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# The Impact of Reclamation of Shiwha-District on Environment

**Hyoun-Young Lee* and Seungho Lee****

**Reclamation of tidal flats has been practiced in Korea since the fifteenth century mainly for agricultural purposes. The total area of reclaimed lands in 1994 was estimated to be 400 km$^2$ which corresponds to 2% of the national farm land. Recently, reclamation has been undertaken extensively, and such a huge project as Saemankum Development will add over 401 km$^2$ by 2004. The impact of coastal reclamation on the environment is enormous. Most of them are presumably instrumental in causing local changes of coastal ecology. Reclamation is expected to be undertaken continuously and adverse effects are expected. The authors intended to identify the impacts of reclamation on the study area, to seek the causes of the environmental problems of Shiwha-District Reclamation, and to analyze its Environmental Impact Assessment to for environmentally sound sustained development.**

**Key Words:** Reclamation, Shiwha-District, water pollution, fresh-water lake, EIA,

## 1. Introduction

The total area of reclamation in 1994 was estimated to be 400 km$^2$ which corresponds to 2% of the national farm land. Most of the reclaimed lands are located along the west coast of the Korean Peninsular especially in Kyongi-Bay and Chonsu-Bay. Recently, reclamation has been undertaken extensively, and such a huge project as Saemankum Development will add over 401 km$^2$ (land, 283 km$^2$; lake, 118 km$^2$) by 2004. As a result, many of the dikes are massive and the enclosures behind the dikes are expansive enough to develop crop-lands as well as urban and industrial sites, and to construct fresh-water lakes for agricultural and industrial use.

The extensive changes of land use/cover due to reclamation affect coastal environments in several aspects. Recently, the Yellow Sea has been subjected to stress in environmental aspects from various sources; industrial waste discharge, sewage inputs from cities, oil spills and other materials associated with maritime transport. The environment of offshore and man-made lake in the study area has been, therefore, aggravated Especially this area is suffering from water pollution.

The authors intended to identify the changes of land use/cover and environment due to reclamation in the Shiwha-District Reclamation in Kyongi-Bay where the water pollution has lead to controversy presently. The study area adjoins the Seoul Metropolitan Region. This region is the core of the nation and more than 40% of the population is concentrated The hinterland of the Shiwha-District includes Ansan-City and six counties (Banwol, Maesong,

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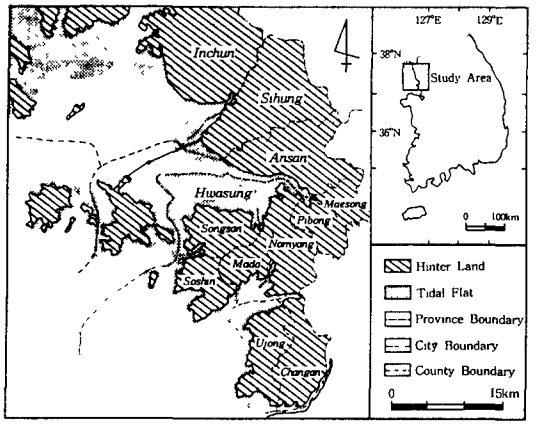


**Figure 1.** Study Area

Pibong, Namyang, Mado and Songsan) of Hwasung-kun.

The authors intended to identify the changes of land use/cover and environment due to reclamation and to seek the causes of the failure of the Shiwha-District Reclamation in environmental aspect

## 2. Data Analysis

Data used in this paper are Landsat_5 TM data and documents such as population, industry, water pollution and sea biota for the period of 1986-1995. A major problem in this study is the lack of environmental data, in addition to the dynamic nature and different types of data. To solve these problems satellite data were used. The authors used two sets of Landsat images at the Laboratory of the Maritime Police in Inchon to identify the changes of land use/cover due to reclamation since the changes take place too rapidly to be obtained from maps or documents.

The amount of atmospheric attenuation is not sufficient to drown out the important terrain signal because of the strong signals from soil, water, vegetation and urban phenomena, and each of those is different from one another. Also, the data used in this study were neither corrected for atmospheric attenuation nor calibrated for surface thermal inertia and moisture capacity. Two predominantly cloud free dates of Landsat data were used for 1985 and 1994. The specific date, type of imagery, bands used in the analysis, and nominal spatial resolution of the sensor systems are summarized in Table 1. Twenty ground control points (GCP) were obtained and both images were rectified to a Transverse Mercator (TM) map projection having 30m x 30m pixels using a nearest-neighbor technique in cubic resampling algorithm in IDRISI, and a root-mean-square error (RMSE) with an average of 0.8 pixel. The RMS statistics for each image are summarized in Table 1.

Densely developed urban areas, forests, agricultural land, water and tidal flats were determined as the categories of land use for training sites The spatial frequency filtering techniques with low frequency were used to enhance the urbanized area using TM band_4 (0.76-0.96$\mu$m). The original TM band_4 images and filtered images were added to give a much enhanced image in which the boundaries of build-up and rural area were greatly enhanced (Duggin, et al , 1988). The low pass filtering method was applied to enhance agricultural area using TM band_4. NDVI (Normalized Difference Vegetation Index) images of the study area were computed using band_3 (0.63-0.69$\mu$m) and band_4 to enhance the forest using the following equation.

$$\text{NDVITM} = \frac{TM_4 - TM_3}{TM_4 + TM_3}$$

To delineate the water body, the specific

**Table 1.** Characteristics of the Landsat Data Used in the Study

| Date | Satellite | Sensor | Band used | Nominal IFOV | Rectification RMSE | Cloud cover |
|---|---|---|---|---|---|---|
| 05/14/85 | L_5 | TM | 3, 4, 7 | 30 x 30 (m) | 0 62 | 0 |
| 09/22/94 | L_5 | TM | 3, 4, 7 | 30 x 30 (m) | 0 64 | 0 |

IFOV Instantaneous Field of View
RMSE Root-mean-square error

percentage linear contrast stretch technique was applied to the TM band_4, and the land use/cover was analyzed using supervised classification with MLC (Maximum Likelihood Classifier) with the supplement of aerial photographs and a field survey. Continuos monitoring data for the environmental changes in the process of the reclamation project were not sufficient to identify the influence of the reclamation on the environment, but the concentrations of water pollution were compared in time series for the period of the reclamation project.

Finally, the layers of administration boundaries were overlaid on a land use map obtained from Landsat images using Geographical Information System techniques through ARC/INFO in order to visualize the effect of the change of land use on temperature fields.

## 3. Reclamation in the Shiwha-District

Early reclamation of tidal flats has been practiced mainly for agricultural purpose. Most of the reclaimed lands are in use for paddies or salt-flats, but some of them are being transformed into residential and industrial sites these days. The purpose of reclamation has changed from enhancing rice production to multi-purpose development.

Planners estimate that the land demand will amount to be 574,000ha for residential or industrial use by 2001. This is equivalent to the 28.99% (129,000ha) of 445,000ha of the land used in 1990 for the same purposes. The 1st Comprehensive National Development Plan was planned to supply 23,000ha (18%) of land as reclamation besides the land converted from forest to agricultural land. However, only 35% of the total land is available for the use of agricultural machines because of the physiography of Korea (Table 2). Consequently cultivated land per household is only about one hectare.

There is, therefore, a necessity to expand the land to cope with urbanization and industrialization. Reclamation is expected to create cropland and industrial sites along the coast to expand the infrastructures including the harbor facilitaties, and to dike fresh-water lakes to supply water for irrigational and industrial use.

The tidal flats in the study area were about 251km$^2$ in 1985. The large tidal ranges (8.1m in Inchon) and complicated ria coastlines with many islands provide benefits in construction of dikes shortening the length of dike per reclaimed area. Furthermore, the atmospheric tide due to

**Table 2.** The Physiography of Korea

| Topography | Ratio (%) | Area (ha) |
|---|---|---|
| Altitude above 100m | 81.1% | 8,050,590 |
| Slope above 15% | 55.5% | 5,516,145 |
| Machines applicable | 35.0% | 3,478,650 |
| Total Area | | 9,939,000 |

Source Rural Development Corporation (1996)

**Table 3.** The Summary of the Shihwa-District Reclamation Projects

| | |
|---|---|
| Year of Reclamation | 1987-96 |
| Length of Dyke | 12.7km |
| Land-fill Area | 17,300ha |
| Fresh-water Lake | 6,100ha |
| Created Crop-land | 4,990ha |
| Created Urban area | 4,030ha |
| Created Industrial Complex | 1,302ha |

Source Rural Development Corporation (1996)

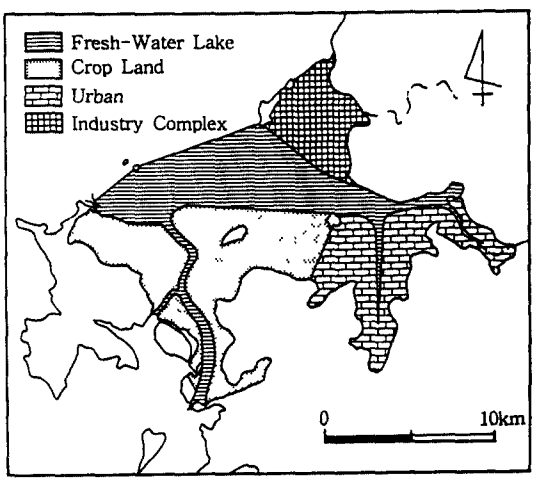


**Figure 2.** The Plan of Shiwha-District Reclamation (Rural Development Corporation, 1996)

the typhoon or sea wave is 2m lower, compared with Japan and The Netherlands

However, we can expect adverse effects on environment even though reclamation produces economic benefits in some ways. The Shiwha-District reclamation is planned as a multi-development project while early reclamations were to foster paddies and fresh-water lakes for irrigation. The length of the Shiwha-District dike is 12.7km which is the second longest in the world. The plan of the Shiwha-District reclamation is described in Table 3. By providing the reclaimed land (17,300ha) and redeveloping the hinterland (24,430ha) by 1996, this project was expected to release the tensions of the Metropolitan Seoul Region where one-third of the population of the nation is concentrated. The reclaimed land is divided into four parts, that is, industrial complex, urban area, agricultural land and fresh-water lake. However, the Shiwha-District is confronted with pollution problems even though the project is not yet completed. Especially, the dead water of the Shiwha fresh-water lake is subjected to severe criticism at this moment.

## 4. The Impacts of the Shiwha-District Project on Environment.

### 4 1 Land Use

The reclamation of the Shiwha-District caused not only expansion of land but also derived land use change in the hinterland. One can recognize that land use changed remarkably from rural to urban in the period of 1985-1994 (Figure 3, see also plate 1). While urban land use increased ten times from 52.4km$^2$ to 199.9km$^2$ in accordance with reclamation, the total green space or permeable land decreased from 258 5km$^2$ to 185 7km$^2$ The agricultural land including the reclaimed increased from 216.1km$^2$ to 323.0km$^2$ during the period. This change of land use may have implications for the local climate and biodiversity The reclamation also caused morphological changes in the coast lines. The construction of large dikes simplified and shortened the coastlines from 130km to 13km Recently, the construction of several highways

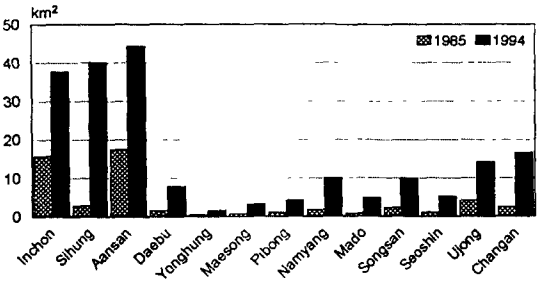


**Figure 3.** The Increase of Urban Land Use for the Period of 1985-1994

has been accelerated to connect the Metropolitan Seoul Region to the coastal area

### 4.2 Population and Industry

The reclamation also derived changes of social structures. In the process of land development, industrialization induced the inflow of population and various firms into this area The population of the hinterland of the Shiwha-District increased from 118,500 in 1986 to 5,543,401 in 1995 which is equivalent to 467% increase during the last decade (Figure 4). The agricultural and fishery population decreased abruptly but employment in industry and services increased noticeably The number of industrial firms also increased 250% from 602 in 1987 to 1,495 in 1995.

While the reclamation of tidal flats altered the pattern of longshore and tidal currents, the mismanagement of the reclaimed land aggravated the oceanic environment and damaged offshore fisheries and shell-culture. The haul of fish in the shallow sea has been decreasing since 1983 which is the year of the onset of the reclamation in the Kimpo area located north of the study area. As a result, many small fishing villages have been closed. Sea cultivation of shellfish, oyster, and algae has also diminished abruptly in the process of the Shiwha-District reclamation The yield of shallow sea cultures dropped abruptly around 1989 when dikes were partially constructed in the study area. The production of mollusca and crustacean from Kyongi-Bay has been reduced from 8,000 ton in 1984 to 1,674 ton in 1993

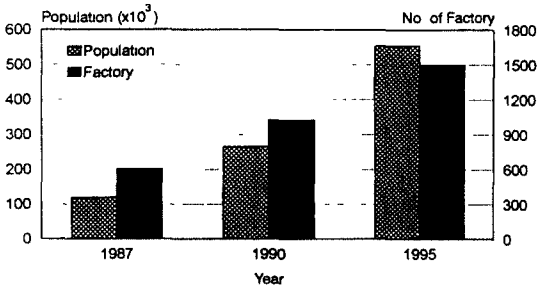


**Figure 4.** The Changes of Population and Industries (Rural Development Corporation · Korea Water Resources Corporation, 1995)

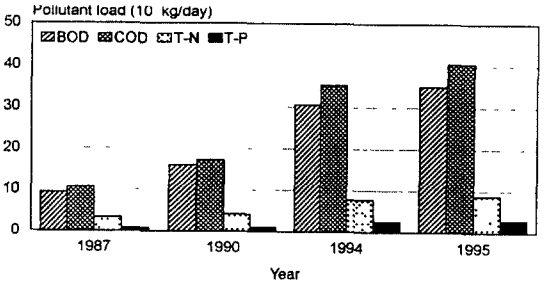


**Figure 5.** The Change of Pollutant Loads in Shiwha-District (Rural Development Corporation · Korea Water Resources Corporation, 1995)

## 4.3 Environmental Changes

Environmental changes are neither measured nor monitored in the study area systematically. It is not easy, therefore, to evaluate the impact of the reclamation on the present environment. However, residents in the study area recognize and complain about the adverse effects of reclamation.

**Total suspended matter:** The water transparency of the Yellow Sea is very low because of the inflow of large amounts of suspended matter from such large rivers as Han-river, Korea and Hwang-hu, China The water is colored brown in bays or estuaries due to the periodic and repetitive tide motions. The turbidity plume expands during rainy season.

The mean salinity of the Yellow Sea is 3.2% varying with seasons. In summer it decreases to 2.7% due to the heavy precipitation and runoff from the land

**Water Pollution:** Since 1985 the Maritime Police have measured water quality in offshore of Inchon in Kyongi-Bay. Annual mean value of COD, T-N and T-P has decreased since 1990 and the water quality of this region was evaluated as 2nd class However, the value of pH (7 9~8.1) has been sustained since 1990 with an evaluation of 1st class (The Ministry of Environment, 1995).

The reclamation is adding stress to the polluted offshore. The fresh-water lake of the Shiwha-District was expected to supply irrigation water into crop-field and to be developed as a recreation site. Nevertheless, this

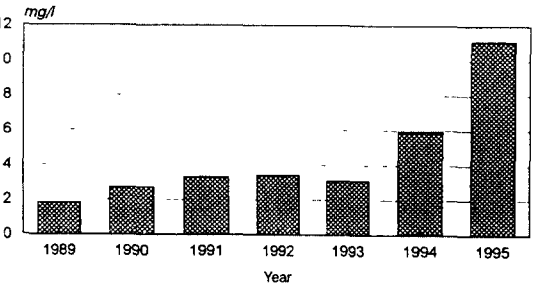


**Figure 6.** The Water Pollution in and around the Fresh-water Lake in the Shiwha-District (Rural Development Corporation · Korea Water Resources Corporation, 1995)

lake confronts severe pollution at present. The major pollution sources of the lake are domestic and industrial waste water from the hinterland

Figure 5 demonstrates the rapid increase of COD and BOD concentrations. Comparing the values of 1987 and 1995, the data show an increase of 376% for BOD, 381% for COD, 266% for T-N and 336% for T-P respectively (Rural Development Corporation · Korea Water Resources Corporation, 1995) The Oceanography Research Institute of Seoul National University collected sea water at a depth of 10m from 18 points offshore for the period of November 17-19, 1995, and analyzed such items as COD, T-N, T-P and heavy metals The average COD concentration was 3mg/l. The quality was evaluated as 3rd class (over 4mg/l) in 12 points among a total of 18.

Figure 6 shows that water quality was more degraded toward the upper side of the lake, and

the value of water pollution became critical except for the outer side of the dike. The highest value of 4.31mg/l appeared at Inchon. T-N concentration also was evaluated as 3rd class (below 0.2mg/l) at 13 points, and 11 points were ranked 3rd class (below 0.3mg/l) for T-P. At five points, COD values have been degraded from 2nd class (below 3mg/l) since 1989 when construction of dikes were undertaken to third class (11.1mg/l) in 1995. The value of 1995 means that the water cannot be used even for industrial purposes.

The pollutants of the lake are traceable to the emission source from Banwol industrial complex and to sewage through such streams as Banwol-chon, Donghwa-chon, Ansan-chon and Shingil-chon. Figure 7 demonstrates the emission of the factory waste from the Banwol complex. The quantity of the pollutants from the industrial complex accounted for 74% (157,300m$^3$/day) of the total emission from the drainage basin. The emmission of the factory waste will increase with the increase of factories and population due to reclamation.

**Sea Biota:** Ecosystems occupying coastal locations are under threat from a variety of human activities To name but a few (Huggett, 1993), gas and oil exploration, urban growth, sedimentation diversion and greenhouse-gas induced the sea-level rise. To protect and preserve ecosystems, it is valuable to know what the effects of proposed human activities are likely to be, and how these effects differ from natural changes. The landscapes of the study area, part of Kyongi-Bay, is one of the most rapidly changing landscape in the world at present.

Industrial waste, agricultural chemicals and fertilizers are extensively used in reclaimed lands. Such pollutants as SS, COD, DO, T-N and T-P are detected from the manufacturing plants and farms in reclaimed lands, which are, in all likelihood, instrumental in causing local coastal changes in ecology.

The water pollution of the Shiwha-District is attributed to the decrease in the number of species of benthonic fauna from 106 in 1981 to 89 in 1995 (Korea Oceanic Institute, 1995). The number of individuals also decreased from

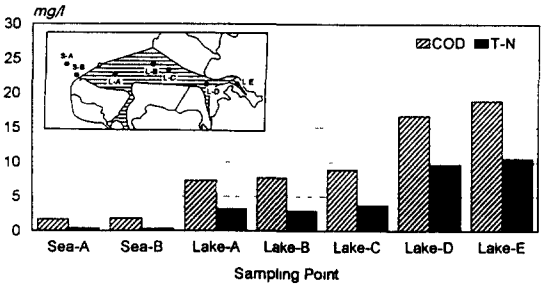


**Figure 7.** Amount of Waste Water in the Shiwha District (Rural Development Corporation Korea Water Resources Corporation, 1995)

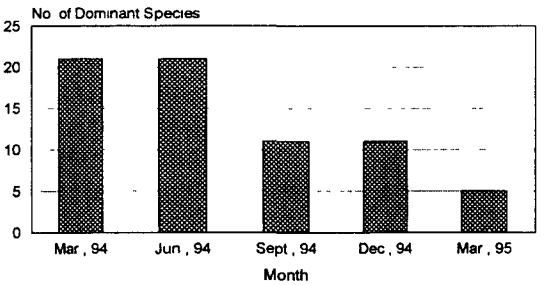


**Figure 8.** The Number of Dominant Species of Benthonic Faunas (Korean Oceanic Institute, 1995)

1,110ind./m$^2$ in 1981 to 628ind./m$^2$ in 1995. The number of dominant species also decreased noticeably (Figure 8) due to pollution. In particular, benthonic fauna has not been discovered since September, 1994 along the coast of Ansan-city. In addition, *Polydropra sp.* and *Capitella capitata*, the index species of pollution fauna appeared around June, 1994 and have been increasing rapidly since then.

## 5. Discussion

Coastal ecosystems are under threat from a variety of human activities. To protect and preserve ecosystems, it is valuable to know what the effects of such proposed human activities as reclamation are likely to be, and how these effects differ from natural changes.

The Shiwha-District Reclamation Project was instrumental in land creation for agricultural, industrial and urban area, The district is, however, suffering from severe environmental

pollution at present. As a result the high population density and rapid economic growth of the hinterland in the process of the reclamation, it became clear during the 1990s that pollution of the lake was going to cause major problems. The water had to contend with an ever-increasing burden of, for example, organic substances, salts, phosphates and heavy metals; dissolved oxygen levels fell alarmingly and the number of zoological species in and around lake declined abruptly.

Even though the EIA(Environmental Impact Assessment) has been practiced since 1981, the EIA for the Shiwha-District Reclamation Project had failed in estimating the growth of hinter land due to the project. The emission of pollutants from industrial complexes and from newly developed residential area into the fresh-water lake has aggravated water quality. Because of the extent and seriousness of pollution from various sources, pollutants should be removed by addition of quantities of fresh water. But such a measure involves considerable expense and poses severe technological problems in the study area due to the limited fresh-water availability. The annual precipitation in this area is concentrated in two or three months, and there are no large rivers to supply enough water. The Shiwha-District Lake, therefore, is almost impossible to function as a fresh-water lake supplying irrigational and industrial fresh-water at present.

A good grasp of detailed reclamation impacts on the environment is very important to establish a purification plan. Monitoring and auditing of the impact of reclamation is recommendable to ensure that a project is designed correctly. The impact monitoring and audit can provide an early warning device which alerts the management of the project or the environment to possible harmful impact before the full potential for damage is realized.

## 6. Conclusion and Remarks

Only rough estimates of potential impacts of reclamation on environment can be made. An area of 33,740ha was expanded for agricultural, industrial and urban purposes by reclamation in the study area. The reclamation also derived industrialization or urbanization in the hinterland. The project was expected to release of the tension of the Metropolitan Seoul Region, and to improve the quality of life. Nevertheless, the ecological environment was rather degraded. The water pollution in the fresh-water lake and outside of the dike recently became social issues. As a result, the Korean Government promulgated new plans for purification of the fresh-water lake in the Shiwha-District, but it costs almost the same amount as construction for the project. Since more reclamations have been practiced continuously and more adverse effects are expected, both systematic studies for a project plan and an EIA based on observation using GIS techniques are necessary to achieve environmentally sustained development. The results of the impact monitoring or the EIA audit study are absolutely necessary.

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# 시화지구 간척사업이 주변 환경에 미친 영향

이현영*, 이승호**

한국에서의 간척사업은 15세기 이후 주로 농업적인 목적으로 이루어져 왔다 1994년 현재 간척사업의 총 면적은 한국 농경지의 2%에 해당하는 400km² 정도이다 최근의 간척사업은 2004년 완공 예정인 새만금지구 개발(401km²)과 같이 대규모로 이루어지고 있다 따라서 간척사업이 주변의 환경변화에 미치는 영향은 막대하여, 해안지형의 변화뿐만 아니라 해양 생태계 변화의 원인이 되고 있다 이러한 간척사업은 앞으로도 계속 이루어질 예정이며, 또한 그에 따른 악영향이 발생할 것으로 판단되기 때문에, 본 논문에서는 시화지구 간척사업으로 인한 그 주변 환경에의 영향을 규명하고 시화 간척사업에서의 환경적 문제점들의 원인을 규명하고자 하였다

시화지구의 간척사업은 주변의 토지이용에 영향을 미쳐, 도시적 토지이용 면적이 1985년 52.4km²에서 1994년에 199 9km²로 급격히 증가한 반면, 녹지 면적은 258.5km²에서 185.7km²로 감소하였다 이에 따라 오염원도 급격하게 증가하여 담수호의 심각한 오염과 같은 악영향이 나타나고 있다. 즉, 시화호의 수질은 공업용수의 기준에 해당하는

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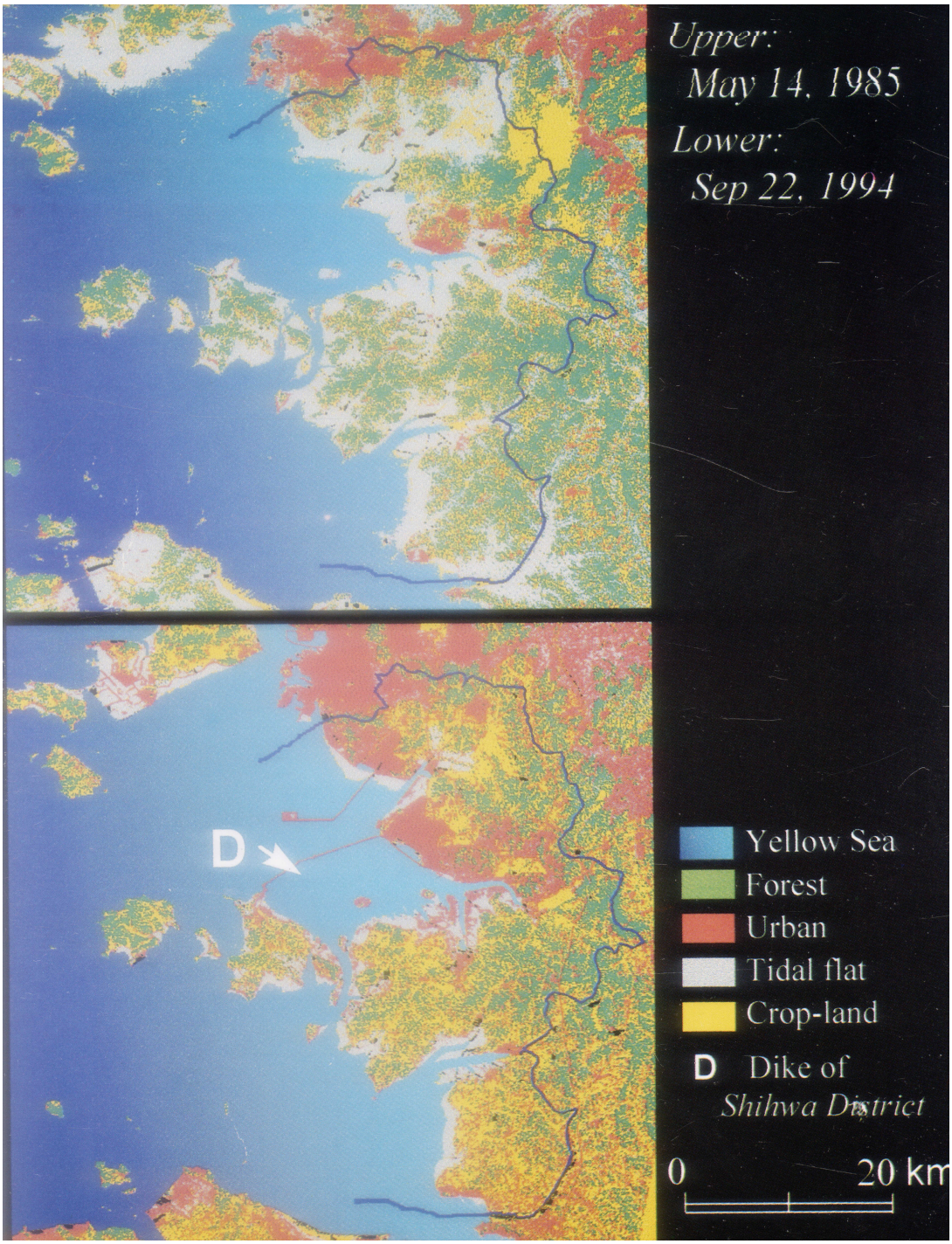


Plate 1. The change of land-use for the period of 1985-1994.

호소수질기준 V등급 상태를 나타내고 있으며, 저서생물의 개체수가 1981년 1,110개체/$m^2$에서 1995년에는 627.9개체/$m_2$로 크게 감소하였고, 1994년부터는 오염지표종인 *Polydropra sp.*과 *Capitella capitata*가 발견되기 시작하였다

주요어 간척사업, 시회지구, 담수호, 수질오염, 환경영향평가