MedWetCoast Project

Wadi Gaza Wetland Area

The Hydrological Study

October 2001 ***The Draft Report***

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CHAPTER ONE

1 Introduction to Wadi Gaza and the wetland site

1.1 Introduction:

It has been said that:
" Rainwater used to flow from the hills and mountains of Hebron and the Northern Negev desert, accumulate in Beer-sheva area, cross the Gaza Strip… and discharge to the Mediterranean… Wadi Gaza used to flow in winter and bring huge amounts of rainwater, disturbing the transportation between the northern and southern parts of the Gaza Strip" (Goodson, 1999).

Although accurate topographical maps are unavailable, the watershed of Wadi Gaza is estimated to cover more than 3500 km^2 of the Northern Negeve Desert and the Hebron Mountains as well as the small catchment in Gaza. The Wadi's length from origin to mouth is about 105 km, where the last 9 km of it is located in Gaza Strip. Its name Wadi Gaza is only for the last part which is located in Gaza. Wadi Gaza has two main tributes one is Wadi Alshari'a which collects water from the Hebron Mountains in the West Bank and the other is Wadi Alshallala which collects water from the Northern Negeve highest. Figure 1.1 shows the other names of the upper parts of the Wadi including Wadi Sheneq, Wadi EI-Khalsa and Wadi Thamela in addition to other small streams. Wadi Gaza continue to flow as one course in its last part in Gaza Strip down to the Mediterranean Sea with a slope of about 1: 450, which is almost flat, while its slope in the upper parts in Negev and Hebron Mountains is about 1: 100 (Awadallah, 2000).

The Wadi gains it's importance from the fact that it is the only surface water resource in Gaza Strip as well it is the main natural feature of Gaza which make it the major place for the biodiversity. The Wadi area is a site of significant importance to migrating water birds, located on the migration route of migrating birds. A recent survey found that on average 250,000 white storks, 70,000 white pelicans and 500,000 raptors migrates across this region from Europe to Africa in autumn and that about a million raptors and 450,000 white storks transit the area from Africa to Europe in spring (Goodson, 1999).

1.2 History:

Wadi Gaza has been known for very long time in the history. The Kan'ani people -the grandfathers of the nowadays Palestinians- who lived in Palestine from 2500 BC and formed their kingdom there called it the Besor (Eddabagh, 1985), from were the biblical language took the name and used it in many verses and locations in the bible such as 1 **Samuel 30,** 9*" David and the six hundred men with him came to the Besor Ravine, where some stayed behind,"* and the verses **1 Samuel 30,** 21*" Then David came to the two hundred men who had been too exhausted to follow him and who were left behind at the Besor Ravine. They came out to meet David and the people with him. As David and his men approached, he greeted them."*

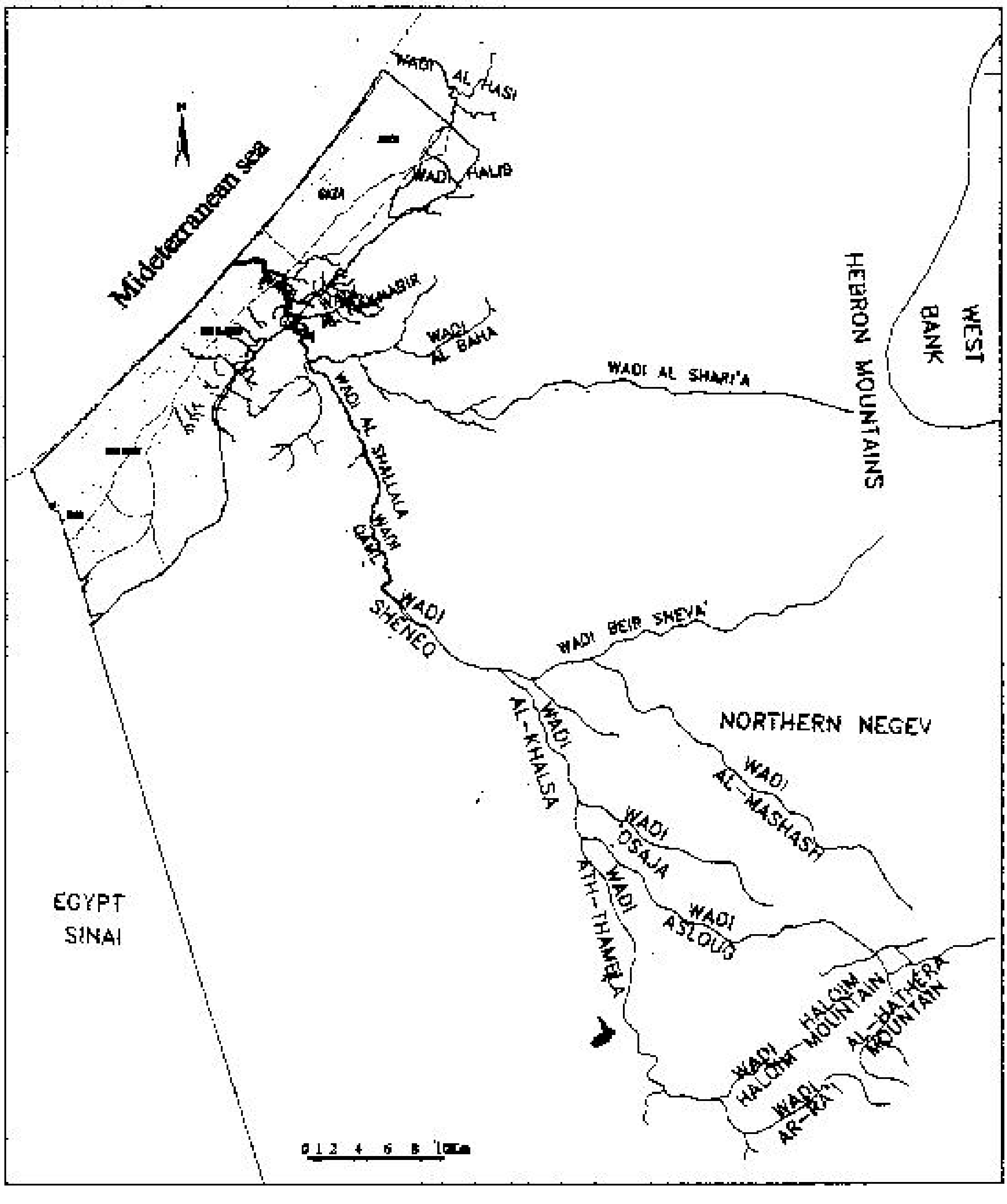

Figure 1.1 Wadi Gaza and it is tributes base map (Awadallah, 2000).

From a geological point of view (which will be detailed later in chapter two), Wadi Gaza has a unique formation from the general geology of the coastal plain, which is the gravel horizon. This gravel horizon forms the floor of Wadi Gaza which is of lower Pleistocene age (Picard, 1943). This aging of the gravel horizon means that the starting of the formation of Wadi Gaza extends back to at least 11,000 years ago.

1.3 The wetland site of Wadi Gaza:

Wadi Gaza wetland area shown in figure 3.1 is located at the down end of the Wadi at the Wadi's mouth. It is covering a small area compared to other wetlands in the world (about 25 hectares). Yet it is very rich in biodiversity and of great significance to migrating birds from Europe to Africa in autumn.

Information gathered from meetings with local and foreign archeologist working in the site of Wadi Gaza suggests according to their findings that the wetland site of Wadi Gaza is old as the wadi it self. Interviews with local community of the area clears out that the wetland site till the late sixties (1960's) was much bigger than it is now. Local people says that the wetland site was permanently flooded and that it was like a jungle starting about 100 to 150 m from the railway line shown in the area map figure 2.2, describing the water seeping out from it at those days as "very sweet". The pressure put on land and groundwater after the second Palestinian migration due to the concentration of large numbers of people in the small area of Gaza strip and the Israeli activities upstream were main causes of the deterioration of Wadi Gaza as well the wetland site of it.

Chapter two

2 Physical Characteristics of Wadi Gaza and the Catchment Area

2.1 Introduction:

The watershed of Wadi Gaza is estimated to cover more than 3500 km^2 of the Northern Negeve Desert and the Hebron Mountains as well as the small catchment sub-area in Gaza it self. Unfortunately no information is available on the upper catchment area of Wadi Gaza beyond the armistice line. All the available information is for the small sub- catchment area located in Gaza.

2.2 Physical characteristics of Wadi Gaza drainage catchment:

According to the master drainage plan done for the Ministry of Planing and international cooperation (MOPIC 1998), there are 6 sub-basins in Gaza strip which drainage to Wadi Gaza as shown figure 2.1 Below. This drainage catchment area is bounded according to the universal grid by the four points in table 2.1. These four points of the catchment area are shown in figure 2.1. Figure 2.2 is showing the detailed sub-basins with the two meteorological stations of rainfall at the catchment area.

P1	P2	P3	P4
31° 31′ 01″ N	31° 29′ 50″ N	31° 27′ 15″ N	31° 24′ 22″ N
34° 25′ 33″ E	34° 30′ 25″ E	34° 21′ 56″ E	34° 23′ 50″ E

Table 2.1 Universal coordinates of Wadi Gaza catchment area

The altitude of this catchment area varies from maximum of 30 m ASL at the armistice line to 0 level at the mouth of the Wadi. The total drainage area inside Gaza from these sub-drainage basins is only 6007 hectares or 60.07 Km^2. This area compared to the large catchment area of the Wadi beyond Gaza strip borders is a very small area. As shown in table 2.1 the estimated volume of discharge from these sub-drainage basins based on 5 year return period is only about 1.0 M m^3, while for example the estimated total volume discharge of wadi Gaza for the hydrological year 1994/1995 is about 20 M m^3.

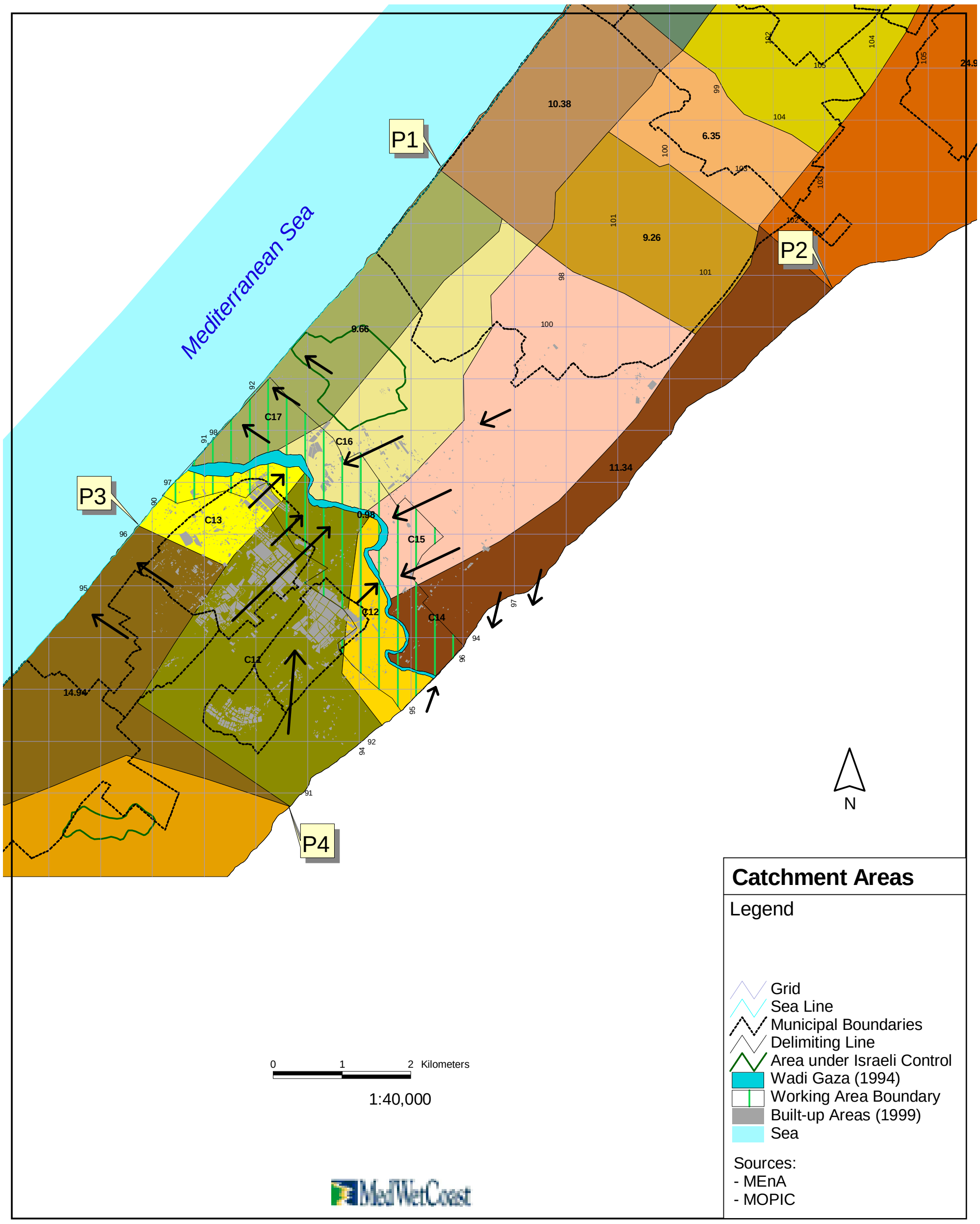

Figure 2.1 Wadi Gaza catchment area coordinate points

Basin	*Total Area dunums*	*Sub-Basin*	*Area dunums*	*Total area*	*Volume (m3)*	*Qmax (m3/sec)*
C11	16100	C11U	7100		172,581	25.78
		C11N	9000	16100	13,051	1.46
C12	2050	C12U	260		6,982	1.72
		C12N	1790	2050	3,717	0.54
C13	3400	C13U	1050		27,149	5.26
		C13T	1050		4,393	0.62
		C13N	1300	3400	2,645	0.34
C14	11150	C14U	2650		66,614	10.91
		C14Z	1550		53,041	10.34
		C14N	6950	11150	14,123	2.16
C15	18400	C15U	17310		412,614	56.41
		C15Z	270		9,680	2.53
		C15N	820	18400	1,752	0.28
C16	8970	C16U	8880		214,023	30.77
		C16T	90	8970	412	0.11
TOTAL	60070	TOTAL	60070	60070	1,002,777	149.23
Volume and Discharge Calculations are Based on Return Period of 5 Years						
		for T=10 y	1,233,415.71	183.55		
		for T=20 y	1,403,887.80	208.92		

Table 2.2 Drainage sub-basins to wadi Gaza

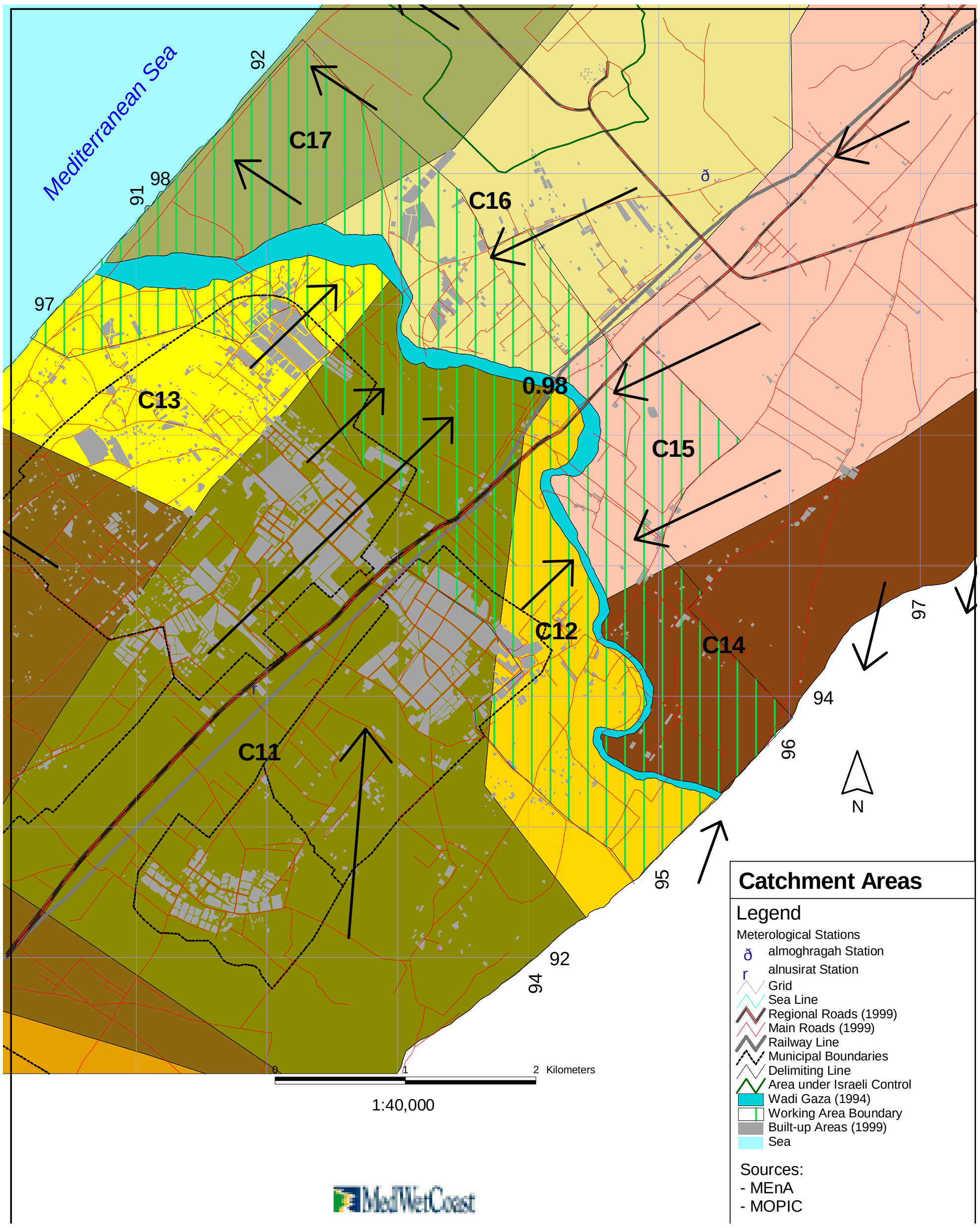

Figure 2.2 Wadi Gaza catchment area with the meteorological stations of the area

2.3 Geology of Wadi Gaza

The Geology of Gaza area is part of the coastal plain geology, which consists of a series of geological formations sloping gradually from East towards the West as shown in figure 2.3. These geological formations are mainly from the Tertiary and Quaternary eras. Important part of these formations is the coastal aquifer of the Gaza area which consists of the Pleistocene age Kurkar Group and recent (Holocene age) sand dunes. The Kurkar Group includes marine and eolian calcareous sandstone ("kurkar"), reddish silty sandstone ('hamra'), silts, clays, unconsolidated sands, and conglomerates (CAMP, 1999).

Wadi Gaza remains a unique upper formation of the geological history of the area. The wadi floor is dominated by considerable aggregation of Pleistocene gravel. This "Gravel Horizon" is originating from erosion of the high mountains in the Hebron Area and the Northern Negeve.

The floor of Wadi Gaza is characterized by the presence of 1-2 m thick gravel horizon, which is poorly sorted, and rich in pottery pieces (Picard, 1943). This horizon as a whole is composed of pebble, cobble, gravel and some boulders with sand and clay matrix. They are mainly calcareous, but flinty ones are also common. Some pebbles contained Nummulites and Gastropods of Eocene age (Elkhodary and Anan, 1985). Their texture varies from micritic to coarse crystalline indicating their source from the Eocene carbonate rocks of Bier Sheva and the Northern Negeve. This gravel horizon extends from the floor of the wadi on both sides to underlie the loess sediments exposed on those sides. The gravel horizon is of lower Pleistocene age (Picard, 1943). This aging of the gravel horizon means that the starting of the formation of Wadi Gaza extends back to at least 11,000 years ago.
In some, localities in the Wadi excavations of gravel from the floor exposed the *Pliocene* sediments underlying disconformably the gravel horizon. These sediments are composed of medium to coarse-grained sands with some fine pebbly layers showing cross and graded-bedding. Thus indicating their shallow marine origin. On the other hand a few number of Upper Pliocene sanddunes was observed in the course of the wadi. They represented positive areas during the deposition of gravel, but overlain by loess sediments. On the other hand a few number of Upper Pliocene sanddunes was observed in the course of the Wadi. These sanddunes are partly hardened and constituted obstacles in the course of the water stream of Wadi Gaza (Elkhodary and Anan, 1985).

To the west of the main road Gaza -Khanyounis and in downstream direction the gravel horizon continues for a while, but with smaller sized and better sorted pebbles.The gravel horizon is generally overlain by loess sediments ranging in thickness from l2-5m or less. It must be mentioned that these loess sediments are accumulated directly on the surface of the already mentioned sanddunes, without gravel horizon in between, indicating that this horizon was deposited only around these sanddunes (Elkhodary and Anan, 1985). The loess is mostly uniform in composition and shows a layer of pebbles, more or less continuously, in its middles parts dividing it into an upper and a lower loess bed. It has to be mentioned that the loess accumulation was not continuous from, base to top and from one side to the another. In vertical direction it is often noticed that the loess accumulation was interrupted either by a flood period (the pebbly intercalation in the middle parts of the loess) or by periods of nondeposition of loess and plant coverage of the surface which caused the formation of brown soil three or four times during the accumulation of the upper loess bed (Elkhodary and Anan, 1985).

Geologic history Of Wadi Gaza Geological formations *Adapted from (Elkhodary and Anan, 1985)*

Picard (1943) mentions that the coastal -plain formations of Palestine during the Pleistocene are as follows (from top to bottom):

Formation	***Epoch***
Upper - Kurkar Complex	Upper Pleistocene
Upper -Gravel Series	Middle Pleistocene
Lower - Kurkar Complex	Transition
Lower - Gravel Series	Lower Pleistocene

Table 2.3 geological formations history of Wadi Gaza

The gravel horizon making the floor of the Wadi and exposed at the base of its both sides represents the Lower- gravel series of the Lower Pleistocene. It was deposited on the surface of cross - and graded-bedded sands and around sanddunes of Pliocene age. The Lower Pleistocene pluvial period (Pluvial A *in Picard, 1943) d*uring which the gravel horizon was deposited followed by an interpluvial period. This is represented by the overlying lower loess bed in the studied area. During a following but shorter pluvial period (Pluvial B in Picard, 1943), the pebbly layer in the middle part of the loess was deposited. This pebbly layer is then overlain by the upper loess bed which is rich in pottery remains and shows 3-4 interruptions in loess deposition through soil-formation. The accumulation of the lower and Upper loess beds, including the pebbly layer in between, is of Middle to Upper Pleistocene age (Pottery remains *in* the upper loess bed). Consequently the formation of Wadi Gaza may be dated back to Late Pleistocene -Early Holocene (Pluvial C in Picard, 1943). Through washing of Loess from the course of the Wadi the pottery remains are concentrated on the wadi floor and mixed with its gravel.

Recently the mouth of the Wadi is mostly covered by eolian sanddunes. These sanddunes are formed by action of wind on friable sandstones belonging to the Upper Kurkar complex exposed in form of a ridge parallel to the Mediterranean coast. The above-described geological formations of Wadi Gaza are what feature differently the geological history of Wadi Gaza from the adjacent and lower general geologic history of Gaza Strip. The most recent study of the general geology of the coastal plain of Gaza strip was made by the Gaza

Environmental Profile, 1994. A modified summary of the study is illustrated bellow:

Geological History and formations of the coastal plain of Gaza area:

Geology of Gaza Strip consists of a series of geological formations sloping gradually westwards as shown in figure (2.3). These formations are mainly from the Tertiary and Quaternary eras. Table (2.4) below summarizes the geological history of the area, which was obtained from oil exploitation logs up to 2000 m in depth.

TERTIARY FORMATION

The Quaternary deposits throughout Gaza area are underlain by the Saqiya formation of the Pliocene, which constitutes part of the Tertiary formations in the area. The Tertiary formation is composed mainly of shallow marine clays, shales and marls. The thickness of this formation is about 1200 m at the shoreline, and it decreases down rapidly to the east. Moreover, it is found in accordance to oil exploitation logs that there are other Tertiary formations such as chalks, limestone, and sandstone at depths of over 2000 m.

QUATERNARY FORMATION

The Quaternary deposits in the area cover the Pliocene Saqiya and have a thickness of about 225 m. The overlying Pleistocene deposits consist of the following formations:

.1 Marine Kurkar formation

The constituents of this formation mainly consist of shell fragments and consolidated quartz sands with calcareous material. The thickness of the shell layer varies between 10 m in the east and increases to 100 m westward. The marine Kurkar deposits form a good aquifer due to its high permeability and porosity.

.2 Continental Kurkar formation

This formation is composed of calcareous sandstone with alternating red loamy sand beds. The thickness of this formation is about 100 m at most. The origin of this formation is marine sediments, which formed parallel to beach ridges .

.3 Recent deposits

These deposits are found at the top of the Pleistocene formation with a thickness up to 25m. These deposits can be divided into four different types:

a. Sand dunes

These dunes extend along the shoreline, and originate partly from Nile River sediments. The thickness of these dunes is about 15 m, and their width is small in the south, increasing northward up to 3 km.

b. Sand, loess and gravel beds

This formation is small in thickness (about 10 m) and it is the main formation of the Wadi Gaza area (near surface).

c. Alluvial deposits

These deposits are spread in the area around Wadi Gaza and have a thickness of about 25 m.

d. Beach formation

This formation is composed of a relatively thin layer of sand with shell fragments. It is mainly unconsolidated ,however; in some places it is cemented due to the precipitation of calcium carbonate.

r a	***Epoch***	***Age in million year BP***	***Formation***	***Environment of deposition***	***Lithology***	***Max. Thickness (m)***	***Water bearing character***
Quaternary	Holocene	0.01	Recent	Terrestrial	Sand, loess, calcareous silt and gravel	25	Locally phreatic aquifer
	Pleistocene	1.8	Continental Kurkar Complex	Eolian Fluvial	Calcareous sandstone and loamy sand	100	Main aquifer
			Marine Kurkar	Near shore	Calcareous sandstone, Limestone (sandy and porus(	100	Main aquifer
Tertiary	Pliocene	12	Conglomerate	Near shore		20	Base of the coastal zone aquifer
			Saqiya	Shallow marine	Clay, marl, shale	1000	Aquiclude
	Miocene	25		Marine	Marl, limestone, sandstone and chalk	500	Aquiclude alternating permeable layers with saline water

Table (2.4) Geology and geological history of the Gaza Strip. (Gaza Environmental profile, 1994).

Geomorphology of wadi Gaza

Many geomorphologic features can be observed along the course Wadi Gaza. As mentioned before the loess sediments were accumulated during previous interpluvial periods on the whole studied area, and particularly on the low -land topography. In recent times the erosional process of the seasonal floods coming from the eastern highland towards the coastal plain in the West took place. A year after year the course of Wadi Gaza became deeper in the loess sediments, until it reached the gravel horizon of the Lower Pleistocene. The studied part of the Wadi represents an old stage. Eight meanders can be observed along its course between the armistice in the East and its mouth at the Mediterranean coast in the west. These meanders were caused by the already existing sanddunes that were standing as obstacles in the course of wadi. Another geomorphologic feature is also observed along the course of the Wadi. It is represented by the existence of one terrace along most of its course on one or on both sides. This terrace represents mostly a climatic knick point. It is marked by the intercalating pebbly layer in the middle parts of the loess sediments.

Morphology of Wadi Gaza:

Wadis Gaza is the largest wadi of Gaza strip it crosses Gaza strip south of Gaza City from East to West. Wadi Gaza length is about 9 km in Gaza and it extends into the armistice border for about 95 km where it collects the water from a big catchment area (3600 km^2) from the Hebron mountains and the Northern Negeve.

The width and depth of Wadi Gaza varies a lot a long it is way to the Mediterranean Sea. It is as wide as 60-40 meters in the eastern and middle part of it, while in the west at its mouth to the sea it becomes more than 400 m wide. The depth of Wadi Gaza as well varies from 12-6 meters in the East, while it becomes less deep in the West up to 3-4 meters till it reaches the zero level at the mouth. Basic morphological information on wadi Gaza is shown in table 2.5. The southern cliff of the Wadi is always higher than the Northern one. Wadi Gaza has a small tribute of it, comes from the south east of Gaza called " Wadi Abu Kattroon " it ends at Wadi Gaza at eastern part of it opposite to Alburaij refugee camp from the northern east side. This tribute is minor one since it depends on the local catchment of Gaza area and doesn’t feed Wadi Gaza with signification quantity of discharge.

At a short distance from the green line (international border) there is another tribute feeds Wadi Gaza, it is called Wadi Alshallalah and it comes from the Northern Negeve.

The major wadi stream channel comes from the Hebron mountains, and this main stream was diverted by the Israelis to an adjacent area where its been stopped their and collected at basins located 6 km east of Gaza.

The vegetation in the Wadi is dominated by Tamarisk growing on the dunes and sand deposits in and around the Wadi bed. The wetter areas have stands of Typha which also fringe the water body near the outlet to the sea. Around 125 ha of saltmarshes recorded in the Gaza Environmental Profile of 1994 have disappeared following construction of the sea bridge at Wadi Gaza mouth in 1996. This has disrupted the outlet, affected windblown sand deposition, improved access to the public, and generally modified the whole of the ecology and geomorphology of the Wadi Gaza estuary. Foundations of the bridge have also blocked the river course and therefore raised the level of water in the wetland pond. While this may be the case, it is evident that sand accumulation, either brought down by Wadi Gaza in recent floods, or deposited during sea storm events is the another proximate cause of the blockage. During westerly storms, seawater may be pushed over the sand barrier into the Wadi, maintaining brackish conditions in the downstream part of the system.

Origin source	Hebron mountains and the Northern Negeve
Mouth	The Mediterranean Sea
Total length from origin	105 km
Length in Gaza strip	9 km
Width in Gaza	20-270m with max. width at the mouth
Topography in Gaza	30 m AMSL at Gaza border gradually dropping to 0 m AMSL at the mouth
Flow direction	From East to West
Main tributaries	Wadi Ashareeaa, wadi Ashallalah

Table 2.5 Basic information on Wadi Gaza

2.4 Hydrogeology

The Hydrogeology of the coastal aquifer consists of one sedimentary basin, the post-Eocene marine clay (Saqiya), which fills the bottom of the aquifer. Pleistocene sedimentary deposits of alluvial sand, graded gravel, conglomerates, pebbles and mixed soils constitute the regional hydrological system. Intercalated clay deposits of marine origin separate these deposits, and are randomly distributed in the area. Their thickness is decreasing to the east and basically they can be classified as aquitards. In the eastern plain the aquifer is semi-confined with an average thickness of 10 m clay, becoming phreatic 4 km from the sea.

The regional groundwater flow is mainly westward towards the Mediterranean Sea. Most of the recharge is at the adjacent uphill eastern aquifer boundary and from dune areas near the coast overlaying the coastal aquifer itself and from the adjacent uphill area in the east zone.

The maximum saturated thickness of the aquifer ranges from 120 m near the sea to a few meters near the eastern aquifer boundary located beyond the Eastern Gaza border. Natural average groundwater heads decline sharply east of the Gaza Strip and then gradually decline towards the sea.

In the Gaza Strip, the coastal aquifer can be divided into three sub-aquifers. These three sub-aquifers overlay each other and are separated by impervious and semi-pervious clayey layers.

Schematization of the hydrogeological cross section of the Gaza Strip aquifer is shown in figure (2.3).

AQUIFER SYSTEM

The aquifer system in the area extends along the coastal plain of the Gaza Strip. It is a continuation of the shallow sandy stone coastal aquifer of Palestine, which is of the Pliocene-Pleistocene geological age. The main aquifer consists of marine deposits of sandstone, calcareous siltstone and red loamy soils as shown in figure 3.7. The thickness of the aquifer is about 80 m at most near the sea and its thickness decreases considerably down to 10 m in the east. The aquifer is composed mainly of clastic sediments overlying impervious clay. It is more or less phreatic in the eastern half. In the western part, the aquifer is divided by clay layers into sub-aquifers. These clay layers are considered in between aquitard and aquiclude. The unsaturated zone thickness varies between few meters to about 90 meters. (Gaza Environmental Profile, 1994)
The main characteristics of the aquifer system are:

- It is composed of recent sandy dunes and calcareous sandstone
- At the shoreline, there are some clay layers, which subdivide the aquifer and fan out inland
- There is a thin clay layer at the extreme east (at the border of Gaza Strip), which covers the aquifer and has a thickness of about 20m.
- Deeper aquifers are below the shale strata are saline.

The aquifer system can be divided into three sub-aquifers:

1. THE UPPER SUB-AQUIFER

The uppermost aquifer (classified as A-aquifer) extends from the shoreline to the east up to 2 km, whereas the lower sub-aquifer (C-aquifer) extends up to 5km. This aquifer is bounded from the top by the water table and at the bottom partly bounded by the first aquitard of silty clay. The thickness of this aquifer varies between 10 to 30 meters.

2. THE MIDDLE SUB-AQUIFER

This aquifer is mainly from Kurkar and micro-conglomerate. It is considered as a partly confined-unconfined aquifer since the semi-permeable clay layer extends eastward up to about 5km. The semi-permeable layer consists of clay with chalk and silty sand. The average thickness of this aquifer ranges from 40 to 50m.

3. THE LOWER SUB-AQUIFER

This sub-aquifer is the deepest one in the shallow aquifer. It is partly bounded by the second semi-permeable layer at the top and by the Saqiya impervious formation at the bottom. This aquifer is considered as confined at the shoreline up to about 5km eastward. The main constituents of this aquifer are sand and chalk with some conglomerate in the middle.

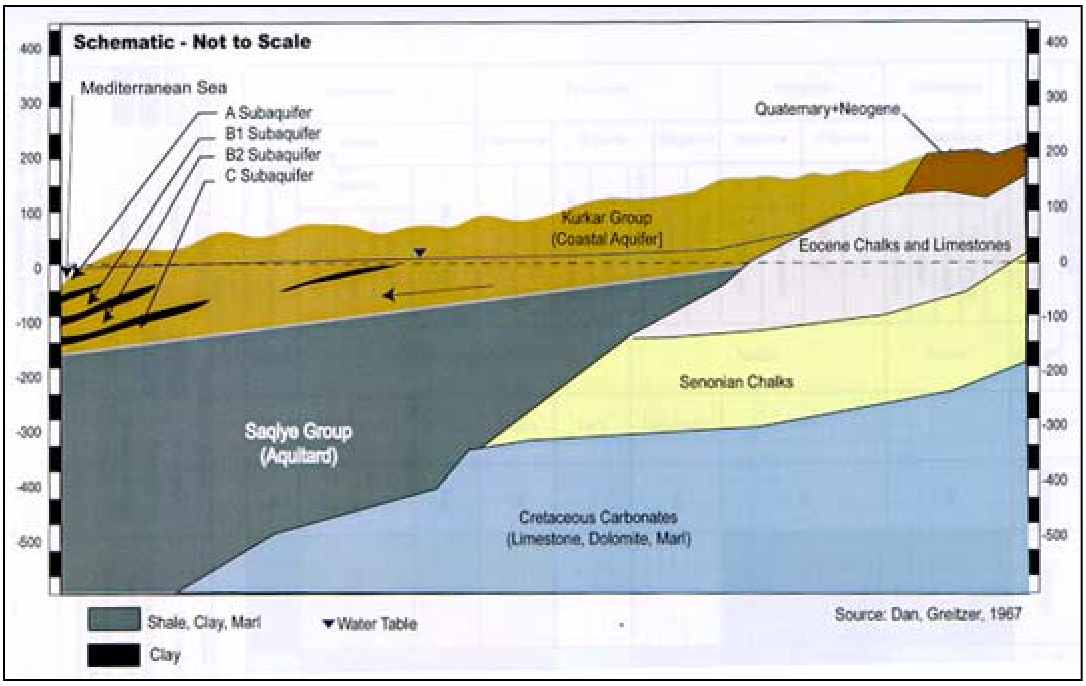

Figure (2.3) Schematic diagram across the Gaza Strip. (CAMP, 1999).

2.5 Climate of Wadi Gaza area and the wetland

2.5.1 Temperature

Wadi Gaza as well as the whole Gaza Strip area is located in the transitional zone between the temperate Mediterranean climate to the East and North and the arid desert climate of the Negav and Sinai deserts to the East and South. As a result the Wadi Gaza Area has a characteristically semi-arid climate. There are tow well defined seasons: the wet season starting in October and extending into April, and the dry season from May to September. Peak months of rainfall are December and January. The average daily mean temperature ranges from 25°C in summer to 13°C in winter, with the average daily maximum temperature range from 29°C to 17°C, and the minimum temperature range from 21°C to 9°C, in the summer and winter respectively.

2.5.2 Humidity

The daily relative humidity fluctuates between 65% in the daytime and 85% at night in the summer and between 60% and 80% respectively in the winter.

2.5.3 Solar radiation

The mean annual solar radiation amounts to 2200 J/cm^2/day.

2.5.4 Winds

Table2. 6 below illustrates the wind speed and wind direction, which is predominantly from the Northwest. There is a significant variation in the wind speed during the daytime, and the average maximum wind speed velocity is

about 3.9 m/s. Moreover, storms have been observed in winter with a maximum wind speed of about 18 m/s.

Month	Wind speed at noon m/s	Most frequent wind direction (12.00-15.00hr(	Max. hourly wind speed at noon m/s
January	4.2	South West	18
April	3.9	North West	13
July	3.9	North West	7
October	2.8	North	11

Table 2.6 wind speed and wind direction in the Gaza Strip. Source:(Gaza Environmental Profile, 1994)

2.5.5 Rainfall

Daily rainfall data on the Wadi Gaza area are available from two rainfall gauging stations shown in Figure (2.4) Ennusairat Gauging Station and Elmughragah Gauging Station. The average yearly rainfall for 26 years of record of these two stations is 335 mm/y. average monthly rainfall is shown in figure 2.5.

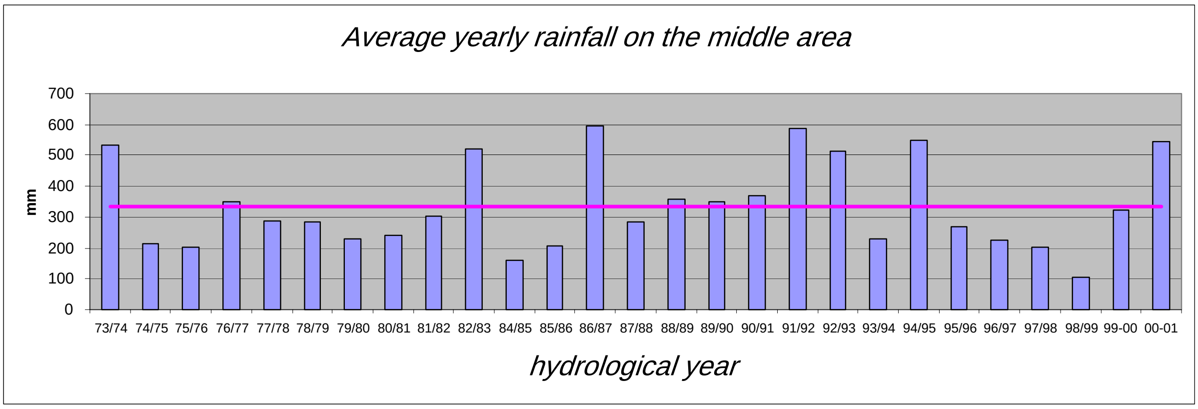

Figure 2.4 Average rainfall on the Wadi Gaza Area

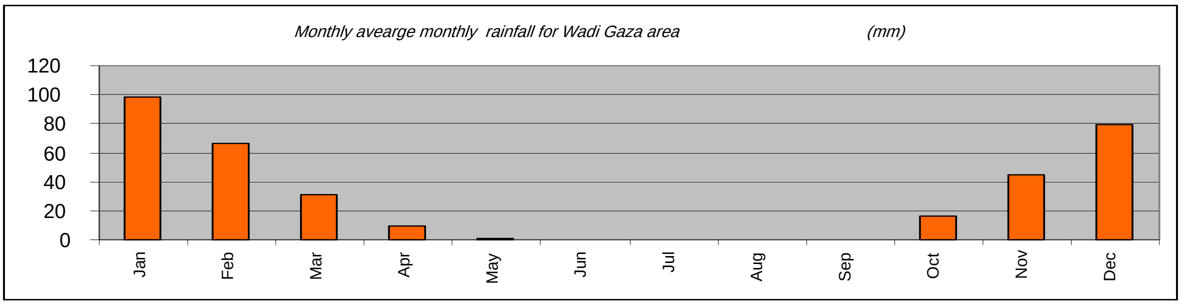

Figure 2.5 Average monthly rainfall on the Wadi Gaza Area

2.5.6 Evaporation

The mean daily evaporation in December is about 2.1mm/d, while in July 6.3mm/d.

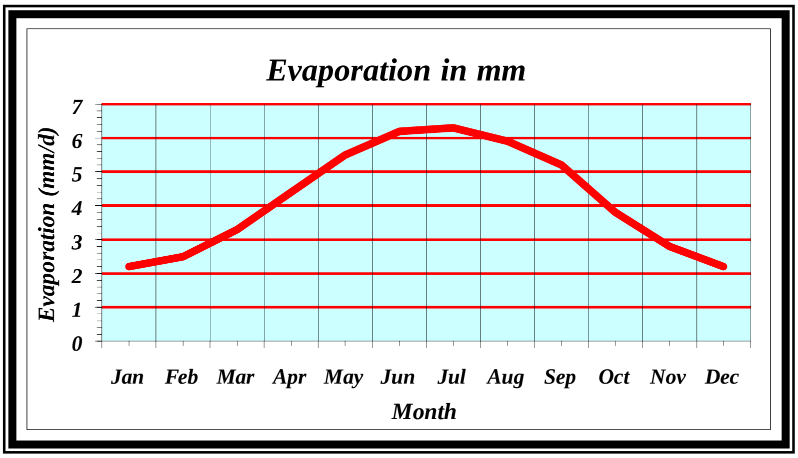

Figure. (2.6): Average evaporation in mm/day in Gaza Strip area (Pan method), the period 1980-1989(Gaza environmental Profile, 1994).

2.6 Water regime and water management in Wadi Gaza:

2.6.1 Surface water of Wadi Gaza

Unfortunately very few data are available on water regime of Wadi Gaza. The only data found on records since 1973 are rainfall data. Other necessary data such as discharges per year, flow time series, water levels, hydrographs, cross sections profiles and topographical maps of reasonable contours to study the rainfall-runoff relationship of the Wadi Gaza area are almost non. The necessary monitoring equipments were purchased through the project for this purpose. Installations of these equipments on site were intended to be finished before 2000/2001 hydrological year. For some out of control reasons the equipments were not installed till now. They will be installed before the hydrological year 2001/2002.

Yet it is evident that," Wadi Gaza used to flow in winter and bring huge amounts of rainwater, disturbing the transportation between the northern and southern parts of the Gaza Strip" (Goodson, 1999). Also due to interviews with the local community of the wadi they confirmed that wadi Gaza used to flow regularly during the winter season for at least two months and used to bring huge amounts of water.
Since the early seventies this amount of water started to decrease considerably due to the built up of check dams and diversion schemes by Israel on the upper course of the Wadi (Photo.., Annex 3).

Since then the volume and duration of flow has decreased much with some occasional flash floods sweeping down the Wadi bed at wet years. The Gaza Strip Environmental Profile (1994) recorded that the flow of the hydrological wet year 1994/1995 occurred ten days per year, and estimated the volume of it as 20 Mm^3 (Photo.. Annex 3.). During the last hydrological year 2000/20001 the flow was recorded for a total of 7 days with two flash floods. One flash flood started from the midnight of 24/12/2001 and continued for 3 days, with estimated discharge volume of 8.64 Mm^3. The other one occurred from the early morning of 23/1/2001 for 4 days, with estimated discharge volume of 9.58 Mm^3. That makes the total estimated volume of discharge for the hydrological year 2000/2001 as 18.22 Mm^3.

Another source of water reaching Wadi Gaza is the untreated wastewater discharged from three wastewater outlets collecting wastewater from four residential areas near by the Wadi. Two of these outlets are discharging their what is theoretically should be only grey wastewater since 1991 from the three refugee camps nearby the area. The last outlet started at the year 1999 from the newly built residential area "Alzahra City" (Map…Annex 3). The total quantity of this wastewater is about 5000 m^3 according to different sources. This quantity is estimated to reach more than 7000 m^3 by the year 2003.

This quantity of wastewater was forming many stagnant and segmented pools in the wadi bed with very low quantity of it reaching the wetland area. At the beginning of June 2001 and because of the complains from the local community about the inconvenience caused to them by mosquitoes living and breeding in these pools, a narrow open channel were made in the course of the wadi that made this wastewater to flow down the wadi bed and to reach effectively the wetland area. At the most down end of the wetland another narrow channel were made to maintain permanent connection between the wetland and the Mediterranean Sea with permanent flow to the sea.

2.6.2 Groundwater of Wadi Gaza

There are 37 abstraction wells in Wadi Gaza area, most of these wells are agricultural wells. Figure 2.7 shows the locations of these wells over the area. The Ministry of Agriculture (MOA) is monitoring water levels in 7 wells on monthly basis since the seventies. Water quality is been monitored twice a year in average in 12 wells in the area. Chloride concentration and electrical conductivity is been monitored since the seventies, while Nitrate concentration monitoring started in the Nineties. These wells are shown in figure 2.11 below.

The analysis of Ground water wells near to the area

The analysis of 12 Ground water wells in the Wadi Gaza area based on half annually collected data; show high levels of chloride, Nitrate concentrations and high electrical conductivity figures (Table 2.7). The levels found categorize most of the wells as contaminated brackish water Figures 2.9 and 2.10. It also shows increasing trends of the previous quality parameters in most of the wells. The 1999 Nitrate concentration map figure 2.9 shows that most of the pollution in groundwater exists to the western area of the Wadi. This result is very much in parallel with the fact that wastewater discharge starts from the middle of the Wadi westwards and that this area is also heavily populated. The analysis of water level data from 7 wells based on monthly observation data; shows mixture patterns of trends according to water level increase or decrease. It also shows the positive significant impact of the wet years on water levels and vise versa for dry years, figure 2.8. This indicates the fast response of the aquifer to surface recharge, which indicates high hydraulic conductivity values. The map of chloride concentration figure 4.4 shows that high chloride concentrations are found at the middle of the Wadi. The interpretation of this result is that most of the existing wells in the area is located densely in the middle area of the wadi as shown in figure 2.11.

	Chloride mg/l	***Electrical conductivity µS/cm***	***Nitrate mg/l***
Mean	923	3769	85
Standard Deviation	321	1863	56

Table 2.7 Statistical summary of quality parameters for 12 groundwater wells near to Wadi Gaza

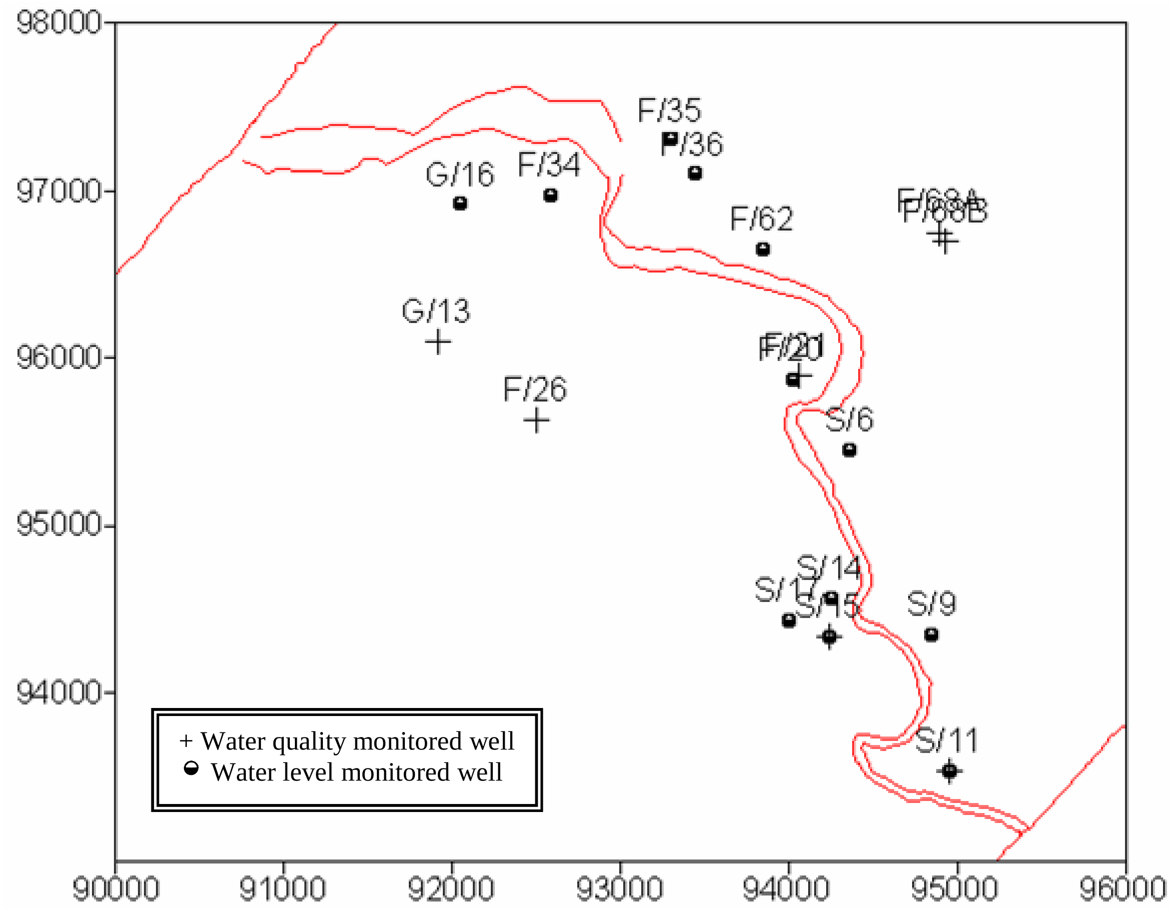

Figure 2.7 Wadi Gaza monitored wells

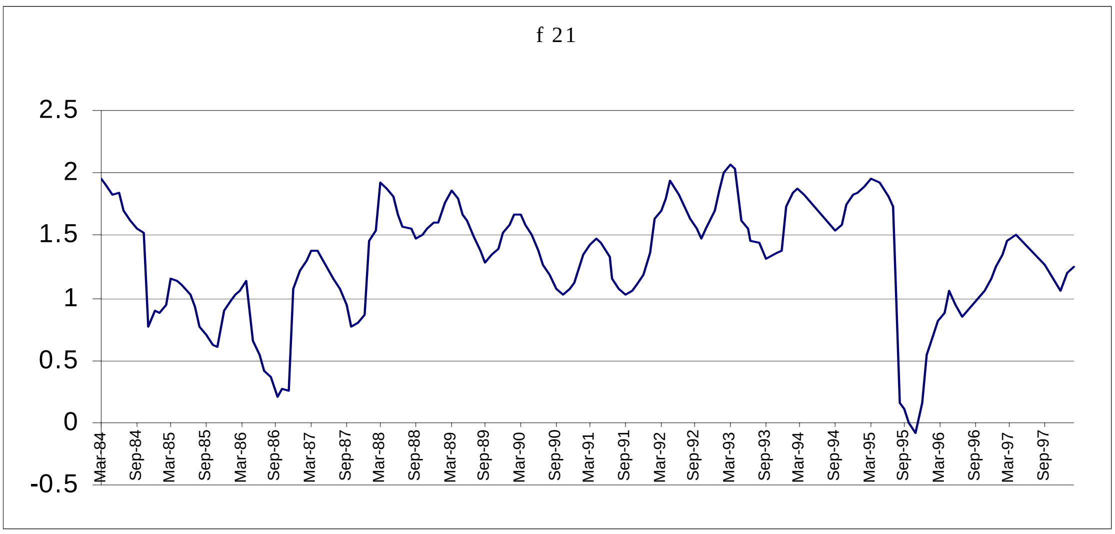

Figure 2.8 Water level Time Series for well F 21 (Notice the wet season observation in March and the dry season observation in September)

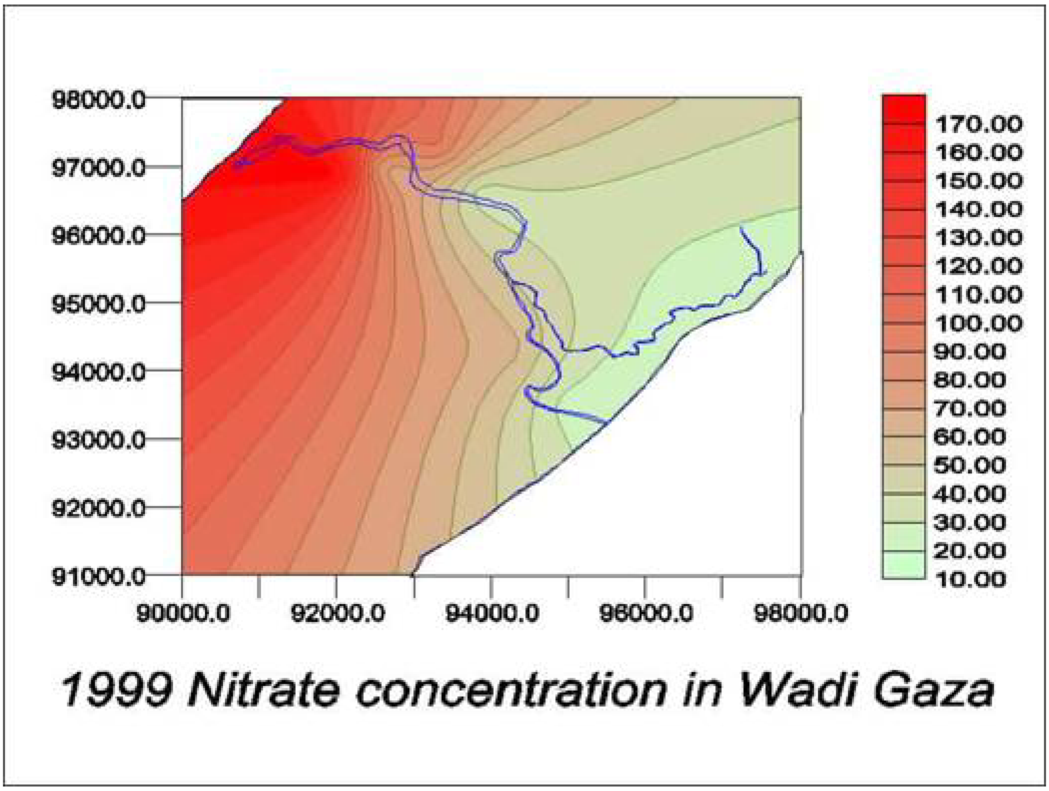

Figure 2.9 1999 Nitrate concentration over the Wadi Gaza Area

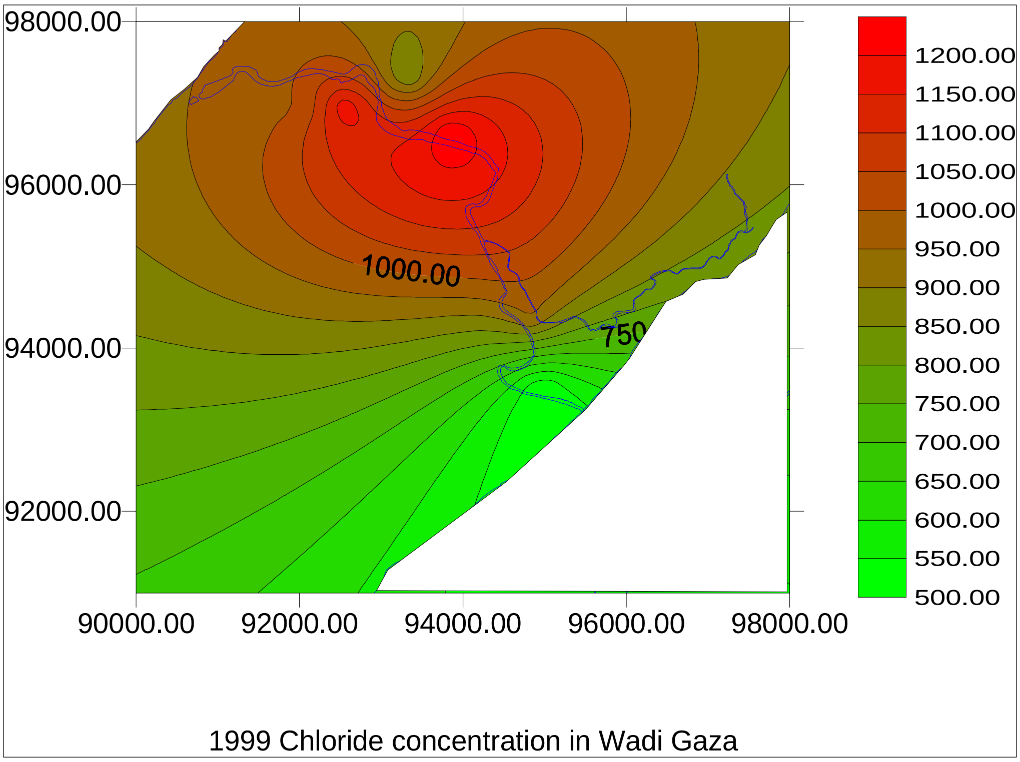

Figure 2.10 1999 Chloride concentration over the Wadi Gaza Area

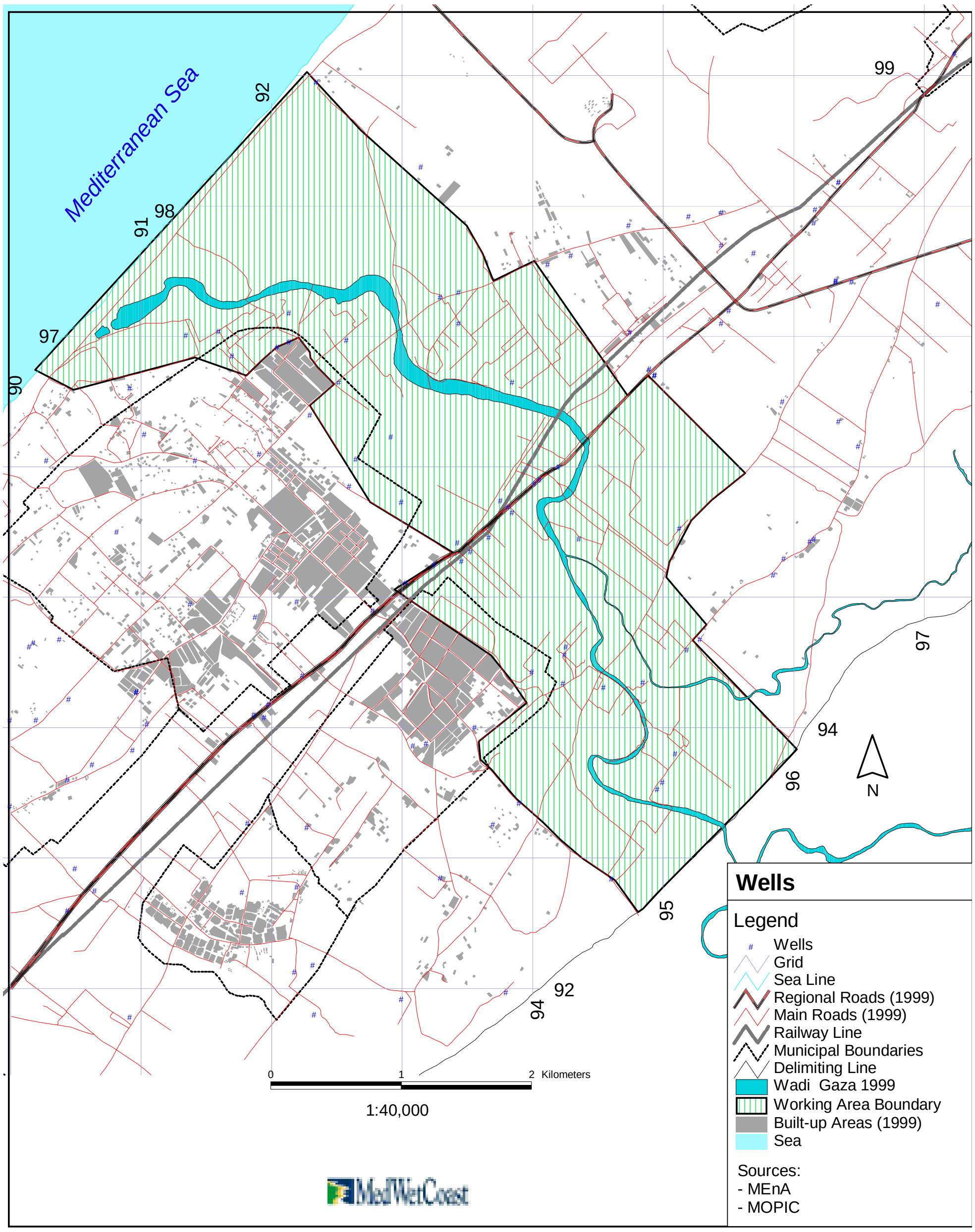

Figure 2.11 Ground water wells over Wadi Gaza Area

Chapter Three

3 The wetland site of Wadi Gaza

3.1 *General Physiognomy of the wetland site:*

Wadi Gaza wetland area is covering small area compared to other wetlands in the world (about 25 hectares). Yet it is very rich in biodiversity and of great significance to migrating birds from Europe to Africa in autumn. Wadi Gaza wetland area consists mainly from three different parts as shown in figure 3.1 below. The Area named "wetland" in figure 3.1 is the main part of the wetland. This area is about 10.14 hectares and is usually permanently flooded with water. During the dry period of summer from June till the end of September some parts of it -where the topography elevates up due to sedimentation- dry out but remains saturated and muddy. The main source of water for the wetland is groundwater from the coastal phreatic aquifer, were water table of the aquifer at the area of the wetland intersects with the topography and emerges up to the surface. Storm water accumulating during the rainy season, and wastewater are two other sources of water in the wetland but with less importance. Due to the closer of the mouth of Wadi Gaza, tidal waves were not effectively reaching the wetland even during winter were they became higher than in summer. As mentioned before, this year at the beginning of June 2001 a channel through the Wadi were made to let wastewater to reach the wetland and another channel were opened from the mouth of the wetland to the sea. The making of these two channels is now maintaining slow flow from the wetland to the sea and will also allow tidal waves in winter to reach the wetland. Emergent reefs dominate the sides of this area.

The area named flood zone is covering an area of about 142 hectares and is seasonally flooded when floods are to occur in winter. The main cause of the flooding of this complete area is the maintaining of the closer of the wadi mouth by the Ministry of Public works in order to keep the Sea Bridge safe from flood. This area is dominated by Tamarisk. The other third area is a small pool used to be a closed fishery pool of an area about 0.65 hectares. The 2000/2001 hydrological year flood breaked down the clayey walls of this pool and storm water mixed with it is water originating from groundwater. The sides of this pool are also dominated by emergent reefs.

3.2 *Hydrological Data of the wetland site:*

The only exact available hydrological data for the wetland site is rainfall data from the two hydrological stations shown in figure 2.2

The volume of water in the wetland pool changes through out the year as well from year to year depending on the amount of rain in that year and the artificial activities done by people to the watercourse of the Wadi. The water level in this pool is also varies a lot over the area of the pool. A hydrological survey done on May 1999 found that the volume of water in the wetland pool is about 65000 m^3.

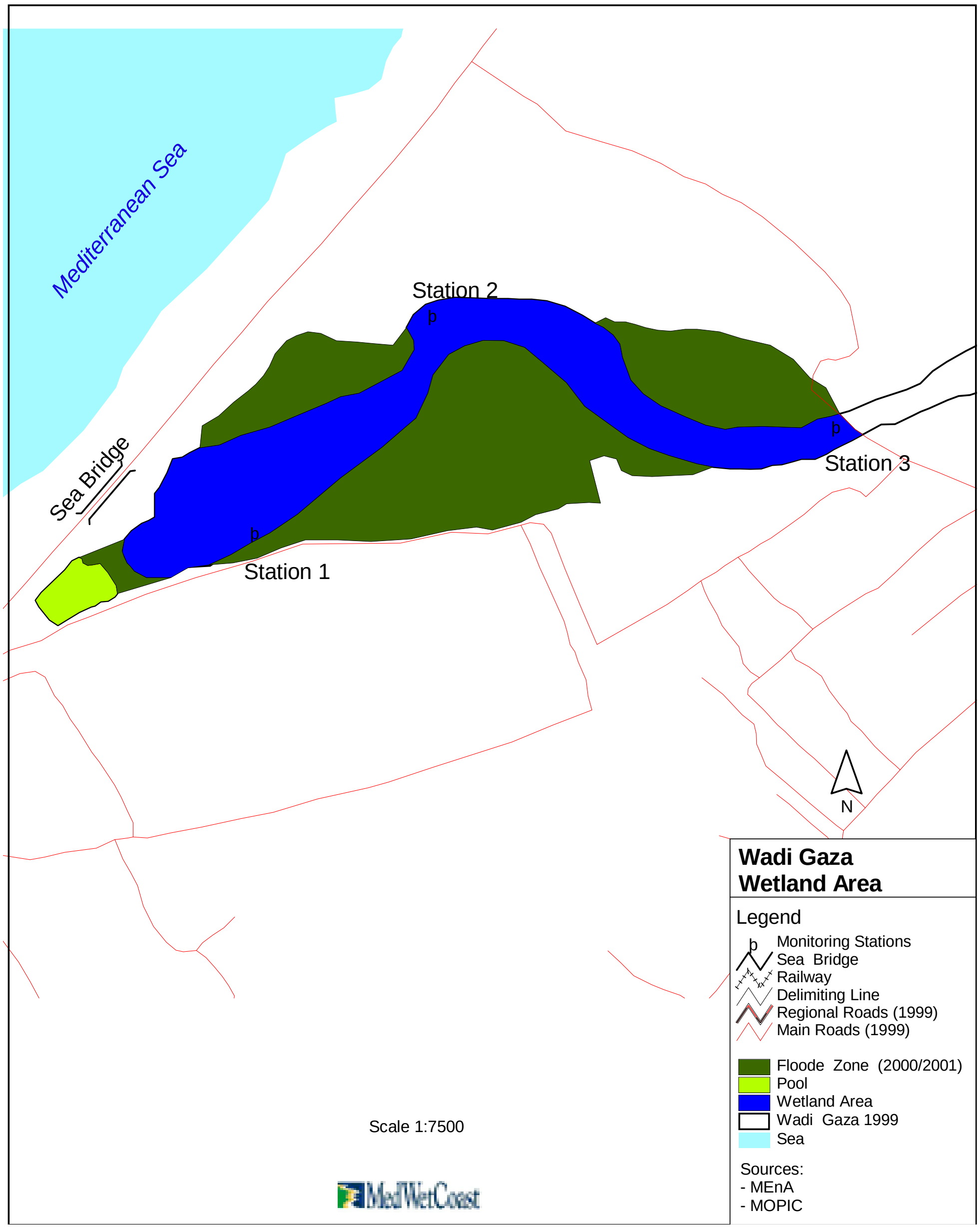

Figure 3.1 Wadi Gaza wetland area

Another survey of water depths in the wetland conducted by Wadi Gaza project team on 21/6/ 2001 after the opening of the two above mentioned channels to and out from the wetland, found out that the water depths in the wetland as shown in figure 4.2. Simple estimation of the water volume at that time makes it as about 81000 m^3.

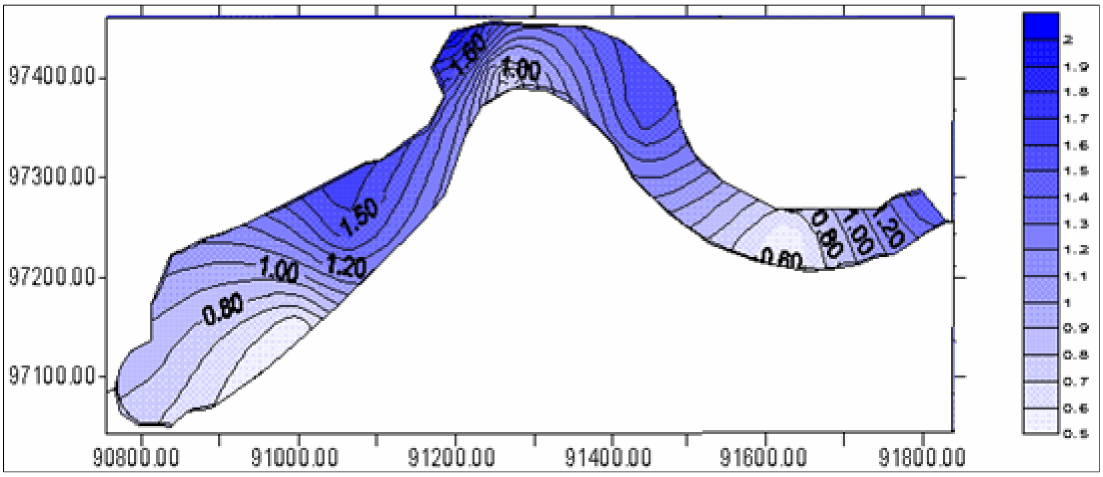

Figure 3.2 Contour map of water depth in the wetland area of wadi Gaza

3.3 Abiotic Quality of the wetland site

To determine the abiotic quality of the wetland site, extensive monitoring program was performed. Three monitoring stations were located at the wetland area as shown in figure 3.1. Describtion of these stations is below:

3.3.1 Description of the monitoring stations

Station 1:
This station is located at the lower part of the pool to the southern side of the wadi, it is entrance is from the National Security road. The station is about 40-50 m from the Wadi mouth to the Mediterranean, hence it is very much affected by tidal waves and storms. Bed reeds are dense and the main aquatic vegetation in the area.

Station 2:
This station is located at the middle of the pool as shown in figure3. 1 to the northern side of the wadi bed. The water depth here is deeper than in station 1 and could be the deepest location of the wetland. To the other side of the wadi opposite to the station emergent reed beds are dense.

Station 3:
Station three is located at the last end of this wetland pool, it is also located at the entrance of the sewage discharged to zone 2, hence the water quality results of this station is very much reflecting the contamination with this wastewater.

3.4 Results of the monitoring program:

			STATION 1			
Temp.(C)	PH	EC(mS/cm)	Sal. (PPT)	TDS (mg/l)	D O (mg/l)	Turb.(NTU)
30	10.12	7.42	4.1	3960	16.64	12.5
34	7.75	9.85	5.5	5370	15.4	22.9
30	7.4	13.5	7.8	7510	8.5	22.2
31	7.62	18.55	11	10580	9.6	7.94
29	7.6	18.91	11.2	10800	8.66	10.4
24.00	7.62	17.93	10.62	10238.40	8.72	17.60
16	7.63	17.83	10.5	10060	9.5	25
17	8.6	2.18	1.1	1097	8.00	56
15.5	8.7	1.85	0.9	924	7.4	133
22.3	7.9	2.16	1.1	1091	4.3	23.7
22.8	8.2	2.73	1.4	1391	13.9	17.3
27	8.12	3.32	1.7	1704	14.5	18.7
32	9.3	4.41	2.3	2290	26.61	322
32.3	8.98	5.3	2.8	2770	21.36	83.7

Table 3.1 Results of the monitoring program in station 1

STATION 2							
	Temp.(C)	PH	EC(mS/cm)	Salinity (PPT)	TDS (mg/l)	D O (mg/l)	Turbidity(NTU)
Oct-00	28.00	10.80	14.36	8.30	8030.00	9.41	12.80
Nov-00	23.00	9.30	13.61	7.87	7612.44	9.15	48.70
Dec-00	16.50	7.70	17.80	10.50	10.09	7.45	20.50
Jan-01	17.00	8.32	1.90	0.95	954.00	6.90	59.50
Feb-01	15.50	8.16	1.60	0.80	793.00	6.50	97.00
Mar-01	21.70	7.77	2.13	1.10	1072.00	5.70	34.00
Apr-01	23.00	8.07	2.77	1.40	1413.00	5.43	15.80
May-01	27.00	8.00	3.40	1.80	1748.00	5.73	11.10
Jun-01							
Jul-01	29.20	8.95	4.37	2.30	2280.00	17.27	75.20
Aug-01	30.90	8.80	4.50	2.40	2340.00	8.88	54.00

Table 3.2 Results of the monitoring program in station 2

				STATION 3			
	Temp.(C)	PH	EC(mS/cm)	Salinity (PPT)	TDS (mg/l)	D O (mg/l)	Turbidity(NTU)
Jan-01	16.70	8.56	1.76	0.88	878.75	5.90	70.80
Feb-01	15.00	7.97	1.48	0.78	731.48	5.25	87.00
Mar-01	23.10	7.84	2.09	1.07	1051.38	4.90	93.50
Apr-01	23.40	7.94	2.68	1.37	1365.43	4.43	128.00
May-01	27.00	8.05	3.29	1.76	1690.21	4.10	143.00
Jun-01							
Jul-01	29.60	7.31	3.13	1.66	1605.36	3.97	233.00
Aug-01	30.70	7.74	2.85	1.46	1449.31	3.20	239.00

Table 3.3 Results of the monitoring program in station 3

station 1						
Feb-01	Pb (ppm)	Cd (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Cr (ppm)
	BDL	BDL	BDL	BDL	0.5198	BDL
station 2						
Feb-01	Pb (ppm)	Cd (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Cr (ppm)
	BDL	BDL	BDL	BDL	0.3214	BDL
station3						
Feb-01	Pb (ppm)	Cd (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Cr (ppm)
	BDL	BDL	BDL	BDL	1.2817	BDL

Table 3.4 Heavy metals concentration in wadi Gaza wetland

station 1				
Feb-01	BOD mg/l	COD mg/l	TN mg/l	TP mg/l
	120	276	15.75	0.72
station 2				
Feb-01	BOD mg/l	COD mg/l	TN mg/l	TP mg/l
	90	175	25.9	0.27
station3				
Feb-01	BOD mg/l	COD mg/l	TN mg/l	TP mg/l
	180	304	50.77	2.33

Table 3.5 BOD, COD and Nutrients concentrations in Wadi Gaza wetland

The results obtained through the monitoring program for stations 1,2 and three are shown in tables 3.1,3.2 3.3 3.4 and 3.5. All samples were taken from shore and were taken as grab samples.

3.4.1 Analysis of the Results:

Station 1:

Staion 1 was located very near to the mouth of the wadi, hence the effect of tidal waves and storms from the sea is very clear in the results. The results are showing high EC's, TDS and salininty figures. Staion 1 also is showing in general higher concentrations of DO oxygen values. As shown in the figures below for station 1 the months of June and July 2000 shoed very high concentration of DO values and that was the effect of algae blooming that was very dense at the time. EC values are noticeably showing sharp decrease after the rainy season.

Station 2:

Station 2 as it is at the middle of the pool, shows medium pattern between station 1 and station 3. EC salinity and TDS and DO values are in general lower than station 1. This result shows the effect of some contamination by untreated sewage coming from upstream. station 2 also shows sharp decrease of EC values after the rainy season.

Station 3:

Station 3 was located at the end of the pool, were domestic wastewater enters the pool from there. The effect of pollution due to the wastewater is very clear in keeping the DO values of low range most of the time. The EC values are lower than in stations 1 and 2.

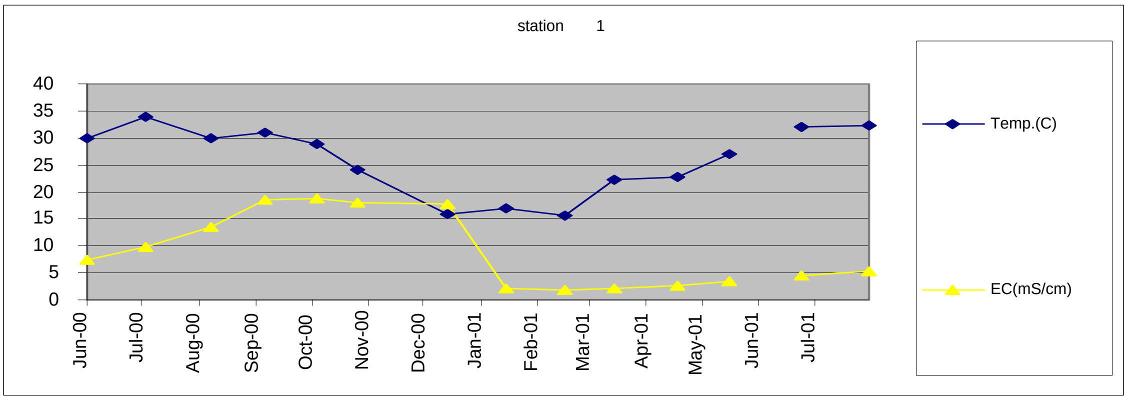

Figure 3.3 Time series of Temp. and EC for station 1

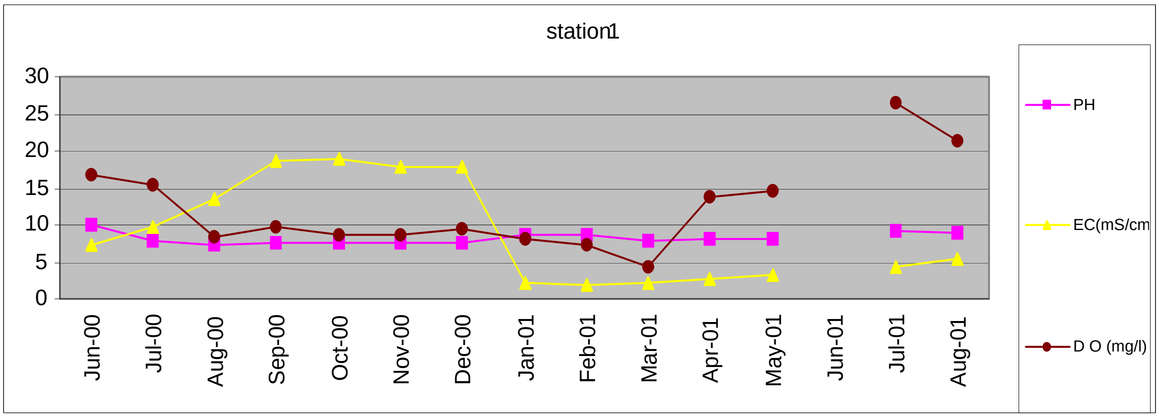

Figure 3.4 Time series of pH, EC and DO for station 1

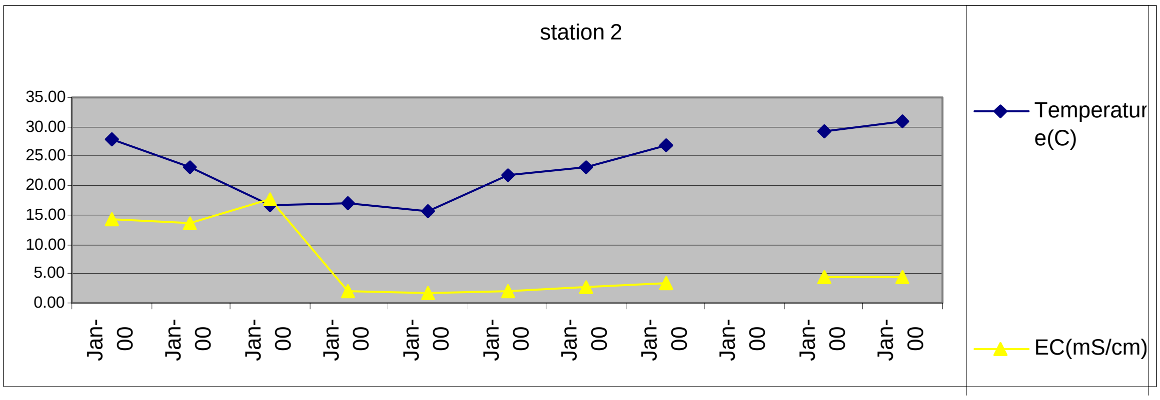

Figure 3.5 Time series of Temp. and EC for station 2

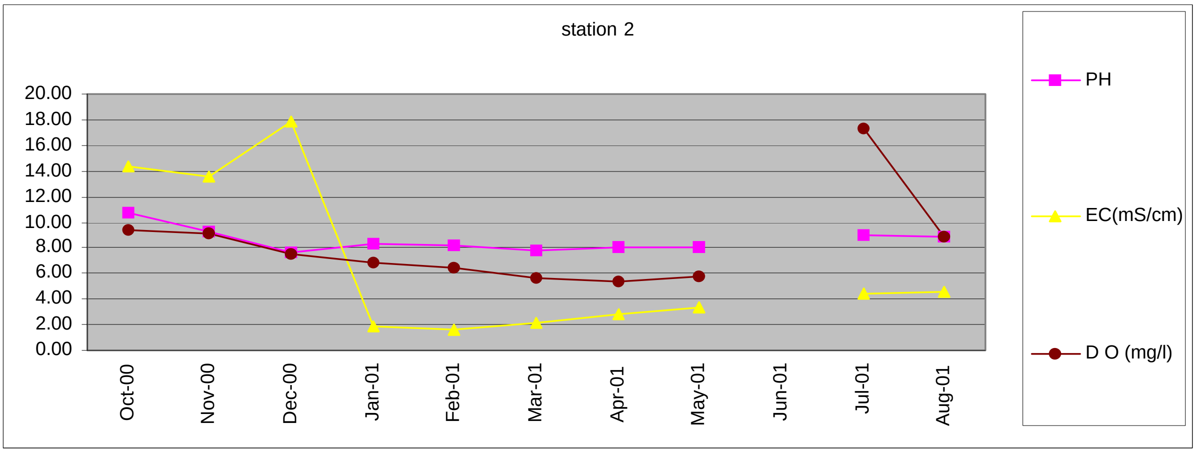

Figure 3.6 Time series of pH, EC and DO for station 2

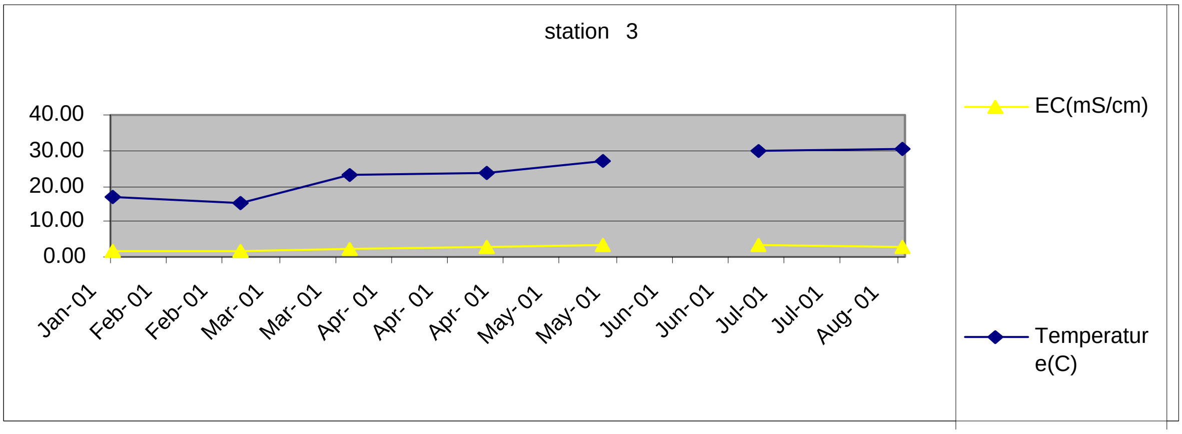

Figure 3.7 Time series of Temp. and EC for station 3

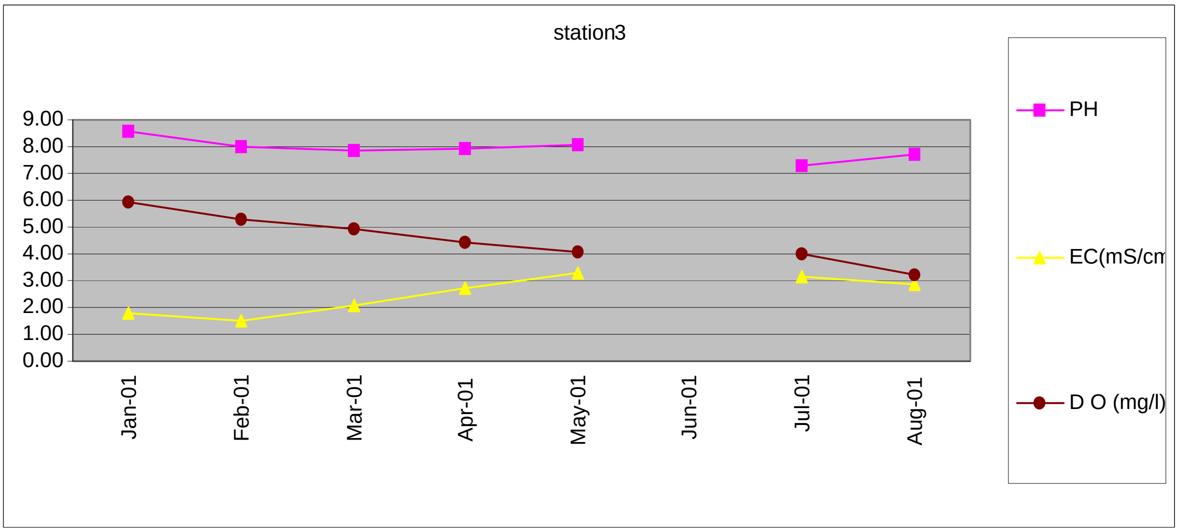

Figure 3.8 Time series for pH, EC and DO for station 3

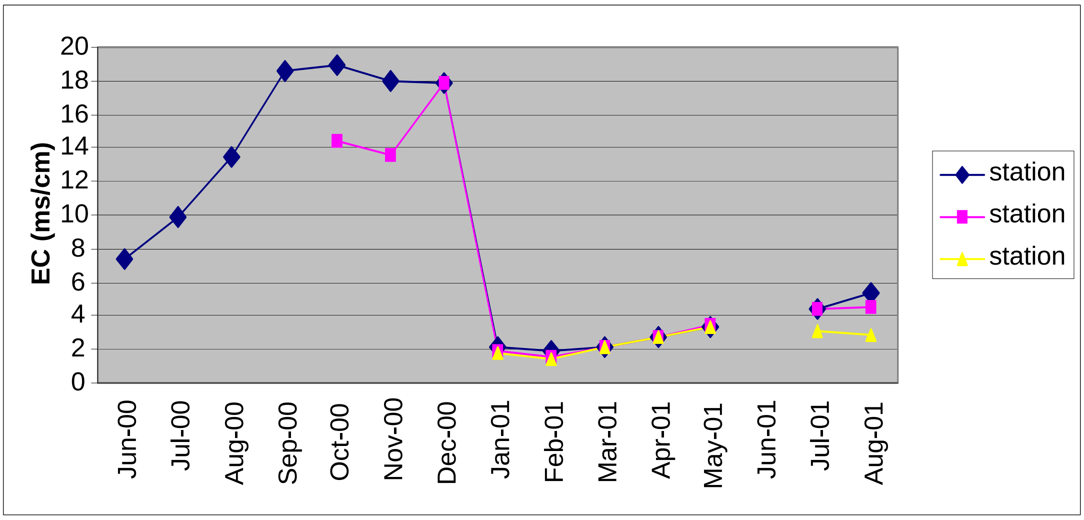

Figure 3.9 Time series of EC for stations 1,2 and 3

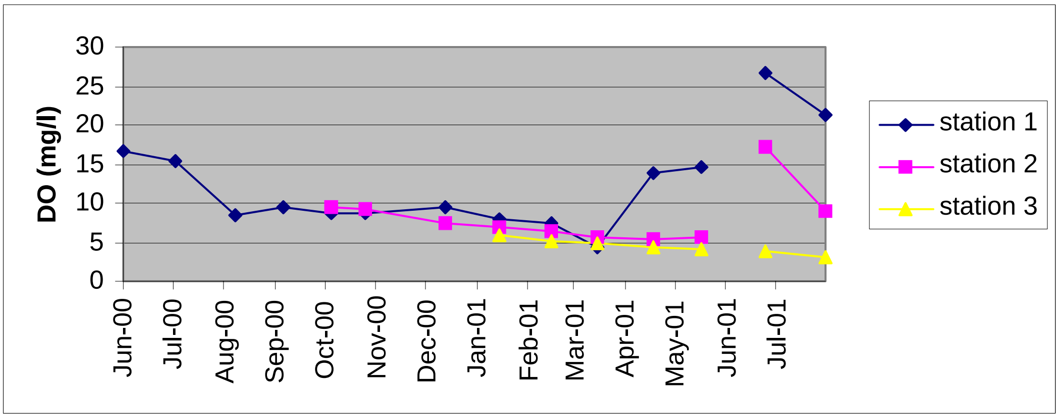

Figure 3.10 Time series of DO for stations 1,2 and 3

Heavy Metals results analysis:

As seen in table 3.4, results are showing the concentrations of heavy metals except for iron below detection limit. This limited Fe concentration can be referred to solid waste dumped to wadi Gaza bed. The results are indicating that no pollution of industrial waste is reaching the wetland.

Nutrients results analysis:

The wadi Gaza wetland pond is already known as to be in eutrophic conditions, since untreated wastewater and runoff from agricultural land at the wadi course are both reaching the wetland area with large quantities. The analysis results are also showing high levels of nutrients. The highest level is noticed to be at station 3 were wastewater enters the pond at that location. At the first year of implementing (year 2000) the project and through the summer season dense and widespread blooms of green alga spreaded all over the wetland pond and completely covered the water surface. Amazingly this year 2001 that phenomenon did not happened although the parameters that made it to happen the previous year did not changed. Therefore this incident should have further studying.

3.5 Dynamics and movements

Sedimentology:

Sediment accumulation poses serious threat to the wetland of wadi Gaza. Last 2000/2001 hydrological year flood events brought vast amount of sediments and it was mainly because of the closer of the flow at the wetland from flowing down freely to the sea. Unfortunately quantifying the amount of it was not possible. Yet it was evident from the spreading of emergent reeds on new and more locations at the pond that these new locations were applied to sedimentation which caused the water depth to become shallow their.

Chapter Four

4 Analysis

4.1 Ecological Interests and Hydrological Functions of Wadi Gaza Wetland

4.1.1 Surface water storage

Wadi Gaza wetland pond acts as important surface water storage reservoir, it has the potential to store a volume of more than 100, 000 m3 of surface water. The groundwater table in Wadi Gaza wetland area intersects with the topography, resulting in no water of it is lost to the aquifer. Thus the use of the wetland area for temporarily storing surface water can provide cheap and convenient water resources especially for agricultural uses.

4.1.2 Improve Water Quality

Wadi Gaza wetland plays important role in improving and treating water discharged to wadi Gaza course. The cleansing power of it provides natural pollution control. That makes it to act as a natural treatment facility. Especially at the time that large quantities of wastewater is been discharged to Wadi Gaza course. Water quality is improved by removing nutrients, pesticides, and bacteria from surface water as they are absorbed or broken down by plants, animals, and chemical processes within the wetland.

4.1.3 Reduce the risk of Flooding

Wadi Gaza wetland performs the function of storing and reducing the peak water flow after storm. This function helps prevent flooding to the agricultural land and houses on both banks of the Wadi.

4.1.4 Wild and Aquatic Life Diversity/Abundance

Wadi Gaza Wetland provides migration, breeding, nesting and feeding habitat for many of waterfowls, shorebirds and other wildlife. It is the home to many plant and animal species including many threatened and endangered species. Wetland eco- systems are among the most productive eco-systems in the world and Wadi Gaza wetland in particular is a unique wetland of the area.

4.1.5 Fishery

Wadi Gaza wetland pond has the potential to be substantial fishery with very high economical value and large productivity.

4.1.6 Recreation

In the whole of Gaza strip the almost only natural recreational area is the coastal zone of Gaza strip. Wadi Gaza wetland area can provide very important and different recreational facility to the whole people of Gaza strip. This also can be a very good tool to increase the people's public awareness of environment and biodiversity.

4.1.7 Uniqueness

Wadi Gaza wetland area is unique place through out Gaza strip and the area. It can give good opportunities for scientific research, in many different scientific fields such as water quality, hydrology, biology, zoology and many others.

4.2 Needs for further studies

- Information on the upper stream catchment area.
- Erosion and sedimentation qualitifying and quantifying.
- Modeling water balance of Wadi Gaza water resources.
- Eutrophication detailed studying.

4.3 Priority objectives

- Opening the wadi mouth to the Mediterranean Sea.
- Treatment or partial treatment of the raw wastewater discharged to the wetland (which mainly causes eutrophication and oxygen depletion of the wetland water).
- Stopping the lowering of groundwater table.
- Stopping any acts and activities that pollute, upset or disturb the wetland area and the wild life of it, such as solid waste dumping, hunting,..etc .
- Stopping the yearly accumulation of sediments at the wetland area that is seriously threatening the existence of the wetland.

4.4 constraints and opportunities for the conservation of the wetland

4.4.1 Constraints:

1. ***Lowering of the ground water table by excessive pumping for agricultural and domestic activities:***

The wetland of Wadi Gaza is mainly deprived of its water by both of construction of upstream dams and the excessive pumping of groundwater in the whole area of Gaza strip. The result is both some loss in overall water supply to the wetland and equally important, an interruption of the seasonal natural cycle of high and low flows that is essential to the pattern of plant, fish, birds and other habitat life. One example of lowering water table in Wadi Gaza area is the well S / 15 as seen in figure 5.1 below

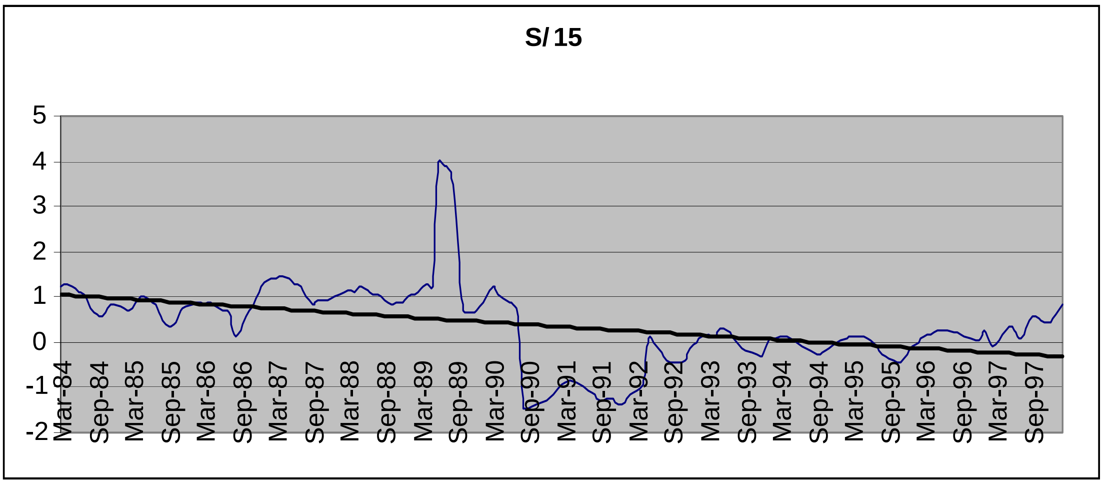

Figure 5.1 Well S /15 time series

2. ***Eutrophication :***

Eutrophication is the main pollution threat in Wadi Gaza wetland area. It generally occurs whenever either fresh or saline waters receive excessive sewage or farm fertilizer runoff.

At the time being Wadi Gaza receives about 4 to 5000 m^3 of untreated wastewater. This quantity is expected to reach 7000 m^3 by the beginning of 2002.

This causes the large blooms of algae clogging waterways and preventing sun light from penetrating into the water .And when the algae die and begin to rot they consume vast amount of dissolved oxygen in the water. Under the wadi Gaza conditions in summer where warm weather encourages the speed growth of the algae.

4.5 Water Management and conservation measures of Wadi Gaza wetland

4.5.1 Short term measures:

- *opening Wadi Gaza mouth to the Mediterranean sea:*

Wadi Gaza no longer discharges its water freely to the Mediterranean Sea. The construction of a concrete bridge at the mouth of the Wadi to ensure non-disturbance of traffic and transportation movement during the rainy season and the closer of the culverts beneath the bridge resulted in a situation where the mouth of the Wadi is closed by sand and clay from the sea most of the year. This closer stopped the natural phenomenon of free water interchange between Wadi Gaza and the Mediterranean Sea as normally occurs under estuarine conditions.

This closer of the mouth has very much effected the hydrology and ecology of the wetland. It raised up the level of water in the pool, resulting in flooding the adjacent agricultural areas till it breaks down at heavy storm events. It also increased very much the sedimentation on the wetland pool at the time of flows, preventing sediments from reaching the sea and hence decreasing the depth of water level of the pool. The closer also have resulted in minimizing the dissolved oxygen levels in the pool, increased eutrophication levels, and deteriorated the general surface water quality of the wetland. It also caused the reduction of population of all kinds of fish, which also affected birds and other habitats either directly for those depending on fish in their food or indirectly by breaking off the food chain of habitats living in the estuarine ecological system.

At the beginning of June 2001 and because of the complains from local community about the inconvenience caused to them by mosquitoes living and breeding in the area. A narrow channel at the most down end of the wetland was made to maintain permanent connection between the wetland and the Mediterranean Sea. The opening of this channel has helped, yet it should be permanent and should widened enough to allow for normal estuary conditions.

- *Stopping the use of oil and pesticides for combating mosquitoes:*

Mosquitoes is an annoying problem for the local community living near to Wadi Gaza and the wetland. Proliferation of mosquitoes in the area, have led many public health authorities to combat the problem, but unfortunately with very harmful techniques to the environment and in particular to the fauna, flora and the water quality of the wetland. Pesticides are sprayed against mosquitoes throughout the area, herbicide is used to kill riparian vegetation (habitat for adult mosquitoes) and motor oil was poured on the water to kill suspended larvae. MEnA and Wadi Gaza project are trying to introduce biological combating methods. The replacement of the old techniques with this new technique should start at the coming of mosquitoes proliferation season.

Medium and long term measures:

- *Cooperation with the upper stream country in management of Wadi Gaza water resources:*

The largest problem that is facing the good understanding and management of the hydrology of Wadi Gaza is that more than 90% of the catchment area and the wadi course itself is located at the upper stream country. Unfortunately, Hydrological Data on this part of the Wadi and what happens there either naturally or artificially are not available to the Palestinians. The acquiring of this hydrological data and cooperation in the management is very important in the management of Wadi Gaza water resources, it can affect any development projects at the down stream of the Wadi in Gaza.

- *Stopping the discharge of raw wastewater to the Wadi course:*

Discharging raw wastewater to Wadi Gaza is a major problem that is threatening the habitat and different species of fauna and flora in Wadi Gaza. It is estimated that about 4000-5000 m^3/day of wastewater is been discharged daily to the Wadi bed. Although some level of natural treatment are happening to this quantity of wastewater before it reaches the wetland, yet it is far from being enough not to pollute he wetland.
The effect of nutrients originating from organic sewage is very serious threat to the integrity of wetland. It is the cause of eutrophication which causes the algal blooming over the surface of the wetland, hence preventing sun light from penetrating into the water body and deoxygenating the water, especially beneath the surface. This is main cause of the extinction of fish and other habitats depending on dissolved oxygen and on fish.
At least some partial treatment to the raw sewage should be made before it is been discharged to the Wadi course.

- *Good management of the Wadi water resources :*

Depletion and deterioration of Gaza Strip water resources (in particular groundwater) is very stressing problem. The wetland of Wadi Gaza is mainly deprived of its water by both of the construction of upstream dams, diversion schemes by Israel and the excessive pumping of groundwater resources in the whole area of Gaza strip. This resulted in both some loss in overall water supply to the wetland and equally important, an interruption of the seasonal natural cycle of high and low flows that is essential to the pattern of plant, fish, birds and other habitat life. Lowering of groundwater table at the wetland area is a very serious threat to the wetland existence and continuation. Although this can not be solved at the level of Wadi Gaza, yet some measures can be taken. They are as follows:

1. Constructing small check dams at the upper parts of the Wadi for the purpose of storing storm water behind. These check dams will be multi beneficial to the integrated management of the Wadi's water resources. It will also create new ecosystems in the area and will increase the wetland extension.
2. Reducing groundwater abstraction of the area. This goal could be achieved through some measures such as: metering the many illegal agricultural wells (since closing them would not be possible) of the area. This will help in reducing the pressure over groundwater resources.
3. Encouraging farmers (baring in mind that many future plans are put to treat the produced wastewater of the area and discharge it to Wadi Gaza) to use non-conventional water resources such as treated wastewater.
4. Helping farmers of the area to update their irrigation techniques to modern and efficient ones.
5. Trying to achieve the Palestinians water rights of the water drained to the upper stream of Wadi Gaza from the Hebron Mountains catchment area.
6. The complete monitoring of the hydrology of Wadi Gaza, part of this will be getting the information on the hydrological situation and management of the upstream catchment area.

4.6 Sustainable use of Wadi Gaza wetland

Sustainable use of Wadi Gaza wetland that will allow it to continue and exist for future generations would not be an easy advance. Yet some sustainable use practices can be depicted. Most of these sustainable use practices will focus on the agricultural sector use, since this sector uses about 70 % of Gaza groundwater resources :

1. Using non-conventional water resources, such as treated wastewater, and harvesting storm water especially for agricultural purposes.
2. Increasing irrigation efficiency.

4.7 Monitoring

4.7.1 Water Quality-monitoring Methodology:

The water quality-monitoring program is a tool for the overall objective of the project in protecting and conserving the biodiversity in Wadi Gaza. To have successful methodology for the monitoring program the following monitoring parameters should be defined:

1. Objectives of the monitoring program.
2. Sampling stations locations and location selection criteria’s
3. Sampling frequency
4. Water quality parameters which will be monitored

4.7.2 Objectives of the Wadi Gaza water Quality monitoring program

The main objective of the quality-monitoring program is to have a base line quality condition. The following objectives of the monitoring program can be identified:

1. To establish a base line water quality conditions of the wadi.
2. To identify pollutant sources.
3. To have a primary assessment of the impact of various domestics, agricultural, and industrial activities on the quality of the wadi water.

4.7.3 Stations Locations:

To establish permanent water quality monitoring stations in important locations of the wadi where corresponding discharges, pollutant source or significant effects that may change the water quality of some locations are known or can be estimated. Samples were taken from the same location each time. All samples were taken from shore.

4.7.4 Frequency:

The frequency of the sampling in general depends on different criteries, the most important here are:

1. Seasonal changes on the chatcment.
2. The sensitivity of the monitored parameter to seasonal, and other changes.

Another factor that plays a role is the cost of the analysis of the samples. The monitoring program in Wadi Gaza was performed monthly. And whenever flash floods occur samples were taken and tested.

4.7.5 Parameters monitored throughout the monitoring program:

Determining which water quality parameters are to be monitored through a monitoring program is not an easy task. Parameters should be carefully selected to serve the purpose of the monitoring program and the objectives set in advance to be achieved through this program. For this water quality program the objectives are as described above and the criteria was always whether the water quality of the wetland can support aquatic life, the fauna and the flora of the habitat in the wadi Gaza area or not. The parameters choosed here were as follows:

Temperature, pH, Electrical Conductivity, Salinity, Total Dissolved Solids, Dissolved Oxygen and Turbidity. These seven water quality parameters were tested in the field using the Ministry of Environment (MEnA) own portable lab. The monitoring of these seven parameters was carriedout successfully with almost no interruptions, since the devices used were always accessible and convenient with minimum cost. The other quality parameters are as follows:

Biological Oxygen Demand (BOD), Chemical Oxygen demand (COD), Heavy metals, Total Nitrogen and Total phosphorus. These water quality parameters were dependent on other ministries and institutions labs such as the Ministry of Agriculture Central Water Lab and Alazhar University labs. The monitoring of these water quality parameters were always under constant interruption for many reasons not least of these reasons is the scatterness of places to do each group of these tests, the high cost of doing these water quality tests and the interruptions due to electricity cuts, and the political situation. Finally and starting from August 2001, Wadi Gaza project together with MEnA has reached an agreement with Gaza Municipality Water Quality Testing Lab to carry out these testes in their lab. This agreement will solve many problems not least of them is that all tests will be done at the same lab, which is thought to be high quality standard lab with modern outfit.