Some unique results on interaction of groundwater and surface water in the Yellow River delta

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Introduction

Yellow River has kept the condition with a shortage of the river water since 1990's in the downstream area. To confirm this influence on groundwater environment in the delta area and Bo-Hai Sea, our intensive research have begun since 2003 (Taniguchi et l., 2004). At our first intensive research, we had some problems as follows: interaction of delta sedimentation and displacement of water, nutrient flux from the groundwater to the sea, and some environmental effects on groundwater condition such as groundwater contamination, seawater intrusion and groundwater decline. Based on the researches in 2003, we had shifted our view from general and wide hypothesis to detail and unique one. The results of groundwater level measurement, water quality, and resistivity measurement in 2003 indicated the heterogeneous flow and saltwater intrusion. In addition, we confirmed heterogeneous interaction of river, groundwater and saltwater depend on the topography and land use, using piezometer method. We also got a result on the displacement rate of the salt water to pure water, using soil sampling method at the one observation line. These results were presented at WPGM (Miyaoka et al., 2004) in Hawaii and AOGS (Onodera et al., 2004) in Singapore, and the preparation of publish is also advancing. But we could not determine the mechanism of heterogeneous phenomena. The spatial variation in displacement rate could not consider also. Therefore, we needed to continue our research with the focused view.

In this year, we conducted twice of intensive research in May and September. Our general objective is continued, but we have some detail objectives; to confirm the mechanism of heterogeneous flow of groundwater, to compare the displacement rate of the new observation line with that in 2003, to confirm the seasonal variation in groundwater quality, to evaluate the seawater intrusion to groundwater. In this newsletter, we want to introduce some unique results in our intensive researches in 2004. These results also will be published in 2005.

2. Method

Our research was conducted from May 6 to May 16 and from September 13 to September 23 in 2004. In our former research, we conducted groundwater measurements and water collections at about 50 wells or boreholes where we collected samples in last year (Taniguchi et al., 2004). Those are shown as solid dots in Fig.1. In addition, resistivity tests and soil profile collections were carried out at the northern observation lines (YN; N1-N5 in Fig.1) and southern line (YS2 in Fig.1).

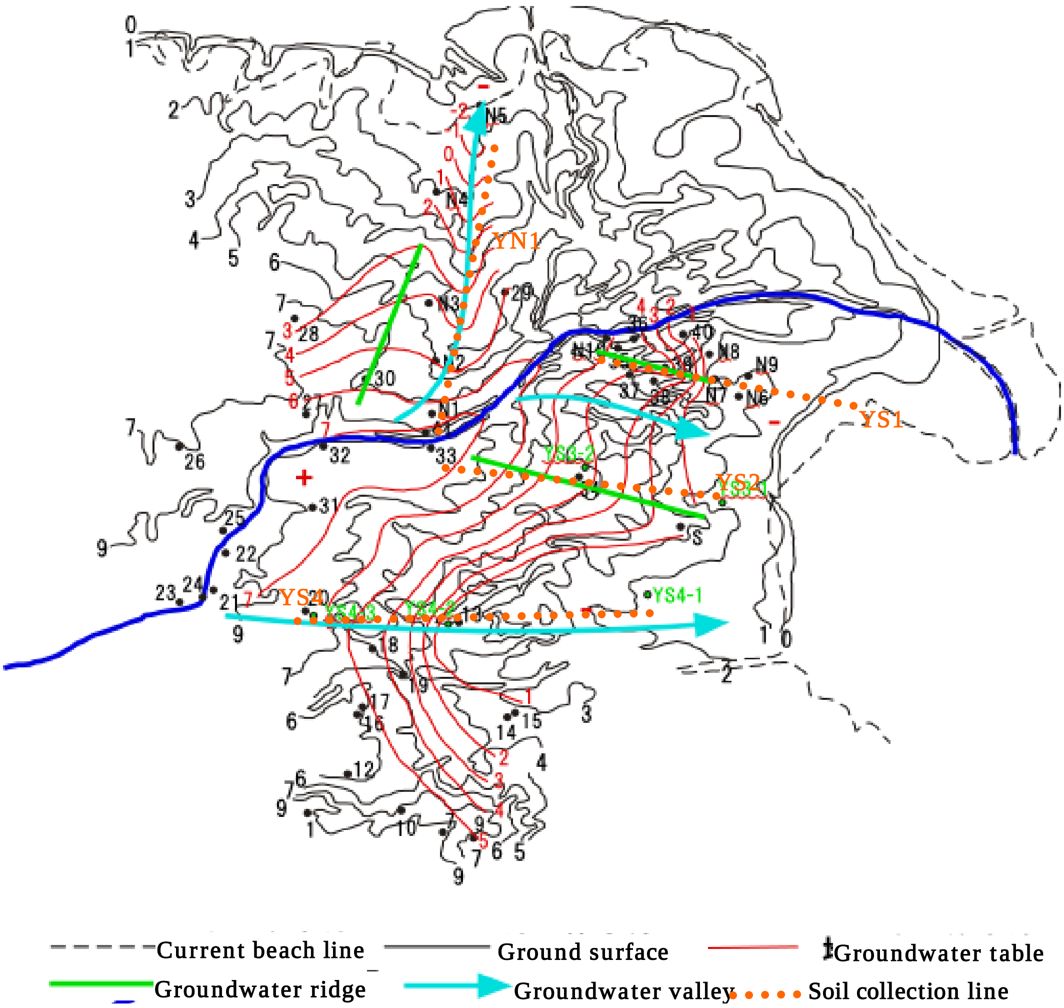

Fig.1 Topographic and groundwater table map and locations of observation sites.

In our later research, we conducted the chemical profile measurements and water samplings in ten wells or boreholes at the south side area of the river. In addition, the resistivity tests and soil profile samplings were carried out at the palaeovalley line and palaeoridge line where we detected by the topographic map and groundwater table map (YS3 and YS4 in Fig.1). We also measured water levels and collected water samples at piezometers located in the riverside area (N10) and seaside area (N9) where we constructed those in last year at both research periods.

Water samples were analyzed in the laboratory for inorganic ions, stable isotopes, and radioisotope as 2003. In addition, we extracted soil samples by the distilled water and 1N NH_4^+ solution, and the solutions were analyzed for inorganic ions. A part of the results of analysis in 2004 has not been completed.

3. Results and Discussion

Groundwater table figuration

Fig.1 shows the groundwater table map in the delta in September 2003. Groundwater table is high at the riverside or upstream area. Groundwater flow is generally from the river to the sea. However, groundwater table is lower than the sea level at the northern area (N5). It means the seawater intrusion. In addition, we can find the micro-relief of

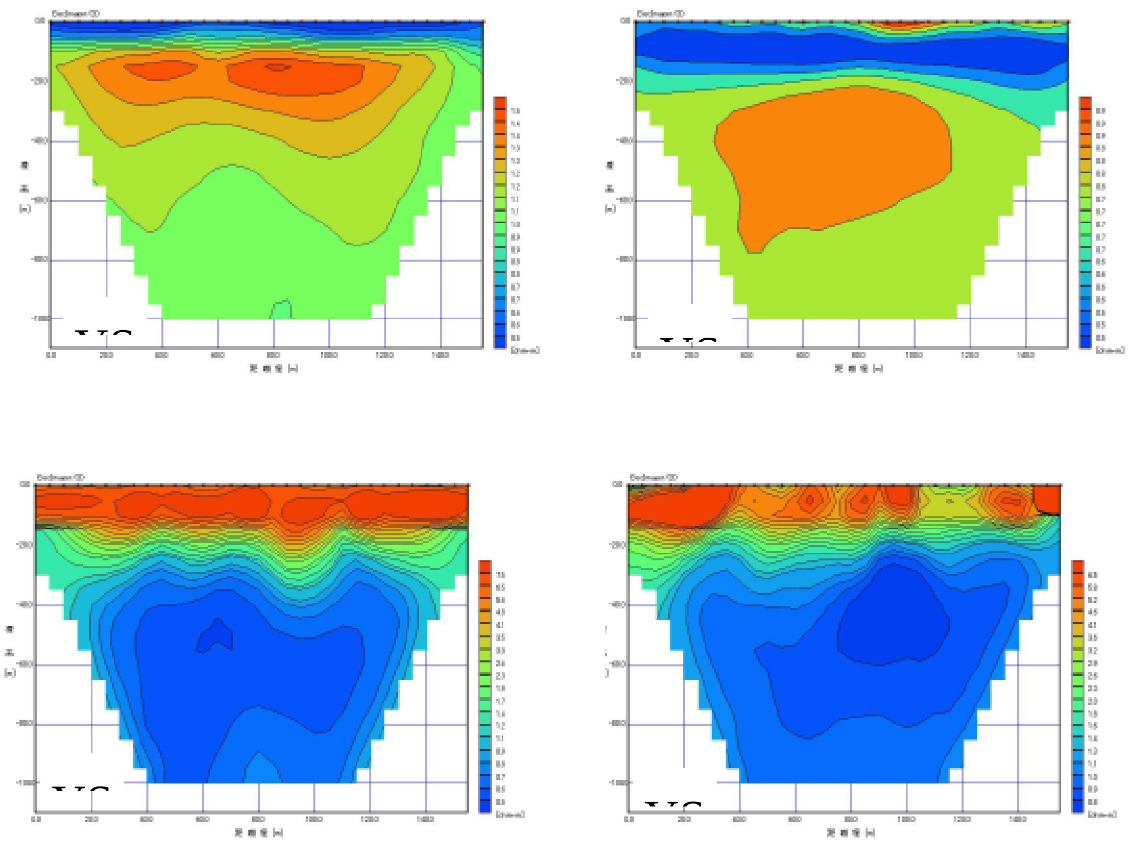

Fig.2 Resistivity profiles at YS3 (palaeoridge) and YS4 (palaeovalley) lines.

the groundwater table. There are one pair of valley and ridge in the northern area of the delta and two pairs in southern area (YS4 and YS3). This type of the micro-relief is negligible in terms of the horizontal groundwater flow in case of the homogeneous porous medium. However, if the valley of groundwater is a palaeovalley, the medium is composed of sandy sediment and muddy sediment in the palaeoridge. That means the large difference in terms of the permeability. On the other hand, seawater tends to intrude into the palaeovalley. Consequently, we suggest that such micro-relief of groundwater is a significant indicator of the nutrient transport or seawater intrusion in the seaside area.

Resistivity profile at the palaeovalley and palaeroidge

Fig.2 shows resistivity profiles at the two measurement lines. YS3 line is on the ridge of the groundwater and YS4 is on the valley, and YS3-1 is located on the seaside. In this figure, the color range from the blue to the red represents the resistivity range from the seawater condition or compact sediment with the low value to the pure water condition or loose sediment with high value. The horizontal axis is the horizontal distance of 160m and the vertical axis is the depth of 100m. The horizontal variation in the resistivity is negligible, whereas the vertical variation is large and two layers appear. The resistivity profile at a palaeovalley is high at the surface layer and low at the deeper. In contrast, the palaeoridge has the inverse profile. This suggests the high displacement rate of seawater to the pure water with the groundwater flux or existence of compact sediment in the surface layer at the palaeovalley. In general, because the permeable sandy sediment buries the palaeovalley, the groundwater

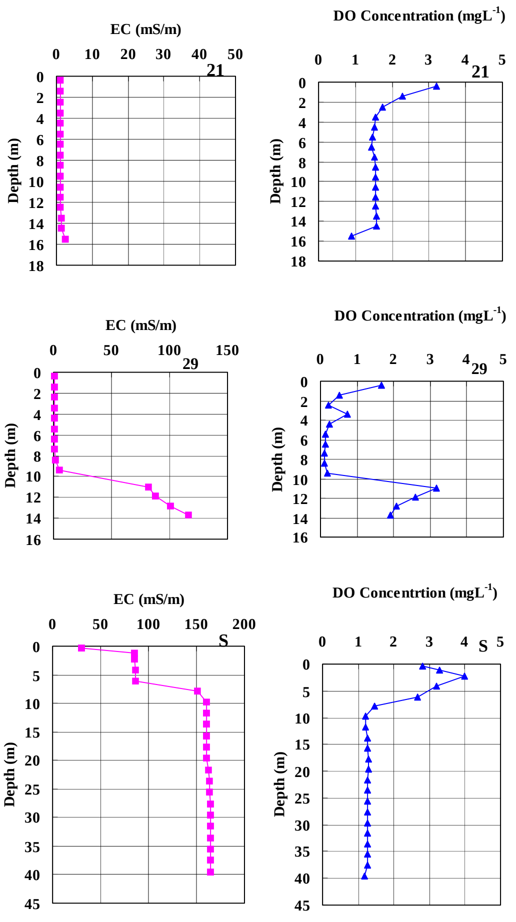

Fig.4 Profiles of electrical conductivity and dissolved oxygen concentration in the boreholes at the riverside (21), the palaeovalley (29), and seaside site (S). Y axis shows the depth below the groundwater table.

flux would be large there. On the other hand, it is a high possibility that seawater tend to intrude into older sediment layer under the palaeovalley because of the low altitude and seawater going to upstream. These trends agree with the resistivity profile. However, we need to confirm whether high salt content water is palaeo-seawater or current seawater with considering the adsorbed content.

Chemical profiles in the boreholes

We conducted the chemical profile measurements at 7 various boreholes by the portable chemical meter (temperature, EC, pH, DO, pressure) and we collected water samples at two or five various depths in each borehole and more 3. Fig. 4 shows the profiles of electrical conductivity and dissolved oxygen concentration at 3 boreholes. One is No.21 at the riverside of western delta, No.29 at the palaeovalley and No.S at the seaside. We represent Y-axis as the depth below the groundwater table. The average EC in the borehole increases from 1mS/m at the riverside to 150mS/m at the seaside. The EC also increases from shallow to deep in the borehole. At the palaeovalley, the EC was very low in the shallow zone of less than 10m but rose up to more than 50mS/cm in the deeper zone. This profile coincides with the resistivity profile. However, the DO concentration is high in the deeper. Because here is so far from the beach, the source of oxygen in the deeper water is not made clear. At the seaside area, the EC exceeded 150mS/cm and this value is equal to be three times of seawater in the deeper zone. This borehole is located at the salt production field with the area of wider than $1km^2$. The high salt content suggests the density flow of enriched seawater to downward. It is necessary to evaluate the source and formation mechanisms of this extremely salty water. As described above, the chemical profile in the boreholes supported the existence of salty groundwater suggested by the resistivity measurements. But we also need to check the geologic profiles in the area.

Variation in chemical property from the river to the sea

The chemical properties of soil profiles were also analyzed after collecting at two palaeoridge and two palaeovalley lines. Fig.5 shows adsorbed cation content and ratio of Na and Ca at the 7 plots on the

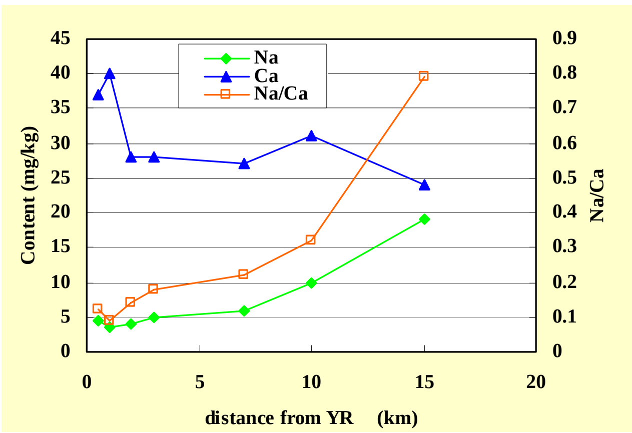

Fig.5 Adsorbed cation content and ratio of Na and Ca from the river (near N10) to the seaside (near N9) on the YS1.

line (YS1) of 15 km from the river (near N10) to the seaside (near N9). We collected soil samples at the 50cm intervals from the ground to the depth of 3m to 4m at each plot. The groundwater table was the depth of 1m to 2m below the ground. Each value in Fig.5 is an average of all values of samples below the groundwater table. The results at a palaeoridge line indicated the continuous trend of displacement from the riverside to seaside. Adsorbed cation extracted by NH_4^+ solution was composed of Na^+ in the seaside area, while it was Ca^{2+} in the riverside area. This means that the displacement from Na^+ to Ca^{2+} occurred in the inland area. Using the simple water balance model, the displacement rate was estimated to be 20 years at 15km of inland from the beach. It is similar to the sedimentation age. However, adsorbed Na^+ content at the 15km from the beach was only one sixth of the value of seabed sediment. This high content coincides with the resistivity property in the surface layer. This means that the soil keeps high Na^+ content as the adsorbed condition in the soil. We need to compare such results with those in the palaeovalley.

4.. New tasks to the next year

Based on our intensive researches in this year, we confirmed some unique results. The heterogeneity of groundwater flow environment and its influence on the displacement rate were so significant facts for the determination of nutrient flux and seawater intrusion in the delta area. However, we also found some tasks. Those are the confirmations of seasonal variation and spatial variation mechanisms in the groundwater flow and nutrient transport as irrigation, land use and palaeo-hydrogeomorphological process, deeper groundwater flow in both the area under the palaeovalley and palaeoridge, heterogeneous nutrient flux to the sea, and the relationship between groundwater flux and Yellow river. Consequently, we need more 4 boreholes at the sites where we conducted resistivity measurements at least.

On the other hand, we have so many other data, which we could not introduce here. For example, those are the automatic data of piezometric head, temperature and conductivity at the new boreholes, seasonal variation in chemical component and isotopic component of groundwater. In addition, we have not discussed the relationship between the groundwater environment and groundwater discharge characteristics etc. Therefore, we will get more results after additional analysis and discussion.

References

Miyaoka et al. (2004): Abstracts of WPGM in Hawaii.

Onodera et al. (2004): Abstracts of AOGS in Singapole.

Taniguchi et al.(2004) : News letter Vol.2 in YRiS Project, 22-26