Chapter III

GIS Techniques and Methodologies

In this chapter, we shall consider basic principles of the geographic information systems and techniques as well as various analysis methodologies:

III.1 Geographic Information System Techniques:

A GIS can be considered as a tool for integration and analysis of geographically referenced data. This definition includes a wide variety of functions, such as procedures for data input, geometrical transformation, distance and overlay analyses, and mapping capabilities. Obviously, a solid link between the geometrical and data base components is assumed for the majority of these functions. Most of GIS programs available today provide these facilities. (Chuvieco, 1993)[69]
Geographic information System (GIS) technology provides the medium for this integration of spatial data and at the same time provides powerful tool for land-use change and map revision (Welsh et al., 1992))[70]. Although there is no universally accepted definition of an Integrated GIS (Hinton, 1996) [71], (Ehlers et al., 1990)[72] defined three levels of integration:

GIS may also be defined according to two main distinctive themes: technological aspects and problem solving aspects **(ESRI, 2013)[115]**. Emphasizing the technological and computer - related aspects of GIS, (Burrough 1986)[74] defined GIS as: "powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from real world for particular set of purposes". Emphasizing the problem solving aspect of GIS and the analytical nature of the system, GIS is best defined as system which uses a spatial database to provide answers to queries of geographic nature (Fisher et al, 1989) [73]

III .2 Techniques for Building a GIS:

Steps for building GIS begin by data collection passes through data processing and ends by the production of the output results.

III .2.1 Data Collection

The data necessary for building a GIS includes: topographic maps, socio-economic data, statistical data, tabular data and field surveys which are carried out for verification and assessment of land-use patterns **(ESRI, 2013)**[115]

III .2.2 Data Processing

A. Input stage

Maps are considered the main spatial input to GIS via various routes, either by digitizing, or by importing data from other computer information system. Digitizing can be performed by manual means (e.g. digitizer tablet) or by automated means (e.g. raster based scanner). Different map features are recognized, as points, lines, and polygons and organized in distinctive separate layers. The ancillary data are scanned into an ASCII format and converted to spreadsheets files. Final editing of the data occurred in the spreadsheets, from which it was exported to Database Format.

B. Editing stage

Data input is time consuming and error-borne procedure. They involve many types of errors. Therefore, data editing GIS is very important process needed to correct digitizing errors, supplement, and add to the initial input data through interactive communication on a graphic display. In our study, this process passes through many stages such as: joining the maps and the correction of joining errors.

C. Attributes input

This involves determining the study area boundary, what coordinate system will be used, which data layers are needed, what features in each layer and its type, what attributes are needed for each feature type, and how the attributes will be coded and organized. The database design consists of three major steps: (i) identify the geographic features and their types; (ii) attributes and data layers required, (iii) define storage parameter of each attribute, and ensure coordinate registration.

D. Production of output

The output of the previously mentioned steps is the geographically referenced data and its associated attributes. Once the coverage is created, an important step has to be carried out to make data usable, which is topology construction. Topology is a mathematical procedure for defining spatial relationships (ESRI, 2004) [75]. By this operation, each feature in the prepared coverage is assigned a unique internal number that define its characteristics and relations with other features. Polygon and point attribute tables (PAT) are created for polygon and point coverage while, Arc attribute tables (AAT) are created for line coverage.

III.3 GIS spatial analysis

GIS functions are used to enable the analysis of the spatial data and their attributes for decision support. Spatial analysis is done to answer questions about the real world including the present situation of specific areas and features, the change in situation, the trends, and the evaluation of capability or possibility using overlay technique and/or modeling and prediction. Therefore spatial analysis ranges from simple arithmetic and logical operation to complicated model analysis. Spatial analysis is illustrated as follows (Murai, 1999) [76]

1. **Query**: retrieval of attribute data without altering the existing data by means of arithmetic and logical operations.
2. **Reclassification**: reclassification of attribute data by dissolving a part of the boundaries and merging into new reclassified polygons.
3. **Coverage Rebuilding**: rebuilding of the spatial data and the topology by "update", "erase", "clip", "split", "join" or "append".
4. **Overlay**: overlay is the basic analysis technique used for detecting changes. It involves composition of multiple maps (two or more) and, a new data set is created, containing new polygons created from the intersection of the boundaries of two or more data sets of separate polygon layers. Intersect operation is used mainly to locate areas of change. This operation selects areas of input coverage overlapping the intersect coverage and thus results in selection of incorrect polygons.
5. **Connectivity Analysis**: analysis of connectivity between points, lines and polygon in terms of distance, area, travel time, optimum paths etc. Proximity analysis by buffering, seek analysis of optimum paths, network analysis, etc. are included.

III.4 Building Digital Elevation Model

Today Digital Elevation Models (DEMs) have become increasingly essential in our life. DEM is defined as a digital representation of the terrain elevation features over a topographical map **(ESRI, 2013)[115].** The variation in elevation of the Earth's surface, the precise topographic data contained in DEM, is very useful in many applications. For example, it helps city planners and scientists in their studies of the environment, and military and emergency services for training and real time operations. It also provides useful topographic information for sustainable planning and management of land use. (Chen et.al. 2004)[77].Visiting every location in a study area to measure the height, magnitude, or concentration of a phenomenon is usually difficult or expensive. Instead, select strategically dispersed sample input point locations, and use Interpolate Surface to assign an estimated value to all other locations. Input points can be either randomly or regularly spaced points containing height, concentration, or magnitude measurements. The resulting grid theme is the best estimate of what the quantity is on the actual surface for each location. The surface interpolators make certain assumptions about how to determine the best estimated values. Based on the phenomena the values represent and on how the sample points are distributed, different interpolators will produce better estimates relative to the actual values. No matter which interpolator is selected, the more input points and the greater their distribution, the more reliable the results.

Interpolation predicts values for cells in a raster from a limited number of samples data points. It can be used to predict unknown values for any geographic point data: elevation, rainfall, chemical concentrations, noise levels, and so on. One problem with creating raster by interpolation is that the original information is degraded to some extent even when a data point falls within a cell; it is not guaranteed that the cell will have exactly the same value**(ESRI, 2013)[115].**

Interpolation is one of many analysis tools in GIS based on the assumption that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics. There are several ways to create raster surfaces from point data

- Using the **Inverse Distance Weighted**(IDW) interpolation method

- Using the **<u>Natural Neighbors</u>** interpolation method
- Using the **<u>Spline</u>** interpolation method
- Using the **<u>Kriging</u>** interpolation method

Each interpolation method makes assumptions about how to determine the estimated values. Depending on the phenomenon to be modeled and the distribution of sample points, different interpolators produce better models of the actual surface. Regardless of the interpolator, the more input points and the more even their distribution, the more reliable the results.

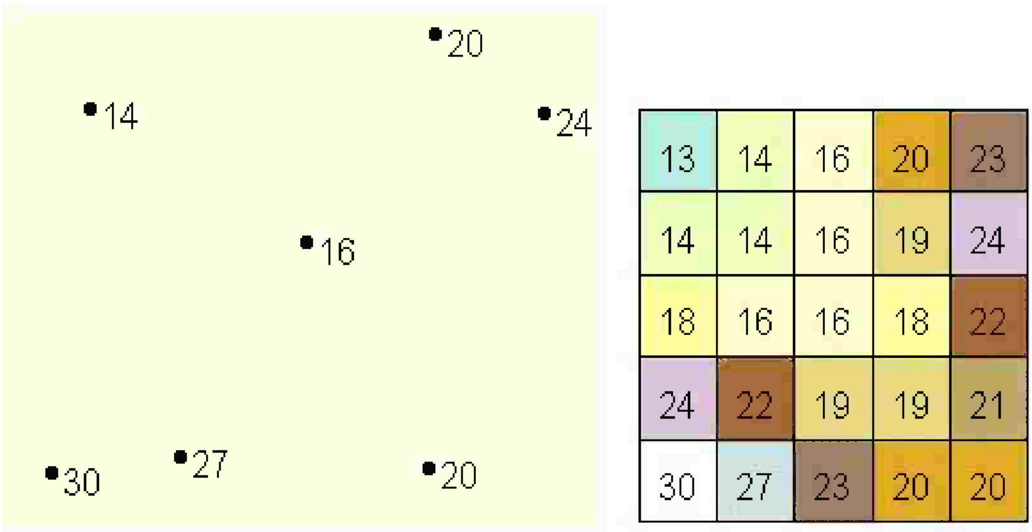


Figure (III -1): Prediction of pixel values using interpolation

III.4.1The Kriging method

This interpolation method assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. Kriging fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location. Kriging is a multistep process; it includes exploratory statistical analysis of the data, variogrammodeling, creating the surface, and (optionally) exploring a variance surface. This function is most appropriate when there is a spatially correlated distance or directional bias in the data. It is often used in soil science and geology. **(ESRI, 2013)**[115]The Inverse Distance Weighted (IDW) and Spline methods are referred to as deterministic interpolation methods because they are directly based on the surrounding measured values or on specified mathematical formulas that determine the smoothness of the resulting surface.

III.4.٢ Making a prediction with Kriging

To make a prediction with Kriging, two tasks are necessary:

1- To uncover the dependency rules.

2- To make the predictions

To realize these two tasks, Kriging goes through a two-step process:

1- The creation of variogram and covariance functions to estimate the statistical dependence (called spatial autocorrelation) values, which depends on the model of autocorrelation **(fitting a model).**

2- Actually predicting the unknown values **(making a prediction).**

It is because of these two distinct tasks that it has been said that Kriging uses the data twice: the first time to estimate the spatial autocorrelation of the data, and the second to make the predictions **(ESRI, 2013)[115].**

Making a prediction: After uncovering the dependence (autocorrelation) in the data and ending with the first use of the data—using the spatial information in the data (to compute distances) to model the spatial autocorrelation—prediction can be made using the fitted model. Thereafter, the empirical semi-variogram is set aside.

The data can be used again to make predictions. Like Inverse Distance Weighted (IDW) interpolation, Kriging forms weights from surrounding measured values to predict at unmeasured locations. As with IDW interpolation, the measured values closest to the unmeasured locations have the most influence. However, the Kriging weights for the surrounding measured points are more sophisticated than those of IDW. IDW uses a simple algorithm based on distance, but Kriging weights come from a semi-variogram that was developed by looking at the spatial nature of the data. To create a continuous surface or map of the phenomenon, predictions are made for each location (cell centers) in the study area based on the semi-variogram and the spatial arrangement of measured values that are nearby.

III.4.3 Raster calculation

In Arc GIS Spatial Analyst, the Map Algebra from Arc-Grid is available in the Raster Calculator. Map Algebra expressions that result in a raster dataset can be typed into the Raster Calculator dialog box, providing access to almost all GRID functionality. Input raster can be in any raster format **(ESRI, 2013)[115]**.

III.5 Methodology

In order to identify the vulnerable areas to sea level rise and the consequent socioeconomic effects on the study area, a geographic information system was designed and built to meet this objective. Building the GIS involves three steps:

III.5.1 Data Collection:

The scope of the current study area is the Abu Qir Bay region in the southern part of the Mediterranean which is well known promising tourist, industrial and agricultural site.

The data used to build GIS are:

*Satellite image (SRTM) spatial reference GCS-WGS-1984 Datum

D-WGS- 1984

*Topographic Map (1:50,000 scale, (2011), Egyptian Survey Authority).

* Socioeconomic data: population, employment, distribution of population in Different economic activities was obtained from (CAMPAS 2006)[56].

III.5.2 Data Processing:

The data includes regional maps, detailed maps, land cover and land use maps. As a first step in data processing is to integrate all data from different sources together, thus the pre-processing operations like registration and rectification of data were used. This was handled Arc/Info and Arc/GIS through the following steps:

III.5.3 Input stage:

The scale 1:50000 was found to be the most appropriate one for this study, containing elevation points was used for the interpolation process to obtain a topographic map of the study site. 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. Abu Qir map (scale 1:50000) representing Abu Qir region, was initially digitized using on-screen digitizing. Each land use type entered as polygons such as cultivated area and residential area, while roads, shoreline, railway which divided to one way direction from El-Maamourah station to Rashid station and two way directions from Egypt station to Abu Qir station are entered as lines. Schools, companies, hospitals and healthy units are entered as points shown in Table (III -1).

Table (III -1): A table showing the database design for map components and layers Configuration

graphic entity	Main categories	Classes	Layer name
Polygon	Land	Cultivated area	Cultivated area
		Residential area	Residential area
	Water Bodies	Sea	Sea
		Lake Idku	Idku lake
graphic entity	Main categories	Classes	Layer name
Polylines	Road	Major road	Major road
	Railway	One direction	One direction
		Two direction	Two direction
	Contour elevation line	Contour elevation line	Contour elevation line
graphic entity	Main categories	Classes	Layer name
Points	Schools	Schools	Schools
	Industries	Industries	Industries
	Hospitals	Hospitals	Hospitals
	Healthy units	Health units	Healthy units
	Archeological sites	Archeological sites	Archeological sites

Table shows the land use layers, their types and description, as well as the number of digitized graphic entities of the study maps-set. Each of these categories covers a certain group of map features.

The second product of the Geographic Information System is the contour elevation line. This will be used in building a Digital Elevation Model (DEM) as will be discussed in the next section.

III.6 Digital Elevation Model building

Building a digital elevation model is the first step to obtain DEM which is considered as the most important GIS layer in this study it generated using contour elevation point map, SRTM satellite data.

The NASA/NIMA (now NGA) Shuttle Radar Topography Mission (SRTM) collected interferometric radar data which has been used by JPL to generate a near-global topography data product for latitudes smaller than 60. As part of the SRTM mission, an extensive global ground campaign was conducted by NIMA/NGA and NASA to collect ground-truth which would allow for the global validation of this unique data set Rodríguez, C.S 2005[118].

The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000 Farr and Kobrick (2000) [119].

The SRTM data sets result from a collaborative effort by the National Aeronautics and Space Administration (NASA) and the National Geospatial-Intelligence Agency (NGA - previously known as the National Imagery and Mapping Agency, or NIMA), as well as the participation of the German and Italian space agencies, to generate a near-global digital elevation model (DEM) of the Earth using radar interferometer. The SRTM instrument consisted of the Space borne Imaging Radar-C (SIR-C) hardware set modified with a Space Station-derived mast and additional antennae to form an interferometer with a 60 meter long baseline Kobrick (2006) [120].

Each elevation is a true value referenced to mean sea level datum recorded to the nearest meter. The horizontal position is referenced to precise longitude- latitude locations in terms of the current World Geodetic System (WGS), determined for each file by reference to the origin at the southwest corner. The elevations are evenly spaced in latitude and longitude at the interval designated in the user header label in South to North profile sequence Wagner, M 2000[121].

A. Verification of contour elevation line

This technique has been used to ensure the accuracy of the contour lines and elevations which were obtained from paper maps of the Egyptian survey authority 1:50000 and 1:25000, this confirmation was conducted because the date of such maps back to 1993.

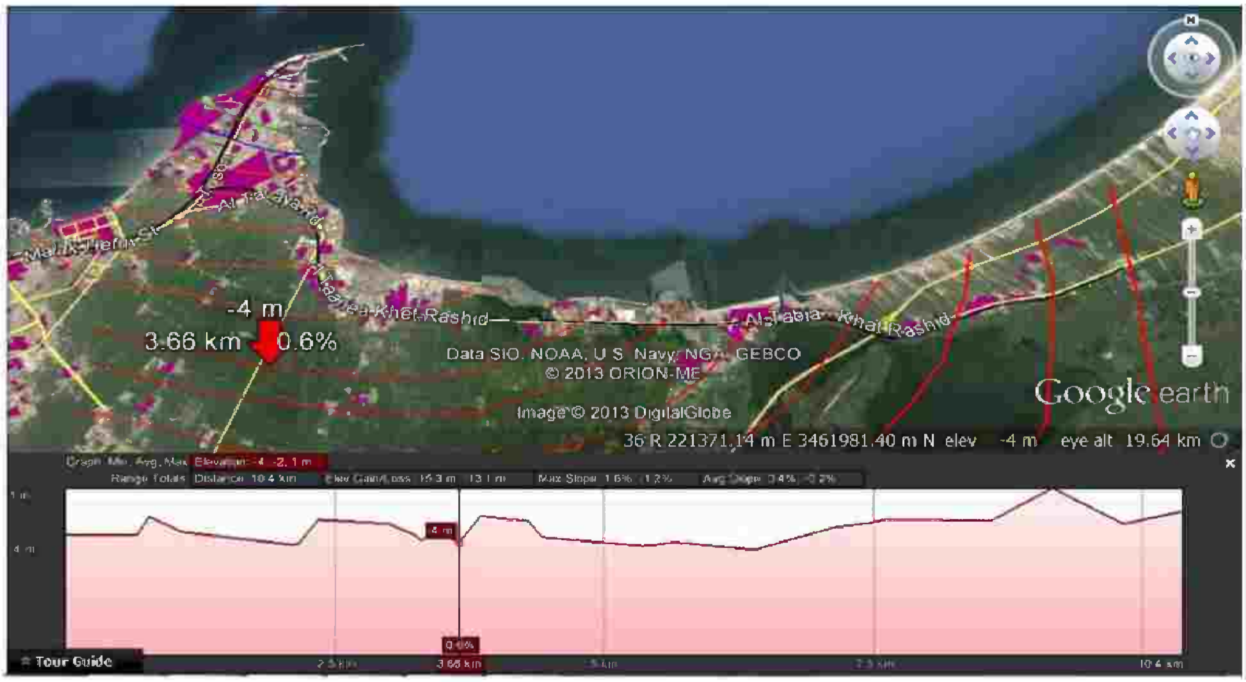


Figure (III -2): Topographic profiles (Red Arrow) as obtained from Google Earth

B. Digital Elevation Model Generation

Generating a digital elevation model is the most important base of this study where it has been of great help in identifying low laying areas and calculating its areas. The basic data for a DEM is based on terrain elevation observations that are derived generally from one of three sources, digitized contours from maps 1:50.000 as shown in **Figure (III -3)** and 1:25000 and using ET GeoWizards tools to convert contour lines to contour line as shown in **Figures (III -4) and Figures (III -5)**, digital satellite imagery (elevation points from SRTM which contained about 2000 points) as shown in **Figures (III -6)** to obtain Digital Elevation Model(DEM), from it can be seen the most risk areas and safe areas that affected by SLR.

1- Most low laying lands are located in east and south Abu Qir Region in addition to those areas around Lake Idku and its vicinity

2- The region west Abu Qir is a relatively high risk region especially urban area located closet coast line.

3- Most of Abu Qir coastal border is located at elevation between -4 below sea level to 1 meter above sea level.

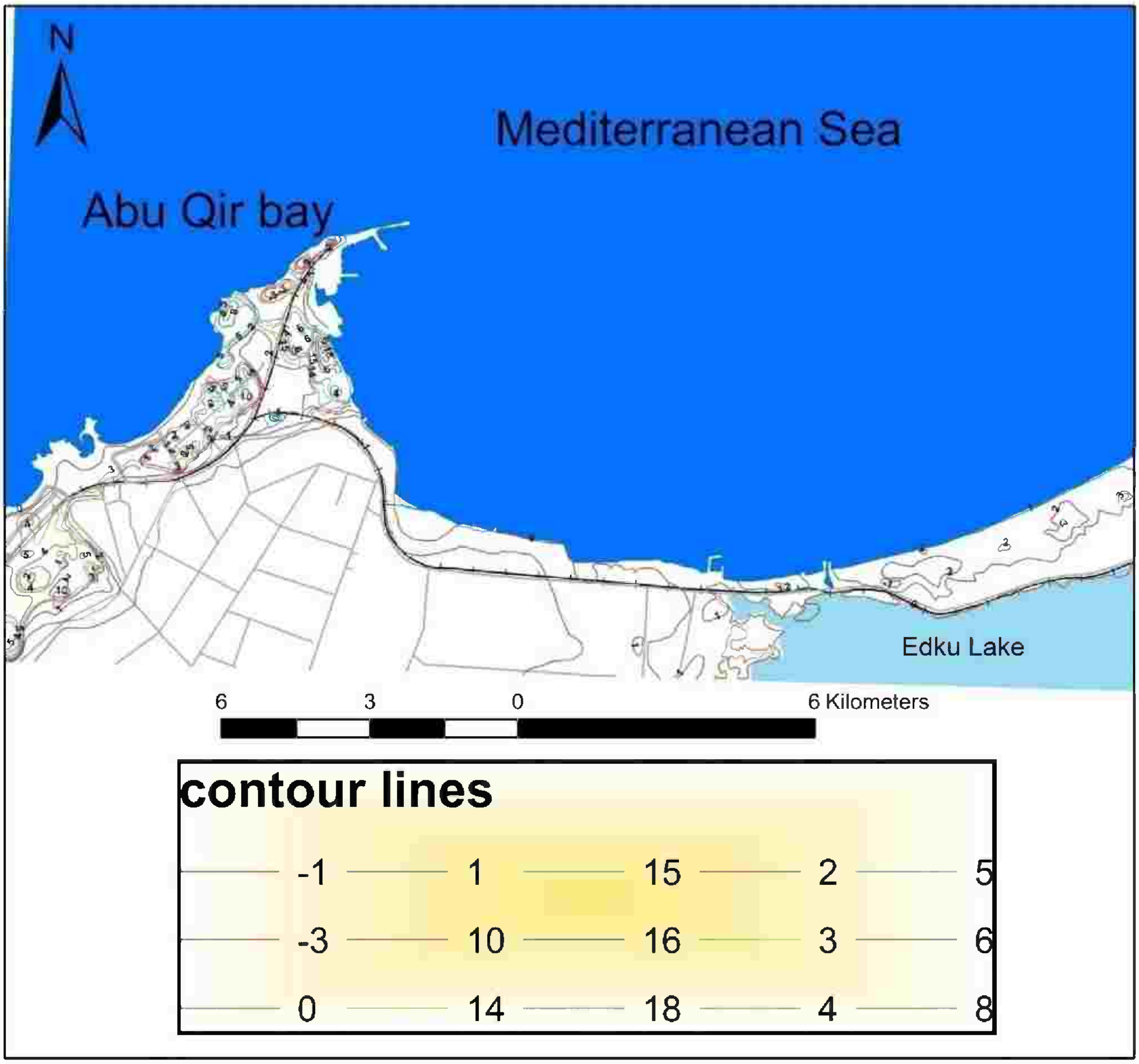
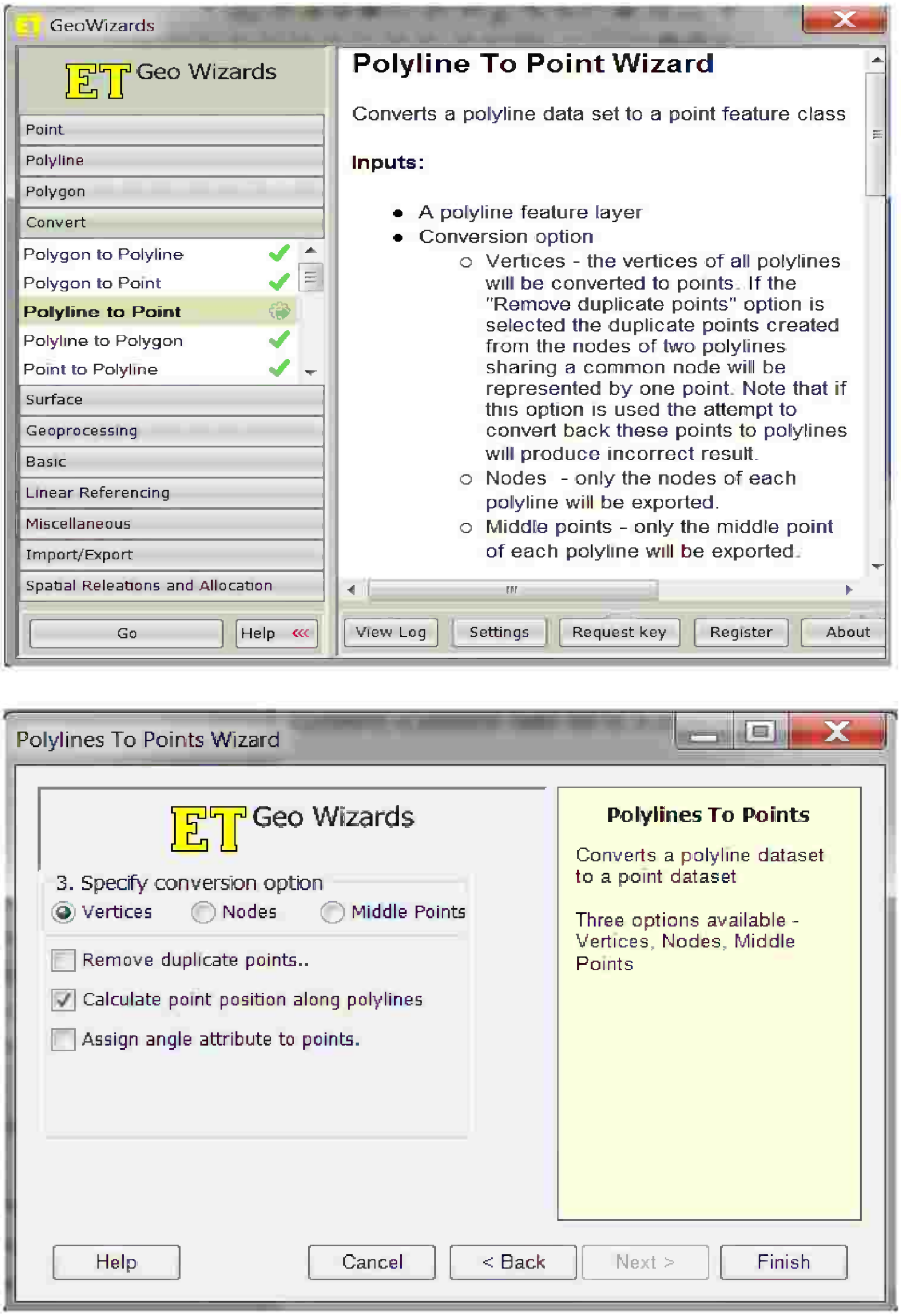


Figure (III -3) Contour lines maps from Egyptian survey authority

ET GeoWizards is a set of wizard type tools that allow Arc GIS users to easily use it. This method is used to convert contour elevation lines map to elevation point to make interpolation Esri, 2013[115].



Figures (III -4): Steps of how to convert Polylines to points

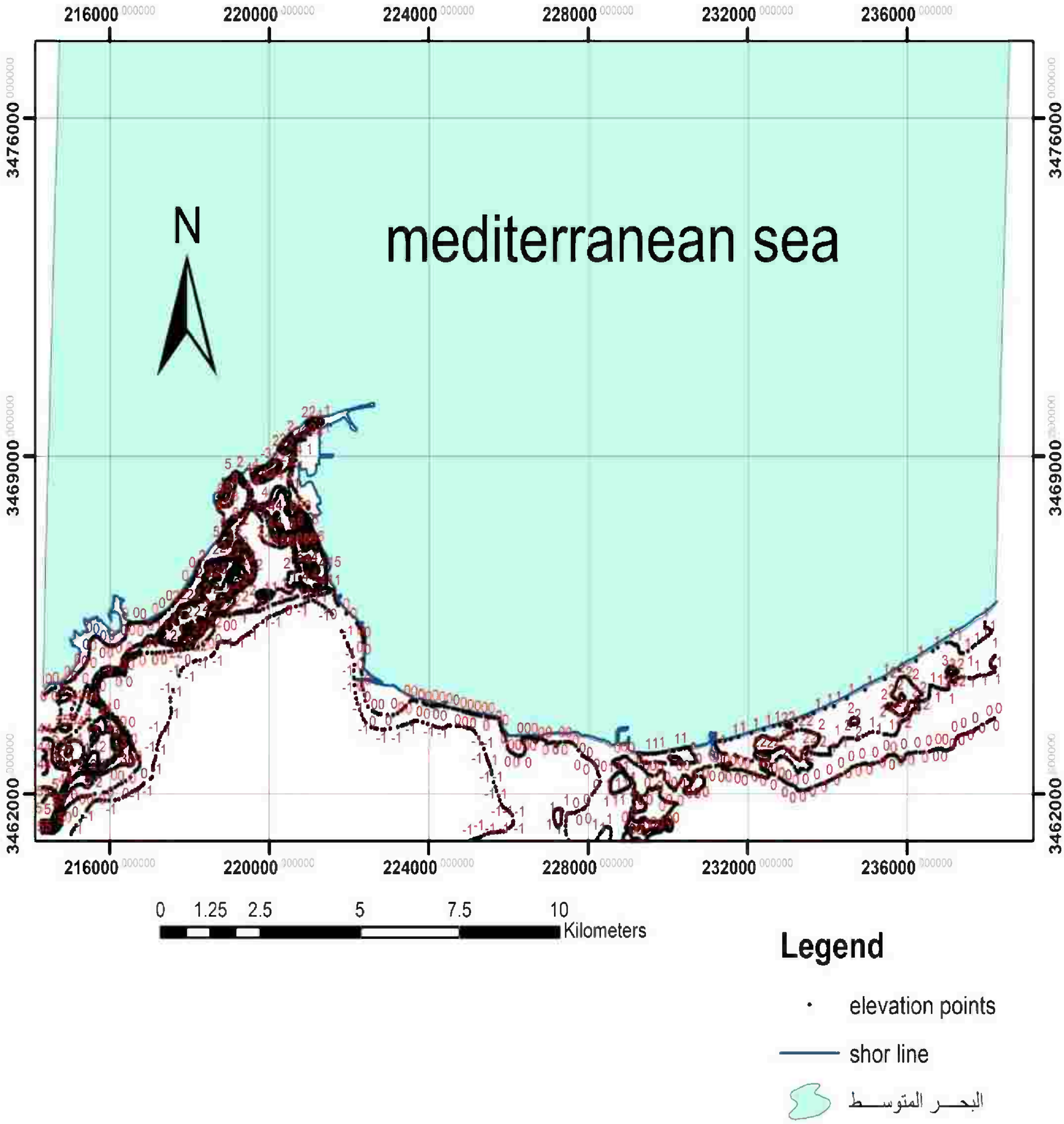


Figure (III -5) elevation points from maps

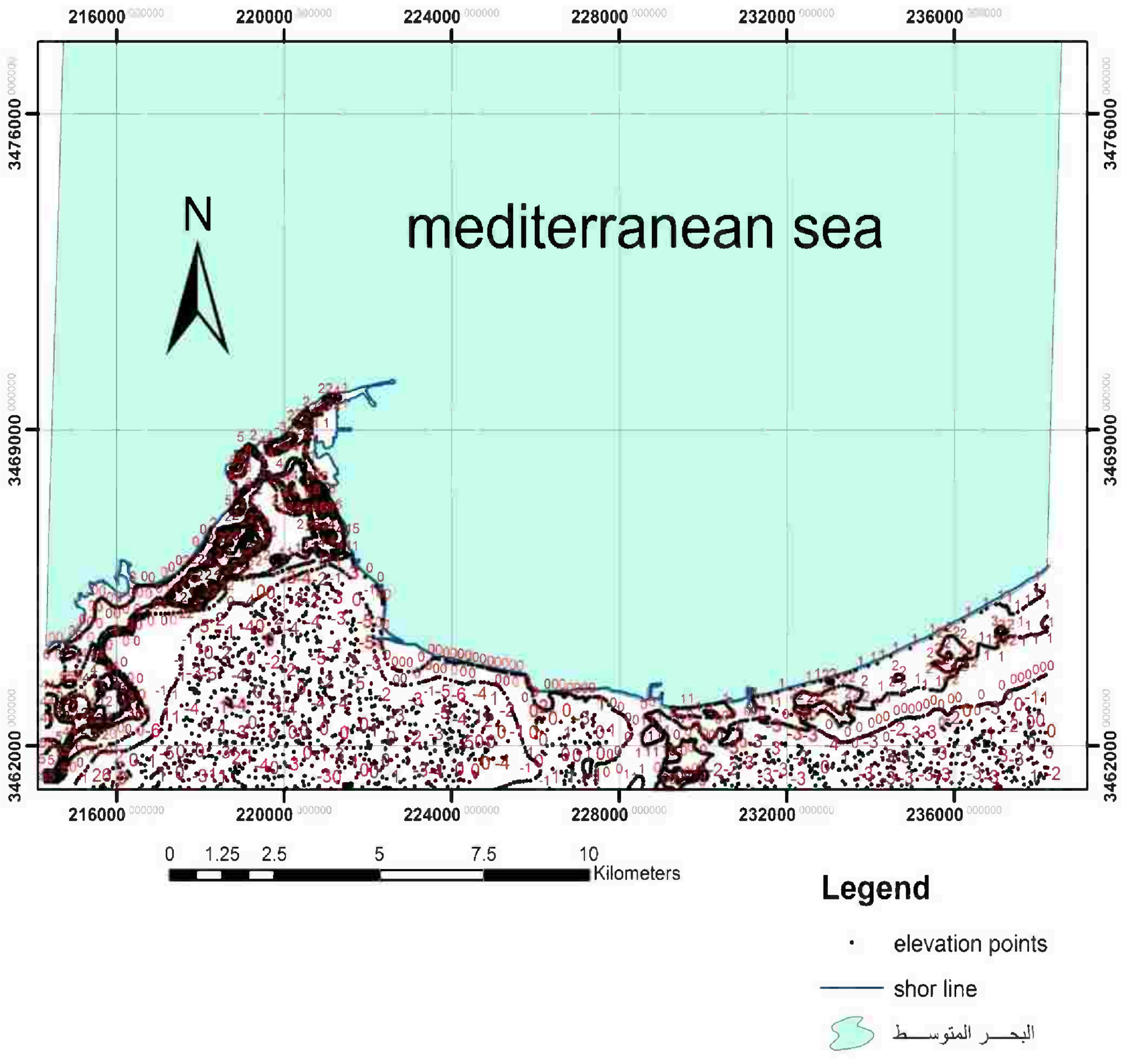


Figure (III -6) elevation points from maps with elevation SRTM

We used the kriging method because it is an optimal interpolation based on regression against observed z values of surrounding data points, weighted according to spatial covariance values. It is a method to build an approximation of a function from a set of evaluations of the function at a finite set of points. Beside there are some advantages of kriging:

- Helps to compensate for the effects of data clustering, assigning individual points within a cluster less weight than isolated data points (or, treating clusters more like single points)

- Gives estimate of estimation error (kriging variance), along with estimate of the variable, Z, itself (but error map is basically a scaled version of a map of distance to nearest data point, so not that unique)

- Availability of estimation error provides basis for stochastic simulation of possible realizations of Z (u)

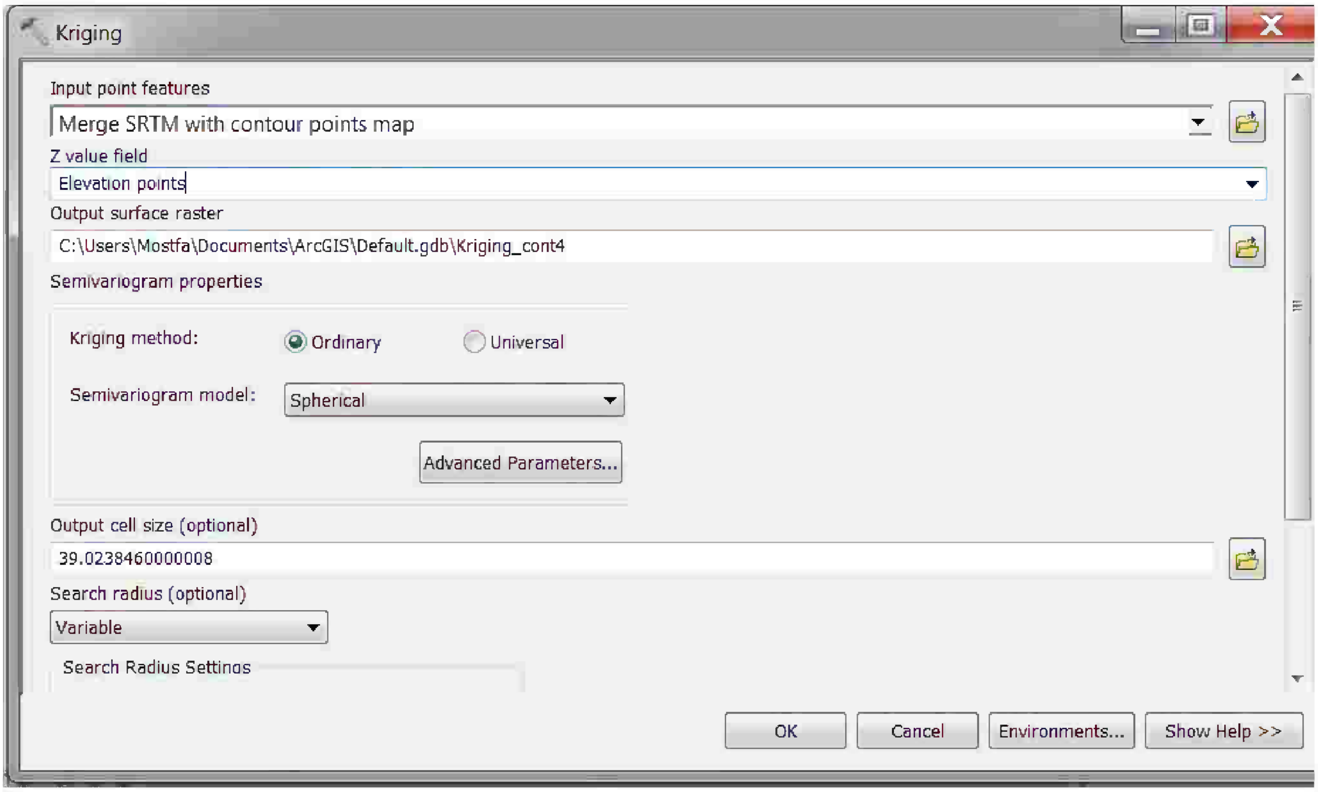


Figure (III -7) Kriging window in Arc/Map program

All interpolation algorithms (inverse distance squared, splines, radial basis functions, triangulation, etc.) estimate the value at a given location as a weighted sum of data values at surrounding locations.

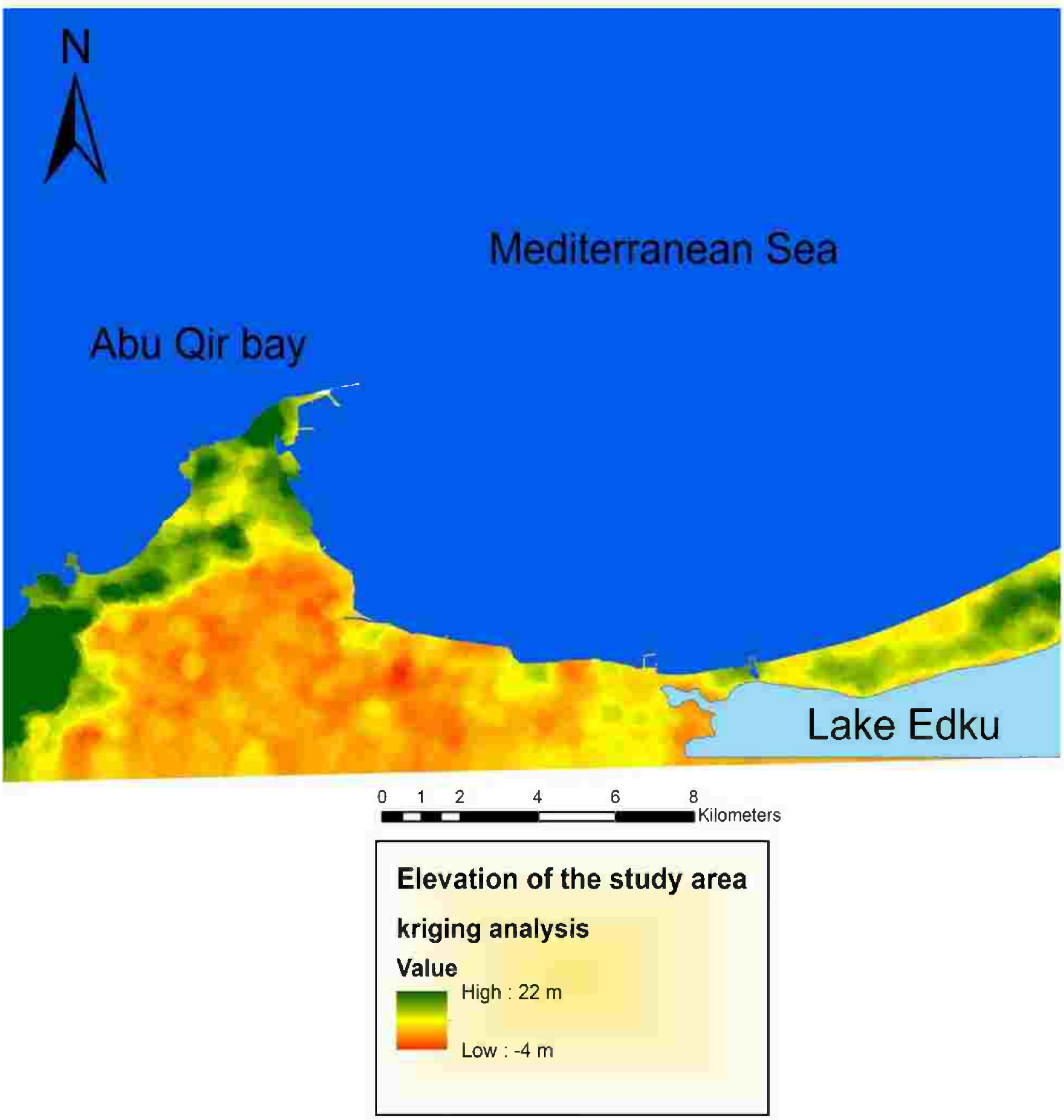


Figure (III -8): The resulting Digital Elevation Model (DEM)

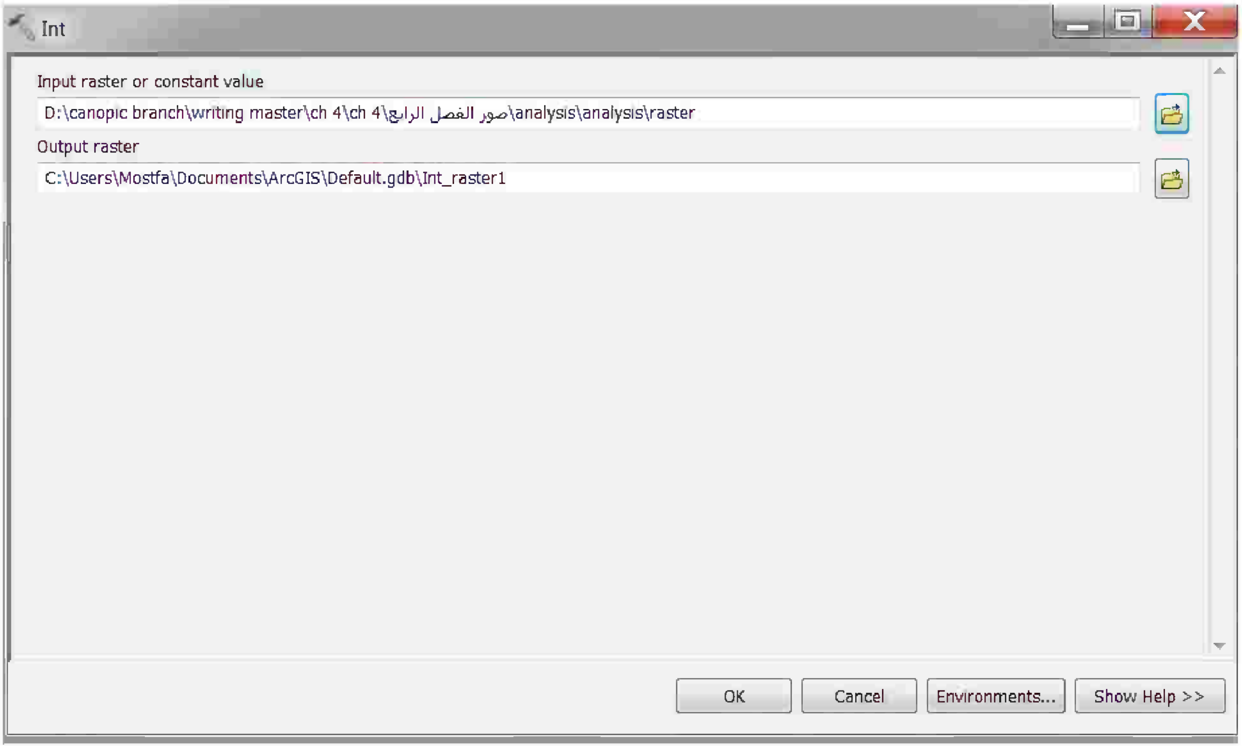


Figure (III -9): Converting value raster to integer type to deal with

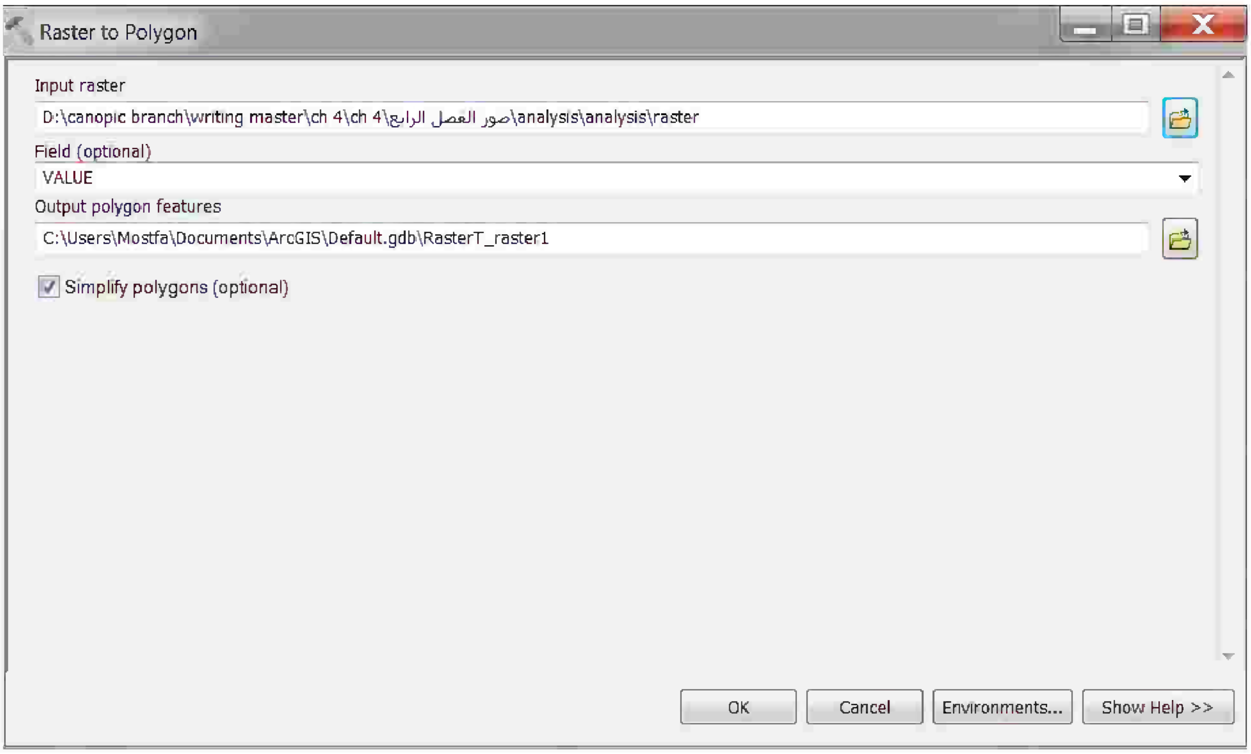


Figure (III -10): Converting the raster that is integer type to polygon to deal with

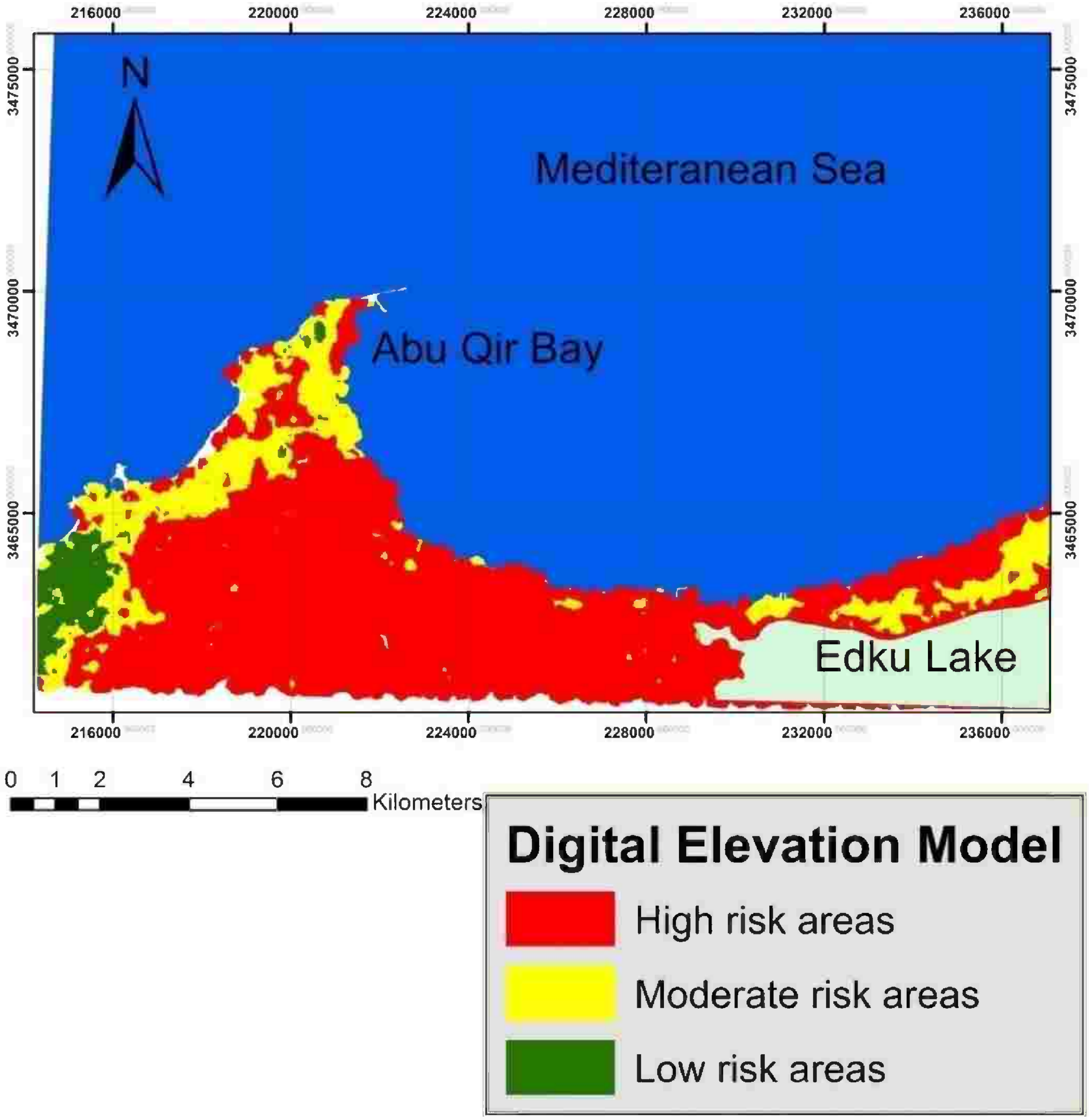


Figure (III -11): Digital elevation model classification in Abu Qir region

D. Overlaying methodology

After building a database for feature classes in Abu Qir city and building Digital elevation point, overlaying between feature classes and DEM were made to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk areas from 4 to 22 meters above sea level **Figure (III -5)**. In addition to from overlaying I will know total of residential areas, cultivated areas, schools, industries, archeological sites, health unites and hospitals located in high risk areas, moderate risk areas and low risk areas.

Overlaying between cultivated areas and DEM to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk areas from 4 to 22 meters above sea level.

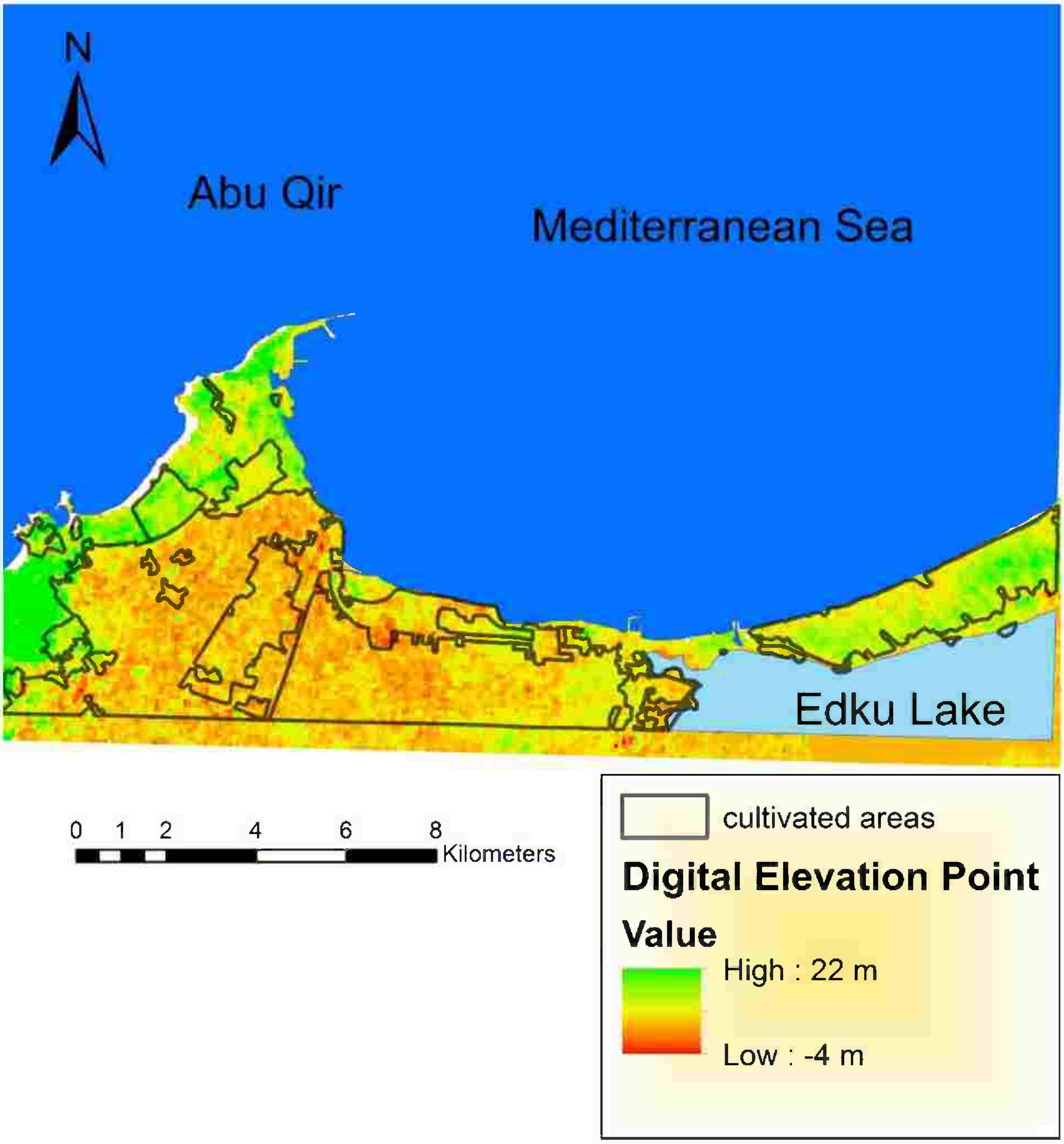


Figure (III -12) Overlaying cultivated areas onDEM in Abu Qir Region

Overlaying between residential areas with DEM to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk areas from 4 to 22 meters above sea level.

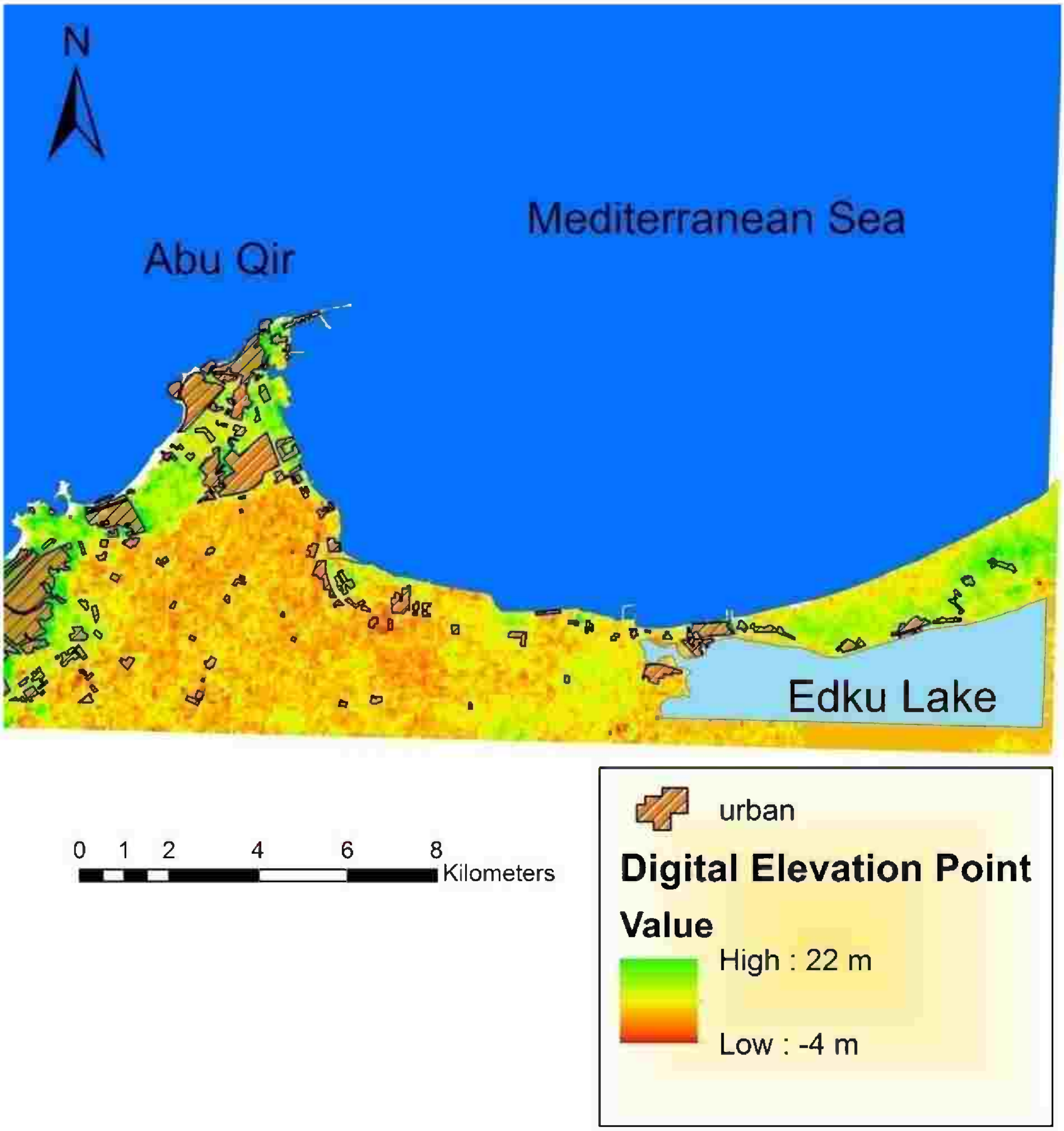


Figure (III -13) Overlaying residential areas onDEM in Abu Qir Region

Overlaying between companies with DEM to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk from 4 to 22 meters above sea level.

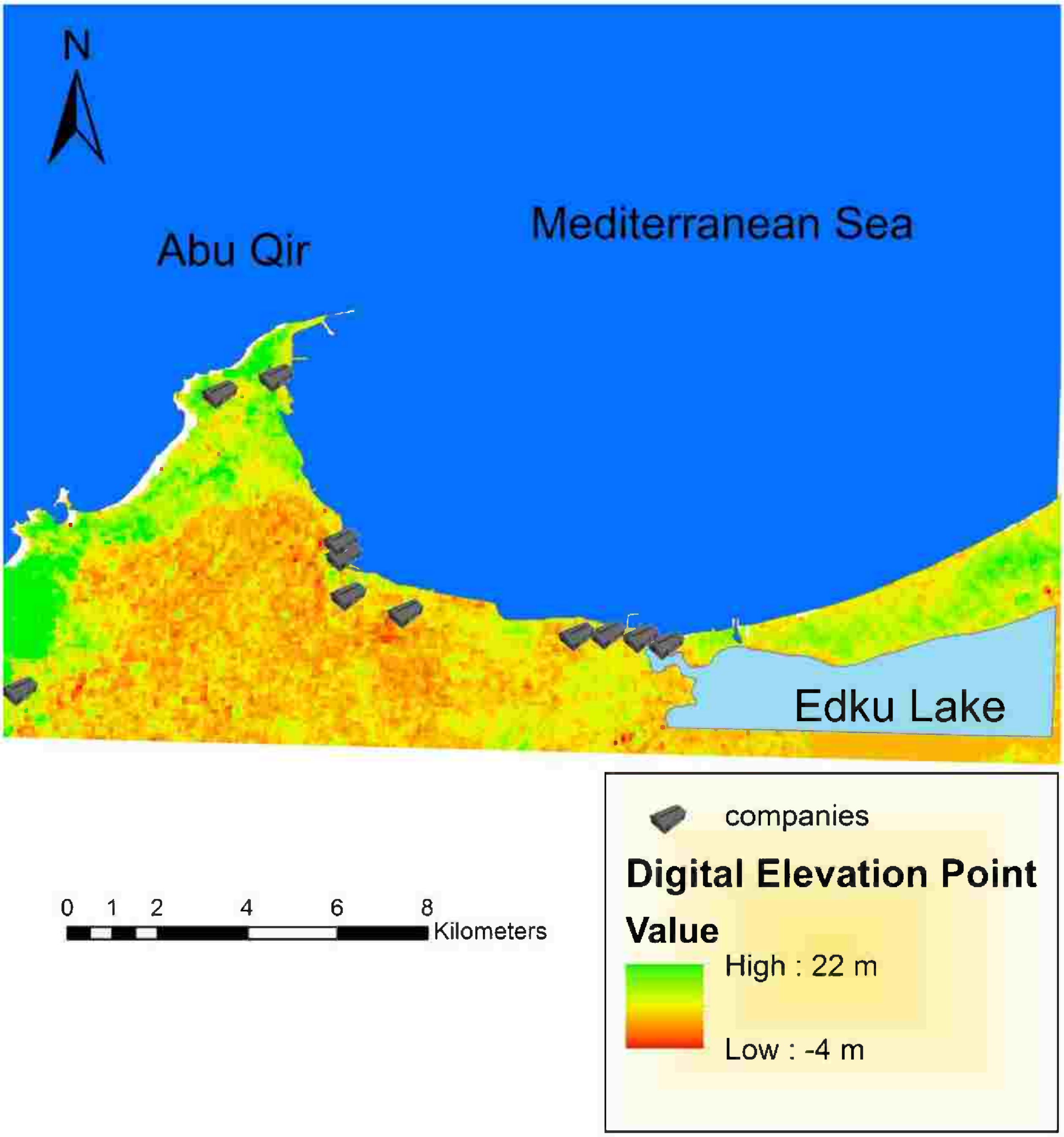


Figure (III -14) Overlaying companies with DEM in Abu Qir Region

Overlaying between schools with DEM to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk from 4 to 22 meters above sea level

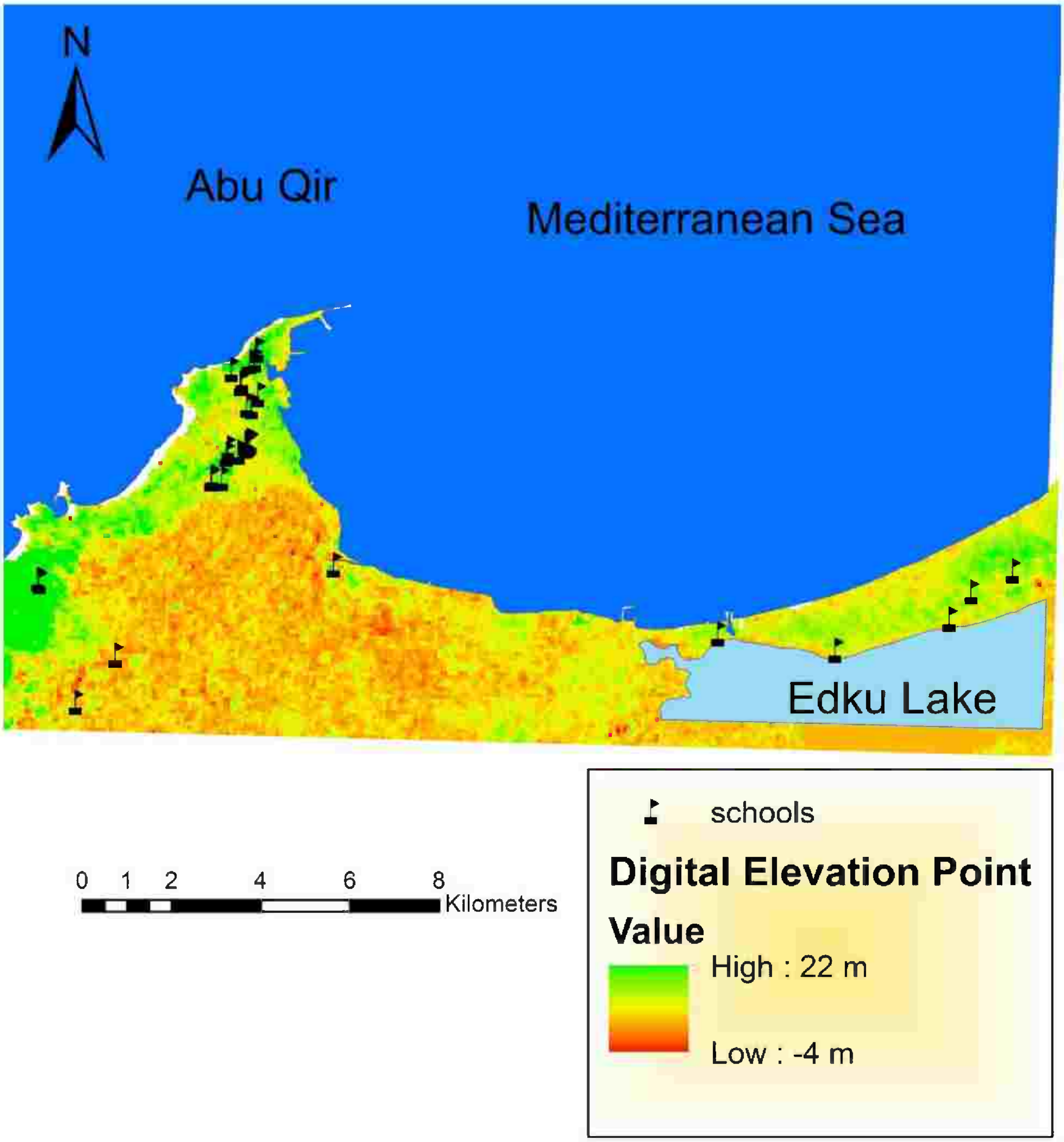


Figure (III -15): Over laying schools on DEM in Abu Qir Region

Overlaying between hospitals and DEM to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk from 4 to 22 meters above sea level

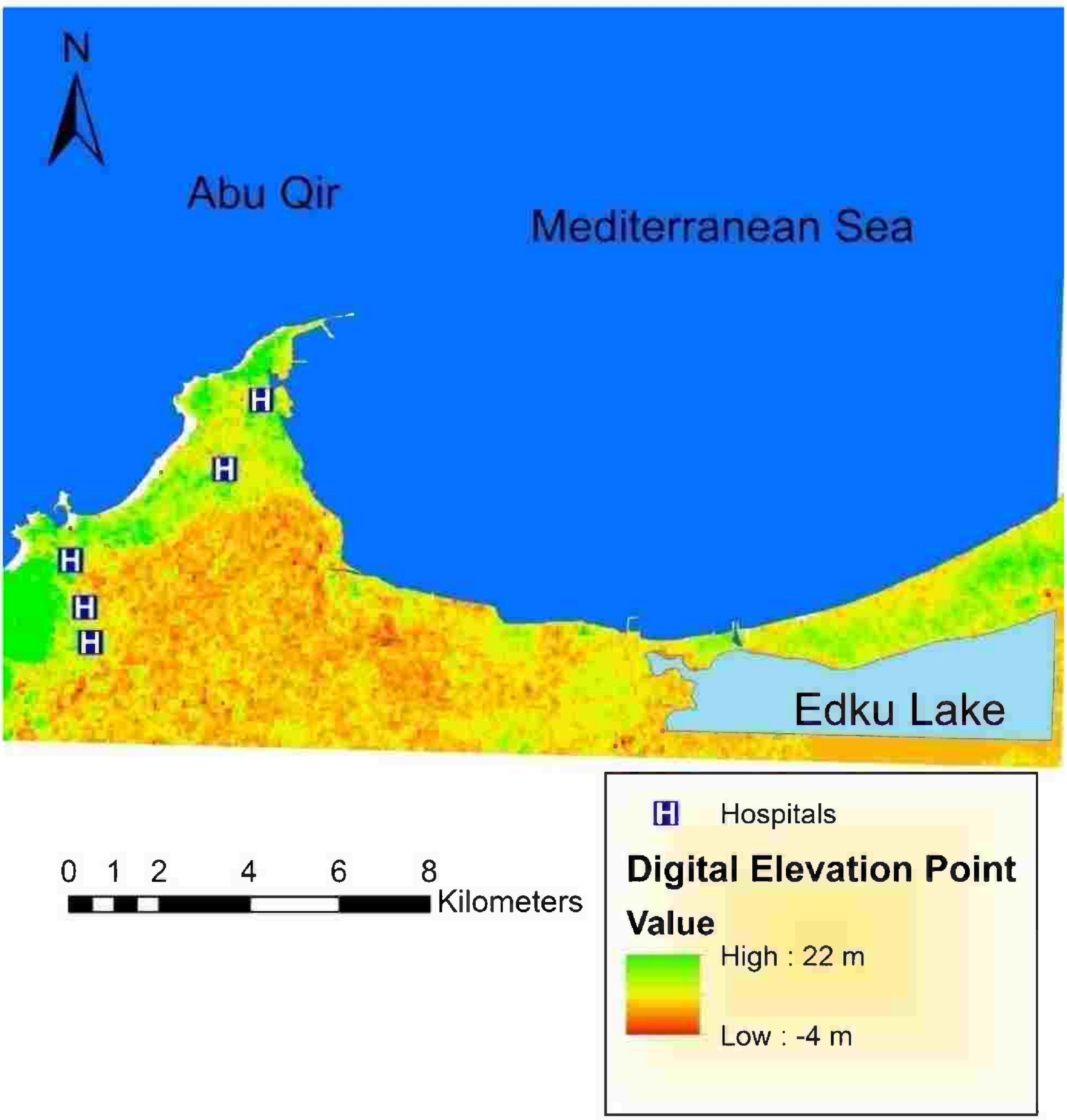


Figure (III -16): Over laying hospitals on DEM in Abu Qir Region

Overlaying between health unites and DEM to obtain the most affected areas to sea level rise and percentage of high risk areas from -4 to -1 under sea level, moderate risk areas from 0 to 3 meters above sea level and low risk from 4 to 22 meters above sea level.

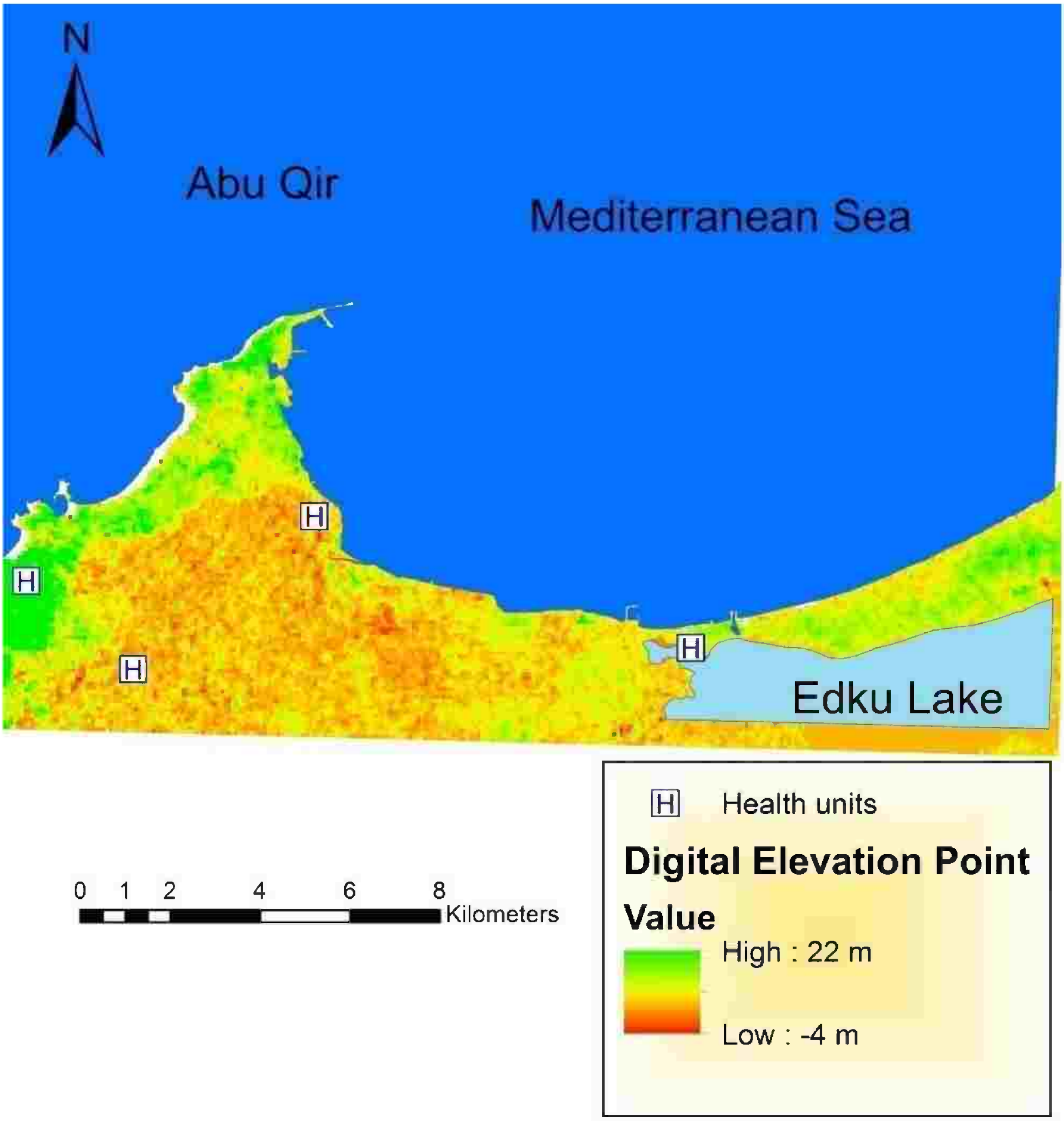


Figure (III -17): Over laying health units with DEM in Abu Qir Region

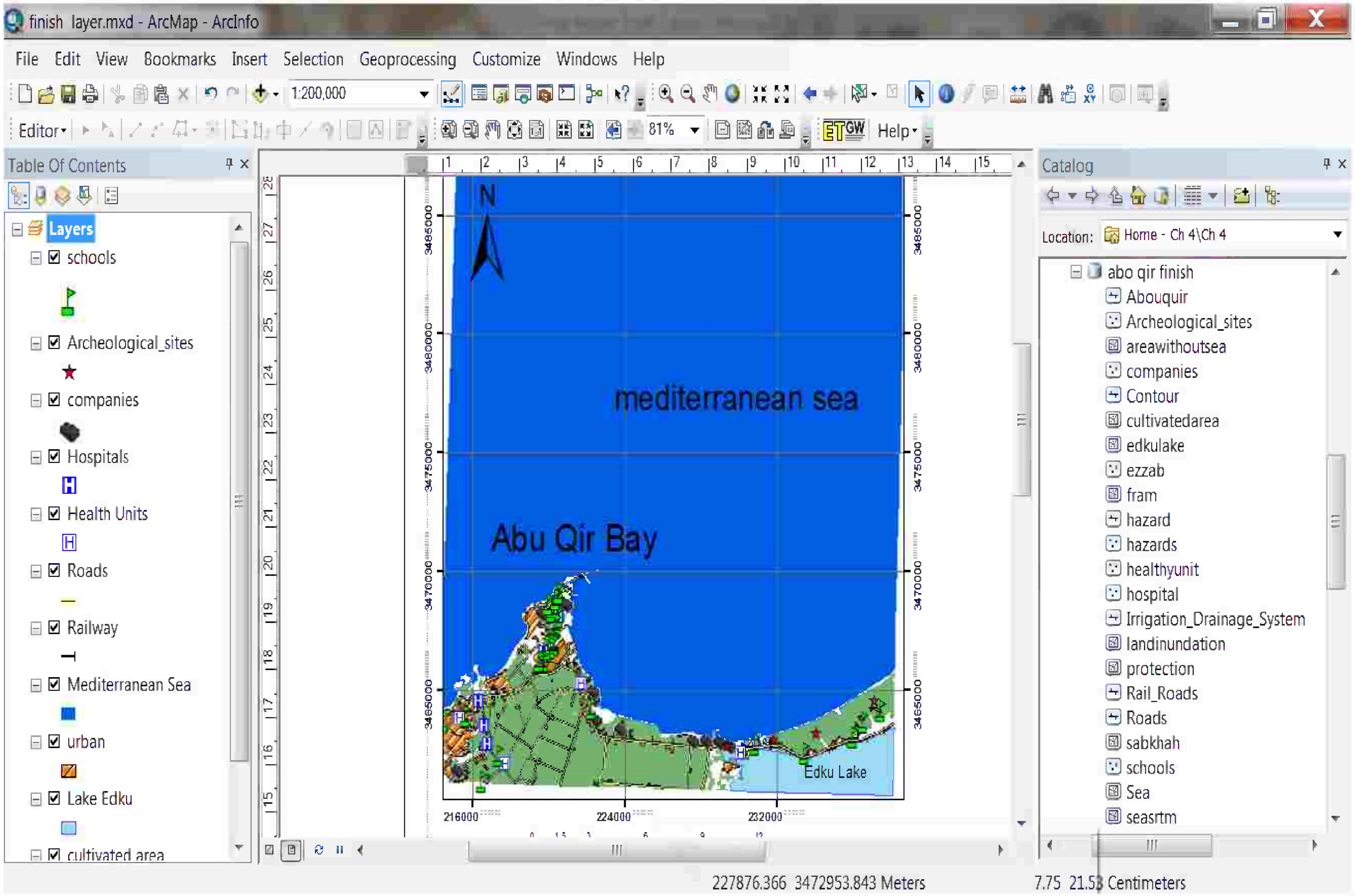


Figure (III -18): Some feature classes on ARC/GI