1998
WATER RESOURCES IN JAPAN

— Global Environmental Problems and Water Resources —

WATER RESOURCES DEPARTMENT
MINISTER'S SECRETARIAT
NATIONAL LAND AGENCY, JAPAN

CONTENTS

Part I Effects of the Global Environment on Water Resources and Efforts Towards Solutions

Preface

As a fundamental constituent of the natural environment, along with soil and air, water supports not only human life, but also a variety of ecological systems. It is also an important national resource, along with land and forests. Under the power of the sun, water in the ocean evaporates, is transformed from cloud into rain and snow that drains through the ground and returns to the ocean via rivers; It is thus a resource that is cyclic, and this is known as the hydrologic cycle. The energy of the sun is harnessed for this hydrologic cycle.

Although we refer to water as a resource, it is only in each process of hydrologic cycle that we use water, as it completes its solar-energized journey. At this time on earth, populations have increased and social and economic activities are increasing too; it is thus impossible to secure even the minimum required volume of water only relying on the hydrologic cycle. We have therefore developed a way of using water as a resource by smoothing out quantitative variations in the hydrologic cycle using reservoirs and similar structures to store water, and making qualitative efforts to improve the properties of the water we store.

Processing water so that it can be used will inevitably involve the use of fossil fuels as long as human efforts are needed to maintain volume and quality. However, since in most cases the natural hydrologic cycle can be made use of, the amount of fossil fuels used is less than it would otherwise be.

Another point is that the various impacts on the global environment from the use of fossil fuels is currently important. It is natural that the result of these impacts on the global environment in turn have an impact on these very water resources in the hydrologic cycle created by solar energy.

"Development that meets the present without compromising the ability of future generations to meet their own needs" is the concept of "Sustainable Development" that was proposed at the "World Commission on Environment and Development" established in 1984 (Chaired by Norwegian Prime Minister Brundtland) and also repeated insistently by Ms. Brundtland at the Rio de Janeiro Conference in 1992. We must keep this principle in mind when handling issues concerning the development and utilization of water resources.

Accordingly, in compiling this white paper, we have directed our attention to global environmental problems, especially to the problems of acid rain and global warming. We have taken the decision to collect, organize, and describe existing knowledge and literature on the current state of development and utilization of water resources as seen from the energy point of view, and future efforts that need to be made in this field. Chapter 1, titled "Water Resources and Global Environmental Problems," describes the effects of changes in the global environment on water resources and current levels of energy consumption in the development and utilization of water resources. Chapter 2 describes energy-saving efforts in the development and utilization of water resources that include efforts being made in the development and utilization of water resources from the viewpoint of the energy consumer, and those being made in such field as hydroelectric power generation from the viewpoint of the energy supplier. Chapter 3 describes the challenges to be addressed, including efforts to reduce energy consumption, and the necessity for technological development to achieve these goals.

Chapter 1 Water Resources and Global Environmental Problems

Interest in changes in the global environment is widening year by year, with an increasing number of international conferences on the global environment being held. A typical recent international conference was the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in June, 1992. The conference adopted Agenda 21 and concluded the United Nations Framework Convention on Climate Change (referred to here as the Framework Convention on Climate Change). Regarding the Framework Convention on Climate Change, the Third Conference of the Parties (COP3) was held in December, 1997, at which the reduction targets for greenhouse gas emissions for the developed countries were decided in the Kyoto Protocol (Target for Japan: 6% reduction over the 1990 level of emissions by the period 2008 to 2012).

We also see international conferences on water resources and the environment held more frequently. The International Conference on Water and the Environment (ICWE) was held in Dublin, Ireland, on January, 1992, at which the Dublin Declaration on Water and Sustainable Development and the Minutes were adopted. In addition to this, Section 18 of Agenda 21, Protection of Quality and Supply of Fresh Water Resources, prescribes the necessity for sustainable development and assessment of effects of climate change on water resources.

In this way, seen from the frequency of the various international conferences being held, global environmental problems are closely connected also with water resources. Therefore, prior to the development and utilization of future water resources, it is necessary to study the relationship between changes in the global environment and water resources as well as the effects of changes in the global environment on the development and utilization of water resources.

1. Changes in the Global Environment and their Effects on Water Resources

(1) Changes in the Global Environment

Typical among the many changes in the global environment that have been taken up as global environmental problems are global warming, desertification, deforestation and the deterioration of forests (especially, tropical rain forests), depletion of the ozone layer, acid rain, decreases in biodiversity, and deterioration in the marine environment.

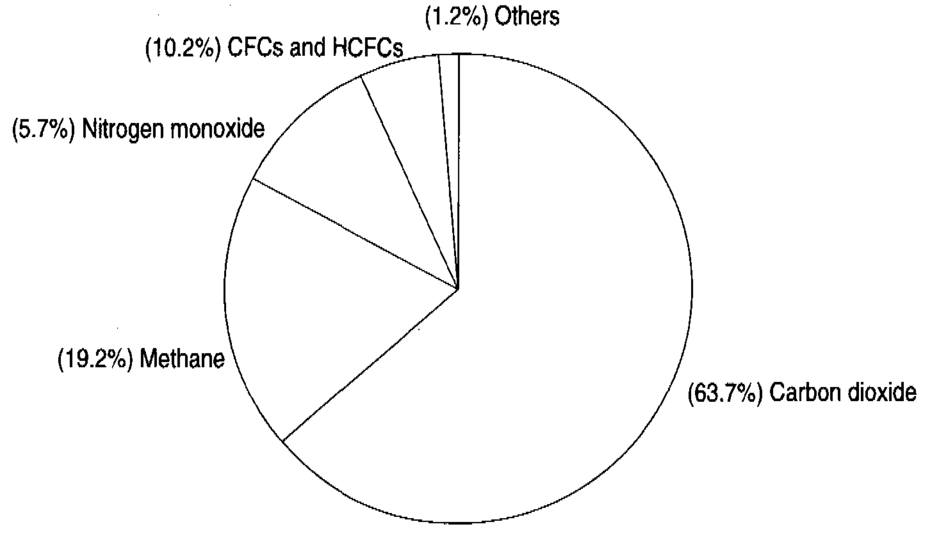
Acid rain is produced by a process in which air pollutants like sulfur oxides and nitrogen oxides resulting mainly from the burning of fossil fuels are turned into sulfate ions and nitrate ions by oxidization in the atmosphere, and these ions are absorbed into rainwater.

Expressed in units of acidity or alkalinity (pH), a value of 7.0 denotes a neutral environment and values lower than this, acidity. However, since carbon dioxide present in the atmosphere dissolves into rainwater, thus usually bringing the pH value of the rainwater to less than 7.0, rainwater with a pH value of up to 5.6 is generally regarded as acid rain.

At present, fog, snow, aerosol or gaseous acid fallout with high acidity are also called acid rain.

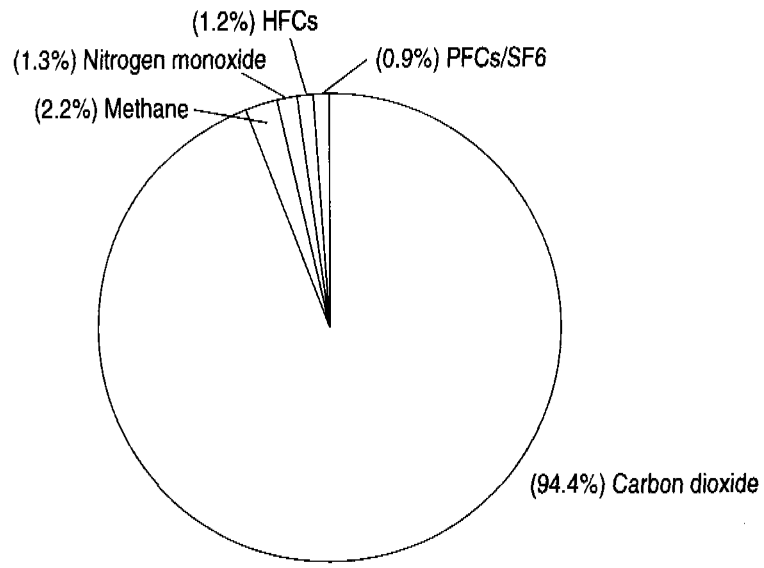
It has been reported that such air pollution is caused not only by pollutants produced in a single country, but also by transboundary pollutants borne by the wind from other countries.

Global warming is attributed to the enhancement of the greenhouse effect due to an increase in the greenhouse gases in the atmosphere. Greenhouse gases exist naturally, but they also are produced artificially, with the volume continuing to increase from the time of the Industrial Revolution. Included among artificially-produced greenhouse gases are carbon dioxide, methane, nitrogen monoxide, and HFCs (hydrofluorocarbons). A global breakdown of the contribution of these artificial greenhouse gases to global warming reveals the highest contribution, about 64%, from carbon dioxide. A national breakdown of the contribution of these gases emitted by Japan shows that carbon dioxide accounted for about 94% of the total contribution in 1993. (Fig.1-1 and Fig.1-2)



Source: White Paper on the Environment

Fig.1-1 Direct Contribution to Global Warming from Greenhouse Gases Emitted from the Start of the Industrial Revolution to 1992



Note: CFCs and HCFCs also are among the greenhouse gases; however, they are excluded from representation because notification of the emitted quantities for these two gases according to the Framework Convention on Climate Change is not obligatory and hence established data on the volume of emission is lacking.
Source: White Paper on the Environment

Fig.1-2 Degree of Direct Contribution to Global Warming from Greenhouse Gases Emitted by Japan (fiscal 1993)

(2) Effects of Acid Rain on Water Resources (Fig.1-3)

The following are typical effects of acid rain on lakes which have been reported overseas:

- Sweden — Of 85,000 lakes with an area of 1 ha and above, 18,000 have become acidified, in about 9,000 of which the habitat of fish has been effected;
- Norway — Acidification of rivers and lakes has caused fish to disappear over an area of 1,300 square kilometers; in addition, the habitats of fish are threatened in an area of 20,000 square kilometers in southern parts of the country.

(Wright, R.F.: Acidification of freshwaters in Europe, Water Quality Bull., 8, 137-142 (1983))

It is thought that acid rain affects forests; cited as possible damage to forests are direct effects from direct rainfall onto leaves and indirect effects from soil acidification. The current blighting of coniferous trees over wide areas of Europe and North America is considered to be due to the composite actions of various factors, such as damage from insects, from the weather, and from air pollution.

No marked effects on lakes and forests in Japan have been reported until now; however, the monitoring study being conducted by the Environment Agency has confirmed the presence of low alkalinity lakes among those that are less affected from man-made pollution. Since some of these low alkalinity lakes are free from man-induced factors in their neighborhood that would affect their acidification, the effects of acid rain cannot be denied.

The Environment Agency uses simulation models to forecast the effects of acid rain.

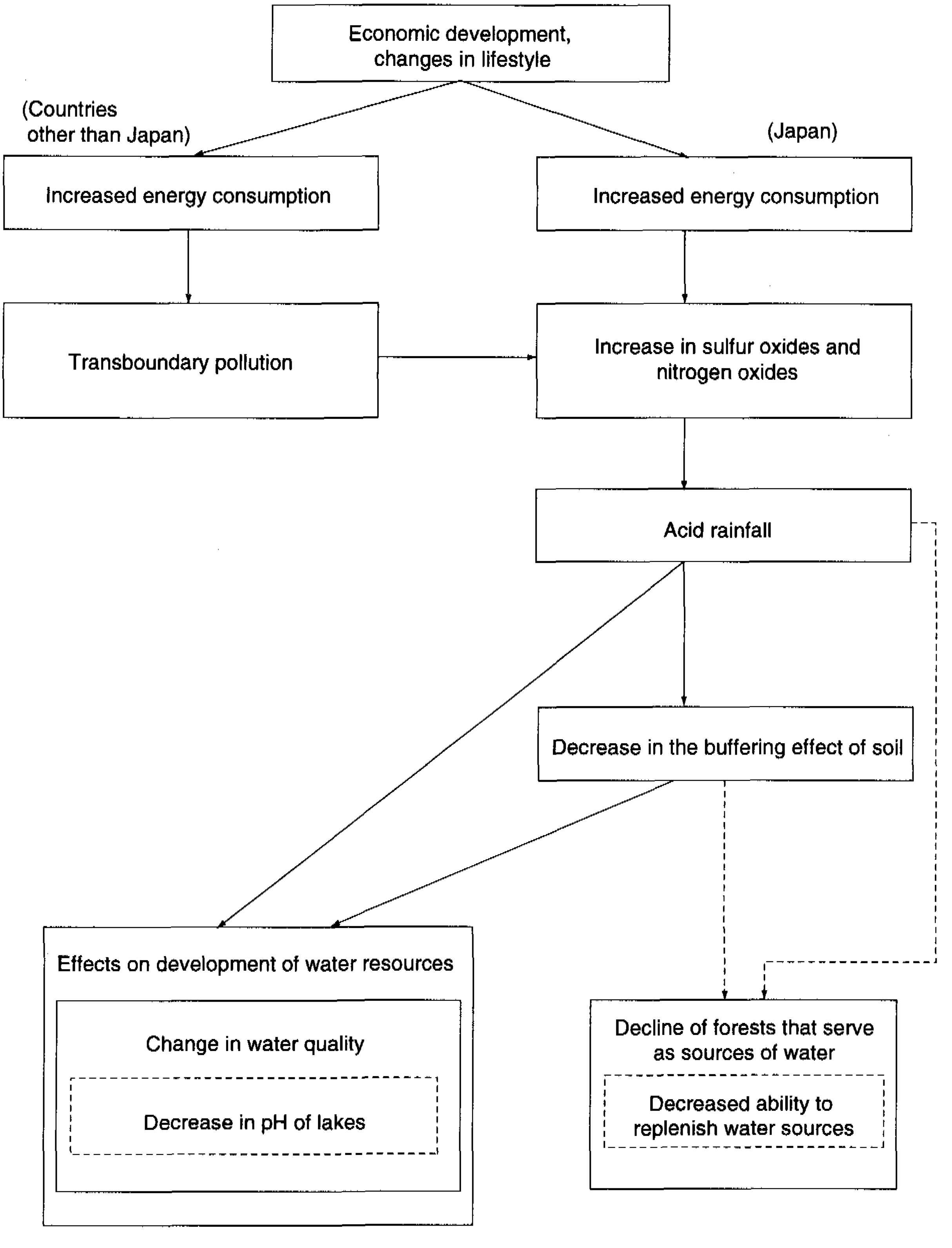


Fig.1-3 Relationship Between Acid Rain and Water Resources

According to this forecast, continuation of current acid rainfall levels will not cause the pH of a lake to fall until neutralizing substances in the soil in the lake's catchment area disappear; within a few years after the disappearance, a sharp decrease in pH occurs, and the lake becomes acidified. Source data from measurements and reference documents differ in the number of years that elapse before acidification begins; however, some predict around 30 years as the shortest period.

Possible effects on water resources are changes in the quality of water in water sources such as lakes and changes in the outflow due to the effect that deforestation has on the recharging of these sources. If the water in a source becomes more and more acidified, the acidity must be neutralized in the water purification process before use.

(3) Effects of Global Warming on Water Resources (Fig.1-4)

a. Effects on water resources

Possible effects exerted by global warming include changes in the air temperature, precipitation, and sea level. From the viewpoint of the effects on potential water resources, changes in precipitation and changes in the total evaporation volumes resulting from changes in the air temperature are thought to be directly linked to global warming.

By using simulation models, different research organizations are currently analyzing how large the effects on air temperature and precipitation are. However, the results obtained from these models are widely dispersed in the degree to which they show an effect on the air temperature and precipitation, and there is much left to do to achieve a satisfactory assessment. Although the data obtained in this way is not sufficient, the Working Group for Assessing the Effects of Global Warming, established by the Environment Agency, used the data to estimate changes in the air temperature and precipitation in the neighborhood of Japan for the hypothetical case where the concentration of carbon dioxide is doubled; according to the estimate based on annual averages, the air temperature would rise about 1 to 2.5 degrees C and the precipitation would change approximately from - 5 to +10%. (Fig.1-5)

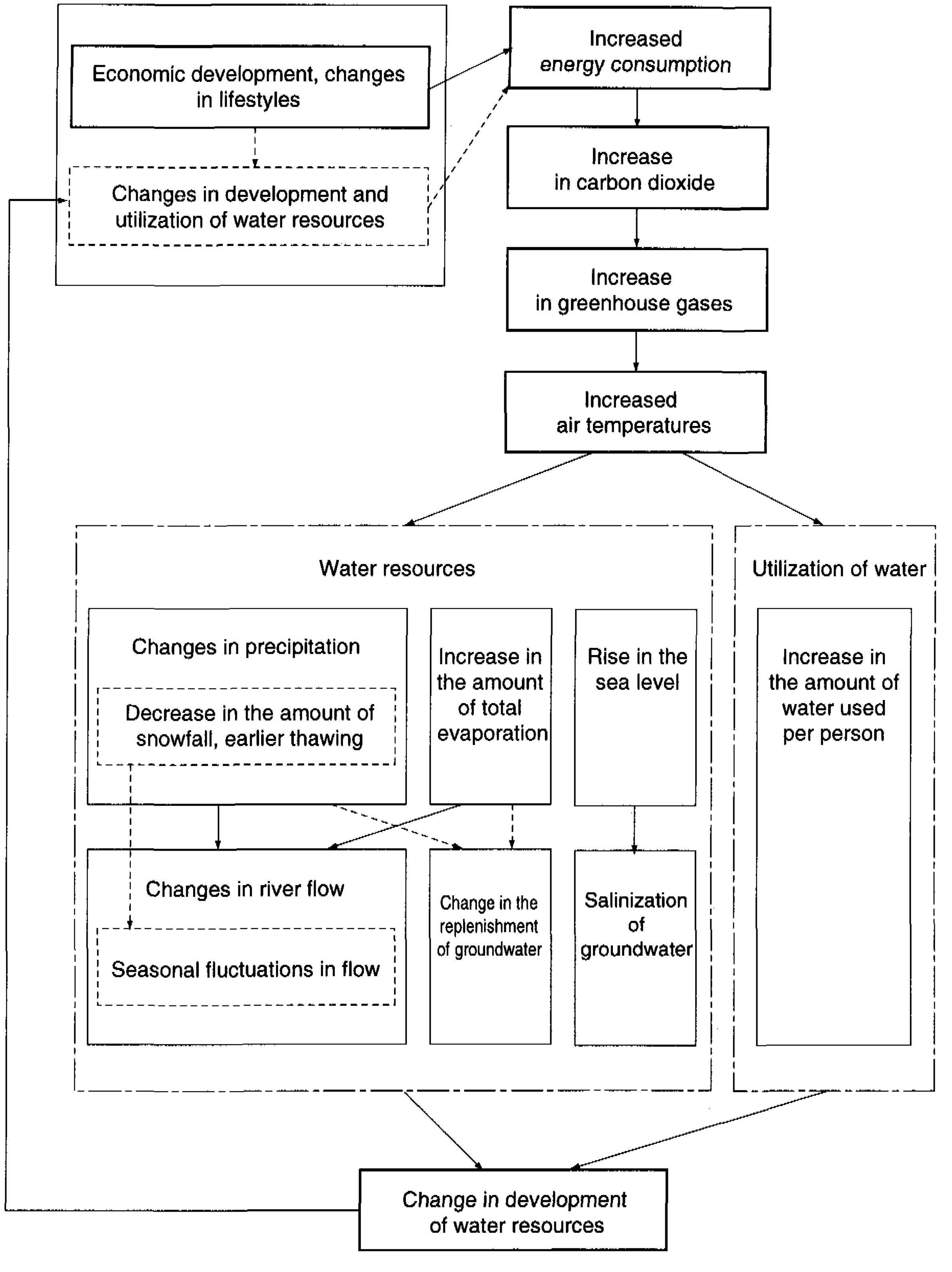
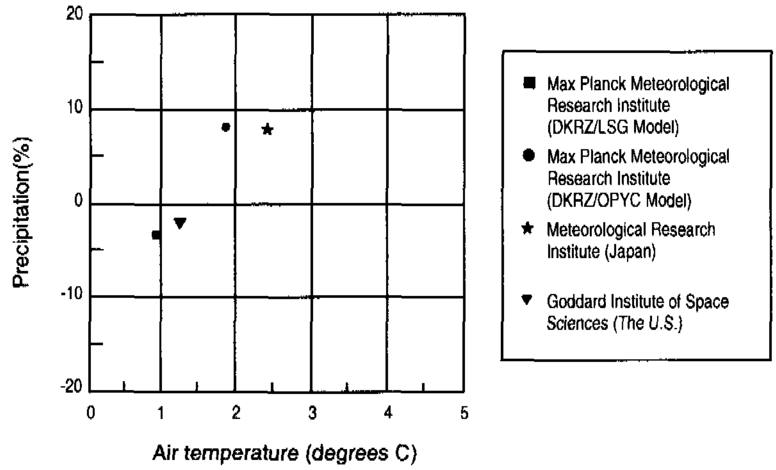


Fig.1-4 Relationship Between Global Warming and Water Resources



Note: Based on "Effects of Global Warming on Japan 1996" by Environment Agency Global Warming Problems Study Meeting

Fig.1-5 Changes in Annual Average Air Temperatures and Precipitation Averaged Regionally Around Japan for the Case Where the Carbon Dioxide Concentration Doubles

Predictions of the magnitude of the effects of the increase in the total evaporation due to a rise in the air temperature have been made; for example, the Ministry of Construction's Public Works Research Institute predicts an increase of 9 to 57 mm in the possible annual total evaporation for a rise in the air temperature of 2 to 4 degrees C.

These predictions allow us to anticipate changes in the potential water resources due to the effects of the global warming. In development of river water, the effects of global warming manifests itself in the form of an increase in the river flow linked to an increase in precipitation and in the form of a decrease in the river flow linked to a decrease in precipitation or an increase in total evaporation. For example, based on the results of Japanese research, the Working Group for Assessing the Effects of Global Warming has reached the following conclusion on the effects on river flow:

- Even with a rise in the air temperature of about 3 degrees C, an increase in precipitation of 10% will, on average, not cause the low-water flow (this refers here to the cumulative flow up to the day of the 100th smallest flow) to decrease significantly, but will cause the high-water flow (this refers here to the cumulative flow up to the day of the 50th largest flow) to increase by about 15%. However, when the total evaporation or thawing predominates, the high-water flow may decrease even with an increase of 10% in precipitation.

Examining seasonal and regional changes also reveals changes in the snow accumulation/precipitation ratio and an advancing in the thawing time caused by global warming. For example, according to an estimate made in Hokkaido by the Hokkaido Development Agency's Public Works Research Institute, when the concentration of carbon dioxide in the atmosphere is doubled, the snow accumulation will be roughly halved, with the thawing beginning about 2 months earlier and ending about 2 to 3 months earlier. Should the flow in the months from April to June decrease, restrictions could be imposed on water intake depending on the situation; the effect could be all the more serious because a large volume of water is needed for agriculture in this period.

Cited as possible effects on groundwater are effects on the amount of groundwater replenishment due to changes in potential water resources and effects on the groundwater due to salinization from a rise in the sea level. Regarding the effect of global warming on the sea level, the model created by the Meteorological Agency's Meteorological Research Institute predicts that, with the contribution from glaciers, ice caps, and ice mantles excluded, the sea level will rise 10 cm to 20 cm on the Sea of Japan coast and 15 cm along the Pacific Ocean and Sea of Okhotsk in 66 to 75 years, when the concentration of carbon dioxide in the atmosphere is expected to double. The Intergovernmental Panel on Climate Change (IPCC) predicts that the contribution from glaciers, ice caps, and ice mantles will be a rise in the sea level of from 11 to 22 cm. It is necessary to consider this contribution when a rise in the sea level with all contributions taken into consideration is to be discussed.

b. Effect on utilization of water

A major effect of global warming in connection with the utilization of water is an increase in demand for water for domestic/business use due to a rise in air temperatures, because the water demand depends generally on the weather. For example, the Ministry of Construction's Public Works Research Institute selected 3 cities, Asahikawa City in Hokkaido, Nagoya City in Aichi Prefecture, and Naha City in Okinawa Prefecture, to estimate the increase in water demand for a scenario in which the average air temperature had risen 1 to 3 degrees C; the results showed that the water demand would rise in the range of 1.2 to 3.2% for a 3 degrees C rise.

A 2% increase in the water demand would require an addition of 340 million m^3 of domestic/business water (taking the 1995 water intake volume as base), which amounts to the volume of water supplied for the public water supply by 14 average-sized dams.

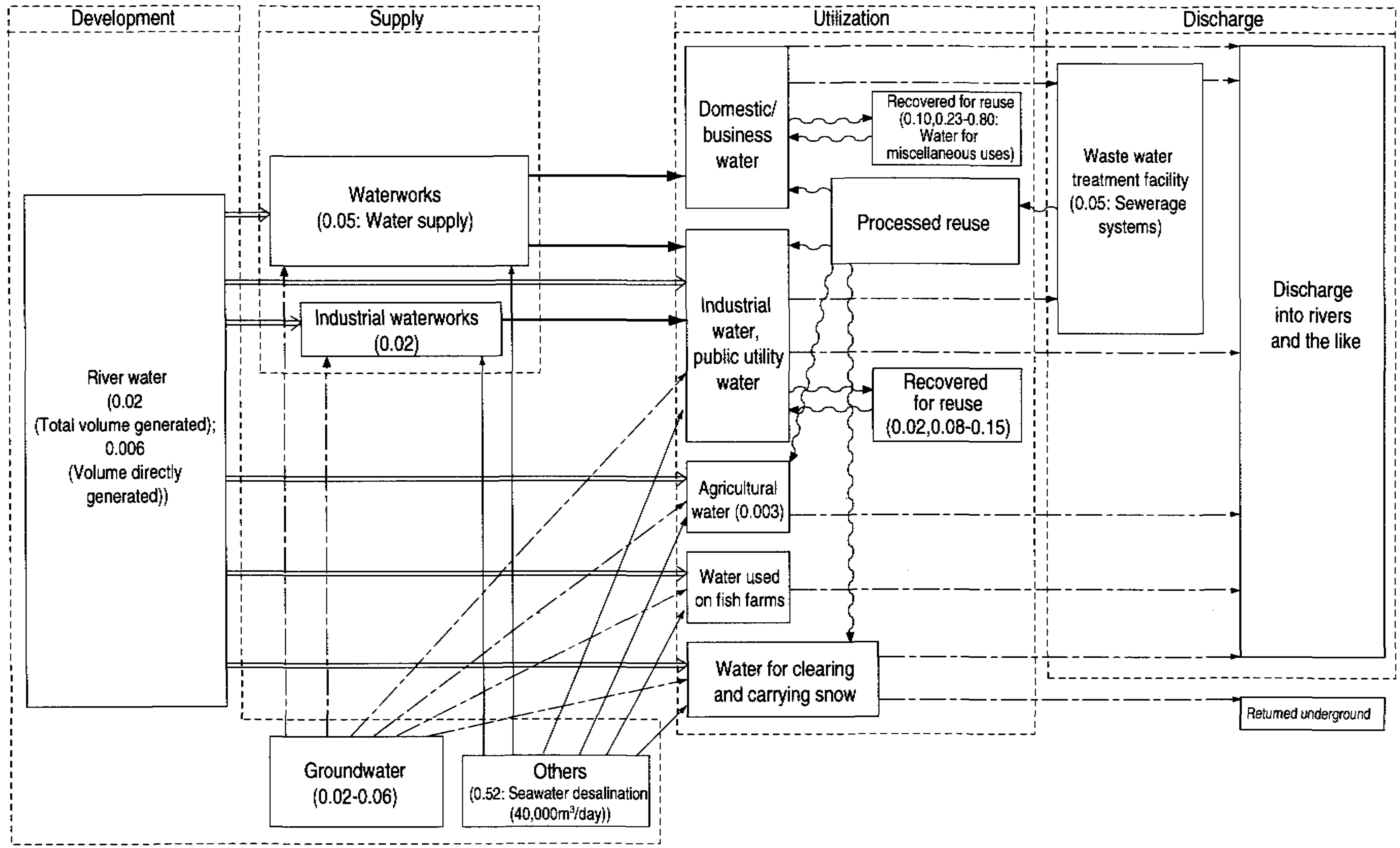
(The volume of water output to the public water supply per dam was calculated from the ratio of the volume of water output by public water supply dams (including multi-purpose dams)/the number of public water supply dams; data is cited from the Dam Yearbook. 1998 version)

2. Current Levels of Energy Consumed for the Development and Utilization of Water Resources

As has been outlined here, changes in the global environment, especially in acid rain levels and global warming, are expected to greatly affect the development and utilization of water resources. Acid rain is said to result from air pollutants such as sulfur oxides and nitrogen oxides produced by burning fossil fuels, while most greenhouse gases, the cause of global warming, originate in carbon dioxide produced by the burning of fossil fuels. Therefore, minimizing the adverse effects of acid rain and global warming on the development and utilization of water resources necessitates energy-saving activities.

On the other hand, since the development and utilization of water resources naturally consume energy in their processes, they contribute, either directly or indirectly, to sources generating carbon dioxide and the like. (Fig.1-6)

However, since water uses solar energy in completing its natural hydrologic cycle, the development and utilization of water resources have many advantages for energy consumption over other resources, especially in the following points: the development and utilization of water resources make use of part of these circulating resources, and can make use of the potential energy between the upper and the lower reaches of rivers.



Note: Figures in the parentheses denote quantities of carbon dioxide generated per m³ (kgC); they cannot be simply compared because they are calculated by different methods and on different assumptions (the calculation methods are described in the text).

Fig.1-6 Flow Representing from the Development of Water Resources to the Discharge of Waste Water

(1) Current Energy Consumption at the Water Resources Development Stage

a. Dams

Development of water resources using dams is characterized by large energy consumption at the construction stage and very small energy consumption at the water management stage. This characteristic results from use of a method that makes effective use of the potential energy difference between the water stored in the upper reaches of a river and its use in the lower reaches.

In the trial calculation, industry correlation tables and similar references were used to calculate, on the basis of construction costs, the volume of carbon dioxide directly and indirectly produced by the whole of society as well as the volume of carbon dioxide produced by the electric power needed for dam operation, and both quantities were added and divided by the volume of water to be developed during the service life of the dam.

The result of the trial calculation shows that the volume of carbon dioxide per m^3 of developed water (equivalent volume of carbon; the same expression is used in the following) for 5 recently constructed dams is about 0.02 kgC. (Table 1-1) For reference, we took the net volumes of energy and concrete used for the dam body construction out of the total quantities used for the dam construction project for trial calculation, obtaining a result of about 0.006 kgC/m^3.

Table 1-1 CO_2 Produced by Development of Water Resources Using Dams

Dam features		Data			Cumulative volume		CO_2 produced in dam operatin (10^6kgC)	Volume of CO_2 per unit water volume developed (kgC/m^3)
Height m	Type	Volume of dam (10,000 m^3)	Planned service life (Year)	Water volume developed (100 million m^3)	Construction stage (10^6kgC)	Concrete used for the body of dam (10^6kgC)		
155	Gravity dam	175	100	107.8	15.3	50.3	4.7	0.0065
111	Gravity dam	51	100	52.6	7.7	19.1	4.7	0.0060
70	Gravity dam	67	100	97.2	9.6	24.3	4.7	0.0040
70	Gravity dam	43	100	39.4	4.0	16.6	4.7	0.0064
Average					9.1	27.6		0.0057

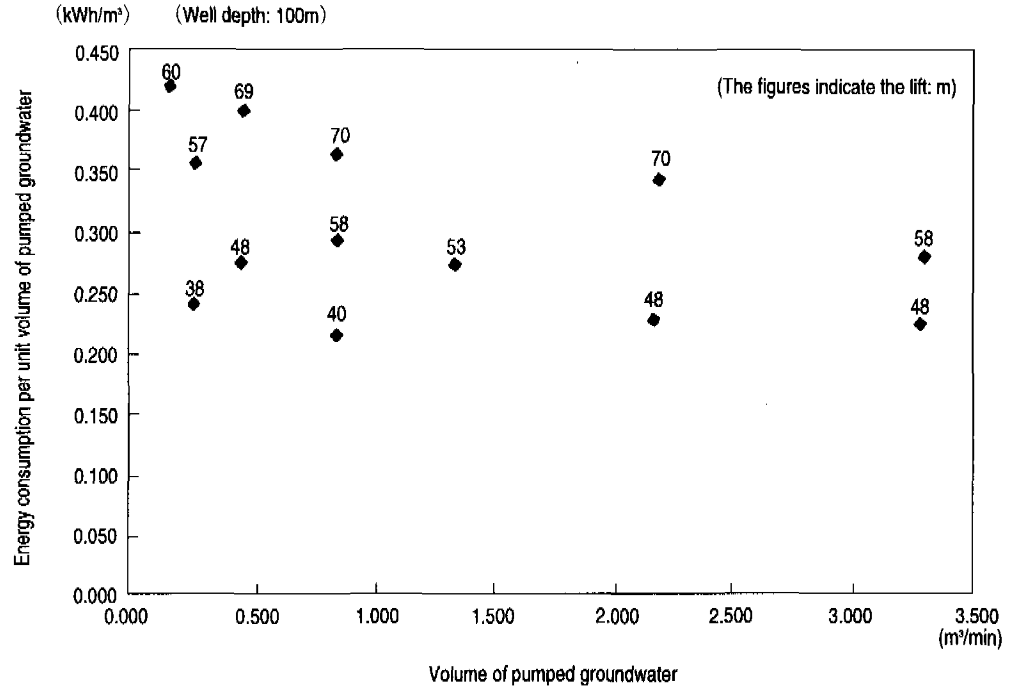
Dam features		Volume of dam (10,000 m^3)	Planned service life (Year)	Water volume developed (100 million m^3)	CO_2 from the industry correlation tables (10^6kgC)	CO_2 produced in dam operation (10^6kgC)	Volume of CO_2 per unit water volume developed (kgC/m^3)
Height m	Type						
140	Rock-fill dam	890	100	113.0	195.5	4.7	0.0177
155	Gravity dam	175	100	107.8	197.2	4.7	0.0187
111	Gravity dam	51	100	52.6	179.1	4.7	0.0350
70	Gravity dam	67	100	97.2	192.4	4.7	0.0203
70	Gravity dam	43	100	39.4	101.6	4.7	0.0270
Average							0.0237

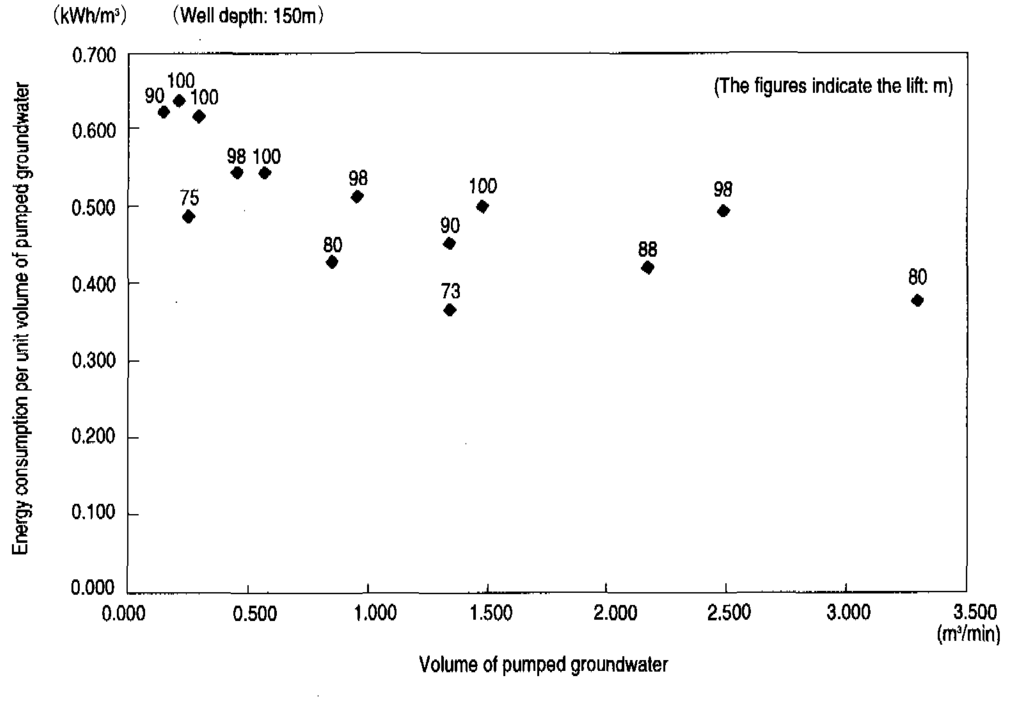
Note: The volume of CO_2 produced in dam operation is calculated per office.

b. Groundwater

Groundwater is usually easy to draw and inexpensive. Since individual users can sink wells to draw water directly, the utilization of groundwater differs greatly depending on the local geology, potential groundwater resources, scale of the well, and the purpose of utilization. For this reason, the overall energy consumption accompanying the utilization of groundwater cannot be assessed in a wholesale manner; however, a rough trial calculation gives the following result.

In utilizing groundwater, energy is consumed mainly by the construction work of sinking the well and the pumping; the former requires fuel to power the equipment to drill the well and the latter requires electricity to pump up the groundwater. Using the data for JIS-specified deep well submersible motors which have an assumed service life of 7 years, the energy consumption per unit volume of pumped water was roughly calculated at a trial basis for 2 well depths; 100 m and 150 m. The results showed that the energy consumption is about 0.2 to 0.4 kWh/m^3 for a well depth of 100 m, and about 0.4 to 0.6 kWh/m^3 for a well depth of 150 m. (Fig.1-7) Of the total energy consumed, the energy required for digging a well is about 1 percent, with most of the rest consumed for pumping. The electrical energy converted into the volume of carbon dioxide produced (calculated on the assumption that carbon dioxide of 0.0977 kgC develops for 1 kWh of energy power) is about 0.02 to 0.06 kgC/m^3 per unit volume of pumped water.





Note: Trial calculations made by the National Land Agency were based on data from "Materials Regarding Standard Production Rates in Well Drilling Work," published by the Japan National Well Drilling Association and "JIS Handbook on Pumps," published by the Japanese Standards Association.

Fig.1-7 Energy Consumption per Unit Volume of Pumped Groundwater

c. Seawater desalination

Seawater desalination technology is used to remove the salt contents from seawater and turn it into fresh water. This technology is used not only for seawater but also for groundwater containing salt and mineral ions to remove the impurities.

Widely-used and commercialized desalination methods are the evaporation, reverse osmosis, and electrodialysis methods. Generally speaking, the reverse osmosis method consumes the least energy for desalination. The actual energy consumption by the reverse osmosis method depends on the scale of the desalination facility and other factors. For example, Japan's largest seawater desalination facility in Okinawa Prefecture with a capacity of 40,000 m^3/day has a track record of electricity consumption per unit volume of desalinated water of about 5.3 kWh/m^3; however, most desalination facilities are small in scale and hence their electricity consumption per unit volume of desalinated water is estimated to be larger than the value cited above.

Desalination facilities are often used not only in isolated islands where water resources are scarce, but also in emergency during the dry season. The volume of carbon dioxide produced for desalination is 0.52 kgC/m^3, calculated on the assumption that the electrical energy used for desalination is 5.3 kWh/m^3 (not including the electrical energy used for the construction of desalination facilities). For reference, the investigation made by the National Land Agency in 1997 shows that the volume of water desalinated by desalination facilities connected with water supply services in fiscal 1996 was 3.58 million m^3 (3.94 million m^3 in fiscal 1995).

(2) Current Energy Consumption at the Water Supply Stage

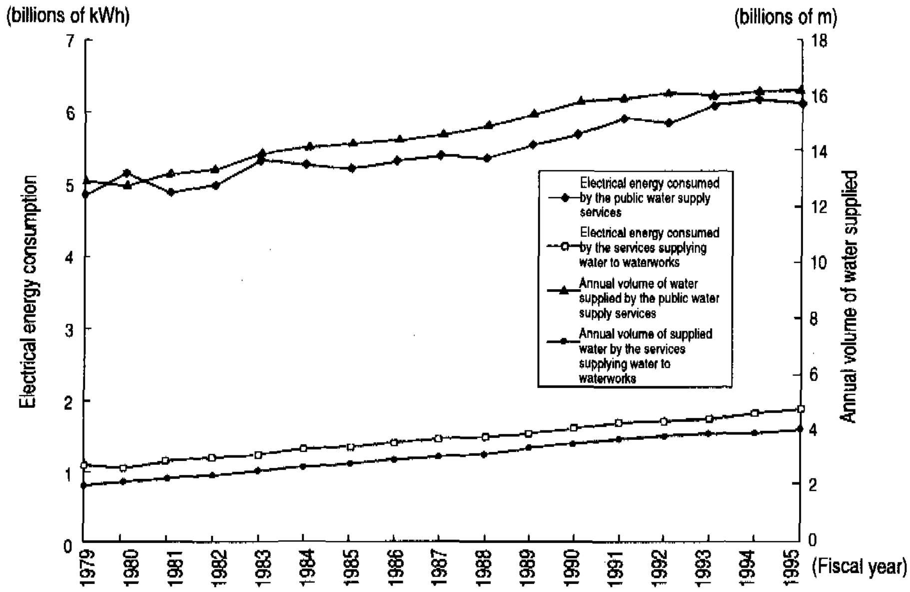
a. Water supply services

① Current energy levels consumed by the water supply services

Energy consumption by water supply services is looked at mainly in terms of electrical energy, because complete statistics for electrical energy consumed by water supply services are available.

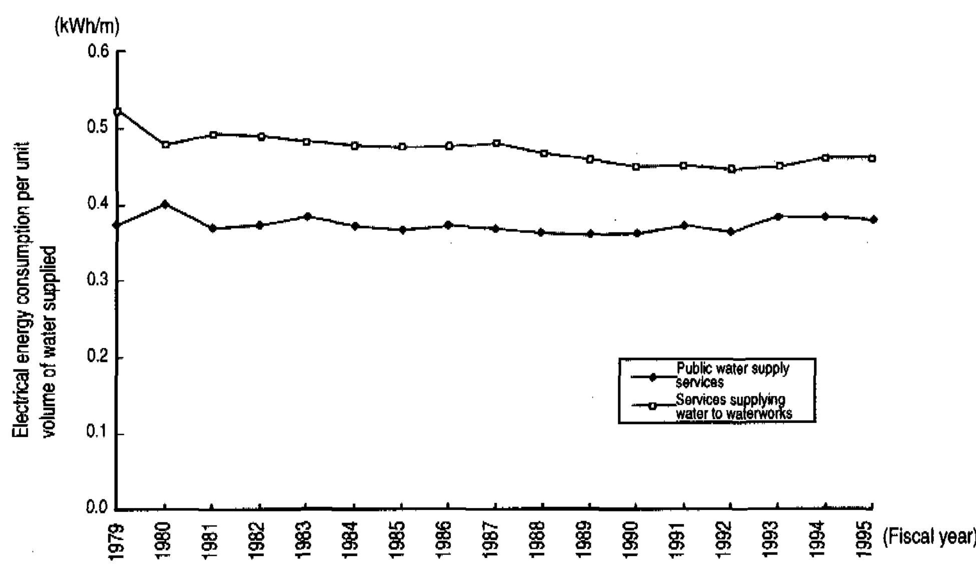
The electrical energy consumed in fiscal 1995 (including energy used for pumping groundwater and seawater desalination) was about 7.9 billion kWh for public water supply services and services supplying water to waterworks. This amounts to about 0.9 % of the total nationwide electrical energy consumption of 881.6 billion kWh, with the volume of produced carbon dioxide equivalent to 772,000 tC.

Fig.1-8 shows the trend in electrical energy consumption, which increases with the volume of supplied water. The electrical energy consumed per unit volume of supplied water is shown in Fig.1-9, with the electrical energy consumption by the public water supply services remaining almost flat compared to that in fiscal 1979 and consumption by the services supplying waterworks tending to decrease. The possible reason for this trend is that the general rationalization achieved in the water supply services has resulted in a decrease in the electrical energy consumption, while the increase in the electrical energy consumed by the expansion of the water distribution areas served by the public water supply services cancels out the decrease due to rationalization; the electrical energy consumption has not decreased as much as for the services supplying water to waterworks. The combined electrical energy consumption for the public water supply services and services supplying water to waterworks is converted into about 0.05 kgC/m³ of volume of carbon dioxide produced.



Note: Based on "Water Supply Statistics" by the Ministry of Health and Welfare.

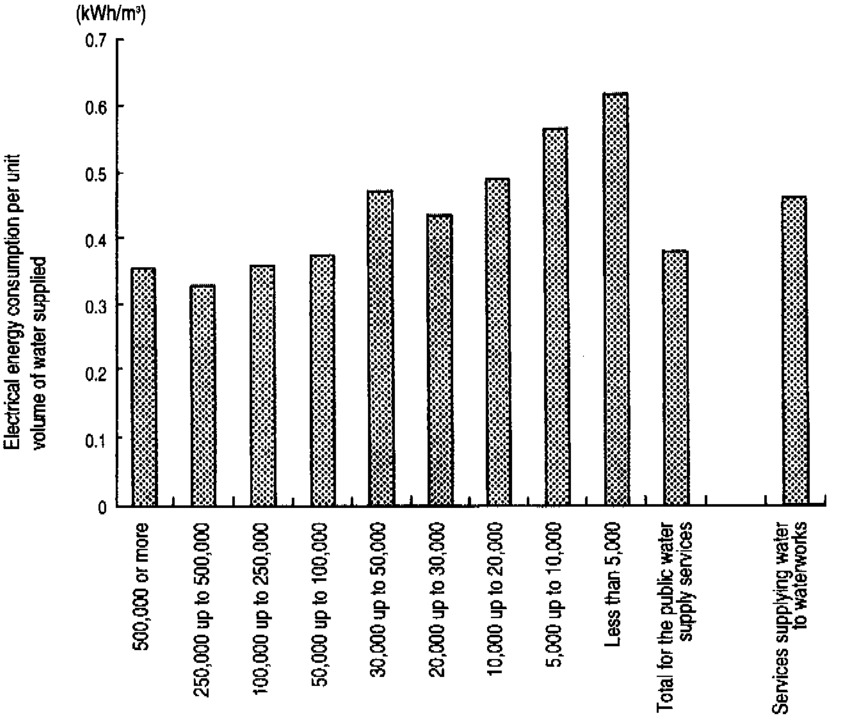
Fig.1-8 Trends in Electrical Energy Used in Water Supply Services



Note: Based on "Water Supply Statistics" by the Ministry of Health and Welfare.

Fig.1-9 Trends in Electrical Energy Used per Unit Volume of Water Supplied by Water Supply Services

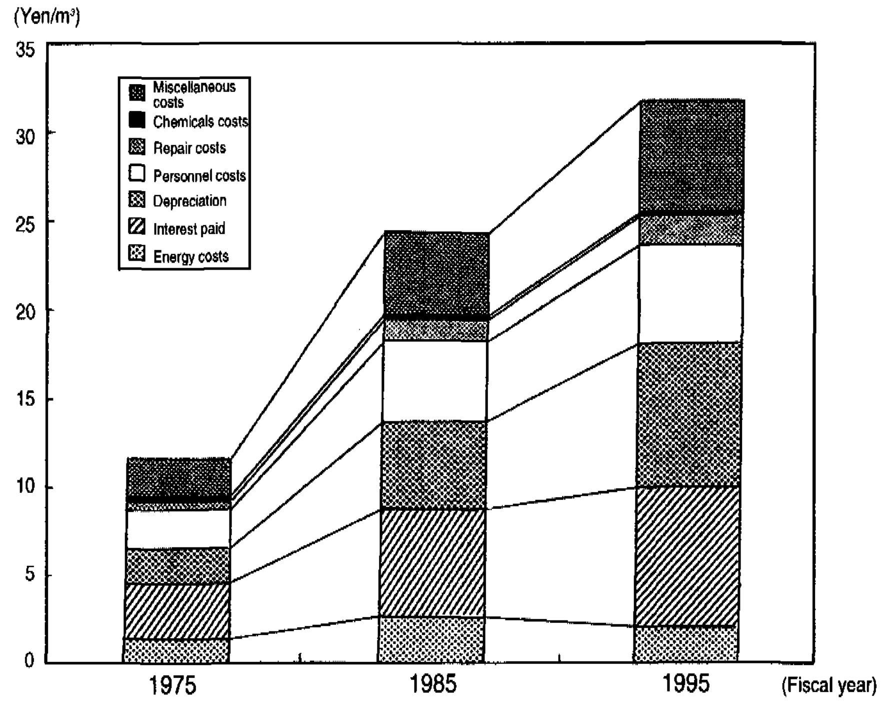
Fig.1-10 shows the electrical energy consumption per unit volume of water supplied by the public water supply by population category. The figure shows that the efficiency rises generally as the scale becomes larger, with the electrical energy consumption per unit volume of water supplied tending to decrease.



Note: Based on "Water Supply Statistics" by the Ministry of Health and Welfare.

Fig.1-10 Electrical Energy Used per Unit Volume of Water Supplied by Water Supply Services (by population category)

For industrial waterworks, most of the energy consumed is electrical energy. The trend in the proportion that the electric power cost forms of the water supply cost (Fig.1-11) shows that the proportion that the electric power cost forms of the total costs changed from 1.4 yen/m^3 (11.8 % of the total costs) in 1975 to 2.7 yen/m^3 (10.9 %) in 1985 and decreased to 2.1 yen/m^3 in 1995 (6.6 %).



Note: Based on "Local Public Enterprise Yearbook" by the Ministry of Home Affairs.

Fig.1-11 Trends in Water Supply Costs for Industrial Water Supply Services

The electrical energy consumption per unit volume of water supplied by industrial waterworks was calculated in the conventional manner on the assumption that the details of the electricity rate and energy charges are the same as those for services supplying water to waterworks; the result was 0.170 kWh/m³, with the volume of carbon dioxide produced per unit volume of supplied water amounting to 0.02 kgC/m³.

② Effect of deterioration of source water quality on energy consumption

The water supplied must be of adequate quality for the purpose. For this reason, the worse the water quality becomes, the more treatment steps are necessary to purify the water properly.

The amounts of energy required for individual secondary treatment are given in Fig.1-12, taken from a survey on the energy used independently by secondary purification facilities connected with waterworks conducted by questionnaire. The figure shows that the energy required per m³ of treated water is 0.01 to 0.1 kWh for granular activated carbon treatment, 0.03 to 0.06 kWh for ozone treatment, and 0.001 to 0.11 kWh for biological treatment. In other words, secondary treatment requires about 0.3 to 22 % more energy than ordinary purification does. In addition, among the purification plants surveyed, the plant requiring the greatest energy consumption for secondary treatment per unit volume of treated water consumed about 0.2 kWh/m³ of electrical energy for granular activated carbon treatment and biological treatment. Converted into volumes of carbon dioxide produced, this amounts to 0.02 kgC/m³, equal to about 40 % of the CO_2 emitted by the ordinary purification and distribution processes.

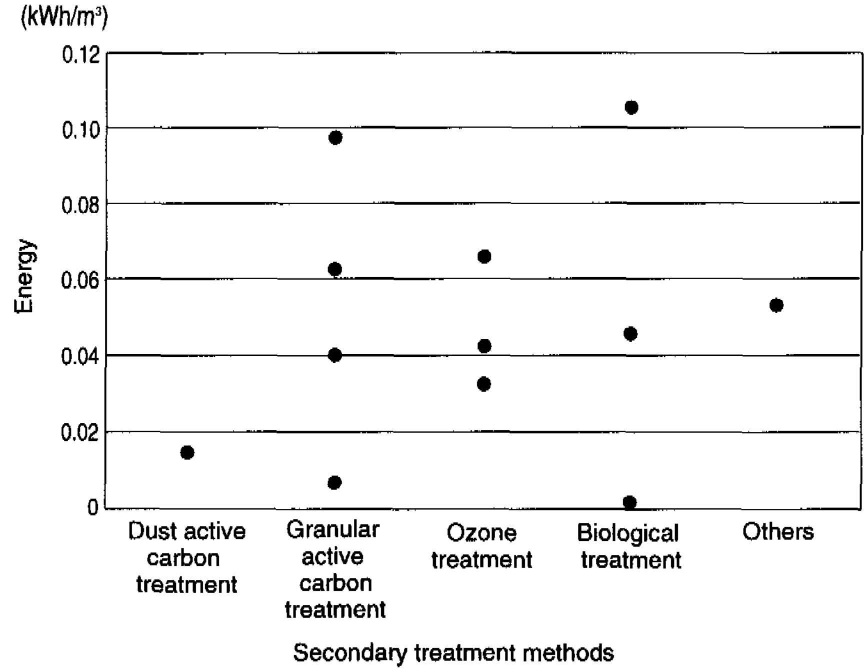
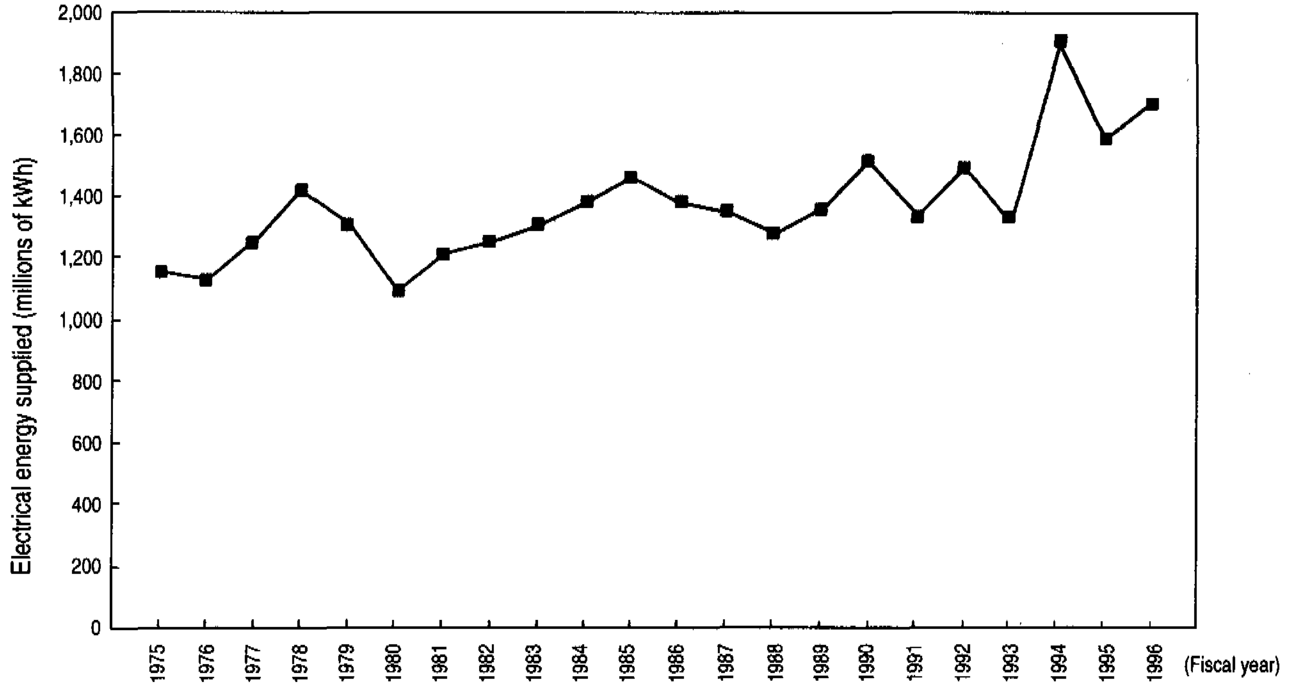


Fig.1-12 Secondary Treatment and Energy Required

b. Agricultural water

Agricultural water storage facilities are primarily of the gravity flow irrigation type that consume less energy. Currently, agricultural water facilities are being expanded and related information, communications, and control facilities are being updated in order to address the increase in demand due to changes in the farm management systems, as well as stronger requests from society for stable water supplies and efficient use of water resources. As a result, farms have taken the lead in putting into practice the effective use of water, and the management and control of wide area water systems. However, irrigation using pumps is adopted where the cost-effectiveness of installing facilities is lower for the gravity flow method than for pumps, or where the elevation of the area to be irrigated precludes any possibility of adopting the gravity flow method; therefore, the energy consumption resulting from operating these facilities is thought to have increased.

The electrical energy supplied to irrigation facilities throughout the country, which include various valves, gates, and pumps at dams, head works, and pumping and discharge stations, as well as information, communications, and control facilities that control these flow control devices, was about 1.16 billion kWh in fiscal 1975, while in fiscal 1996 it was about 1.75 billion kWh, an increase of about 1.5 times. This amounts to about 0.2 % of the total electrical energy consumption nationwide of about 903.5 billion kWh in 1996, with a corresponding volume of carbon dioxide produced per unit volume of consumed electricity of 0.003 kgC/m^3.



Note: The figures on electrical energy supplied for discharging irrigation water were compiled by the Agricultural Electrification Association.

Fig.1-13 Trends in Electrical Energy Supplied for Discharging Irrigation Water

(3) Current Energy Consumption at the Water Utilization Stage

a. Reuse of sewage water and industrial waste water

Before industrial waste water and domestic waste water such as sewage water can be reused, energy is required to treat the waste water. Biological treatment, membrane treatment, and combined biological and membrane treatment are the main treatment methods used. When a higher quality of treated water is required, treatment by activated carbon or ozone treatment is added. The energy required for this water treatment depends largely on the flow of treatment, volume of water to be treated, and the required water quality. In the treatment of water for miscellaneous uses, the quality of the original water and the volume of water to be treated make the energy consumption per unit volume of water larger than the energy consumption required by a similar treatment system for the public water supply. (Table 1-2) Treatment of rainwater consists mainly of the removal of earth and sand in sand basins and strainers, which requires less energy.

Table 1-2 Energy Consumed in Miscellaneous Uses of Water

Method	Treatment capacity (m^3/day)	Volume of carbon dioxide produced by electrical energy consumption (kgC/m^3)
Individual cycling method	30-500	0.38-0.80
Community cycling method	1,700-5,000	0.23-0.57
Wide area cycling method	5,000-15,000	0.10

Note: Examples of model calculation performed by the National Land Agency and Tokyo Metropolis.

b. Recovery of industrial water

Recovering industrial water also requires energy including electrical energy. Except when used as a measure against to deal with groundwater problems, the recovery method is generally used when the combined costs for discharging waste water into rivers and for supplying fresh water from an industrial waterworks system are higher than those for recovery of waste water.

Therefore, recovery is thought to be feasible for cooling water and air conditioning water, for which the water quality before discharging is not much different from that before use. The electrical energy consumption for recovery depends on the equipment used. For example, recirculating water through cooling towers requires an electrical energy consumption of about 0.2 kWh/m^3, which amounts to a volume of produced carbon dioxide of about 0.02 kgC/m^3.

For product processing and for cleaning water where the difference between the quality of water before discharge and that before use often exceeds a certain predetermined level, whether water can be effectively recovered for reuse depends on cost feasibility studies on the electrical energy consumption for recovering water of a sufficient quality from the waste water in question. Various references have presented trial calculations on the cost of the electrical energy required to recover and reuse product processing water and cleaning water. Table 1-3 shows some examples from the trial calculations; some cases in which recovery is actually used give electrical energy consumptions in the range from 0.8 to 1.5 kWh/m^3. This amounts to a volume of produced carbon dioxide of about 0.08 to 0.15 kgC/m^3.

Table 1-3 Trial Calculation of Costs for Electrical Energy Used for Recovery and Reuse of Water Used for Treating and Cleaning Products

Assumptions for recovery and reuse	Total costs (Yen)	Electrical energy consumption as a proportion of the total costs (kWh/m^3)	Source
Reuse of waste water in a synthetic fabric dying factory (trial calculation based on a water consumption of 5,000 m^3/day)	84	0.8	Zousui Gijutu (Water Making Technology) Vol.6, No.1 (1980)
Reuse of water used for product processing and cleaning for the same purpose in a toilet paper factory (trial calculation based on a water consumption of 1,000 m^3/day)	67	0.3	Zousui Gijutu (Water Making Technology) Vol.9, No.2 (1983)
Reuse of waste water in a used paper pulp factory (trial calculation based on a water consumption of 5,000 m^3/day)	111	0.4	Zousui Gijutu (Water Making Technology) Vol.18, No.1 (1992)
Reuse of waste water in a used paper pulp factory (trial calculation based on a water consumption of 1,000 m^3 /day)	235	0.3	
Costs for desalination treatment after sand filtration of waste water in a glass factory (actual costs based on a water consumption of 432 m^3/day)	34	1.0	Zousui Gijutu (Water Making Technology) Vol.10, No.2 (1984)
Reuse of water used for cleaning for the same purpose in a small-sized air-conditioner factory (actual values)	192	1.4	Zousui Gijutu (Water Making Technology) Vol.3, No.3 (1977)
Reuse of domestic waste water for cooling water and cleaning water in a shipyard (actual values)	154	0.8	Zousui Gijutu (Water Making Technology) Vol.3, No.1 (1977)
	259	1.5	
Reuse of individual processed water in a factory with a capacity of at least 100 m^3/day (rough values based on a water consumption of 3,591 m^3/day)	63	0.6	Zousui Gijutu (Water Making Technology) Vol.4, No.2 (1978)
Reuse of processed water from batch processes in a factory with a capacity of more than 50 m^3/day (rough values based on a water consumption of 5,365 m^3/day)	85	0.7	

Notes: 1. Values for the total costs and electrical energy consumption were valid at the time when the trial calculations were made and are different from current values.
2. Values described as "trial" or "rough" are based on trial calculations or rough calculations, and are not taken from cases where reuse methods were actually introduced.

In areas where measures to resolve problems with groundwater and shortages of water exist, or where restrictions on waste water are enforced, recovery is accepted as inevitable regardless of the costs. (Refer to Water Resource Topic 2)

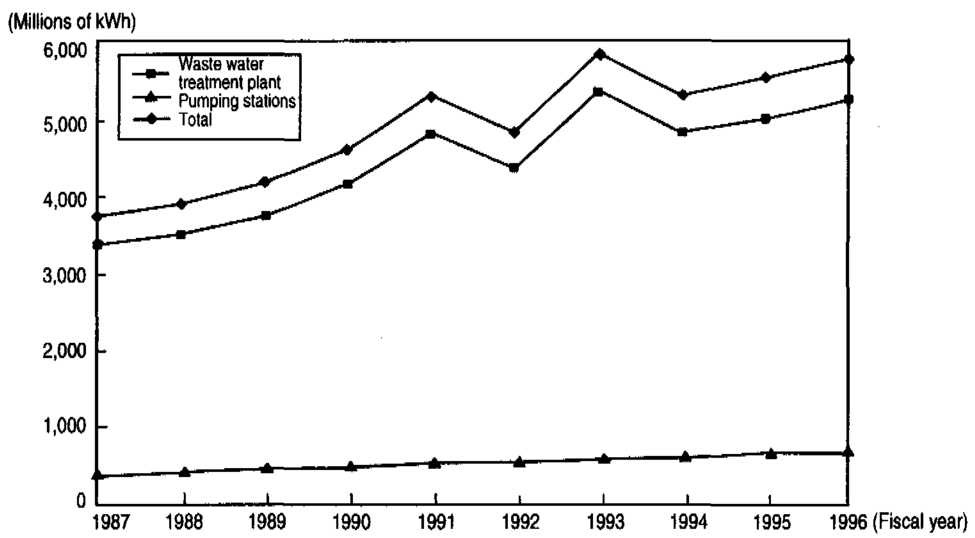
Although it is difficult to analyze costs that include electrical energy consumption for the recovery of industrial water on a nationwide basis, the percentage of recovered water in industrial water in 1995 accounts for 77.2 % of fresh industrial water consumption (About 41.7 billion m^3 used by enterprises employing 30 or more persons). Therefore, energy must have been used for recovering this volume of water.

(4) Current Energy Consumption at the Water Discharge Stage

Water used as domestic/business or industrial water is discharged directly into rivers and other waterways via waste water treatment facilities (including sewerage systems, community waste water facilities, and combined septic tanks). Effluent standards have been prescribed for specific enterprises with facilities specified in the Water Pollution Control Law. For this reason, a waste water treatment facility must treat waste water so that the effluent satisfies the effluent standards; energy is consumed in this treatment.

As shown in Fig.1-14, electrical energy consumption by the sewerage services in fiscal 1996 was about 5.7 billion kWh (About 5.5 billion kWh in fiscal 1995). This accounts for about 0.63 % of the total electrical energy consumption of 903.5 billion kWh in the same year. The electrical energy consumption per unit volume of treated water here is 0.48 kWh/m^3, amounting to a volume of produced carbon dioxide of 0.05 kgC/m^3.

The trend in the electrical energy consumption tends to increase with an increase in the proportion of waste water treatment facilities such as sewerage systems, although the trend changes irregularly from year to year.



Note: Based on "Statistics on Sewerage Systems" by the Japan Sewerage System Association.

Fig.1-14 Trends in Electrical Energy Used in Sewerage Services

(5) Current Energy Consumption including Indirect Consumption between Development and Discharge Stages

As shown above, energy is consumed for water resources in each of the development, supply, utilization, and discharge stages. Energy is consumed directly in the use of electrical energy in running pumps for water intake or purification treatment to improve water quality; in addition to this apparent consumption, a considerable amount of energy is used indirectly in the construction of water resources development facilities and in updating and maintaining waterworks and waste water treatment facilities, because these facilities are constructed using concrete and steel products that consume a large volume of energy in the production processes.

It is difficult to determine exactly the indirect energy consumption because a wide variety of materials are used in constructing water resources development facilities and updating and maintaining waterworks and waste water treatment facilities. In spite of this difficulty, trial calculation gives a figure of 109 trillion kcal for the energy consumption in fiscal 1995; the trial calculation was performed in the conventional manner, based on data from the industry correlation tables and other tables, in order to determine the volume of fossil fuels consumed both directly and indirectly in the construction of water resources development facilities, updating and maintaining waterworks and waste water treatment facilities, and in the utilization of waterworks and sewerage systems. This volume accounts for about 2.8 % of the total fossil fuel consumption of Japan, and for about 2.9 % of the volume of carbon dioxide produced by Japan.

Chapter 2 Energy-saving Efforts in the Development and Utilization of Water Resources

As summarized in Chapter 1, changes in the global environment, especially the phenomena of acid rain and global warming, affect the development and utilization of water resources, and these in turn produce carbon dioxide directly and indirectly in their processes, and this causes more acid rain and global warming. For this reason, reducing the effects of acid rain and global warming requires energy saving to be promoted on a global scale; in the development and utilization of water resources also, efforts directed at saving energy as well as reducing costs and saving water have been made in many instances.

1. Efforts Made on the Energy Consuming Side

(1) Efforts at the Water Resources Development Stage

a. Dams

A variety of energy-saving efforts have been made in water resources development facilities such as dams with the aim of reducing construction costs. In many of these construction projects, energy-saving efforts combined with cost-saving efforts are being made. Specific measures include:

- Private-use power generation facilities used for dam operation are installed to effectively utilize the potential energy of water; 51 facilities in Japan; maximum output: about 32,000 kW;
- Reduction of cement consumption by adopting rationalized construction method of concrete dams like the RCD method and mixing fly ash (Fig. 1-15);
- Use of low-quality aggregates produced from rock quarries and the use of excavation rubble for filling;

b. Groundwater

Development and improvement of submersible motor pumps have helped produce highly-efficient equipment for pumping up groundwater.

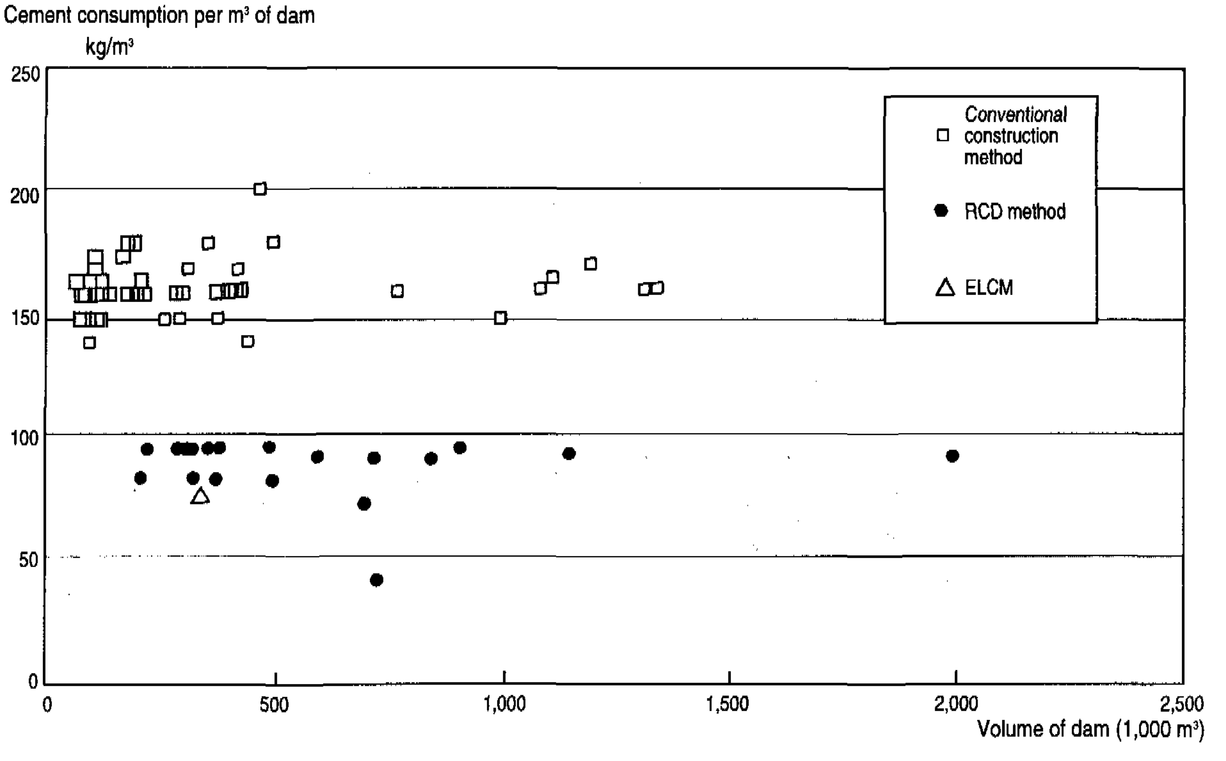
Also effective in saving energy are research and development of high-quality and energy-saving equipment, improvement of existing pump turbine blades, use of efficient, application-oriented equipment, and efficient operation through the use of electronic equipment.

c. Seawater desalination

For seawater desalination, 3 desalination methods, evaporation, electrodialysis, and reverse osmosis, have been commercialized. From the viewpoint of reduced energy consumption, the reverse osmosis method is popular in Japan. (Fig.1-16)

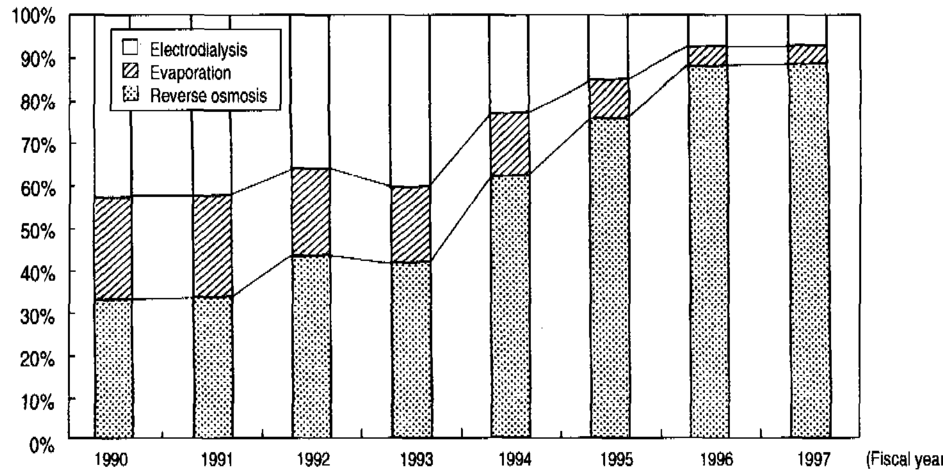
In addition to widespread commercialized desalination methods, the permeation/evaporation method that enables use of low-level waste heat or solar heat, and a desalination method based on the LNG cold heat refrigeration technique, which uses the currently virtually-untapped cold heat of liquefied natural gas as an energy source for seawater desalination, are under technological development.

For widespread commercially available desalination methods also, technological development is underway of more effective use of energy and reduction of costs. For example, tests and research activities are being carried out on the reverse osmosis method with the aim of improving the efficiency of the device that recovers the energy emitted under pressure, and of increasing the fresh water production efficiency (Fresh water recovery rate).



Note: Surveyed by the National Land Agency
The unit cement consumption is given by subtracting admixtures such as fly ash from the binder in 1m³ of embankment volume.

Fig.1-15 Volume of Cement Used per Volume (m³) of a Concrete Dam Constructed by the Concrete Depositing Method



Note: Prepared using data from past editions of "Water Resources in Japan".

Fig.1-16 Trend in the Percentage Capacity of Desalination Facilities by Desalination Methods (for domestic/business use)

(2) Efforts at the Water Supply Stage

a. Waterworks

Many waterworks are making efforts to save energy by implementing the following measures:

- By replacing old equipment by highly energy-efficient equipment such as rotational speed controls capable of keeping the water flow and distribution pressure constant under fluctuating demand, as well as selecting machines and equipment to suit the size of the demand;
- By using the incoming water for hydroelectric power generation before distribution, making use of the difference in elevation, or the water pressure of the incoming flow;
- By introducing new sources of energy such as solar batteries and fuel cells to supply power for reservoirs;
- By making use of gravity flow, using the topography to eliminate or reduce energy consumption in supplying water;
- By drying the sludge from the water purification process using sunlight;
- By using water sources or reservoirs in the order of higher energy efficiency when more than one water source or reservoir is available;
- By reducing the water supply pressure during the night.

The visible results of these measures vary widely because the supply and demand structure and similar factors vary with the waterworks; for example, it is estimated that the introduction of a rotational speed control leads to a reduction in the electrical energy consumption of between several % to several tens of %.

Although measures to eliminate water leaks are not direct efforts toward energy saving, they contribute to reducing energy consumption as a result of reducing dead water.

b. Industrial waterworks

Viewed from measures being taken in each sector, efforts being made by industrial waterworks are about the same as those being made by ordinary waterworks. Industrial waterworks, however, are making efforts in some areas that are specific to their needs; one such area is the practice of maintaining a uniform water supply to users, with the aim of leveling off the supply load, and another is in the area of efficient water supply through the combined services of normal waterworks and industrial waterworks.

These cases show clearly that a number of industrial waterworks have already put efforts into practical energy-saving measures.

c. Agricultural water

Since energy consumption associated with the supply of agricultural water affects the costs of running the facilities, the following efforts are made in planning, designing, maintaining, and operating agricultural water facilities with the aim of reducing costs:

- At the planning stage, efforts are made toward maintaining efficient water pressure levels by good design of the pipeline facilities;
- At the design stage, efforts are made toward efficient use of equipment by installing pumps of different diameters used in combination to match seasonal water intakes and the supply of agricultural water, and by installing pump rotational speed controls to meet changes in water intake volumes;
- Effective utilization of potential energy by installing improved hydroelectric power generation equipment at certain water discharge facilities for agricultural irrigation (11 facilities; maximum output: 8,430 kW)

In addition, timely replacement of obsolete equipment in maintaining and running agricultural irrigation facilities contributes to energy saving.

(3) Efforts at the Water Utilization Stage

a. Reuse of sewage water and industrial waste water

In reusing sewage water and industrial waste water, in order to reduce utilization costs, it is important to reduce the energy needed for water treatment; for this purpose, technological development and commercialization efforts are being made to develop highly-efficient, inexpensive water treatment methods. Furthermore, some waste water treatment plants use the gas produced in the sludge treatment process to generate power, with the aim of reducing electrical energy charges and to effectively utilize resources at the same time. In promoting the reuse of water for miscellaneous uses in large-scale redeveloped areas, the wide area recirculation method or the community recirculation method that require relatively small energy consumption per unit volume of water are adopted.

b. Recovery of industrial water

A considerable amount of energy is consumed in recovering and reusing industrial water; from the viewpoint of reducing water utilization costs, a number of enterprises are making efforts to reduce the energy required to recover and reuse industrial water, and some examples of energy saving in the recovery of industrial water are given here:

- Practice of using cascades for cooling water to reduce the water consumption;
- Water supply pressures, which have been the same throughout a particular water supply system, are reviewed to determine exact pressures necessary for individual processes; on the basis of the review, processes where the flow needed can be ensured with a lower pressure are equipped with dedicated pumps that work with a low head of water;
- Pumps in which the volume of water changes intermittently or continuously are equipped with rotational speed controls to reduce the electrical energy consumed by the pumps;
- Introduction of equipment that controls the electrical energy consumption in cooling towers with changes in the air temperature and volume of water.

In these cases, efforts to reduce energy consumption often result in reducing the water consumption too.

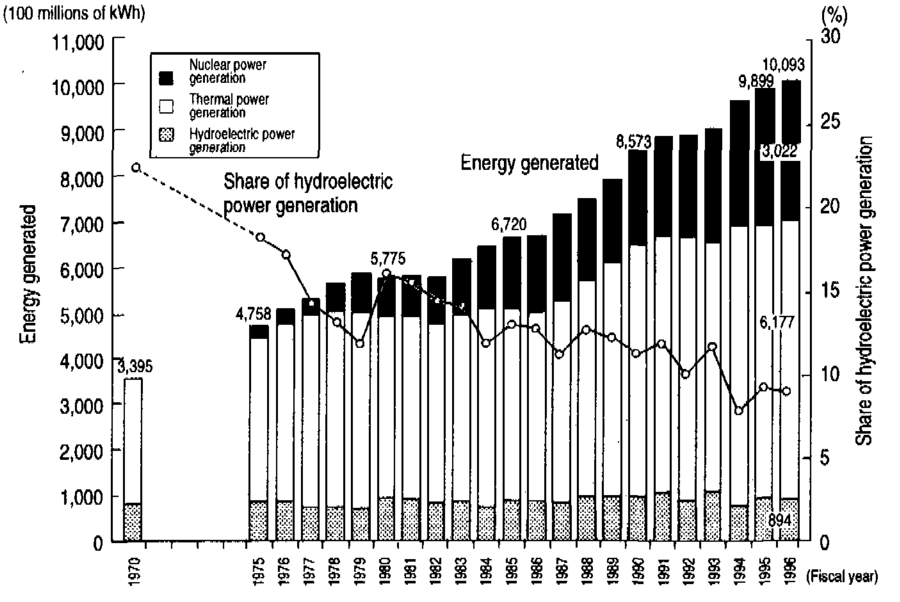
2. Efforts on the Energy Supply Side

As described in Chapter 1, development and utilization of water resources consume energy either directly or indirectly and hence produce carbon dioxide and other gases. On the other hand, proper use of water resources has made them an important source of energy with less environmental loading. Therefore, the role of water resources will be increasingly important because the utilization of water resources contributes to developing measures to suppress emissions of carbon dioxide and other gases.

(1) Hydroelectric Power Generation

Hydroelectric power generation generates electricity by making use of potential energy.

The electrical energy generated by hydroelectric power generators in fiscal 1996 was 89.4 billion kWh, accounting for nearly 10 % of the total electrical energy generated in the year. (Fig.1-17) Comparison with the track record for the previous year shows a 2.0 % increase in the total generated energy but a 2.0 % decrease in the hydroelectric energy generated due to a lower precipitation. As of the end of March, 1997, 1,690 hydroelectric power stations are installed throughout the country, with a maximum output of 44 million kW, a 2.2 % increase over the previous year, which accounts for about 20 % of the total installed power generation capacity.



Notes: 1. Based on "Electric Utility Industry Handbook, Fiscal 1997 Version" by the Commission on Statistics of the Federation of Electric Power Companies.

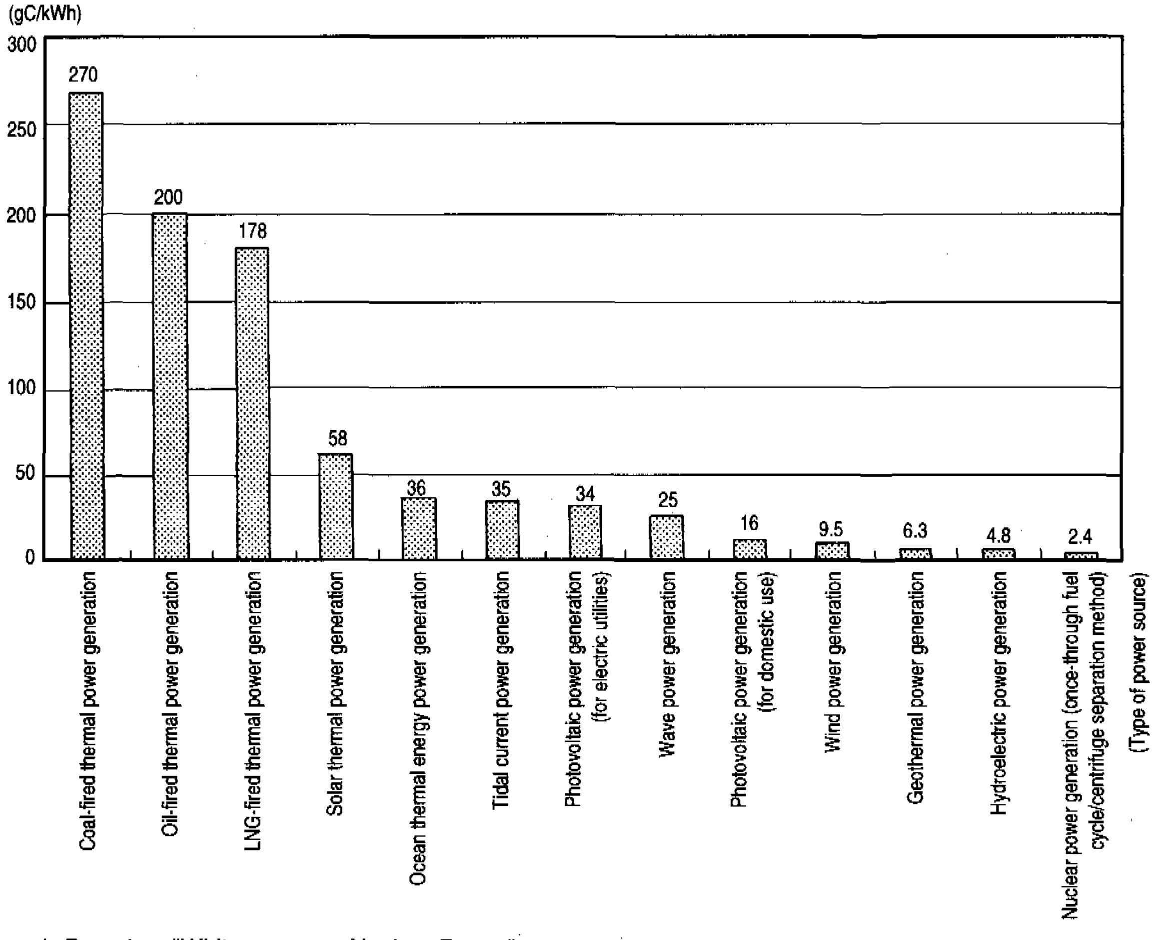
2. Thermal power generation includes geothermal, photovoltaic, fuel cells, and wind power generation.

3. The figure for the generated energy is for fiscal 1996.

4. The figure for the installed power generation capacity is given for the end of March, 1997. However, the installed capacity of private power stations with a maximum capacity of less than 500 kW is not included.

Fig.1-17 Trend in Energy Generation

From 1892 on when the first hydroelectric power station in Japan was installed to supply general power, hydroelectric and thermal power were in a "master-servant" relationship; however, since the former half of the 1960's when the relationship was reversed, the proportion of hydroelectric power generation has decreased steadily.



Notes: 1. Based on "White paper on Nuclear Power".
2. Prepared on the basis of documents published by the Central Research Institute of the Electric Power Industry including: Analysis of the Service Life of Power Generation Systems Y94009; Analysis of the Life of Nuclear Power Generation Technology; and Analysis of Life Cycle Energy.

Fig.1-18 Carbon Dioxide Production per kWh by Type of Power Source

Wholly produced within the country, as a form of virtually inexhaustible energy, hydroelectric power gives excellent stability of supply and provides clean energy that is free from carbon dioxide and sulfur oxides as by-products of the generation process.

Compared with other power sources in terms of the energy consumption associated with development and utilization, hydroelectric power generation not only emits less carbon dioxide than thermal power generation, but also is much more effective than the clean energy generated by photovoltaic or wind power generation in terms of the suppression of carbon dioxide production. (Fig.1-18)

(2) Use of Water as Thermal Energy

Hot spring water has been used as a heat source for horticultural greenhouses and residential heating, while groundwater, with its temperature relatively stable throughout the year, is used as cooling and air conditioning water and in snowy regions, snow melting water. In addition, warm discharge water from factories and similar establishments is used for pisciculture.

Notably these days, thermal energy obtained from water like river water and sewage water, which exists in a large volume and exhibits less seasonal changes in temperature than the atmosphere, is being used. River water and sewage water are characterized by a temperature that is lower in summer and higher in winter than atmospheric temperature. Although their temperature is relatively low, they exist in large volumes. Improvements in low-temperature heat source utilization technologies using heat pumps has enabled the energy in water at different temperatures to the surroundings to be efficiently used. As examples, in-house heating systems in sewage treatment plants and district heating systems that supply warm and cold water over a wide area have been introduced. (Table 1-4)

Table 1-4 Community Heat Supply Services Utilizing Hydrothermal Sources

Name of service area	Type of service	Source of heat	Date of start of supply
Hakozaki	Warm water, cold water, hot-water supply	Heat from river water	April, 1989
Makuhari New City Center High-tech Business	Steam, warm water, cold water	Waste heat from sewage water treatment	April, 1990
Seaside Momochi	Warm water, cold water	Heat from seawater	April, 1993
Ton-ya-cho, Chiba City	Warm water, steam, cold water	Heat from a waste water recovery system	October, 1993
Chu-o, Takasaki City	Warm water, cold water	Heat from groundwater	December, 1993
Osaka Nanko Cosmo Square	Steam, warm water, cold water	Heat from seawater	April, 1994
1 chome, Koraku	Warm water, cold water	Heat from raw sewage water	July, 1994
1 chome, Temmabashi	Warm water, cold water, steam	Heat from river water	January, 1996
Toyama Station North Area	Warm water, cold water	Heat from river water	July, 1996
Bancho, Takamatsu City	Warm water, cold water	Groundwater, sewage water	February, 1997
Morioka Station West Exit Area	Warm water, cold water	Heat from untreated sewage water, waste heat from transformers	November, 1997
Shimo-Kawabata Redeveloped Area	Warm water, steam, cold water	Heat from a waste water recovery system	January, 1999 (Scheduled)

Notes: 1. Based on "New Energy Handbook" by the Agency of Natural Resources and Energy (as of February 1997).
2. Including projects under construction.

Tree-planting in urban areas can be regarded as an example of utilization of the heat of evaporation of water; more and more urban areas are exposed to the heat island phenomenon that is caused by excessive covering of the ground and the heat output from the consumption of energy by air conditioning, transport facilities, factories, and the like. In addition, the trend towards planting greenery around buildings has become increasingly common with the aim of creating green spaces that give peace of mind and comfort, and shade.

Chapter 3 Future Efforts

As has been described in the preceding chapters, changes in the global environment, especially the phenomena of acid rain and global warming, affect the development and utilization of water resources; conversely, the very development and utilization of water resources consume energy obtained from fossil fuels either directly or indirectly, thereby resulting in the production of carbon dioxide and other gases that in turn cause acid rain and global warming.

Should the effects of acid rain and global warming become clearly observable, it will become necessary to address these consequences in the development and utilization of water resources; however, the priority must be to save energy to prevent this occurring, and to achieve this goal, efforts should be made across the board. Since acid rain and global warming affect the development and utilization of water resources, we should not only rely on these efforts; we should also make the maximum possible effort ourselves towards energy saving in the development and utilization of water resources.

1. Efforts on the Energy Consuming Side

In order to prevent changes in the global environment from affecting the development and utilization of water resources, it is important to aggressively push ahead with extensive efforts toward energy saving in the process of development and utilization using a variety of technologies.

(1) Efforts at the Water Resources Development Stage

a. Dams

In developing new water resources, it is desirable to formulate plans that are oriented toward the more effective use of potential energy. In a dam construction project, most of the energy consumption occurs at the development stage, and it is therefore necessary to further reduce the energy consumption through technological development in the design and execution of the construction project. On the other hand, at the water management stage also, it is necessary to promote technological development to reduce energy consumption.

b. Groundwater

Although the volume of water drawn from individual wells is small, about 15.81 billion m^3 of groundwater is used annually throughout the country. This is a fact that must not be overlooked from the viewpoint of the energy consumption associated with using groundwater. In the future, it is necessary to conduct research and development into reducing the energy consumption by excavating machines and pumps.

c. Seawater desalination

Seawater desalination not only consumes more energy but also costs more than other sources of water; therefore, its use as a systematic supply method in ordinary times poses problems. However, it is important as a water source in isolated islands and peninsulas where securing water resources through rainfall alone is difficult, and for emergencies such as water shortages and disasters. From these viewpoints, it is necessary to continue technological development to reduce the energy consumption of desalination systems.

(2) Efforts at the Water Supply and Utilization Stages

a. Waterworks and industrial waterworks

In the waterworks services, the priority is to further push ahead with measures to eliminate water leaks to save energy and to ensure that the water taken in is supplied to users as effectively as possible. In updating and improving facilities, the gravity flow method should be adopted in supplying water, while energy-saving treatment methods that enable more efficient water purification processes should be employed while maintaining the required water quality. In addition, of equal importance is the promotion of energy-saving measures such as the effective use of natural energy. In building facilities also, it is possible to consider ways of reducing energy consumption with regard to the manufacturing materials used to construct the facilities and in their processing. Since deterioration of source water quality affects the energy needed for purification, the water intake and discharge locations should be changed if necessary.

Similar energy-saving measures should be taken for industrial waterworks.

b. Agricultural water

In using water for agriculture, the following efforts should be continued to reduce energy consumption: adoption of the gravity flow method for irrigation systems such as pipelines and the formulation of efficient plans for facilities; installation of pumps that pump water and use energy efficiently; use of untapped hydroelectric energy by installing small hydroelectric power generators; and timely replacement of obsolete facilities. In building facilities also, it is possible to consider ways of reducing energy consumption with regard to the manufacturing materials used to construct the facilities and in their processing.

It will also become necessary to push ahead with further reduction in energy consumption by introducing power generating facilities that use natural energy like wind power and solar power.

c. Reuse of sewage water and industrial waste water

In recovering sewage water and industrial waste water, continued efforts should be made for research and development into improving water treatment technology to reduce energy consumption. In building reuse facilities also, it is possible to consider ways of reducing energy consumption with regard to the manufacturing materials used to construct the facilities and in their processing.

d. Recovery of industrial water

A number of enterprises have been making efforts to reduce the volume of energy consumed in the recovery of industrial waste water. Notably, 77.2 % of fresh water for industrial use is supplied from recovered water, and estimates based on past trends show that the recovery rate will remain flat or increase slightly. For this reason, it is necessary to push forward with further reduction in energy consumption in recovering industrial water by urging technological developments in this field.

(3) Efforts of Individual Nationals

a. Efforts at the water utilization stage

When water is used in households, energy is not directly used. As described above, however, energy is consumed in the development, supply, and discharge stages. Therefore, an increase in water consumption will likely lead to an increase in energy consumption in the development and supply stages. For this reason, it is important for each country to become fully aware that using water consumes energy, and water saving should be promoted from this viewpoint.

b. Efforts at the water discharge stage

Introduction of secondary water purification facilities causes the energy consumed for water purification to increase.

According to a survey conducted by the National Land Agency, about 40 % of waterworks predict that the energy consumption per unit volume of supplied water will increase in the future and about 40 % of the respondents attribute the reason to the introduction of facilities and equipment to improve water quality such as secondary water purification facilities.

Many secondary water purification facilities have been installed because of the deterioration of water quality at the source. On the assumption that installing secondary water purification facilities causes the energy consumption per unit volume of water to increase, the priority must be to maintain good water quality at the source to reduce the energy consumption per unit volume of water; however it is also important for each household to be careful about the quality of the water that they discharge after use.

This follows from the fact that in treating sewage water in waste water treatment facilities, deterioration of the water quality before treatment results in an increase in the energy that must be used to treat the water, and thus improving the quality of the water that is discharged is a point to be considered.

2. Efforts on the Energy Supply Side

From the viewpoint of reducing carbon dioxide and other gases produced as a result of energy use, it is important to make continued efforts toward using and exploiting water resources in a sustainable way.

(1) Promoting Hydroelectric Power Generation

Since the former half of the 1960's when the national power supply policy was reversed to make hydroelectric energy subservient to thermal energy, the proportion of hydroelectric power generation has decreased steadily. However, hydroelectric power is purely domestically-produced energy and characterized by freedom from emissions of carbon dioxide and other gases.Taking into account the decreasing scale of power generation facilities, deterioration in geographical conditions, and the impact of development on the environment, it is now necessary to make continued efforts to reduce costs in promoting hydroelectric power generation.

(2) Promoting the Use of Water as Thermal Energy

Utilization of heat energy extracted from water is expected to continue increasing because it is a clean, untapped heat source and effective in preventing global warming.

To promote the use of energy from water, continued efforts are required in technological development in reducing the costs of updating and improving facilities and improving the efficiency of the heat pumps. To utilize this form of energy properly, it is important to minimize unwanted effect from warm or cold water returned to its source or flowed back into underground on the environment and problems related to land sinkage when withdrawing large amounts of groundwater.

3. Studies on Measures against Acid Rain and Global Warming

First, efforts must be made to prevent acid rain and global warming; however, it is equally important to conduct full-scale studies on measures against potential changes in the global environment so that such occurrences can be addressed appropriately.

(1) Measures against Acid Rain

To reduce acid rain, it is necessary to reduce emission of sulfur oxides and nitrogen oxides, the substances which are the root of the problem; in Europe and North America, a convention has already been held on ways to reduce emissions.

In some countries, lime is sprayed on lakes affected by acid rain to neutralize the water.

In Japan, efforts are typified by the enforcement of regulations on the emissions of sulfur oxides and other gases from factories, designed to reduce the factors that contribute to the volume of acid rain at source. However, there has not yet been any reduction in the volume of sulfur ions in rain, because the increase in the number of automobiles has caused emissions of these gases to rise.

Under these circumstances, the Environment Agency conducted a nationwide survey to monitor the actual state and effects of acid rain; at the international level, the Agency proposed creation of an Acid Deposition Monitoring Network in East Asia in which 10 East Asian countries and relevant international organizations will participate.

Although the observatories throughout the country reported an average acidity with a pH of 4.9 in acid rain precipitation in 1993 and a pH of 4.8 in 1994 and 1995, evidence of the effects of acid rain have not been reported in Japan up to the present. However, it is necessary to make continued efforts to clarify the situation to be ready to find solutions, because it is feared that there will be possible effects on water resources such as changes in water quality.

(2) Measures against Global Warming

Firstly, efforts must be made to prevent the global warming by promoting energy saving and by other means; however, it is also necessary to clarify and find solutions to situations in which changes in river water and groundwater, and changes in the demand trends for domestic/business water occur as a result of global warming.

For this purpose, it is important to build up information on the possible effects of global warming on water resources and demand trends. Although many research organizations have made various studies and analyses, the effects of global warming are mostly uncertain; in the present circumstances, detailed information on these effects published by the research organizations is not consistent. Regarding the effects of precipitation, not only changes in the average precipitation but also changes in the frequency of occurrence of heavy and light precipitation affect the development and utilization of water resources; however, knowledge in this field is not yet fully developed compared to progress in research into changes in the average precipitation. The same applies to estimations of the effects on groundwater levels of possible rises in the sea level. For these reasons, it is necessary to make continued efforts to build up information concerning the possible effects of global warming on water resources.

In formulating long-term plans for water demand and supply, we must always be adequately prepared to deal with future changes, and this includes continued studies on techniques to formulate plans that incorporate the possible effects of global warming on water resources.

Concluding Remarks

Water resources are essential to human activity, and although our utilization of these resources affects only a small part of the hydrologic cycle, that utilization inevitably consumes energy in various forms from the intake to discharge. As described in Chapter 1, Japan uses about 0.9 % of its total electrical energy consumption for supplying water through the public water utilities, and about 0.6 % for waste water treatment. In other words, more than 1.5 % of Japan's total electrical energy use occurs in the processes from supplying water through the public water utilities to discharging water through the sewage works; in this way, energy consumption is an important issue that we must not forget in discussing problems with water resources.

However, there are many ways of developing water resources, which naturally consume different amounts of energy. From among these, the method selected for a particular area should be the one that fits the natural and social condition of the area best; the selection of a method should not only depend on how much energy that method consumes. Thus, when the problem of selection is viewed from the standpoint of reducing energy consumption, it is important to make efforts to minimize the energy consumption for all of the viable ways of developing water resources.

A survey of track records shows that when the quality of water in the source is poor, the energy consumption for treating such water increases about 40 % compared to treatment of water of good quality. While administrative organs and enterprises make efforts in prevention of water pollution as their duty, efforts to be made by each one of the nationals to eliminate pollutants before discharge also are important in reducing energy consumption.

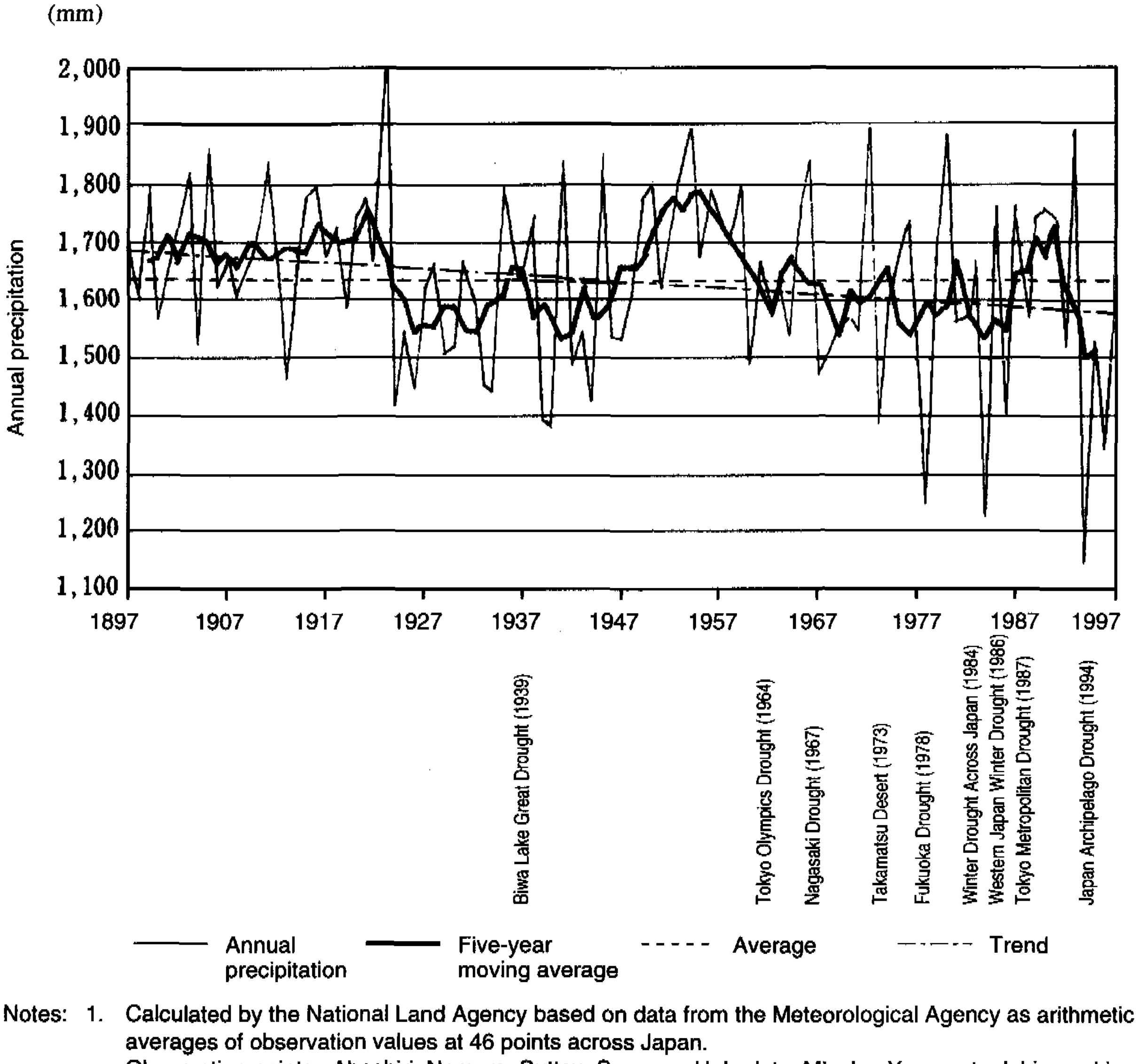
Although the proportion of hydroelectric power generation to the total generated energy has decreased to less than 10 % as a result of the policy that makes hydroelectric subservient to thermal, use of water resources should be aimed at producing energy like hydroelectric energy that does not rely on foreign resources. In addition, some people are looking to the extraction of thermal energy from water to alleviate the heat island phenomenon. It is extremely important to properly evaluate these roles and their effects in order to make best use of them.

Constrained by time, we have collected and compiled existing knowledge and literature in this document; however, the issues surrounding the utilization of water resources and energy are still fraught with areas that have yet to be clarified and areas where there are not yet sufficient statistics. We hope that further investigations, studies, and the compilation of statistics will continue. And we will be happy if, in addition to those who are involved in the problems and issues of water usage, we have managed to stimulate the interest of ordinary people in the issues of water resources and energy.

Part II

1. Recent Weather Conditions

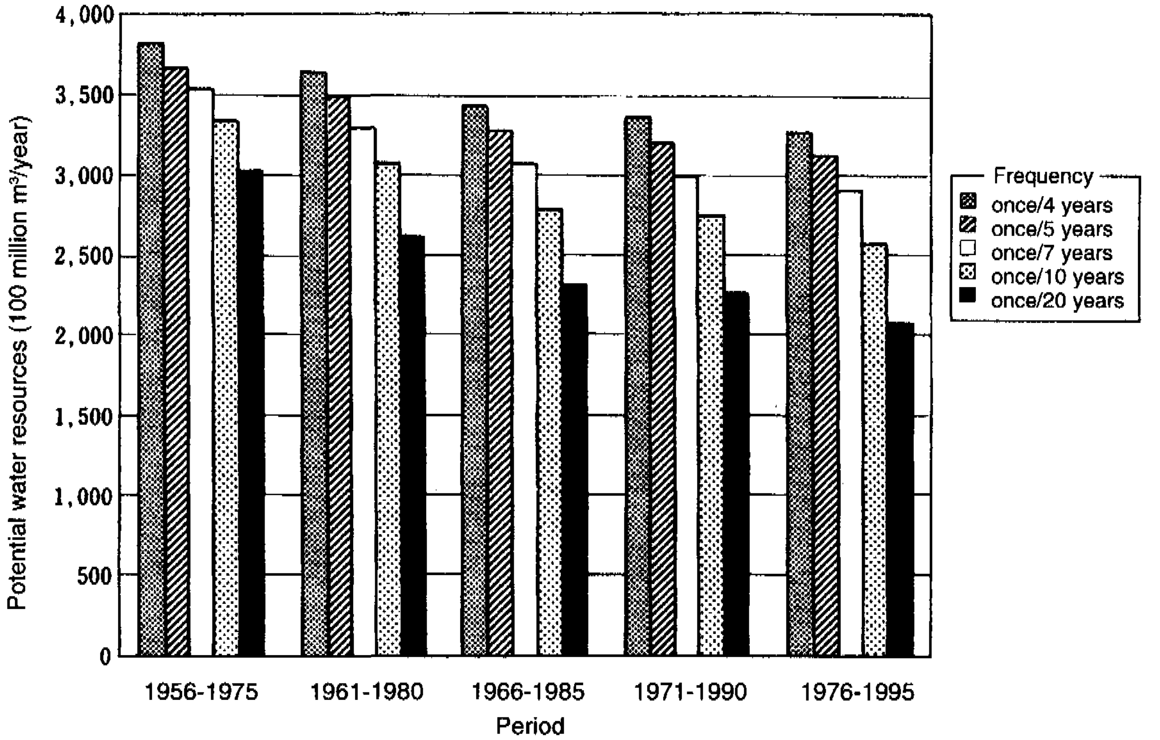
- The average annual precipitation in Japan is 1,714 mm (based on rainfall at about 1,300 sites across the country during the period from 1966 to 1995).
- In 1997, precipitation exceeded the level of a normal year in parts of Hokkaido, Tohoku, Hokuriku, Chugoku, etc. but fell short of a normal year's level in northern Tohoku, Pacific coastal regions from Kanto to Kyushu, etc. Precipitation was 80% or less of a normal year's level in parts of Kanto, Tokai, Shikoku, Kyushu, etc.



Notes: 1. Calculated by the National Land Agency based on data from the Meteorological Agency as arithmetic averages of observation values at 46 points across Japan.
Observation points: Abashiri, Nemuro, Suttsu, Sapporo, Hakodate, Miyako, Yamagata, Ishinomaki, Aomori, Akita, Fukushima, Maebashi, Kumagaya, Mito, Utsunomiya, Kofu, Tokyo, Nagano, Kanazawa, Niigata, Fukui, Hamamatsu, Nagoya, Gifu, Hikone, Kyoto, Osaka, Wakayama, Okayama, Sakai, Hamada, Izuhara, Hiroshima, Tadotsu, Tokushima, Matsuyama, Kochi, Kumamoto, Miyazaki, Fukuoka, Saga, Nagasaki, Kagoshima, Naze, Naha, and Ishigakijima
2. Trend is based on regression lines.

Fig. 2-1 Yearly Changes in Precipitation in Japan

- The amount of potential water resources of the country is about 420 billion m^3, and about 280 billion m^3 in a dry year. The amount of potential water resources in a dry year is on the decrease. (Fig. 2.2)

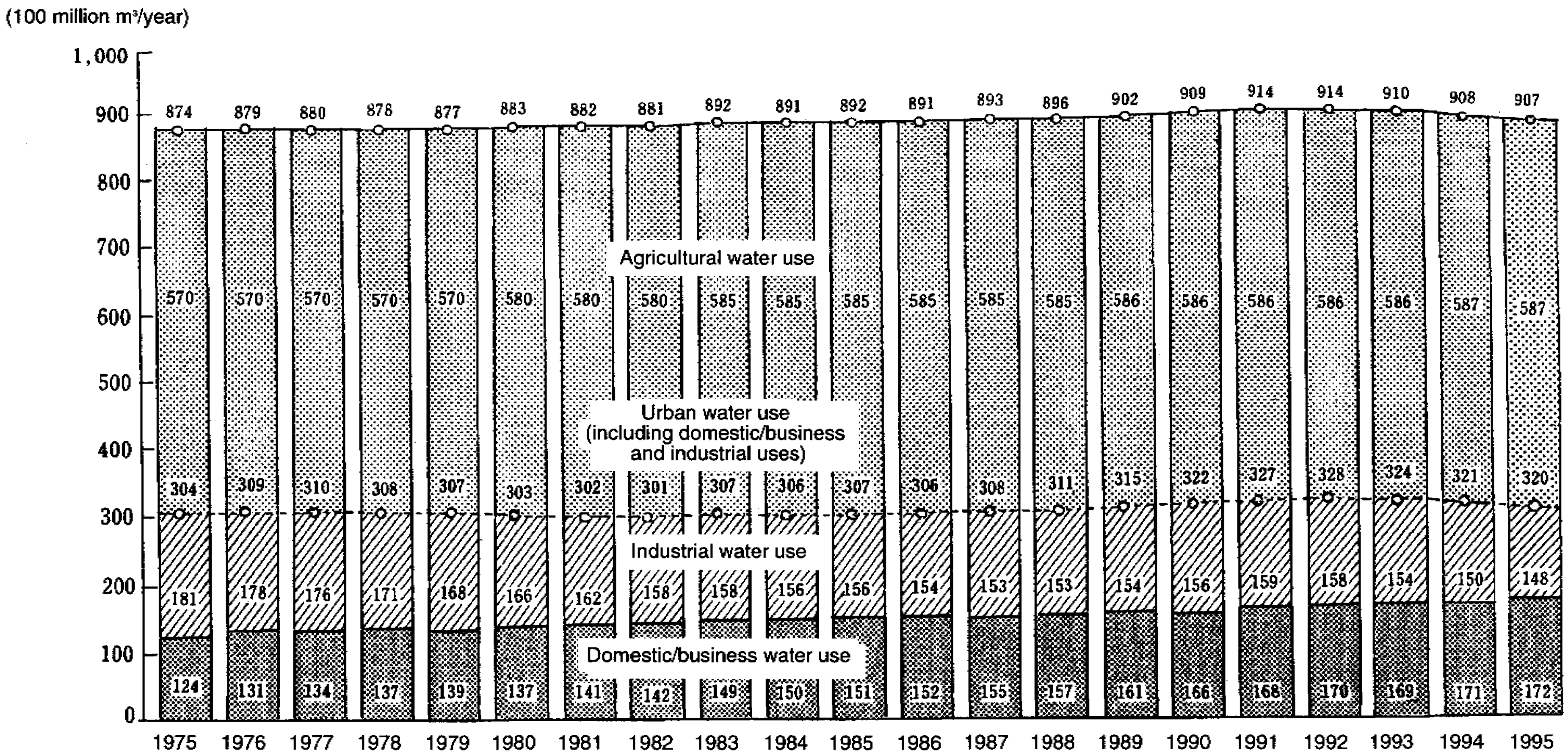


Note: Calculated by the National Land Agency based on data from 1956 to 1995.

Fig.2-2 Potential Water Resources in Japan Over Time

2. Current State of Water Use

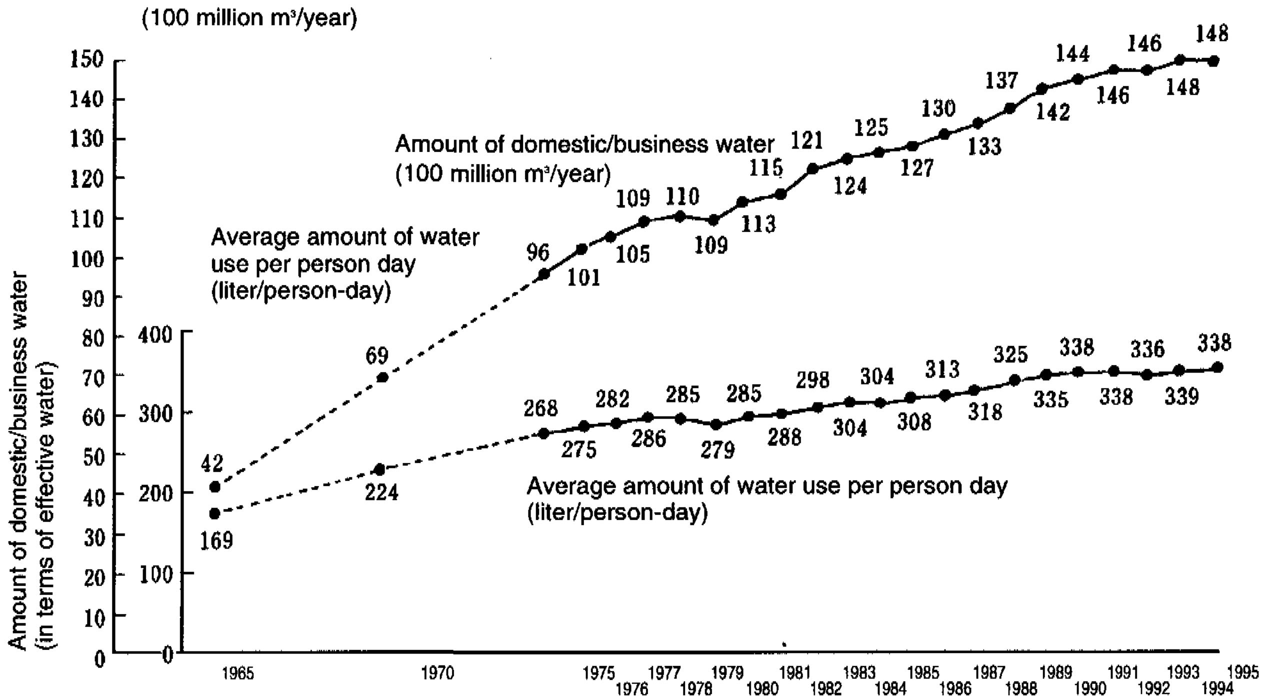
- In 1995, water of about 90.7 billion m^3 in total was used in Japan on an intake basis. A breakdown of the total by use is about 17.2 billion m^3 for domestic/business use, about 14.8 billion m^3 for industrial use and about 58.7 billion m^3 for agricultural use (these numbers do not include the water used by public utilities, or used for melting or washing away snow). (Fig. 2-3)



Notes:
1. The values are estimated on an intake basis by the National Land Agency.
2. Industrial water is fresh water replenishment from the sources, excluding the amount used by public utilities.
3. For agricultural use, the values for 1981 and 1982 are estimates in 1980 and; 1984 to 1988 are estimates in 1983; and those for 1990 to 1993 are estimates in 1989.
4. Some totals are inconsistent with the sums of breakdown items because of the rounding process.

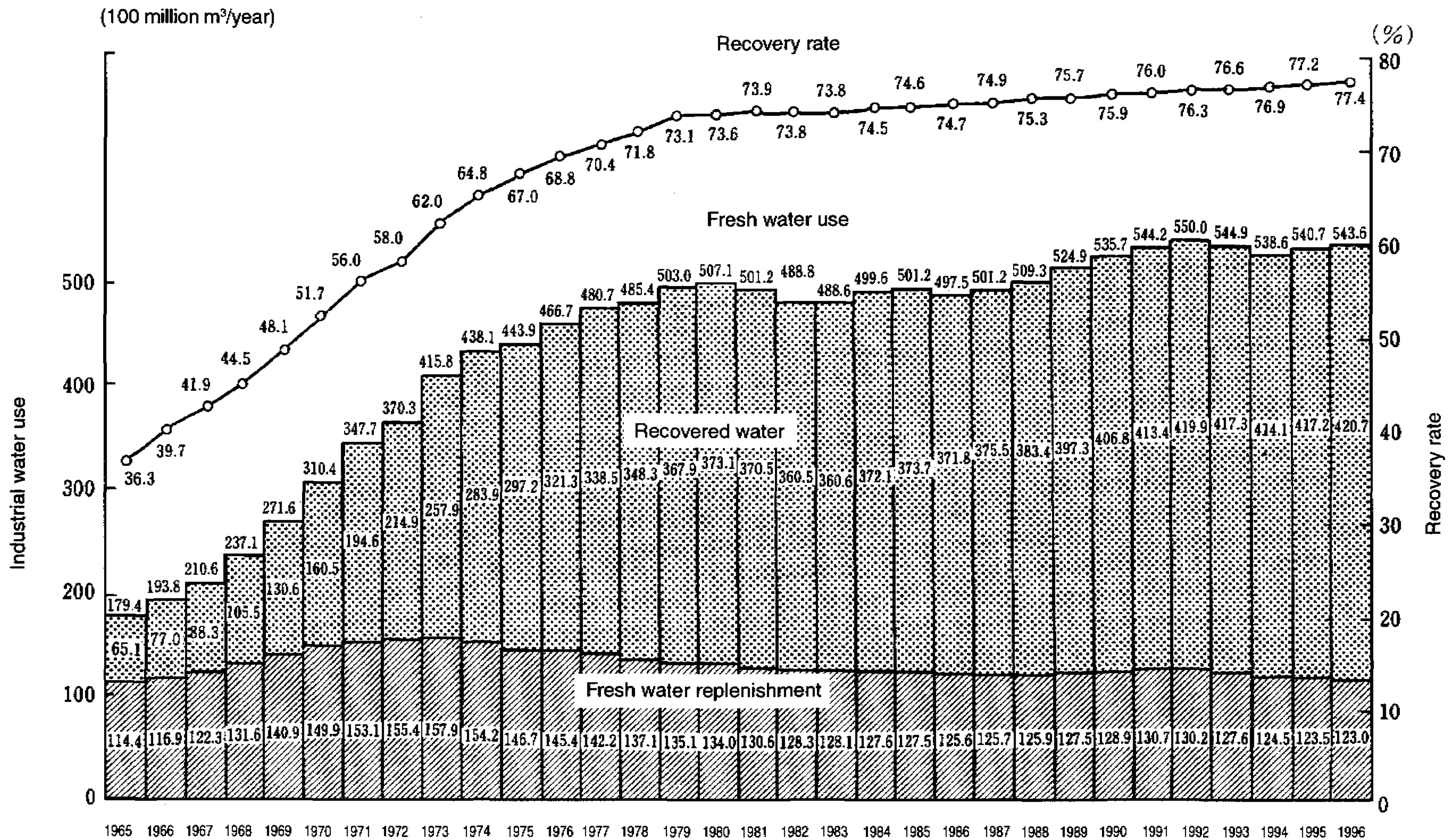
Fig.2-3 Water Use of the Entire Country

- Domestic/business use of water in 1995 was about 14.8 billion m³ (on an effective-water basis), a 0.2% increase over the previous year, and the average water use per person per day was 338 ℓ. (Fig. 2-4)
- Industrial use of fresh water in 1995 was about 54.1 billion m³ (on an effective-water basis), a 0.4% increase over the previous year. Water recovery rate was about 77.2%, a 0.3% increase over the previous year. As a result, fresh water replenishment decreased by 0.8% from the previous year to about 12.4 billion m³. (Fig. 2-5)



Note: Based on a study by the National Land Agency.

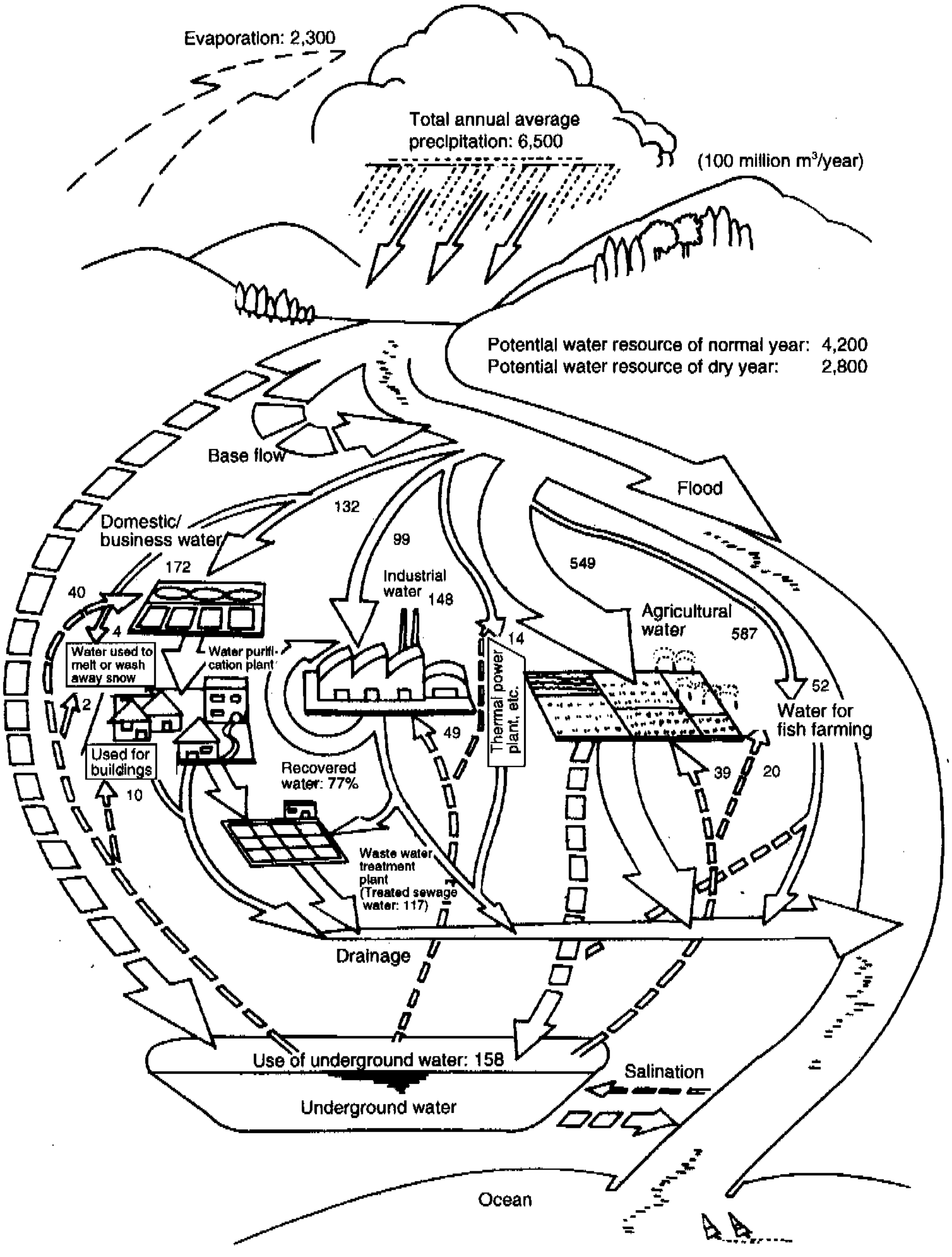
Fig. 2-4 Changes in the Amount of Domestic/Business Water



Notes: 1. Based on "Census of Manufactures" by the Ministry of Inernational Trade and Industry.
2. The data are on establishments with 30 employees or more.
3. Water used by public utilities is not included.

Fig. 2-5 Changes in Industrial Water Use

- As for water to melt or wash away snow, snow melting pipes used about 0.2 billion m^3 per year and snow gutters to wash away snow used about 0.4 billion m^3 per year. Water of about 8.3 billion m^3 per year was used for aquaculture purposes, and about 1.4 billion m^3 per year for public utilities.



Notes: 1. Total annual average precipitation, evaporation, and potential water resource are calculated by the National Land Agency based on data for 1966-1995.

2. Domestic/business water and industrial water are the values for 1995, and water used by public utilities is the value for 1994 according to the National Land Agency.

3. River water for agricultural use is the value for 1995 according to the National Land Agency. Underground water is based on "Current State of Agricultural Use of Underground Water" (by a survey on the actual volumes for September 1984 to August 1985) by the Ministry of Agriculture, Forestry and Fishery.

4. Water for fish farming, and water for melting and washing away snow are the values for fiscal 1996 according to the National Land Agency.

5. Water for buildings (except that for melting and washing away snow) is based on "Survey on Actual Volumes of Pumped-up Underground Water" (for 1971-1995) from the Environmental Agency and surveys on the state of actual water uses by local governments.

6. "Wastewater treatment plant" includes sewage, community drainage, and integrated treatment tanks. Treated sewage water is the value for 1996 according to the Ministry of Construction.

7. Thermal power plant, etc. includes nuclear power plant, gas supply plant, and thermal supply plant.

Fig. 2-6 Water Balance in Japan

3. Current State of Development of Water Resources

(1) River Water

- River water resources for urban use developed by water resource development facilities, such as dams, amount to about 16.4 billion m^3 per year (as of the end of March 1998). Of this amount, about 9.3 billion m^3 and about 7.1 billion m^3 are supplied for domestic/business use and industrial use respectively in a year.
- In fiscal 1997, 21 additional water resource development facilities for urban and agricultural use were completed across the country. The amount of water developed by these facilities is about 342 million m^3 per year for urban use (about 214 million m^3 per year for domestic/business use and about 128 million m^3 per year for industrial use) and about 155 million m^3 per year for agricultural use.
- As of the end of March 1998, the amount of unstable intake of water (the amount of water to be taken only when river flow is sufficient) for urban use is about 2.3 billion m^3 per year in the country, or about 7.2% of the total urban water.

(2) Underground Water

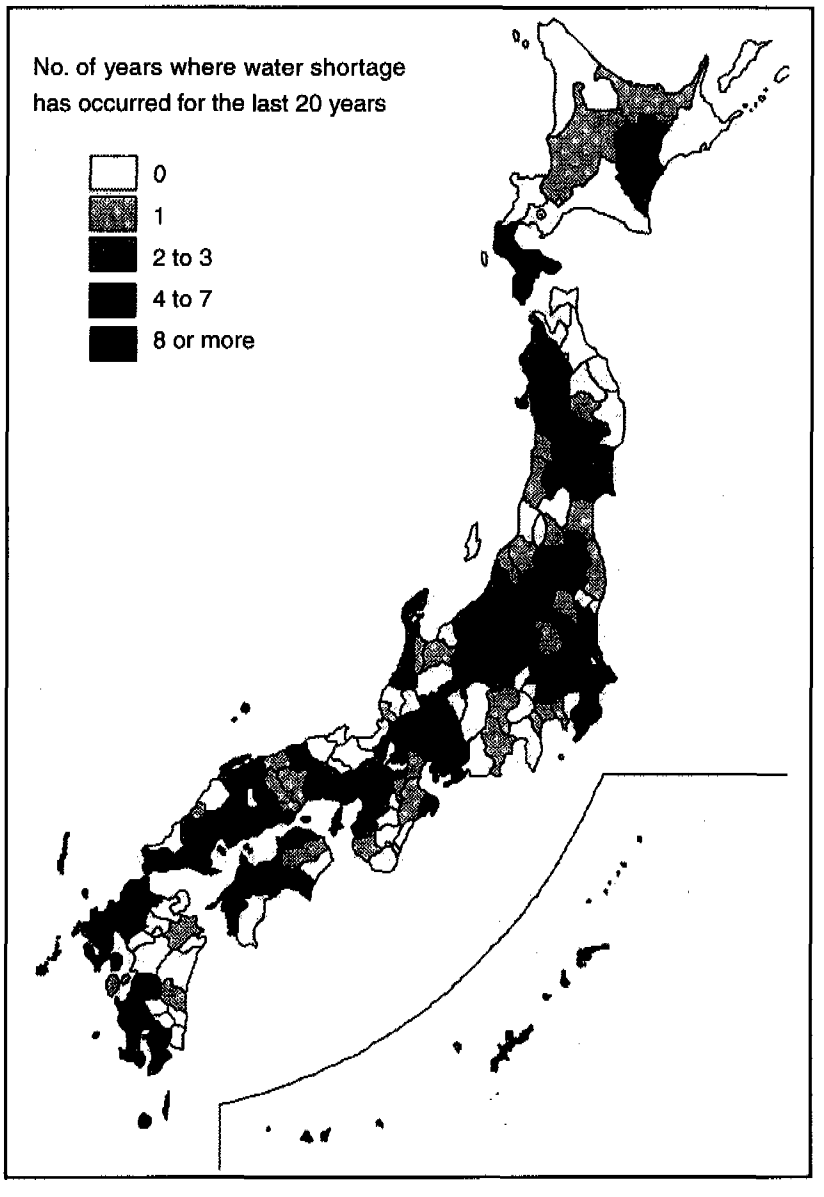
- The total amount of underground water used is about 15.8 billion m^3 per year. The ratio of dependence on underground water is about 14% for the total of urban and agricultural use (the ratio of dependence on underground water is about 28% for urban use).

(3) Other Water Resources

- In fiscal 1996, the quantity of treated sewage water amounted to about 11.7 billion m^3, and 192 sewage disposal plants supplied treated sewage water of about 0.13 billion m^3 for outside reuse.
- As of the end of fiscal 1996, 600 facilities—about 29% of all facilities in the country that use rainwater for miscellaneous purposes—use rainwater for miscellaneous purposes, such as flushing toilet water, and the amount of such water usage is about 5 million m^3 per year.
- The amount of fresh and drinkable water produced by sea water desalination plants is about 3.58 million m^3 per year.

4. Water Shortages in 1997

- The Kanto region suffered water shortages in the winter season. In March through May, the intake of water was limited in the Kanto, Tokai and Shikoku regions, and in October, the intake of water was limited in the Tokai, Shikoku and other regions. As for tap water, about 320,000 inhabitants were affected across the country, and the quantity of water corresponding to about 5.9 days' use for the affected population was not available.

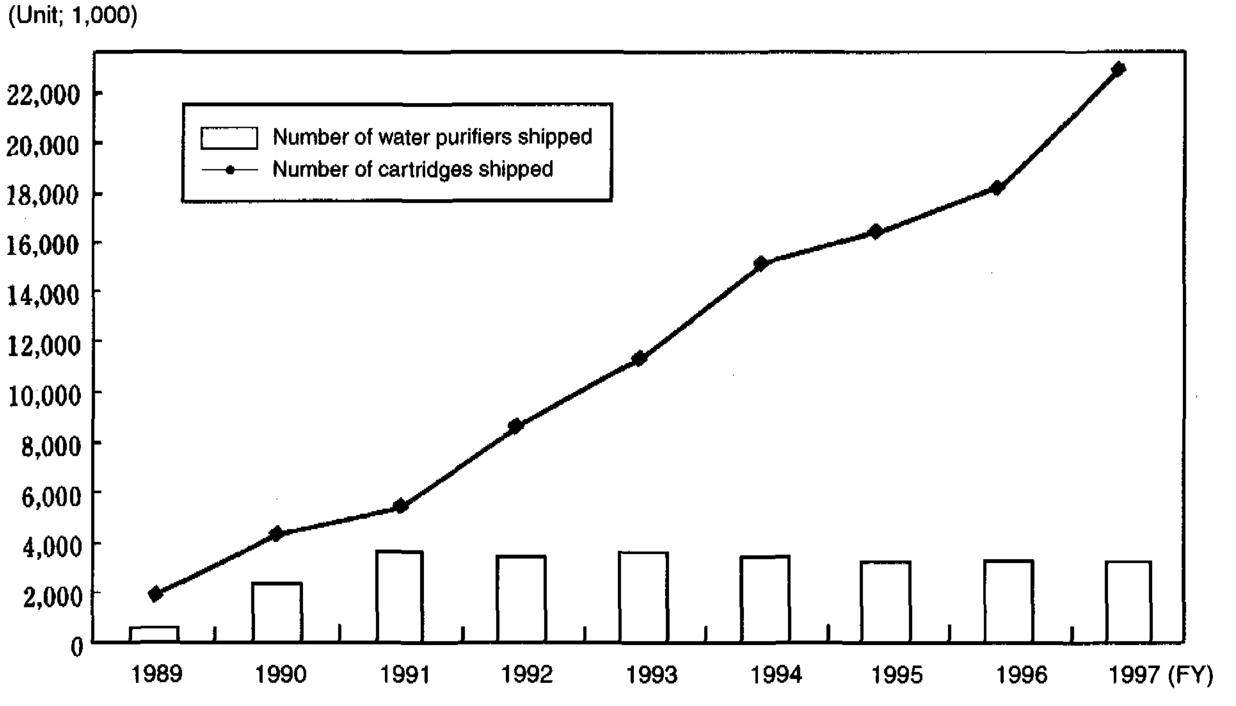


Notes: 1. Based on a study by the National Land Agency.
2. This covers years where water supply has reduced or terminated for 1978-1997.

Fig. 2-7 Number of Years Where Water Shortage Has Occurred

5. Water Resources and the Environment

- Spurred by an increasing interest in the quality of tap water, the annual production quantity of mineral water has sharply grown in recent years, and water purifiers have rapidly disseminated into households. (Fig. 2-8)



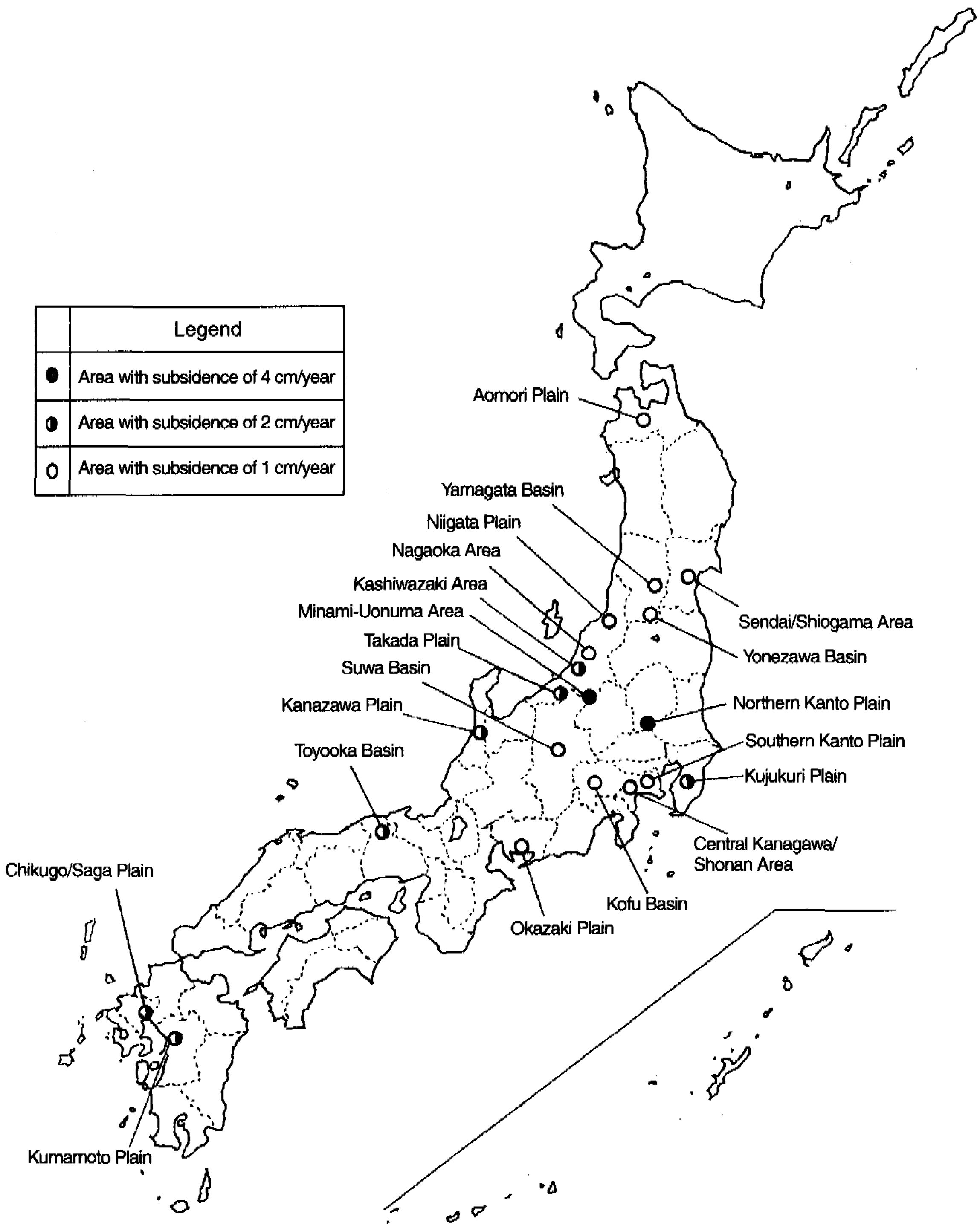
Note: Based on a study by the Japan Water Purifier Association.

Fig. 2-8 Changes in the Number of Water Purifiers and Cartridges Shipped

- To maintain appropriate water quality, various laws have been enacted. Since an incident of tap water infection with a pathogenic protozoan called cryptosporidium resistant to chlorine sterilization occurred in June 1996, "Guidelines on Tentative Countermeasures against Cryptosporidium in Tap Water" were formulated in October 1996, and studies are still continuing under the "Study Meetings on Countermeasures against Pathogenic Protozoans Including Cryptosporidium" and others.
- Chemical substances which are suspected to be endocrine disrupter chemicals (so-called "environmental hormone" disrupters) were detected in rivers and lakes. Since the relationship between concentration and adverse effects on human beings, effects on the ecosystem, etc. are not clear for such chemical substances suspected of being environmental hormone disrupters, relevant information must continue to be collected.

6. Preservation of Underground Water and its Appropriate Use

- In fiscal 1996, regarding the state of land subsidence in the country, there were 20 areas with land subsidence of one or more centimeters in a year (9 areas, a total of 258 km^2, with two or more centimeters of land subsidence). (Fig. 2-9)



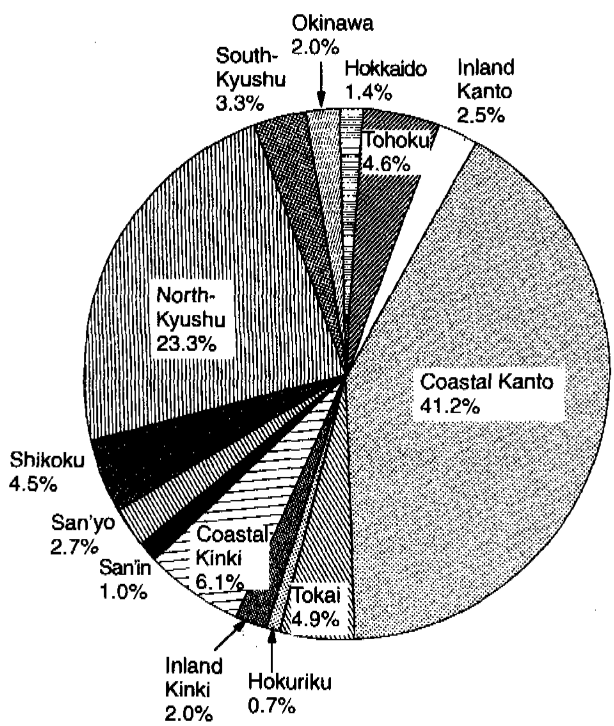
Notes: 1. Based on Outline State of Subsidence across the Country (Environment Agency).
2. The figures are based on recently measured maximum annual subsidence at benchmarks for each area.
3. Areas where the causes of subsidence are unclear are exluded.

Fig. 2-9 State of Subsidence in the Country (for Fiscal 1996)

- Concerning the maintenance of appropriate water quality, surveys conducted in fiscal 1996 revealed that water from some wells could not achieve the water quality standard in terms of six substances including trichloroethylene.

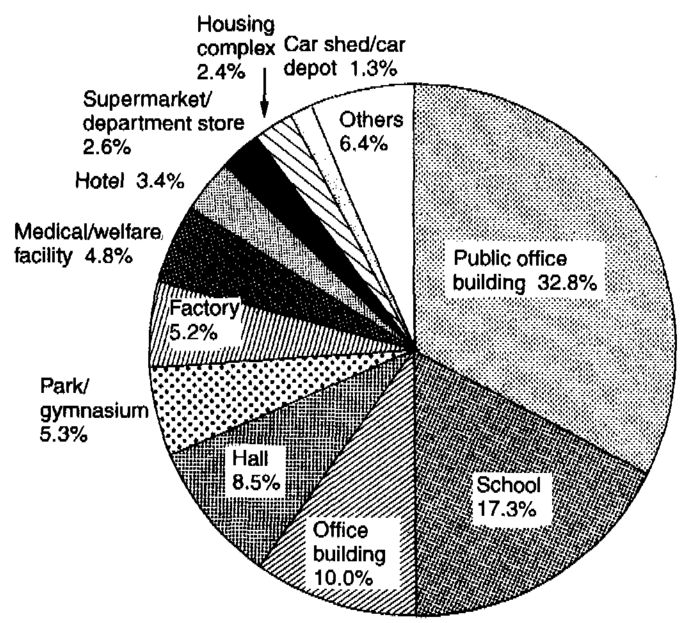
7. Efficient Use of Water Resources

- As of the end of fiscal 1996, water for miscellaneous purposes is used by about 2,100 facilities in the country: about 324,000 m^3 in total per day. This amount is equivalent to about 0.8% of the total quantity of water for domestic/business use.
- By region, the quantity of water for miscellaneous purposes used in the coastal areas of the Kanto region and North-Kyushu region accounts for a majority of the total quantity used in the country. (Fig. 2-10)
- By facility, the use of water for miscellaneous purposes at public office buildings, schools and office buildings accounts for about 60% of total use. (Fig. 2-11)



Note: Based on a study by the National Land Agency.
(as of the end of fiscal 1996)

Fig. 2-10 Conditions of Use of Water for Miscellaneous Purposes by Region



Note: Based on a study by the National Land Agency.
(as of the end of fiscal 1996)

Fig. 2-11 Conditions of Use of Water for Miscellaneous Purposes by Facility

8. Enhancement of Measures for Reservoir Areas

- For the Special Land Holding Tax exemption implemented in fiscal 1996 applicable to manufacturing industries and hotel enterprises located within reservoir areas, the term of validity for the exemption was extended in fiscal 1998.

9. Activities Related to Water Resources in Fiscal 1997

- Establishment of action plans for measures to reduce costs of public works
- Trial implementation of the flexible operation method for dams
- Comprehensive inspection of dam projects
- Organization of the fifth symposium on water resources
- Introduction of a system for reevaluating public works
- Recommendations in a report titled "Constructing a Society Using Sustainable Water Resources in the 21st Century" produced by the Water Resource Fundamental Problem Study Group
- Decision on a new Comprehensive National Development Plan

10. Issues and Policies concerning Water Resources (Creation of Sound Water Circulation System)

- Improvement of security at times of water shortage
  1) Ensuring an appropriate level of safety
  2) Promotion of countermeasures against abnormal water shortage
- Planned development of water resources
  1) Development of water resources to ensure the basic supply capability
  2) Appropriate utilization of underground water and enhancement of extensive management
  3) Use of treated sewage water, etc. for recycled water resources
  4) Introduction of sea water desalination facilities
- Efficient utilization of existing water resource development facilities, etc.
- Effective utilization of water resources and demand-supply adjustment
- Risk management for water resources
  1) Comprehensive responses at times of water shortage
  2) Comprehensive responses at times of earthquakes, incidences of aggravation of water quality, etc.
- Preservation and maintenance of the water environment
- Reevaluation of cultural functions of water
- Comprehensive water management

11. Water Resource Topics

Water Resource Topic 1

Trend of the Amount of Potential Water Resources

The amount of potential water resources is an indicator that is calculated by the National Land Agency so that the Agency may determine the amount of water resources to be developed based on precipitation and its trend. The total land of Japan is divided into several regions, and for each region, the amount of potential water resources is obtained by multiplying the value calculated by deducting evaporation from precipitation by the land area of each region. The amount of potential water resources in the country is obtained by adding up the amounts for each region. Since the amount of potential water resources includes the amount of rainwater that quickly flows into the sea, it does not necessarily indicate the total amount of potential water resources to be developed in Japan, but is a useful yardstick.

Since the amount of potential water resources is the aggregate of unique values for each region which occur at a certain frequency (for example, once in 10 years, etc.) as a yardstick, it will not necessarily decrease even if a record low precipitation is registered. Thus, the amount of potential water resources shows the trend of precipitation during a period for which aggregation is made. The estimation by the National Land Agency revealed the following: when the amounts of potential water resources which occur at certain frequencies (once in 20 years, once in 10 years, once in 7 years, once in 5 years and once in 4 years) within 20-year periods starting from 1956, 1961, 1966, 1971 and 1976 are compared, *the amount of potential water resources which occurred once in 10 years in a 20-year period starting from 1956 occurs more frequently in later 20-year periods.* (See Fig. 2-2)

The amount of potential water resources by region is following the same trend.

Factors for Increasing the Water Recovery Rate

After a significant increase in 1965 and later years, the water recovery rate leveled off around 1980 but thereafter continued to increase very slightly up until now. Many people have cited various reasons for an increase in water recovery rate. Here, we consider how the water recovery rate has changed due to each of the following three factors.

① Measures for underground water as the first factor

Although underground water is a valuable water resource, if the amount of underground water taken exceeds the rechargeable level, the groundwater level will fall, leading to various groundwater problems. Therefore, regulations are imposed under the Industrial Water Law and the Guidelines on Measures for the Prevention of Land Subsidence, etc. *In the areas for which these regulations are imposed, the recycling of industrial water is being promoted in response to regulations on the exploitation of underground water, etc.*

For example, in industrial zones (classification according to industrial statistics: the same for the remaining part) within the areas for which regulations on the exploitation of underground water are imposed under the Industrial Water Law and the areas for which the Guidelines on Measures for the Prevention of Land Subsidence, etc. are imposed, the average water recovery rate in 1995 was 82.4%, some 5.2% higher than the national average (77.2%).

② Countermeasures against water shortage as the second factor

Water shortages have occurred mainly in regions with insufficient supply of water. Since industrial production will be significantly affected if the use of industrial water is curbed due to a water shortage, *the recycling of industrial water is being promoted more in regions that are more at risk of water shortages than in other regions.*

For example, in industrial zones within the areas prone to water shortages (those areas where failure of water supply or reduced water supply occurred in six years or more from 1977 to 1996), the water recovery rate in 1995 was 83.3%, some 6.1% higher than the national average. In industrial zones where water shortages occurred in eight years or more, the water recovery rate was 85.7%, 8.5% higher than the national average.

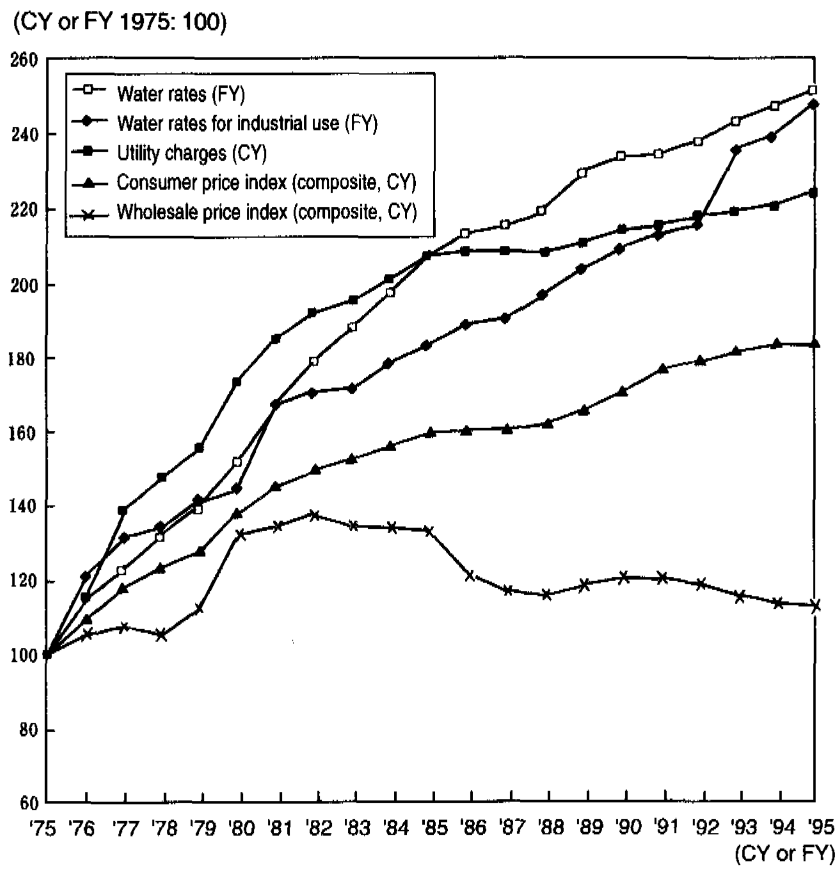
③ Effluent control as the third factor

Factory effluent is controlled under the Water Pollution Control Law. In many regions, regulations are more stringent than those stipulated in the law, in accordance with additional regulations stipulated in the same law, etc. Depending on regions or industrial categories, regulations for effluent are becoming more stringent as effluent increases. In some regions, the total amount of effluent has been reduced in accordance with the total effluent reduction scheme as stipulated in Article 4.3 of the law. Therefore, it is estimated that in these regions, *the recycled use of effluent is being promoted more strongly to reduce the amount of effluent than in other regions.*

For example, in industrial zones where the total effluent reduction scheme as stipulated in Article 4.3 of the Water Pollution Control Law is applied, the water recovery rate in 1995 was 85.4%, 8.2% higher than the national average.

Comparison of Water Rates and Commodity Prices, and the Ratio of Water Rates to Consumer Expenditure, etc.

A comparison shows that the consumer price index, wholesale price index, utility charges, water rates and water rates for industrial use in 1995 are 1.81 times, 1.10 times, 2.21 times, 2.48 times and 2.45 times those in 1975 respectively. (Fig. 2-12)



Notes: Composite figures are used for the consumer price index and wholesale price index.

Fig. 2-12 Changes in Water Rates, Water Rates for Industrial Use, etc.

The ratio of water rate to the average monthly figure of gross consumer expenditure (household spending) was 0.6% in fiscal 1995, and the ratio has remained almost the same in the last 20 years. (Table 2-1) *The ratio of water rate (for public water supply, small water supply system and industrial water works) to industrial production was 0.15% in 1995,* which is higher than the ratio in 1980 (0.10%). By industry, the ratio of water rate to industrial production is comparatively high at 0.33% for chemical products and 0.32% for food products. (Table 2-2)

Table 2-1 Ratio of Water Rate to the Average Monthly Figure of Gross Consumer Expenditure

(All households in cities with population of 50,000 or more)

Item \ FY	1975	1980	1985	1990	1991	1992	1993	1994	1995
Gross consumer expenditure (in yen)	160,475	234,946	278,592	317,289	332,898	339,224	339,480	338,507	334,069
Water rate (in yen)	831	1,294	1,802	2,057	2,071	2,108	2,190	2,187	2,130
Ratio (%)	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Notes:
1. Based on "Water Supply Statistics" by the Ministry of Health and Welfare.
2. The water rate is calculated based on Water Supply Statistics. Gross consumer expenditure is based on the Annual Report on Family Income and Expenditure Survey by the Statistics Bureau, Management and Coordination Agency.

Table 2-2 Ratio of Water Cost to Industrial Production

(%)

	1980	1985	1990	1995
Food	0.176	0.278	0.291	0.324
Textile products	0.061	0.152	0.149	0.181
Wood, wood products and furniture	0.040	0.083	0.085	0.091
Pulp, paper and paper products	0.204	0.168	0.234	0.287
Publishing and printing	0.011	0.016	0.015	0.016
Chemical products	0.285	0.291	0.281	0.334
Petroleum and coal products	0.057	0.087	0.064	0.079
Plastic products	0.043	0.085	0.074	0.081
Rubber products	0.023	0.049	0.082	0.094
Ceramic, stone and clay products	0.158	0.172	0.159	0.177
Steel	0.074	0.148	0.139	0.177
Non-ferrous metal products	0.097	0.123	0.118	0.134
Metal products	0.071	0.092	0.089	0.097
Industrial machinery	0.095	0.095	0.078	0.083
Electrical machinery	0.056	0.070	0.058	0.070
Transportation equipment	0.042	0.058	0.042	0.047
Precision instrument	0.104	0.168	0.146	0.164
Other manufacturing products	0.074	0.105	0.078	0.083
Total of manufacturing industries	0.103	0.136	0.126	0.147

Notes:
1. For 1980, 1985 and 1990, the 1980-1985-1990 linked input-output tables were used, and for 1995, the updated nationwide I-O table was used.
2. Water cost is the total of costs for public water, small water and industrial water supply undertakings. Water cost does not include costs borne by factories which occur at the time of taking water, recycling and discharging waste water.
3. Industrial classification is based on the aggregated sector classification table (47 sectors) in the updated nationwide I-O table, so the industrial classification does not correspond with the major groups in the Census of Manufacturers.

Procurement of Water in Case of a Large-Scale Earthquake

The quantity of water needed by disaster-stricken inhabitants and businesses when a large earthquake strikes will increase and the use of water will change over time. The Water Supply Bureau of Kobe city has compiled a report on the conditions after the Great Hanshin Awaji Earthquake struck. According to the report, demand for drinking water rose immediately after the earthquake; in the second week demand for taking a bath increased; and in the third week demand for the supply of tap water increased for making daily life more comfortable or for starting business. By the fifth week, the patience of citizens and businesses had become almost exhausted. (Table 2-3)

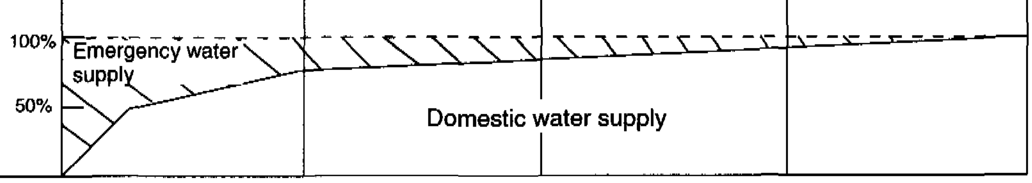
Table 2-3 Changes in Requests by Citizens/Businesses in Kobe City after the Great Hanshin Awaji Earthquake

Requests by citizens/businesses made by telephone (time series)					
		1st week (Jan. 18-24)	2nd week (Jan. 25-31)	3rd/4th week (Feb. 1-14)	5th week or later (Feb. 15-)
Inquiries from citizens	Prospects for the supply of tap water	*Prospects for the restart of tap water service*	*Please give us detailed* and accurate information. When can we use tap water?	*Detailed information is not* available. The city's public notices are not reaching us.	*Our patience is almost* exhausted.
	Emergency supply of water	Where and when can we expect water supply trucks? (Location and timing.) Water supply was required by dialysis hospitals.	Please give us a notice of water supply trucks (please send water supply trucks to nearby locations/ we don't know where water supply trucks are located). Please install water supply tanks at shelters (please increase the quantity and number of water supplies).	Water supply is not enough. (The quantity/ number of water supplies and timing of supply.) (Water is supplied at nearby locations.)	Transport by water tanks is burdensome. I'm tired.
	Leakage of water, etc.	Please halt the overflow of water. (Leakage of water was reported by many persons.)	I want to take a bath. (Leakage of water was reported by many persons.)	Please restart the supply of tap water, even though we were told that tap water cannot be resumed. (Leakage of water was reported by many persons.)	What are you doing about my repeated requests? (Leakage of water was reported by many persons.)
Key words		Wanting to know	Frustration	Anxiety and impatience	Anger and intense grief
Inquiries from businesses	Manufacturing industries	Needed for the supply of foodstuffs. Needed for the supply of materials for rehabilitation (ready mixed concrete/steel).	Where should we send our tank trucks to pick up water?	We would like to restart our business (liquor industry, etc.). We need water even if it costs.	
	Service industries	We need water for our cold stores (perishable foods). Water should be provided to banks.	Water is needed for rehabilitation workers when they stay overnight (hotels, etc.). Water should be provided to public baths.	We want to restart our business.	
	General	We need water for rehabilitation work.	Please inform the prospects for the supply of tap water because we want to restart our business (employment and production plans).	We need water soon. Please give us a specific schedule for restarting the supply of tap water.	We will lose our customers; this is a matter of life or death.

Note: Materials compiled by the Water Supply Bureau of Kobe city.

Based on the lessons and requests from citizens and businesses after the Great Hanshin Awaji Earthquake, the Water Supply Bureau of Kobe city established a *"Plan to Improve the Seismic Resistance of Water Supply Facilities of Kobe City"*. The plan aims to improve the seismic resistance of all water supply facilities so that emergency rehabilitation works may be completed within four weeks after a large earthquake similar to the Great Hanshin Awaji Earthquake, and sets four-stage targets for emergency water supply and rehabilitation works. (Table 2-4)

Table 2-4 Procurement of Water after a Large Earthquake (Plan to Improve the Seismic Resistance of Water Supply Facilities of Kobe City)

Phase Number of days after earthquake	Phase-1 within 3 days	Phase-2 within 10 days	Phase-3 within 21 days	Phase-4 within 28 days
Target water quantity	3 *l*/day-person	20 *l*/day-person	100 *l*/day-person	250 *l*/day-person
Recovery rate for domestic water supply				

Note: Prepared based on materials of the Water Supply Bureau of Kobe city.

The contents of the *Shizuoka Prefecture Regional Disaster Prevention Plan,* assuming a Tokai earthquake (magnitude 8), are as follows: within three days after an earthquake, inhabitants use water stored in their homes; for the fourth day to seventh day, drinking water is procured through the supply of water by voluntary disaster prevention units and emergency water supply by municipalities; for the eighth day and thereafter, some sort of assistance in the supply of water is assumed to be given by prefectural and national governments, etc. (Table 2-5)

Table 2-5 Procurement of Water after a Large Earthquake (Shizuoka Prefecture Regional Disaster Prevention Plan)

Number of days after earthquake	within 3 days	4-7 days	8-30 days	After 30 days
Needed quantity of water	3 *l*/day-person	3-20 *l*/day-person	20-100 *l*/day-person	100 *l*-quantity(*l*) of water before disaster/day-person
Means to procure water	Stocks of water	Emergency water supply by voluntary disaster prevention units and municipalities	Establishment of provisional common tapes, wells, spring water, etc.	Emergency rehabilitation of fresh water facilities

Note: Prepared based on materials of Shizuoka prefectural government.

Types of Water Purifiers

Water purifiers are based on various principles such as the activated carbon method, filtration film method, ceramic method, and so forth.

The activated carbon method exploits the property of activated carbon to absorb odors, etc. This method is suitable for eliminating chlorine, organic materials, etc.

In the filtration film method, water is passed through a film with micropores to remove impurities. In this method, performance depends on the size of the micropores. In water purifiers, a bundle of films of several hundred or thousand with holes of 0.01-0.4 micron (hollow fiber film) are generally used. This method is suitable for removing bacteria, iron rust, impurities, etc.

The filtration film method uses hollow fiber films, or a reverse osmosis membrane which allows only molecules of 0.0001-0.0002 micron to pass through. Although the latter method can supplement the removal property of the activated carbon or hollow fiber film method, filtration is impossible unless large pressure is applied to water.

Thus, the majority of water purifiers sold now use activated carbon as well as hollow fiber film. Chlorine, organic materials, etc. are removed by activated carbon and then bacteria, iron rust, impurities, etc. are removed by hollow fiber films. (Fig. 2-13)

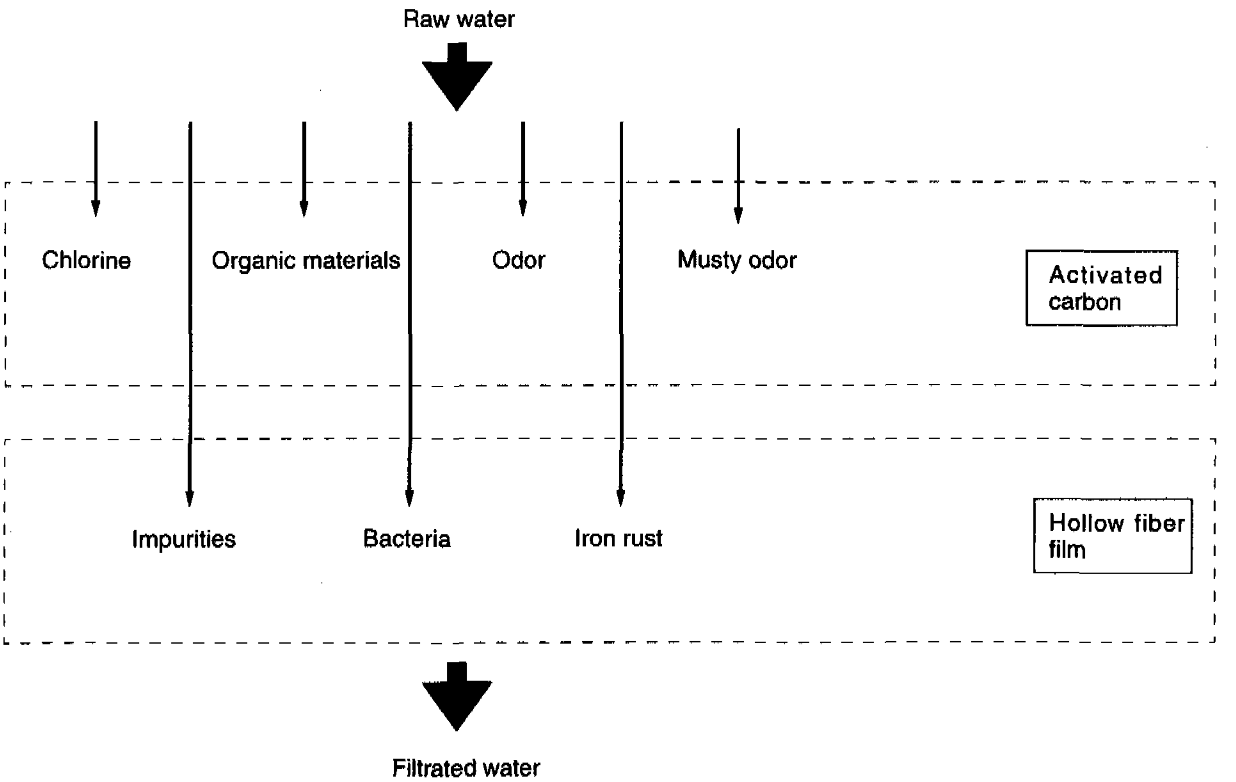
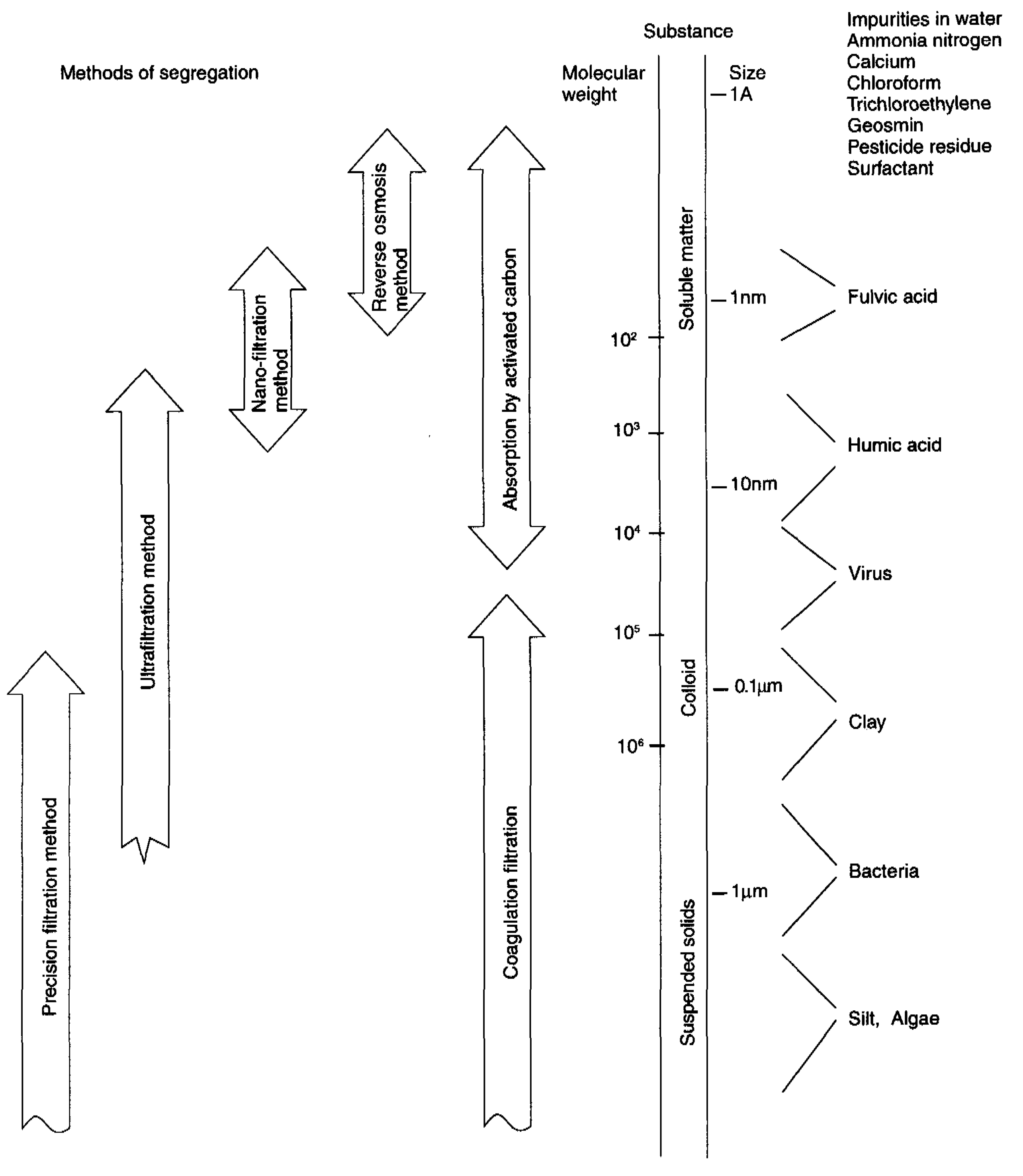


Fig. 2-13 Function of Water Purifiers Using both Activated Carbon and Hollow Fiber Film



Note: According to the film classification based on the size of the particles to be segregated, hollow fiber films used in water purifiers correspond to ultrafiltration film or precision filtration film.

Source: Guidelines on Introduction of Film Filtration Facilities for Small-Scale Water Supplies November, 1994, Water Purification Process Association

Fig. 2-14 Size of Impurities in Water and Methods of Segregation

Examples of Groundwater Management Plan

Groundwater management to prevent land subsidence through ordinances restraining the pumping-up of groundwater, or through artificial recharging of groundwater, to preserve or restore spring water, etc. is implemented in many locations in the country. However, there are very few examples of comprehensive and extensive groundwater management covering two aspects of quality and quantity, and focusing on the appropriate and reasonable use of groundwater, preservation of the quality of water and the recharging of groundwater.

This section introduces the "Comprehensive Preservation & Management Plan for Groundwater in the Kumamoto Area" which was drawn up by Kumamoto prefectural government and Kumamoto city office with the cooperation of related municipalities and organizations.

In the Kumamoto area (Kumamoto city and neighboring 15 municipalities) with a population of 900,000 which is about half of the total population of Kumamoto prefecture, almost 100% of domestic/business water is supplied by groundwater and larger quantities of groundwater are used for industrial purposes. With the aim of securing the groundwater environment for the long term and ensuring a good regional environment by establishing a sound water circulation in the region, the Comprehensive Preservation & Management Plan for Groundwater, which includes numerical targets for the recharging quantity, the quantity to be pumped up and the quality of groundwater, was established in March 1996.

The Comprehensive Preservation & Management Plan for Groundwater in the Kumamoto Area defines the following three measures to achieve the above targets: 1) measures to preserve the quantity of groundwater, 2) measures to preserve the quality of groundwater, and 3) measures to monitor the groundwater level. In particular, the following measures have been already implemented or are now being examined, in addition to existing schemes.

- A subsidy scheme for establishing infiltration inlets by households (since fiscal 1997)
- Introduction of the subsidy scheme for establishing infiltration facilities around vinyl hothouses (Kumamoto city, since fiscal 1992)
- Implementation of recharging experiments using paddy field in the winter (since fiscal 1996)
- Introduction of a loan scheme for establishing groundwater use rationalization facilities (Kumamoto city, since fiscal 1991)
- Subsidies for improving forests (since fiscal 1991), establishing infiltration inlets (since fiscal 1997) and establishing consolidated private sewage treatment tanks (since fiscal 1991), provided by the Kumamoto Ground Water Fund founded by Kumamoto city office as a main partner in fiscal 1990
- Deliberations on the upstream area support system which is based on the "beneficiaries

(of groundwater) pay principle" (since fiscal 1997)

Directives for preserving groundwater are expected to be compiled to provide regulations for development activities, etc. in the recharging areas. Based on the directives, guidelines on development activities, etc. are to be established in fiscal 1998.

Use of Water for Miscellaneous Purposes in Case of Disaster

Facilities for using water for miscellaneous purposes are generally established to help reduce the use of fresh water as a countermeasure against water shortages. Since such water is available to some degree even when the supply of tap water is suspended due to a disaster and stored water may be used for fire-fighting, efforts have begun to establish new facilities for using water for miscellaneous purposes in order to meet the needs for fire-fighting, too.

■ An example of Sumida-ward, Tokyo

The Sumida ward office of Tokyo has made efforts to utilize rainwater for urban fire-fighting, in addition to procuring its own water resources, preventing city flooding and restoring the regional water cycle. The use of rainwater stored at "ROJISON" is a typical sample of these efforts. "ROJISON" is a symbol of safety for the streets; "ROJISON" is a rainwater tank with the capacity of 3 to 20 m^3 which collects water from the roofs of neighboring houses. Such rainwater is usually used to grow plants and for fire-fighting water or drinking water in an emergency. Since its introduction in 1988, twelve "ROJISON" have been installed in Mukojima and Kyojima areas in Sumida ward.

Photo 2-1 "ROJISON", Water Tank Installed on a Street

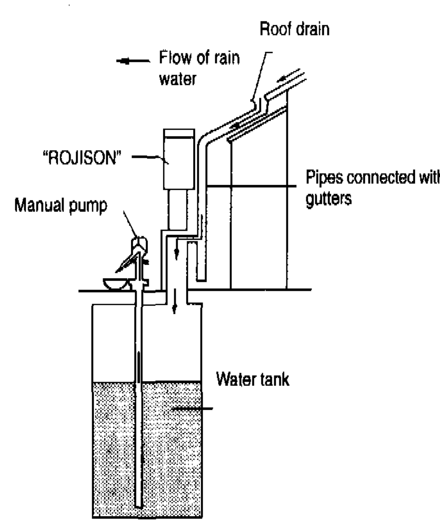


Fig. 2-15 The Structure of "ROJISON"

■ An example of Kobe city

In Kobe city, water kept in the swimming pools of schools used as shelters was used as flush water after the Great Hanshin Awaji Earthquake. Based on this and other experience, Kobe city has begun to establish facilities for using water for miscellaneous purposes when rehabilitating elementary or junior high schools damaged by the earthquake. In particular, swimming pools are being built on the roof, and water tanks installed on the roof or beneath class rooms, etc. in order to store rainfall from the roof. Usually, water stored in water tanks is used as flush water, etc. In case of a disaster, water stored on the roof will be used for fire-fighting and flush water in case of a power failure immediately after a disaster.

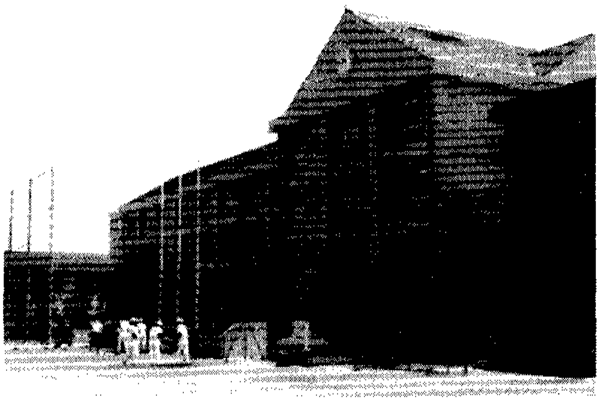


Photo 2-2 Overview of Tobimatsu Junior-High School Established by Kobe City

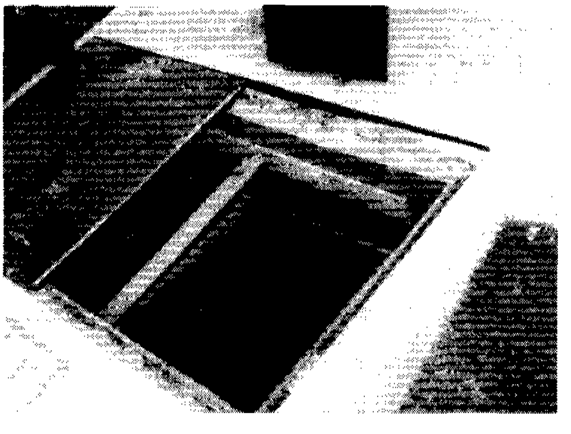


Photo 2-3 Underground Tank for Water for Miscellaneous Purposes

Promotion of Exchanges and Partnerships between Inhabitants of Upstream and Downstream Regions

—Oyama Town, Oita Prefecture—

The new Comprehensive National Development Plan encourages development of national land and regions through "participation and coordination", and exchanges and partnerships between inhabitants of upstream and downstream regions should be promoted in order to preserve and restore a healthy water cycle.

This section introduces the "Oyama Life Consulate in Fukuoka" of Oyama town of Oita prefecture as an example of promoting exchanges and partnerships between inhabitants of water resources and water utilization areas.

■ *In Oyama town of Oita prefecture where the Oyama dam is being constructed to supply water to urban areas in Fukuoka prefecture, work has started to develop "water relationships" as in the case of territorial or blood relationships, utilizing the construction of the dam as a good opportunity. Thus, the town has worked to create an extensive community involving urban areas in Fukuoka prefecture. The town is creating a new design for lives to help build partnerships through mutual exchanges between inhabitants of the upstream and the downstream regions of the Chikugo River, between urban and rural areas, and between Oyama town office and Fukuoka city office, instead of promoting town development only within the town.*

As a part of town development, the *"Oyama Life Consulate in Fukuoka"*— a cultural center to help provide non-urban amenities for the citizens of Fukuoka city or an urban exchange facility to help create non-rural enjoyment for the inhabitants for Oyama town—started providing services on April 23, 1998 at Atagohama (nicknamed "Marina Town"), Nishi-ward, Fukuoka city in order to *distribute information from Oyama town to downstream areas and promote exchanges between upstream and downstream areas.*

The Oyama town office plans to develop *the "Oyama Life Consulate in Fukuoka" into a facility with the following functions. This will enable the inhabitants of Oyama town and the citizens of Fukuoka city to share in the nature and culture around them, and build their future beyond that of a "specialist shop."*

- A function as a restaurant where visitors can enjoy rural or urban dishes in season and various food cultures.
- A communication function where citizens of Fukuoka city and inhabitants of Oyama town may develop mutual understanding and enrich their lives.

- A function as a market or bazaar where fresh vegetables and processed fruit from Oyama town are directly sold to citizens and other products or services are sold or provided.

Photo 2-4 The "Oyama Life Consulate in Fukuoka" Which Started Service in April 1998

Current State of Water Resources in the World

In every corner of the world, water is used for daily lives or economic activities. According to a report of the United Nations, the flow of water of rivers, etc. is about 43 trillion m^3 a year, obtained by excluding evaporation and the quantity absorbed by plants from rainfall on land areas on earth. *The flow of water per person in the world totaled about 7,000 m^3 in 1995, which was a 40% decline compared with the level of 1970 due to an increase in global population.*

The flow of water of rivers, etc. is generated by a limited number of rivers. For example, the Amazon River accounts for 16% of the world's total flow of water, and the Zaire River in Congo accounts for one-third of the total flow of water in Africa. On the other hand, the flow of water in dry and quasi-dry regions which account for about 40% of the world's total land area accounts for just 2%. Thus, *water resources are unevenly distributed around the world.*

The flow of water per person is significantly affected not only by the flow of water of rivers, etc. but also by the population distribution. For example, the flow of water of the Asian Continent is the largest among all continents, but the flow of water per person is the smallest because of the large population.

Of the world's total water flow of rivers, etc. as mentioned above, the flow of water readily available for human beings is estimated to be about 9 trillion m^3 and water of 3.5 trillion m^3 is stored in dams, etc. In total, about 12.5 trillion m^3 of water is available for human beings.

According to the report, *half of this available water is already used by human beings. Since the world's population is expected to increase by 50% in the next fifty years and demand for water is also expected to increase due to economic growth and changes in lifestyles, the quantity of water will not be enough.*

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Date: 18 Aug 1998 17:12:00 +0900
Mime-Version: 1.0
From: 水資源調査室<mizcho@nla.go.jp>
Subject: NLA White Paper on Japan's water resourc
To: 中村　浩一郎<a753302@nla.go.jp>, 曽田　英揮<b753201@nla.go.jp>
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白書についての質問・意見を転送します。

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Date: 18 Aug 1998 18:53:00 +0900
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Subject: NLA White Paper on Japan's water resourc
To: mizcho@nla.go.jp <mizcho@nla.go.jp>
Content-Type: text/plain; charset=us-ascii
Content-Transfer-Encoding: 7bit

Dear Sir/Madam,

On the Water Online site (http://news.wateronline.com/industry-news/19980810-475.html) mention was made of the NLA White Paper on Japan's water resources. Is this report or a summary of its findings available in English? If so, we would appreciate receiving a copy.

I would like to mention it Source Water and Sanitation Weekly. SOURCE is a weekly news bulletin on water and sanitation produced by the Documentation Unit of the IRC International Water and Sanitation Centre. It is sent free of charge to subscribers by E-mail and will also be made available on IRC/s Web Page (http://www.irc.nl). SOURCE includes short news items, forthcoming events and courses, project updates, new publications and vacancies related to water and sanitation in developing countries, with an emphasis on rural and peri-urban areas.

Regards,

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