THE NILE DELTA IN A GLOBAL VISION

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ABSTRACT

The Nile is the world's longest river. It begins south of the equator in the north-central section of the African continent where its principal flow is known as the White Nile. It then travels an incredible 4,130 miles (6,645 kilometres) before arriving at its terminus in the vast triangle-shaped Nile Delta in northern Egypt. The delta region, north of Cairo, then drains into the Mediterranean Sea. A delta is a low-elevation plain where sediment is deposited at the mouth of a river. Nile Delta is characterized as tide-dominated delta where river mouths hit the sea in areas affected by large tidal ranges. The Nile Delta is one of the oldest intensely cultivated areas on earth. It is very heavily populated, with population densities up to 1600 inhabitants per square kilometre. The low lying, fertile floodplains are surrounded by deserts.

Only 2.5 % of Egypt's land area, the Nile delta and the Nile valley, is suitable for intensive agriculture. Most of a 50 km wide land strip along the coast is less than 2 m above sea-level and is protected from flooding by a 1 to 10 km wide coastal sand belt only, shaped by discharge of the Rosetta and Damietta branches of the Nile. Many activities have impact on eutrophication and contamination status, the ecological value and environmental condition of the Nile Delta region such as agriculture development, and industrial activities within the catchments and inadequate rural sanitation.

Excessive irrigation applications lead to water logging problems in vast areas of the region. The continuous seawater intrusion creep explores the problem of groundwater salination year after year. Recent increases in global population, together with enhanced standards of living, have created greater demand on water resources, requiring improved groundwater management. Any new groundwater development should take into account the possibilities of saline intrusion, and ensure adequate control, with prevention of saline intrusion being seen as the ideal.

While a reasonably clear picture exists in terms of salinity of water, availability of usable information on other water quality parameters is very limited. There is an essential need for a rational water data collection and management program. Large volumes of domestic and untreated industrial effluent are still discharged into the river and water channels. In addition, significant proportions of fertilizers and pesticides used are leached into the water system. Potential groundwater contamination from fertilizers could be a concern. Applications of nitrogen, phosphate and potassium fertilizers in the Egyptian agriculture increased nearly 4-fold during the 1960-1988 periods.

Keywords: Nile Delta, Geography and Hydrology, Water Resources, Water Degradation

INTRODUCTION

Nile Delta is characterized as tide-dominated delta where river mouths hit the sea in areas affected by large tidal ranges, the delta shape can be extensively reshaped by the twice a day flood and ebb tidal currents moving in and out of the river mouth. This usually happens in bays and estuaries where the river mouth is protected from much wave activity. The relentless in and out currents of tides can sculpt the sediment into elongate tidal bars. At the head of the bay there may be a classic looking delta, in this location referred as bay-head delta, but farther seaward is a zone of lots tidal bars, islands and inlets caused by tide reworking. A vertical stratigraphic section through this type of deposit will be dominated by lots of mud and sands that show bidirectional (ebb-directed and flood directed) cross bedding and not much evidence of wave reworking (e.g. beaches) nor or strongly prograding rivers (e.g. dominated lobate deltas).

All deltas undergo alternating construction to destruction phases due to fundamental changes in the relative influence of sediment input from rivers and redistribution by marine coastal processes. During the past 7000 years world deltas, including the Nile, have been in an overall construction phase. However, the Nile delta has converted to a destruction phase during the past 150 years, triggered by water regulation which has disrupted the balance among sediment influx, erosive effects of coastal processes, and subsidence. This former destruction has been altered to the extent that it is no longer a functioning delta but, rather, a subsiding and eroding coastal plain.

Symptoms of the destruction phase of the Nile delta include accelerated coastal erosion and straightening of the shoreline, reduction in wetland size, increased landward incursion of saline groundwater, and build-up of salt and pollutants to toxic levels in wetlands and delta plain. Without seasonal flushing by floods, the former delta plain surface is now incapable of recycling and/or removing agricultural, municipal and industrial wastes generated by Egypt’s rapidly expanding population. Moreover, the remaining capacity of the system to regenerate itself will further diminish as water is diverted away from the delta for new irrigation and municipal projects in the Egyptian desert, and water allocations to Egypt are decreased by upstream countries.

NILE DELTA GEOGRAPHY AND HYDROGEOLOGY

At Cairo, the Nile spreads out over what was once a broad estuary that has been filled by riverine deposits to form a fertile delta about 250 kilometres wide at the seaward base and about 160 kilometres from north to south. According to reports written in the first century A.D., seven branches of the Nile ran through the delta. Since then, humans and nature have closed five of them. The only two remaining channels are Rosetta, whose mouth is located just east of Alexandria, and Damietta, whose mouth is located at the northeast tip of the Delta. The other five mouths, which have been proven both historically and geologically to have existed, are indicated on the map below. The Nile Delta, most of which is under cultivation, is an area of fertile alluvial soils and abundant water. Cairo and Alexandria, Egypt's two largest cities are located in this region, as shown in Fig.1.

The Nile Delta is one of the oldest intensely cultivated areas on earth. It is very heavily populated, with population densities up to 1600 inhabitants per square kilometer. The low lying, fertile floodplains are surrounded by deserts. Only 2.5 % of Egypt's land area, the Nile delta and the Nile valley, is suitable for intensive agriculture. Most of a 50 km wide land strip along the coast is less than 2 m above sea-level and is protected from flooding by a 1 to 10 km wide coastal sand belt only, shaped by discharge of the Rosetta and Damietta branches of the Nile. Erosion of the protective sand belt is a serious problem and has accelerated since the construction of the Aswan dam.

In ancient times the Nile Delta was recorded as having seven tributaries; however the flow has been controlled so that now there are only two main branches, the Damietta and Rosetta. The Nile Delta measures approximately 100 miles / 160 kilometres north to south, and 150 miles / 240 kilometres east to west at its widest in the north. The rich silt soil of the Nile delta is the most fertile in all Africa. Whereas in many places in the world the topsoil is measured in mere inches, in the Nile Delta is varies from 50 to 75 *feet* in depth. The delta area would have provided plenty of water and rich soils for the crops needed to produce sufficient food reserves to overcome the 7-year famine that occurred at the time of Jacob's entry into Egypt.

Re-establishing some level of natural hydrology is the only credible solution for attaining equilibrium among sediment accretion on the delta plain to offset subsidence, progradation along the coast to offset erosion, and sufficient water influx to flush and remove the high levels of salt and pollutants throughout the system. However, increased Nile water and sediment discharge could begin to restore a functioning delta system only if there is a substantial reduction in human impacts.

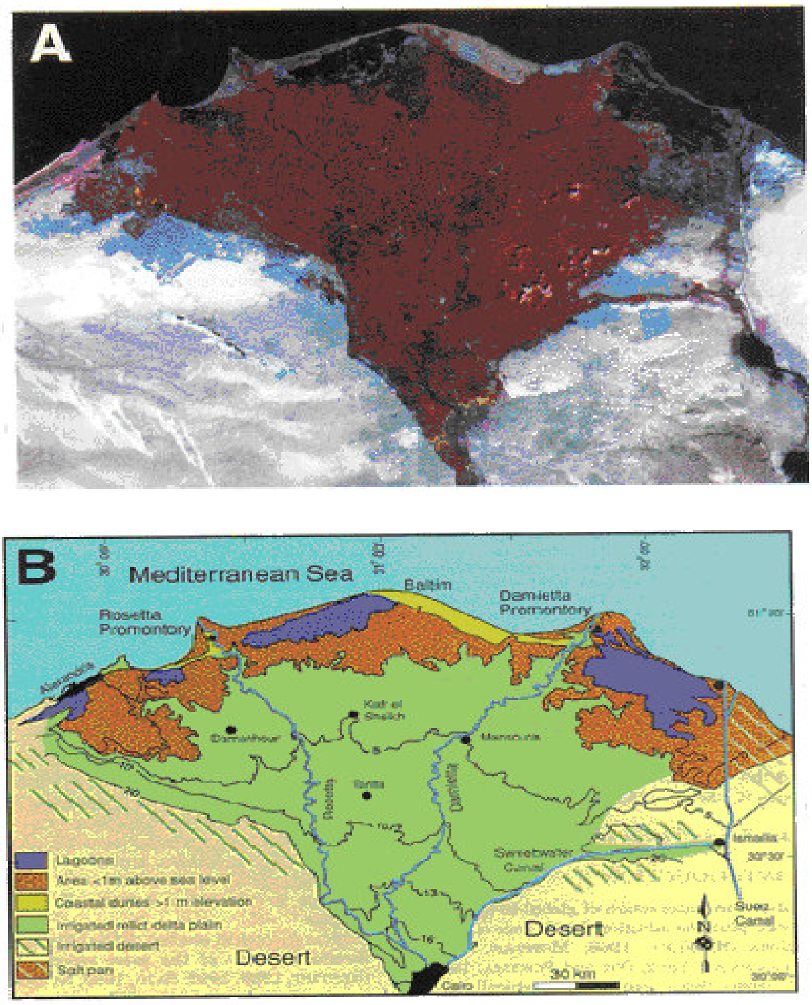

Figure 1. Landsat mosaic (A) shows urban expansion (yellow); development of large sand dunes (pink); coastal erosion, and salt pans. Map B shows topographic and geographic features of the Nile delta and major cities

The contrast between the lush vegetation of the Nile delta and river course and the dry sand of the Sahara can be seen spectacularly in this enhanced true colour Medium Resolution Imaging Spectrometer (MERIS) image. The grey area to the bottom of the "triangle" of the delta is Egypt's Capitol, Cairo. The Delta is lush with vegetation and its many canals work their way through the land. The Delta fans out like a palm tree trying to reach the Mediterranean. Vast fields of cotton, maize and rice decorate the flat landscape and the buffalo graze, plow or turn wheels for the grinding of the grain. During the winter months it is wise to bring a raincoat because of the high clouds that blow in from the Mediterranean. Along the coast itself, a sweater may be needed in the evenings. In the image detail, just the Nile delta itself is shown, but this time in MERIS bands to enhance the spectral difference over land and to show up the sedimentation from the delta into the Mediterranean. Looking closely we can see the different channels of the Nile cutting their way towards the sea. The black areas represent cities on the shores of the channels; El Mansure, Tanta and El Mahalla el Kubra are the three cities in the centre of the delta, with Cairo again clearly visible at the base. The blue plume offshore is caused by sediment from the river being pumped into the sea.

NILE DELTA SOURCE WATER ASSESSMENT

The water resources in the Nile Delta region have experienced drastic events in the last three decades since the operation of the High Aswan Dam. Many activities have impact on eutrophication and contamination status, the ecological value and environmental condition of the Nile Delta region such as agriculture development, and industrial activities within the catchments and inadequate rural sanitation. Excessive irrigation applications lead to water logging problems in vast areas of the region. The continuous seawater intrusion creep explores the problem of groundwater salination year after year. Moreover, the domestic, industrial, sewage and agricultural drainage to surface and groundwater with all known effluents deteriorate the ecosystem in the Nile Delta.

In the past, the quality of most groundwater was not a major concern. Treatment usually consisted of chlorination and, if necessary, the removal of iron and manganese and other specific constituents. But within the last 10 years, it has become apparent that because of human activities many of the nation's groundwater aquifers have been contaminated by compounds other than those present in the natural environment. Many of the compounds that have been found in groundwater are known to be carcinogenic and/or mutagenic. Although their concentrations might be minute, the presence of these compounds is clearly a serious threat to the nation's groundwater resources. Principles of groundwater flow and process fundamentals have to be integrated to model the fate and transport of contaminants in the saturated zone. Both advective and dispertive transport of the contaminant have to be included in the contaminant transport model, as well as, the physical, biological, and chemical reactions.

It is important to realize that the groundwater at any given point represents a mixture of waters of different origin (surface waters as well as groundwater) and, therefore, also with different composition in terms of dissolved constituents, etc. The dissolved components reflect the various reactions between water and solid geologic phases (weathering, dissolution/precipitation, redox reactions, complication, etc.) that are continuously taking place along the water pathway, Fig. 1. Shows inter-connections between inland freshwater bodies. Thus, the water at any individual sampling location is generally not at equilibrium with the various geologic phases at the sampling place, with few exceptions. This is, of course, due to dynamic mixing of water from various sources, but also due the fact that true chemical equilibrium are rarely achieved between the common silicate components in the bedrock and the water phase.

The groundwater pressure is generally refered as piezometric head, while the subsoil phreatic surface of the clay cap is called shallow water and both water heads fluctuate around the year. The groundwater piezometric heads depend mainly nowadays on the irrigation practices on a regional scale while the shallow water table fluctuates in response to local irrigation practices, seepage from adjacent canals and field drainage depth. The difference in levels between the piezometric heads in the aquifer and the watertable in the aquitard causes the vertical movement through the clay cap. The direction of movement is determined by which level is higher compared to a common reference plain. Applying this phenomenon to the the Nile Delta region where the difference in levels of groundwater head and shallow water table causes upward flow through the clay cap. The catchment area can be divided on the basis of the above analysis into three zones; the downward movement zone in the south, upward movement zone to the north, and the seawater intrusion zone along the seashore. An early estimate of the upward seepage in the Nile Delta was made by Farid, 1979.

Recent increases in global population, together with enhanced standards of living, have created greater demand on water resources, requiring improved groundwater management. Any new groundwater development should take into account the possibilities of saline intrusion, and ensure adequate control, with prevention of saline intrusion being seen as the ideal. Any intrusion carries with it the risk that the matrix of the aquifer will become contaminated, causing a permanent loss of freshwater storage capacity. Where the possibility of intrusion exists, appropriate monitoring procedures should be routinely carried out. A network of sampling piezometers should be established to monitor heads and salinity changes along the coastal fringe. Actual methods for controlling saline intrusion vary widely according to geology, extent of the problem, water use, and economics. They generally rely on the principle that, in order to limit sea water intrusion, some fresh water outflow above the saline wedge must be maintained. They can be broadly divided into methods relying on barriers and those dependent on aquifer management; some of these are discussed briefly below.

The distinguishing physical features of groundwater flow which include relatively low flow velocities, often qualify aquifers to act as sinks for nutrients, toxicants, organic matters and other substances that produce significant water quality problems. The water quality of groundwater in the Nile Delta region is varying from place to another where the water salinity decreases towards the west direction. Field investigations revealed the existence of significant concentrations of Fe, Zn, Cu, Pb, and Cr in groundwater. Toxic substances of heavy metals and pesticides enter the groundwater with precipitation, drainage water and industrial wastes, which contaminate the aquifer.

STATE OF THE ART IN NILE DELTA WATER STUDIES

Egypt's agricultural sector is unique in that over 95% of its agricultural production is derived from irrigated land and its irrigation waters originate outside of its borders. On the macro level, the last two centuries of modern Egypt have witnessed considerable development starting by the construction of the Delta Barrage (1898) to assure summer cotton irrigation in the Nile Delta, and the establishment of an intensive canal networks for irrigation, and ending by the construction of the Aswan High Dam in the sixties of the nineteenth century. However, the average annual flow during the last decade has been slightly decreased than the long term average. The concentration on the macro level was on the hardware part of the system, while the present and the future will concentrate on the software of the system. Such activities include improvements in operation and maintenance, demand management, re-cycling, capacity building, and user's participation. Present agricultural water use accounts for about 84% of the total water use while industrial, municipal and navigational use accounts for 8%, 5%, 3% respectively, (Abu Zeid, 2000).

The exact nature and details of these inter-relations are not clear yet. A new factor that adds to the complexity of the issue is the water quality changes. Agriculture is the largest water user in Egypt. It is essentially dependent upon irrigation, and consumes the bulk of the available water (about 84%). The total irrigated area now amounts to 7.4 million acres. The future expansion programs depend very much on the availability of additional water resources. Surface irrigation systems are used in most old agricultural lands of Egypt, with an application efficiency which is still considered low. Excess irrigation water applications contribute to the groundwater shallow aquifers and to water logging problems. Water pumped from such aquifers or re-used through re-cycling of agricultural drainage water brings up the overall water use efficiency to a reasonable value.

While a reasonably clear picture exists in terms of salinity of water, availability of usable information on other water quality parameters is very limited. There is an essential need for a rational water data collection and management program. Large volumes of domestic and untreated industrial effluent are still discharged into the river and water channels. In addition, significant proportions of fertilizers and pesticides used is leached into the water system. Potential groundwater contamination from fertilizers could be a concern. Applications of nitrogen, phosphate and potassium fertilizers in the Egyptian agriculture increased nearly 4-fold during the 19601988 period.

Use of pesticides has increased as well, but not at the same rate of fertilizers. In early 1991, use of herbicides to control aquatic weeds in Egypt was stopped. Increasing water pollution from industrial and domestic sources, if allowed to grow unchecked, is likely to reduce the amount of water available for various uses in the future. Legal basis of controlling water pollution already exists through law 48 of 1982 on the Protection of the River Nile and Water Ways from Pollution". The law established stringent effluent standards for various organic and inorganic pollutants. Lack of proper funds for treatment of industrial wastes and for providing adequate municipal wastewater treatment plants, has hindered, so far, the full enforcement of the law. Salinity and water logging from irrigation practices has been a problem. However, Egypt has embarked on the construction of an extensive drainage system, a significant part of which is already operational (3.9×10^{6} acres). For the long term sustainability of agriculture, drainage should continue to receive priority (Abu Zeid, 2000).

STATEMENT OF CRITICAL REGIONAL WATER PROBLEM

Understanding the groundwater recharge process is essential in protecting groundwater and streamflow source quality. Short transit times associated with the recharge process can potentially adversely affect groundwater quality due to lack of attenuation time or contaminant decay. Recharge water from an agricultural field, for example, containing pesticide may infiltrate through the subsurface and potentially impact groundwater quality for drinking water. In addition to groundwater recharge contamination potential, mechanisms controlling recharge play an important role the soil/stream water chemistry. Preferential flow bypasses the soil matrix and reduces the ability of the soil react with solutes carried by the infiltrating water. Preferential flow decreases the time for infiltrating water containing contaminants or nutrients to react with the soil-plant and microbial system.

Residence time estimation offers benefits to evaluating recharge water flow through the subsurface to groundwater sources. Mean residence time (MRT) determined from seasonal isotope variations in input water (precipitation) and output water (subsurface water or streamflow) can provide information about groundwater recharge processes and contamination vulnerability. Seasonal variations of environmental isotopes (i.e., deuterium and oxygen-18) in water are attenuated during movement through the subsurface system. This attenuation is related to the recharge pathways (both matrix and macropore controlled) and residence time of the system. Thus, MRT can be used in assessing whether a groundwater source is vulnerable to contamination from recharge on the surface or in providing a hydrologic connection from surface water to groundwater. A surface hydrologic connection is needed to provide evidence of "direct influence of surface water" to groundwater sources.

INTEGRATED SUSTAINABLE DEVELOPMENT OF THE NILE DELTA

The relationship between Nile Delta agricultural activities and groundwater return flow is poorly understood. In virtually every study, investigators have opined that groundwater discharge may account for some, if not all, of the unexplained increases in many constituents. However, in each instance a detailed investigation of ground– and surface water interaction (and the associated impacts on instream water quality) is highly recommended. It is therefore within the dual context of applied research and policy–driven inquiry that we propose the following study.

The results and benefits generated from the integrateted sustainable development of the Nile Delta, proposed by the present study and a series of following studies, will be significant in several respects. First, our multi-level approach to model development and parameter estimation will provide a template for modeling complex ground - and surface water systems in other areas; especially those dominated by irrigated agriculture. By combining simple mixing-cell models, environmental isotopes and vadose zone modeling with airborne geophysics and on-the-ground field testing, we expect to constrain model error and uncertainty in a manner that will raise confidence in groundwater and solute transport model results.

Second, the proposed drilling and sampling program will yield useful information regarding the chemistry of sediments and associated groundwater in the Nile Delta area. Long speculated as a potential source of groundwater solutes in the Nile Delta, this study will, for the first time, help quantify the physical and chemical nature of the Pleistocene soils and stratigraphy that comprise the shallow aquifers in the region. Third, by integrating the results of this effort with ongoing surface-water studies by the investigators in the Nile Delta, we will acquire critical information regarding the nature of groundwater solute discharge to the Nile River, and the associated impacts on instream water quality. This is significant in that current surface water quality programs do not model the hydrobiological processes associated with solute exchange at the ground-surface water interface.

Lastly, the results of the present study will provide critical information to planners, regulators and other basin stakeholders as they attempt to assess the impacts of large-scale changes in land-use activities on the hydrology and chemistry of the lower Nile River; and provide a blueprint for addressing similar problems in other countries within the region, including Nile River riparian countries.

CONCLUSIONS

The water resources in the Nile Delta region have experienced drastic events in the last three decades since the operation of the High Aswan Dam. Many activities have impact on eutrophication and contamination status, the ecological value and environmental condition of the Nile Delta region such as agriculture development, and industrial activities within the catchments and inadequate rural sanitation. Excessive irrigation applications lead to water logging problems in vast areas of the region. The continuous seawater intrusion creep explores the problem of groundwater salination year after year. Moreover, the domestic, industrial, sewage and agricultural drainage to surface and groundwater with all known effluents deteriorate the ecosystem in the Nile Delta. An overview of the Nile Delta has been highlighted. Water Resources assessment and critical regional problem statement are addressed. An integrated sustainable development Scenario of the Nile Delta is prroposed in the present study. The results and benefits generated from the proposed present study will be significant in several respects to provide critical information to planners, regulators and other basin stakeholders as they attempt to assess the impacts of large–scale changes in land–use activities on the hydrology and chemistry of the lower Nile River; and provide a blueprint for addressing similar problems in other countries within the region, including Nile River riparian countries.

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