Lecture 3

Case of KOREA

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Sustainable Water Resources Planning and Management in Korea: Perspectives and R&D

October 22. 2002.

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ABSTRACT

Korean government estimates the amount of water shortage will be 0.1 billion cubic meters in 2006, and 1.8 billion cubic meters in 2011. To add to the water shortage problems, Korea has endured frequent climatic extremes recently: five years of drought and three years of floods for the last ten year period (1993~2002). In order to resolve water-related problems a new comprehensive water resources plan (Water Vision 2020) is established to target year 2020. The Water Vision 2020 presents the principle strategies of water resources policy on the long-term and comprehensive viewpoints. To support the Water Vision 2020 technically, "Sustainable Water Resources Research Project", a ten-year research project, has been launched in 2001 as one of 21st Century Frontier R&D Program by the Korean government. Most of experts in Korea and a few researchers in abroad are involved in this research program to investigate policies and technologies needed in planning and operation for integrated water management including surface/ground water and alternative water resources. This manuscript describes the difficult state of the water resource planning in Korea and a new direction of sustainable water resources management in Korea.

Key Words: Korea, water shortage, sustainable water management

1. INTRODUCTION

The limitations of the water resources policy used in Korea since the 1960's are now surfacing. Although water demand continues to increase, the development of water resources by traditional methods has become environmentally, politically and socially difficult to sustain. As a result, the discrepancy between supply and demand is beginning to appear, and disputes concerning preferential allocation of limited water resources are occurring. Korean government estimates the amount of water shortage will be 0.1 billion cubic meters in 2006, and 1.8 billion cubic meters in 2011. To add to the problems, Korea has endured frequent climatic extremes recently: five years of drought and three years of floods for the last ten year period (1993~2002).

In order to resolve water-related problems it expects to happen in the future, new comprehensive water resources plan called Water Vision 2020 (Korean Ministry of Construction and Transportation, 2001) is established to target year 2020. Water Vision 2020 is considering the changes in the situation around water resources as well as paying attention to the problems concerning the people and the land. It presents the principle strategies of water resources policy on the long-term and comprehensive viewpoints.

To support the Water Vision 2020 technically, "Sustainable Water Resources Research Project", a ten-year research project for new water resources policy and technology has been launched in 2001 as one of 21st Century Frontier R&D Program supported by the Ministry of Science and Technology. One of the main objectives of the research project is to solve the water shortage problem for the next ten year period by adapting sustainable water resources management. To achieve the objective, policies and technologies needed in planning and operation for integrated water management including surface/ground water and alternative water resources are investigated.

This manuscript describes the difficult state of the water resource planning in Korea and a new direction of sustainable water resources management in Korea.

2. DIFFICULTIES OF NATIONAL WATER RESOURCES PLANNING

Since 1960s, the Korean government has established the National Water Resources Plan for water demand and supply prospect, water resources development and its use, flood and river environmental management, and it has made a fundamental guideline for them on the long-term and comprehensive viewpoints. The first National Comprehensive Water Resources Plan in 1965 made a basic strategy to promote the development of agriculture reservoirs for increasing crop products and hydropower generation dams to cope with electric power demand. The second National Comprehensive Water Resources Plan in 1980 was executed for the development of large multipurpose dams, estuary barrages, and river improvement for reduction of flood damage. In 1990, the third National Comprehensive Water Resources Plan have been established for stabilization of nationwide water supply using wide-area water supply network, reduction of flood damage, and formation of healthy river environmental. Recently, in 2001, the forth National Comprehensive Water Resources Plan settling 2020 as its target year is presented. This section describes the difficulties experienced in the past National Water Resources Planning in Korea.

2.1 Large Rainfall Fluctuation

Large differences exist in annual rainfall in Korea. When one of the worlds longest annual rainfall record from Seoul of 213 years from 1770 to 1990 is examined, the large fluctuations are apparent (Kim et al., 1993). Since the standard deviation of the annual precipitation accounts for 31% of the mean, 95% confidence lower limit is 1.65 times of 31%, 51% less than the mean. To satisfy water usage demand with 95% confidence level, the supply volume must be guaranteed with approximately 50% of an average annual rainfall. In Korea, approximately a half of the rainfall in Korea is lost to evapotranspiration. The amount of water lost to evapotranspiration would be assumed to not be affected by rainfall volume and as

a result, if rainfall decreases by half, the amount of water available for use would be decreased by 1/4. As a result, in Korea, a reservoir capable of storing rainfall over a long period of time is needed. In other words, to ensure water supply, Korea needs to maintain at least one years supply of usable water.

2.2 Insufficient Standards of Water Supply System

The representative water resource supply, the multi-purpose dams of Korea, currently operate under the standards established during the drought from 1967 to 1968. Most of the large scale water resource projects developed in the 1970s used the criteria set from the 1967-68 drought because the data were readily available and the experience of the drought were fresh in the mind of the developers. However, as historical data clearly show that the drought of 1967-68 is far from an extreme drought. Korea experienced an extreme drought in the early 1900s from 1884 to 1910, a period of 27 years. For 27 years, the average rainfall did not exceed 70% of the average annual rainfall for the 213 years recorded. As a result of the drought period, insurrections and extreme social unrest occurred and even the Korean monarchy crumbled.

The 1967-68 drought condition standard used to establish the water resource policy for usable water supply does not sufficiently reflect Koreas drought characteristics. This policy was established considering the insufficient financial conditions of the 1970s. In addition, this policy, created for a population of 20 million Seoul Metropolitan people, is insufficient to provide usable water supply for the current population. This fact has been one of the most serious problems facing Korean water resource policy.

Although the problem of insufficient design level still remains, the Water Vision 2020 established in 2001 adopted an equivalent drought recurrence interval instead of the fixed 1967-68 drought condition. Thirty years of drought recurrence interval for urban water supply and ten years for agricultural water supply were used as a planning standard throughout the country.

2.3 Rapid Increase of Water Demands

Water demand has rapidly increased since 1965. Domestic water use is increasing due to population growth, the improvement of the life standard, and urbanization etc. Industrial water use had been largely used up to 1980s, while the water use is slightly increasing since 1990s due to the recycling ratio and the change in the structure of industries. As for agriculture water use, it is increasing due to the wide utilization of paddy fields and the progress in irrigation of dry fields. Since 1990, instream water use (environmental water use) is rapidly increasing due to the raising awareness in river environments. (Table 1)

It is expected that total water demand is going to increase steadily from 2001 to 2020. In the estimate of future domestic water use in Water Vision 2020, we consolidate demand management policy, targeting water pricing, leakage control, gray water reuse, and the spread of water-saving equipment. In addition, the estimate takes population growth and economic conditions into account, considering the achievements in domestic water use in the past. In regard with the basic unit of domestic water in future, it is anticipated to reach 348 litter/capita/day in 2011, which was 280 litter/capita/day in 1998 on the national average. The amount shows a steady increase by about 2% per year, reaching 8.6 billion cubic meters in 2011, which was 7.2 billion cubic meters in 1998. (Table 2)

Table 1. Changes in the water demand (unit : billion cubic meters/year)

water use	1965	1980	1990	1998
total	5.1	15.3	24.9	32.8
Domestic water	0.2	1.9	4.2	7.2
Industrial water	0.4	0.7	2.4	2.9
agricultural water	4.5	10.2	14.7	15.6
Instream water	-	2.5	3.6	7.1

Table 2. Prospects of water demand (unit : billion cubic meters/year)

water use	2001	2006	2011	2016	2020
Total	**33.6**	**34.7**	**36.9**	**37.4**	**37.8**
domestic water	7.2	7.6	8.6	8.8	8.9
industrial water	3.3	3.7	4.0	4.3	4.6
agricultural water	15.6	5.7	15.9	15.9	15.9
instream water	7.5	7.7	8.4	8.4	8.4

A steady increase in industrial water use is also anticipated, although the recycling ratio will be rising. The amount of demanded industrial water use is likely to reach 4.0 billion cubic meters, which was 2.9 billion cubic meters in 1998 on the national average.

In the future, the decrease of acreage of farmland will be expected up to 2011 due to the urbanization and regional development. However, it is expected that agricultural water use will not immediately fall down in proportion to the decrease of acreage of farmland. Rather

than that, owing to the change of farming form, irrigation water for winter seasons such as greenhouse farming, increase of irrigation of dry fields and stock-farming water, the agriculture water use will change in slight increase. The use will reach 15.7 billion cubic meters in 2011, which was 15.6 billion cubic meters in 1998.

The needs for conservation and improvement of water environment are expected to intensify more to maintain and create natural and living environment, and to improve water quality. Therefore, it is anticipated that the environmental water use will be steadily increased, reaching 8.4 billion cubic meters in 2011, which was 7.1 billion cubic meters in 1998.

2.4 High Usage of Renewable Water Resources

The water available for use is the quantity that remains after evapotranspiration. If more than the remaining amount is used, whether from groundwater or surface water, the ultimate result is the drying up of water resources. As a result, the usable water quantity is referred to as renewable water resources and is used as an index to represents water scarcity of a country. In Korea, the national water resources plan states the renewable water sources to be 73.1 billion cubic meters/year. When the volume is divided by the population, the total annual volume available for use per person is 1,550 cubic meters. United Nations Economic and Social Commission for Asia and the Pacific (1992) estimated for 26 countries in Asia the average available annual water to be 4,143 cubic meters. The water available to Koreans is only 37% of the average for Asia.. Among the 26 surveyed counties in Asia, the only two nations below 1,700 cubic meters are Korea and Singapore.

Korea's heavy water use contributes to the water shortage problems. According to the national water resources plan, Korea uses 33.1 billion cubic meters of the 73.1 billion cubic meters available for use annually. Because 7.1 billion cubic meters is used for in-stream flow, the withdrawal water use becomes 26.0 billion cubic meters. Accordingly, approximately 35.6% of the renewable water resources are being used currently.

United Nations Department for Policy Coordination and Sustainable Development (1997) used this percentage to determine the water stress of a nation. Water usage under 10% does not result in water stress. Water usage between 10-20% is considered normal. Water usage between 20-40% results in water stress above normal and requires intensive management of supply and demand. If water usage percentage rises above 40%, a serious water shortage problem may result. In this scenario, water resources depend more and more on depleting groundwater and desalinization. Accordingly, to manage supply and demand, a special plan is needed. Water usage above 40% could be not sustainable and the water shortage may work

to limit essential economic progress. The average water use is 35.6% in Korea and as a result, an asserted effort to regulate supply and demand is needed. It is important to keep in mind that 35.6% is only an average and in some watersheds, the water usage percentage far exceeds the 40% limit. In most of these watersheds, the environmental quality continues to degrade. Without a decrease in water use, such a high percentage of water use makes the management of a sustainable water resource very difficult.

2.5 Increase of Frequency and Peaks of Floods

In the last 15 years, Korea has experienced large-scale floods never recorded before. In 1987, a large flood in the Keum river watershed caused 1 trillion won (about two billion US dollars) worth of property damage. In 1990, an intense rainfall recording 400mm in the southern Han river basin caused break of levee near Seoul and resulted in a large flood. In 1996 at the Hantan river basin, a concentrated rainfall measuring over 600mm overwhelmed the Yonchun dams flood control volume and flooded the downstream region. Shortly thereafter, the dam collapsed. In August 1998, a surprising record rainfall fell across Korea. As a result, in the Chiri mountain range, flash floods occurred, a reservoir in Kangwha-do collapsed, and in Chungrang stream and mid-and-small river basins, property damage as well as loss of lives occurred. In 1999 at the Imjin river basin, a rainfall event over 700mm destroyed Yunchun dam once again, and caused severe flood damage in Moonsan and Yunchun.

The recent flood damage can be attributed to the change in rainfall characteristics. It is worth noting that rain events in 1998 broke the old records, such as the 118.6mm rainfall in one hour in Seoul. In the last twenty year period, most of the rainfall records were broken throughout country.

As stated before, the serious problem Korean water resources policy faces today is how to counteract the extreme floods. The recent flood events are new conditions never dealt with before. Accordingly, the construction methods established during different circumstances are no longer effective. Extreme rainfall events have increased compared to before and as a result, flood policy has also increased. In contrast, the flood control ability of multi-purpose dams have declined. Questions about the effectiveness of flood control facility properties such as flood frequency, safety factors, and clearance are beginning to arise. Questions are also arising about the flood control ability of multi-purpose dams. To maintain the flood prevention level like before, the flood control volume must be increased and the water supply volume must be decreased.

3. NEW DIRECTIONS

To resolve the difficulties of water resources planning, Korea's water resource policy needs to be revised. The current policy focused on water supply needs to be changed to a policy that focuses on the management of water resources as a priority. This shift in policy does not mean the abandonment of water resource development. The conversion to a policy of management should consider water supply guarantee, flood safety guarantee, and the improvement of the environment as priorities.

3.1 Sound and Stable Water Utilization

Increase of continuous water demand is prospected in the future due to growth of population and economics, urbanization, and extension of domestic water supply etc. However, implementation of structural measures like as building of dams to secure water resources are getting to be more difficult, since there is a scarcity of suitable dam building sites and raising awareness in river environments. To solve these situations, we need to promote the sound development of water resources through the multilateral water sources. At the same time, we should build up the society leading water conservation and make strategies to augment available water resources on the development of advanced water management technology. On these conditions we aim at acquiring balance in water demand and supply in most of the areas on the basis of the existing project standard that is a drought with recurrence interval of about 30 years.

3.2 Formation of Safe Land against Flood

A variety of flood control projects have been implemented to protect life and property against floods, but substantial flood damages would not be reduced. Frequent occurrences of rainfall over design flood standards have been immediate cause. However, rapid growth in population and its concentration in flood prone have made flood damages more serious areas since 1980s. At the same time, "damage potential" for floods is more increasing. Principle measures to solve these problems are channel improvements such as channel widening, levee construction and reinforcement, and riverbed dredging so that flooding of less than the design flood can be discharged without inundating land along the river. Besides of channel improvement, we are going to make a plan for basin improvement that the natural flood behavior of drainage is largely retained or improved. In addition, measures of pre-disaster mitigation and the development of accurate flood forecasting technology will be positively reinforced.

3.3 Creation of River Environment in Harmony with Nature

To protect flood damages, we have implemented channel improvement works through river channel straightening and construction of banks covered with concrete so that the fruit of flood

loss prevention has been obtained. However, these works deprive creatures living in and around the rivers of their living spaces. From a different perspective, the environment of rivers has begun to be reevaluated as being important and rivers are seen as providing free open spaces for the general public in the cities and for use in outdoor sports. In this way, we have been given great responsibility for the care of our natural environment while at the same time are entrusted with devising new ways of protecting and preserving diverse river functions.

3.4 Research for Sustainable Water Resources Management

The difficult water situation made the government (Ministry of Science & Technology and Ministry of Construction) launch a huge and long range (10 year long) R&D program called Sustainable Water Resources Research Project in the name of 21C New Frontier Project from the last year (2001).

The program is divided into five research areas: (1) technology for integrated management of water resource, (2) technology for the assurance of surface water, (3) technology for the assurance of ground water, (4) technology for the assurance of alternative water resource, and (5) creative technology for the assurance of water resource. Most of experts in water and wastewater including scientists and engineers are, wholly or partially, involved in this national program. It is expected that Korea can solve the problems of water shortage by securing extra 3 billion cubic meters of water in 2011 as the program proceeds.

In the areas of alternative water resource security, development and application of water reuse technology is regarded as one of the major approach to satisfy two aspects, that is, pollution reduction and production of new source of water. It is known that 66 percents of wastewater produced a day end up with the discharge of 10 million cubic meters per day of treated effluent from municipal wastewater treatment plants. Calculation simply tells that 0.36 billion cubic meters of new water resource per year can be available if only 10 percent of wastewater could be reused. Technologies mainly focused on are such as the membrane bio-reactor (MBR), nanofiltration (NF), soil aquifer treatment (SAT), and advanced oxidation processes (AOPs)/ toxicity monitoring.

4. SUMMARY AND CONCLUSIONS

The limitations of the water resources policy used in Korea since the 1960's are now surfacing. Although water demand continues to increase, the development of water resources by traditional methods has become environmentally, politically and socially difficult to sustain. As a result, the discrepancy between supply and demand is beginning to appear, and

disputes concerning preferential allocation of limited water resources are occurring. To add to the problems, Korea has endured frequent climatic extremes recently.

Korea's water resource policy needs to be revised. The current policy focused on water supply needs to be changed to a policy that focuses on the management of water resources as a priority. This shift in policy does not mean the abandonment of water resource development. The conversion to a policy of management should consider water supply guarantee, flood safety guarantee, and the improvement of the environment as priorities.

The new direction of water management will be guided effectively by the comprehensive and long range (10 year long) R&D program called Sustainable Water Resources Research Project in the name of 21C New Frontier Project from last year (2001). Most of experts in water and wastewater including scientists and engineers are, wholly or partially, involved in this national program. It is expected that Korea can solve the problems of water shortage by securing extra 3 billion cubic meters of water in 2011 as the program proceeds.

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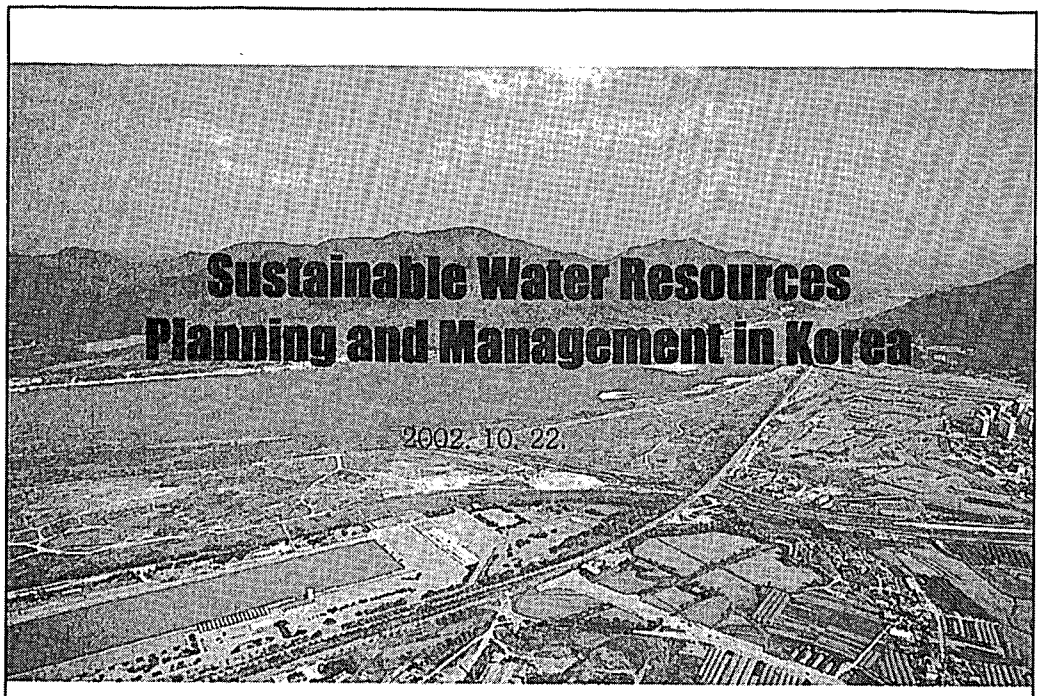
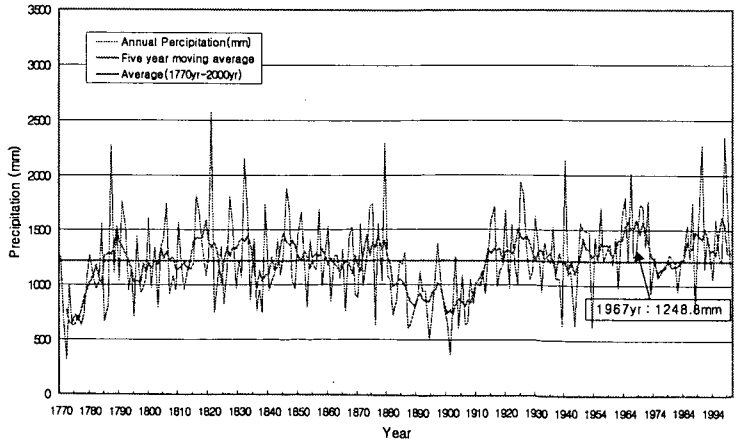


1

Annual Rainfall Fluctuation
Seoul: 1770-2000

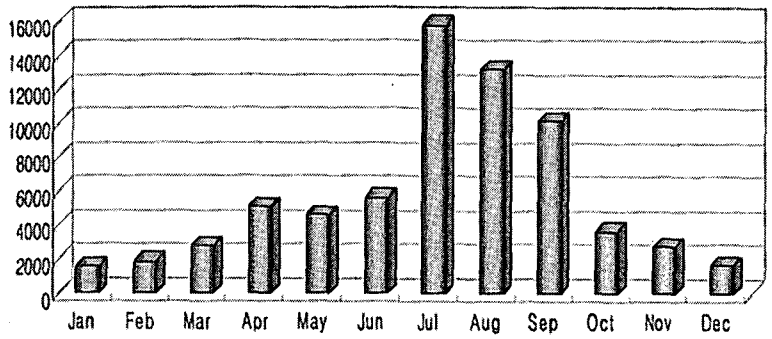


2

• Uneven Seasonal Rainfall Distribution

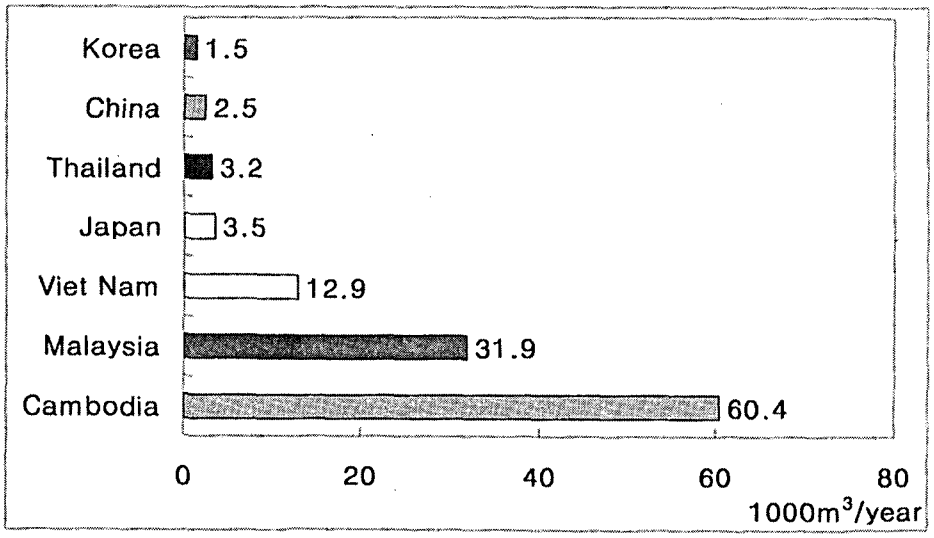
– Two thirds of annual rainfall is occurred during the summer season.

Monthly Runoff in mcm



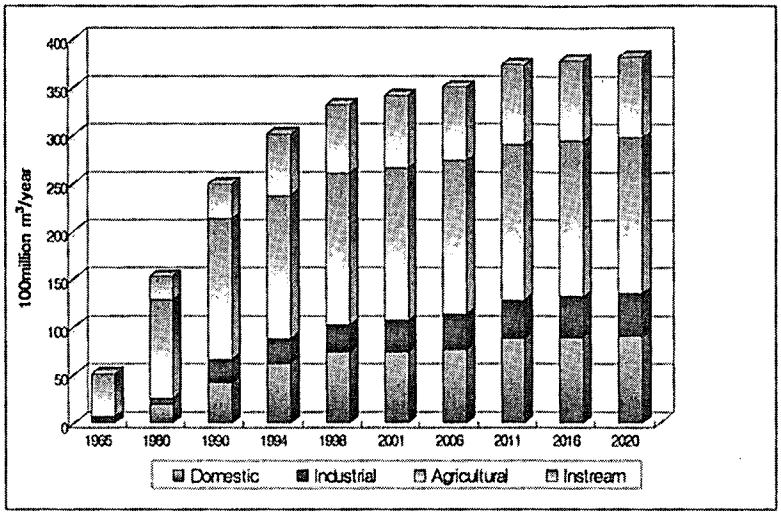
3

Renewable Water Resources Per Capita



4

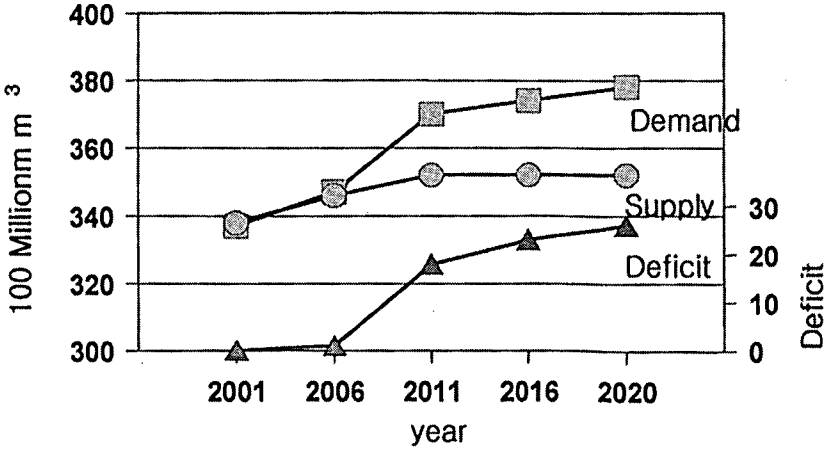
Water Demands



5

Water Demands

– Water Shortage begins from 2006



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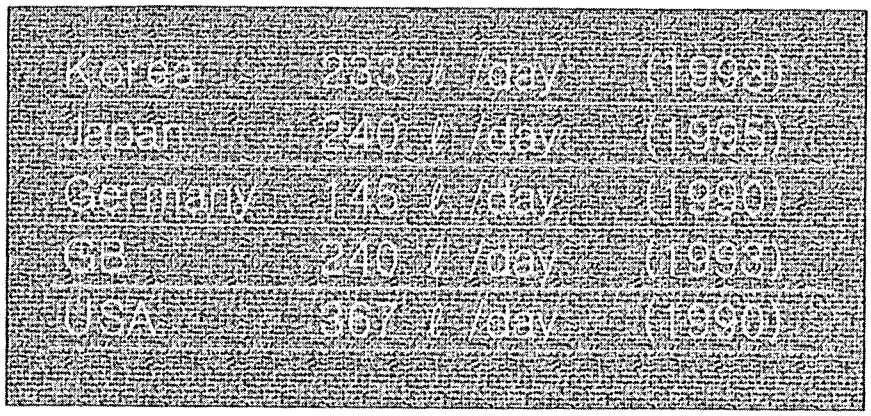
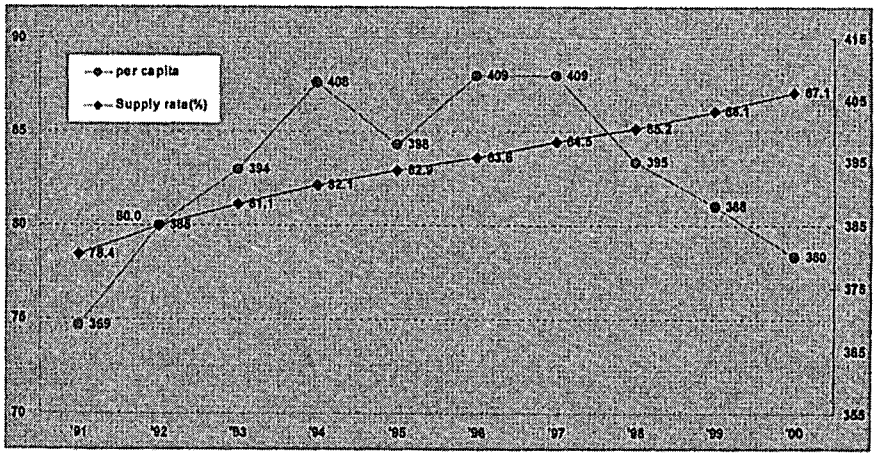
Household Water Use per Capita



7

Domestic Water Supply Status



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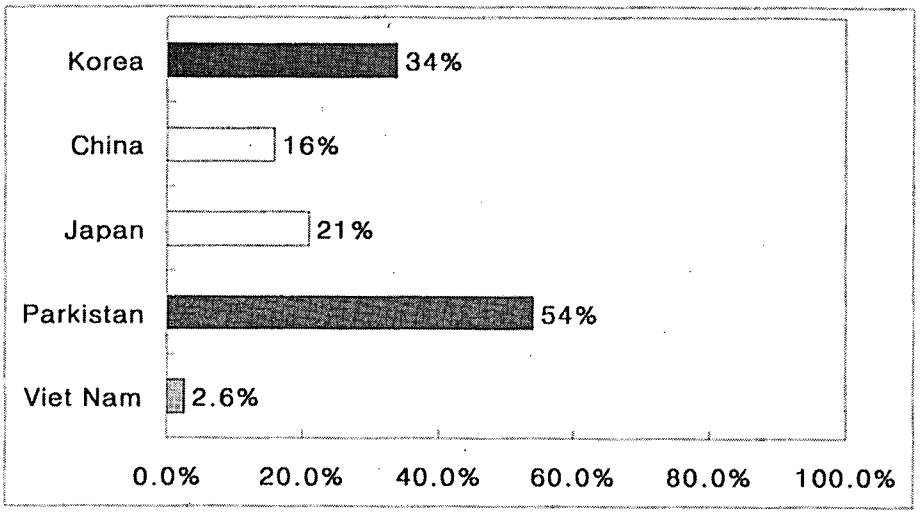
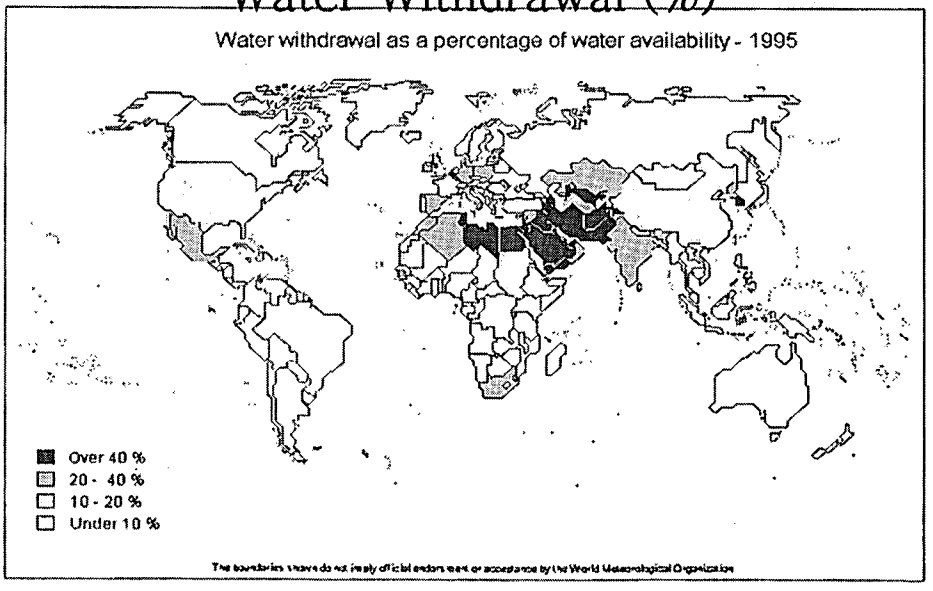
Percentage of withdrawal



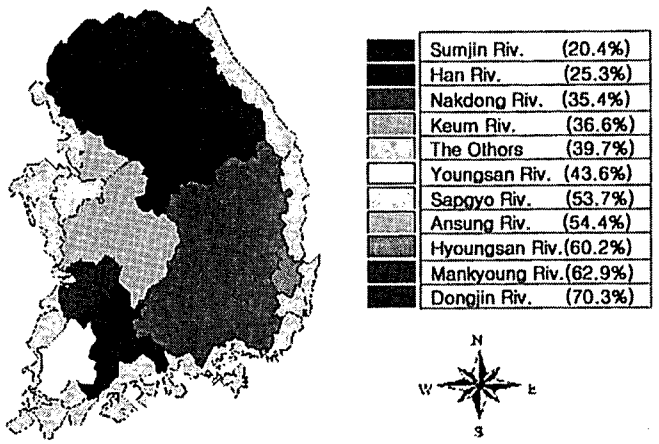
9

Water Withdrawal (%)



10

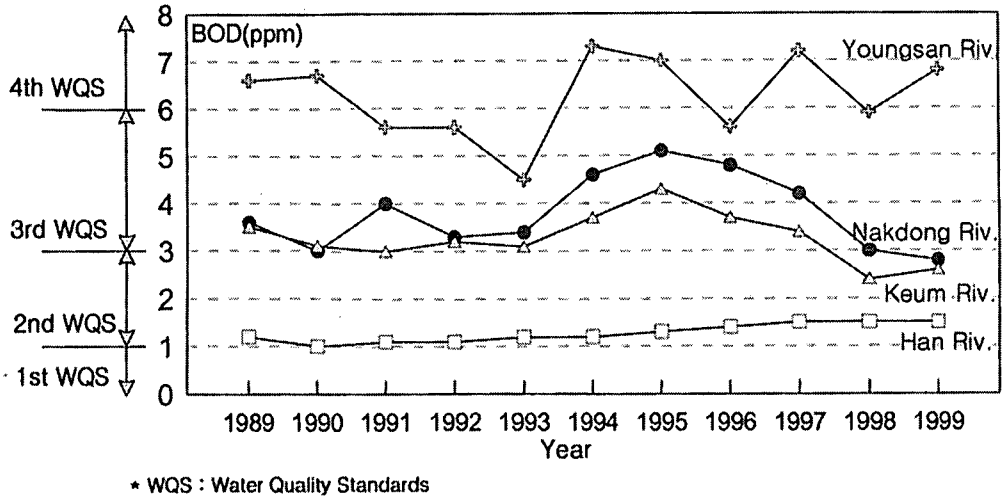
Highly Uneven Regional Water Withdrawals



• Water withdrawals from most of medium/small watersheds exceed 50%.

■ Water Quality

– environmental satisfactory ratio is low

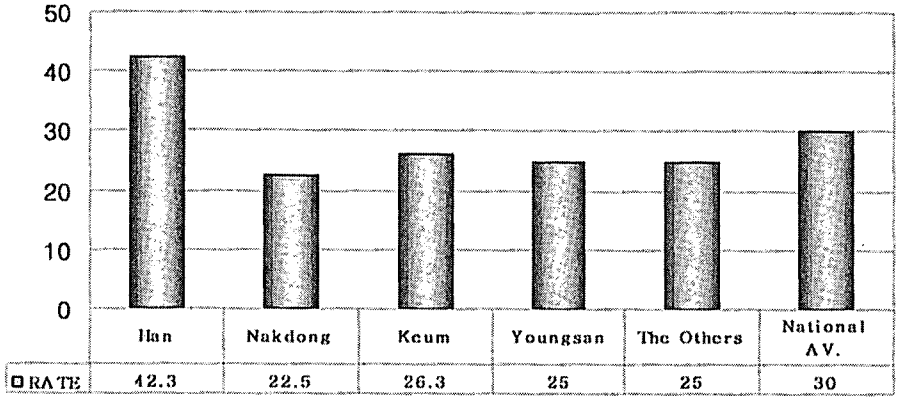


* WQS : Water Quality Standards

12

Success Ratio for Water Quality Standards

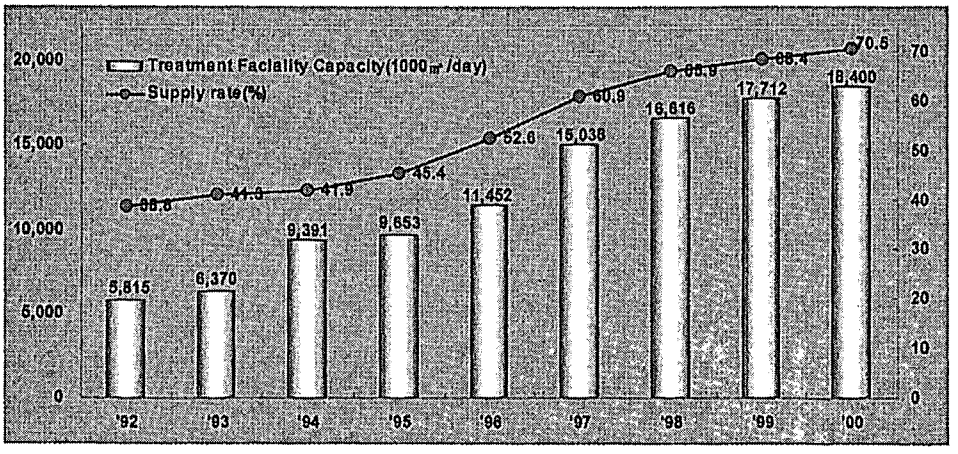
- Since 1991, 194 reaches are monitored.
- 29.4 percents are satisfactory in 2001.



	Han	Nakdong	Keum	Youngsan	The Others	National AV.
RATE	42.3	22.5	26.3	25	25	30

13

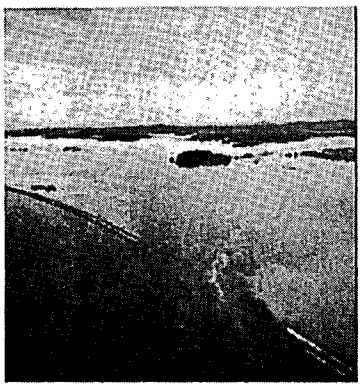
Waste Water Treatment



14

Increase of Frequency and Peak of Floods

• Floods After '1990 : 1990, 1996, 1998, 1999, 2000

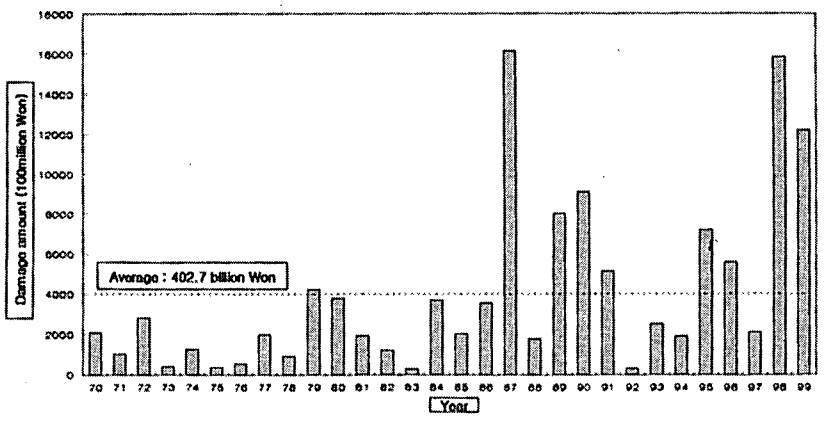


'1990

'1998

Trends of Annual Floods Loss

- increases owing to urbanization and climatic changes since 1980's



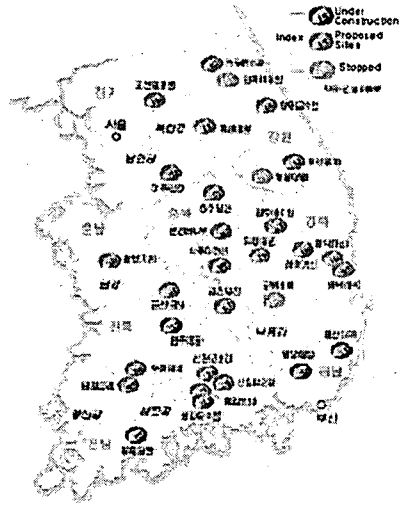
16

Sound and Stable Water Utilization

Demand management by efficient use and reuse of water resources

Development of water resources through the multilateral water sources

Acquiring balance in demand and supply with recurrence interval of about 30 years



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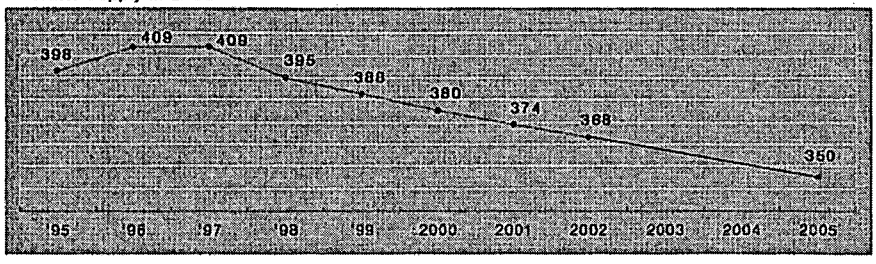
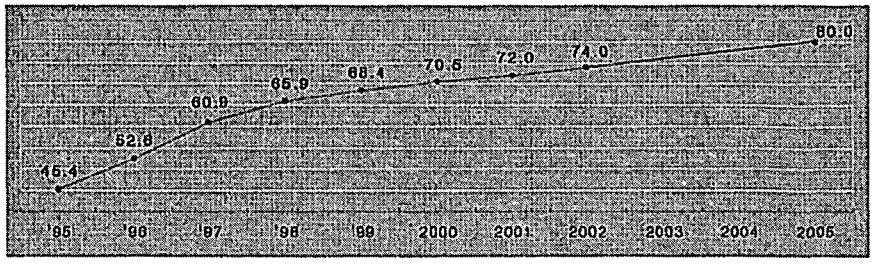
Water Supply in LPCD



Waste Water Treatment



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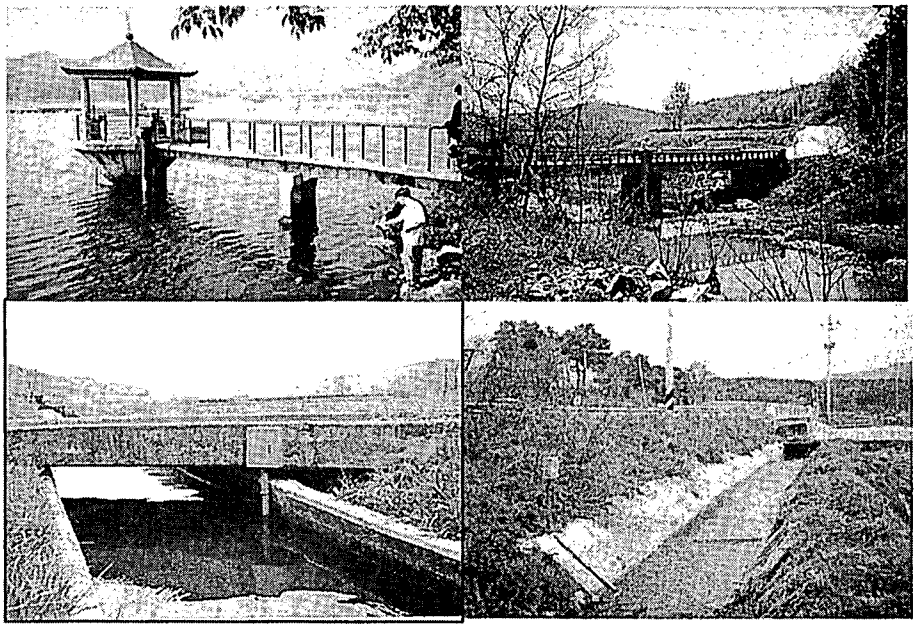
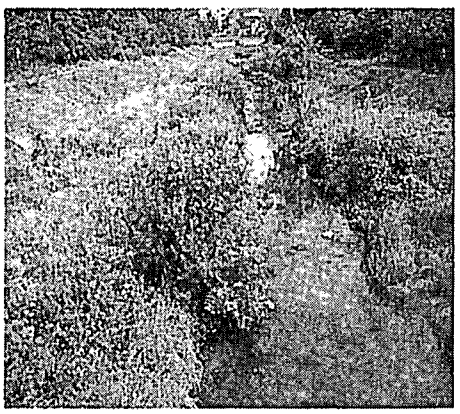


19

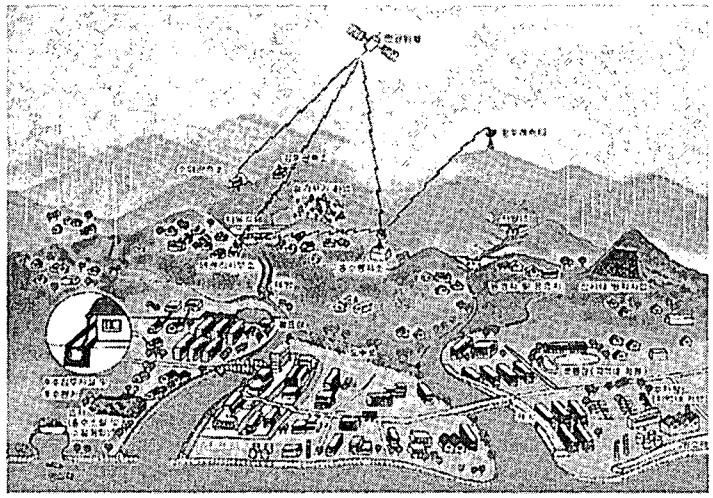
Creation of River Environment in Harmony with Nature



20

Formation of Safe Land against Flood

- **Integrated River Basin Management for Flood Control**



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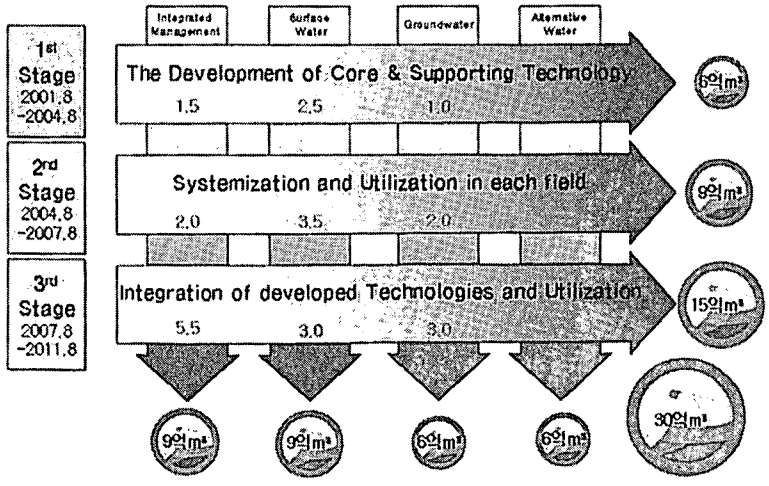
Target Water for Each Stage



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Summary

- Limitations of the water resources policy used in Korea since 1960's are now surfacing.
  - difficulties to make new developments for increasing demand
  - difficulties to improve water environments
  - difficulties to prepare measures for frequent climatic extremes
- Korea's water resource policy has been shifted to new directions
  - demands management for improving water use efficiencies
  - pollutants management for improving water qualities
  - sustainable floods management
- The new direction of water policy is guided by strong R & D program.
  - will secure extra 3 billion cubic meters in 2011 (10% of water use)

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