Coastal Water Resources Vulnerable to Climatic Change by Sea Level Rise (Gaza Strip Coastal Aquifer Case Study)

Ashraf M. Mushtaha[1, 2] & Kristine Walraevens[2]
[1]Director of Environmental and MIS Department, CMWU, Gaza Strip - Palestine
[2]Laboratory for Applied Geology and Hydrogeology, Ghent University, Krijgslaan 281-S8, 9000 Gent, Belgium

ABSTRACT

Gaza Strip will be exposed to the global climate change effects the same as the other countries. According to the survey and primary findings of UNDP-PAPP Report 2009, agriculture and water resources are the most vulnerable to climate change and are expected to be exposed to direct effects of temperature, precipitation change and sea level rise, but still the potential impact of global climate change is one of the least addressed factors in water resources planning in developing countries. Moreover, the potential impacts of climate change have not been quantified at local level yet. This paper aims to evaluate the groundwater resource under sea level rise scenarios for Gaza Strip. To evaluate the potential impact of sea level rise as an impact of climate change on Gaza water resources, a 3D groundwater model is used after calibrating the developed model versus the existing situation. The results show that all the groundwater along the coastal line will be directly affected and around 66 Km^2 of the aquifer will be invaded by sea water in a very short time.

KEYWORDS

Gaza Strip, Groundwater Modeling, Climate Change, Sea Level Rise, MODFLOW

BACKGROUND

Gaza Strip is a coastal area along the Eastern Mediterranean Sea. The total area of the Gaza Strip is about 365 km^2. The Gaza Strip forms a transition zone between the semi-humid coastal zone in the North, the semi-arid zone in the East, and the Sinai desert in Egypt in the South. The population of the Gaza Strip reaches more than 1.7 Million inhabitants (PCBS, 2012). The population is expected to be around 2 Million inhabitants in the year 2015 and about 2.9 Million inhabitants by the year 2025 (CMWU, 2010).

Groundwater is the main water resource in the Gaza Strip. Gaza aquifer is a saline coastal aquifer with freshwater lenses floating above saline water, both near the coast and inland. The thickness of the aquifer ranges from few meters in the South East to about 180m in the North West of the Gaza Strip. The general groundwater flow pattern is from inland areas to the sea. Gaza aquifer is classified as unconfined aquifer and therefore is susceptible to all sources of pollution. The aquifer comprises tertiary and quaternary formations. The bottom of the aquifer consists of shallow marine clays, shales and marls called Saqiya Formation. The aquifer itself consists of consolidated quartz sands with calcareous material called Kurkar Formation. The aquifer has high permeability and porosity values.

Amnesty International (annual report, 2009) states that only 10% of the Gaza Coast Aquifer has fresh water suitable for drinking. Water situation in the Gaza Strip has been deteriorating in both quantitative and qualitative aspects. Increasing temperatures in the area will lead to an increase of water demand for drinking, other human usage and crops, which shall not only threaten the food security but also the economic stability and all life aspects.

According to the reports of the National Communication Arab Countries, a rise of one degree in temperature will increase the value of evapotranspiration by 2.3% in Saudi Arabia (UNFCC, 2011). The expected increase in water requirements for agriculture will be about 6% by 2020 in Lebanon and 7 to 12% in the Kingdom of Morocco.

INTRODUCTION

The coastal aquifer in the Gaza Strip is the only natural source of water supply for all activities (domestic, irrigation and industrial supply). The groundwater is being pumped through more than 5,000 wells all over the Gaza Strip. The latest published figure for groundwater abstraction was around 169 Million Cubic Meter (MCM) for the year 2011 (CMWU, 2012). More than 50% of the abstracted groundwater was for domestic water supply (89 MCM). Groundwater recharge from different components (i.e. rainfall, agricultural return flow, water and waste water network losses, and waste water collection lagoons) is around an average of 100 – 110 MCM yearly (Mushtaha, 2010).Yearly groundwater balance difference is around 50 to 60 MCM, which is being pumped out from the groundwater, causing seawater intrusion and/or groundwater level decline in areas that are far away from the coast. Both have a common result which is groundwater quality deterioration. Existing stresses to the Gaza Coastal Aquifer from both heavy abstraction and low recharge quantities have led to groundwater quantity and quality deterioration. Another major stress is threatening the aquifer as a result of global climatic change effects as sea water level rise.

The most significant environmental effects of climatic change for the people of occupied Palestinian territories (oPT), over the course of this century, are projected to be a decrease in precipitation and significant warming. Annual precipitation rates are deemed likely to fall in the Eastern Mediterranean decreasing 10% by 2020 and 20% by 2050, with an increased risk of summer droughts (UNDP-PAPP, 2009). The impact of climatic change on the water resource will strongly affect livelihood in the area in the future. This will lead to adaptation focusing at the regional and local level on water insecurity and food insecurity. The climatic change impacts in Gaza are further compounded by the Israeli occupation and siege imposed on Gaza Strip since long years. A higher variability in precipitation translates into reduced yields for rainfed agriculture, and could also mean greater frequency of flash floods. Reduced amounts of precipitation will mean greater strain on the deteriorating quality of the groundwater resource. Increased temperatures will also lead to abstracting more water from the only source (groundwater), and also temperature increase will lead to desertification, particularly in the South. Finally, sea level rise will contaminate the coastal soil and increase the saline intrusion already experienced throughout Gaza Strip. The Palestinian National Authority (PNA) recommends to adopt a Climate Change Adaptation Strategy for the oPT as the most effective means by which the PNA can enhance the capacity of the Palestinians to cope with current and future climate hazards. This is the first study in the Gaza Strip showing the sea level rise effects to the only groundwater resource.

OBJECTIVES

This paper will discuss the sea level rise scenarios on the Gaza Coastal Aquifer, by analyzing different cases as: sea level rise by 25cm and by 100cm. The study uses full 3D groundwater model MODFLOW v.4.2 to predict the effects of sea level rise to the coastal aquifer in the Gaza Strip.

GROUNDWATER MODEL DEVELOPMENT

Model Description

The model active area is 1,162.5 km^2 (figure1). The model boundary extends beyond the Gaza Strip political boundaries towards the North where a no flow boundary is adopted (parallel groundwater elevation contour lines), towards the East where the coastal aquifer pinches out (no flow boundary), towards the South in Egypt, where data do not exist and a no flow boundary is assumed, and finally towards the West where the Mediterranean Sea is located (head fixed to zero).

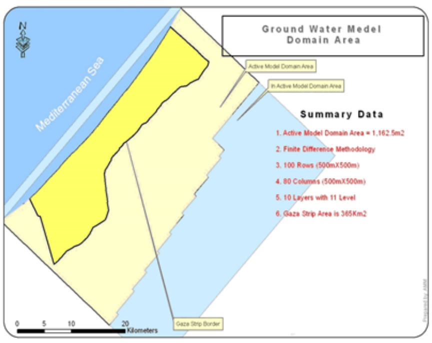

Figure1: Regional Groundwater Boundaries Map

Visual Modflow v4.2 is a 3Dmodel with finite difference method used to generate the model grid which divided into 500m X 500m cells. The vertical discretization is used to present the nature of the aquifer where clay layers are separating the unconfined aquifer from the semi-confined aquifer along the coastal zone and extend around 2Km inland towards the East as shown in the 3D map in figure2. Hence eleven layers have been used to present this complicated discretization of the Gaza aquifer.

The model was run for steady state simulation for year 1998, where figure 3 and 4 represent the calibrated recharge values and calibrated groundwater elevation respectively. Afterwards transient model simulation and calibration has been performed from year 2000 to year 2004, in which a verification simulation has been carried out from year 2005 till year 2010.

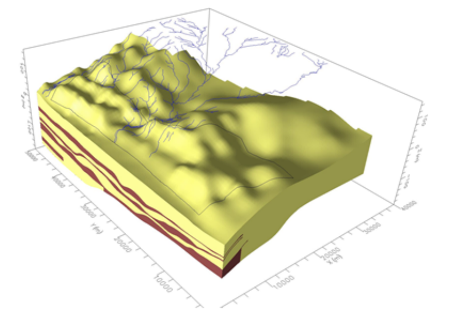

Figure **2**: 3D Map for the Gaza Coastal Aquifer

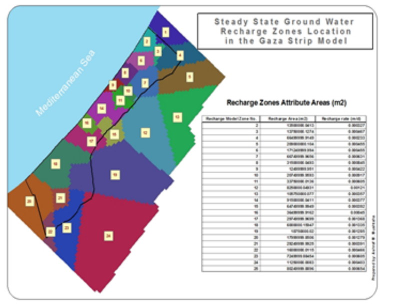

Figure **3**: Model Recharge Zones Distribution

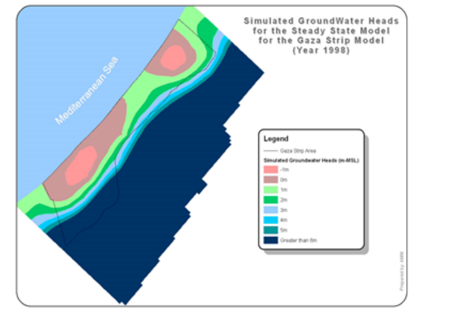

Figure **4**: Calibrated Groundwater Elevation Map

SEA LEVEL RISE SCENARIOS

The model will be capable to simulate the groundwater flow under different sea level rise scenarios (25cm, and 100cm). The main objectives of the numerical model will be to show the impact of sea level rise on the Gaza Coastal Aquifer for 10 years after sea level rise event.

25cm Sea Level Rise

The model was run on a monthly basis for 10 years. The results show that the seawater will reach about 2Km in the Gaza Coastal Aquifer, especially in the South within the first 5 years of simulation, while at 10 years of simulation the seawater will reach more than 2.5Km in the Gaza Coastal Aquifer in the South. Table 1 shows the seawater invasion of the different areas after 5 and 10 years of simulations.

Table 1: Sea Water Invasion Distance from the shoreline (25cm sea level rise effects)

Governorate	Simulation Time	
	5 years	10 years
North	1.0 Km	1.3 Km
Gaza	1.5 Km	1.6 Km
Middle	1.0 Km	1.3 Km
Khan Younis	1.5 Km	2.0 Km
Rafah	2.0 Km	2.6 Km
Total Area of seawater intrusion	44 Km^2	50 Km^2

100cm Sea Level Rise

The model was run on a monthly basis for 10 years. The results show that the seawater will reach about 2Km in the Gaza Coastal Aquifer, especially in the South within the first 5 years of simulation, while at 10 years of simulation the seawater will reach more than 2.8Km in the Gaza Coastal Aquifer in the South. Table 2 shows the seawater invasion of the different areas after 5 and 10 years of simulation; where figure 5, 6, 7 and 8 show the seawater invasion area in different areas of the Gaza Coastal Aquifer.

Table 2: Sea Water Invasion Distance from the shoreline (100cm sea level rise effects)

Governorate	Simulation Time	
	5 years	10 years
North	1.2 Km	2.0 Km
Gaza	1.5 Km	2.2 Km
Middle	1.2 Km	1.6 Km
Khan Younis	1.5 Km	2.2 Km
Rafah	2.0 Km	2.8 Km
Total Area of seawater intrusion	45 Km^2	66 Km^2

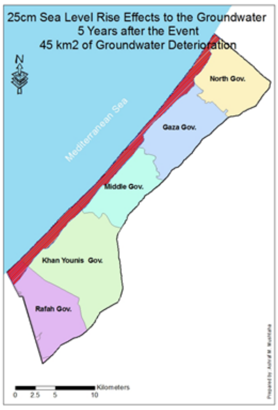

Figure 5

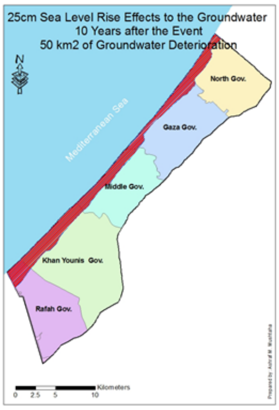

Figure 6

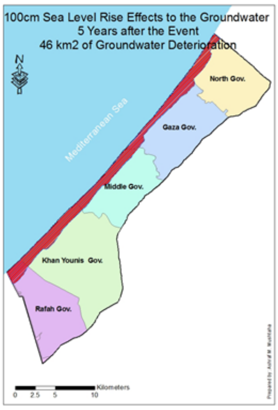

Figure 7

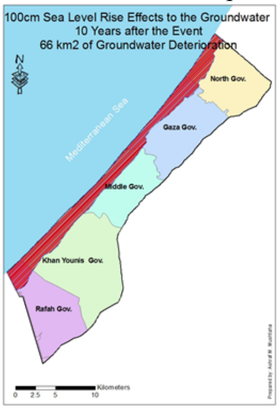

Figure 8

DISCUSSION AND ANALYSIS OF THE RESULTS

The model results show that the most affected areas are those where domestic wells are concentrated (within 2 km from the shoreline). Those wells are located in sand dune areas in the North Gaza and Western Rafah Governorates. Added to that an acceleration of seawater intrusion occurs in the North and South of the Gaza Strip where the water level is below mean sea level. The model shows that the two applied scenarios have the same trend but one is faster than the other.

Each five years of simulation, a map has been generated to show the extent of sea water intruding in the aquifer underneath Gaza Strip, and based on that an area calculation has been done to show the destroyed aquifer from the sea level rise action. Most destruction occurs at the early stage of the event, while afterwards it will be mainly depending on the aquifer abstraction regime. The area calculated shows that around 45km^2 of the Gaza aquifer will be intruded by seawater, whereby the groundwater will be no more suitable for drinking.

CONCLUSIONS:

1. There is a major impact of a sea level rise to the Gaza Coastal Aquifer.
2. The groundwater resource in the Gaza Strip will be polluted by saltwater.
3. The seawater will replace 45Km^2 of freshwater in the Gaza Coastal Aquifer after 5 years in both scenarios'.
4. The seawater will replace 50Km^2 and 66Km^2 of the Gaza Coastal Aquifer after 10 years with 25cm and 100cm of sea level rise respectively.
5. The 1.7 million inhabitants living in the Gaza Strip will have insufficient and unacceptable water resources.

RECOMMENDATIONS:

1. The related Palestinian institutions should look for new water resources (i.e. seawater desalination) to secure suitable drinking water to the Gaza Strip people.
2. Minimizing the abstraction rate especially in the West of North and Rafah Governorates may decrease the damage of seawater intrusion in case of sea level rise.
3. Create a positive pressure zones inland will minimize the sea water intrusion movement towards the negative pressure zones (inland) by creating a recharge areas in the Western area and along the Mediterranean coast.

REFERENCES

Mushtaha. 2010. Water Resource Status, CMWU

UNDP-PAPP. 2009. Analysis of the climatic change in the oPt

Amnesty International. 2009. Annual Report

Palestinian Central Bureau of Statistics (PCBS). 2012. Census Final Results Population Report

UNFCC. 2011. Second National Communication

IPCC. 2007. Intergovernmental Panel on Climate Change (2007) Climate Change and Water, Technical Paper IV, Geneva

Contact Information: Ashraf M. Mushtaha, Coastal Municipalities Water Utility, Gaza Strip, State of Palestine and PhD Student, Geology and Hydrogeology Department, Ghent University, Belgium, Phone: 972-599-487742, Fax: 972-8-2822896, Email: amushtaha@cmwu.ps or ashraf3@hotmail.com