discharge (km$^3$) through Rosetta branch during the period 1966-1989 (Beltagy, 1994)

Table (1): Annual fresh water discharge (km$^3$) in the Mediterranean through Rosetta branch during the period 1966-1989 (Beltagy, 1994)

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge</th>
<th>Year</th>
<th>Discharge</th>
<th>Year</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>5.86</td>
<td>1976</td>
<td>4.4</td>
<td>1984</td>
<td>5.22</td>
</tr>
<tr>
<td>1969</td>
<td>2.04</td>
<td>1977</td>
<td>7.56</td>
<td>1985</td>
<td>3.58</td>
</tr>
<tr>
<td>1971</td>
<td>4.06</td>
<td>1979</td>
<td>6.05</td>
<td>1987</td>
<td>2.6</td>
</tr>
<tr>
<td>1972</td>
<td>3.3</td>
<td>1980</td>
<td>5.4</td>
<td>1988</td>
<td>2.75</td>
</tr>
<tr>
<td>1973</td>
<td>2.75</td>
<td>1981</td>
<td>5.15</td>
<td>1989</td>
<td>2.51</td>
</tr>
</tbody>
</table>

The Rosetta branch provides fresh water to Mahmudia Canal for domestic needs of the region. It also provides fresh water for various agricultural applications and discharges the rest of fresh water in the Mediterranean for balancing pressures of erosion and salt-water intrusion in the region. The quality of water in the Rosetta branch is generally high, however, due to increasing pollution load due to industrial, domestic and agricultural waste drainage canals are usually highly polluted and could leak into groundwater or into the lake leading to serious environmental impacts

Groundwater has been utilized for various domestic applications in areas with no other sources of water. In an investigation of the quality of water in about thirty wells of maximum depth 40m, located north of Mahmudia Canal, it was found that none of these wells is suitable for drinking purposes (Nasr, 1994).

**Water Quality of Abu-Qir Bay**

Abo Qir Bay receives polluted discharge through El Tabia Pumping Station at its southern edge. The daily discharge is about 2x10$^6$ m$^3$. The monthly average discharge of El Tabia Station is presented in Table (2); Hamza et al, 1994.

Table (2): Monthly average discharge at El Tabia Station

<table>
<thead>
<tr>
<th>Month</th>
<th>Discharge($10^6$m$^3$)</th>
<th>Month</th>
<th>Discharge($10^6$m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>36.145</td>
<td>July</td>
<td>51.953</td>
</tr>
<tr>
<td>February</td>
<td>28.00</td>
<td>August</td>
<td>47.93</td>
</tr>
<tr>
<td>March</td>
<td>45.32</td>
<td>September</td>
<td>55.951</td>
</tr>
<tr>
<td>April</td>
<td>46.85</td>
<td>October</td>
<td>53.879</td>
</tr>
</tbody>
</table>
In order to monitor and assess water quality conditions in the bay, an Environmental Information Monitoring program (EIMP) has been established by the Egyptian Ministry of Environment to monitor conditions in the bay over the past 6 years. The main objective for the (EIMP) of Abu-Qir Bay is to establish baseline knowledge of the water quality through continuous survey from which a database is built up. The results of this study will be used to establish quantitative and causal relations between pollution sources and pollution impact.

Eutrophication, from a Socio–political perspective, becomes a concern as soon as it starts to endanger an important part of our marine environment as Abu-Qir Bay. Therefore, for all practical purposes, a simple definition has been adopted that defines eutrophication to be a form of nutrient pollution that degrades and endangers natural resources of our marine environment. Eutrophication is therefore, considered to be a symptom of pollution, whereby addition of excess nutrients leads to excess growth of algae which perhaps leads to high mortality of heterotrophic organisms, particularly fish and benthic organisms. Negative impacts of eutrophication include:

1. The reduction of tourist–recreational value of coastal water due to reduced transparency, changes in the color of seawater, phytoplankton blooms and modified shore communities ...... etc.

2. Health impacts of algal toxic extra metabolites, directly or by accumulation in seafood organisms.

3. The loss of fisheries resources, mainly as:
   b. Reduced or collapsed recruitment of inshore, estuarine and tidal lagoon fish and shellfish.
   c. Hindrance of aquaculture and / or inquiring the quality of its product,

In Abu-Qir Bay, eutrophication in superficial waters results from several phenomena:

- Winter vertical mixing of water.
- Discharge of effluents (River Nile, domestic, agricultural and industrial effluents).
- Natural terrestrial run off.

The Egyptian Ministry of Environment EIMP/EEAA has established an environmental monitoring program for Abu-Qir Bay. The program has stressed monitoring at:

- Major industrial settlement along the Bay.
- Coastal communities i.e. Abu-Qir, Maadia, Idku and Rashid villages.
- River Nile estuary at Rosetta.
- Outlet of Lake Idku.

Parameters, which have been covered by the program, include:
1. **Basic physical parameters**: These include depth and vertical profile of salinity, specific conductivity, temperature, pH and dissolved oxygen (DO) and water transparency (Secci disc). CTD (YSI) was used for measuring the physical parameters.

2. **Bacteriological parameters** (total coliform, faecal coliform and faecal streptococci). Special rode with glass carrier has been used for collection of samples.

3. **Eutrophication parameters**: These include total suspended matter (SPM), nitrate, nitrite, ammonia, total nitrogen, total phosphorus, silicate and chlorophyll.

### 1- Physical Parameters

Conductivity, Salinity, pH, depth, water temperature and Dissolved oxygen were measured using 600XL Multi-parameter water Quality Monitor (CTD) YSI incorporated. The data stored in the field in YSI 610 microcomputer (Data logger) and transferred the laboratory computer using powerful software (PC6000).

**a. Conductivity:** The YI water quality monitor (CTD) was used to determine conductivity.

**b. Salinity:** Salinity is determined automatically from the 600XL conductivity readings according to algorithms found in *Standard Methods for the Examination of Water and Wastewater*.

**c. pH:** The 600XL employs a field replaceable pH electrode for the determination of hydrogen ion concentration.

**d. Depth:** The 600XL equipped with depth sensor to measure depth.

**e. Temperature:** The 600XL was used to determine the water temperature.

**f. Dissolved Oxygen:** The 600XL was used to determine the dissolved oxygen in seawater.

### 2- Bacteriological Parameters

Sampling techniques, preparation, handling and preservation of marine water sample were done according to the guidance described in the International Organization for standardization (ISO) No. 5667/9 (1992). Detection and enumeration of coliform organisms and presumptive E.Coli were done using method and media described in the International Organization for Standardization (ISO) No. 9308-1 (1990) whereas faecal streptococci bacteria were detected and enumerated according to International Organization for Standardization (ISO) No. 7899/2 (1984).

### 3- Eutrophication Parameters

Six stations were selected to represent Abu-Qir Bay (Figure 1). Water samples were collected at depth of about 2.5 m the samples were filtered through filter paper (GF/C). The dissolved inorganic nutrient salts (including nitrite, nitrate, ammonia, phosphate and silicate) were analyzed spectro-photometrically or using auto-analyzer for NO₂, NO₃, P, and Si.
Nitrite (NO$_2$): The determination of nitrite (NO$_2$) was carried out according to Grasshoff (1983a)

Nitrate (NO$_3$): The determination of nitrate (NO$_3$) was carried out according to Grasshoff (1983b)

Total phosphorus and total nitrogen (TP & TN): Total method used for determination of total nitrogen and total phosphorous was performed according to Valderrama (1981)

Ammonia (NH$_4$): The method used for determination of ammonia was conducted according to Koroleff (1983a)

Reactive phosphate (PO$_4$): The method used for determination of reactive phosphate was carried out according to Koroleff (1983b)

Reactive silicate (Si): Determination of reactive silicate was performed according to the method described by Koroleff (1983)

Chlorophyll-a: Chlorophyll-a extraction and measurement was performed according to Strickland and Parsons (1972).

Suspected Particulate Matter (SPM): Suspended particulate matter was measured according to the method described by Van Loon (1982).

Analysis by using auto-analyzer: Auto-analyzer was used to determine NO$_2$, NO$_3$, PO$_4$ and Si.

Discussion

1- Physical parameters

1. Monitoring of physical parameters revealed that salinity was generally low in front of fresh water outlets like Maadia and Rashid. With respect to pH values, slightly alkaline values were recorded for Abu-Qir Bay. Low values of dissolved oxygen were observed sometimes in the Bay.

2. Relatively high water temperature was observed most of the time in front of Electrical Power Station of Abu-Qir Bay. This is due to cooling water of power station discharged into the bay. This phenomenon was continued during the monitoring years (from 1998 – 2002).

3. High DO values were detected in surface water of the Maadia during May. This is due to the high rate of mixing and presence of strong surface currents. Sometimes the presence of high amount of phytoplankton causes photosynthesis which lead to increase of DO, while the lower DO values were recorded in the deep water. This could be attributed to the discharge of untreated wastewater into the bay through Maadia outlet, Tabia outfall plus cooling water from the Electrical Power Station.

4. The investigation of sea water temperature during year 2000 revealed thermal pollution in Abu-Qir Bay in front of Electrical Power Station especially in summer and autumn seasons. Relatively lower salinity values were observed at Rashid.

5. Two cases of DO deficiency have been detected during year 2000: the first one was below the Egyptian guideline (4 mg/l) and the second was hypoxia (< 3
mg/l). Deficiency of DO (< 4 mg/l) has been detected during May 2000 at Abu-Qir Bay. Also during July 2000 at eastern of Abu-Qir city and finally during November at Maadia. Hypoxia (< 3 mg/l DO) has been detected in bottom water of Maadia during May 2000 and during Sept.2000 at Electrical Power Station and Maadia and finally during November at eastern Abu-Qair City and Electrical Power Station.

6. It is worthy to mention that the River Nile does not contribute to decrease salinity in front of Rashid during March and May. This is due to the change of seawater current being from sea towards Rashid estuary.

2-Bacteriological parameters

Bacteriological investigation for pathogenic bacteria (Total coliforms, E.coli and faecal Streptococci) in Abu-Qir Bay during the last five years (1998 – 2002) revealed the following:

1. The sites especially in form of outlets like Maadia, Rosetta and outfalls were contaminated by faecal pollution indicating bacteria with counts exceeding the acceptable numbers adopted by the European Community Standards (ECS). In general Idku site did not exceed the permissible numbers during most of monitoring campaigns.

2. Faecal contamination found in Abu-Qir Bay is due to discharge of untreated Sewage water in the bay. Discharging the wastewater into the sea is considered of potential risk to public health through direct infection to swimmers and / or eating contaminated seafood.

3-Eutrophication

1. Monitoring of eutrophication parameters i.e. nitrite, nitrate, ammonia, phosphorous, silica, chlorophyll-a and SPM at Abu Qir during 1998 revealed high levels at eastern Abu Qir City, Electrical Power Station, El-Maadia outlet and Rashid. Those high levels were due to discharge of untreated wastewater into Abu-Qir Bay.

2. During year 2000, the regional and bimonthly variations of nitrate and nitrite along Abu-Qir Bay showed relatively low levels during the whole period of investigation except in Sept. at Electrical Power Station where the nitrite was relatively high.

3. High levels of dissolved inorganic nitrogen (DIN) were detected in the bay. This may be due to the impact of discharge of domestic, industrial and agricultural runoff into the bay. Normal levels were observed for phosphate, silicate, SPM and chlorophyll-a during 2000.

4. Relatively low levels of nitrate and nitrite were recorded at Abu-Qir Bay, while high concentration of total nitrogen was observed to the east of Abu-Qir City. This is due to the impact of discharge of untreated wastewater into the bay. Moreover, normal levels of reactive phosphate and dissolved inorganic nitrogen (DIN) were recorded.

5. Relatively, high levels of chlorophyll-a and suspended matter were observed in front of outlets like El-Maadia and Rashid estuary.

6. Maadia and Rashid sites were characterized by increasing primary production (relatively high levels of chlorophyll-a). This may be related to
the influence of drainage water brought by the River Nile or industrial wastewater like Electrical Power Station or mix of industrial and agricultural wastewater like Maadia.

7. The results of nitrite showed low levels during the whole period of investigation. High concentrations of dissolved inorganic nitrogen (DIN) were recorded at Electrical Power Station and Maadia.

8. In general gradual improvement for water quality of Abu-Qir Bay has been noticed during the period of the investigation (1998-2002). Continuous surveillance and enforcement of the Egyptian environmental law No. 4/94 are expected to be the main reasons for this improvement.

Fig (4) represents variation of water quality index over hot spots of the Mediterranean coast of Egypt over the years 1998-2004 (Nasr et al, private communication). It shows that the conditions at Abu Qir Bay are improving slowly over years however still far from control sites (Baghoush and Ras El Kanayes).

E- Socioeconomic Systems and Conditions

This part is based on data obtained during field visits, interviews with experts, local communities, statistics and available studies.

Population

There are four major cities in the study area; Kafr El-Dawar Rashid, Idku and Al Maadia. These cities have an over all populations of about 991800 (Censes, 1996). Population growth rates for the study area are not available but national growth rate
decreased from 2.75% in 1968 to 2.8% in 1996. Kafr El-Dawwar the biggest city of Beheira governorate lies in the south of the study area. It contains about 232000 populations. It encompasses important industries; textile and dying, chemicals, canning and food processing.

Rashid City is located on the Nile east of the study area. It has a population of around 85000. The town has an urban character with many historical building and sites. Idku City hosts about 88000 inhabitants. Al Maadia Town has a population of about 8800. It is important for local fisheries because of its new harbor.

Generally the areas east and west of Lake Idku are densely populated and several villages lie in the vicinity of the major cities. There are not settlements in the area north –east of Idku because there are not cultivated land or irrigation facilities.

Socio-economic poles
Mainly there are two economic poles in the study area: agriculture and fishing. Those economic sectors not only form economic bases but also adjust the social life for the peoples in the study are. Those two socio-economic poles interact and integrate to draw the individuality of the study area. In this part we discuss: Maine activities sectors, Employment and Land use.

Maine activities sectors
There are three major economic activities as follows:

A-Agriculture activity
The agriculture in the project area is characterized by the irrigated cultivation of date palms, fruit trees and traditional crops. Animal husbandry is very limited and there is little production of milk or milk products. Very few people produce honey. Bee keeping is mostly confined to the plantations of orange trees. Some of the agricultural land is permanently under cultivation, some parts are only cultivated for a certain period of time during the year. In rare cases fields are abandoned or neglected. Cultivation of crops in the lake Idku region follows the tradition three year cropping pattern with cotton, rice and vegetables grown in the summer and wheat, barely, beans and vegetables in winter. Generally, returns from trees are higher than from traditional crops. Palm trees are mainly cultivated in a belt along the coastal strip. Towards the south, palm tree plantations are fewer and more fruit trees and traditional crops dominate the agriculture of production: The uppermost level is the canopy of the palm leaves. Intermediate plants are fruit trees such as guava, citrus fruits, keki and mango. On the ground there are tomatoes, onions, potatoes, zucchini and aubergine (eggplant). Table (3) and Table (4) show the main agricultural products in Idku.

Table (3): Main Agricultural products in Idku for 1996/97: Trees

<table>
<thead>
<tr>
<th>Tree</th>
<th>Area Feddan</th>
<th>Volume of production (ton)</th>
<th>Average ton per Feddan</th>
<th>Average number of trees per Feddan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palm (Date)</td>
<td>8.709</td>
<td>52.254</td>
<td>9</td>
<td>80</td>
</tr>
<tr>
<td>Guava</td>
<td>4.986</td>
<td>40.390</td>
<td>8.1</td>
<td>400</td>
</tr>
<tr>
<td>Apple</td>
<td>1.252</td>
<td>8.764</td>
<td>7</td>
<td>500</td>
</tr>
<tr>
<td>Orange</td>
<td>252</td>
<td>2.020</td>
<td>8</td>
<td>400</td>
</tr>
</tbody>
</table>
Table (4): Main Agricultural Products in Edku District for 1996/97; Crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area in Feddan</th>
<th>Volume of production</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>5.029</td>
<td>15.087</td>
<td>Ton</td>
</tr>
<tr>
<td>Cotton</td>
<td>4.829</td>
<td>34.768</td>
<td>Quintal+</td>
</tr>
<tr>
<td>Beans</td>
<td>3.390</td>
<td>20.340</td>
<td>Ardab*</td>
</tr>
<tr>
<td>Wheat</td>
<td>3.070</td>
<td>49.120</td>
<td>Ardab*</td>
</tr>
<tr>
<td>Tomato</td>
<td>1.660</td>
<td>12.450</td>
<td>Ton</td>
</tr>
<tr>
<td>Maize</td>
<td>941</td>
<td>23.532</td>
<td>Ardab*</td>
</tr>
<tr>
<td>Water melon</td>
<td>800</td>
<td>880</td>
<td>Ton</td>
</tr>
<tr>
<td>Aubergine</td>
<td>11</td>
<td>87</td>
<td>Ton</td>
</tr>
<tr>
<td>Pepper</td>
<td>10</td>
<td>25</td>
<td>Ton</td>
</tr>
<tr>
<td>Onion</td>
<td>10</td>
<td>65</td>
<td>Ton</td>
</tr>
<tr>
<td>Total</td>
<td>19.750</td>
<td>32.071**</td>
<td>Ton</td>
</tr>
</tbody>
</table>

+ 1 Quintal = 100kg.
* Unit of Volume (no metric unit available).
** excl. figures for beans, wheat, maize.

Source of Data: IDSC of Local Unit of Idku, 1998.

More and more trees, such as palm and guava, are being grown on the sandy lands because they are less sensitive to the high groundwater levels.

Table (5): Summary of Agricultural Structure in the Project Area.

<table>
<thead>
<tr>
<th>Trees: date, guava, orange, apple, mango, mandrian</th>
<th>Ownerships &amp; Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muddy land: 100% private</td>
<td>Salinization problems, high investments for soil improvement; Some dunes, mostly stable-they are used as resource for leveling the land.</td>
</tr>
<tr>
<td>Sandy Land: 2/3 private, 1/3 rented from government.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crops: tomato, Alfalfa, aubergine, beans, wheat, barley, zucchini, pepper.</th>
<th>Ownership &amp; Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% in transition from public to private ownership; 5% rented from government.</td>
<td>Sandy land leveled and reclaimed by the state in the 1960’s.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trees: date, citrus, guava, apple, mango.</th>
<th>Ownership &amp; Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% in transition from public to private ownership; 5% rented from government.</td>
<td>Sandy land leveled and reclaimed by the state in the 1960’s.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crops: tomato, Alfalfa, wheat, aubergine, beans, barley, zucchini, pepper.</th>
<th>Ownership &amp; Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-6 4.000 L.E.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trees: date, guava,</th>
<th>Ownership &amp; Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governmental (TDA); 1-100, very</td>
<td>0-5.000 L.E</td>
</tr>
<tr>
<td>Description</td>
<td>Crops:</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Dispersed private cultivation</td>
<td>tomato, zucchini, aubergine, rice</td>
</tr>
<tr>
<td>without registration.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
B-Fisheries activity

Apart from agriculture, fisheries and aquaculture there are other important sources of income in the project region. In Edku district, about 10% of the population depends on marine and freshwater fisheries. In Maadi Town and its surrounding villages, the portion is 50%.

An estimated 300 fish farms are located in the lake whereas the vast majority is rather small; there are three large fish farms. Two of them are located in the south-east of the lake and one in the lake’s north at Kawm Bilag. Kawm Bilag Fish-Farm has a total area of 2000 feddan year (450 L.E/ year per feddan). About 30 fish farms are located at the western edge of Lake Edku, east of Kawm at Tarfayah. These belong to the Fishing Authority. Currently, the north-western tip of Lake Idku is converted into fish-farms.

Marine Fishing is very important in Maadia. There are more than 270 boats registered in the Maadia fishing port. Fish catches have risen from 1.500 tons in 1984 to about 11.500 tons in 1996. The Maadia fishing port was extended under a Japanese grant aid project at a total cost US $20.5 million. For this extension, a total of 130 feddan (54.6 ha) of agricultural land to the west of Halawani Agricultural Cooperative was acquired for building. Table (6) shows the structure of fisheries in Edku district for 1996.

Table (6): Fisheries in Edku

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of Fishers</th>
<th>No. of boats</th>
<th>Size of area</th>
<th>Production in tons/year</th>
<th>% of total production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea</td>
<td>7.857</td>
<td>306</td>
<td>35 km along the coast</td>
<td>11.522</td>
<td>51</td>
</tr>
<tr>
<td>Lake Idku</td>
<td>4.000</td>
<td>1.619</td>
<td>17.000 feddan</td>
<td>8.193</td>
<td>36</td>
</tr>
<tr>
<td>Fish farms (lake)</td>
<td>425</td>
<td>---</td>
<td>5.228 feddan</td>
<td>2.093</td>
<td>9</td>
</tr>
<tr>
<td>Drains/ Canals</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>743</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>12.282</td>
<td>1.925</td>
<td>---</td>
<td>22.497</td>
<td>100</td>
</tr>
</tbody>
</table>

1 feddan = 4200m²

c- Industrial activities

Up until recently, industry played a minor role within the study area. Apart from some heavy industry west of Maadia there was almost exclusively light industry. This was concentrated in Rashid, Edku and Khadrah. Several factories for brick production were located along the banks of the Nile north of Rashid. Small-scale industries for baskets, ropes, tiles and carpentry as well as car repair shops were common. Traditional fishing boat and yacht building was also important. A substantial number of yachts were exported to Arab countries such as Qatar, Saudi Arabia and Kuwait. In Edku Town the weaving industry is widespread in small-scale factories with about 121 production plants. Several heavy industrial plants were located on the coast west of Maadia. These are paper, fertilizers and chemicals, petroleum and electricity.
Recent discovery of huge gas reserves in the region has changed the situation drastically. A huge liquefaction plant has been recently built and a Petrochemical plant is planned nearby. These plants, together with the initiation of the International road across the region and associated land use changes are expected to change the socioeconomic pattern in the region, creating jobs and imposing pressures on resources. Unless a strong institutional capability for monitoring, assessment and law enforcement is created, unplanned development will damage the already sensitive and fragile environment in the area.

**Employment**

Generally most of residents of the study area work in agriculture or fishing. However, in the west of the study area a high proportion of employees work in factories and industrial plants west of Maadia or in services sector in Alexandria. Unfortunately there is high rate of unemployment in the southern part of the study area. Actually there is not enough land to cultivate.

Table (7), gives an overview of inhabitants and regional economic related to three major cities in the study area. There seems to be some shortage of agricultural labors in the east of the study area. So during the main harvesting season labour come from nearby to work on the farms. These hired labour are mainly from Kafr El Dawar. This means that part of the surplus labour force in southern part of the study area is assimilated here.

<table>
<thead>
<tr>
<th>Economic Activities</th>
<th>Rashid</th>
<th>Edku</th>
<th>Kafr El Dawwar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture and Fishing</td>
<td>18482</td>
<td>13799</td>
<td>58952</td>
</tr>
<tr>
<td>Industry and construction</td>
<td>636</td>
<td>3553</td>
<td>24974</td>
</tr>
<tr>
<td>Services</td>
<td>11257</td>
<td>6031</td>
<td>19242</td>
</tr>
<tr>
<td>Not adequately described</td>
<td>1864</td>
<td>23845</td>
<td>6260</td>
</tr>
<tr>
<td>Total of working people</td>
<td>37163</td>
<td>47228</td>
<td>109428</td>
</tr>
<tr>
<td>Unemployed</td>
<td>75833</td>
<td>73908</td>
<td>304585</td>
</tr>
</tbody>
</table>

*Source of Data: 1996 Census*

**Land use**

Land use in the study area is dominated by irrigated agriculture. Fisheries, aquaculture and residential also form significant clusters. The aquaculture is mainly situated inside and around Lake Idku. Activities of agriculture and aquaculture interact and integrate into the study area. On the other hand, industry forms clear spots and is expected to play a much larger role in the area after recent discoveries of oil gas in the bay. In fact, already existing industries create clusters at the west of the study area on the Abu Qir bay, at the south in Kafr El Dawar City and recently in the North West coast of Abu Qir Bay as petrochemical and gas liquefaction industries. To date tourism has not played any significant role in the study area. The region is generally characterized by fast unplanned changes of land use.
Status of land ownership

There are different patterns of ownership and user rights in the study area. There are cases where lands are regulated under different regulations and also where land is in transition of ownership. Formal registration of private ownership to deceased persons is common. Parts of agriculture land have been under cultivation for many generations and parts have been reclaimed under one of the reclamation schemes within the past 50 years. The inheritance system has resulted in increasing smaller farms, especially in those areas, which have been under cultivation for many generations.

Table (8) clearly shows that more than 80% of all landowners in the Beheira Governorate have less than 3 feddan (1.26 ha). In Beheira this is only 50% of the farmers. In terms of farm size, the smallholders in Beheira are statistically somewhat better off than the majority of farmers in Egypt. Most owners in the project area have one plot of land as a farm. Only a minority owns land in different locations.

Table (8): Distribution of Agricultural land by Size of Ownership in the Beheira Governorate

<table>
<thead>
<tr>
<th>Size of Land in Feddan</th>
<th>Owners</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Less than 1</td>
<td>128.914</td>
<td>49.6</td>
</tr>
<tr>
<td>1-</td>
<td>52.335</td>
<td>20.1</td>
</tr>
<tr>
<td>2-</td>
<td>31.452</td>
<td>12.1</td>
</tr>
<tr>
<td>3-</td>
<td>17.635</td>
<td>6.8</td>
</tr>
<tr>
<td>4-</td>
<td>10.788</td>
<td>4.2</td>
</tr>
<tr>
<td>5-</td>
<td>8.686</td>
<td>3.3</td>
</tr>
<tr>
<td>10-</td>
<td>5.531</td>
<td>2.1</td>
</tr>
<tr>
<td>20-</td>
<td>2.580</td>
<td>1</td>
</tr>
<tr>
<td>50-</td>
<td>1.264</td>
<td>0.5</td>
</tr>
<tr>
<td>100 and over</td>
<td>596</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>259.781</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source of Data: CAPMAS, 1997. 1 Feddan = 4200m²

Traditionally, a person has user rights if he reclaims a certain plot of land and nobody else claims rights on it. After 15 years of cultivation, the land is considered to be owned by that person. Small holders kept their land but all agricultural land was organized into state controlled agricultural co-operatives. By the time of the revolution, some of the government land, which could have been cultivated, had not been reclaimed. Private individuals without formal acknowledgment did this later, either under an official reclamation scheme or. Some private owners have a formal registration for their land. Others do not possess such a formal document, but are considered to be owners under traditional law.

The management of government land is not carried out by a single administration in Egypt. Different authorities are responsible, such as the Ministry of Agriculture, Ministry of Housing and Utilities and Urban Communities, Ministry of
Tourism, Ministry of Defense etc. The respective authorities will be identified during the exact definition of the alignment. This appears to contradict the fact that the Tourism Development Authority of the Ministry of Tourism owns the coastal strip north of Lake Edku. All the non-urban land here was assigned to the TDA in 1992 by decree 445/1992. Its boundaries are the outlet at Maadia to the west, the railway to the south and a line 1.5 km parallel to the eastern banks of the Rashid Branch in the Kafr El Sheikh Governorate.

A special ownership system is the so-called “Kela System” which is confined locally to the area west of Idku. The Kela System is based on a 2.05 m broad strip running more or less vertically from the shoreline to either the road or the railway line. Most of the farms today consist only of 2 or 3 strips.

The dunes in the project area are a very important resource for local agriculture. The sand is taken for leveling the low lying land which is prone to salinization. The heavy exploitation of the dunes has resulted in a considerable depletion of some of them. In certain locations they have almost completely disappeared. The present dunes can be classified into two groups with regard to user rights: there are no formal regulations for the use of the larger mobile dunes east of Idku. Illegal quarrying of the sand is carried out on a large-scale. For the smaller isolated fixed dunes further east individuals have exclusive user rights. These rights are not formalized but are the consequence of long established practice.

Water uses

Irrigation

The irrigation water is free of charge and readily available for almost all land that officially declared as agriculture land. Most of it is connected with the Nile-fed governmental irrigation system. The irrigation system in the study area is a combined gravity and water lifting system. This system typically consists of a main canal system that takes its water from the head regulator located at the Nile. Water is the distributed along the branches. At the third level canales distribution canals receive water according to rotation schedule. Pumps are then used to lift water from these channels to irrigate the fields. The largest and the most important irrigation canal in the study area is the Mahmudia Canal with width of 25 m.

On land that is not officially declared as agriculture land, the holders have to build irrigation and drainage arrangement at their own expense. The agricultural authorities clean and clear canals and drains regularly. Alternatively drain provides another source of irrigation water. This can cause problems because the water from the drains is partly contaminated.

Drainage

Whereas the irrigation system is generally well established in the study area, the drainage system is somewhat less well developed. In some cases fertile lands are not cultivated for the reason that of lake of drains. Seeing as the area east of Idku is not officially acknowledged as agriculture land, there was no drainage system until recently. Generally the lake of drains is dealt with two different manners; either by digging drains or by making ground using sand from the nearby dunes.
**Drinking water**
All water for drinking purposes is processed surface water from the Nile. Pipelines from the processing stations supply it. But there are few hamlets in the study area not connected to drinking water network. The people living in those hamlets get their water from public pipes in neighboring village.

**Sewage**
In rural areas sewage treatment is practically not existent. Sewage is disposed of in pits close to the houses. Public or private operated disposal cars empty those pits. The wastewater from these cars is fed into drains. Some villages discharge their sewage into Lake Idku.

Rashid City has sanitary network under construction. But at this moment there is deterioration in the environmental conditions of the town itself. In Idku town a sewage system was established for the main roads a few years ago.

The outlet of the main drain from Kafr El Dawwar is the main source of pollution in the area. It discharges huge amounts of agriculture and industrial effluent.

**Solid Waste Disposal**
There is practically no efficient waste collection system. In general, a substantial amount of solid waste is thrown into canals and drain. Especially in and around the villages, the open canals and drains are litter with all kinds of domestic refuse in most cases.

**Water supply and Wastewater Questionnaire Survey**
Alexandria Local Assembly has carried out a survey for all Alexandria districts including Abu Qir city district (1999). The objective of the survey was to:

1. Assess quality of services offered by Water Supply Company and Waste Water Facilities
2. Assess the awareness of the public of the relationship between environment, quality of life and health
3. Identify problems of extension of services of water supply and wastewater
4. Assess satisfaction of the quality of water and services
5. Assess the welling to pay for providing better services

Results indicated that water supply and quality of water are of highest priority and that most people are welling to pay for improved water supply and sanitation

**Cultural Heritage and Archaeology**
For the clarification of the tourism potential possessed by the region, it was important to survey all available tourist areas that may form an attraction poles for internal and external tourism.

**On Land archaeology**
The inland monuments constitute a set of 9 forts ruins and the restored recognized monument of Qait-Bay Castle, and “Sidi Abdel Razek” shrine. Fig (5) shows the location of most important archaeological sites along the bay.

**Submerged Archeological Sites**
The archeological sites submerged under the western part of Abu Qir bay are an attractive salvage operation for marine archeologists and would also stimulate the
tourist industry. The following famous submarine archeological remains exist under Abu Qir Bay:

**Canopus and Herakleion cities**

Ruins of the ancient cities of Canopus and Herakleion, dated from Greek to Byzantine times, were discovered at depths of 6-7 m in the western part of Abu Qir bay (Toussoun, 1934; Bernard, 1970; Stanley et al., 2001). Artifacts have been recovered in recent times by fishermen from the bay, and the sites were first explored by hard-hat divers in 1933 (Toussoun, 1922). The Canopus and Herakleion were positioned west of the mouth of the old Niles’s Canopic branch. This branch was one of the seven distributaries that flow in this region west of Edku inlet between 600 BD and 300 AD. The Canopic branch was navigable and its water was received from the Rosetta branch. Of these seven distributaries, five have since silted up, leaving the present-day Rosetta and Damietta branches. These sites are 1.6 and 5.4 km, respectively, east of the Abu Qir headland. At each site, ruins were found over an area exceeding 0.5 km². Recent investigations using side-scan sonar have recorded large...
features such as walls, bases of temples, columns, stellae, and statues. According to Bernard (1970) structures in Canopus at the time were still positioned close to the shore until the early seventh century. The temples and walls remained exposed for another century, until after 731 AC. Different theories have been attributed to the submergence of these cities, these are:

1- The effect of a rise in sea level and subsidence (which to gather account for less than 3 m of vertical offset since AD 700).
2- The effect of active earthquake activity. However, no earthquake activity was recorded in Egypt during AD743 or 745 (Saloviev et al., 2000).
3- The result of sudden riverbank failure of the low-elevation margin of the river banks (Stanley et al., 2001). Unfortunately, the Canopic Nile mouth did not reach the two cities at the time of disappearance of these cities. In addition, the Nile records at El Rhoda gauge between 741 and 742 were above moderate and were not a very high flood (Said Arabic article, 2002).
4- According to Said (2002) assessment the two cities had disappeared gradually and not suddenly (due to neither floods nor earthquakes). The disappearance came gradually due to the erosion and processes by current and waves across 400 years same as the old Brullus.

Bonaparte's Fleet
On 1st August 1798 the British naval units commanded by Admiral Nelson sank most of Napoleon's flotilla at Abu Qir Bay. The remains of the fleet particularly the Napoleon's flagship (L'Orient) are visible underwater in calm sea. Submerged remains are cannons, guns, anchors, coins, cups (Morcos, 1997).

f- Problems and conflicts of the Region:
During the field surveys, it was observed that there are some obstacles, which could impact the natural resources and slow the development in the study area; it should be taken into consideration. These obstacles are:

1. Shortage of institutional capabilities
Severe shortage of institutional capabilities of all sectors is the main problem in the region. The lack of proper urbanization services of all kinds including fresh water supplies, wastewater systems, solid waste disposal systems, planning and enforcement systems, healthcare systems and even the law enforcement systems. As a result, there are many problems with marketing of products, recycling of waste, transportation and roads. The absence of enforced plan of development constitutes a very serious draw back for sustainable development.

2. Shortage of Transportation Network:
In spite of the transportation network from Alexandria to Rosetta is recently connected to the International Highway, still secondary roads are very narrow especially at some points of presence of some settlements such as that near Lake Edku inlet. Nowadays, the international coastal road passes through the region with some big bridges crossing the Lake Edku, as in Figure (4). Detailed studies are needed to assess the type and magnitude of this road impacts on the whole region.
3. Coastal Erosion:

The Nile Delta with its classic fan shape has been evolving since Upper Miocene time (10 million years B.C.), (Said, 1981). The Rosetta Nile branch is one of the two major distributaries of the River Nile. This branch has developed the triangular headland Rosetta promontory trending NNW. Its mouth extends about 12 km into the Mediterranean Sea. The Nile Delta coast forms a unique depositional environment, in which sedimentation is controlled by a combination of some environmental factors (such as waves, currents, tides, etc) and river discharge. As a result of that it became a subject to frequent changes.

Since the building of Aswan High Dam (1964), an imbalance between the two major forces affecting the shore (erosion and accretion) has occurred. As a result of this, a strong decrease in the amount of sediments accreted (the amount of sediments decrease from 120 million tons per year to only a trace amount). These have caused significant and rapid changes along the shore of the North West Nile Delta coast. These rapid shoreline changes could create catastrophic physical, biological and socio-economic problems. The historical shoreline retreat along the study area was reported using both satellite remote sensing data and field measurements, (e.g. El-Raey, 1995). Two photos illustrate both erosion areas (in the western coast of the area)
and accretion zones (in the western coast of the area) were taken through field visits, Figures (5 and 6).

Two protection sea walls have been building to protect the coast from the high rates of erosion. The eastern wall is 3.6 km length, while the western one is 1.6 km length. Both walls have 6 meters depth and 6 meters height. During the last few years, the seawater is reached the walls and began to surround it, which is a very serious sign, Figure (7). Nowadays, there are some experiments from different companies to protect the coastal line, like the huge concrete bags that put parallel to the coastline.

4- Water pollution

Water is available for irrigation through the River Nile, Rosetta branch. It is also available for domestic needs through pipelines connected to Alexandria network. The region is relatively rich in water resources; however, problems are mainly related to water quality rather than quantity. Increasing salinity and intrusion of saline water into the soil has impacted many sectors. Palm tree are cultivated to avoid this problem, however, the rest of crops are definitely affected one way or another.

Industrial pollution has impacted both marine and fresh water resources. Marine monitoring has indicated the presence of several hot spots. Fresh water analyses from drains dumping in the lake and in the bay have indicated very low water quality.

Low performance of water and sanitation utilities is considered most serious. Egyptian policies is optimizing the use of freshwater and exploring the use of new non-conventional water resources such as desalination, wastewater reuse, and agriculture drainage water. Water quality problems in the region vary among water bodies depending on location, flow, water use, population density, industrialization extent, availability of sanitation systems and the social and economic conditions. Discharge of untreated, or partially treated, industrial and domestic wastewater, leaching of pesticides and residues of fertilizers and navigation are often factors that affect the quality of water in the Nile River, canals, drains, and Idku Lake.

The agriculture sector is the largest user and consumer of water in the region. The highest water consumption crop in study area is rice. However the development in the overall water supply coverage has been rapid and impressive, the sanitation service coverage varies widely throughout the country.

Coverage rates for sanitation systems, although improved for urban areas, are much less than those of water supply. In areas without sewerage network, wastewater is often collected in septic tanks or other forms of on-site disposal systems. These installations are frequently leaking and overflowing due to poor construction and lack of maintenance. They are a major source of water pollution and unhygienic living conditions.

5-Low education and awareness

Most of the residences have a law level of awareness and a high percentage of the populations are of low education level.
Figure (5): Areas of Coastal Erosion (mainly in the western coast)

Figure (6): Areas of Coastal Accretion (mainly in the eastern coast)

Figure (7): The Western sea wall of Rosetta Promontory
6. Dune Quarrying:

Sand dunes in the study area have unique characteristics, which are not found in most of sand dunes in Egypt. Sand dunes in the area are covered completely by grass which makes it stable and gives it a very unique nice-beautiful view. This dunes overlooking view is most suitable and attractive to tourism activities.

The sand dunes in the study area are found mainly in two locations: one starting from Idku city and takes the north direction toward Rosetta, while the other is in Abu Mandour area, and is perpendicular to the first one. Sand dunes have a great ecological benefit in the management of the area. It gives a nice view, and provides attractive locations to tourists who search for quite and unique places to visit.

Continued mining and reclamation of sand dunes will threaten the natural defense of the remarkable coastal dune belt along the backshore of the study area. In addition to natural defense, these dunes are considered as an essential landscaping element in terms of coastal development and as a natural protection element from beach erosion as well also, these dunes host thousands of remarkable Palm trees that characterized this beauty region. Unfortunately, intensive illegal mining activities for the coastal dune belt west of Idku inlet is being carried out. More than 20 trucks have been observed in one quarry site dredging hundreds of cubic meters of dune sand per day. This activity was observed during the recent team field visit to investigate the process of ground truth. It is expected that the impact of sand dune mining and use for agricultural applications will have serious adverse impacts on soil salinity and tourism activities in the area. The huge quarrying process illustrated in the next two photos taken through field visits, Figures (8 and 9).
Figure (8): Roots of palm trees appear due to the severe quarrying.

Figure (9): Large areas lost due to severe quarrying.
7. Water Logging and water bogging:

Most of the study area is flat and lies at low-lying elevations except some locations to the south such as the two belts of sand dunes. Most of coastal parts are logged areas. So, the project site should be selected carefully to avoid water logging. As a result of severe cutting of sand dunes, water logging problems in the study area in the very near future are expected to be aggravated. In addition, it has been noticed that serious seasonal variations of sea invasion occurs in the area. The affected stack holders of this phenomenon are farmers and fisherman. Farmers have to remove the logged water manually in an inefficient way, Figure (10).

8. Climate change and Salt water intrusion

Many examples of salt water intrusion in the agricultural and mixing of fresh and salt water exists. This is exacerbated by anthropogenic activities of soil quarrying in many localities and lack of integrated control. In fact, recent satellite images indicate increased inland water which may be attributed to increased salt water intrusion. The area to the south west of our region is known to be lying below sea level and is expected to be most vulnerable to impacts of sea level rise and salt water intrusion in the future. This problem has not been addressed in any plan for development of the region.

9. Land subsidence in Abu Qir Bay

The vertical motion of land, subsidence or emergence refers to the lowering or emerging of the land surface relative to a geodetic datum. Vertical motion varies locally depending upon rates of isostasy, tectonism, compaction and anthropogenic influences (groundwater or oil withdrawal) or combination thereof. Subsidence and emergence is generally independent on world (eustatic) sea-level changes. Measurement of subsidence requires removing the effects of changing sea level, which has been rising during much of the past ~18,000 years. Land subsidence and
emergence due to neo-tectonism play an essential part in increasing or decreasing sea level.

Unfortunately, there have been no tide gauges deployed at Abu Qir bay to estimate relative sea-level rise. However, Stanley (1990) and Stanley and Warne (1993) estimated long-term average subsidence rates from core samples across the Nile delta region including Abu Qir Bay (Figure 1A and B). Their estimation is based on carbon-dated sediment cores recovered across the coastal zone of the Nile delta. The processes of compaction and dewatering of the thick accumulated deposits of fluviomarine deltaic mud sequence formed in the Holocene has induced higher rates of subsidence ranging from 1 to 5 mm/yr. Subsidence has been considerably lower in a westerly direction, ranging from 5 mm/yr at Port Said in the east to ~1 mm/yr farther to the west at Alexandria region (Stanley and Warne, 1993). Thickness of Holocene strata beneath the modern delta plain is a direct function of subsidence, which ranges from 50 m at Port Said and tends to decrease or be nearly absent westward below the Alexandria coastal plain. Accordingly, subsidence at Abu Qir bay attains a maximum of 3 mm/year at the Rosetta promontory.

Several impacts are expected due to land subsidence and sea-level rise on Abu Qir bay coastal zone. Beach erosion, saltwater incursion in groundwater would be increased, the ecosystem of Idku lagoon, and hence fish resources, would probably adjust to gradually changed conditions of salinity and water temperature. Changes in the salinity conditions of the coastal lagoons may lead to impacts on the ecology of Idku lagoon and fisheries. Strengthening shoreline defenses against beach erosion is an effective way to mitigate possible consequences of sea-level rise and land subsidence. Preserve the coastal dunes by fixation probably by water-tolerant plants and prohibiting sand quarrying as well. Other adaptive options include adapting new agricultural practices with improved efficiencies for using freshwater and developing salt-tolerant plants. The nonstructural adaptive responses could be landward retreat of areas of small populations to areas above 2 m contour and little investment to save localities may be the most effective and economic response to sea level rise particularly in vulnerable areas of high risk.

10. High Rates of Unemployment

The high rates of unemployment represent an important factor that exacerbates deterioration of the quality of environment in the region. It is important to develop work in SME to help alleviate this problem.

In general the following items represent major problems:
1) Literacy rates are high, especially for women. Access to safe drinking water and sanitation for the rural population is quite low in many areas.
2) Public social safety nets are generally quite weak in rural areas, a problem which is accentuated by the high variability in agricultural income from year to year, and which leaves a large fraction of the rural population vulnerable.
3) Regional solid waste management projects are virtually nonexistent.
4) Land and coastal degradation and desertification.
5) Urban, agricultural and industrial pollution and lack of planning.
6) Weak institutional and legal framework.

**Options of development and improvements**

Several important decisions are necessary for improvement of the situation in this region. These decisions include but not limited to:

1. Initiation of a large scale plan for development of this region based on integrated coastal zone management. Tourism and industry should be the core of this plan.
2. Identification of gaps of capabilities and needs of the community based on a detailed questionnaire analysis and field visits.
3. Building up of institutional capability on data collection, data transparency and dissemination to identify long time series indicators of performance.
4. Carrying out an intensive awareness program for upgrading of tourism capabilities in coordination with NGO.
5. Building up of a monitoring program for follow up and continuous assessment of performance and socioeconomic characteristics of the region.
2- Data basis

a. Building GIS

Preparation of Maps-Set:

Various scales were reviewed for checking the suitable one to the scale of the study. The scale 1:25000 was checked and it was found that the study area would fit in 15 maps of that scale, besides the excessive amount of details would cause confusion and interference between maps features while reading the map. More difficulties would be expected during further phases of manipulation and digitization.

The scale 1:50000 was found to be the most appropriate one for this study, as with its regional coverage, all necessary map features were obviously interpreted and coded. The study area was covered in 6 maps of this scale (as shown below in Figure 11).

![Fig 11 A map showing the map-set covering all limits of the study area in 6 maps of the scale 1:50000, with longitudes and latitudes.](image)

By reviewing the previous map, a thematic boundary map was derived that shows the study area (Figure 12) with all of its boundaries. It covers an area of 1338.223 km² (133822.3 Hectare) with an overall perimeter of 191.383 km.
As shown in the previous map, the study area of “Abu Qir Bay” is bounded from the north with the Abu Qir Bay (Mediterranean Sea), the “Mahmoudia” Canal from the south, a cut-off of the urban fabric of Alexandria city from the west, and a narrow zone past the River Nile from the east. Three Governorates are involved in the study area. Alexandria Governorate with an area of 91.04 km², Beheira Governorate with an area of 1058.69 km², and Kafr El-Sheikh Governorate with an area of 168.73 km².

The main natural geographic features that exist in the study area are:
- The Mediterranean Sea coast to the north, expressed in “Abu Qir Bay”
- The river Nile (Rosetta branch) to the east
- The “Mahmoudia” Canal to the south
- Lake Edku centered in the study area and having an approximate area of 129.273 km²

b. The Geographic Base of the GIS:

1. Base Map Preparation

A mosaic was prepared for photo-scanning by a flat bet scanner in several slices to fit with the geometrical size of the scanner. Using the Corel PhotoPaint software, all slices were aggregated and stitched altogether to form the main geographic reference on which the GIS intended to be built relies.

2. Scaling

A vector depending software was used for the purpose of digitizing the map features. AutoCAD software was used for this purpose for its high digitization capabilities. The previous master map was appended as an image inside the AutoCAD drafting environment, scaled so that its borders translate the real dimensions of the

Fig. 12 The geometrical shape of the study area, showing its natural boundaries and Governorates limits.
study area. Thus the measurement units support the user with real distance values, and hence the geographic base map was ready to be generated.

3. Digitization

The Geographic base of the GIS will be expressing the spatial format of data in the GIS under construction. Each map entity is pointing to (or expressing) a feature in the study area, illustrated by the drafting means (polygons - lines- points), and encoding means (thickness – appearance with colors or hatching).

By examining the map components, it was found that it would be more efficient if all components would be classified into certain categories or classes for main graphic entities: polygons, lines, and points, as shown in Table 8. The table also shows the number of digitized graphic entities of the study maps-set.

Table (8): A table showing the database design for map components and layers configuration

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<th>Layer</th>
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Each of these categories covers a certain group of map features, for example: water bodies, roads, canals, drains, urban spots, etc., so that each category contains several sub-components (classes) of that particular category. Table 1 also shows the main idea of database design, and the layers configuration as the basis of the GIS under construction.

4. Graphic Formats

It is an important issue - in this phase – to take into consideration the assignment of all graphic entities to the graphic formats recognized by the GIS software to be used later. In other words, all graphic entities digitized from the base map should be assigned to one of three main formats: polygons, lines, or points.

For example urban clusters can be assigned to the polygon format, while a transportation road can be assigned to the line format (for its linearity), and a well or an urban landmark can be assigned to the point format.

5. Updating and Verification of Spatial Data

The utilized maps-set was surveyed, edited and revised in 1993. Thus, it was necessary to identify the main alterations that took place between that year and the present one. Two methods were applied for this task; the remotely sensed satellite imagery and the ground truth revision field trips.

Examples of the geo-database in arc/map are shown in figures (13 and 14)
Figure 13: Creating and Management of Geo-database in Arc/Map.

Figure 14: Management the Geo-database using ArcCatalog
c. Remote Sensing Data Analysis

1. R.S. Satellite Imagery

Several satellite images were used as a reference data source (which is an important application of remote sensing techniques in building Geographic Information Systems). Images (shown in plates 1, 2, and 3) of different types and dates were acquired, like:

Plate 1 A Panchromatic Spot image of 10 meters resolution dated 2002.

Plate 2 A Thematic Mapper image of 30 meters resolution dated 2000.

Plate 3 A false color composite of the previous image.

Images were subjected to geometric corrections for: shift, skew, and scaling to the utilized study scale. Then the images were entered separately as different layers in the drafting system, with exact registration and matched superimposition with all digitized graphic entities. By displaying each image together with all graphic entities, it was possible to identify the changes and the variations that took place between 1993 and the date of the satellite image.

2. Field Trips for Ground Truth Revision and Verification

For the sake of increased precision and truth reliability of the digitized maps, the research consultancy team has undergone two field trips covering the study area through all its main sectors that cover the majority of all available diversity of land cover, and urban land uses.

The first field trip was carried on the 26\textsuperscript{th} of January 2003, from 8:00 to 17:00, and has got the following surveying path shown in figure 15. It emphasized the surveying and investigation of the Northern part of the study area, from Alexandria to the Western parts of “Kafr El-Sheikh” Governorate.
The second field trip was carried on the 14th of August 2003, from 8:00 to 17:00, and has got the following surveying path shown in figure 16. It emphasized the surveying and investigation of the Southern part of the study area, from Alexandria to the western parts of Kafr El-Sheikh Governorate, and then returning through the northern part again.

3. Photographic Documentation of Land Features

These trips aimed to compare the present real situation with the digitized base map, and thus identifying all differences and non-matching points and features. Photographs were taken to the main land features of interest that have got any relation to the study issues and procedures.

The following plates show a variety of photographs taken in the study area, with a key map (Figure 17) that shows the location and the target of the taken photograph.

---

**Fig 16.** The path of the second field trip covers most of the northern, middle and southern sectors of the study area.

**Fig 17** Final plots for all GIS layers showing digitized land features and acting as a key map for the following photographs
Photograph 1-12. Photographs taken during the second field trip, showing the main features characterizing the land cover.

P.1

An old building used as a storage place

P.2

Aquaculture ponds

P.3

Fish culture, in culturing ponds

P.4

The barrage of Edfina city, that controls the flow of the river water to the estuary
A public park in Motoubess city (Kefr El-Sheikh governorate)

El-Geddeya Bridge (to the South of Rosetta city) crossing the Nile

Palm trees land cover distributed in various locations at the study area

Water logging and salt precipitation, in various places near the seashore
4. Color Coding and Further GIS Steps

Each coverage is coded with a selectable colour for visual differentiation, and suitability to other coverages. Features shown in figure 13 are in the line format. Further procedures for building the GIS are transforming the area features to the polygon format, and hence, it would be possible to go on through the analytic stage of the GIS.

Acquired alphanumeric data relevant to the digitised features are entered as well through the table module usually used in GIS software. By the completion of that phase, a live linkage between the spatial and aspatial format of data would be
maintained and the GIS would be ready for the analytic phase, and also for the conditional data retrieval.

d. Land Cover/ Land use analysis using satellite images

Rosetta zone (Rosetta-Idku area) is considered a promising virgin area for future development. It possesses a number of important resources such as the coastal-landscaping view, relatively low population density, extension of wetland, and neighborhood to historic sites of Rosetta and Alexandria cities. In addition, the existence of wide varieties of water bodies environments including the Mediterranean Sea, Nile River and Idku lagoon.

Due to increased pressures on natural resources and the rapid land cover land use changes, it has been decided to monitor and study this area in depth. Site selection of infrastructure, facilities requires, collection, storing, analyzing and presenting in spatial terms large amounts of environmental and social data needed to decide on locations that will cause minimum environmental harm, and promote growth and development. This aspect lends itself to the use of satellite images processing as a modern tool that can organize and analyze sizable amounts of spatially referenced data.

A SPOT image covering the study area was processed. The satellite image has a spatial resolution of 20 meters; its date of acquisition was August 16, 1995. The SPOT image consists of three spectral bands covering the visible and near infrared spectral regions. The image was geometrically corrected using both topographic maps sets of scale 1:15000 and the GPS reading during field survey. Twenty-eight ground control points were chosen carefully and checked in the field for either the registration and rectification or the further processes like accuracy assessment. The final registration accuracy was tested and found to be acceptable.

Then the SPOT image is displayed and visually analyzed. Visual interpretation was based on the prior information obtained during the first trips to explore the region identified the extension of different land cover classes in the area. The images of the three spectral bands are combined together in the false color composite (band 1, band 2 and band 3 as Red, Green and blue respectively) as shown in Figure (11). Different land cover classes appear in different color codes according to their spectral signatures represented by tonal variations in the three raw spectral images. In spite of being false colors, it represent standard colors, i.e. the red color areas represent the vegetation, the grey colors represent urban, the blue represent the water masses, . . .etc.

Unsupervised cluster analysis is carried out to classify the image into various classes according the difference among their spectral characteristics; it represents the natural clustering of the pixels around its mean (i.e. it needs neither prior information of the area nor high experience). The unsupervised classification then provided a preliminary legend for different land cover classes present in the study area. Various classes of land, water masses, urban zones, bare soil, and vegetation types are identified and displayed in the unsupervised classified image.

A number of field visits are carried out to the study area for ground truth observations. Different locations are identified in the image and their land use
determined covers are checked in the field for verification using Ground Positioning System (GPS-Garmin).

Ground truth observations helped the selection of training areas to carry out the supervised classification and assessment of the accuracy of classification. A supervised classification analysis is carried out according to standard CORINE classification scheme, (Eunis, 2002) by using Maximum Likelihood technique and the training areas identified in the field.

There are 9 separate classes obtained from the supervised classification of the satellite image, these layers are:

1. Discontinuous urban fabric
2. Road and rail networks and associated land
3. Permanently irrigated land
4. Fruit trees
5. Complex cultivation patterns
6. Beaches, dunes, and sand plains
7. Inland marshes
8. Salt marshes
9. Water courses

The resulted supervised classification image of the nine-land cover classes is presented in Figure (18). As for 1995 scene, all images were obtained by supervised classification using not only first level CORINE scheme but also level 2 classifications. Figure (19) represents supervised classification image of 2004 scene (second level).
Changes of Land cover pattern in the region

Since the building of Aswan High Dam (1964) in southern Egypt, an imbalance between the two major forces affecting the shore (land loss and gain) has occurred. As a result of this, a strong decrease in the amount of sediments accreted the amount of sediments decrease from 120 million tons per year to only a trace amount (Frihy, 1988). These have caused significant and rapid changes along the shore of the northwest Nile Delta coast. These rapid shoreline changes could create catastrophic physical, biological and socio-economic problems.

The ratio of river sediments discharge into the Mediterranean to those lost by the different environmental factors is playing the major role in the advance or retreat of the coastal region of the Delta. Recently, this ratio is sufficiently large due to the large quantities of sediments discharged into the Mediterranean annually (estimated to be more than 120 x 106 tons/year) (Hammad et al., 1979). This large amount of annually discharged sediments built up the central hump of the Delta at Brullus and the two promontories at Rosetta and Damietta (Sestini, 1976).

In this section the procedures of extracting land cover maps from satellite images will be discussed in details. Also, the change detection analysis and techniques using

Figure (18): Supervised 2nd level CORINE classified image

Figure (19): Supervised classified image of 2004 Scene (CORINE 2nd Level)
multi-date multi-sensor satellite images will be discussed as well. As a result of the change detection analysis of the satellite images a time series analysis of the different land cover classes will be achieved and analyzed.

**Data availability:**

The data used through this study collected from different sources, it consists of satellite images with different types of sensors and in different dates, topographic maps, and field survey measurements

1. **Satellite images:**

Four multispectral satellite images were selected in five different dates. The date span was select to be five years. The five satellite images used in this study are summarized in the next table:

<table>
<thead>
<tr>
<th>Satellite Name</th>
<th>Sensor</th>
<th>No. of Spectral bands</th>
<th>Spatial resolution</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDSAT MSS</td>
<td>Four</td>
<td>80 meter</td>
<td>1985</td>
<td></td>
</tr>
<tr>
<td>LANDSAT MSS</td>
<td>Four</td>
<td>80 meter</td>
<td>1990</td>
<td></td>
</tr>
<tr>
<td>SPOT HRV</td>
<td>Three</td>
<td>20 meter</td>
<td>1995</td>
<td></td>
</tr>
<tr>
<td>LANDSAT TM</td>
<td>Seven</td>
<td>30 meter</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>LANDSAT ETM</td>
<td>Seven</td>
<td>15 meter</td>
<td>2004</td>
<td></td>
</tr>
</tbody>
</table>

2. **Topographic maps:**

Six topographic maps were used in the study, they were produced by Military Survey Department; Ministry of Defense. They cover 1.Kafr El-Dawar, 2.Damanhour, 3.Dessouk 4.Abu Qir, 5.Rosetta, and 6.Edfina. The scale of those maps is 1:50,000.

3. **Field survey:**

A number of field visits were done in addition the information collected from the previous field visits to the study area in the 80’s and 90’s period. The objectives of these field visits were to collect in situ data about land cover classes description and to define ground control points (GCPs) for georeference processes. Also, during the several field visits the team identifies the various problems facing the study area and the local people’s activities. As examples for those problems:

1. Coastal erosion; that is considered as the major problem in the area, thus there are several ways to protect the coast from the action of sea waves and currents, like the next two photos.
2. Open solid waste dumpsites: in this region there is no sanitary landfill site for the solid wastes. All the wastes are dumped on the vacant areas which would impact tourism negatively.

**Change Detection Assessment:**

Changes occurring on the earth's surface can generally be attributed to either natural or anthropogenic forces. Natural changes relate to both seasonal and annual variations in climatic conditions, and are often reflected by variations in natural land cover. The impacts of human-induced change are not necessarily restricted to areas where intentional modification of the landscape has taken place (Pilon et al., 1988). The change detection procedures assume that a change in surface cover or surface
material will produce a corresponding change in the reflectance of the study area. For example, a weathering event in the coastal system may produce fresh erosional and depositional surfaces. New surfaces will consequently be picked out as areas of increased reflectance between different dates because weathered material in arid environment has a characteristically lower reflectance than fresh material. Also, change appears when a certain land cover is changed to another one, as in water logging problems; the “water courses” class replace the original classes present originally in the same spot such as “Salt marshes” class or “Beaches, dunes, and sand plains” class.

As we mentioned before, the change detection analysis is carried out between 1990 and 2004 with periods of spans of about 5 years each.

1- Land Cover Changes between Year 1990 and 2000:

In order to assess the changes in land covers occurred within five years periods (1990-1995-2000), three satellite images were used, Landsat TM-1990, SPOT-HRV, 1995 and LANDSAT-TM, 2000. A change detection analysis of classified images was carried out and tables of area coverage of each land cover were obtained for each 5 years interval.

To visualize the changes occurred over the period between year 1995 and year 2000, for instance for each separate land cover, a simple technique is used. It is summarized as follows:

1. For each land cover class, a re-coding process was applied on the basis of giving that class a value “2” for the older date (year 1995) and value “3” in newer one (year 2000), while giving other classes and background a value “1” for both years.

2. Multiplying the two re-coded images, change detection image for that land cover class is created. This image has four main classes:
   a) Lost areas (appears in red colors) from 1990 to 2000, which have a value “2” (i.e. 2*1);
   b) No changes areas (Blue color), which has a value “6” (i.e. 2*3);
   c) Gained areas from 1995 to 2000 (appears in Green colors), which has a value “3” (i.e. 3*1);
   d) Other classes and background (appears in Yellow color), which have a value “1” (i.e. 1*1).

All previous steps are repeated to create a final change image for each land cover class, representing areas of change (either positive or negative) and no change. The final change detection images resulted of each land cover classes are shown in the Figures (20 to 23)
Figure (20): Changes in “Annual crops associated with permanent crops” class
Figure (21): Changes in “Beaches, Dunes, and Sand plains” class

Figure (22): Changes in “Discontinuous urban fabric” class
Figure (23): Changes in “Fruit trees and Palm” class

By comparing the statistics obtained from the three images of 1990, 1995 and 2000, two tables (table 9 and table 10) were obtained expressing changes occurred of each land cover class measured in km² and percentage of initial land cover in 1990 over the periods (1990-1995) and (1995-2000), respectively.

Table (9): Changes occurred between years 1990 and 1995 (in km²)

<table>
<thead>
<tr>
<th>Class</th>
<th>1990 Area</th>
<th>1995 Area</th>
<th>Change in Area (km²)</th>
<th>Change% from original Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Courses</td>
<td>576.60</td>
<td>572.34</td>
<td>-4.26</td>
<td>-0.74</td>
</tr>
<tr>
<td>Natural Grassland</td>
<td>23.21</td>
<td>15.02</td>
<td>-8.19</td>
<td>-35.30</td>
</tr>
<tr>
<td>Salt Marshes</td>
<td>80.70</td>
<td>63.97</td>
<td>-16.73</td>
<td>-20.73</td>
</tr>
<tr>
<td>Permanently Irrigated Land</td>
<td>75.85</td>
<td>49.04</td>
<td>-26.81</td>
<td>-35.34</td>
</tr>
<tr>
<td>Beaches, Dunes, and Sand Plains</td>
<td>52.73</td>
<td>52.02</td>
<td>-0.71</td>
<td>-1.34</td>
</tr>
<tr>
<td>Complex Cultivation Patterns</td>
<td>95.89</td>
<td>117.05</td>
<td>21.16</td>
<td>22.07</td>
</tr>
<tr>
<td>Annual Crops Associated with Permanent Crops</td>
<td>145.07</td>
<td>188.88</td>
<td>43.81</td>
<td>30.20</td>
</tr>
<tr>
<td>Fruit Trees and Palms</td>
<td>133.31</td>
<td>109.89</td>
<td>-23.42</td>
<td>-17.57</td>
</tr>
<tr>
<td>Discontinuous Urban Fabric</td>
<td>52.25</td>
<td>47.67</td>
<td>-4.58</td>
<td>-8.77</td>
</tr>
</tbody>
</table>
It is noticed that drastic changes in land cover are detected natural grassland, fruit and palm trees and in discontinuous urban Fabrics

**Coastal changes between 1990 and 2004:**

Coastal, near shore and offshore areas represent some of the most difficult areas in which to conduct accurate geologic and geomorphic mapping. Along many coasts, the coastline is continuously changing because of the combination of natural forces and man-made modifications. Under such dynamic conditions, topographic base maps are often out of date. Moreover, many of the world's coastal areas and shallow seas have never been properly mapped and even when dynamic changes are absent, accurate maps or charts simply do not exist.

Historical photographs, charts, and maps can provide a general picture of changes. These charts, although quite accurate, have two principal limitations when detailed monitoring of historical changes is desired: the first is that charts are not sufficiently detailed to allow for a thorough analysis of changes in environment; the second is that charts are normally produced at large intervals (40-50 years are common). Hence, careful understanding and interpretation of short-term physical changes and morphological responses is not possible with this type of data. Satellite images became an especially important tool for the field oceanography, because such image data are generally more current than available base maps.

Thus, remote sensing can provide a unique data set for application to each type of approaches, often providing key information for management decisions. This is particularly true for dynamic landforms, such as the barrier islands and spits, because

<table>
<thead>
<tr>
<th>Class</th>
<th>1995 Area</th>
<th>2000 Area</th>
<th>Change in Area (km²)</th>
<th>Change% from original Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Courses</td>
<td>572.336</td>
<td>580.37</td>
<td>8.0335</td>
<td>+1.4</td>
</tr>
<tr>
<td>Natural Grassland</td>
<td>15.02</td>
<td>39.44</td>
<td>24.4243</td>
<td>+ 162.6</td>
</tr>
<tr>
<td>Salt Marshes</td>
<td>63.97</td>
<td>79.54</td>
<td>15.5738</td>
<td>+24.3</td>
</tr>
<tr>
<td>Permanently Irrigated Land</td>
<td>49.04</td>
<td>62.58</td>
<td>13.5403</td>
<td>+27.7</td>
</tr>
<tr>
<td>Beaches, Dunes, and Sand Plains</td>
<td>52.02</td>
<td>60.54</td>
<td>8.5239</td>
<td>+16.3</td>
</tr>
<tr>
<td>Complex Cultivation Patterns</td>
<td>117.05</td>
<td>114.63</td>
<td>-2.4198</td>
<td>- 2.06</td>
</tr>
<tr>
<td>Annual Crops Associated with Permanent Crops</td>
<td>188.88</td>
<td>189.52</td>
<td>0.6423</td>
<td>+0.34</td>
</tr>
<tr>
<td>Fruit Trees and Palms</td>
<td>109.89</td>
<td>43.198</td>
<td>-66.6918</td>
<td>-60.7</td>
</tr>
<tr>
<td>Discontinuous Urban Fabric</td>
<td>47.668</td>
<td>58.78</td>
<td>11.1119</td>
<td>+23.6</td>
</tr>
</tbody>
</table>
satellites, particularly LANDSAT with its high spatial and spectral resolution. LANDSAT (ETM) has nine spectral bands with spatial resolution of 14 meters) can provide repetitive synoptic relatively low cost information source.

In order to assess coastal changes of the study area in the period from year 1990 to year 2004 (1990, 1995, 2000, and 2004), a specific scheme was used and it could be described as follows:

1. Each image was unsupervised classified into 120 clusters,
2. All the clusters were compared among their spectral signature to union all the water bodies classes into only one class called “Water”,
3. On the other hand all other classes were overlapped to produce one class represent all the terrestrial areas, that class named “Land”,
4. Both classes were overlapped to build a binary-like image (which has only two single values) as in Figure 24,
5. Specific values were assigned to the two classes, the following table represent the values assigned to the two classes:

<table>
<thead>
<tr>
<th>Image Year</th>
<th>Assigned Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water Class</td>
</tr>
<tr>
<td>1990</td>
<td>1</td>
</tr>
<tr>
<td>1995</td>
<td>3</td>
</tr>
<tr>
<td>2000</td>
<td>9</td>
</tr>
<tr>
<td>2004</td>
<td>11</td>
</tr>
</tbody>
</table>
Changes were calculated by two steps, first the changes between year 1990 and 1995 then the changes between year 2000 and year 2004.

To calculate changes between years 1990 and 1995, both images were arithmetically added. The resulted image has eight different values each of them represent specific information. The following table represents the resulted eight different values and what each value represents:

<table>
<thead>
<tr>
<th>Value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Represent</td>
<td>Water</td>
<td>Land</td>
<td>Water</td>
<td>Water</td>
<td>Land Loss</td>
<td>Land</td>
<td>Land Gain</td>
<td>Land</td>
</tr>
</tbody>
</table>

The resulted image was recoded into only four classes by combining values 1, 3, and 4 into one class which has a value “1” and entitled “Water Bodies”; values 2, 6, and 8 into one class which has a value “2” and its name is “Land Classes”; while the third class represents the “Land Loss” and has a value “3”; and finally, the fourth class 7 is assigned to value “4” and represents “Land Gain”, as in Figure 25.
Figure (25): Changes occurred between year 1990 and year 1995.

As mentioned earlier, to calculate the changes between years 2000 and 2004, both images were arithmetically added. The resulted image has eight different values each of them represent a specific information. The following table represents the resulted eight different values and associated classes:

<table>
<thead>
<tr>
<th>Value</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>1</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Represent</td>
<td>Water</td>
<td>Land</td>
<td>Water</td>
<td>Land</td>
<td>Water</td>
<td>Land Loss</td>
<td>Land Gain</td>
<td>Land</td>
</tr>
</tbody>
</table>

The resulted image was recoded into only four classes by combining values 9, 11, and 20 into one class has a value “5” and its name is “Water Bodies”; values 10, 13, and 23 into one class has a value “10” and its name is “Land Classes”; while the third class represents “Land Loss” and has a value “21”; finally, the fourth class 23 is assigned to value “20” and represents “Land Gain”, as in Figure 26.
The next table concludes the two previous steps and illustrates the values of the two resulted images:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Represent</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Water</td>
<td>Land</td>
<td>Land Loss</td>
</tr>
</tbody>
</table>

Both resulted images were then arithmetically added together as the previous way, the resulted image describes changes starting from year 1990, through years 1995, and 2000, and finally to year 2004. That image contains a 24 values representing different themes. That image could be represented in three different ways, first only Land Loss classes could be collected in an image of Land Loss history during the whole period, as illustrated in Figure (27). Second, the Land Gain history could be summarized in Figure (28).

The changes occurred between year 1995 and years 2000 were also estimated by the same way of the two periods (1990-1995, and 2000-2004), Figure (29) illustrates that changes.

Figure (29): Changes occurred between year 1995 and year 2000.

Finally, the total changes image could also be extracted from all the previous results. That image illustrates the cumulated Land Loss and Land Gain areas over the whole period (Figure 30).
According to the previous results of coastal changes (those changes that occurred at the Mediterranean coast and those changes occur around the internal wetlands like Edku lake), interpretation of the changes in terms of land use changes and activities in the region are necessary.

Third Level Corine Classification and Analysis

All classified images (acquired at different dates) illustrated earlier in the report were supervised classified using digital image classification techniques (ERDAS IMAGINE), with information about the study area from previous field surveys during the period of satellite image acquisition dates. In order to produce land cover maps with higher CORINE classification level, satellite images available have a maximum capability to do that. The higher CORINE level requires higher spatial resolution of satellite images used.

Satellite images that need to be supervised classified with CORINE first level of classification needs a satellite image sensor with a suitable spatial resolution i.e. the most suitable satellite images of the available data are the LANDSAT satellite image of the sensor MSS, TM, and ETM with spatial resolution 80, 30, and 14.25 meters respectively, Also SPOT image with 20 meters spatial resolution is suitable for that purpose.

Figure (30): Total changes from 1990 to 2004
Classification of satellite images with CORINE second level of classification needs a satellite image with spatial resolution better than 20 meters, i.e. the most suitable satellite image of the available data is the LANDSAT satellite image of the sensor ETM (the year 2004 scene) with spatial resolution 14.25 meters (after sensor merging process).

The LANDSAT ETM image dated 2004, was supervised classified with 1st Level of CORINE, as illustrated in figure (33), then it was classified using the 2nd level with more field data and observations. Figure (34) illustrates the supervised classification result of the year 2004 LANDSAT ETM image.

Figure (33): Supervised Classification of 2004 Scene according to 1st Level of CORINE Land Cover Scheme
Figure (34): Supervised Classification of 2004 Scene according to 2nd Level of CORINE Land Cover
In order to produce land cover map for the study area with CORINE 3\textsuperscript{rd} level classification, a combination of databases collected from several field surveys is needed. That was achieved by converting the supervised classification image of year 2004 from raster format into vector format (ARCVIEW format). Using GIS techniques, the converted classified image was separated into 11 GIS layer (the 11 classes of the CORINE 2\textsuperscript{nd} level). In each GIS layer all pixels were examined using GPS on the field (detailed field studies). A lot of changes have been done to the pixels in the vector layers.

Five figures representing the main five categories of land covers according to CORINE classification scheme:

1. Built-up areas
2. Agricultural areas
3. Forest and natural areas
4. Wetland and salt marshes
5. Water

Figures (35 through 39) illustrate the main five categories.

Finally, the 3\textsuperscript{rd} level CORINE classification image for 2004 scene was created by overlapping the five categories (main classes) GIS layers, as in Figure (40), while the detailed legend for that image will be presented separately due to the large number of items used.
Figure (35): “Built-up Areas” category

Figure (36): “Agricultural areas” category
Figure (37): “Forest and natural areas” category

Figure (38): “Wetland and salt marshes” category
Figure (39): “Forest and natural areas” category
I- Built-up Areas
1. Continuous urban fabric
   - Residential buildings of City and Town centers
2. Discontinuous urban fabric
   - Residential buildings of Villages and Urban Peripheries
3. Industrial or commercial units
   - Urban and suburban Factories
4. Construction sites
   - Low density buildings
   - Rural construction and demolition sites

II- Agricultural Areas
1. Permanently irrigated land
   - Arabale land and market gardens
2. Complex cultivation pattern
   - Intensive unmixed crops
   - Small-scale intensive unmixed crops

III- Forest and Natural Areas
1. Natural grassland
   - Mediterranean tall humid grassland
2. Beaches, dunes, and sand plains
   - Coastal dunes and sand habitats
3. Sparsely vegetated areas
   - Miscellaneous inland habitats with very sparse or no vegetation

IV- Wetland and Salt Marshes
1. Inland marshes
   - Inland wetland
   - Coastal wetland
2. Salt marshes
   - Coastal salt marshes and saline reedbeds

V- Water
1. Water bodies
   - Surface standing waters
2. Coastal lagoons
   - Brackish coastal lagoons
3. Estuaries
   - Surface running waters
Conclusion of change detection Analysis

Recent results of the analysis of satellite images change detection as integrated with earlier results (El Raey et al, 1995) have revealed the following:

1. A strong component of erosion and accretion along the coast and particularly at the promontory has been in operation at a high rate until 1990. It is still in operation at a slower rate in 2004 and waterlogged areas still appear in low elevation areas

2. The loss of fruit and palm trees class has started earlier than 1990 and continued throughout the period and has reached its highest rate in 1995-2000. Socioeconomic consideration of such activity as well as its potential implications has to be thoroughly investigated.

3. The large increase in natural grass land in the area may be associated with the establishment of the international road and the drive of people to establish ownership of the land through fake cultivation. This has to be also investigated through direct contacts with stakeholders.

4. A serious increase in the rate of changes in discontinuous urban fabric has also been observed over the same period indicating socioeconomic pressures and shortage of law enforcement capabilities.

Environmental Sensitivity

Different land use patterns are shown in the strip of Abu Qir Bay; including agricultural, industrial, cultural and residential uses. Unfortunately, these patterns are often environmentally insensitive in a variety of different ways. They generally require more maintenance, chemical fertilizers and pesticides, supplemental irrigation to achieve the desired aesthetic effect, and produce different emissions. These practices can contribute to a number of current environmental problems, from air and water pollution to social and economic issues.

Environmental sensitivity is an approach to understand how could uses be involved in the environmental deterioration in the Abu Qir Bay area. Environmental sensitivity has a number of applications in land-use planning and other forms of development. It may be used both to aid, and explain decision-making. It can form part of the Strategic Environmental Assessment process and, more specifically, can be used in the environmental appraisal of plans and policies for aggregates provision (Niva, 2005). In the following the methodology and results of studying environmental sensitivity are described.

Methodology

Environmental sensitivity mapping provides a strategic overview of the environmental situation and the ability to development in a region. It is a technique that was developed to integrate numerous datasets into a single composite layer in a GIS (RPI, 2005). Environmental sensitivity analysis is based on the number of environmental spatial phenomenon. To model the environmental sensitivity spatially, a simple model includes four components are proposed. These components are:

1. Source.
2. Receptor.
3. Distance between the source and receptor.

4. Weight of environmental risk produced by source.

Considering $s_1, s_2, s_3 \ldots$ are different environmental risk resources. These sources influenced in receptor $R$ by different weight $w_1, w_2, w_3 \ldots$. The distance between $R$ and $s_1, s_2, s_3 \ldots$ are $d_1, d_2, d_3 \ldots$. The total sensitivity for $R$ is calculated as the following:

$$ES = \sum_i \left( \frac{w_i}{d_i} \right)$$

The environmental sensitivity layer was created using raster approach. The Raster approach enables generalization of the original data and analysis in the GIS. The size of the grid is very important. The method was developed using a one hectare grid size.

**Environmental Sensitivity Criteria**

For this project, five environmental sources were identified by the project team. The following table lists the criteria of these sources and their associated weights as a measure of environmental sensitivity. 100 points are distributed among these items, the more the points the higher the importance and the more weight that is given to that item in the analysis. The summation of points is re-calibrated to 10.

<table>
<thead>
<tr>
<th>Source</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Land</td>
<td>0.4</td>
</tr>
<tr>
<td>Population</td>
<td>0.7</td>
</tr>
<tr>
<td>Coastal strip exposed to SLR</td>
<td>1.4</td>
</tr>
<tr>
<td>Drainage System</td>
<td>2.9</td>
</tr>
<tr>
<td>Large Industrial Complex</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Two notes should be mentioned here, the first that the impact of SLR is limited to that lands have elevation less than 3 m.

**Modeling Environmental Sensitivity**

Using ArcGIS 9.0 and Spatial Analyst extension, a simple procedure is designed and implemented for mapping the environmental sensitivity in the area of Abu Qir Bay. The following diagram shows this procedure.
Results of sensitivity analysis

The result is raster layer, every pixel in this layer has a digital number, and this digital number denotes the environmental sensitivity in this pixel. Figure 41 shows the environmental sensitivity in the area categorized in five classes; very low, low, moderate, high, and very high sensitive.
Figure 41. Classified Environmental Sensitivity map
Questionnaire

From analysis of satellite images and ground based observations, it was realized that several important environmental problems have been identified in the study area. These problems were associated with various human activities. It was considered very important to contact stakeholders in the region in order to identify and assess sources of these problems and to upgrade environmental awareness of stakeholders. A questionnaire was prepared by the team and a plan for administration of the questionnaire was carried out according to the following steps:

1. **Preparation step:**

   Several round table meetings were carried out with SMART project team members to discuss issues and main goals of the questionnaire ended by reaching a final questionnaire form (Appendix 1). Identification of main problems of changes that may be revealed through analysis of questionnaires, such as losses of palm trees, soil removal activities and options for further development were identified.

2. **Contacting NGO’s:**

   The SMART team decided that the questionnaire should be administered through a specialized NGO in that field, because of their intimate correspondence with the local community and their experience in the field studies. The team selected the Arab Association of Environmental Experts (AAEE), which is a NGO operating in Alexandria and adjacent region to do that.

   Several meetings between SMART team members and AAEE team members were carried out to illustrate objectives of the study, main ideas and to stress the need to exchange information with local community and local decision makers during direct person-to-person contact to upgrade awareness and collect their opinion on environmental problems in the area and their interests of development. Ten members of AAEE were selected to carry out questionnaires and they were given condensed orientation towards the problem.

3. **Field trips:**

   Both SMART and AAEE members visited the study area for completing the work. The area was divided into four main sub zones according to the major stakeholders in each sub zone. Each sub zone was covered by a team supervised by a well-qualified person who has high experience in the main activity in that sub-zone.

   1. Sub zone “A”: representing the coastal areas and the main stakeholders are fishermen, low percentage of farmers and some inhabitants. Fishermen of Lake Idku belong to this zone.

   2. Sub zone “B”: represents residential areas (inside Rosetta City), the stakeholders are mainly workers, decision makers, local peoples, students and others.
3. Sub zone “C”: represents the urban fringes of Rosetta City (south direction), Rosetta aquaculture farms and agriculture areas. The stakeholders representing this sub-zone are fishermen and aquaculture farms owners and workers as well as farmers.

4. Sub zone “D”: represents the new industrial zone on the Mediterranean coast and the coastal zone farmers. The stakeholders representing this sub-zone are mainly industrial field workers (engineers, laborers, etc); and some farmers. For example if the main stakeholder are fishermen the team will included one or two educated fishermen who speak their language and break barriers that are usually present between simple low educated peoples and others.

Figure 3: Main sub zones of field trips of the Questionnaire

During the field trips to the area, the stakeholders were in contact with the team. The discussions were extended and faithful and the results were in some times un-expected. The following series of photos illustrate the contact between the team and different stakeholders.
Oil Industry worker (stakeholder) during discussing with team member.
Farmers Stakeholder

Local inhabitants Stakeholder
Workers and students Stakeholders
After completing the questionnaire, team members got together to discuss and analyze results obtained from various sub zones and stakeholders. Some conclusions were reached directly during the contact with stakeholders, such as:

Most of “farmers” stakeholders suffer from the un-fair prices of their products such as palms, tomatoes, and vegetables. They have to destroy their harvest by their own hands to reduce costs that became higher than the benefits. This is a very serious problem because it affects the palm trees in the region dramatically. In the last few years, farmers used to cut the growing top of the palm in order to kill it for three reasons: (1) to reduce the amount of palms, so the prices of it increases (this is their idea), (2) to make spaces in the field to cultivate fruits that give higher prices instead of palms and 3) to sell palm trees by exporting it outside the region and the country as well. Next photos represent the organized cutting process of the palm trees. All those three reasons if kept with their percentages will destroy the palm trees in whole region that is characterized by most precious palm species in whole Egyptian lands.
Open spaces among palms cultivated with other fruits underneath

Killing of palm trees
The earlier conclusion reached by agriculture experts (REF) that the dramatic decrease of palm trees in the region was due to a specific disease affecting the palm trees, in our opinion is false. The next photo proves that conclusion.
Analysis and interpretation of the results questionnaire analysis have revealed that:

1. The dramatic decrease of palm trees in the region was mainly due to frustrated activities of stakeholders and not due to a specific disease affecting the palm trees. Infected trees represent a very small percentage of the problem if they exist at all.

2. The local peoples and fishermen stakeholders are not well satisfied with projects in their area that do not provide their children with job opportunities. Their priorities for development include infrastructure, industry, tourism and fishing industries as it provides more jobs to their children.

3. The decision makers – as usual – blame other stakeholders of their low environmental awareness and education.

4. All of the stakeholders could be patient for the improvements to their environment if there are some signs of improvement.
5. The tourism skills and marketing (even for their already existing products) are absent from most of stakeholders and they need a specific program for raising their awareness concerning tourism and marketing of resources.

6. Most of the stakeholders notice that further environmental problems appeared in the last few years such as coastal erosion and excessive soil salinization. Most of them wait for the Governorate to fix those problems with help of foreign investors.

7. The role of NGO is very limited due to severe shortage of funds and many administrative problems for action.
3. Model Application

A-Telemac Model application

Brief area description

The Abu Qir bay lies between 31.27-31.47°N and 30.07-30.33°E, with a maximum depth of 30 m and water volume of 4.3x10⁹ m³. The area of the bay is about 430 km². It receives a substantial load of pollution from the various land-based activities surrounding it and from the River Nile drainage and Lake Edku inlet (Figs. 1).

Figure 1. Study area of Abu Qir bay showing main features including drains, canals, Lake Idku and Rosetta branch of the River Nile. The position of the wave gauge is also indicated.
Characteristics of the studied area

The most recent bathymetric survey was carried out in 1986 by the Shore Protection Authority (SPA) (Frihy et al., 1991). The survey map has a scale of 1:100,000, with average survey soundings every 500m. This map has been converted to digital format as seen in the attached AutoCAD Bathymetry file (Fig. 2), contours in meters. The shoreline is updated to 2000 using land survey.

Wave regime was statistically analyzed based on wave records at Abu Qir Bay (west of Rosetta promontory) (see Fig.1 for the wave gauge location). Waves were measured using a Cassette Acquisition System directional wave recorder (CAS) over 13 months between 1988 and 1990. The system is a portable, self-contained remote recording system for sensing waves and wave-induced currents (Boyd and Lowe, 1985). The wave gauge was installed about 18 km offshore and in 16 m water depth. The gauge was mounted about 5m below the mean sea level, and 10m above the seabed. Wave data are recorded for 34 minutes every 6 hours per day (Frihy et al., 2003).

The coastline of the Nile delta is typical of micro tidal semi-diurnal nature. Recorded daily water level variations measured from the mean sea level in the study area reveal high-high and low-low water level of 37cm and –38cm, respectively, with a tidal range of 75cm (Fanos et al., 1991).

Water quality issues

The pollution inputs in the bay are from two main sources:
a) **El Tabia Pumping Station (TPS)**, in the south-east part of the bay with about $2 \times 10^6$ m$^3$ day$^{-1}$ discharging capacity. It was estimated that about $730 \times 10^6$ m$^3$ of waste waters are discharged annually through this point source, in a channel (El Amia) of 200 m length. These wastes are mainly industrial, with some agricultural and domestic contribution.

b) **Lake Edku** (31.27°N, 30.15°E). This coastal lagoon is almost an agricultural drain. It covers an area of 126 km$^2$ with a mean depth of 1 m. Through its connection with the bay (El Boghaz inlet) about $389 \times 10^6$ m$^3$ of agricultural wastewater is discharged annually into Abu Qir Bay.

### Objectives fixed for TELEMAC modeling

The Telemac model can simulate water level variations and flows in response to various forcing functions in lakes, bays and coastal areas. The water levels and flows are approximated in a numerical finite element grid and calculated on the basis of information on the bathymetry, bed resistance coefficients, wind field and boundary conditions.

The Subief model simulates the spreading of a substance in the environment under the influence of the fluid flow and the existing dispersion processes. The substance may be a pollutant of any kind or any other water quality parameters.

### TELEMAC modeling

TELEMAC-2d solves the equations of Barré de Saint-Venant in the two horizontal space co-ordinates $U(x, y)$. The main results are the mean vertical velocity and water height.

### Data descriptions

**Initial condition:** A CONSTANT ELEVATION is prescribed throughout the model. This initializes the free surface elevation at a constant value.

**Boundary conditions:** The boundary conditions are prescribed as follow:
- At the Northern part of the Mediterranean
  - Depth condition (open boundary with prescribed depth)
  - Velocity condition (open boundary with free velocity)
- At the coastline and boundary of Edku Lake
  - Depth condition (closed boundary”wall”)

- Initial condition: A ‘CONSTANT ELEVATION’ is prescribed throughout the model. This initializes the free surface elevation at a constant value supplied by the keyword “INTIAL ELEVATION.”

- Bathymetry: the bathymetrical data and coastal limits of Abu Qir bay was digitized from the Admiralty Charts.
- Wind Data: Wind speed in (m/s) and direction in (degree) were obtained from the record of the meteorological station at Alexandria. Wind data were recorded every 6 hours. Wind direction is generally North East.

- Tide Data: The tide data was estimated by the Service Hydrographique et Oceanographique de la Marine (http://www.shom.fr/fr_page/fr_serv_prediction/ann_marees_f.htm).

- Water Quality Data: The simulated pollutant is Nitrate which is considered as a passive tracer for the simulated time period. Flow rates of (0.0005 m$^3$/s) are imposed at Tabia station.

**Model construction**

![Model construction and Bathymetry.](image)

**Figure 3: Model construction and Bathymetry.**
Mesh description

The mesh is condensed along the coast line and in the lake as shown in figure 4. Coarse mesh was generated on the mouth of the lake.

Figure 4: Model mesh
Boundary Conditions

Figure 5: Model boundary condition
Model calibration / validation

- **Hydrodynamic model validation**
  Measured currents (intensity & direction) at one location during the months of June at location of: X=236965 Y=3459940.
  Comparisons between measured and simulated currents during the month of June (Figure 6) were performed.

![Graph comparing measured and simulated currents for June](image)

**Figure 6:** Comparison between the measured and simulated currents for the month of June.

- **Water Quality model validation**

**Description of scenarios simulated**

Scenario I
  - **Hydrodynamic conditions**
  The first computation involves studying the effect of tides only on the free water surface, velocity and on the depth of water. The simulations performed for three periods: March June and August. Tide and wind data used in TELEMAC computation are for the year 2000 (Figure 7).
Figure 7: Tide Data June 2000
Figure 8: Flood currents produced for Scenario I at the beginning of the simulation
Water quality conditions

A water quality simulation was performed using SUBIF-2D. In the simulations, the dilution of a passive tracer is calculated. The pollutant to be simulated is Nitrate. The simulation is studying the dilution of a passive tracer under the influence of currents generated by only tide.

Figure 9: Flood currents produced for Scenario I at the end of the simulation
Scenario II

- **Hydrodynamic conditions**

The second computation involves studying the effect of tides and on the free water surface, and wind. The simulations performed for the month of June. Tide data used in TELEMAC computation are for the year 2000 (Figure 7).
Figure 11: Flood currents produced for Scenario II at the beginning of the simulation

Figure 12: Flood currents produced for Scenario II at the end of the simulation
Conclusions

1. Abu Qir Bay and Lake Edku were simulated with TELEMAC 2D and SUBIEF 2d. The verification of the model shows good match with the measured data. The simulation is very useful in the management of Water Quality of the Abu Qir bay.

2. This study is considered as a base for the simulation of any scenario or condition which may occur in the study area.

3. It is highly recommended that the Telemac system should be available in a management unit for the Bay.
B- Suitability analysis and Land use Model

**Suitability analysis:**

The geographic database is now completed as explained in previous sections. The developed GIS contain specific data based on topographic maps, satellite image analysis, and ground based surveys. Each of the layers in the geographic database contains specific information required for the siting analysis.

In this section, the analysis phase of the project will be described. First, the objectives and criteria of the analysis will be established and defined. Some physical, legal, and environmental criteria are defined for performing site analysis. Spatial land suitability analysis will then be carried out to identify potential areas suitable for development. The proposed areas will be assessed to select most suitable sites.

By the end of this section, the potential sites for the development will be identified, and the data will be presented map in the form of representing proposed sites suitable for development.

**Criteria for site suitability analysis:**

The analysis objectives involve finding suitable sites for new tourism development in the study area of Rosetta-Idku region. Tourism development objectives narrowed the selection to the locations along the coastal zone, in the study area. Suitability depends on the characteristics of the site itself and on the locations of other facilities, as well as other requirements to minimize environmental impacts.

Specific sites will be selected if they meet predefined requirements or suitability criteria. The overall aim is to meet all criteria or goals to the greatest extent possible and to choose the most desirable plan from a set of possible options. The criteria of suitability are set as follows:

a. **Environmental and legal criteria:**

To meet the strict legal aspects and environmental guidelines, the following criteria are taken into consideration:

1. Location of any construction must be beyond 200 m of the shoreline (i.e. setback distance) according to Environment Law no. 4/1994.
2. Site must be beyond 50 m of highways, railways, and major roads to avoid accidents, noise, and pollution hazards.
3. Locations of the proposed sites must be beyond 100 m minimum buffer zone of major industrial activities.
4. Sites must be beyond 100 m of towns, and residential areas.
5. Sites must be beyond 100 m of historical sites.
6. Sites must be beyond 100 m of lakes, water streams, and drainage canals.
7. Location of sites should be characterized by the ease of access through a good network of roads, and accessible from highways.
8. Locations of the proposed development areas are preferred to be centralized, and not to be distributed among existing urban settlements.

b. Planning criteria:

(1) The type of soil is the most important criteria. It is necessary to choose soil types suitable for development. Areas of fragile soils such as Sabkha and soft mud are not suitable for development, and therefore must be excluded.

(2) Slope suitability is also an important criterion. Slopes must not exceed 30% to achieve common construction considerations. Areas of 5-10% slopes are acceptable, but they are not considered the most suitable. Areas of slopes between 10% and 15% are defined as the most suitable areas. Those areas having slopes of 15-30% will be considered if a viewing panorama is to be achieved.

(3) The proposed areas should have a minimum elevation of 0.5 m above sea level. This minimum elevation is determined as a safety margin for the expected sea level rise due to climate change and subsidence.

(4) The potential sites for development are preferred to be facing the prevailing wind direction. This condition will make proposed areas to catch the prevailing wind, mainly from north and north-west directions.

(5) Potential sites are preferred to be overlooking a panoramic view. This means that the sites are either overlooking sand dunes or the sea side. Areas overlooking the beautiful sand dunes or/and hosting palm trees will be given higher rank than other areas overlooking sea side weights for each criterion can else be imposed.

Steps of suitability analysis:

After reviewing the criteria for the analysis, it is found that more attributes to coverages are needed in the data base in order to complete the analysis. These new coverages will be derived from the existing layers. All data are then combined as a new coverage to identify all polygons which meet the criteria:

1. First, the coverage of soil types is used. This data layer contains polygons, coded for different classes of soil types. This layer is used to assign a new attribute "FRAGILE" equal to 1, if the soil is fragile and not concrete. The attribute "FRAGILE"=0 for stable soil types.
2. The second criterion concerning slopes requires the use of the data layer SLOPES. Areas having slopes of 30% or greater are recoded to a value of 0. Areas having slopes of 10-15% are recoded to the value 1. Those areas having slopes of 15-30% are recoded to a value of 2. Finally, areas having slopes of 5-10% are recoded to a value of 3. The new codes are assigned to a new attribute "SLOPESUIT". The value of "SLOPESUIT" depends on the degree of suitability of the range of slopes. SLOPESUIT = 0 for unsuitable slope. Its value is 1 for the most suitable. The SLOPESUIT = 2 for moderately suitable, under the condition that the area is viewing a panorama and overlooking sand dunes or sea. Finally, the SLOPESUIT = 3, for less suitable slopes.

3. To define areas that meet the third criterion of minimum elevation, the digital elevation model (DEM) coverage is used. A new attribute "ABOVEHALF" is assigned. ABOVEHALF=0 for all areas having elevations less than 0.5 meter above sea level, and 1 for other areas.

4. The criteria defined to meet legal and environmental guidelines stated that any new development must be:
   (a) beyond 100 m of residential areas,
   (b) beyond 200 m off the shore line,
   (c) beyond 50 m of highways, railways, and major roads,
   (d) beyond 100 m of industrial sites,
   (e) beyond 100 m of historical sites, and
   (f) beyond 100 m of lakes, streams, and canals.

To define areas that meet these requirements, buffer generation is required. Buffer generation is a geographic operation used when the analysis requires the identification of the areas surrounding geographic features. Buffer operation generates zones within a given distance of a pre-specified set of coverage features. The buffer operation creates polygon coverage with an item named INSIDE. Those regions outside the buffer zones have INSIDE=1 and 0 otherwise.

The following coverages are used to perform the buffer analysis: COAST_LINE, TRANSPORTATION, HISTORIC_SITES, SURF_WATER, DRAIN_CANALS, INDUSTRIES, and RESIDENT_AREAS.

The following steps are carried out:
   (a) Using the city and town boundaries layer, assign a new attribute "URBAN"=1 for areas of cities or towns, 0 otherwise. Generates buffers 50 m wide around cities, town, and other residential centers. Assign the attribute "NEAR_RESIDENT"=1 for the buffer, 0 outside.
   (b) Use COST_LINE layer to generate buffer 200 m wide along the shoreline. Assign the attribute "IN_COAST"=1 for the buffer area, 0 outside.
   (c) Use the TRANSPORTATION layer to generate buffers 50 m wide around roads and railways. Assign the attribute "IN_WAYS"=1 for the buffer, 0 outside.
(d) Use the layer of INDUSTRIES to generate buffers 50 m wide around industrial sites. Assign the attribute "IN_INDUSTRIES"=1 for the buffer, 0 outside.

(e) Use the layer of HISTORIC_SITES to generate buffers 50 m wide around historical sites. Assign the attribute "IN_HISTORICS"=1 for the buffer 0 outside.

(f) Use the layers of SURF_WATER to generate buffers 50 m wide around lakes, water streams, and drainage canals. Assign the attribute "IN_WATER"=1 for the buffer, 0 outside.

Topologically overlay the objects in the previous layers to obtain a new layer of suitability. Assign the attribute "SUITABLE" to the objects in the new layer according to following rules:

<table>
<thead>
<tr>
<th>Value</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable soil, slope &gt; 30%, or within buffer zones</td>
<td></td>
</tr>
<tr>
<td>Stable soil, slope 10-15%, and outside buffer zones</td>
<td></td>
</tr>
<tr>
<td>Stable soil, slope 15-30%, and outside buffer zones</td>
<td></td>
</tr>
<tr>
<td>Stable soil, slope 5-10%, and outside buffer zones</td>
<td></td>
</tr>
<tr>
<td>Areas having the attribute SUITABLE = 0, are unsuitable,</td>
<td></td>
</tr>
<tr>
<td>Areas having the attribute SUITABLE = 1, are most suitable.</td>
<td></td>
</tr>
<tr>
<td>Areas having the attribute SUITABLE = 2, are moderately suitable.</td>
<td></td>
</tr>
<tr>
<td>Areas having the attribute SUITABLE = 3, are less suitable.</td>
<td></td>
</tr>
</tbody>
</table>

Locations of fine and medium sand are identified.

7 - In order to deliberate and conserve areas of sand dunes and palm trees, buffer zones 100 m around sand dunes and palm trees are created. All the buffers of GIS layers are overly to produce unsuitable areas. The final suitability map is shown in the next Figure.

The result of combining and considering all suitable criteria produces the final suitability map indicates that the most suitable area for tourism development lies to the north of Idku city. This area possesses the following characteristics:

- It meets the above mentioned suitability criteria,
- It is very close to transportation facilities of roads and railways including the new international coastal road. This gives the area the advantage of easy access to tourists and working people as well as transporting goods and services.
- The area has a close and easy access to the coast. The littoral currents pattern in this coastal area is suitable for tourism activities.
- The selected area is characterized by the presence of sand dunes as well as large areas of palm trees.
In conclusion, directing attention of decision makers, planners, and investors to Rosetta-Edku region to overcome future adverse impacts of changes in the area is of extreme importance. Erosional problems, water logging and pollution are extremely important factors which should be taken into consideration any development in the area. As sea level rise is a global phenomenon, a strategic plan has to be prepared to adapt to the environmentally uncertain future situations of the region. The precautionary principal has to be well specified criteria to select potentially safe areas on the long run. Remote Sensing, GIS combined with field observation, offers very viable techniques for integrated development of coastal areas.

The following conclusions come out of the suitability analysis:

1. Results of suitability analysis based on well established criteria set by environmentalists and planners, could all be simultaneously met. Suitable areas for tourism development have been identified.

2. Areas of various suitability levels were also identified for decision makers and planners for consideration of other socioeconomic parameters not include in the GIS and criteria.

3. Next iteration planning will identify zones of main land uses separated by suitable buffer zones for services.

![Final suitability map of the region](image-url)
The following recommendations have also been reached:

(1) The system developed could be used, after periodic updating as a decision support system for dynamic management of the development in the area.

(2) The system is a prototype which and is recommended to be replicated for integrated development of other areas.

(3) The geographic information system developed in this work is a necessary prerequisite for any strategic environmental assessment in the area.
4. Discussion

a. Identified conflicts and suggested relief

1. Recent discovery of gas reserves in the bay has prompted general policy to building huge gas liquefaction and petrochemical industries along the bay shore. The plan must include zones for industry, residential, tourism and agriculture.

2. Water quality is still deteriorating due to salt water intrusion; soil transport is still in progress. Marine pollution is improving due to better industrial control. Water treatment plants and sewage systems are necessary for soil conservation, archeological sites protection and upgrading of health conditions.

3. Unplanned urbanization and building of resort villages without consideration for the needed infrastructure is still progressing. This may lead to increased water pollution. A strong institutional capability in monitoring and assessment is necessary for law enforcement.

4. Low income, shortage of awareness and high unemployment rates are the main driving forces leading to low water quality. Planned industrial and tourism development, building a Marina and revival of fishing industries may be possible relief for upgrading conditions.

5. A severe problem of excessive solid waste on both the domestic and agricultural sectors is clear. These reach waterways. A solid waste disposal and management plan that involves establishment of a compost plant is necessary.

6. Problems of storage, transportation and marketing of products have been limiting income. This has forced many to abandon fruit and palm tree cultivation, causing loss of biodiversity and income of farming. Cultivation of new salt tolerant species, establishing of marketing institutions and paving necessary roads would greatly improve conditions.

7. Conflicts exist among various administrative authorities concerning aspects of development and overlapping administrative authorities e.g.

   1. Fisheries and water resources authorities over fish cages in the Nile and contribution to WQ
   2. Division of Abu Qir bay among Governorates of Alexandria and Behaira delays coherent policies
   3. Division of low elevation area south of the bay between the two Governorates

b. Plan for development

A preliminary plan for development of the region has been advanced. The plan involves an integrative view of the suggested development. An iterative approach has been followed through consultation with team members, stakeholders and the GIS. Zonation and qualification of important sectors including tourism, residential, agricultural and industrial areas will be carried out in the last iteration of the plan. The following second level iteration map shows the most important features in the second iteration plan. The team, with the experience gained in
the field. Plans to carry out a third level iteration with zonation based on sensitivity analysis in order to reach a final conclusion on the plan.

Fig 42: Proposed second iteration plan for the Rosetta region. A third iteration with zonation will be worked out.

**Third level iteration plan for development**

Based on the above results the team met several times to discuss possible ways for development of the region taking into consideration past experience, geographic system analysis and sensitivity analysis of the region. A third iteration map was reached and is presented below. Zones are identified as follows:
Tourism Zones

Two zones were selected for tourism purposes. The first zone proposed to be assigned to tourism purposes is located on the west side of the Nile estuary and named $Z_{t1}$. It occupies the estuary area of the river, and stretched for about 14 kilometers to the south with an average width of 3 kilometers. This zone covers an extension towards the east covering the west bank of the river Nile and “Qait-Bey” fortress, and then extending to the south just till the Northern borders of Rosetta urban cluster.

The second zone $Z_{t2}$ covers “Abu-Qir” city with a little extension to the south. The two zones stand at the beginning and at the end of Abu-Qir bay making two determinants of the sea front.

Industrial Zones

Three zones were selected for the conglomeration of industrial activities attempting to isolate them from neighboring sensitive land uses. $Z_{i1}$ is the first industrial zone covering all industrial firms and plants located just after “Abu-Qir” city and containing industries of paper, fertilizers, petroleum refinement, electricity generation power station, and others. The second industrial
zone $Z_{i2}$ covers “Kafr Ad-dawwar” city with all industrial plants included within its urban cluster mainly for textile and spinning industry.

The third and last zone $Z_{i3}$ is selected due to the construction of a new installment for natural gas liquefaction at the north of “Idku” city. Due to its inappropriate location cutting the extension continuity of the tourism zone, it is considered one event of inappropriate site selections and utilizations.

**Estuary Zone**

Estuary zone $Z_e$ of high tourism potential and high environmental sensitivity. This area is to be preserved and protected from violation and permanent constructions.

**Urban Expansion and Services Area**

Zones identified for future expansion of urban clusters of main cities. The first zone $Z_{u1}$ is for the future expansion of “Rosetta” city, buffered from the sea-shore with the tourism zone $Z_{t1}$. It is located to the Southwest of Rosetta city and to be linked to it by a binding road through palm trees cultivated area $Z_p$. The second zone $Z_{u2}$ is for the future expansion of “Idku” city extending towards the South and the Southwest.

**Recreational Buffers for Urban Areas**

Zones identified as separation buffers between sensitive areas and threat imposing areas. Three zones were identified; the first $Z_{g1}$ is located around the urban cluster of “Rosetta” city protecting the palm trees cultivation from further unplanned urban expansion and agricultural land violation.

The second zone $Z_{g2}$ is buffering the urban cluster of “Idku” city from the industrial zone previously described ($Z_{i3}$).

The third is a longitudinal strip on the coast of the bay starting from the main industrial zone $Z_{i1}$ till the future expansion zone of “Idku” city $Z_{u2}$. This strip of land contains some palm trees cultivation and four monumental location of forts ruins.

**No Construction Area (Swamps and Salt Marshes)**

This zone $Z_s$ stretching as a 1.5 km wide strip starting from the Nile estuary and extending towards the east on the sea front of “Kafr El-Sheikh” governorate is classified as a “No Construction Area”. It is mainly a shore back formed of swamps and salt marshes, and most of its area is liable to inundation and submergence with seawater seasonally or permanently.

**“Idku” City Sea Sanctum**

This area lying between the urban cluster of “Idku” city and the bay-shore is to be kept without any alteration. No constructions or any other utilization that may thrust the urban area towards the shoreline should be allowed. At the present time, a petrochemical plant is intended to be installed in this area up-wind to “Idku” city, making the city liable to environmental impacts threatening the human community and the natural environment at this location. Such land uses shouldn’t be permitted to take place in these locations, but shifted to the appropriate site in the industrial zones illustrated before.
Palm Trees
A zone mainly composed of palm trees land cover $Z_p$. It is located in three clusters. One on the east side of the river in “Kafr El-Sheikh” governorate, the second is just at the west of “Rosetta” city and the third is located between “Idku” and “Rosetta” cities to the northeast of “Idku”. The total area of this zone reached about 104.6 km$^2$.

Arable Land
This zone $Z_c$ includes partially cultivated land with unstable agricultural conditions. Covering an area of about 44.6 km$^2$, it neighbors the coastal areas and partially shares their problems of salinization and salt water inundation. This zone includes two locations, the first is located to the west of “Rosetta” city, and the second in two close spots just below the northern coast of the Delta beneath the zone $Z_s$ described in section 2.6.

Partly Cultivated Land
These are tiny scatters of irregular land partially utilized for the agricultural purposes. They fill the gaps between other zones like those for agriculture, industry, or tourism.

Farms and Private Cultivated Land
A spot $Z_f$ located below “Abu-Qir” city including the “Tousson” area, mainly containing land pieces classified as private farms “Ezba” and private agricultural land with residences for their owners.

Agricultural Land
The zones $Z_{a1}$ and $Z_{a2}$ with the majority of land area, and covering a most of the study area, mainly utilized for agricultural purposes. The first zone lies in “Behera” governorate, while the second zone lies in “Kafr El-Sheikh” governorate. These zones contains dense networks of regional, primary, and secondary roads, primary and secondary canals, and primary and secondary drains which serve the agricultural land and manage the water supply and disposal for cultivating important yields that serve the region and the neighboring ones.

Lake “Idku” Zone
This zone of the region’s central lake “Idku Lake” $Z_L$ with a total estimated area of about 178.6 km$^2$ is formed of a mixture of a major central water body with scattered swamps and bushes surrounding it. The displayed zone limits are those intended to be maintained through this developmental proposal, as the present limits of the lake are much less than the displayed ones due to continuous violation to its boarders and the abstraction of its water body surfaces to be used as private fish culturing ponds.

Proposed executive actions are presented to maintain these objectives:
- Revitalization of the Lake Environment
- Protection against further violation imposed on its boarders
- Removal of all present surpasses
- Enforcement of regulations against violations and continuous monitoring
Buffers and Preventive Belts

They are strips zones proposed to be allocated around the industrial spots to act as preventive belts halting and forming geographic limits for further industrial expansion on the cost of any other surrounding land cover.

Post “Abu-Qir” Industrial Buffer

This linear zone $L_{u1}$ stretches from the west (boarder of “Abu-Qir” city urban area) to the east (neighboring the western edge of “Idku” lake). The zone surrounds the industrial area $Z_{i1}$ which contains various gigantic industrial installments for paper, fertilizers, electric power generation, and petroleum refinement industries.

“Karf Ad-dawwar” Industrial Buffer

The linear zone $L_{u2}$ stretching around the industrial zone of “Kafr Ad-dawwar” city $Z_{i1}$, bounds its activity and forms an isolation buffer from the surrounding land uses, and an expansion limit for its future expansion.

Proposed Additive Monitoring Locations

The study has proposed four additive monitoring stations for environmental surveying and ranging.

The four stations ($S_1$-$S_4$) were settled in four locations surrounding the old geographic boundaries of “Idku” lake, in a manner to be able to cover the majority of the water body with its internal components of farms, islands, swamps, and fish-culture basins.

Linear Buffers for Linear Features

They are restriction linear strips of land surrounding a certain land feature. This aims protection, preservation and development possibility for this feature, and also preventing further contacts between this feature and the human impacts.

“Mahmoudeya” Canal Buffer

This buffer $B_1$ tracks the linear path of “Mahmoudeya” canal that forms the southern boarder of the study area. The buffer width reached 500 m from both side forming a zone where further constructions are proposed to be restricted.

Northern International Road Buffer

This buffer $B_2$ is of a proposed width of 1000m, 500m from each side. It is a “No-Further-Construction” area for maintaining security for both, residents and the fluent mobility of moving vehicles.

Proposed Southern Road Buffer

This proposed “No-Further-Construction” buffer $B_3$ is of a width of 500m, 250m from each side, to guarantee the absence of any conflict between any type of constructions and the proposed route. The buffer also extends around the
branching terminals that emerge from the route to serve all of the surrounding areas.

**Nodal Zones**

New transportation nodes \( N_1 \) and \( N_2 \) were proposed to act as major intersection and linking points for major transportation axes.

The first nodal zone \( N_1 \) is located at the south-eastern section of “Kafr Ad-dawwar” city. This node is located where the Proposed Southern Road crosses the “Mahmoudeya” canal to intersect with Alexandria agricultural road. The proposed node \( N_1 \) would act as a southern entrance for the region giving access to the southern sectors for rapid moving vehicles and avoiding the usage of narrow local roads spreading and interfering with the urban fabric of cities and villages.

The second nodal zone \( N_2 \) is located at the “Edfina” barrage, which crosses the river Nile and links its western bank to its eastern one. This nodal crossing facility is proposed to continue through the Proposed Southern Road forming an eastern entrance for the region through the river Nile; thus linking the region to the eastern bank of the river Nile in “Kafr El-Sheikh” governorate.

Both of the two nodal zones \( N_1, N_2 \) are acting as determinants or start-end points for the proposed southern road. All together with the proposed southern road, they would form a specific transition in the local transportation system in the region. Fast moving vehicles, massive transportation vehicles, and passenger’s transportation facilities would benefit from such addition as narrow conflicting roads would be avoided and kept for minor usage by local residents.

7. **Discussion**

   a. **Conflicts and suggested relief**

   Major conflicts of this region include:
   
   - Excess water resources has to be integrated with better control of industrial and agricultural wastewater quality
• High resources of the region with very limited planning and infrastructure. Establishing large scale services and building up institutional capabilities are necessary prerequisites for any development

• Large products with limited marketing. It is necessary to upgrade storage and marketing of products through encouraging the private investors for building factories and use already existing excess unemployment

• Destruction of palm trees and fruit trees should be stopped through upgrading awareness and carrying out integrated management plans

b. Plan for the development

A plan for development based on integrated coastal zone management approach and establishing an institutional capability for periodic monitoring and assessment has to be carried out.

c. Dissemination

1. A paper was submitted and presented at the SEA to SEA Conference held in Cairo Feb. 14-16, 2005. The paper was entitled: Remote Sensing and GIS for Sustainable Development of the Coastal Area of Abu Qir Bay, Egypt”

2. A questionnaire was administered and carried out through cooperation with a NGO. Stakeholders involved included:
   a. Decision makers
   b. Fishermen
   c. Factory workers
   d. Farmers
   e. Investors
   f. More than 100 personal contacts were carried out with stakeholders in the field

3. An Abstract of a paper was submitted to the “International Conference on Environmental Change in Lakes, Lagoons and Wetlands of the Southern Mediterranean Region”, to be held 4-7 January 2006. The paper entitled: “Sustainable Development of the Coastal Area of Abu Qir Bay, Egypt”.

4. Lectures were presented by the team leader at several national meetings including:
   1. National Authority of Remote Sensing and Space Sciences (NARSS), Egypt
   2. Institute of Graduate Studies and Research, University of Alexandria
   3. Training course for Iraqi stakeholders on Mesopotamian restoration
c. Conclusions

1. The team has explored the study area through literature survey, field observations and satellite image analysis. Collected data and indicators have been analyzed and interpreted in terms of prevailing conditions in the region. Water resources, geomorphological conditions, pollution sources, socioeconomic conditions, have all been surveyed and explored. Problems of the region have been well identified and conflicts analyzed.

2. A Geographic Information System at a scale of 1:50,000 have been built. Data concerning important parameters such as land use, topography, transportation networks, administrative boundaries, and archeological sites have been encoded. Sensitivity analysis and suitability analysis have been carried out for proper planning of development of the region.

3. Satellite images of the years 1990, 1995 and 2000 and 2004 have been classified and analysis of change detection indicates dramatic changes of land cover and land use in the region. At least two important land use changes were detected:
   a. One deals with excessive rates of deterioration of fruit and palm trees in the region;
   b. The other is the sudden increase of vegetation associated with development of the international road.

   Further investigations of these problems were carried out through questionnaire administration, analysis and interpretation in order to assess socioeconomic considerations behind these changes.

4. Indicators of the variability of physical, chemical and biological parameters of the bay have been collected and a time series analysis explored to identify and assess relationships among parameters.

5. A Telemac model for identification and assessment of future implications of changes in the region has been developed and is under calibration and verification.

6. A questionnaire survey has been carried out through cooperation with a nongovernmental organization. The main objective was to collect data and to disseminate information to stakeholders.

7. An integrated iterative plan of development for the region based on principles of Integrated Coastal Zone Management (ICZM) has been introduced.
5. References:

2. Awad, Hasan and Nabiha Yousef; Nile River delta: Rosetta branch and Edku Lagoon;
9. EEAA, 1996; Framework for National Plan for Integrated Coastal Zone Management in Egypt; EEAA.

18. Fouda Y. E., Sustainable Management of Scarce Resources in the Coastal Zone (SMART), GIS and Spatial Data Base Building Procedures For “Abu-Qir” Bay, Egypt, First annual report, August 2003, http://www.ess.co.at/SMART/


8. Appendices

SMART Planning Survey

Please answer the following questions:

Q. Stakeholder Type
Which of the following best describes the type of stakeholder you are?
- Inhabitant
- Fisherman
- Farmer
- Worker
- Decision Maker
- Land owner

Q. Water payment
How much do you pay for water services on a monthly basis?
__________________________________

Q. Water quality
Have you noticed any deterioration of water quality in recent years?
- through visual inspection
- Chemical analysis
- hearing from others
- suspecting due to pollution
- other means

Q. Points Strength
What in your opinion are points of strength?
- Potential for tourism
- Potential for agriculture
- Potential for industry
- Potential for fisheries and aquaculture
- Other

Q. Environmental Problems
What are the most important environmental problems in the region?
- Solid waste accumulation
- Salt water intrusion and excessive water salinity
- Fish cages in the River Nile
- Drinking water pollution
- Marine pollution
- Soil removal
Q. Palm trees damaging
Fake land holdings
Waterlogging and waterbogging
Shortage of sewer system
Shortage of institutional capabilities
Shortage of awareness and educational systems
Others, mention

Q. Health Problems
What would you say is the most urgent health problem facing this region at the present time?
- Waterborne diseases
- Cancer
- Health care costs/ Insurance
- Prescription drug costs
- Heart disease
- Smoking
- Malnutrition/ Hunger
- Alcohol abuse
- Drug abuse
- Obesity
- Other (specify) __________________________
- No opinion

Q. Pollution changes
Have you noticed any changes in pollution levels in the region m
- Water pollution increase
- Water pollution decrease
- Marine pollution increase
- Marine pollution decrease
- Gaseous pollution increase
- Gaseous pollution decrease
- Solid waste increase
- Solid waste decrease
- Other

Q. Palm Trees losses
What in your view are the reasons for the sudden large losses of palm and fruit trees in the region?
- Lack of markets
- Upgrading land prices
- Loss of productivity
- Problems of transportation of products
- Shortage of skills of packaging and exporting
- Administration problems
- Economic problems and lack of trained personnel
Monopolies and lack of institutional capabilities

Others

Q. Vegetation along roads
What are the reasons behind spreading of vegetation along the international road in general and in the region at large
- Better access to agricultural land
- Availability of water resources
- Demonstrating land holdings
- Better investment opportunity after International road
- Others

Q. Nile Cage Aquaculture
What is your opinion on Nile cage aquacultural activities
- It is useful because it offers opportunities for employment
- It offers opportunities for investment
- It does not pollute the source of water by waste
- It does not violate any laws or regulations
- There are many other polluting sources

Q. Sewage
How is the municipal and solid waste disposed
- Trenches
- Transported to disposal sites
- Left as it is
- Do not know

Q. HeadingTooLong1
How is the industrial and agricultural waste transported and disposed?
- Through identified and/or protected drains
- Within agricultural land
- Through drains to lake
- Do not know

Q. Urban encroachment
How do you manage building a new house for your children
- Violate regulations against building in agricultural land
- Live together
- Immigrate to cities
- Build over old homes
- Other

Q. Industrial activities
What is your view of the industrial activities in progress in the region?
- It causes no conflicts with my interests
- It causes a lot of pollution
It offers good employment opportunities
❖ It is necessary for development but requires better control
❖ Other

Q. Improvements
What are the most important ways for improvement of environmental conditions and regional utilities:

❖ No Action
❖ BOOT
❖ Self motivated NGO
❖ Local Companies and/or investors
❖ Governmental organizations
❖ Encouraging investments
❖ Upgrading awareness
❖ Enforcing laws
❖ other

Q. Sector of Development
What are the most promising sectors for development in the region
❖ Tourism
❖ Industry
❖ Agricultural
❖ Fishing
❖ Other

Q. ICZM
Are you aware of availability of ICZM technologies for integrated coastal zone management with?
❖ Zonation
❖ Public participation
❖ Law enforcement
❖ Integration
❖ Common benefits
❖ Better employment
❖ Equity
❖ Others

Q. Climate Change
Have you noticed any evidence of climate change in the region?
❖ Sea level rise
❖ Excessive salt water intrusion
❖ Increased waterbogging
❖ Increased temperature impacts
❖ Increased soil salinity
❖ Other evidences (name)
Q. Adaptation to SLR
If the sea rises by half meter, you may have to take action. What of the following actions would you prefer:

- Immigrate to another safer location
- Change job but stay in the same place
- Retreat
- Wait for government to take action
- Think of another way to utilize available land
- No action

Q. Soil Transport
What would you feel about soil transport for landfilling of other sites?

- It is a very effective way for avoiding soil salinity at some spots
- It solves one problem and creates another in another location
- It creates problems without solving anything

Q. Development tasks
What would be your suggestions for the best actions for development?. Rate on a scale of 10:

- Carry out a high quality water conservation and management programs (physical and/or economic)
- Carry out drastic changes and control of waste pattern through upgrading awareness and reducing pollution
- Building wastewater treatment plants (cost, location)
- Considering other water resources such as extension of fresh water from Alexandria (expenses)
- Re-cultivation of palm and fruit trees, building packaging factories and upgrading transportation systems
- Persuading big industries to invest in upgrading infrastructure
- Encouraging tourism through building necessary infrastructure
- No action

Demographics
Please provide the following demographic information. It will only be used to make statistical comparisons between different groups of respondents; it will not be used to profile individual respondents.

Q. Gender
What is your gender?
- Male
- Female

Q. Age
How old are you?
- Under 20 years
Q. Education
Which of the following best represents the highest level of education that you have completed?
- Some high school or less
- High school graduate
- Attended some college
- Associates degree
- Bachelors degree
- Post-college graduate

Q. Employment Status
Are you currently employed?
- Yes, full-time
- Yes, part-time (30 hours or less per week)
- No

Q. Marital Status
What is your marital status?
- Married
- Single, never married
- Widowed
- Separated or divorced

Q. Purchase Medium
How or where did you purchase your product?
- Retail Store
- Wholesale Store
- Superstore
- Catalog
- Direct Mail Flyer
- Gift/Someone Else Purchased

What are the ages ranges of any children 18 years of age or younger living in your household? Choose all that apply.
Q. DuplicateHeading1
Under Age 6 years
☑ Aged 6-12
☑ Aged 13-18
☑ Have no children 18 or under living in household

Contact Information
This section is optional, please fill out this section only if you would like us to get in touch with you.

Q. ContactInformation
First Name __________________________________
Last Name ___________________________________
Address 1 _____________________________________
Address 2 _____________________________________
City __________________________________________
State _________________________________________
Zip / Postal Code _______________________________
Home Phone _________________________________
Work Phone _________________________________
E-mail _________________________________
Fax _______________________________

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