Prediction of the Impact of Global Warming on Groundwater Environment in Coastal Aquifer of Seyhan River Delta, Turkey

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1. Introduction

According to IPCC Third Assessment Report (TAR), the global average surface temperature by the global warming is projected to increase by 1.4 to 5.8 ℃ over the period 1990 to 2100 years. And the global mean sea level is projected to rise by 0.09 to 0.88 meters. It seems that the global climatic change will impact on regional groundwater environment, and its impact will affects irrigation system, plant growth, and regional agricultural economy.

Based on such prediction, the purpose of this study was considered as prediction of the impact of global warming on groundwater environment. This report summarizes the result by February 2004 about 1) laboratory experiment of salt water intrusion for investigating the influence of sea level rise, 2) development of theories for saturated -unsaturated, density-dependent flow model, and 3) groundwater environment in Seyhan river delta, Turkey.

2. Laboratory experiment of salt water intrusion for investigating the influence of sea level rise

If sea level rise, zero-meter area in coastal area will be expanded. In zero-meter area, it seems that groundwater water quality in costal aquifer becomes bad due to salt water intrusion, and that wave will overcome dike.

The barrier wall installed imperfectly It is considered as one of the methods of preventing salt water intrusion. Fujinawa and Masuoka (2003) investigated the effect of salt water intrusion prevention by the barrier wall installed imperfectly, using experiment equipment as shown in Fig.1.

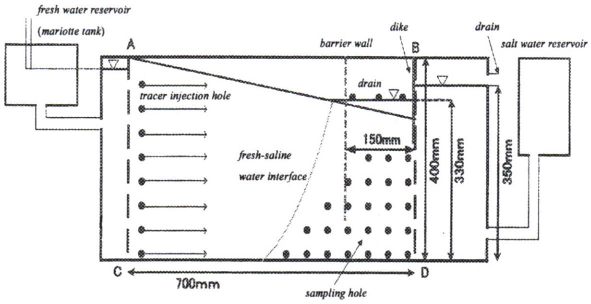


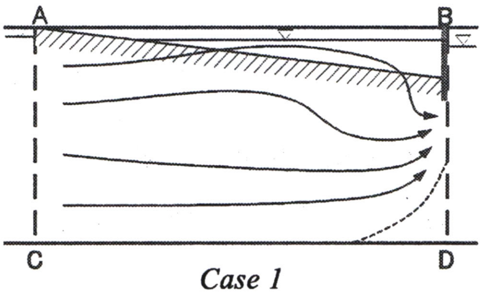
Fig.1 experiment equipment for investigating the influence of sea level rise in zero-meter area (Fujinawa and Masuoka,2003)

The experiment was performed about three cases; Case1 that salt water level is higher than the sample top end, Case2 that that water which collected inside dike is drained, Case3 that barrier wall installed imperfectly is set, draining the water inside dike. As a result of the experiment, it became clear that salt water intrusion advances, if water inside dike is drained, and that water gathers inside the barrier wall although salt water intrusion could be prevented, if barrier wall installed imperfectly is set (Fig.2).

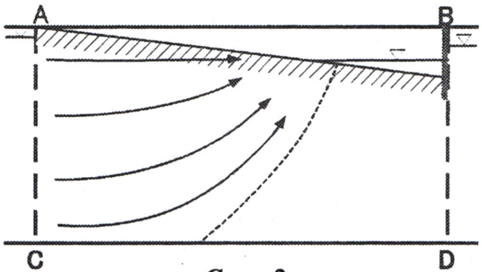
3. Development of theories for saturated -unsaturated, density-dependent flow model

Within a non-deformable porous media, the governing equation for flow of non-compressive fluids with variable density is given by

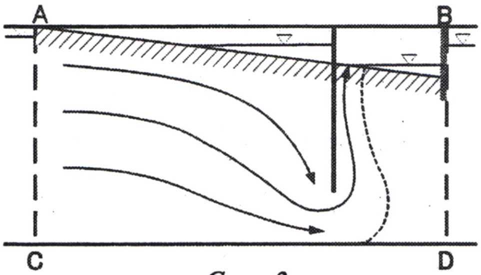
$$\nabla \cdot K_f \left(\nabla h_f + \frac{\rho}{\rho_f} \nabla y \right) = C_s \frac{\partial \rho}{\partial t} \qquad (1)$$



Case 1



Case 2



Case 3

Fig.2 The fresh- salt water interface and the streamline on the experiment (Fujinawa and Masuoka,2003)

where ρ、ρ_f are the density of fluid and fresh water, K_f、h_f are the hydraulic conductivity and the pressure head in terms of fresh water, and y is the upward vertical coordinate.

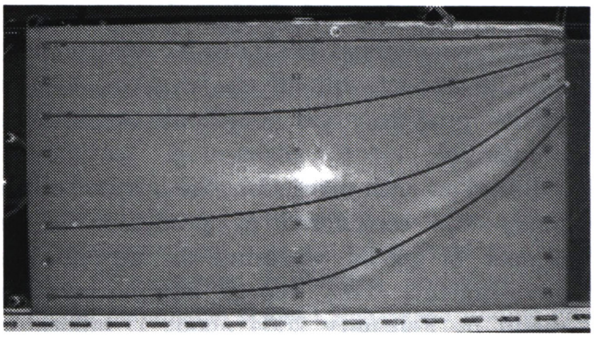
The governing equation for transport of conservative mass is given by

$$\nabla \cdot D\nabla C - \mathbf{v} \cdot \nabla C = \frac{\partial C}{\partial t} \qquad (2)$$

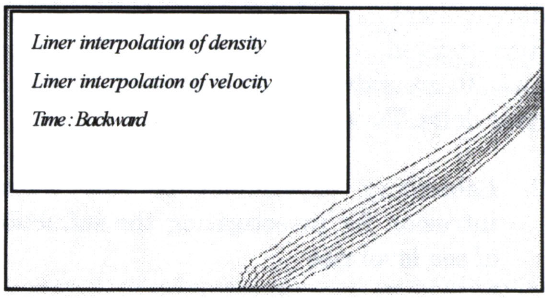
where D is the dispersion coefficient, C is the concentration of salt, and $\mathbf{v}$ is the fluid flow velocity vector.

The above mentioned variable density flow model which couples a fluid flow equation with a mass transport equation was applied to numerically solve the salt water intrusion problem. A finite element method was used to solve the fluid flow equation and a characteristic finite element method was developed to solve mass transport.

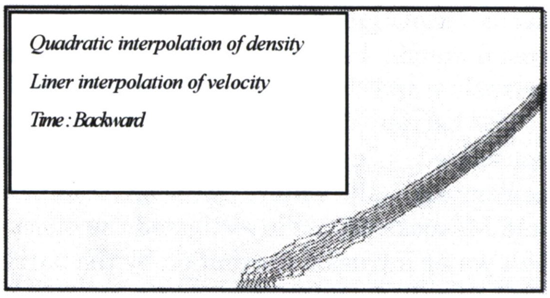
Fig.3 shows the result of a salt water intrusion experiment, and the result of the numerical analysis using two kind of methods under the same conditions. Liner interpolation of density, liner interpolation of velocity, and backward difference method of time was used in simulation (a). Quadratic interpolation of density, liner interpolation of velocity, and central difference method of time was used in simulation (b). The numerical analysis result of simulation (a) reappeared the experiment result with narrow fresh-saline water interface more appropriately than simulation (b).



Salt water intrusion experiment



Simulation (a)



Simulation (b)

Fig.3 Comparison of a salt water intrusion experiment and numerical analysis result

4. Groundwater environment in Seyhan river delta

4.1 Topography and Geology

Table.1 shows the stratigraphy around Seyhan river delta. Table.1 is created by contrasting geologic map which Taylan (1983) created and 1/250,000 geologic map of MTA (1962). Fig.4 shows the surface geologic map.

Seyhan river delta is bounded by Seyhan dam and the Mediterranean sea along N-S direction and Berdan and Ceyhan river along E-W direction. The delta reaches about 52km along N-S direction, and about 56km along E-W direction. The altitude of Adana located in the northern part of the delta is about 25m, and an average slope is about 0.5‰.

The hill located in the north side of the delta consists of shale formed during the Neogene. Especially, the HANDERE formation be rich in calcic. The KARİCİ (calcareous sediment, travertine) formed by evaporation of groundwater during the Pleistocene era is distributed on the HANDERE formation.

Over the delta, the alluvium with richly clay covers the KURANŞA formation which consists of sand, gravel, and conglomerates. Around KARATAŞ in coastal area and Ceyhan river, the hill with the altitude of about 60m which consists of shale of the Paleogene is located. It seems that this hill upheaved by folding.

Fig. 5 shows a geology section from ADANA to the Mediterranean sea. In Seyhan river delta, good gravel of continuity is distributed from upper to middle region. In lower region, clay is most rich, and sand and gravel are distributed in the shape of a patch. The gravel layer is comparatively distributed near the surface around ADANA.

According to Taylan(1983), the transmissivity values of Seyhan river delta changes between 500 and 2000 m^2/day, and points of high transmissivity values are at the northern part of the delta. Kruttaş et al. (1994) shows that the hydraulic coefficient in Seyhan river delta ranges between 10 and 150m/day. On the other hand, Çetin et al. (2000) shows that the hydraulic coefficient in near YUZBAŞI of lower region ranges between 2.57 and 4.11m/day.

Table.1 Stratigraphy around Seyhan delta

※It created by contrasting Taylan(1983) and MTA(1962)

geologic time					stratigraphy	minutes
Cenozoic	Quaternary	Holocene		present ~	ALLUVIUM	
		Pleistcene		10,000 years ago ~	KARİCİ	The calcareous sediment(travertine) of Quaternary. It is formed by evaporation of groundwater during dry age.
					TERRACE GRAVEL	It deposits on river bed by the thickness of 50 to 100 m.
					KURANŞA formation	It is formed by gravel, clay, and conglomerage.
	Neogene	Pliocene		1.8 million years ago ~	HANDERE formation	Calcareous mudstone or shale. It is blue-gray and mussive. A sandstone layer is inserted and it has a zone of gypsum, anhydrite, and a halite.
		Miocene	Late	5.0 million years ago ~		
			Middle		KOSON ŞEYL formation	It is soft and bluish gray. And it is blockey, muddy, calcareous and fossiliferous shale. The thickness is about 500 m.
			Early		KUZGUN formation	It consists of red-brown gravel and sand. Shale including conglomerate with cross-beddings. Lithological change of the lateral and vertical direction is shown.
	Paleogene	Oligocene		22.5 million years ago ~	KARATAŞ clastic facies	Foldings of muddy layer and gray-brown shale including graywacke and calcar. It is calcareous and was formed under water.
		Eocene		38.5 million years ago ~		

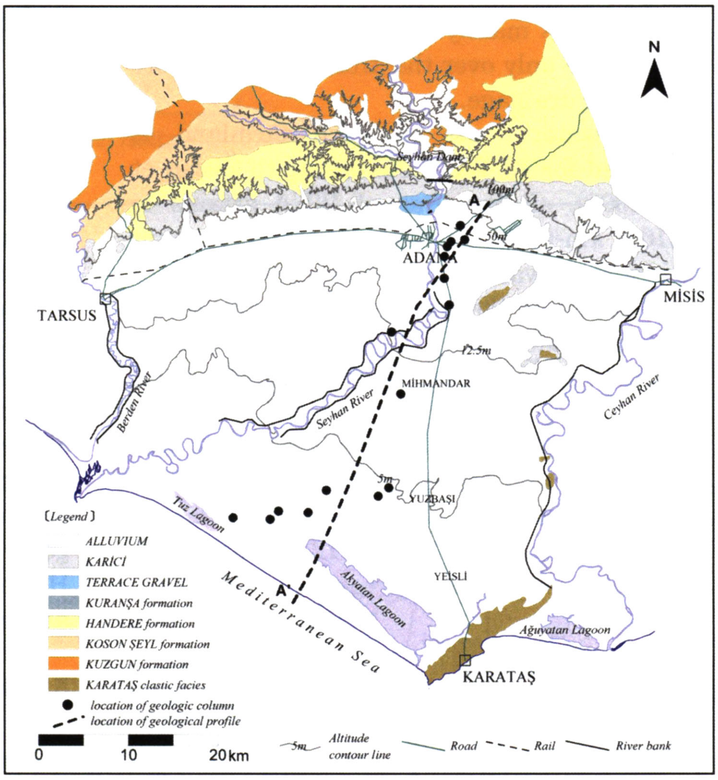


Fig.4 Surface geologic map around Seyhan delta

※It created by contrasting Taylan(1983) and MTA(1962)

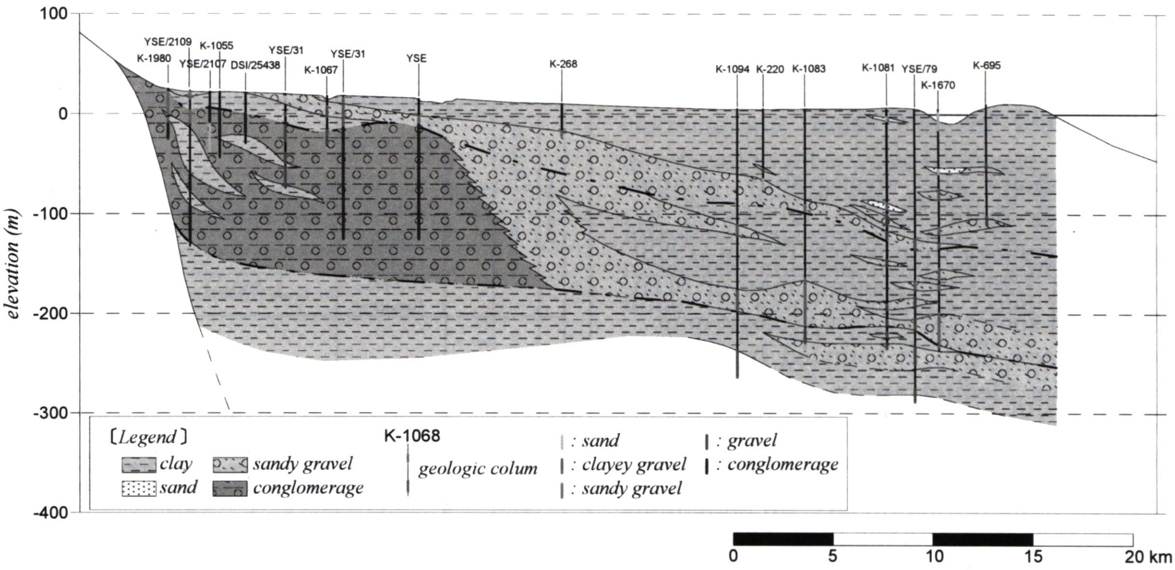


Fig.5 Geological profile in Seyhan delta

4.2 Land and Water use

The land use of Seyhan river delta is mostly used as farmland except for the city of Adana. Field crop is mainly distributed. Rice crop is distributed only over the area along the shore with poor drainage.

The water use at each farmland is managed for 18 WUA. According to Özcan et al. (2002), all the area of WUA attains to 1216.9 km^2(Table.2). The maximum amount of irrigation water released from Seyhan river is 90 m^3/sec by the left bank side, 54m^3/sec by the right-bank side. The irrigation water is distributed to farmland through the irrigation canal.

Kruttaş et al. (1994) presumed that 60% of the water used for irrigation infiltrates into the soil, based on 1.53×10^9m^3 water released from Seyhan river and 6.12×10^8m^3 water drained through drainage canal in 1980.

Table.2 Area of WUAs (Özcan et al.,2002)

	WUAs	*Area (ha)*		WUAs	*Area (ha)*
(the left bank)	*Kızey*	4,860	*(the right bank)*	*Yeşilova*	3,740
	Akarsu	8,943		*Seyhan*	3,610
	Cummhuriyet	2,655		*T.Onköy*	11,983
	Çotlu	2,425		*Toroslar*	13,700
	Güney	16,890		*Altınova*	6,150
	Gökova	4,289		*Pamukova*	12,037
	Yenigök	1,864		*Çukurova*	6,847
	Kadıköy	9,808		*Y. Seyhan*	4,895
	Gazi	6,394			
	Ata	600			
	sub total	58,728		*sub total*	62,962
				total (km^2)	1,216.9

4.3 Groundwater

According to the Potentiometric contour map in September, 1980 (Fig. 6) which Taylan (1983) created, potentiometric level in Seyhan river delta is located in a depth of several meter under surface. The highest level is about 25m in altitude in the northern ADANA. In the upper stream of Seyhan river, potentiometric contour line shows the shape of a ridge. On the other hand, in the middle region of Seyhan river and the Ceyhan river, potentiometric contour lines show the shape of a valley.

Fig. 7 shows electric conductivity of groundwater which DSI measured and the electric conductivity of groundwater which authors measured on November 4, 2003 and November 6. The values are increasing as it goes to lower region from upper region. However, the electrical conductivity values are high in the northwestern part of the delta.

5. Summarize

The study result by February, 2004 is as follows.

1) From the salt water intrusion experiment, it becomes clear that sea level rise has big influence on the groundwater environment in coastal aquifer.
2) The highly precise saturated-unsaturated, density-dependent flow model(2D) was

developed.

3) The feature of hydrogeology, land use, water use, distribution of groundwater level, and distribution of electric conductivity in Seyhan river delta becomes clear.

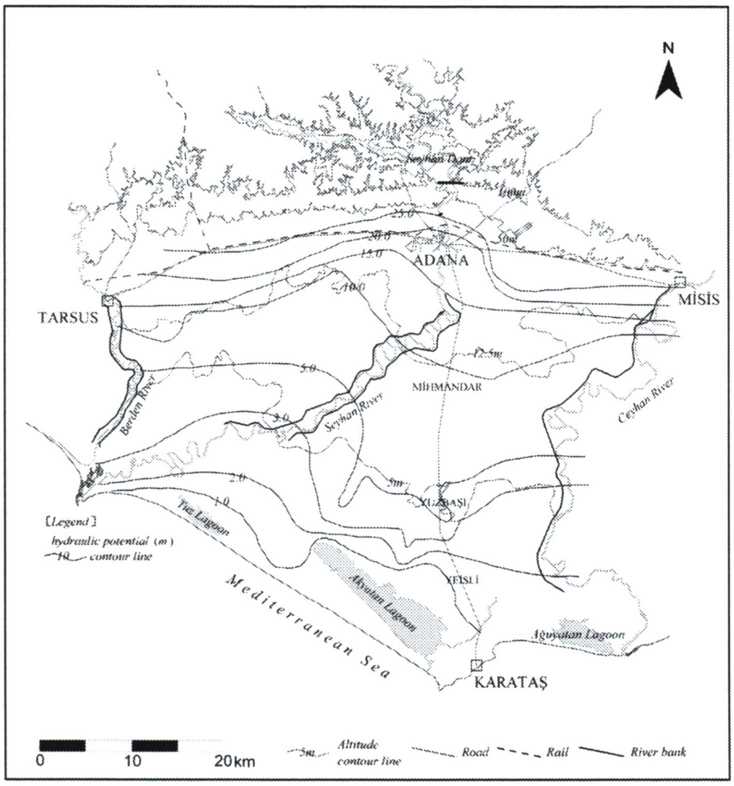


Fig.6 Potentiometric contour map in Seyhan delta (Taylan,1983)

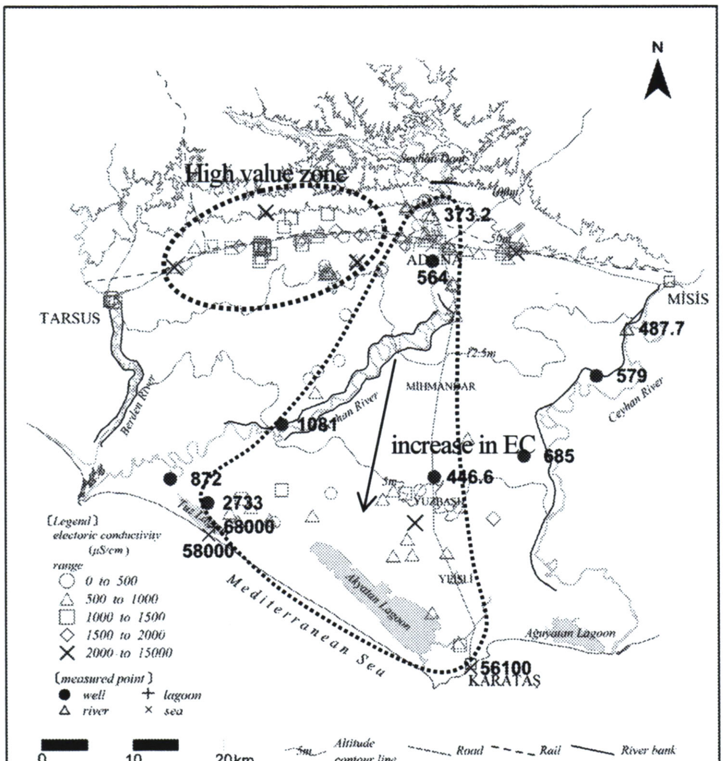


Fig.7 Distribution of electric conductivity of each well in Seyhan delta

6. References

IPCC, 2001: Climate Change 2001: the Scientific Basis. *Contribution of Working Group I on the Third Assessment Report of the Intergovernmental Panel on Climate Change, New York*, 881.

K. Fujinawa, K. Masuoka, 2003: The basic study on the influence which a sea level rise affects salt water intrusion to the coastal aquifer of zero -meter area and and the measure, *Japanese Association of Groundwater Hydrology 2003 spring meeting summary*, 62-65.

A. Taylan, 1983: Adana Ovası Hidrojeoloji Raporu Planlama Aşaması, DSI, *unpablished.*

T. Kurttaş, N. Karahanoğlu, 1994: Modeling of Adana Plain (Turkey) by Means of Finete Difference Method, *15. Yıl Sempozyume. Special issue*, 103-122.

M. Çetin, H. Özcan, F. Topaloğlu, 2000: Monitoring and Evakuation of In Situ Hydraulic Conductivity and Groundwater Quality of the Pilot Area in the Lower Seyhan Plain, Adana, Turky, *International Symposium on Desertification/ 2000-Konya.*

H. Özcan, M. Çetin, F. Ö. Özcan, 2002: Water User Association and Land Use, *International Conference on Sustinable Land Use and Management/ 2000-Çanakk.*