PART-C Water Master Plan

CHAPTER 1 OUTLINE OF WATER MASTER PLAN

1.1 Framework of Water M/P

(1) Target Year and Target Area of Plan

The target year of the Water M/P is the year of 2035, 25 years later from 2010. The target areas of the plan are 3 Regions: Al Baha Region, Asir Region and Jazan Region.

(2) Components of Water M/P

The contents of the Water M/P are as follows:

- ◆ Water Resources Development Plan
  - Conventional Water Resources (Surface Water, Shallow Groundwater and Deep Fossil Groundwater)
  - Non-conventional Water Resources (Desalinated Sea Water and Reclaimed Sewerage Water)
- ◆ Water Supply Plan for Municipal Water and Industrial Water
- ◆ Demand Management (Municipal Water, Industrial Water, Agricultural Water)
- ◆ Operation & Maintenance and Management Plan
  - Total Water Resources Management Plan
  - Monitoring Plan
  - Water Resources Conservation Plan
  - Capacity Building Plan
  - Organization and Management System
- ◆ Basic Design and Cost Estimate
- ◆ Implementation Schedule
- ◆ Evaluation of Proposed Water M/P

1.2 Water M/P of Planning Methods

It is decided upon the water M/P based on water policy/ strategy/action plan on water resource development in the southwest region in Part B of Chapter 5.

(1) Target Water Resources Development

Table C.1-1 shows the target water resources, development methods and users. As the deep fossil groundwater does not exist in the target area, the conventional water resources are all the renewable water resources available.

Table C.1-1 Target Water Resources, Development Methods and Users

Water Resources		Development Methods	Users
Conventional Water Resources	◆ Surface Water	• Storage by Dam & Reservoir • Direct Intake from Reservoir • Recharge Water from Reservoir	• Municipal Water • Industrial Water • Agricultural Water
	◆ Shallow Groundwater (Circulation Water)	• Pump up from Shallow Well	
	◆ Deep Fossil Groundwater	• Pump up from Deep Well	
Non-Conventional Water Resources	◆ Desalinated Sea Water	• Production by Desalinated Plant	• Municipal Water • Industrial Water
	◆ Reclaimed Wastewater	• Production by Sewerage Treatment Plant (Tertiary)	• Part of Municipal Water (Greening) • Part of Industrial Water • Agricultural Water

＜Conventional Water Resources Development＞

Target

Conventional water resources are classified into i) surface water, ii) shallow groundwater (within hydrological cycle), iii) and deep fossil groundwater. There is no deep-fossil groundwater in the target area. Therefore, surface water and shallow groundwater are targeted as new developments in renewable water resources.

Surface Water Development

The Method of surface water development is proposed, i) by dam reservoirs, ii) by combination of dam reservoirs and downstream aquifers, iii) and by recharge dams.

Developed surface water is used for both specified and unspecified water use. The specified use is for new (municipal and industrial) water supply projects and irrigation projects. On the other hand, unspecified use is for compensation to the users who will be affected by new water resources development. Generally, the priority of water allocation is given firstly to unspecified use and secondly (new) to specified use. Then, priority within unspecified use is given firstly to water supply and the secondly to irrigation use, as a general rule. Considering such situation, safety factor against drought is set at 97%, of which meaning is as follows:

Planned amount of water with 98% safety factor is defined: under this amount, 30% of water shortage will happen within 3 to 30 years, for which period water balance was analyzed. This water shortage will be compensated by a combination use of underground dams and downstream aquifers. At least, water supply will be secured against drought by the above method. However, it must be confirmed in the next step (F/S).

Shallow Groundwater Development

Groundwater has already been fully developed, and it is impossible to develop any more for municipal and irrigation use on a large scale. “Groundwater/surface water development by combination use of dam reservoir and downstream aquifer” and “groundwater development by recharge dam” is only options of groundwater development in large scale.

<Non-conventional Water Resources Development>

Non-conventional water resources are classified into desalination and sewage treatment.

Desalination.

According to water demand prediction and potential analysis of renewable water resources, it is necessary to continue and expand desalination projects to meet the water demand for municipal and industrial water use. Desalination water is stable and is not affected by annual climate fluctuation. However, it still costs more than renewable water. Therefore, transmission cost for desalination projects must be reduced by shortening of transmission routes.

Sewage Treatment

According to “Investigation and Engineering Design for Treated Wastewater Reuse in the Kingdom of Saudi Arabia” in 2009, projects for sewage treatment are newly planned in the target areas. Treated sewage generated by the above project is proposed to reuse for purposes below:

- Municipal and industrial use
- Irrigation use
- Measures against sea water intrusion (artificial recharge by treated sewage)

(2) Water Supply Plan

Based on water demand forecasting (OPTION-1) considered in section B of Chapter 3, planning examination of the maintenance plan for water supply plants were carried out.

This water demand forecasting (OPTION-1) has the "KSA" country government closed to the value that the Government considers as the target value (productive capacity including 20% of leakage of water) .

However, the amount demanded is deducted in consideration of the use (5% of a city water duty, and 30% of the amount of industrial water) of sewer resurgent water. Furthermore, a water service diffusion rate in large cities are 100% by 2020, 100% by 2035 in municipal areas (50% in 2010), 100% by 2035 in the district communities (40% in 2010).

Conventional water sources, such as dam, shallow groundwater and deep fossil water (Wajid Aquifer) are subjected to the main water sources, and water by desalinization of seawater is also subject to the main water source. The plan water supply of MOWE is used for the plan water supply of conventional type water sources.

The Red Sea water lifeline (alternative-1) selected in section B of Chapter 5 is considered as a water transportation route.

(3) Management of Water Demand

Municipal Water

In order to decrease the water consumption of municipal water on the demand side, the measure for water demand reduction according to the demand characteristic is examined.

Moreover, the economical effect produced by demand fluctuation is examined using the result of the sensitivity analysis concerning the demand of Municipal water. The evaluation case was carried out as follows.

- 10% reduction of the water supply source unit
- Demand by the present water supply unit
- A 5% improvement of the leakage-of-water rate.

In any case, the demand in the planned target year (2035) is assumed. Furthermore, the proposal about future demand management is performed based on these examination results.

Water for Agricultural Use

About the irrigation amount of water, the demand management amount of irrigation water is important. This is because the present water-resources potential is not enough.

From this viewpoint, in accordance with the plan Decision335 by MOA, crop conversion of fruit trees, which can be expected to increase in demand in neighboring towns, and vegetables with small unit water consumption from crops with large unit water consumption (e.g. feed crop, cereals) are important.

Moreover, irrigation use of sewer resurgent water should also be promoted. Based on these examinations, agriculture for each state will be proposed.

Management Control of Maintenance

The following matters are examined about the management control of maintenance for the exploitation of water resources.

- Comprehensive water management system (dam, Red Sea water lifeline, and an executive organization)
- The groundwater recharge by using dams (Cooperation with dam and aquifer in the downstream area, development of the groundwater which cooperated with recharge dam)
- Monitoring (rainfall , water level / discharge of Wadi , groundwater level)
- Conservation of water resources (surface water, groundwater)
- Establishment of organization and, operation and maintenance system
- Personnel training, capacity development
- The educational campaign for water use

CHAPTER 2 WATER RESOURCES DEVELOPMENT

2.1 Non-Conventional Water Resources Development

In the study area (Al Baha, Asir, and Jazan), though the renewable water resources (surface flow and groundwater) as conventional water resources exist, non-renewable water resources (fossil aquifer) do not exist. In the study area, many dams are in construction-completed status, or under construction. It was determined as construction completed or a promising large discharge dam was already under construction from the Google photograph interpretation and topographical map (1 / 50,000) survey by JICA Study Team. The Development of surface flow is carried out by such dams. On the groundwater aquifer, which can be developed as large municipal water and agriculture water, is already developed and large groundwater development is impossible using a dam other than groundwater recharge.

2.1.1 Development Methods of Renewable Water Resources

The following development methods of renewable water resources (surface water and shallow groundwater) are the most appropriate in the Target Area (Al Baha Region, Asir Region and Jazan Region).

Surface Water Development by Large Dam

For the purpose of water use, surface water is developed by large scaled dams and reservoirs with double or triple volume of annual discharge volumes. Reservoirs are continuously stored and used through the year. Developed water is conveyed to the consumer areas.

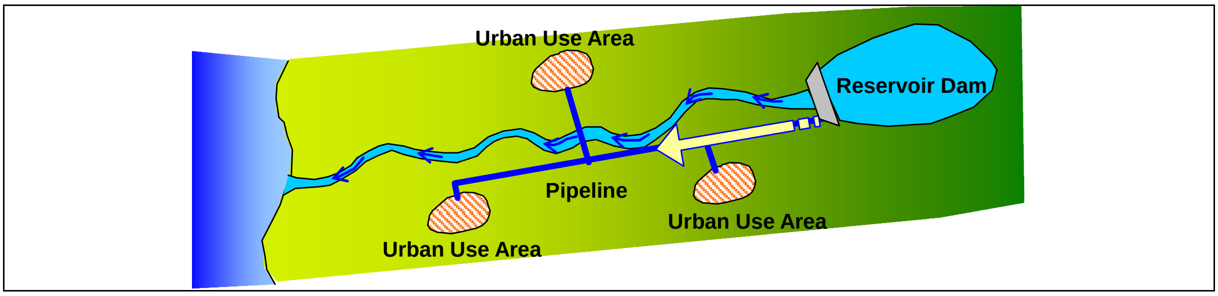


Figure C.2-1 Surface Water Development by Large Dam

Development of Surface Water and Groundwater by the Combination of Large Dams and Groundwater Aquifers

In case of small sized dams or limited annual flow regime at dam sites, surface water is recharged and stored in the groundwater aquifer to increase development volume. To increase recharge volume, recharge wells and trenches are employed.

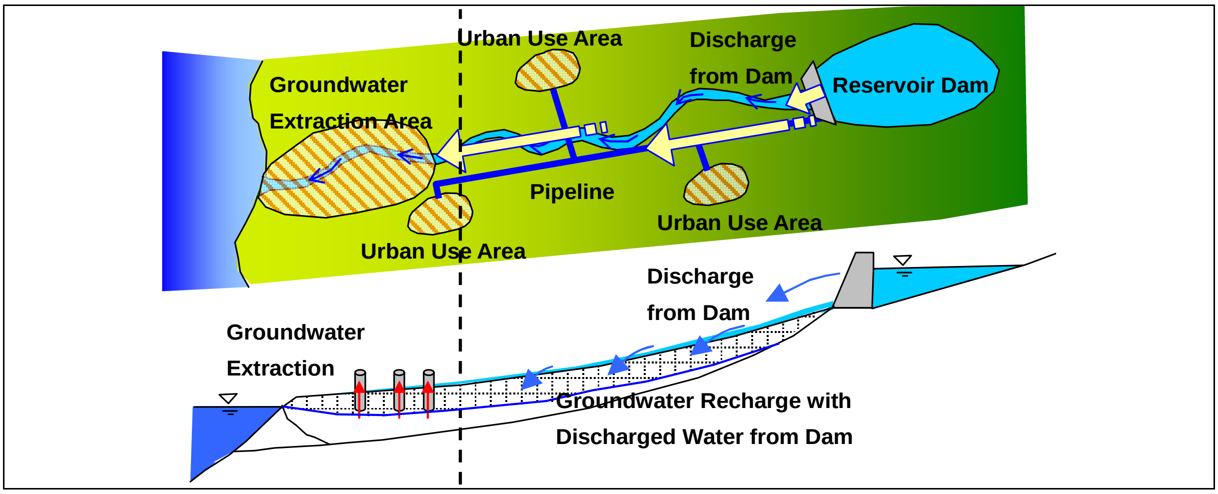


Figure C.2-2 Surface Water & Groundwater Development by Combination with Large Dam and Aquifer

<u>Groundwater Development by the Recharge Dams</u>

Recharge dams with facilities of natural discharge are constructed to increase recharge volume in the course of wadi by changing the flow patterns.

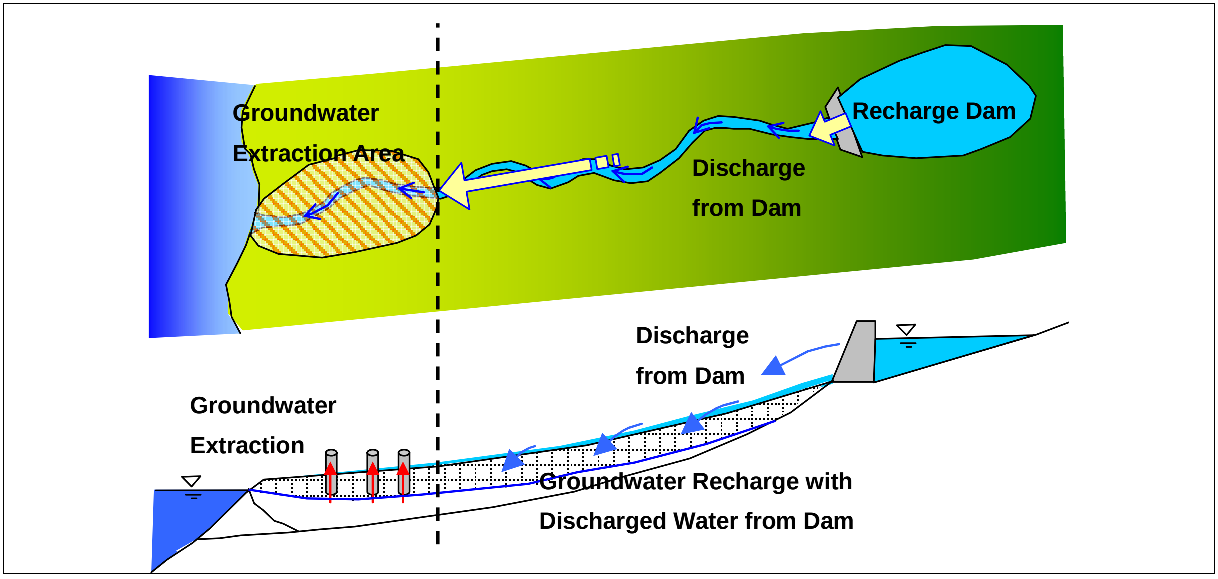


Figure C.2-3 Groundwater Development by the Recharge Dams

2.1.2 Target Development Discharge of Dam of Future Water Supply Plan and Irrigation Plan

The target dam of the future water supply plan of study areas and irrigation is as shown in Table C.2-1.

Table C.2-1 Target Dam of Future Water Supply Plan and Irrigation Plan Relevant to Three Regions

Region	Status	Name of Dam	Location of River	Catchment Area (km^2)	Annual Flow (MCM/y)	Reservoir Volume (MCM)	Specific Flow *1 (MCM/y/km^2)	Specific Reservoir Volume *2 (y)
Al Baha	U/C	Aradah	East(Desert)	304	15.2	68.0	0.050	4.5
Asir	Exi.	King Fahd	East(Desert)	7,600	69.1	325.0	0.009	4.7
Asir	U/C	Tabalah	East(Desert)	863	12.3	68.4	0.014	5.6
Asir	U/C	Ranyah	East(Desert)	4,375	99.6	219.8	0.023	2.2
Asir	U/C	Hirjab	East(Desert)	788	16.8	4.6	0.021	0.3
Jazan	Exi.	Jizan	West(Redsea)	1,317	78.9	51.0	0.060	0.6
Jazan	U/C	Baysh	West(Redsea)	4,600	104.6	193.6	0.023	1.9
Jazan	U/C	Damad	West(Redsea)	907	61.5	55.5	0.068	0.9
Makkah	U/C	Hali	West(Redsea)	4,843	122.3	249.9	0.025	2.0
Makkah	U/C	Qanunah	West(Redsea)	2,000	21.3	79.2	0.011	3.7
Makkah	U/C	Yiba	West(Redsea)	2,242	81.3	80.9	0.036	1.0
Total				29,839	682.9	1,395.9	0.023	2.0
		Total	East(Desert)	13,930	213.0	685.8	0.015	3.2
		Total	West(Redsea)	15,909	469.9	710.1	0.030	1.5

[Note] *1: Specific Flow=Annual Mean Flow / Catchment Area、*2: Specific Reservoir Volume =Reservoir Volume/ Annual Mean Flow

(1) Calculated Method Development Volumes

As shown in TableC.2-1, since the reservoir water volume of some dams has a dam which will be several times the volume of annual average inflow, development calculation is carried out as over year storage type dam and reservoir. The development flow (amount of water developed for water supply, irrigation, and unspecified use) by these dams is calculated in the following step. A Baysh dam and a Hali dam are shown as a calculation case. (Figure C.2-4 to Figure C.2-8 references)

Hydrologic Equation of Reservoir

The Hydrologic equation of reservoir is shown with the following method.

$$\Delta V(i) = V(i) - V(i-1)$$
$$= Qin(i) – Qsp(i) – E(i) – Qdv(i)$$

Here,

ΔV(i)	= The volume of change of the reservoir of Δt hours from time (i) to time (i-1)
V(i)	= Reservoir volume of time (i)
V(i-1)	= Reservoir volume of time (i-1)
Qin(i)	= The volume of inflow of the reservoir of Δt hours from time (i) to time (i-1)
Qsp(i)	= The volume of discharge of the spillway of Δt hours from time (i) to time (i-1)
E(i)	= The volume of evaporation of the reservoir of Δt hours from time (i) to time (i-1)
Qdv(i)	= The volume of development of Δt hours from time (i) to time (i-1)
Δt	= Calculation (unit of account: January)

Reservoir Volume

As effective reservoir volume of each dam is not available, 80% of the total reservoir volume is assumed.

Volume of Inflow to Reservoir

The calculation uses the monthly discharges that are simulated with daily rainfall data for 30 years (1975 - 2004)

Flow from Spillways

When the flow over the effective volume of a dam breaks out, the reservoir lower stream is stocked to spillways. Therefore, this discharge is excepted from the target for development.

Amount of Evaporation from Reservoir

Evaporation from the reservoir is obtained based on the daily evaporation rate (5 mm/day).

Scheme of a Development Flow

The development flow studied by the JICA Study Team shows a volume of specific water utilization, and a volume of non-specifying water utilization. The volume of specific water utilization is the volume of irrigation aiming at new water supply and irrigation. The volume of non-specifying water utilization is the existing groundwater utilization quantity of the dam lower stream. When such utilization quantity is repaired with new water supply flow or irrigation flow, the volume of non-specifying utilization serves as zero.

Safety of Development Discharge for Draught

The development volume is the case which some 70 % of the design development volume has occurred for three years in the calculation period of 30 years. Namely, (3 years x 70%＋27 years)/30years = 97% ∗ (97% of the total expected development volume). In addition, in the same way, another case: [(3 years x 70%＋27 years)/30years = 97%] is examined. Water shortage breaks out for three years, Though the amount of water running short by cooperation with the underground dam of the dam lower stream and groundwater recharge is securable, there is the necessity to check the detailed analysis.

(2) Calculated Result Development Volumes

The calculated development volumes of the main dams and dams planned for the water supply are tabulated in Table C.2-2 below. The table reveals as follows:

- Hali Dam, Baysh Dam and King Fahd Dam show large development volumes and high development ratios.
- On the contrary Tabalah Dam and Hirjab Dam show small development volumes and low development ratios.
- Dams having larger reservoir volume compared with annual flow volumes show higher development ratios. (Development Volume / Annual Flow Volume)
- Due to good annual flow regime, dams in the west side (Red Sea side) basins show higher development volume than dams in the east side basins.

Table C.2-2 Development Discharge of Main Dams for Three Regions

Name of Dam	Location of River	Annual Flow (MCM/y)	Reservoir Volume (MCM)	Development Safe 97%*1			Development Safe95%*2		
				Development Discharge (MCM/y)	Development Volume (1000m^3/d)	Development Ratio*3 (α)	Development Discharge (MCM/y)	Development Volume (1000m^3/d)	Development Ratio *3 (α)
Aradah	East(Desert)	15.2	68.0	6.7	18	44%	7.5	21	49%
King Fahd	East(Desert)	69.1	325.0	55.3	152	80%	57.3	157	83%
Tabalah	East(Desert)	12.3	68.4	3.6	10	29%	3.8	11	31%
Ranyah	East(Desert)	99.6	219.8	32.9	90	33%	37.9	104	38%
Hirjab	East(Desert)	16.8	4.6	3.4	9	20%	4.4	12	26%
Jazan	West(Redsea)	78.9	51.0	23.7	65	30%	25.2	69	32%
Baysh	West(Redsea)	104.6	193.6	73.2	201	70%	90.0	247	86%
Damad	West(Redsea)	61.5	55.5	24.0	66	39%	25.8	71	42%
Hali	West(Redsea)	122.3	249.9	97.8	268	80%	104.0	285	85%
Qanunah	West(Redsea)	21.3	79.2	6.4	18	30%	7.4	20	35%
Yiba	West(Redsea)	81.3	80.9	24.4	67	30%	26.0	71	32%
Total		682.9	1,395.9	351.4	964	51%	389.3	1,068	57%
Total	East(Desert)	213.0	685.8	101.9	279	48%	110.9	305	52%
Total	West(Redsea)	469.9	710.1	249.5	685	53%	278.4	763	59%

[Note] *1:Development Safe97%=30% of development volume is insufficient once in 10 years、*2:Development Safe 95%=50% of development volume is insufficient once in 10 years、*3:Development Rate(α)=Development Volume/Annual Flow

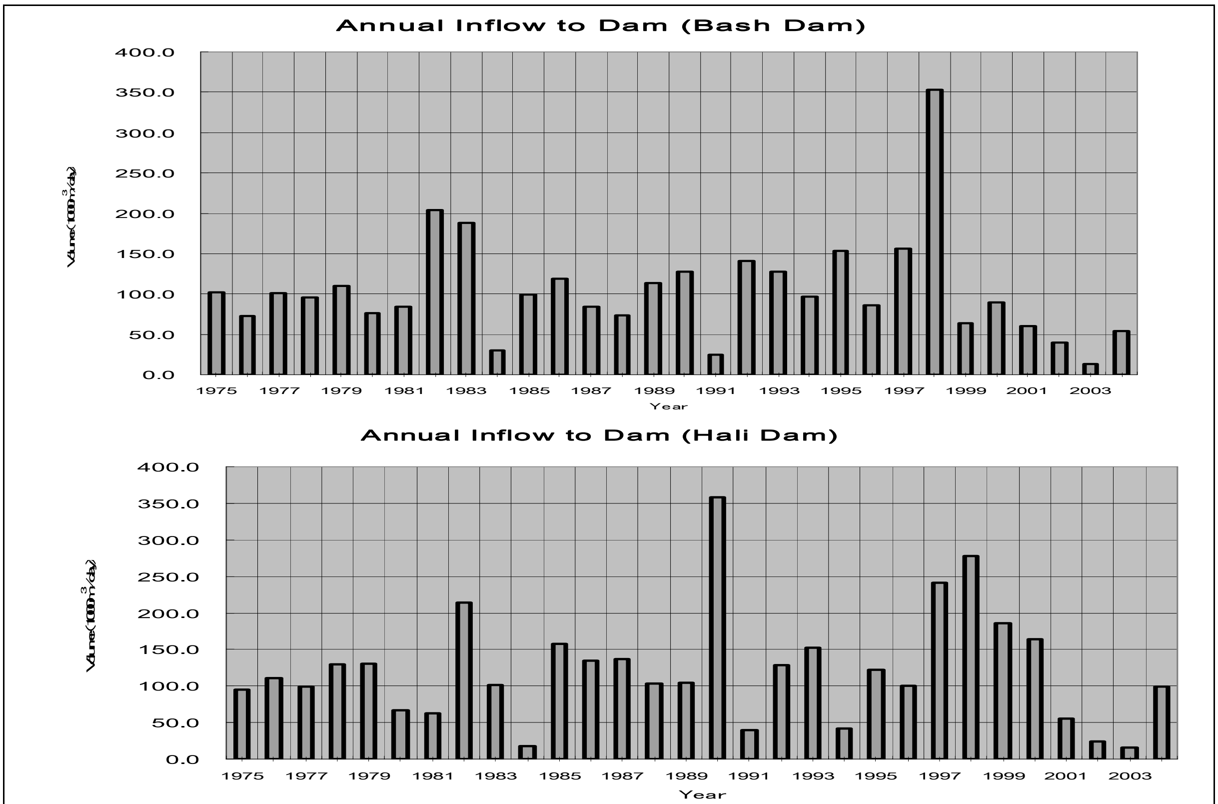


Figure C.2-4 Annual Inflow to Dam (Baysh Dam and Hali Dam)

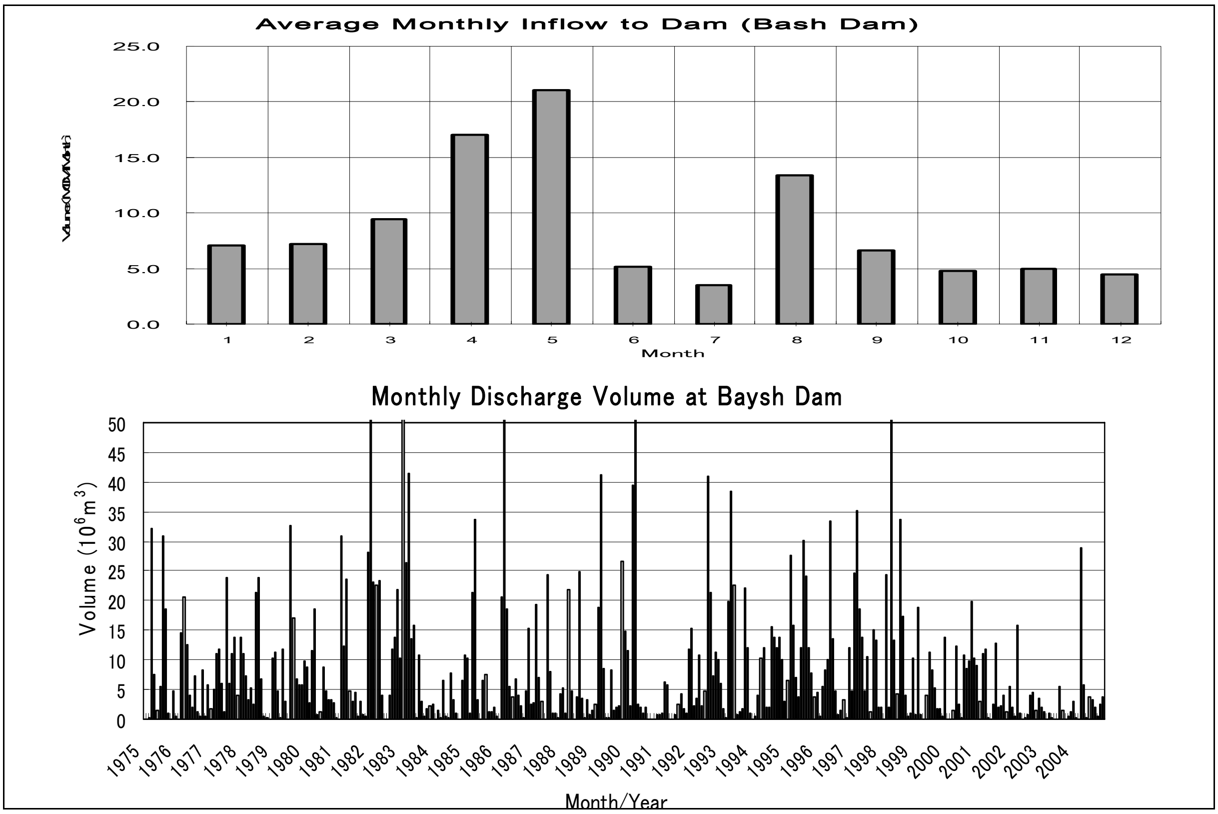


Figure C.2-5 Monthly Discharge Volume to Dam (Baysh Dam)

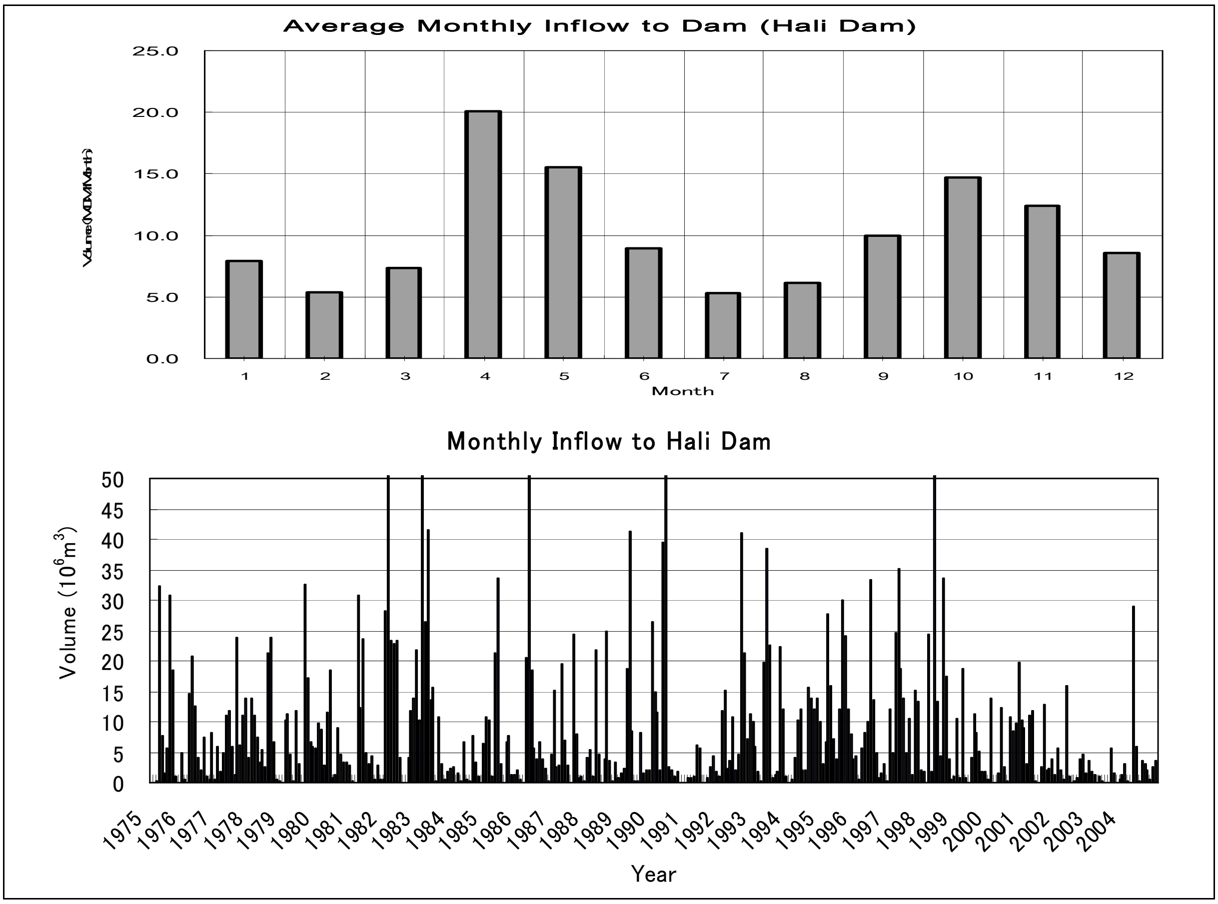


Figure C.2-6 Monthly Discharge Volume to Dam (Hali Dam)

<Baysh Dam>

	Annual Inflow	Design Development Volume	Actual Development Volume	Evaporation Volume	Water from Spill Way
Volume (MCM/Y)	105	73.5	71	13	21
Rate (%)	100%	70%	68%	12%	20%

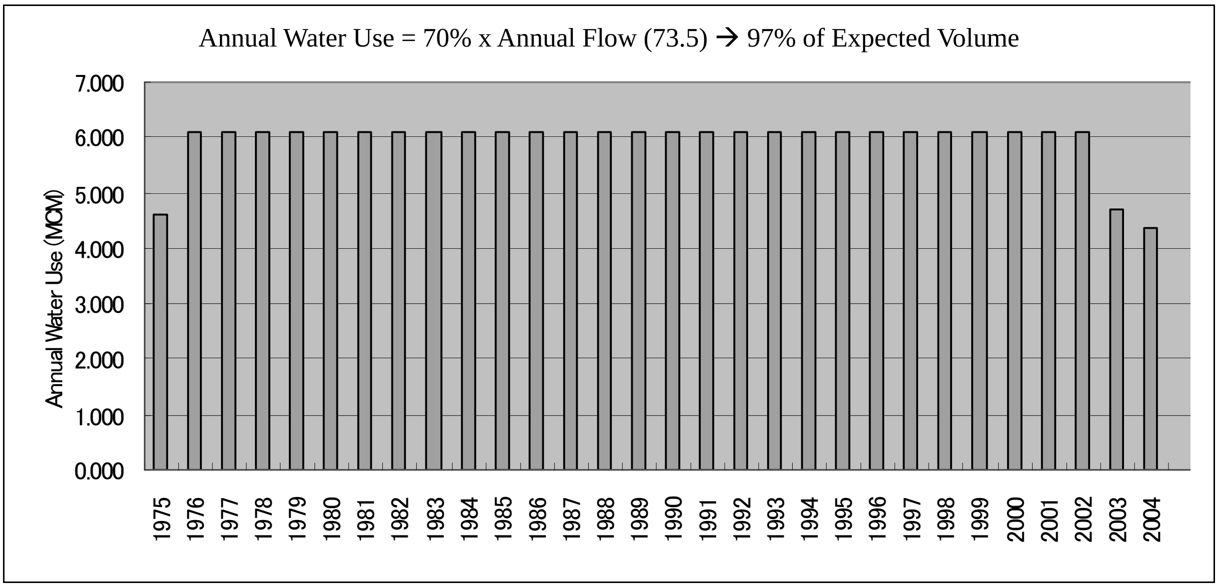


Figure C.2-7 Water Resources Development by Baysh Dam

<Hali Dam>

	Annual Inflow	Design Development Volume	Actual Development Volume	Evaporation Volume	Water from Spill Way
Volume (MCM/Y)	122	97.6	95	11	16
Rate (%)	100%	80%	78%	9%	13%

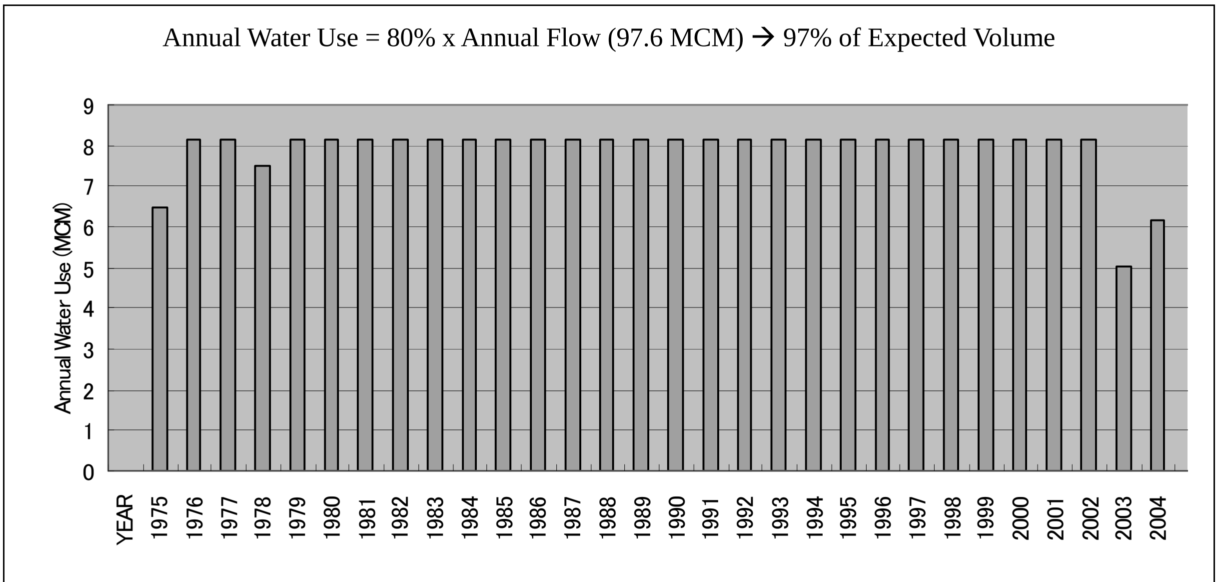


Figure C.2-8 Water Resources Development by Hali Dam

2.2 Non-Conventional Water Resource Development Plan

Desalinated seawater and reclaimed waste water are classified into non-conventional water resources and used for various purposes. Desalinated seawater is used for municipal water and industrial water, and reclaimed waste water is used for greening of municipal water, a part of industrial water and some of agricultural water. The service coverage of reclaimed waste water for agricultural use is still low.

The desalinated seawater is the aquatic resources, which are the effects of time of water supply to the urban regions and emergency correspondence at the time of abnormal drought with an aspect of stable water supply. Desalinated seawater is already supplied within the three regions in the Target Area of the M/P, and an expansion of the plants is stimulated now by MOWE.

The reclaimed waste water is utilized only in the Asir Region among the three regions at present. Reclaimed waste water is supplied by truck haul, and it is used for tree planting and agriculture. A plan to spread the use of the reclaimed waste water is processing for the future.

2.2.1 Desalinated Seawater

(1) Current Situation of Desalinated Seawater in Target Year

The three (3) desalination plants of Al Shuaibah (in Makkah Region), Al Shuqaiq (in Jazan) and Farasan (at Farasan Island in Jazan Region) are in operation and are supplying desalinated water to nine (9) governorates in 3 regions. The expansion of production capacity and pipelines are undertaken at each plant. Current situation and future plan for each plan are as follows:

- In the Al Baha Region, desalinated seawater (10,000m^3/day) from Shuaiba Plant is transmitted to 4 municipalities via Taif in Makkah Region. The Al Baha Region is requesting the expansion of the pipeline (70,000m^3/day) to SWCC. But the decision has not been made yet.
- In the Asir Region, desalinated seawater (83,900m^3/day) from Shuqaiq Plan is transmitted to 3 municipalities via Ad Darb in Jazan Region. At the year of 2010 or later, the expansion (196,000m^3/day) will be completed.
- In the Jazan Region, desalinated seawater (3,000m^3/day) from Shuqaiq Plan is transmitted to Ad Darb in Jazan Region. Also in Farasan Island, the plant (1,000m^3/day) is in operation. Up to the year 2015, desalinated seawater of 72,000m^3/day will be delivered to municipalities in Jazan Region. Also Farasan Plant will be reinforced to the capacity of 9,000m^3/day.

(2) Desalinated Seawater as Water Source for Municipal Water and Industrial Water

It is indispensable for desalinated seawater projects to continue and expand in order to suffice the demand of municipal water and industrial water, judging from the water demand projection and water resources potential analyzed in this Study. SWCC projects implemented under supervision of MOWE shall be implemented considering the following matters:

- **Stable and Reliable Water Source**:

Desalinated seawater is a stable and reliable water source to secure the expectations of the water supply quantity compared with renewable water resources that are affected by annual fluctuations, the most prominent characteristics in the semi-arid areas.

- **High Production Cost:**

Although the production cost of desalinated seawater falls by technical progress, 3 times - 4 times are still high (SWCC Annual Report 2008, 2.40SR/m^3) in comparison with the renewable water production cost by dams. An investment capital interest rate of dam construction is assured to be 8% a year.

- **Minimum Water Transmission:**

As the desalinated seawater is produced near the sea, the cost of water transmission increases because the place of consuming is far from the sea. For example, according to the same above report, transmission cost from Shuqaiq Plan to Abha is 5.18 SR/m^3. It is self-evident to plan the construction of new plants as near as possible to consuming areas to reduce transmission costs.

2.2.2 Reclaimed Waste Water

The reclaimed waste water production volume in the Target Area is planned as shown in Table C.2-3 which is prepared by the Study "Investigation and Engineering Design for Reclaimed waste water Reuse in the Kingdom of Saudi Arabia" in 2009. The plans are as follows with the present situation for the sewerage treatment and the future plans.

- In the Al Baha Region, there are presently no sewerage treatment plants, but plans for treatment plants in six main cities are planned for construction up to the year of 2020. The capacity at 2020 will meet the capacity and network in 2035.
- In the Asir Region, there are three treatment plants in the main cities (Abha, Khamis Mushayt and Bisha), and reclaimed waste water is to create greenery in the cities. The plant capacity of Abha is 35,000m^3/day and the same amount of reclaimed waste water is utilized. The plant capacity of Khamis Mushayt is 35,900m^3/day and 14,500m^3/day (40% of capacity) is currently operated. The plant capacity of Bisha is 10,000m^3/day and only 1,000m^3/day is currently operated due to low levels of networking and negated use of reclaimed wasete water .
- In the Jazan Region, there is one treatment plant in Jizan with the capacity of 20,000m^3/ day, but the present throughput (10,000m^3/ day) is being drained into the Red Sea with no use at all.

Table C.2-3 Reclaimed Waste Water Generation and Treatment Capacity in 2020

Region	Municipality	Generation Volume of Reclaimed Waste Water (m³/day)				Treatment Capacity in 2020 (m³/day)
		Current	Projection			
		2007	2010	2020	2035	
Al Baha	Al Bahah	0	18,766	18,418	18,766	20,000
	Biljurashi	0	7,277	7,142	7,277	8,000
	Al Mukhwah	0	3,485	3,421	3,485	4,000
	Al 'Aqiq	0	2,326	2,283	2,326	3,000
	Qilwah	0	2,113	2,074	2,113	3,000
	Al Mandaq	0	1,678	1,647	1,678	3,000
	Total	0	35,645	34,985	35,645	41,000
Asir	Khamis Mushayt	58,189	60,394	92,923	101,847	106,000
	Abha	41,991	43,582	50,342	55,177	56,000
	Bishah	10,188	10,574	19,523	21,398	22,000
	Rifaydah			10,405	11,405	12,000
	Muhayil			10,131	11,104	12,000
	Al Namas			4,941	5,415	6,000
	Zahran al Janub			4,340	4,757	6,000
	Al 'Alayah			3,601	3,946	
	Al Majardah			3,034	3,325	3,000
	Tanumah			2,781	3,048	
	Sarat Abidah			2,511	2,752	3,000
	Far'at Turayeb			1,849	2,026	
	Al Ithnayn			1,476	1,617	3,000
	Tathlith			1,367	1,498	
	Bahr Abu Sakynah			1,069	1,172	3,000
	Tibalah			1,054	1,155	
	Total	110,368	114,550	211,347	231,642	232,000
Jazan	Jazan	20,000	23,141	34,790	43,909	48,000
	Sabya	0	0	12,434	18,832	
	Abu 'Arish	0	0	11,379	14,362	
	Samtah	0	0	6,251	7,889	
	Baysh	0	0	5,730	7,232	12,000
	Damad	0	0	4,281	5,403	
	Ahad al Musarihah	0	0	4,252	5,366	6,000
	Az Zabyah	0	0	2,490	3,142	36,000
	Ad Da'ir	0	0	2,490	3,142	3,000
	Farasan	0	0	2,965	3,743	6,000
	Al Badi' Wa al Qarfi	0	0	1,950	2,461	
	Al 'Aliyah	0	0	1,805	2,278	3,000
	Al juradiyah	0	0	1,716	2,165	12,000
	Hakimah	0	0	1,702	2,147	

Region	Municipality	Generation Volume of Reclaimed Waste Water (m³/day)				Treatment Capacity in 2020 (m³/day)
		Current	Projection			
		2007	2010	2020	2035	
	Al Madaya	0	0	1,669	2,107	
	Al Shuqayri	0	0	1,669	2,107	
	Al Mat'an	0	0	1,648	2,080	
	Al Tuwal	0	0	1,489	1,879	
	Misliyah	0	0	1,419	1,791	
	Mizhirah	0	0	1,283	1,619	
	Abu as Sala'	0	0	1,274	1,607	3,000
	Ad Darb	0	0	1,248	1,575	3,000
	Al Husayni	0	0	1,240	1,565	
	Total	20,000	23,141	107,174	138,401	132,000

Source:「Investigation and Engineering Design for Reclaimed Waste Water Reuse in the Kingdom of Saudi Arabia」(2009)

The water supplied for municipal and industrial use is drained as sewage. The users of this water supply and water supply providers are treating sewage from the viewpoint of environmental safeguards and hygiene while allowing it to operate naturally.

As mentioned above, waste water treatment plants in the main cities are planned to be construct up to the year of 2020. See Table C.2-4.

Table C.2-4 Use of Reclaimed Waste Water at the Year of 2020

Items	Al Baha	Asir	Jazan
(1) Waste Water Volume (1000m³/day)	35	211	107
(2) Treatment Capacity (1000m³/day)	41	232	132
(3) Municipal Water Demand (1000m³/day)	80	436	325
(4) Industrial Water Demand (1000m³/day)	1	13	3
(5) For Municipal Use (5%) and Industrial Use (30%) (1000m³/day)	4	26	7
(6) For Agricultural Use (1000m³/day)：(1)-(5)	31	185	100
(7) For Agricultural Use（MCM/year）	11.3	67.5	36.5
(8) Agricultural Demand（MCM/year）	53.9	268.4	1,501.9
(9) Rate of Agricultural Use (7)/(8)	21 %	25 %	2 %

As shown in the table above regarding the recycle use of reclaimed waste water, utilization for municipal water and industrial water is limited and relatively small but for agricultural water is large. In the Al Baha Region and the Asir Region, the rates of agricultural use (Available Reclaimed Waste Water for Agricultural Use / Total Agricultural Demand in Region) are 21% in Al Baha and 25% in the Asir Regions. This means that the reclaimed waste water will become a promising water resource for agricultural use in the regions of Al Baha and Asir.

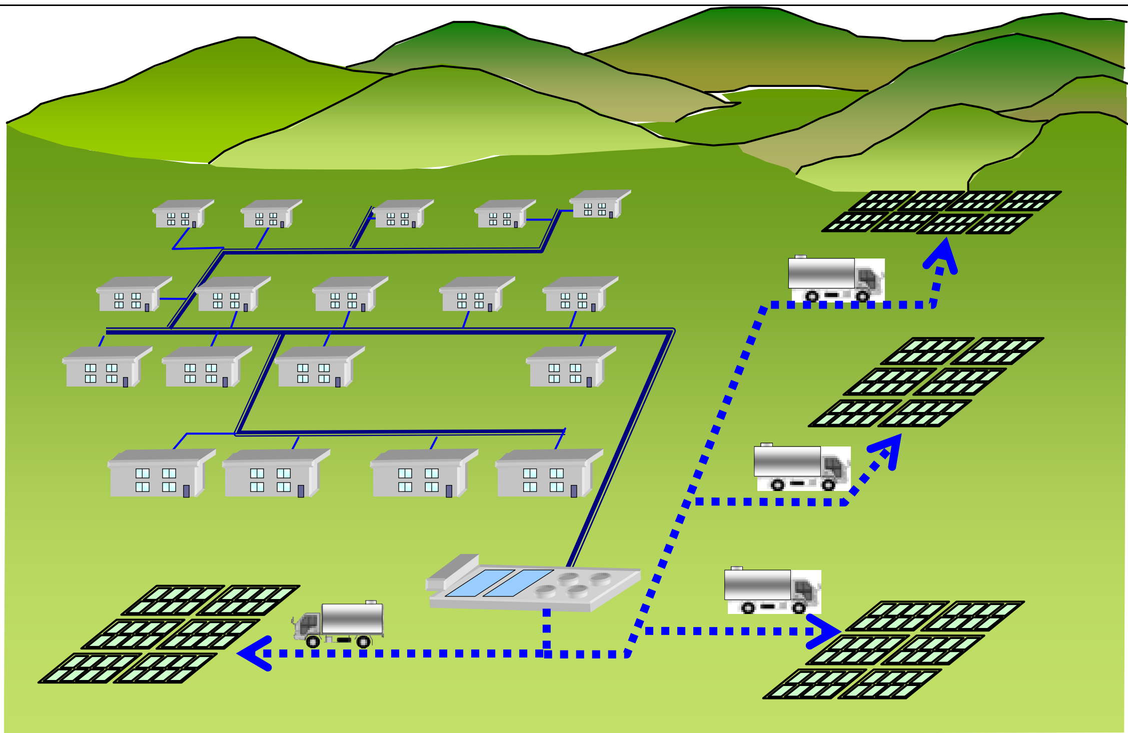
<Recycle Use of Reclaimed Waste Water → Utilization Merritt for Municipal and Industrial Uses>

If 5% of the municipal water is replaced with reclaimed waste water, consequently the municipal water demand will decrease by 5%. According to SWCC Annual Report 2008, the water unit price (production cost and a transportation cost) of desalinated seawater is 8.0 SR/m^3 from 3.5 SR/m^3. In particular, transportation costs increase, and the water supply to the plateau city rises.

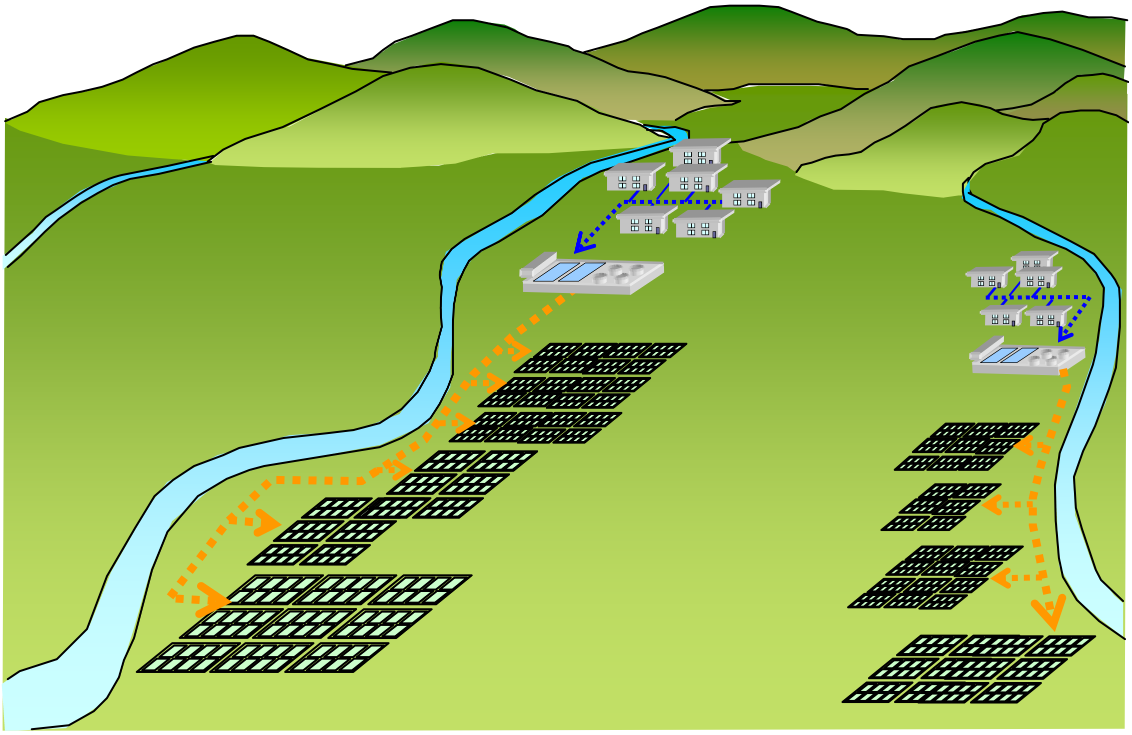
For example, the decrease in government subsidies for one year reaches SR67.8 Million if 5% (25,800m^3/day) on city water demand 516,000m^3/day at 2020 in Al Baha Region and Asir Region, and government subsidy supposes with 90% (8.0SR/m^3 x 90% = 7.2SR/m^3).

<Proposal → Recycle Use of Reclaimed Waste Water for Agricultural Use>

As shown in Table -5.6, recycle rate of reclaimed waste water for agricultural use (more than 20%) is high in the Al Baha and Asir Regions. Therefore, to promote agricultural use of reclaimed waste water, "Distributed System of Sewage Treatment and Recycle Use" is recommended than "Intensive System" in Al Baha Region and Asir Region. See Figure C.2-9.



Sewage Treatment and Recycle Use 【Intensive System】

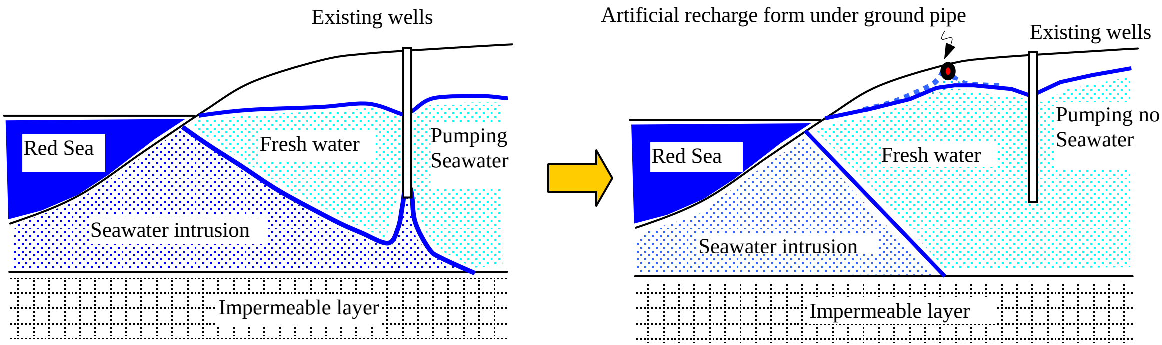


Sewage Treatment and Recycle Use【Distributed System】

Figure C.2-9 System of Sewage Treatment and Recycle Use

<Reuse of Reclaimed Waste Water → Measures against Seawater Intrusion → Proposal of Implementation of Artificial Recharge by Treated Sewage>

There are excellent aquifers along the Red Sea, which is composed of sand and gravel in Quaternary Plains. On the other hand, great amount of groundwater is pumped from the aquifer for agricultural and domestic use. As a result, the groundwater level is being lowered, and seawater is intruding into the coastal aquifer. For countermeasures against this, the rising of the groundwater level by artificial recharge is effective. It is recommended to use reclaimed waste water as an artificial recharge water resource.
This method can be applied by use of reclaimed waste water discharged from Jizan city. The southern part of Jizan city, where seawater intrusion is taking place, should be the target of this method.



(a) Before Artificial Recharge **(b) After Artificial Recharge**

Figure C.2-10 Measures against Seawater Intrusion by Treated Sewage

There are two methods for artificial recharge. These are, i) Artificial recharge through surface water (pond and trench) and ii) Artificial recharge though wells.

- Measures against seawater intrusion should be implemented in large area along the coast. From this view point, artificial recharge by wells is not realistic due to the huge cost for drilling many wells. Furthermore, the target for artificial recharge is unconfined aquifer and artificial recharge through well drilling is not necessary in case of unconfined aquifer.
- It is effective to put underground pipes with holes near the ground surface (around GL-0.5m) along the coast. Reclaimed waste water should be drained though the underground pipes. This method has advantages in cost. Underground pipes can be extended from treatment plant along the Red Sea.
- Amount of reclaimed waster water available for artificial recharge is limited. This should be implemented only for urban areas where the seawater intrusion is serious. Local cities in the southern part of Jazan Region, where lowering of the groundwater level is serious, should be targets for this method.
- Reclaimed waste water will be purified by natural filtering when it flows though sandy aquifers. However, underground pipes should be located far from the existing wells (more than 100m from wells).
- Reclaimed waste water from the underground pipes should be used to grow vegetation by planting vegetation along the pipes.

The feasibility (F/S) study on the use of reclaimed waste water for water source of artificial recharge shall be recommended.

CHAPTER 3 WATER SUPPLY PLAN

3.1 Basic Condition of Water Supply Planning

3.1.1 Basic Condition for Planning

The basic conditions for formulation of water supply plan in the M/P are as follows,

Types of Water Resources

As the water supply plan of 3 regions, Al Baha, Asir, Jazan, domestic, institutional, commercial and industry water are to be studied. Water resources are categorized into four (4) categories such as surface water (Renewable Water), ground water (Renewable Water), ground water (Fossil and Non-Renewable Water) and Desalinated water.

Since the reclaimed waste water is being pulled from the water demand, it is considered as water resources.

Integrated Water Supply Plan

Of the agencies in charge of water resources development, there are two in Saudi Arabia. One is the Ministry of Water Resources, which is responsible for developing natural water resources such as surface water by dams and groundwater by wells. Another is the SWCC, which is responsible for developing desalinated seawater. However, the water related agencies are apt to act on their responsibilities separately. Consequently, no one agency knows when the comprehensive water supply achievement plan is ineffective.

Recently, MOWE has been constructing many large dams in south-west regions, which will soon be completed. In addition, SWCC has plans to expand desalination plants and transmission networks. While, there is a plan that fossil water will be transferred from Wajid Aquifer in Najran Region to the eastern parts of Asir Region. As stipulated in the JICA M/P Study, the integrated water supply plan will be proposed based on the 'Red Sea Life Line' that was proposed in Chapter 5, Part-B.

Water Demand

Since the future water demand plan is formed based on the water consumption rate and the water service coverage in accordance with the criteria of MOWE, it shows the larger tendency than the present water demand.

In implementation of supply facilities planning, the growth of demand needs to be grasped suitable.

Priority Use and Maximum Use of Natural Renewable Water Resources.

Water development costs are identified to be cheaper in order of natural renewable water, fossil water and then desalinated water. Thus, in this M/P, it is the priority to use water from natural resources.

Since fossil water is non-renewable water, developing it is limited only to interior areas where it is far from the sea and water resources are scarce.

Natural Water Resources are Prioritized to be Utilized in the Regions where Have Water Source Facilities are Located, or Basins.

Generally, renewable water can be secured in large wadi basins, which exist in two (2) regions and intake facilities such as dams exist in multiple regions. However, renewable water should appropriately be allocated in the region where water sources are located. In the KSA, local residents have the perception that natural water belongs to the assets of local natives. Therefore, water resource development should be prioritized in regions and basin where development renewable points are located.

Building Extensive Water Supply Network among Region's Independent Water Supply System

There is a possibility that scarcity of water may take place regionally when water demand increases by season due to the local concentration of people on vacation. As a preparedness mechanism for such situations and emergency cases, a built-up extensive network of the water supply system is recommended.

Water Supply Facilities are Recommend to be Developed and be Used as far as Possible Near Site from Water Demand Places.

The cost of water transmission becomes higher in proportion with the length of pipeline. Therefore, it is recommended to supply the water demand from nearby facilities to reduce the cost of water use.

Allocation of Water Resource between Sectors

The amount of water production will be applied to each dam according to the supply plans.

3.1.2 Current Water Source and Water Supply Amount

Current water sources and water supply amount in the targeted regions are summarized in Table C.3-1.

Table C.3-1 Amounts of Water Production in the Existing Facilities

Region	Resources	Name of Facility	Volume(1000m^3/d)	Remarks
Al Baha	**1. Renewable Water**		**19,000**	
		<Dams>	14,000	
		Aradah Dam	*(5,000)*	
		Al Aqiq Dam	*(4,000)*	
		Tharad	*(5,000)*	
		<Wells>	5,000	
		Qilwah	*(2,000)*	
		Mukhwah	*(1,000)*	
		Al Aqiq	*(1,000)*	
		Others	*(1,000)*	2 resources
	2. Desalinated Seawater		**10,000**	
		Shuaiba	*10,000*	
	3. Total		**29,000**	
Asir	**1. Renewable Water**		**40,000**	
		<Wells>	40,000	
		Bisha	*(15,000)*	2 resources
		Balqarn	*(1,000)*	
		Al Majardah	*(4,000)*	
		An Namas	*(2,000)*	
		Tathlith	*(3,000)*	
		Ahad Rifayda	*(2,000)*	2 resources
		Sarat Abidah	*(2,000)*	
		Zahran Al Janub	*(1,000)*	
		Khamis Mushayt	*(1,000)*	
		Abha	*(2,000)*	2 resources
		Muhayl	*(6,000)*	2 resources
		Rijar Almah	*(1,000)*	
		Al Birk	*(1,000)*	
	2. Desalinated Seawater		**82,000**	
		Shuqaiq	*(82,000)*	
	3. Total		**122,000**	
Jazan	**1. Renewable Water**		**136,000**	
		<Wells>	136,000	
		Ad Darb	*(2,000)*	
		Al Rayth	*(2,000)*	
		Baysh	*(16,000)*	4 resources
		Al Idabi	*(3,000)*	
		Ad Dair	*(3,000)*	
		Sabya	*(22,000)*	4 resources
		Damad	*(4,000)*	2 resources
		Al Aridah	*(2,000)*	
		Jazan	*(22,000)*	3 resources
		Abu Arish	*(17,000)*	3 resources
		Al Harth	*(7,000)*	
		Ahad Al Musarihah	*(21,000)*	
		Al Juradiyah	*(11,000)*	2 resources
		Al Tuwal	*(4,000)*	
	2. Desalinated Seawater		**4,000**	
		Shuqaiq	*(3,000)*	
		Farasan	*(1,000)*	
	3. Total		**140,000**	

The existing pipeline network of water sources, water demand and supplied water are shown as follows:

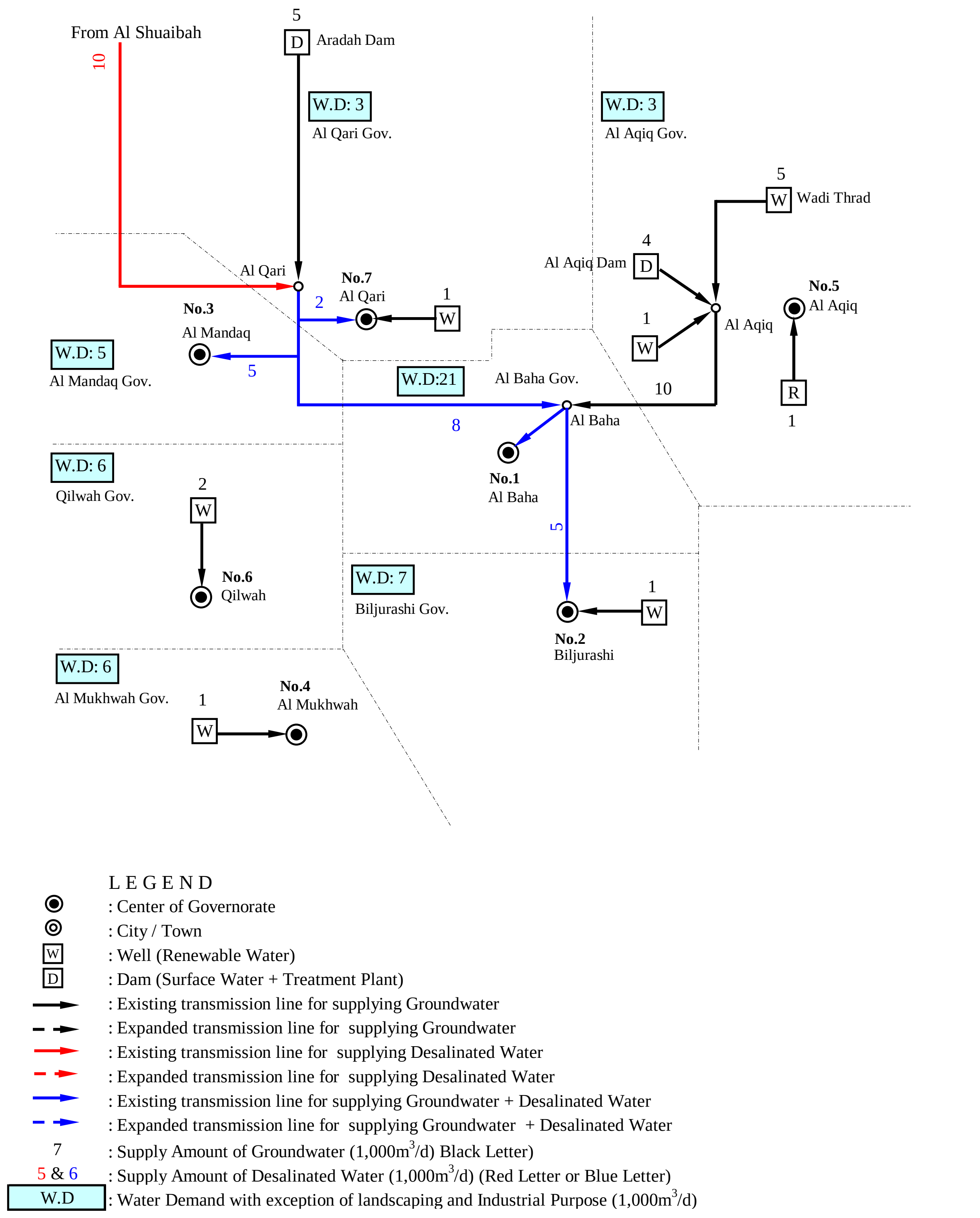
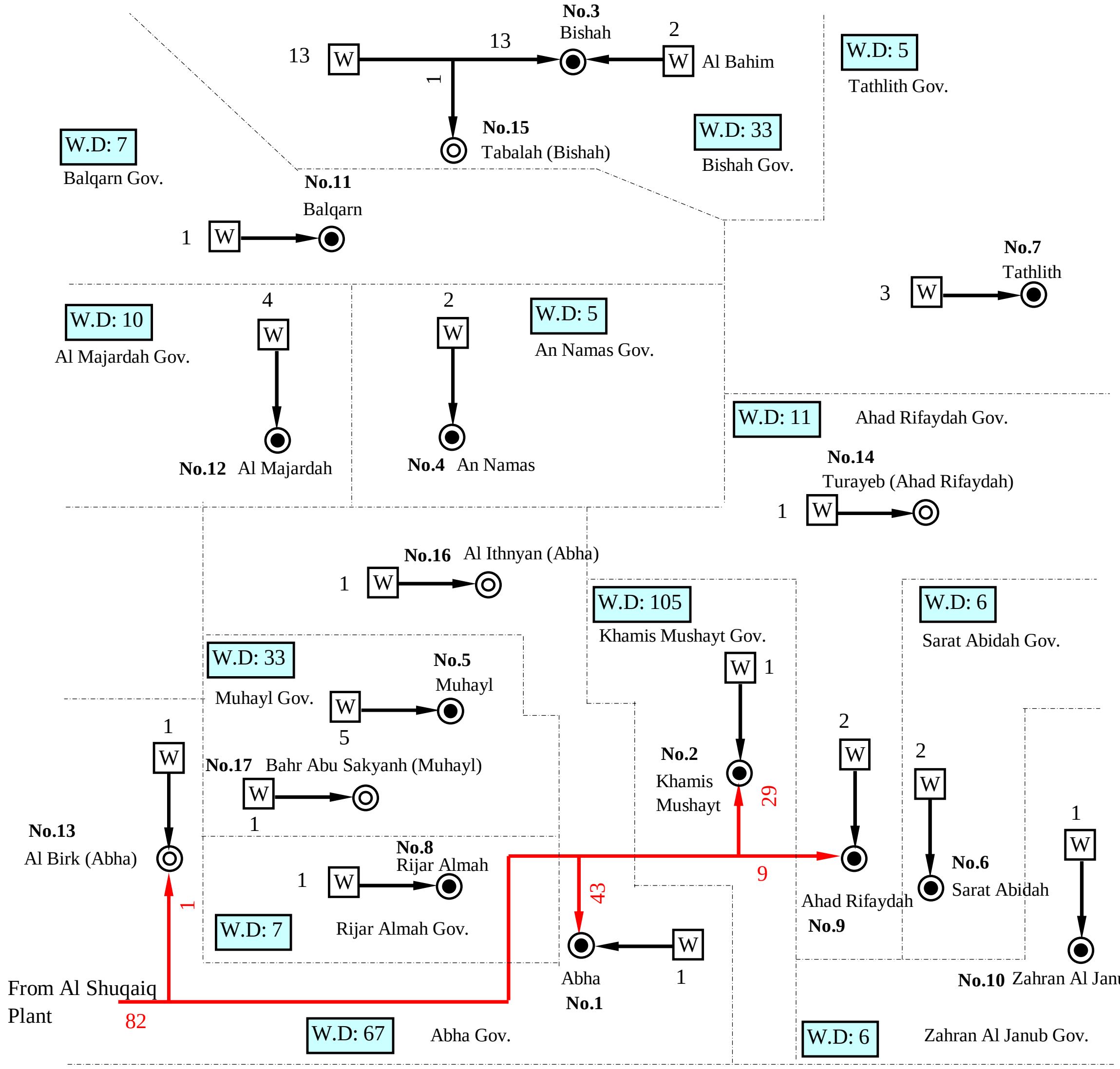


Figure C.3-1 Water Supply Network in Al Baha Region（Current）



LEGEND

- ◉ : Center of Governorate
- ◎ : City / Town
- W : Renewable Water (Well)
- (black solid arrow) : Existing transmission line for supplying Groundwater
- (black dashed arrow) : Expanded transmission line for supplying Groundwater
- (red solid arrow) : Existing transmission line for supplying Desalinated Water
- (red dashed arrow) : Expanded transmission line for supplying Desalinated Water
- (blue solid arrow) : Existing transmission line for supplying Groundwater + Desalinated Water
- (blue dashed arrow) : Expanded transmission line for supplying Groundwater + Desalinated Water
- 7 : Supply Amount of Groundwater (1,000m^3/d) Black Letter)
- 5 & 6 : Supply Amount of Desalinated Water (1,000m^3/d) (Red Letter or Blue Letter)
- W.D : Water Demand with exception of landscaping and Industrial Purpose (1,000m^3/d)

Figure C.3-2 Water Supply Network in Asir Region（Current）

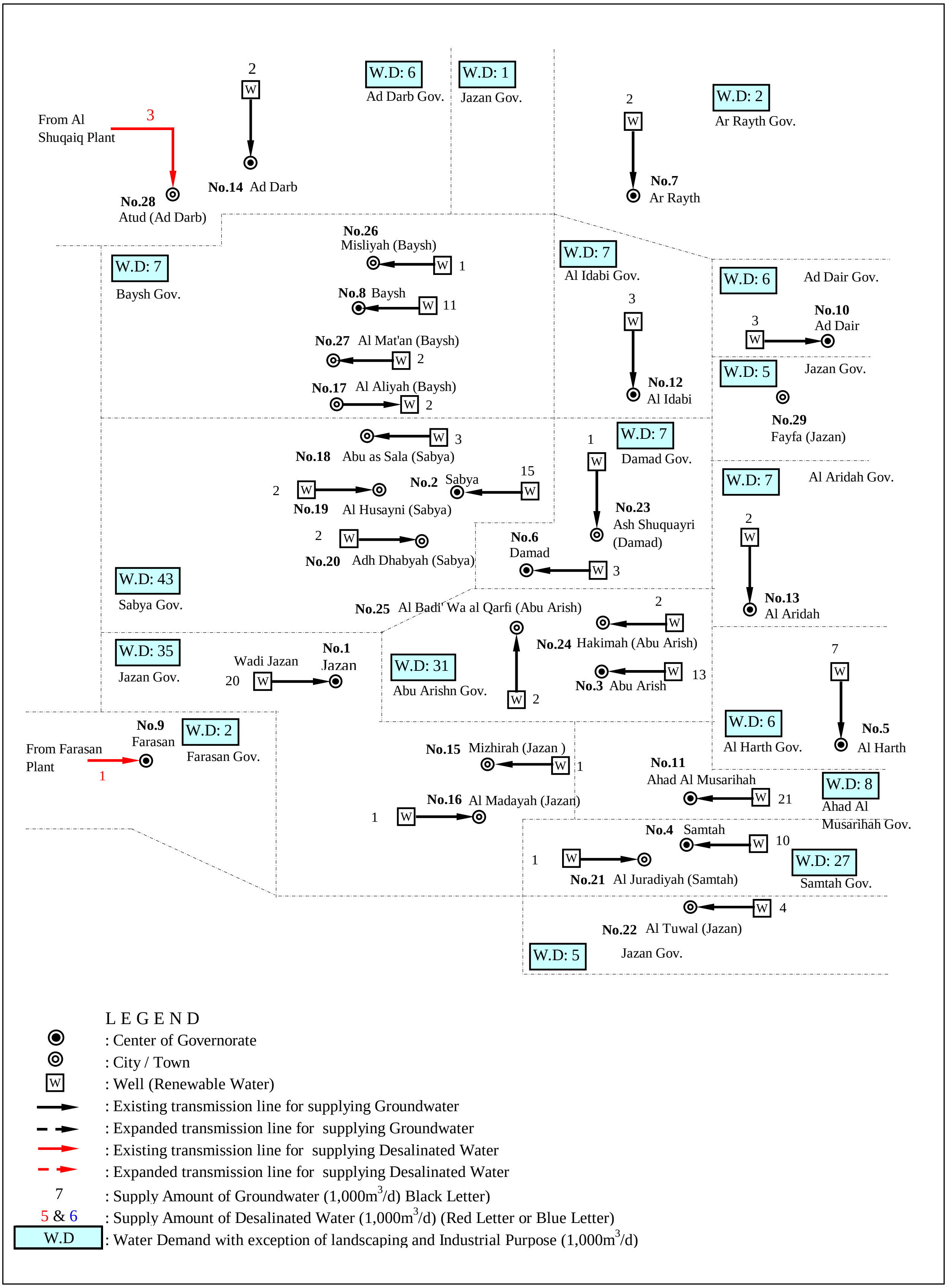


Figure C.3-3 Water Supply Network in Jazan Region（Current）

3.1.3 Water Production Facilities Required for Water Supply Planning

(1) Water Production Capacity and Planned Amounts of Supply of Dam under Construction and Planning

The amount of water supplied to dams, which was examined in the planned water production in Chapter 2, Part-C is shown in Table C.3-2. The planned amounts of supply was planned by MOWE, but as that of Tabalah and Qanunah Dam is higher than the planned production capacity, planned amounts of supply will be applied for the planned production capacity.

Table C.3-2 Water Production Capacity and Planned Amounts of Supply of Dam under Construction and Planning

Dam	Annual Average Flow (MCM/y)	Storage Capacity (MCM)	Planned Production Capacity*1 (MCM/y)	Planned Production Capacity*1 (1000m^3/d)	Rate of Development*2	Planned Amounts of Supply *3 (1000m^3/d)	Remarks
Tabalah	12.3	68.4	3.6	10	29%	16	→ 10
Ranyah	99.6	219.8	32.9	90	33%	68	
Hirjab	16.8	4.6	3.4	9	20%	9	
Baysh	104.6	193.6	73.2	201	70%	58 = 25+33	
Damad	61.5	55.5	24.0	66	39%	36	
Hali	122.3	249.9	97.8	268	80%	70 = 35+35	
Qanunah	21.3	79.2	6.4	18	30%	30	→ 18

[Note] *1: Safe rate for development97%= 30% short of planned water production once a year, *2: Rate of development= Planned water capacity/ annual average flow, *3: Planned amounts of supply= water flow form dam utilized for supply (MOWE plan)

(2) Water Production Facilities and Production Capacity

Water production facilities such as dams, Wajid Aquifer and desalination plants and their production capacity are shown in Table C.3-3, Figure C.3-4 to C.3-6.

Table C.3-3 Water Production Facilities and Production Capacity

Name of Region	Targeted Year	Development Resources	Dam/Governorate	Development Volume (m^3/d)	Remarks
Al Baha	2010-2015	Surface Water	Hali Dam	35,000	Makkah Region
			Nilah Dam	6,000	
			Qilwah Dam	5,000	
			Al Janabin Dam	5,000	
			Total	51,000	
	2015-2020	Desalination Plants	Dawqah Plant	75,000	New plant
	2020-2025				No development
	2025-2030		Dawqah Plant	25,000	Extension
Asir	2010-2015	Surface Water	Baysh Dam	25,000	
			Hali Dam	35,000	Makkah Region
			Tabalah Dam	10,000	
			Total	70,000	
		Desalination Plants	Shuqaiq	156,000	Extension
		Fossil Water	Wajid	29,000	
	2015-2020	Surface Water	Hirjab Dam	9,000	
			Ranyah Dam	68,000	
			Qanunah Dam	18,000	
			Total	95,000	
	2020-2025	Desalination Plants	Shuqaiq Plant	75,000	Extension
		Fossil Water	Wajid	32,000	Extension 2nd
Jazan	2010-2015	Surface Water	Baysh Dam	33,000	
			Damad Dam	36,000	
			Total	69,000	
		Desalination Plants	Shuqaiq	72,000	Extension
			Farasan	8,000	
			Total	80,000	
	2015-2020	Surface Water	Qissi Dam	9,000	
		Desalination Plants	Sabya Plant	35,000	New plant planned by the JICA
	2020-2025	Desalination Plants	Sabya Plant	160,000	Extension 2nd
	2030-2035	Desalination Plants	Sabya Plant	55,000	Extension 3rd

Note: New desalination plant is planned by the JICA Study Team

3.2 Proposed Water Supply Plan

3.2.1 AL Baha Region

(1) Plan for Water Demand and Water Supply

The water demand and water supply of Al Baha and Asir Regions are shown in Table C.3-4, Table C.3-5, Figure C.3-4 and Figure C.3-5.

Table C.3-4 Water Production Plan in Al Baha Region

Water Resource	-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
1.Existing (m^3/day)	**29,000**	**59,000**	**19,000**	**19,000**	**19,000**	**19,000**
1.1 Renewable Water	**19,000**	**19,000**	**19,000**	**19,000**	**19,000**	**19,000**
Aradah Dam (B)	5,000					
Al Aqiq Dam (B)	4,000	14,000	14,000	14,000	14,000	14,000
Wadi Thrad Dam (B)	5,000					
Qilwah Well (B)	2,000					
Mukwah Well (B)	1,000					
Al Aqiq Well (B)	1,000	5,000	5,000	5,000	5,000	5,000
Others Wells (B)	1,000					
1.2 Desalination	**10,000**	**40,000**	**0**	**0**	**0**	**0**
Shuaiba D.P (M)	10,000	40,000	0	0	0	0
2.New (m^3/day)	**-**	**51,000**	**91,000**	**91,000**	**116,000**	**116,000**
2.1 Renewable Water		**51,000**	**16,000**	**16,000**	**16,000**	**16,000**
Nilah Dam (B)	-	11,000	11,000	11,000	11,000	11,000
Qilwah Dam (B)	-					
Al Janabin Dam (B)	-	5,000	5,000	5,000	5,000	5,000
Hali Dam (M)	-	35,000	0	0	0	0
2.2 Desalination		**0**	**75,000**	**75,000**	**100,000**	**100,000**
Dawqah D.P (M)	-	-	75,000	75,000	100,000	100,000
Total (m^3/day)	**29,000**	**110,000**	**110,000**	**110,000**	**135,000**	**135,000**
Water Demand(m^3/day)	**50,000**	**64,000**	**79,000**	**94,000**	**111,000**	**131,000**

[Note] (B):Al Baha Region, (M):Makkah Region

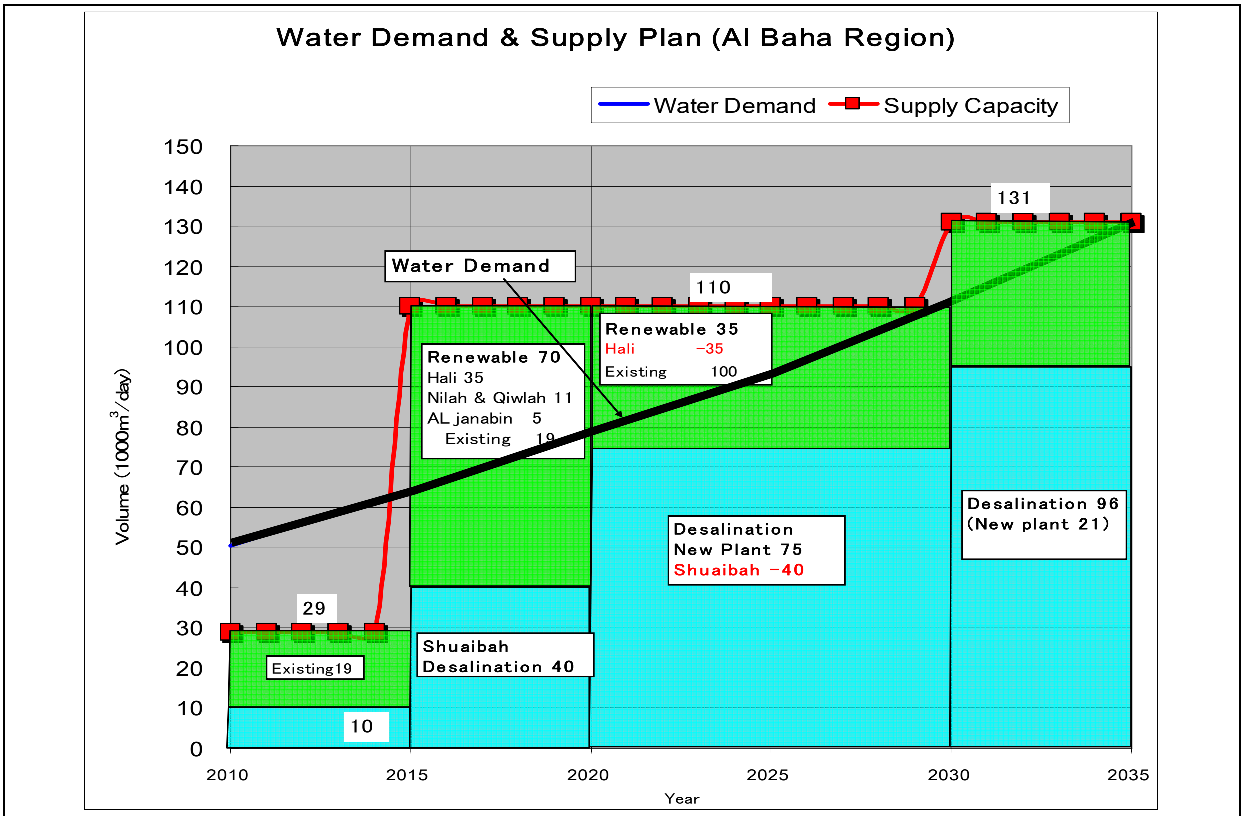


Figure C.3-4 Projection of Water Demand and Water Production in Al Baha (2010-2035)

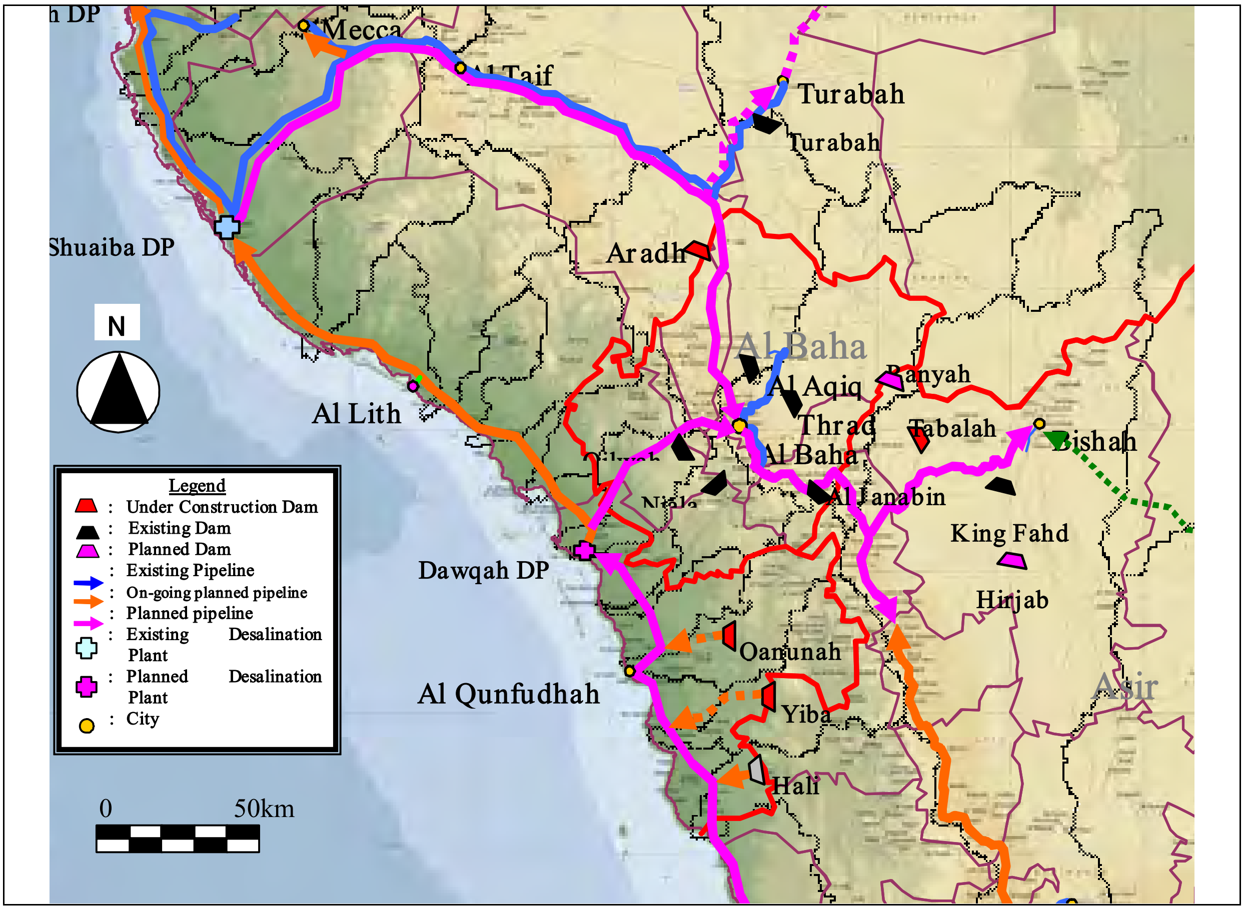


Figure C.3-5 Dams and Desalination Plants in Al Baha Region

(2) Production of Plant for the Five Years

<Plans for the Year of 2011-2015>

The water demand for the year 2015 in the Al Baha Region amounts to 68,000m^3/day. Currently, Hali Dam and Qanunah Dam, located in the areas close to Asir in the Makkah Region, are under construction and will be completed by 2011. As a principle source, water production in these dams is utilized for the Makkah and Asir Regions. However it is proposed that the water produced in the dams will temporarily be utilized for the Al Baha Region by 2020 because there are no intake, or transmission facilities in the Makkah and Asir Regions. The Al Baha Region seriously faces water a shortage and is close to the proposed pipeline route.

Table C.3-5 Water Production Plan in Al Baha Region (2011-2015)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		**70,000**	**64**
• Existing Facilities	Existing	19,000	
• Hali Dam	New	35,000	
• Nilah&Qilwah	New	11,000	
• AL Janabin Dam	New	5,000	
◆ Desalination		**40,000**	**36**
• Shuaibah Plant	Existing	40,000	
Total		**110,000**	**100**

Water production of 35,000m^3/day from Hali Dam and 30,000m^3/day from Qanunah Dam will be proposed. 35,000m^3/day of Hali Dam is supplied to Al Baha Region. In addition, water supply from Nilah & Qilwah Dams (11, 000m^3/day) and Al Janabin Dam (5,000m^3/day) will be planned. The total capacity of water production amounts to about 70,000m^3/day.

Moreover, the total amount of 110,000m^3/day including water production of 40,000m^3/day, which transferred from Shuaibah Desalination Plant in Makkah, can be supplied to Al Baha Region. Consequently, total water production will make up 1.7 times the water demand in 2015.

Proportion between renewable and desalination water is 70,000m^3/day (64%) versus 40,000m^3/day (36%). The capacity of water production is 42,000m^3/day greater than water demand in 2015. This concludes to be the required amount of water for dwellers.

Facilities plan for water supply from 2011 to 2015 is shown in Table C.3-6.

Table C.3-6 Water Supply Facilities Plan in Al Baha Region (2011-2015)

Facililities	Demensions
Pipeline A	Section:Dowqa-Al Baha, Length=115Km
Pipeline B	Section:Dowqa-Hali, Length=108Km

Note: Location of facilities is shown in Figure C.6-1.

<Plans for the Year of 2016-2020>

Desalination plant (Dawqah Plant) that is exclusively utilized for Al Baha Region is proposed. After completion of Dawqah Plant, 35,000 m^3/day out of 65,000m^3/day transferred from Hali Dam. In addition, Qanunah Dam is transferred to Asir Region through transmission pipelines between Al Baha and Al Alayah (Asir Region) and will be newly constructed.

Now that water production by 2016 exceeds water demand, the plant capacity is planned to be 75,000m^3/day to store the returned water. Meanwhile, renewable water production decreases to 35,000m^3/day. Accordingly, proportion between renewable and desalination water is 35,000m^3/day (32%) versus 75,000m^3/day (68%).

Table C.3-7 Water Production Plan in Al Baha Region (2016-2020)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		35, 000	32
• Existing Facilities	Existing	*70, 000*	
• Hali Dam	New	*(−35, 000)*	
◆ Desalination		75, 000	68
• Shuaibah Plant	Existing	*0*	
• Dawqah Plant	New	*75, 000*	
Total		110, 000	100

Facilities plan for water supply from 2016 to 2020 is shown in Table C.3-8.

Table C.3-8 Water Supply Facilities Plan in Al Baha Region (2016-2020)

Facililities	Demensions
Dawqah Desalination Plant	Production Volume: 75,000 m^3

Note: Location of facilities is shown in Figure C.3-5.

<Plans for the Year of 2021-2025>

When the water production in 2021 exceeds water demand of 97,000m^3/day for the year 2025, additional water production will not be required during this period.

<Plans for the year of 2026-2035>

The Water demand for the year 2030 in the Al Baha Region amounts to 115,000m^3/day. As development of renewable water is maximized, extension of desalination plants will be significant measures to secure water demand after 2031. Additional water production of 25,000m^3/day will be extended in the Dawqah Plant, which amounts to 100,000m^3/day totally. Consequently, the total capacity consequently exceeds water demand of 135,000m^3/day in the year of 2035.

Table C.3-9 Water Production Plan in Al Baha Region (2026-2030, 2031-2035)

Water Production	Category	Production (m³/day)	Rate (%)
◆ Renewable Water		35, 000	26
• Existing Facilities	Existing	*19, 000*	
• Al Janabin dam	New	*11, 000*	
• Nilah & Qilwah	New	*5, 000*	
◆ Desalination		100, 000	74
• Dawqah Plant	Existing	*75, 000*	
• Dawqah Plant	Extension	*25, 000*	
Total		135, 000	100

A breakdown of renewable water in 2035 shows 11,000m^3/day at Nilah & Qilwah Dams, and 5,000m^3/day at Al Janabin Dam as well as 19,000m^3/day (Existing) at Aradah, Aqiq, Thrad Dams and Wadis. Total water production amounts 135,000m^3/day including desalination water production of 100,000m^3/day.

Facilities plan for water supply is shown in Table C.3-10.

Table C.3-10 Water Supply Facilities Plan in Al Baha Region (2026-2035)

Facilities	Demensions
Dawqah Desalination Plant	Extension Production Volume: 25,000 m^3

Note: Location of facilities is shown in Figure C.3-5.

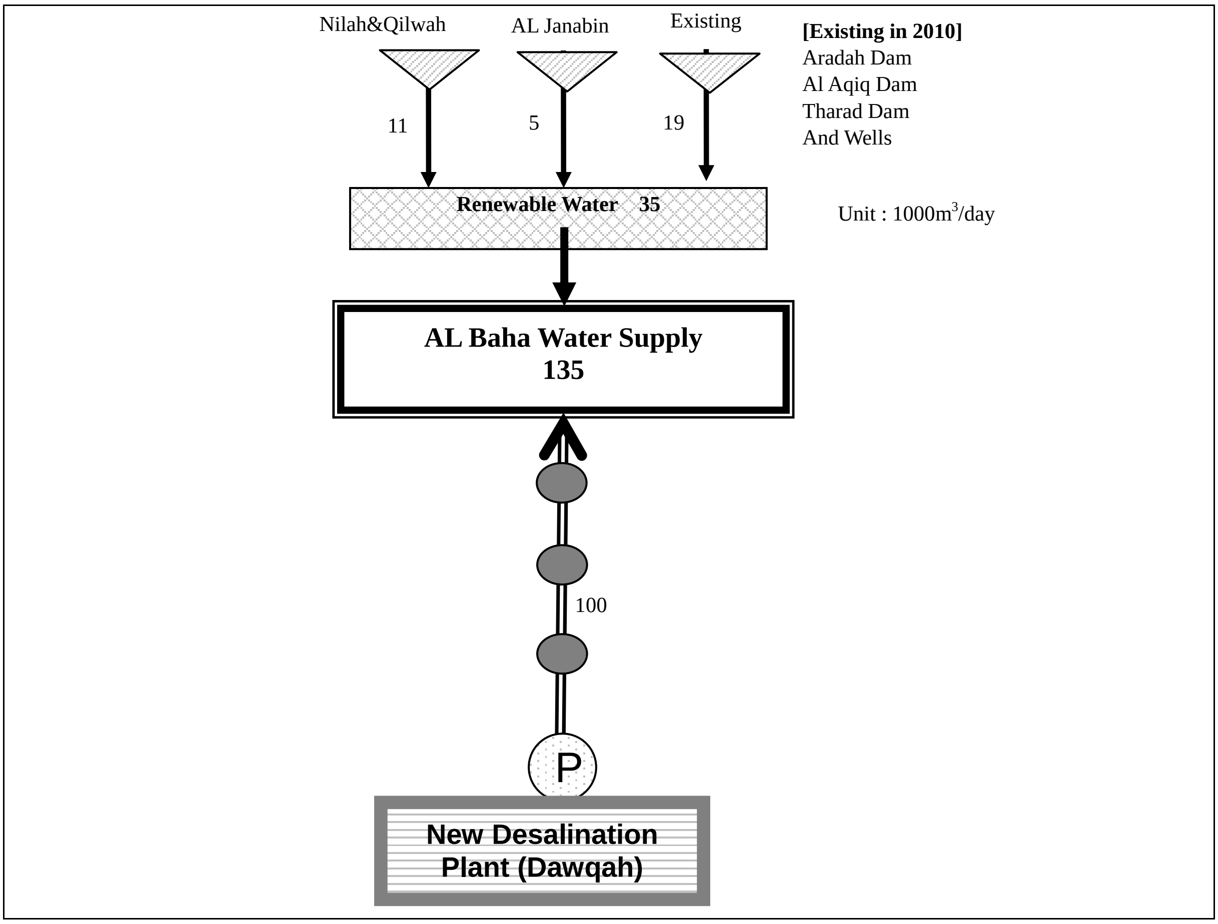


Figure C.3-6 Water Supply Plan and Water Sources in Al Baha Region (2035)

3.2.2 Asir Region

(1) Plan for Water Demand and Water Supply

The water demand and water supply in the Asir Region are shown in Table C.3-11 and Figure C.3-7.

Table C.3-11 Water Production Plan in Asir Region

Water Resource	0000-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
1.Existing (m^3/day)	**122,000**	**122,000**	**122,000**	**122,000**	**122,000**	**122,000**
1.1 Renewable Water	40,000	40,000	40,000	40,000	40,000	40,000
Existing Wells	40,000	40,000	40,000	40,000	40,000	40,000
1.2 Desalination	82,000	82,000	82,000	82,000	82,000	82,000
Shuqaiq D.P (J)	82,000	82,000	82,000	82,000	82,000	82,000
2.New (m^3/day)		**245,000**	**375,000**	**482,000**	**557,000**	**557,000**
2.1 Renewable Water		70,000	200,000	200,000	200,000	200,000
Bayash Dam (J)	-	25,000	25,000	25,000	25,000	25,000
Hali Dam (M)	-	35,000	70,000	70,000	70,000	70,000
Tabalah Dam	-	10,000	10,000	10,000	10,000	10,000
Hirjab	-		9,000	9,000	9,000	9,000
Ranya Dam	-		68,000	68,000	68,000	68,000
Qanunah Dam (M)	-		18,000	18,000	18,000	18,000
2.2 Desalination		146,000	146,000	221,000	296,000	296,000
Shuqaiq D.P (J)	-	146,000	146,000	221,000	296,000	296,000
2.3 Fossil Water		29,000	29,000	61,000	61,000	61,000
Wajid Fossil Water	-	29,000	29,000	61,000	61,000	61,000
3.Total (m^3/day)	**122,000**	**367,000**	**497,000**	**604,000**	**679,000**	**679,000**
4.Water Demand(m^3/day)	**295,000**	**361,000**	**432,000**	**495,000**	**571,000**	**648,000**

Note) (J):Jazan Region, (M):Makkah Region

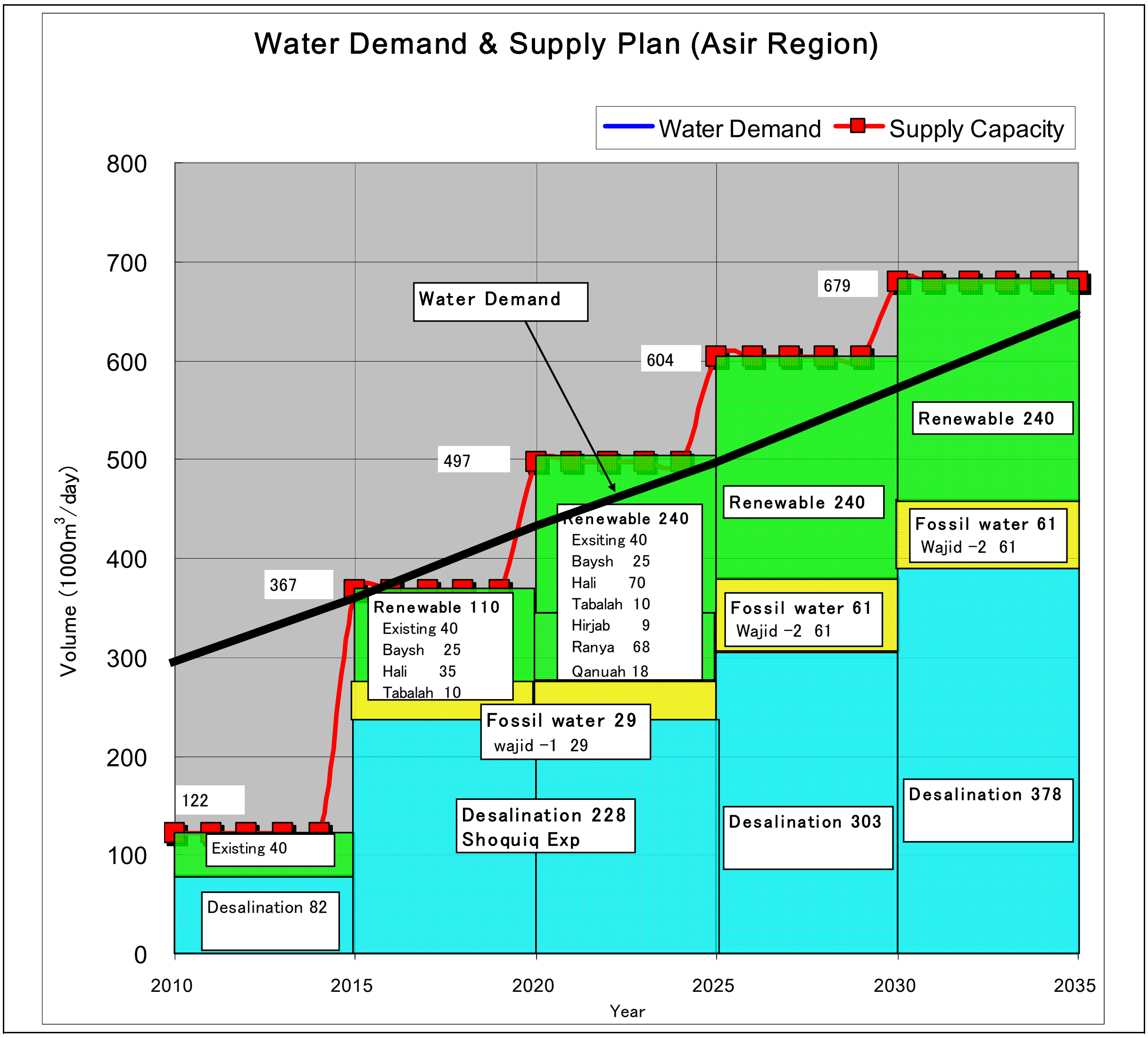


Figure C.3-7 Projection of Water Demand and Water Production in Asir (2011-2035)

Figure C.3-8 Dams and Desalination Plants in Asir Region

(2) Production of Plant for the Five Years

<Plans for the Year of 2011-2015>

The Water demand for the year 2015 in the Asir Region amounts to 361,000m^3/day. Renewable water of 25,000m^3/day is provided from Baysh Dam in the Jazan Region, 35,000m^3/day from Hali Dam in the Makkah Region, and 10,000m^3/day in the Tabalah Dam under construction in the Asir Region accounts for the total water production of about 70,000m^3/day.

Table C.3-12 Water Production Plan in Asir Region (2011-2015)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		110,000	30
• Existing Facilities	Existing	40,000	
• Baysh Dam	New	25,000	
• Hali Dam	New	35,000	
• Tabalah Dam	New	10,000	
◆ Desalination		228,000	62
• Shuqaiq Plant	Existing	82,000	
• Shuqaiq Plant	Expansion	146,000	
◆ Fossil		29,000	8
• Wajid Aquifer	New	29,000	
Total		367,000	100

Accordingly, the total amount of renewable water production 110,000m^3/day including the existing water production is 40,000m^3/day.

Meanwhile, as for desalination, the capacity of Shuqaiq desalination plant will be expand to 228,00m^3/day by 2015 from 82,000m^3/day as of 2011.

Wajid fossil water of about 29,000m^3/day, which is under construction in the Najran Region, is planned to be transferred to the internal land of the Asir Region

All of water production of renewable, desalination and fossil water by 2015 will be 367,000m^3/day, which results in 30%, 62% and 8% of total water production for renewable, desalination and fossil water respectively.

Facilities plan for water supply is shown in Table C.3-13.

Table C.3-13 Water Supply Facilities Plan in Asir Region (2011-2015)

Facililities	Demensions
Pipeline D	Section:Shuqaiq-ABha, Length=124Km
Shuqaiq Desalination Plant	Production Volume: 228,000 m^3
Wajid Aquifer Facilities	Section: Wajid- Tath Lith, Length=150 Km

Note: Location of facilities is shown in Figure C.3-8 and C.6-1.

<Plans for the Year of 2016-2020>

Water demand for the year 2016 in the Asir Region amounts to 432,000m^3/day. Hirjab and Ranyah Dam are proposed to be constructed by 2020. Water production of 9,000m^3/day provided from Hirjab Dam and 68,000m^3/day from Ranyah Dam are prospected, which amounts to a total water production of 77,000m^3/day. Water of 53,000m^3/day produced at Hali and Qanunah Dams, which is provided to the Al Baha Region is planned to be returned to the Asir Region.

Accordingly, total renewable water production amounts 240,000m^3/day which is maximized at this period including additional renewable water of 130,000m^3/day.

Desalination and fossil water will not be developed because water production of 29,000m^3/day (fossil) and 228,000m^3/day (desalination) developed by 2016 can be sustained. Total water production amounts 497,000m^3/day.

Proportion between renewable, desalination and fossil water is 51%, 44% and 5% respectively.

Table C.3-10 Water Production Plan in Asir Region (2016-2020)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		**240,000**	**48**
• Existing Facilities	Existing	*110,000*	
• Hirjab Dam	New	*9,000*	
• Ranyah Dam	New	*68,000*	
• Hali Dam	Expansion	*35,000*	
• Qanunah Dam	Expansion	*18,000*	
◆ Desalination		**228,000**	**46**
• Shuqaiq Plant	Existing	*228,000*	
◆ Fossil		**29,000**	**6**
• Wajid Aquifer	Existing	*29,000*	
Total		**497,000**	**100**

Facilities plan for water supply is shown in Table C.3-15.

Table C.3-15 Water Supply Facilities Plan in Asir Region (2016-2020)

Facililities	Demensions
Pipeline E	Section:Shuqaiq-Ar Birk, Length=96Km
Pipeline H	Section:Abha-Al Janoub, Length=148Km
Pipeline G	Section:Abha-Al Alayan, Length=216Km

Note: Location of facilities is shown in Figure C.6-1.

<Plans for the Year of 2021-2025>

After 2025, since natural renewable water cannot be expected due to total exploitation of the area, increases in water demand will be accommodated by fossil water and desalination water development.

Fossil water development of 32,000m^3/day as secondary expansion is accounted. Desalination water of 75,000m^3/day which is supplied to Jazan Region will be changed to transfer to Asir Region by 2025. Total desalination water in the Asir Region will be 303,000m^3/day. These amounts of water are equal to the maximum capacity of Shuqaiq desalination plant. Total water production will be 604,000m^3/day.

Proportion between renewable, desalination and fossil water is 40%, 50% and 10% respectively.

Table C.3-16 Water Production Plan in Asir Region (2021-2025)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		**240,000**	**40**
● Existing Facilities	Existing	*240,000*	
◆ Desalination		**303,000**	**50**
• Shuqaiq Plant	Existing	*228,000*	
• Shuqaiq Plant	Expansion	*75,000*	
◆ Fossil		**61,000**	**10**
• Wajid Aquifer	Existing	*29,000*	
• Wajid Aquifer	New	*32,000*	
Total		**604,000**	**100**

Facilities plan for water supply is shown in Table C.3-17.

Table C.3-17 Water Supply Facilities Plan in Asir Region (2021-2025)

Facililities	Demensions
Pipeline C	Section: Al Baha-Al Alaya, Length=105Km
Pipeline I	Section: Al Alayan -Bisha, Length= 96Km
Wajid Aqufer(Stage II)	Section: Tathlith – Bisha, Length=96Km

Note: Location of facilities is shown in Figure C.6-1.

<Plans for the Year of 2026-2035>

Breakdown of renewable water by 2035 shows 133,000m^3/day provided from Ranyah Dam, Hirjab Dam and Qanunah Dam in the Asir Region and 75,000m^3/day from Hali Dam in the Makkah Region as well as 133,000m^3/day (Existing). Total renewable water production amounts to 240,000m^3/day. In addition, desalination water of 378,0000m^3/day provided from Shuqaiq plant and fossil water of 61,000m^3/day from Wajid Aquifer also are available as water production capacity. Total water production amounts 679,000m^3/day, which results in excess water demand of 648,000m^3/day for the year 2035.

Table C.3-18 Water Production Plan in Asir Region (2026-2035)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		**240,000**	**35**
• Existing Facilities	Existing	*240,000*	
◆ Desalination		**378,000**	**56**
• Shuqaiq Plant	Existing	*303,000*	
• Shuqaiq Plant	Expansion	*75,000*	
◆ Fossil		**61,000**	**9**
• Wajid Aquifer	Existing	*61,000*	
• Wajid Aquifer	New	**679,000**	**100**
Total		**240,000**	**35**

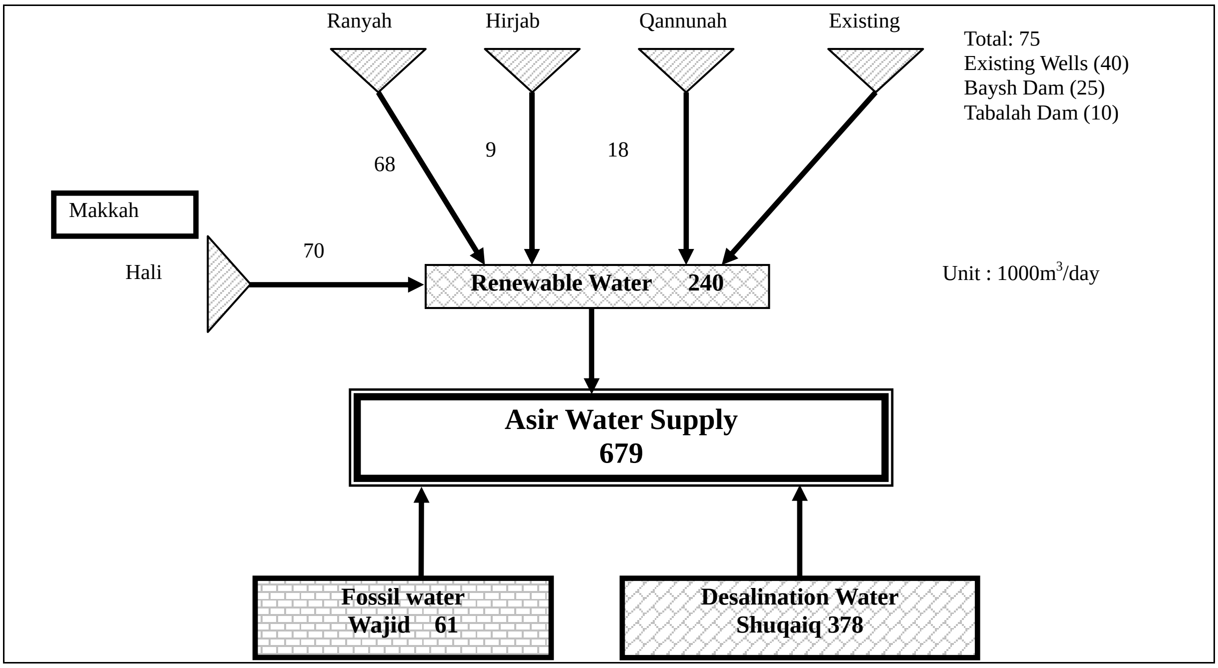


Figure C.3-9 Water Supply Plan and Water Sources in Asir Region (2035)

3.2.3 Jazan Region

(1) Plan for Water Demand and Water Supply

The Water demand and water supply of Jazan Region is shown in Table C.3-19 and Figure C.3-10.

Table C.3-19 Water Production Plan in Jazan Region

Water Resource	-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
1.Existing (m^3/day)	**140,000**	**140,000**	**140,000**	**137,000**	**137,000**	**137,000**
1.1 Renewable Water	**136,000**	**136,000**	**136,000**	**136,000**	**136,000**	**136,000**
Existing Wells	136,000	136,000	136,000	136,000	136,000	136,000
1.2 Desalination	**4,000**	**4,000**	**4,000**	**1,000**	**1,000**	**1,000**
Shuqaiq D.P	3,000	3,000	3,000	0	0	0
Farasan D.P	1,000	1,000	1,000	1,000	1,000	1,000
2.New (m^3/day)	**-**	**149,000**	**193,000**	**246,000**	**246,000**	**301,000**
2.1 Renewable Water	**-**	**69,000**	**78,000**	**78,000**	**78,000**	**78,000**
Baysh Dam	-	33,000	33,000	33,000	33,000	33,000
Damad Dam	-	36,000	36,000	36,000	36,000	36,000
Qissi Dam	-	-	9,000	9,000	9,000	9,000
2.2 Desalination	**-**	**80,000**	**115,000**	**168,000**	**168,000**	**223,000**
Shuqaiq D.P	-	72,000	72,000	0	0	0
Farasan D.P	-	8,000	8,000	8,000	8,000	8,000
Sabya D.P	-	-	35,000	160,000	160,000	215,000
3.Total (m^3/day)	**140,000**	**289,000**	**333,000**	**383,000**	**383,000**	**438,000**
4.Water Demand(m^3/day)	**203,000**	**238,000**	**286,000**	**329,000**	**379,000**	**436,000**

[Note)] (J):Jazan Region, (M):Makkah Region, (N): Najran Region

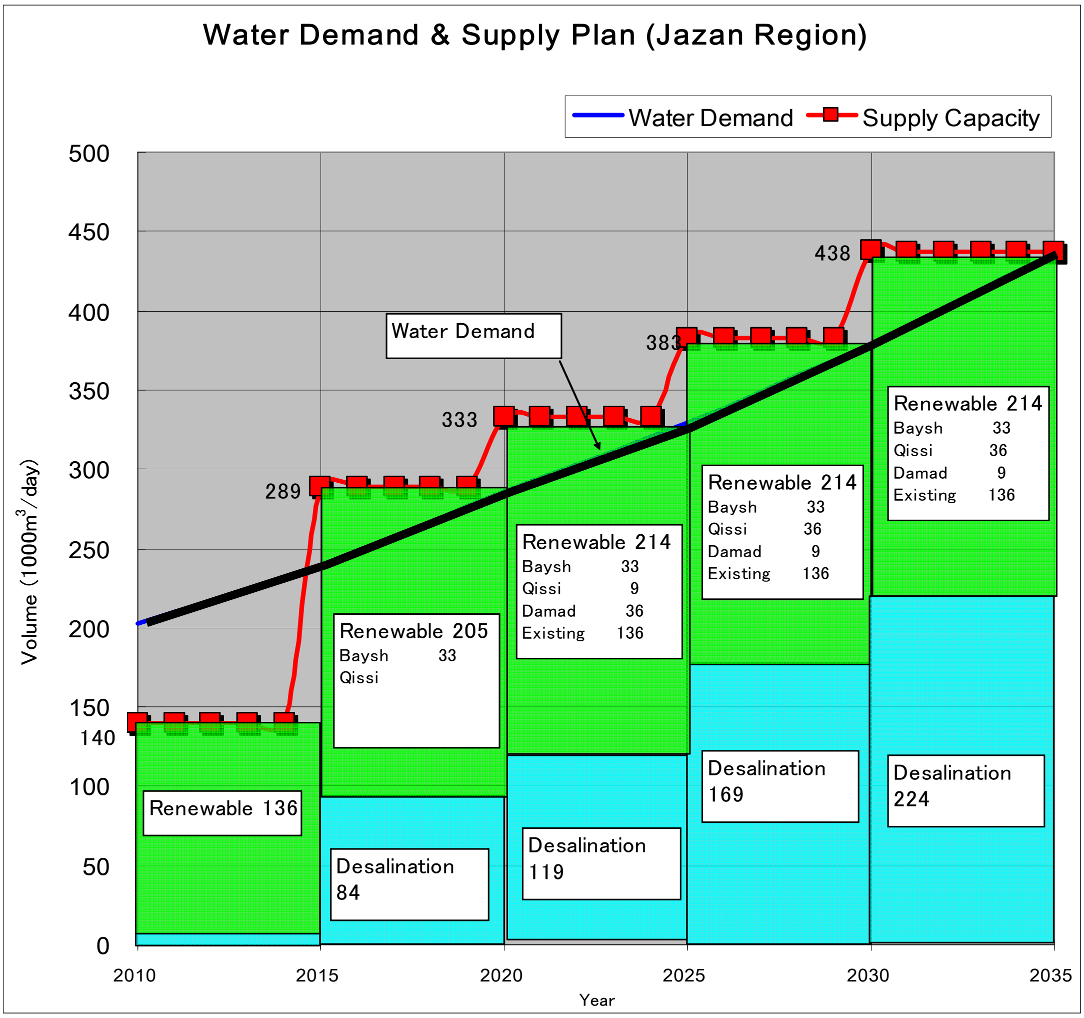


Figure C.3-10 Projection of Water Demand and Water Production in Jazan (2011-2035)

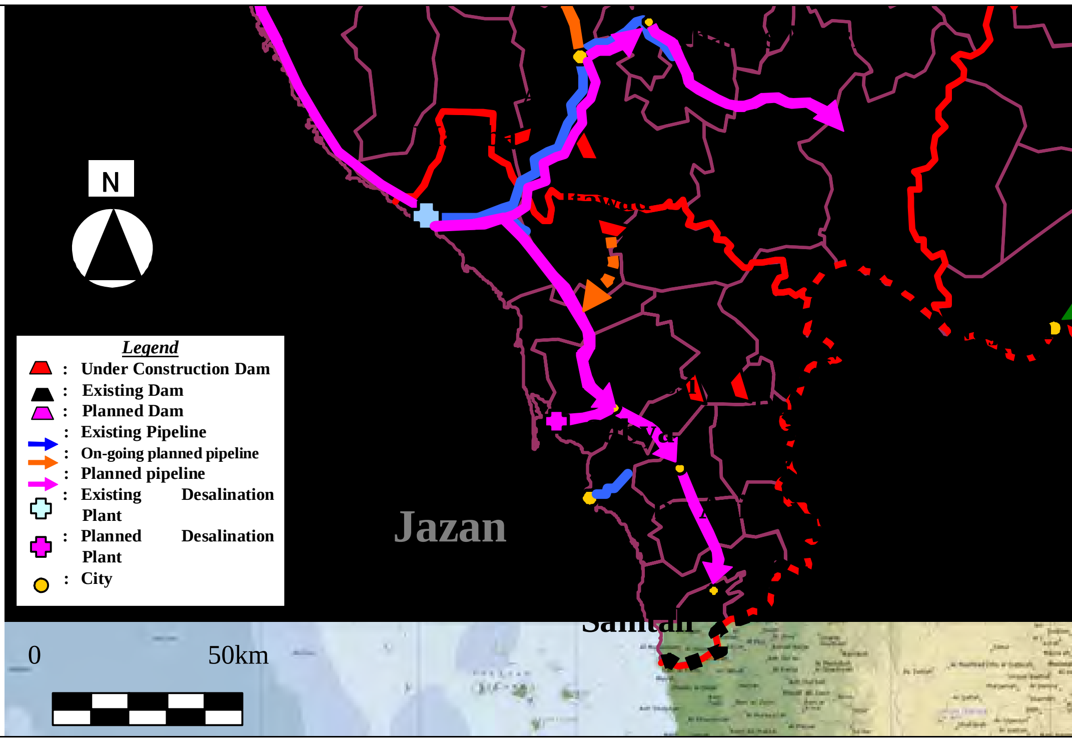


Figure C.3-11 Dams and Desalination Plants in Jazan region

(2) Production of Plant for the Five Years

<Plans for the Year of 2011-2015>

Water demand for the year 2015 in Jazan Region amounts to 238,000m^3/day. As new development of renewable water resources, Baysh Dam and Damad Dam are under construction as of 2010, which will be completed by 2011. Water production is expected to be 33,000m^3/day from Baysh Dam and 36,000m^3/day from Damad Dam. The development of water from the Baysh Dam will be integrated in the network system of water supply. While water developed by Damad Dam will be applied for local use, Renewable water, which enables supply to the Jazan Region, will be 205,000m^3/day to include existing water.

Desalination water of 75,000m^3/day will be supplied from Shuqaiq plant including the current desalination water of 3,000m^3/day. While, Farasan desalination plant will be extended to be 9,000m^3/day.

Accordingly, the total production of renewable and desalination water amounts to 289,000m^3/day for the year 2015. Renewable water and desalination make up about 71% and 29% of total water production respectively.

Table C.3-20 Water Production Plan in Jazan Region (2011-2015)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		205, 000	71
• Existing Facilities	Existing	*136, 000*	
• Baysh Dam	New	*33,000*	
• Damad Dam	New	*36,000*	
◆ Desalination		**84,000**	**29**
• Shuqaiq Plant	Existing	*3,000*	
• Farasan Plant	Existing	*1,000*	
• Shuqaiq Plant	Expansion	*72,000*	
• Farasan Plant	Expansion	*8,000*	
Total		289, 000	100

Facilities plan for water supply is shown in Table C.3-21.

Table C.3-21 Water Supply Facilities Plan in Jazan Region (2011-2015)

Facililities	Demensions
Pipeline F	Section: Shuqaiq-Samta, Length=151Km

Note: Location of facilities is shown in Figure C.6-1.

<Plans for the Year of 2016-2020>

Water demand for the year of 2020 in the Jazan Region amounts to 286,000m^3/day. Qissi Dam with capacity of 9,000m^3/day will be completed. After completion of this dam, there are no dam construction plan and few possibilities to develop renewable water. Renewable water amounts 214,000m^3/day. Even if Qissi Dam is completed, water demand cannot be covered by water production for the year 2020. Therefore, 75,000m^3/day of desalination water is supplied by Shuqaiq desalination plant, the remaining water is supplied by the newly constructed desalination plant in Jazan (tentatively named Sabya Plant) about 35,000m^3/day. Total desalination water production amounts to 119,000m^3/day including 9,000m^3/day provide from Farasan plant.

All of the water production of renewable and desalination water by 2020 will be 333,000m^3/day, which results in 64% and 36% of the total water production for renewable, desalination water respectively.

Table C.3-22 Water Production Plan in Jazan Region (2016-2020)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		**214,000**	**64**
• Existing Facilities	Existing	*205,000*	
• Qissi Dam	New	*9,000*	
◆ Desalination		**119,000**	**36**
• Shuqaiq Plant	Existing	*75,000*	
• Farasan Plant	Existing	*9,000*	
• Sabya Plant	New	*35,000*	
Total		333, 000	100

Facilities plan for water supply is shown in Table C.3-23.

Table C.3-23 Water Supply Facilities Plan in Jazan Region (2016-2020)

Facililities	Demensions
Sabya Desalination Plant	Production Volume: 35,000 m^3

Note: Location of facilities is shown in Figure C.3-11.

<Plans for the Year of 2021-2025-2030>

Water demand for the year 2025 in the Jazan Region amounts to 329,000m^3/day. The potential of renewable water is insufficient for covering the water demand. Therefore, a desalination plant with the capacity of 160,000m^3/day is required to be extended. Total water production amounts 383,000m^3/day including renewable water of 214,000m^3/day (by 2025).

Water transmission from Shuqaiq desalination plant to the Jazan Region will be suspended. The total capacity of Sabya plant amounts to 160,000m^3/day extending 125,000m^3/day, which is a substitute for water production of 75,000m^3/day provide from Shuqaiq desalination plant. Water demand of 379,000m^3/day for the year 2030 can be covered by total capacity of 383,000m^3/day.

Proportion of renewable water and desalination is 56% and 44% of total water production respectively.

Table C.3-16 Water Production Plan in Jazan Region (2021-2025-2030)

Water Production	Category	Production (m^3/day)	Rate (%)
◆ Renewable Water		214, 000	56
• Existing Facilities	Existing	*214, 000*	
◆ Desalination		169, 000	44
• Shuqaiq Plant	Existing	*0*	
• Farasan Plant	Existing	*9, 000*	
• Sabya Plant	Expansion	*160, 000*	
Total		383, 000	100

Facilities plan for water supply is shown in Table C.3-25.

Table C.3-25 Water Supply Facilities Plan in Jazan Region (2021-2025-2030)

Facililities	Demensions
Sabya Desalination Plant	Extension Production Volume: 160,000 m^3

Note: Location of facilities is shown in Figure C.3-11.

<Plans for the Year of 2031-2035>

The Water demand for the year 2035 in the Jazan Region amounts to 436,000m^3/day. Water demand will be covered by the extended water production of 55,000m^3/day in Sabya Plant. Consequently, the total water production amounts 438,000m^3/day, which is composed of desalination water of 224,000m^3/day (51%) and renewable water of 214,000m^3/day (49%).

Table C.3-26 Water Production Plan in Jazan Region (2031-2035)

Water Production	Category	Production (m³/day)	Rate (%)
◆ Renewable Water		214, 000	49
• Existing Facilities	Existing	*214, 000*	
◆ Desalination		224, 000	51
• Farasan Plant	Existing	*9, 000*	
• Sabya Plant	Existing	*160, 000*	
• Sabya Plant	New	*55, 000*	
Total		438, 000	100

Renewable water in 2035 amounts to 214,000m³/day including water production of 78,000m³/day provided from Baysh, Qissi and Damad Dam, and 136,000m³/day from wells. While, desalination water production amounts to 224,000m³/day provided from Farasan and Sabya plants. The total water production amounts to 438,000m³/day, which meets water demand of 436,000m³/day for the year 2035.

Facilities plan for water supply is shown in Table C.3-27.

Table C.3-27 Water Supply Facilities Plan in Jazan Region (2026-2030)

Facililities	Demensions
Sabya Desalination Plant	Extension Production Volume: 55,000 m³

Note: Location of facilities is shown in Figure C.3-11.

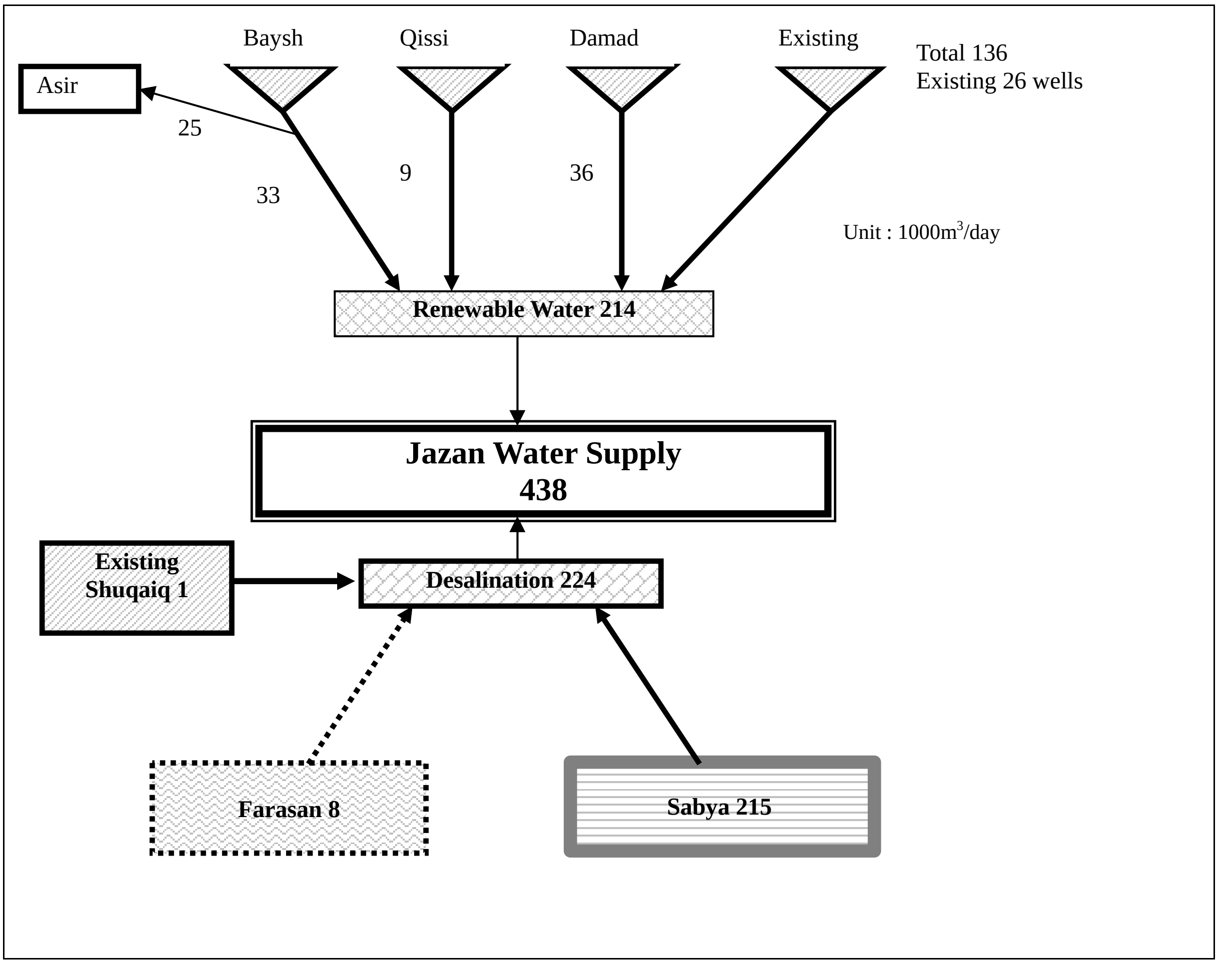


Figure C.3-12 Water Supply Plan and Water Sources in Jazan Region (2035)

CHAPTER 4 MANAGEMENT OF WATER DEMAND

4.1 Municipal Water

4.1.1 Measures for Demand Management

In order to decrease water consumption on the demand side, it is necessary to work on the measures according to the above-mentioned characteristic, so the following proposals are performed.

(1) The Measure of "3-R Movement of Water"

In the area where the coverage rate of public water service is low, per capita water consumption is generally low. As well, it is suggested that water is carefully used without waste in such areas. Since such recognition is implemented in the usual study, it is recognized that "water is a precious resources" in this study.

Concerning wasted resources known as conventional garbage, the "3R" measure is taken (Reduce the amount of resources used, Reuse and Recycle), and the results are from the viewpoint of the effective use of resources now. This measure is also applicable to water, which is a precious and limited resource.

The methods here raise concern about the rule of water saving and preservation of precious water resources, so the "3R" campaign (Reduce of water consumption, Reuse of the water used once, and Recycle by which the water used once are processed appropriately and reused)" is proposed.

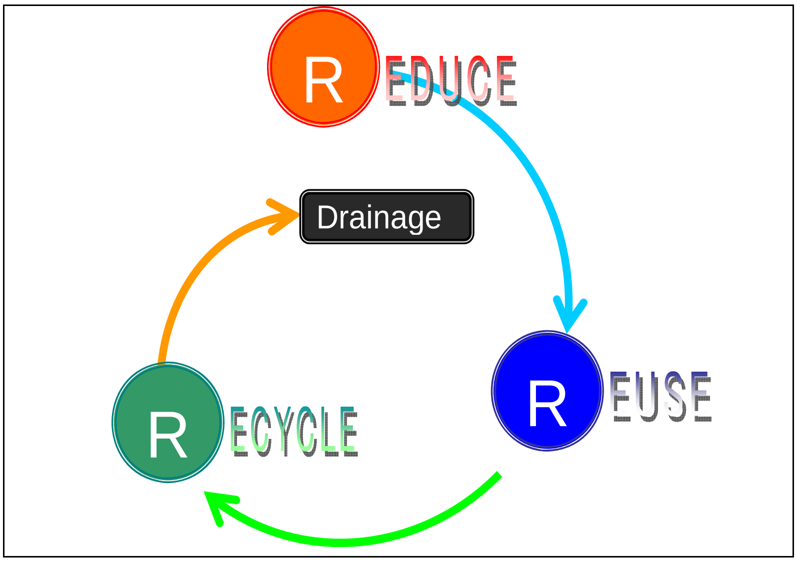


Figure C.4-1 Image Map of Water Saving Activities(3-R) of Municipal Water

The first pillar (Reduce) focuses on "reduction of the amount used", and the second pillar (Reuse) is reuse of water that was once used. For example, in the KSA before the five times a day prayer in mosque and in order to purify the body, there is the custom to use water. It seems that such water is collected and used for surrounding tree planting city water etc. The third pillar (Recycle) is recycling of water. This collects water used in factories, for example, and after it is purified, it is used for rinsing water or other uses in factories again.

Table C.4-1 Example of Water Saving Activities

Reduce	• Saving water consumption (a toilet, wash, a bath, cook, etc) • Preventive measures of leakage of water
Reuse	• Collect used water in Mosque. And use it for greening etc
Recycle	• Reclaimed waste water ⇒ fruit tree, roadside trees, etc • Reuse purification water and cooling water in a factory after processing the water.

(2) Water-saving Activities in School Life

The effects are large especially when studying the activities taken place in school life. Children transmit at school what one learns at home from parents. Moreover, even if the child once mastered good water use custom at an earlier age, the possibilities of becoming an adult with the same customs are not high. Moreover, since worshiping in mosques has become a daily part of life in the KSA, it is thought that the promotion of a water educational campaign needs further examination.

(3) Encouragement of Using Water Saving Type Apparatus

Water saving by water use apparatus has the feature that the fixed water-saving effect will be automatically acquired irrespective of a user's consciousness if apparatus is introduced, it continues and the effect of introduction is large.

In the field of municipal water, circulation use in an air conditioner is performed, and also exploitation, such as a water-saved type flush toilet bowl of water, is progressing.

In the field of water for domestic use, the amount of water used by apparatus in relation to water use is very large. For this reason, the improvement of main flush toilet bowl, washing machine, showers, etc. which are apparatus in relation to water use is effective for reduction of the amount of the water for domestic use. In the KSA, a living standard will also improve increasingly from now on, and it will be expected that introduction of the apparatus for water supplies is promoted.

As an triggar which advances 3R, the law which promotes the apparatus introduction for water supplies of a saved-water type flush toilet bowl, a washing machine, etc., and a system, for example, the government, pay a subsidy as the government from now on, and the measure depended without carrying out purchase motivation to citizens etc. can be considered.

With an industrial water sector, it is a section where tackling of water saving is easy to start in circulation use of cooling water and temperature control water, etc. Furthermore, in order to raise a recycle ratio, maintenance of the saved-water type apparatus in a manufacturing process is needed.

(4) Water Demand Management by Water Supply Charge

The amount of the domestic water used occupies the greatest proportion of municipal water. The main factors influencing water use volume for indoor domestic water are the number of family members (coverage of family baths, washing machines, flush toilets, automatic dishwashers, etc; width of house, and a domestic income) etc. The factors related to the amount of outdoor domestic water use are the width of the yard, the amount of watering in for gardens, the number of cars possessed including washing them), etc. In addition, a water charge is also one of the important factors.

In the results of an investigation of Japan (National Land Agency), it was found that 24% of amount-of-water change is explained by consumer spending and the water supply price, and 47% is explained by the spread gap of main water use apparatus, such as flushed toilets. Because the living environments are different between the KSA and Japan, although it is not necessarily the tendency for an example of Japan to be the same also in the KSA, it is thought that the spread of consumer spending, a water supply price, and water use apparatus is important as main factors.

Research at John Hopkins University in the USA reports that if the water supply price is doubled, indoor domestic water use will decrease by 20%. Although it was concluded that reform through increasing the price of water service is difficult, it can be said by adding a water supply charge we can significantly control the amount of water used to some extent.

(5) Proper Water Charge and its Collection

About water charge, the fee structure of the block progressive charge system is taken. However, in the example of Riyadh, as shown in the following Figure C.4-2, almost all water users are included in the cheapest charge classification. Furthermore, flux meter is not installed in each user's place in many cases, and the point that organization which collects a meter-rate based charge as the actual condition is not made is also pointed out.

In the area currently supplied with the pipeline network even in the research zone, similarly, meter is not installed and grasp of the amount used and collection of the charge based on it are not performed as a matter of fact. For a setup of suitable water charge, recovery of the cost by it, and reduction of water consumption, it is required to perform meter installation in a research zone.

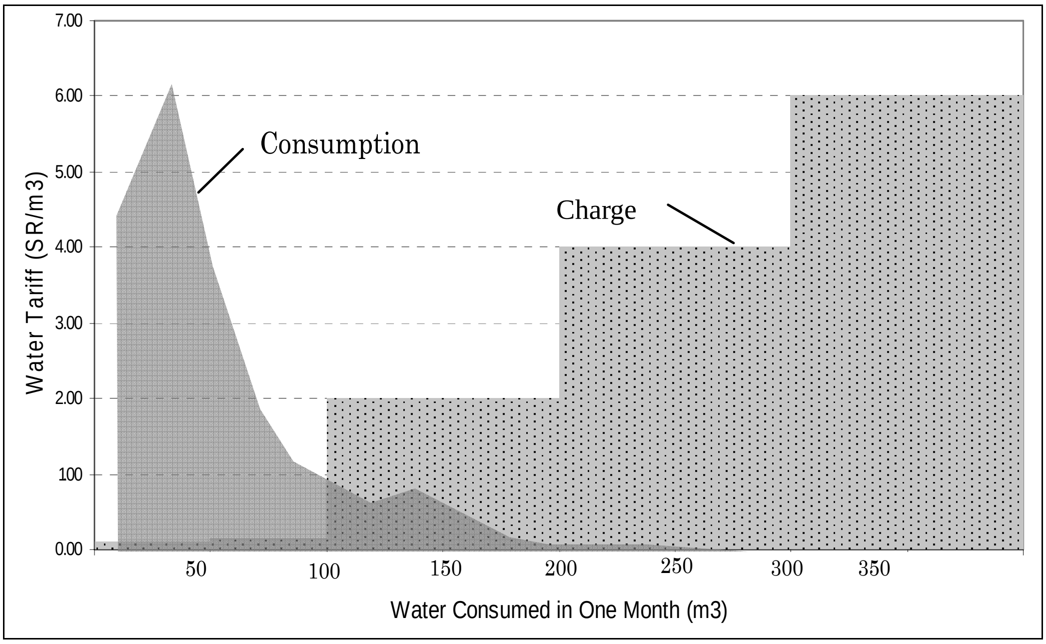


Figure C.4-2 Amount of the Water Use and Water Charge in Riyadh (Accommodation Area)

4.1.2 Curtailment Effect in Financial Aspect by Decrease of Demand

Here, the economical effect produced by changes of demand is examined using the result of sensitivity analysis about the demand of municipal water described in 3.1.7, Chapter 3.
Based on a sensitivity-analysis result, economical evaluation is tried for 10% reduction of a LCD, 5% improvement of leakage ratio and continuation the demand by the present water supply unit in the future. In any case, the demand in a planned target year (2035) was assumed.

(1) The Effect in the Financial Aspect by 10% of LCD Reduction

The standard of LCD for water supply plan by deliberations with MOWE is a larger water supply standard physical unit as compared with the neighboring countries in an arid region. Here, the economical effect over the amount demanded reduced when the present actual condition is referred to and is reduced 10% is examined.

Table C.4-2 The Effect in the Financial Aspect by 10% of LCD Reduction

	Makkah Region	Al Baha Region	Asir Region	Jazan Region	Najran Region
Municipal Water Demand (Standard) (1000m^3/day)	2,278	135	648	436	178
Demand at the 10% of LCD Reduction (1000m^3/day)	2,065	118	585	389	160
The amount of demand retrenchment (1000m^3/day)	213	17	63	47	18
Government assistance equivalent to reduction of water (*1) (million SR/year)	279.9	44.7	165.6	61.8	23.7 (*2)
				Total	575.7
(Reference) The newly developed amount of water by dam Name of dam (Development of water: 1000m^3/day)	Rabigh (44) Maruwani (36) Al Lith (16) Yiba (38) (Total 144)	Nilah (11) Al Janabin (5) (Total 16)	Ranya (68) Hirjab (9) Tabalah (16) Baysh (25) Qanunah (30) Hali (70) (Total 218)	Baysh (33) Qissi (9) Damad (36) (Total 78)	

*1) Calculation of the government assistance equivalent to reduction amount of water referred to the method of examination of the use merit of "report 3.2 sewer reuse of reclaimed waste water." As for Al Baha and Asir, 7.2SR/m^3 (8.0 SR/m^{3}x 90%=7.2 SR/m^3), Makkah, Jazan, and Najran assumed the water unit price of desalinization-of-seawater water to be 3.6SR/m^3 (4.0 SR/m^3 x 90%=3.6 SR/m^3).
*2) Najran region assumed as evaluation that it was desalinization-of-seawater water here, although desalinization-of-seawater water was not supplied.

The amount of reduction of the demand at the time of 10% of LCD reduction is as being shown in Table C.4-2 in amount of money. In the five regions, the sum total of 575,700,000 SR can save in one year.

When the newly developed amount of water by dam construction estimates this again, it becomes larger than the development amount of water by the dam under present plan in Makkah region and Al Baha region, and also even other states are equivalent to the development amount of water by two or more dams.

Since the unit cost of developing water by a dam is cheaper than desalinization of seawater, if priority is given to dam development, curtailment of the quantity of production of desalinization of seawater will turn into mitigation of a fiscal burden after all.

(2) The Effect in the Financial Aspects in the Case of Continuing the Present LCD Level

Level of LCD tends to increase by change of a lifestyle, or improvement in economic strength. However, the fixed water-saving effect is expectable with the measure of various water saving including 3-R movement. Here, economical evaluation was performed about assumption that the present water supply level is maintained as is by water-saving efforts of citizens.

Table C.4-3 The Effect in the Financial Aspect in the Case of Continuing the Present LCD Level

	Makkah Region	Al Baha Region	Asir Region	Jazan Region	Najran Region
Municipal Water Demand (Standard) ($1000m^3$/day)	2,278	135	648	436	178
Demand at the present LCD level (*1) ($1000m^3$/day)	2,066	122	583	392	160
The amount of demand retrenchment($1000m^3$/day)	212	13	65	44	18
Government assistance equivalent to reduction of water (*2) (million SR/year)	278.6	34.2	170.8	57.8	23.7 (*3)
				Total	565.1
(Reference) The newly developed amount of water by dam Name of dam (Development of water: $1000m^3$/day)	Rabigh (44) Maruwani (36) Al Lith (16) Yiba (38) (Total144)	Nilah (11) Al Janabin (5) (Total 16)	Ranya (68) Hirjab (9) Tabalah (16) Baysh (25) Qanunah (30) Hali (70) (Total 218)	Baysh (33) Qissi (9) Damad (36) (Total 78)	

*1) It presumed from the demand of Option4 and Option5 of sensitivity analyses.
*2) Calculation of the government assistance equivalent to reduction amount of water referred to the method of examination of the use merit of "report 3.2 Reuse of reclaimed waste water."
As for Al Baha and Asir, 7.2SR/m^3 (8.0 SR/m^3x 90%=7.2 SR/m^3), Makkah, Jazan, and Najran assumed the water unit price of desalinization-of-seawater water to be 3.6SR/m^3 (4.0 SR/m^3 x 90%=3.6 SR/m^3).
*3) Najran region assumed as evaluation that it was desalinization-of-seawater water here, although desalinization-of-seawater water was not supplied.

The amount of reduction of the demand in the premise of supplying the present water supply level over the future is as being shown in Table C4-3 in amount of money. In the five regions, the sum total of 565,100,000 SR can save in one year.

If the newly developed amount of water by dam construction estimates this, it will become larger than the development amount of water by the dam under present plan in Makkah region again, and also it is equivalent to two or more dams in other states.

Since the newly developed water value by a dam is cheaper than desalinization of seawater, if priority is given to dam development, curtailment of the quantity of production of desalinization-of-seawater water will turn into mitigation of a fiscal burden after all.

(3) The Effect in the Financial Aspects by 5% of Leakage Reduction

Since there was no data of the actual condition of the pipeline network leakage and a leakage-of-water rate improvement plan, etc. demand forecasting of main enumeration was performed with the application of 20% contained in the basic scenario of MOWE. It presumed how much economical effect there is if a national target which considers as 15% is attained.

Table C.4-4 The Effect in the Financial Aspects by 5% of Leakage Reduction

	Makkah Region	Al Baha Region	Asir Region	Jazan Region	Najran Region
Municipal Water Demand （Standard） (1000m^3/day)	2,278	135	648	436	178
Demand at the 5% of leakage Reduction (1000m^3/day)	2,171	124	616	411	169
The amount of demand retrenchment(1000m^3/day)	107	11	32	25	9
Government assistance equivalent to reduction of water (*1) (million SR/year)	140.6	28.9	84.1	32.9	11.8 (*2)
				Total	298.3
(Reference) The newly developed amount of water by dam Name of dam (Development of water: 1000m^3/day)	Rabigh (44) Maruwani (36) Al Lith (16) Yiba (38) (Total144)	Nilah (11) Al Janabin (5) (Total 16)	Ranya (68) Hirjab (9) Tabalah (16) Baysh (25) Qanunah (30) Hali (70) (Total 218)	Baysh (33) Qissi (9) Damad (36) (Total 78)	

*1) Calculation of the government assistance equivalent to reduction amount of water referred to the method of examination of the use merit of "report 3.2 sewer reuse of reclaimed waste water." As for Al Baha and Asir, 7.2SR/m^3 (8.0 SR/m^3x 90%=7.2 SR/m^3), Makkah, Jazan, and Najran assumed the water unit price of desalinization-of-seawater water to be 3.6SR/m^3 (4.0 SR/m^3 x 90%=3.6 SR/m^3).
*2) Najran region assumed as evaluation that it was desalinization-of-seawater water here, although desalinization-of-seawater water was not supplied.

The amount of reduction of the demand in the premise of supplying the present water supply level over the future is as being shown in Table C.4-4 in amount of money. In the five regions, the sum total of 298,300,000 SR can save in one year.

When the newly developed amount of water by dam construction estimates this, it is equivalent to the development amount of water by two or more dams in each state again.

Since the newly developed water value by a dam is cheaper than desalinization of seawater, if priority is given to dam development, curtailment of the quantity of production of desalinization-of-seawater water will turn into mitigation of a fiscal burden after all.

4.1.3 Proposal of Demand Management

In a survey area, municipal water demand cannot be supplied only by renewable water resources. And it is necessary to compensate an insufficiency with desalinated seawater or fossil groundwater. Since cost of producing unit water by desalinated seawater is expensive compared with renewable water resources, desalinated seawater gives priority to and uses renewable water resources, and it becomes water supplies economical as a whole to adjust the quantity of production of desalinated seawater.

For this reason, if water saving is improved and reclaimed waste water can be used as a part of municipal water, finally the quantity of production of desalinated seawater is reducible, and the financial expenditure to produce and supply desalinated seawater which the government of KSA subsidizes can be reduced.

It is important from the field of mitigation of the fiscal burden of a government to manage the demand of municipal water as a result.

Here, it is based also on the result of 4.1.2 and the proposal about future demand management is performed.

(1) The Proposal Concerning Reduction of LCD

- **Promote introduction of the water saving type apparatus in household (a washing machine, a dishwasher, a flush lavatory, etc.).**

  The capability of the water saving type apparatus is released, the support system for people according to the grade of water saving is prepared, and promotion of introduction of the saved type apparatus of water is aimed at. In construction of a public facility, a commercial use building and a residence, a rule should be established for introduction of the water saving type apparatus.

  Reduction of the amount of the municipal water will be achieved by performing continuous publicity work and tackling with a long-term water-saving target and plan.

- **Promotion of renewal of an institution for the improvement in a recycling rate of the water in a factory**

  The demand of industrial water hardly occurs for the time being other than Makkah region, and Asir region.

  Since an industrial expansion is expected, a measure is required in Makkah region, or Asir region.

  The system which serves as advantageous conditions by loan etc. in introduction of the water saving type apparatus is founded, and promoting water saving by introduction of saved-water type apparatus, and recycling of water etc. when the factory need renewal of institution or factory is newly constructed. The recycling rate of the water for every factory etc. is released, and a manager is also made to recognize the importance of water saving.

  Moreover, since it leads also to reduction of the amount of water used by tightening up drainage regulation of a factory, legal revision etc. is performed.

- **Water rates and the water-saving motivation**

  Present water rates are very cheap, in view of a global level. Water saving is promoted by setting up water rates appropriately. Moreover, since it leads to reduction of the amount of drainage and thus lead to reduction of municipal water use, the fee structure of the present sewer use is improved to collect appropriate sewer usage charge.

  It is necessary to put into practice the installation of flow meter so that the amount used can grasp correctly.

- **Promoting recognition of importance of water saving by education and enlightenment.**

  It can lead to reduction of water consumption by improvement of water-saving consciousness by enlightenment through expanding the measure of free distribution of water saving kit by MOWE and 3-R activity in schools and public opportunity.

(2) The Proposal Concerning Improvement of Leakage Ratio

- **Planned renewal of a decrepit pipeline**

  The largest factor of leakage of water is the leakage of water by degradation of a pipeline. In the O&M stage, a system for suitable control of maintenance of a pipeline with a long-term view is strengthened.

  Moreover, although extension is also long and the water pipe of an end also requires time and effort, since the leakage of water in the end supplied to each house cannot be disregarded, either, incorporating in an updating plan is important.

  Also in order to obtain the fund which updates intentionally, it is important to maintain a suitable water charge level.

- **Checking and verifying the amount of supply by a flow meter and actual amount of water supply to users**

  Grasp the area which leakage of water has produced by checking and verifying the amount of supply by a flow instrument and the actual amount of water supply, and it becomes possible to focus on areas effectively where improvement of a leakage-of-water rate should be carried out.

- **Introduction of leakage-of-water diagnostic technology**

  Apparatus and diagnostic technology for leakage-of-water discovery are introduced, and the early detection organization of leakage of water is built.

  In Japan, since the Tokyo Waterworks Bureau has attained the top-level low leakage-of-water rate also in the world of around 3% and leakage-of-water diagnostic technology is excellent. This kind of technology should be master by training etc. is desired.

Although promotion of demand management needs many costs, as already seen, there is an effect to the extent that the riverhead development by many dams becomes unnecessary only by a unit of LCD becoming small 10%. It is important to examine the cost which can apply a water-saving target to demand management supposing a financial burden reducibility.

4.2 Management of Agricultural Water Demand

4.2.1 Future Planting Plan for Water Demand Control

The water development of surface water for agriculture use is not expectable except new water development at the Baysh dam and Damad dam under construction in Jazan region. The water resource development in the future can be considered about reuse of reclaimed waste water, and the groundwater development by the well group with a central focus on the underground dam.

Although the reuse rate of reclaimed waste water with 2% of agricultural demand in Jazan region as of 2020 is too small, but in the Al Baha region and Asir region, 20% or more is used and these are promising water resources. On the other hand, the development of the groundwater by an underground dam is planned in Jazan region, it does not serve as promising water resources judging from the present condition of a lowering groundwater level, and a viewpoint of the water-resources potential. Therefore, in future the water development for agriculture use is considered that reuse of a reclaimed waste water will become main measures.

Since water development can not be expected, the demand management plays important roles in the future. The issues on the water management are summarized as follows.

- Popularization of modern irrigation system is behind.
- Since measurement of irrigation water is inaccurate, superfluous irrigation has occurred.
- The technical assistance on water management to the farmers is insufficient.
- Farmer's water-saving awareness is too low.

Specially, support of the water management technology to the farmers is required by popularizing water-saving irrigation method and the water-saving awareness to the farmers needs to be popularized. Furthermore, from a viewpoint of demand management, crop conversion to vegetables with small water requirement and fruit tree which can expect increased demand from a fodder crop and other crops with large water requirement is considered to be the most realistic measure according to Decision 335 by MOA.

As mentioned above, regarding the water resources for agriculture, reuse of a reclaimed waste water and groundwater development by a renewable well group shall be performed, and crop conversion consisting mainly of vegetables and fruit trees from cereals and fodder crop is proposed judging from a viewpoint of demand management.

The water balance simulation at the time of enforcing the water-saving irrigation as demand management and reuse of the reclaimed waste water as new water resources, and conversion of the planted area as agricultural policy, etc. are examined, and the result of the possible planted area according to the region in 2035.

(1) Preconditions in Examination

In the estimate for agricultural water use and demand prediction, as information is insufficient and examination of long-term water demand and supply balance are not completed, data and the plan for water supplies which are collected in the statistical yearbook prepared by MOA and the MOA regional office are adopted as assumption conditions. The main things are as follows;

The amount of the present water use for agriculture

- Based on the data such as the planted area, a crop coefficient and etc., the net water requirement is computed and then the gross water requirement is computed in consideration of the conveyance loss and the irrigation application loss.

The prediction conditions for future agricultural water demand

- Planted area is constant from 2007 to 2035.
- Since the planted area is constant, the planted area according to region and the period of the above are constant.
- Although irrigation efficiency is set up for every crop, the above-mentioned period is constant.

The setting conditions of estimate for the agricultural water use in the water demand-and-supply balance simulation of a sensitivity analysis etc.

- The target water resource is renewable water, and the result of the water resources potential calculation by SWAT model is used as basic data.
- Surface water in the water demand-and-supply balance simulation gives priority to the water supply to a city, and supplies 30% of total water, and then assigns the remaining of 70% to water use in the down stream and agricultural water use.
- Irrigation efficiency is set 85% in target year from 70% of present condition, supposing a sprinkler, drip irrigation and etc. popularizing further in the future, and irrigation efficiency increasing about vegetables and fruit trees.
- The reuse of the sewage water for every region sets up based on the data prepared by Ital Consult.
- Regarding the planting crops, the demand of fruit and vegetable will be increased in the future, and these planting are performed in the farming land outside a city focusing on vegetables with less water requirement and fruit trees, and assign renewal water with the priority to these crops.
- Since it is water balance simulation in case the absolute quantity of water resources is insufficient, all the amounts of losses assume that repetitive use is carried out in order to understand a sever water shortage condition.

Although the demand for agricultural water use is calculated based on many assumptions explained in the above, many problems in each region such as water level decline and dry up of the well for agriculture use are occurring. Since the phenomena such as salty water intrusion are also seen in the observation wells along the coastal line of Jazan region, accordingly it is obvious that the potential of the water resources for agricultural use is limited.

(2) Calculation Examination

The calculation examination are 3 region as follows.

<Al Baha Region>

Comparison of the agricultural water demand and the renewable water resources in 2007 will generate a water shortage in Al Baha, Al Mandaq, and Al Qari governorate.

The planted area of the 2007 level is securable in gross by the reuse of reclaimed waste water and the water-saving irrigation in the planned target 2035 year.

Regarding Mandaq governorate, 250ha of planted area needs to be reduced in 2035. (250ha reduction of the planted area of cereals/fodder crops will be carried out from the 2007 level)

Table C.4-5 Water Balance Simulation and Planted Area in Al Baha Region

No	Items	Governorate							Total
		Albaha	Biljurashi	Almandaq	Almukwah	Alaqiq	Qilwah	Alqari	
(1)	Planted Area in 2007 (ha)	563	490	589	209	1019	21	1560	4450
(2)	Planted Area in 2035 (ha)	563	490	564	209	1019	21	1560	4425
(3)	Agricultural Water Demand in 2007 (MCM)	6.8	5.9	7.1	2.5	12.3	0.3	18.9	53.9
(4)	Agricultural Water Demand in 2035 (MCM)	6.8	5.9	6.8	2.5	12.3	0.3	18.9	53.6
(5)	Water Supply Demand (MCM)	1.4	0.7	0.4	5.7	3.0	4.9	0.3	16.4
(6)	Water-resources Potential (MCM)	2.6	10.0	3.5	14.4	35.4	21.9	11.6	99.4
(7)	Water-resources after water supply (MCM)	1.2	9.3	3.1	8.7	32.4	17.0	11.3	83.0
(8)	Water Balance in 2035 (MCM) (7)-(4)	-5.6	3.4	-3.7	6.2	20.0	16.7	-7.6	29.4
(9)	Water Saving (MCM)	1.1	0.9	1.1	0.4	1.9	0.0	2.9	8.4
(10)	Waste Water Re-use (MCM)	2.2	0.8	0.0	0.4	0.3	0.2	0.2	4.2
(11)	Return Flow (MCM)	2.7	2.4	2.7	1.0	4.9	0.1	7.6	21.4
(12)	Water Balance (MCM) (8)+(9)+(10)+(11)	0.4	7.5	0.1	8.0	27.2	17.1	3.1	63.4
(13)	Change of cultivation area (ha) in 2035	0	0	-250	00	00	00	00	-250
(14)	Change of irrigation water (MCM) in 2035	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	-0.3

[Note] (9): Development of Modern irrigation system, (10): Waste water re-use (Data source: By ITAL CONSULT)
(11): Return flow (Irrigation losses) = Demand*(1-1/1.67) = Demand*0.4

<Asir Region>

Comparison of the agricultural water demanded and the renewable water resources in 2007 will generate a water shortage in Khamis Mushayt, Bisha, An Namas, Ahad Rifaydah, Zahran Aljanub, and Balqarn governorate.

By the reuse of reclaimed waste water and the water-saving irrigation in the planned target 2035 year, the planted area of the 2007 level is securable in gross except for two governorates.

Regarding An Namas and Ahad Rifaydah governorate, the planted area of 255ha and 40ha still need to be reduced respectively.

Table C.4-6 Water Balance Simulation and Planted Area in Asir Region

No	Items	Governorate							
		Abha	Khamis Mushayt	Bishah	Annamas	Muhayil	Sarat Abidah	Tathlith	Rijal Alma
(1)	Planted Area in 2007 (ha)	3,591	1,947	6,554	**965**	1,366	521	661	435
(2)	Planted Area in 2035 (ha)	3,591	1,947	6,554	**710**	1,366	521	661	435
(3)	Agricultural Water Demand in 2007 (MCM)	45.8	24.8	83.6	12.3	17.4	6.6	8.4	5.5
(4)	Agricultural Water Demand in 2035 (MCM)	45.8	24.8	83.6	8.4	17.4	6.6	8.4	5.5
(5)	Water Supply Demand (MCM)	3.9	3.3	4.9	0.3	2.8	0.7	1.0	0.4
(6)	Water-resources Potential (MCM)	65.5	10.2	47.0	2.5	39.9	92.7	56.3	16.1
(7)	Water-resources after water supply (MCM)	61.6	6.9	42.1	2.2	37.1	92.0	55.3	15.7
(8)	Water Balance in 2035 (MCM) (7)-(4)	15.8	-17.9	-41.4	-6.3	19.7	85.4	46.9	10.2
(9)	Water Saving (MCM)	5.1	2.8	9.3	1.4	1.9	0.7	0.9	0.6
(10)	Waste Water Re-use (MCM)	13.8	25.5	6.2	1.5	5.1	0.8	1.4	0.0
(11)	Return Flow (MCM)	18.3	9.9	33.4	3.4	7.0	2.7	3.4	2.2
(12)	Water Balance (MCM) (8)+(9)+(10)+(11)	53.0	20.2	7.5	0.0	33.7	89.6	52.6	13.0
(13)	Change of cultivation area (ha) in 2035	0	0	0	**-255**	0	0	0	0
(14)	Change of irrigation water (MCM) in 2035	0.0	0.0	0.0	-3.9	0.0	0.0	0.0	0.0

No	**Items**	Governorate				Total
		Ahad Rifaydah	Zahran Aljanub	Balqarn	Almajardah	
(1)	Planted Area in 2007 (ha)	**1,441**	539	2,303	741	**21,054**
(2)	Planted Area in 2035 (ha)	**1400**	530	2,303	741	**20,759**
(3)	Agricultural Water Demand in 2007 (MCM)	18.4	6.8	29.4	9.4	268.4
(4)	Agricultural Water Demand in 2035 (MCM)	16.7	6.8	29.4	9.4	262.8
(5)	Water Supply Demand (MCM)	1.7	0.4	0.2	0.8	20.4
(6)	Water-resources Potential (MCM)	5.6	5.4	18.1	21.2	380.5
(7)	Water-resources after water supply (MCM)	3.9	5.0	17.9	20.4	360.1
(8)	Water Balance in 2035 (MCM) (7)-(4)	-12.7	-1.8	-11.5	11.0	97.3
(9)	Water Saving (MCM)	2.0	0.7	3.3	1.0	29.8
(10)	Waste Water Re-use (MCM)	4.0	1.3	1.6	0.9	62.1

No	Items	Governorate				Total
		Ahad Rifaydah	Zahran Aljanub	Balqarn	Almajardah	
(11)	Return Flow (MCM)	6.7	2.7	11.7	3.8	105.1
(12)	Water Balance (MCM) (8)+(9)+(10)+(11)	0.0	3.0	5.1	16.7	294.3
(13)	Change of cultivation area (ha) in 2035	**-40**	0	0	0	-295
(14)	Change of irrigation water (MCM) in 2035	-1.7	0.0	0.0	0.0	-5.6

[Note] (9): Development of Modern irrigation system, (10): Waste water re-use (Data source: By ITAL CONSULT)
(11): Return flow (Irrigation losses) = Demand*(1-1/1.67)=Demand*0.4

<Jazan Region>

A water shortage occurs in almost all the governorate, and the water balance simulation serves as 1,200 MCM minus.

Although the amount of water resources newly securable by the reuse of sewage water and the water-saving irrigation by the planned target 2035 year serves as about 44MCM, when this is converted into vegetable cultivation, it is only about 6,200ha.

Table C.4-7 Water Balance Simulation and Planed Area in Jazan Region

No	Items	Governorate							
		Jazan	Sabya	Abu Arish	Samtah	Alharth	Damad	Arrayth	**Baysh**
(1)	Planted Area in 2007 (ha)	**3,589**	**22,785**	**9,395**	**28,175**	**8,452**	**3,797**	**5,839**	**584**
(2)	Planted Area in 2035 (ha)	**902**	**5,726**	**2,361**	**7,080**	**2,124**	**954**	**1,468**	**147**
(3)	Agricultural Water Demand in 2007 (MCM)	47.5	301.3	124.3	372.6	111.8	50.2	77.2	7.7
(4)	Agricultural Water Demand in 2035 (MCM)	47.5	77.7	27.8	11.9	0.3	18.2	48.0	7.7
(5)	Water Supply Demand (MCM)	28.0	15.6	11.4	9.1	4.8	3.2	1.3	5.9
(6)	Water-resources Potential (MCM)	61.2	50.9	21.9	6.4	2.9	10.9	28.6	25.5
(7)	Water-resources after water supply (MCM)	33.2	35.3	10.5	-2.7	-1.9	7.7	27.3	19.6
(8)	Water Balance in 2035 (MCM) (7)-(4)	-14.2	-42.3	-17.3	-14.6	-2.3	-10.5	-20.7	11.9
(9)	Water Saving (MCM)	0.9	5.7	2.4	7.1	2.1	1.0	1.5	0.1
(10)	Waste Water Re-use (MCM)	3.5	5.5	3.8	2.7	0.0	2.3	0.0	0.6
(11)	Return Flow (MCM)	19.0	31.1	11.1	4.8	0.1	7.3	19.2	3.1
(12)	Water Balance (MCM) (8)+(9)+(10)+(11)	9.1	0.0	0.0	0.0	0.0	0.0	0.0	15.7
(13)	Change of cultivation area (ha) in 2035	**-2,687**	**-17,058**	**-7,034**	**-21,094**	**-6,328**	**-2,843**	**-4,372**	**-437**
(14)	Change of irrigation water (MCM) in 2035	0.0	-223.7	-96.5	-360.7	-111.4	-32.1	-29.2	0.0

No	Items	Governorate						Total
		Farasan	Addair	Ahad Almusarihah	Alidabi	Alaridah	Addarb	
(1)	Planted Area in 2007 (ha)	**718**	**406**	**22,540**	**812**	**4,290**	**2,176**	**113,558**
(2)	Planted Area in 2035 (ha)	**180**	**102**	**5665**	**204**	**1,078**	**547**	**28,539**
(3)	Agricultural Water Demand in 2007 (MCM)	9.5	5.4	298.1	10.7	56.7	28.8	1501.9
(4)	Agricultural Water Demand in 2035 (MCM)	9.5	5.4	28.4	10.7	31.2	25.1	349.3
(5)	Water Supply Demand (MCM)	0.0	4.9	9.0	5.3	6.2	2.3	106.9
(6)	Water-resources Potential (MCM)		26.9	19.1	28.4	23.8	16.4	322.9
(7)	Water-resources after water supply (MCM)		22.0	10.1	23.1	17.6	14.1	216.0
(8)	Water Balance in 2035 (MCM) (7)-(4)		16.6	-18.2	12.3	-13.6	-11.0	-123.8
(9)	Water Saving (MCM)		0.1	5.7	0.2	1.1	0.5	24.0
(10)	Waste Water Re-use (MCM)		0.4	1.2	0.0	0.0	0.4	20.3
(11)	Return Flow (MCM)		2.1	11.3	4.3	12.5	10.0	135.9
(12)	Water Balance (MCM) (8)+(9)+(10)+(11)		19.2	0.0	16.8	0.0	0.0	60.7
(13)	Change of cultivation area (ha) in 2035		**-304**	**-16,875**	**-608**	**-3,212**	**-1,629**	**-84,481**
(14)	Change of irrigation water (MCM) in 2035		0.0	-269.7	0.0	-25.6	-3.7	-1152.6

[Note] (9): Development of Modern irrigation system, (10): Waste water re-use (Data source: By ITAL CONSULT)
(11): Return flow (Irrigation losses) = Demand*(1-1/1.67)=Demand*0.4

Based on the result of water balance simulation with the 3 regions mentioned above, in Al Baha region and Asir region, it is possible to maintain agriculture by the crop conversion. However, in Jazan region the water demand for agricultural use is large, and the shortage of water resources is inevitable. As a measure against future, a method only has reducing the planted area until it balances renewable water-resources potential. Accordingly, following agricultural measures are proposed in order to reduce the planted area.

- From a viewpoint of fresh-vegetables self-supply, vegetable cultivation will be promoted and the planted area in the planned target 2035 year will set to 7,164 ha of the twice in 2007 (3,582ha).
- Regarding fruit trees, Jazan region has Tropical Fruit Research Center (Jazan Agriculture Research Center) of MOA, moreover, since the fruit trees which mainly continue to be concerned with the mango has consumption in the region, reduction shall not be performed but 5,525ha of the 2007 level shall be maintained.
- According to Decision No.335, planting of a fodder crop with much water consumption does not carry out.
- The amount of water resources produced by reducing the planted area of cereals and fodder crops are preferentially converted to vegetables and fruit farming, and the remainder is taken as a plan to assign the sorghum cultivation which is typical crops of Jazan region.

The planted area and the water demand at the time of implementing the above-mentioned measures become as follows, the fruit tree can maintain the 2007 level, and the vegetable can secure the planted area of the twice in 2007.

Table C.4-8 Reduction Plan of Planted Area in Jazan Region

Crops	Current Status(2007)		Target Year（2035）		Compared to 2007
	Planted Area (ha)	Water Demand (MCM)	Planted Area (ha)	Water Demand (MCM)	
Cereal	92,200	1,030	15,900	190	93% Reduction
Fodder	12,200	340	0	0	Stop
Fruit	5,500	110	5,500	110	2007 Maintain
Vegetable	3,600	30	7,100	50	2007 Doubling
Total	113,600	1,510	28,500	350	75% Reduction

4.2.2 Proposal to Future Agriculture Development

The proposal to the agricultural development in each region is summarized as follows based on the plan of the above-mentioned planting conversion, a reduction plan and etc.

<Al Baha Region>

Although in Al Baha region, small-scale wheat cultivation has been maintained by the traditional agricultural technique using the climate blessed till the first half of the 1980s, by having developed the large machinery agriculture using fossil water in Riyadh and Qassim (Buraydah) regions with many flatlands by the free distribution policy of farmland which aims at 100% of a grain self-sufficiency rate, the subsidy policy on well drilling and etc., cereals cultivation in the hilly and mountainous area where is small farmland and where a production cost is high was obliged to decline. As the result, 70% of farmland is converted into the fruit tree now. In the case of Al Baha region, since the renewable water resources which covers the planted area of the 2007 level are secured, it is possible to develop the agriculture consisting mainly of fresh vegetables and fruit cultivation also in the future taking advantage of high elevation.

<Asir Region>

Asir region is divided roughly into the hilly and mountainous agricultural area centering on Abha Governorate, and the flat-ground agriculture area centering on Bisha Governorate. Since it is expected that the outskirts of Abha are blessed with water resources, fruit growing consisting mainly of the vegetables centering on a open field cultivated tomato and a grape cultivation are prosperous, and consumption of vegetables and fruit trees increases in connection with population increase, the agriculture consisting mainly of vegetables and fruit trees can be continued in the future.

The water resources around Bisha which locates in the North of the region are not enough. It is necessary to perform the planting conversion in future, and the water-saving irrigation needs to perform reuse of reclaimed waste water etc.

Moreover, the diligent farmer who is practicing the organic farming is located in Abha Governorate and the organic farming is getting popularity from the safety of a food in Saudi Arabia. Accordingly by popularizing the organic farming through this farmer, differentiation with other regions is attained, and the policy which promotes the agriculture of Asir region can be considered.

<Jazan Region>

Although the planted area aiming at 2035 can secure planting of the scale in 2007 about fruit trees and vegetables, it stops planting of fodder crop, and 93% reduction of planted area about cereals is required.

The agriculture in the region will cooperate with "Jazan Agriculture Research Center" which FAO is carrying out technical assistance in the region. If the fruit tree which suited the climate of the region, and the agriculture in suburban areas which specialized in vegetables are promoted and water resources have a margin, it is possible to survive in the intensive agriculture of performing cash crop cultivation such as maize, millet, sesame and etc.

According to a hearing at the MOA regional office, it is pointed out that a farmer's aging and luck of successor are becoming big issues in the region. It is also a problem that the Agriculture of Saudi Arabia is performed by Saudi peoples as a manager and foreigner as a farmer, therefore MOA does not like to advice to foreigners positively.

If the present condition mentioned above and insufficient water resources are taken into consideration, it will be judged that the agriculture in Jazan region is obliged to a decline. Therefore, other industries which accept agricultural population need to be introduced.

Fortunately, the Jazan Economic City project is progressing near Sabya which locates in 60km northwest of Jazan, and the number of the labor force of this project will be needed about 300,000. On the other hand, the number of the agricultural labor force in Jazan is about 30,000; accordingly acceptance by this project is possible enough.

Therefore, if the issues mentioned above are not solved, industrial structure should be transformed and the surplus farmer should be assigned to the labor force of Jazan Economic City. In addition, when carrying out industrial structure conversion, necessity has the political to the small-scale farmer which has made its living by traditional agriculture.

The total amount of groundwater extraction of Jazan province is (740 MCM/year), which is as twice as large as groundwater development potential (402 MCM/year). It will result in future draw down of groundwater level, which was analyzed by computer simulation on condition that the current pumping is continued in the future. The result is shown in Figure C.4-3. It was expected that groundwater level will be under sea level in large area of the central and southern part of Jazan Region by the year of 2035 and 2060. Then, seawater will intrude into aquifers along the coast in large scale. On the other hand, groundwater level will recover by reducing pumping rate. As shown in Figure C.4-4, draw down of groundwater level will stop by 70% reduction of the pumping amount, and furthermore, groundwater level will go up by 90% reduction of pumping amount.

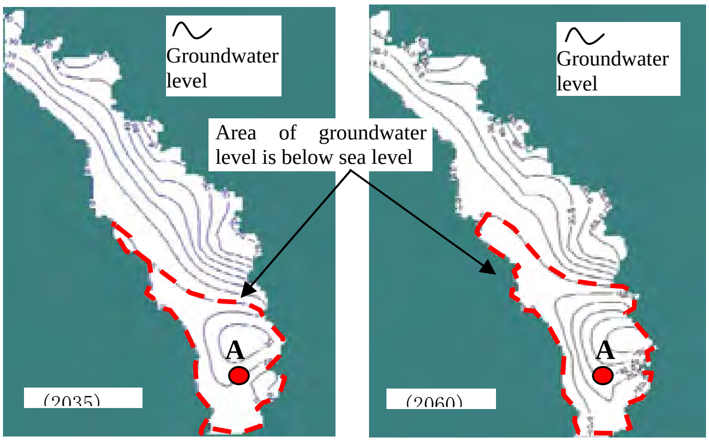


Figure C 4-3 Predicted Draw Down of Groundwater Level under Current Pumping Rate

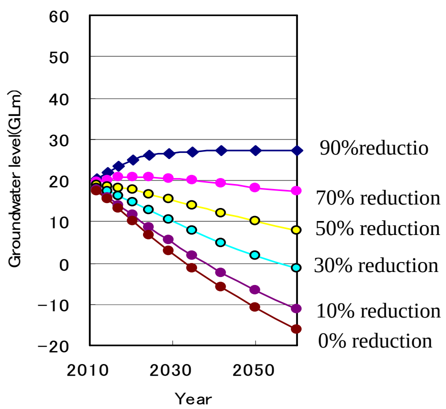


Figure C 4-4 Recovery of Groundwater Level by Redaction of Pumping Rate

CHAPTER 5 OPERATION AND MAINTENANCE, AND MANAGEMENT PLANS

5.1 Integrated Water Management System

(1) The Range and Object Facilities of Management

The object facilities of control of water management system shall be as follows.

- The renewable water development facilities planned by this M/P of Al Baha Region, Asir Region and Jazan Region
- The pipeline facilities which connects main facilities, and pump stations.

(2) The Organization Related to Management

In a M/P, the system which manages renewable water (surface water, groundwater) positively and intentionally is proposed. Renewable water resources had not almost been the targets of intentional management until now by the public organizations. Most of surface water and groundwater have been managed and used individually, especially by the agriculture sector. An exception is the renewable water from dams and wells which the MOWE and its Directorate Offices have managed for domestic water supply. For this reason, only the MOWE and its Directorate Offices are the existing public organization which is executing management and supply of renewable water.

In this M/P, an Integrated Water Resources Management plan which covers across the Regions is proposed. Establishment of RWPC (Renewable Water Production Corporation) is proposed as an organization which becomes a core for using especially renewable water intentionally. Moreover, the Water Authority is proposed as a committee which performs coordination between the MOWE and the MOA. The relation of the organizations in connection with Integrated Water Resources Management for wide area water supply system is later mentioned as an improvement proposal of water administrative organization, and is shown in Figure C.5-15. The action proposal that each related organization is expected to execute is as being shown in the following table.

Table C.5-1 Action Performed to Candidate Organization

Organization	Action
Water Authority	To adjust about the matter about the object for water supplies and management which are related among two or more ministries and government offices is performed. For example, there is a matter concerning MOWE and MOA like water for agricultural use.
Ministry of Water and Electricity (MOWE)	To execute necessary investigations, preparation of plans, implementation of projects and monitoring etc. in order to supervise development of the water resources of the region, management, and conservation
	To talk with the RWPC and decide water allocation of the renewable water for domestic and industrial water sectors
	To talk with the MOA and the RWPC and decide water allocation of the renewable water for the agriculture sector
	To supply domestic water, carry out treatment of sewage and supply reclaimed sewage water to the area where NWC does not cover (Directorate Offices)
	To supervise organization and activities of SWCC and RWPC, and give guidance to them
	To give instructions about proper use of agricultural water in the agricultural water sector in collaboration with the MOA
Ministry of Agriculture (MOA)	To check practice of the agriculture plan in the regions To calculates required water for agriculture based on the agriculture plan in collaboration with agricultural water sector and RWPC
	To promote setting up water use organizations by farmers
	To give guidance for managing farm to save water and to promote improvement and updating of irrigation facilities to save water
	To give instructions about proper use of agricultural water in the agricultural water sector in collaboration with the MOWE
Renewable Water Production Corporation (RWPC)	To develop renewable water resources to utilize and prepare detail water supply plan based on the decided renewable water allocation to each water use sector by the MOWE, and execute the plan
	To grasp usable quantity of renewable water based on the monitoring data of reservoirs and wells
	To execute discussion/request about use and supply of renewable water with related

Organization	Action
	organizations under the instruction and help of the MOWE and the MOA
	To discuss with the MOWE and adjust deliberations of the quantity of production of the desalinated seawater by SWCC and the amount of supply of the renewable water to NWC by RWPC
	To discuss with the MOWE and MOA and adjust deliberations of the quantity of renewable water to the agricultural water sector
	To execute supply of renewable water to each water use sector in a neutral and a fair position
Water-for-agricultural-use sector	To prepare a farming program and the plan for water use under instruction of the MOA
	To manage demand of agricultural water sector and target allocation of renewable water decided by the MOWE based on the farming program and the plan for water use under instruction of the MOA
	To promote setting up water use group in the agricultural sector, which is organized at proper area by farmers
Saline Water Conversion Corporation (SWCC)	To take measures to the stable supply of desalinated seawater in cooperation with MOWE and NWC
National Water Company (NWC)	To supply municipal water stably to water users

(3) Basic Policy of Water Supply Management

Basic of water service management are carried out as follows.

- Efficient and economical water management is performed combining different water resources, such as renewable water, desalinated seawater, reclaimed waste water and fossile groundwater.
- Usually, in principle, the water resources developed in each region are used in each region where it is developed.
- The water resources shall be used flexibly and inter-regionally when severe drought might occur in any region because of maldistribution and yearly or seasonal fluctuation of rainfall.

(4) Layout Planning of the Management Office for Water Supply Management

In order to carry out above-mentioned management, a management office is to be placed in each region and a comprehensive management office which watches and controls regional water management. Moreover, an operation office is installed at main facilities.

The place where a management office is installed is determined with careful attention to the following point so that the activities of a management office can be carried out smoothly.

Attachment of a Management Office to a Operation Office of an Important Facility

The dams and wells which develop large water resources should be placed as the important facilities, and need to be taken as manned management facility.

Efficient management is performed by putting a management office side by side to such a facility's operation office.

Selection of a Place of the Management Office for Broader-based Water Supply System

Center of a broader-based water supply system should be placed where it is convenient to water management and O&M of facilities for efficient performance, considering arrangement of the facilities and traffic conditions etc..

Social Environment Coonditions

The place of management office is to be selected where it is convenient to have meetings with organizations and water users related to water management so that communication and adjustment for water management are performed closely. Living environment of the personnel of a management office is also to be considered.

Economic and Safe Conditions

A management office is to be placed where acquisition of land is easy, and its geology and geographical conditions are good so that disasters are hard to occur. The image figure of the water resources management for carrying out above-mentioned management is shown below. A "RWPC water management office" shall be arranged in the Al Baha region and the Asir region, and the "RWPC comprehensive management office" which watches and controls regional offices shall be placed in the Jazan region.

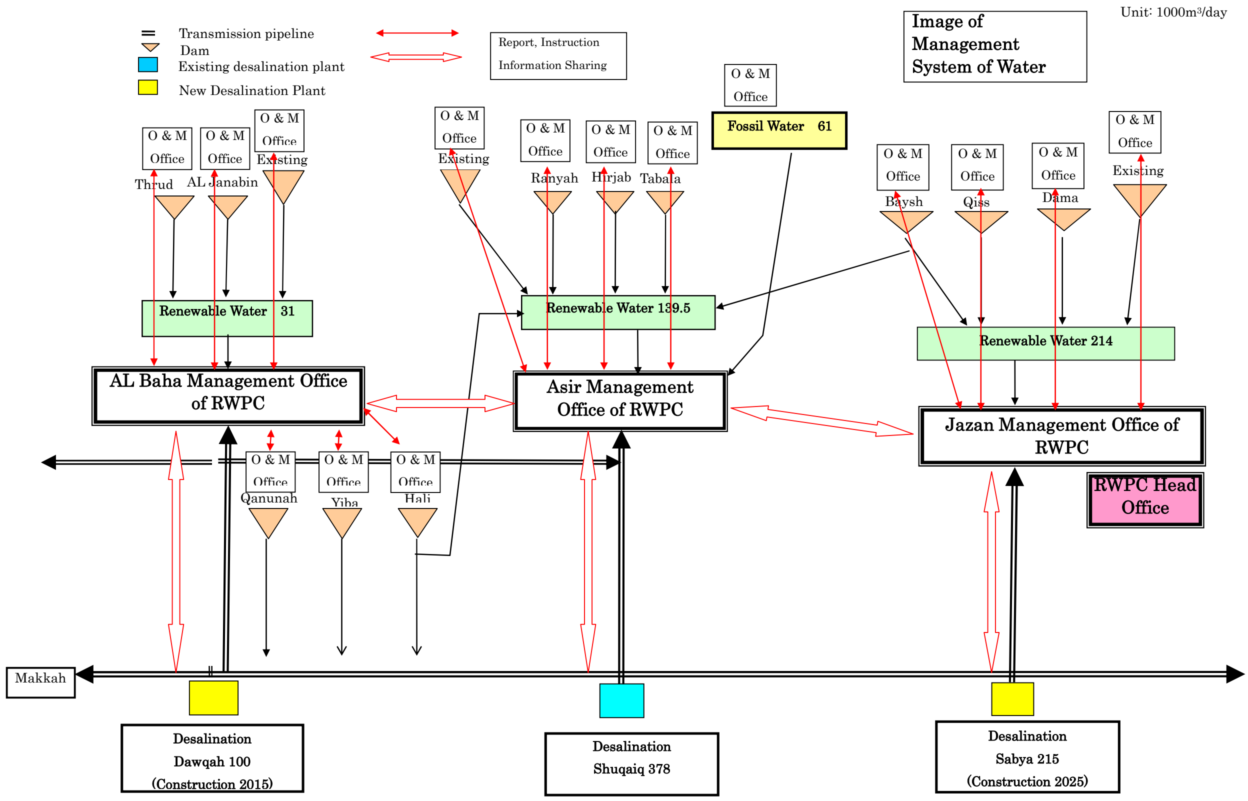


Figure C.5-1 Image Figure of Water Resources Management

5.2 Groundwater Recharge by Dams

5.2.1 Surface Water Development in Combination with Dam and Groundwater Aquifer

As shown in Table C.5-2, the development volume and development volume of each dam is decided relating to the annual flow regime and scale of reservoir volume. Therefore the surface water development in combination with dam and groundwater aquifer is examined as follows.

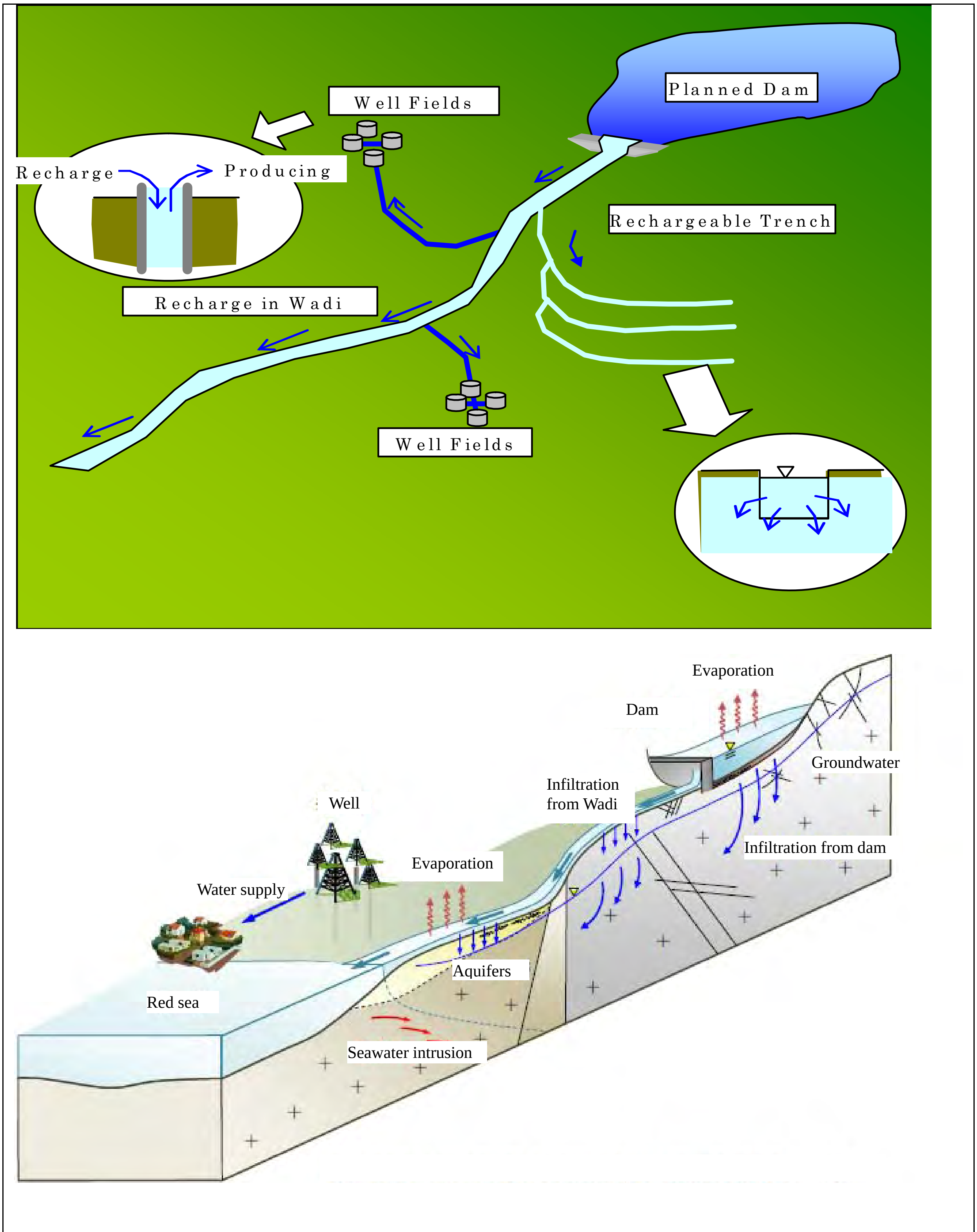


Figure C.5-2 Recharge of Water from Dam into Aquifer

(1) Examination of Development Volume

It is checked that a promising aquifer is downstream from each dam now. Though about the details of the hydraulic geology condition, it is unknown. Though the model used by development volume calculation of the above dam is used, and the validity of the water resources development by cooperation with a dam and a downstream underground aquifer is survey.

Each dam of reservoirs volume (multiple of the effective volume of a dam), and development volume and a development rate is adopted for index and these indexes are examined. Where, the calculation conditions of the above and different conditions are as follows.

- Reservoirs volume is considered as the sum total of the volume of a dam, and reservoirs volume (void volume) of an underground aquifer.
- When there is a flow over effective volume, this flow becomes invalid discharge and is excepted from the object for development.
- The osmosis losses (loss by evaporation etc.) to the amount of evaporation and aquifer from the reservoir surface of a lake were assumed to be daily evaporation of about 5mm.
- It was considered as the flow which can develop 97% at the time of the ability to develop that there is no shortage for 30 years as examination of the development volume of a dam as a planned development flow.

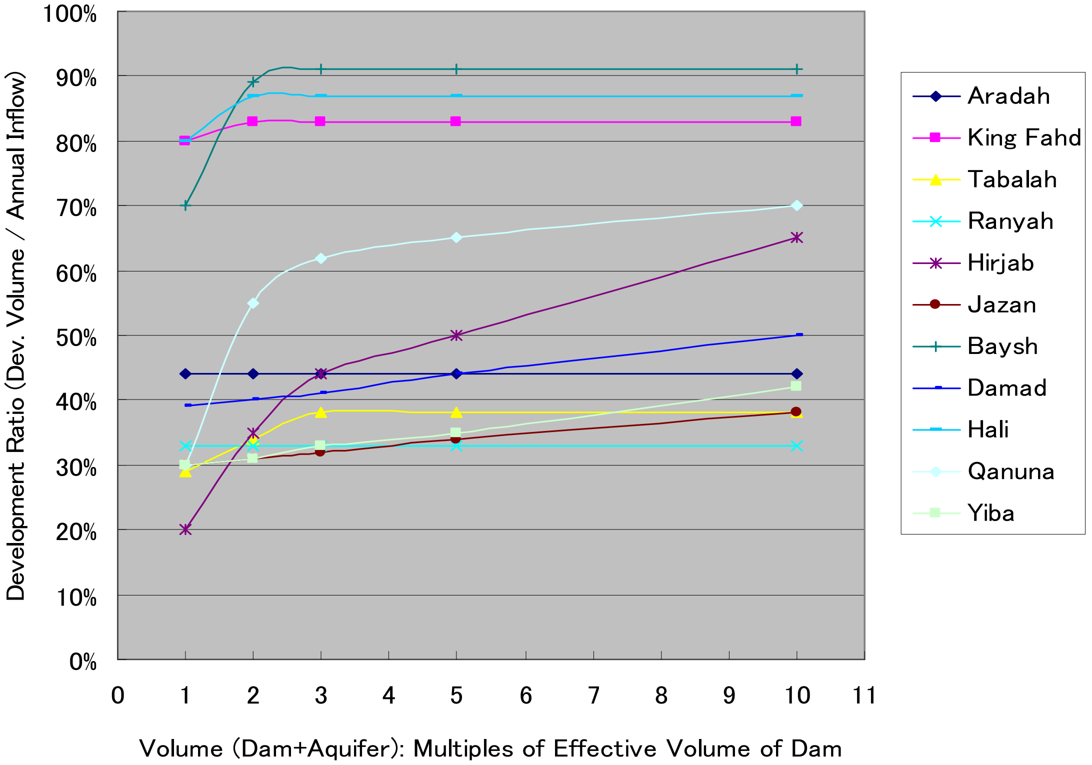
(2) Result of Development Volume

Table C.5-2 shows the relationship between the development volume and total volume (Reservoir Volume + Aquifer Volume). As a result, the larger volume is the higher rate of development such as King Fahd Dam, Baysh Dam and Hali Dam, except for Aradah Dam and Ranyah Dam.

These preliminary calculation, 1) Storage volume is made into zero as an initial condition of an aquifer, 2) The percolation loss to an aquifer is considered as an equivalent for surface-of-a-lake evaporation of a reservoir, 3) The percolation well or percolation canal for promoting recharge artificially are not taken into consideration. A result of the safe side is brought for the reason. Anyway, since it turned out that the water resources development of the wadi by cooperation with a dam and a downstream aquifer is effective, it is the next steps and recommends a detailed examination.

Table C.5-2 Development Volume of Dam in Combination with Aquifer

Dam	V1	V2	V3=V2		V3=2xV2		V3=3xV2		V3=5xV2	
	Reservoir Volume (MCM)	Average Flow (MCM/y)	Deve. Volume (MCM/y)	Deve. Rate	Deve. Volume (MCM/y)	Deve. Rate	Deve. Volume (MCM/y)	Deve. Rate	Deve. Volume (MCM/y)	Deve. Rate
Aradah	68.0	15.2	5.3	35%	6.7	44%	6.7	44%	6.7	44%
King Fahd	325.0	69.1	34.5	50%	44.9	65%	51.1	74%	57.3	83%
Tabalah	68.4	12.3	1.8	15%	2.5	20%	3.1	25%	3.7	30%
Ranyah	219.8	99.6	26.9	27%	32.9	33%	32.9	33%	32.9	33%
Hirjab	4.6	16.8	8.4	50%	10.9	65%	12.2	73%	13.8	82%
Jazan	51.0	78.9	24.1	31%	26.0	33%	27.6	35%	30.0	38%
Baysh	193.6	104.6	71.2	68%	83.7	80%	93.1	89%	95.2	91%
Damad	55.5	61.5	24.6	40%	25.2	41%	26.5	43%	28.3	46%
Hali	249.9	122.3	79.5	65%	100.3	82%	105.2	86%	106.4	87%
Qanunah	79.2	21.3	3.0	14%	4.9	23%	6.4	30%	10.0	47%
Yiba	80.9	81.3	24.8	31%	26.0	32%	27.6	34%	30.1	37%



No joint operation (Dam + Aquifer): Volume (Dam + Aquifer -= 1)

Figure C.5-3 Variation of Dam Development Volume in Combination with Aquifer

5.2.2 Increase of Groundwater Recharge by Facilities

Generally, groundwater is recharged by surface water through wadi bed in the Study Area. To increase groundwater recharge from surface water, construction of groundwater recharge dam along wadi is effective. It is possible to increase groundwater recharge by controlling discharge from recharge dam. In planning of recharge dam, characteristics of groundwater recharge from wadi should be examined as explained below:

Wadi Flow and Flow Distance

How much groundwater can be recharged depends on scale of wadi discharge (see Figure C.5-4). Large discharge will flow passing though target area for water use, and finally discharge into Red Sea in the western part of the Shield area. Such discharge can be called ineffective discharge in view point of groundwater use.

Interval of Discharge

Part of transmission loss of wadi will not become groundwater recharge. If soil between wadi bed and groundwater table is dry, water infiltrating from wadi will be absorbed by the soil and will not reach groundwater table (see Figure C.5-5). On the other hand, if the soil is wet, water will readily reach groundwater table. Dry/wet condition of the soil depends on interval of water discharge from dams. Discharge of shorter interval will make the soil wetter, and amount of groundwater recharge will be increased.

As mentioned above, to increase groundwater recharge, ineffective discharge should be prevented, and adequate discharge should be kept with short interval or continuously.

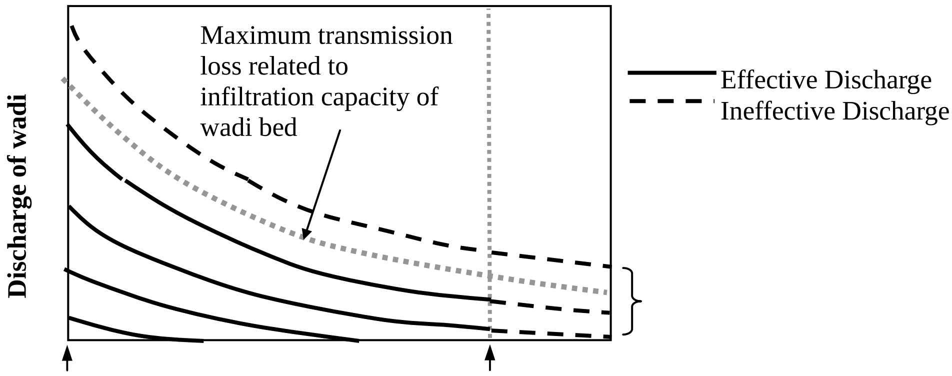


Figure C.5-4 Wadi flow and Flow Distance

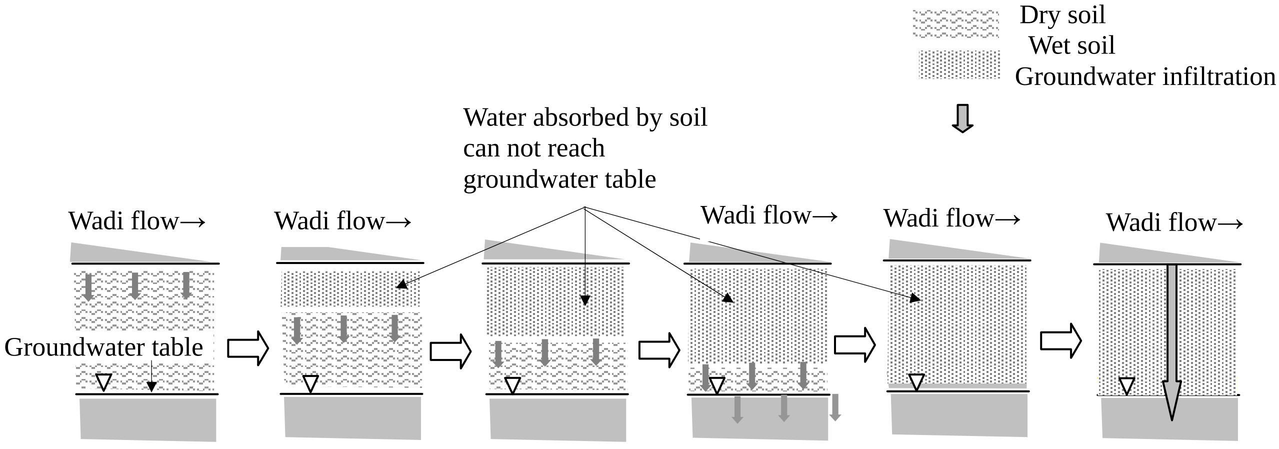


Figure C.5-5 Groundwater Recharge and Soil Moisture

Adequate Discharge

Discharge from recharge dam must be controlled to prevent ineffective discharge that will finally flow into Red Sea, considering size of alluvial plain along Red Sea. Size of alluvial Plain is shown in Table C.5-3. On the other hand, in the area of west side of Shield, amount of discharge from recharge dam should be decided considering distance between the dam to the target area for water use.

Table C.5-3 Size of Alluvial Plain along Red Sea

Region	Width of alluvial plain (Distance form mountain to sea)	Average gradient of wadi bed along alluvial plain
North to Central (Makkah and Asir Region)	30-40km	0.003-0.005
South (Jazan Region)	10-50km	0.001-0.0045

To decide adequate rate of discharge from dam, relation between discharge and flowing distance must be examined. For this purpose, the equation below is proposed in Study Area.

$$Vx = Vo \times (1-a)^{x} \quad \text{(Wheater, 1993)}$$

$$a = 118.8 \times (Vo)^{-0.71}$$

Vo : Discharge from recharge dam (m^3/day)

Vx : flow rate at X (km) downstream from recharge dam (m^3/day)

Relation between flow distance and transmission loss by drawing off is shown in Figure -5.24.

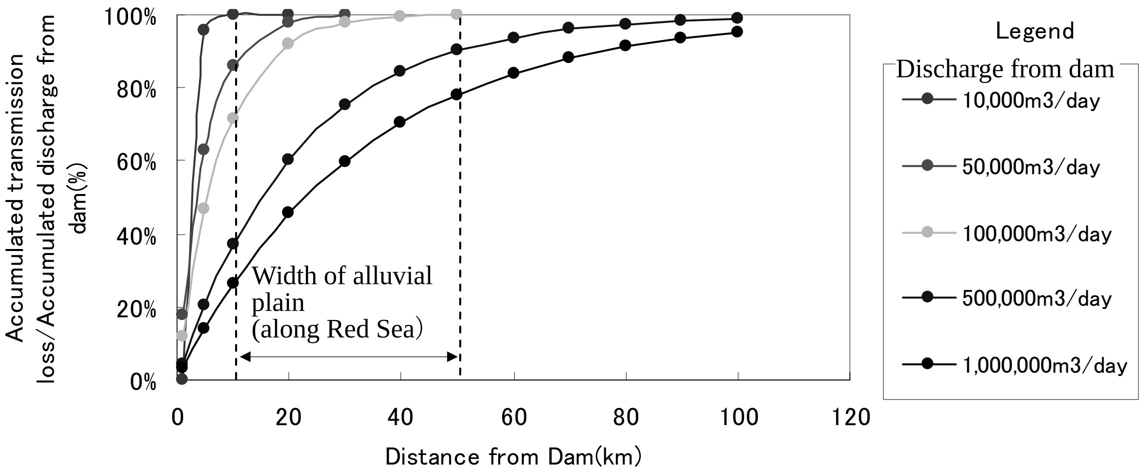


Figure C.5-6 Example of Transmission Losses and Flow Distance (by Wheater Equation)

According to the example in Figure C.5-6, flow rate of 500,000m^3/day from recharge dam can fully become transmission loss within alluvial plain before reaching Red Sea. However, this flow rate depends on parameter of Wheater equation.

Interval of Discharge

Transmission loss can be efficiently changed into ground water recharge by controlling interval of discharge. Relation between transmission loss and groundwater recharge of the Study Area is proposed as below:

Groundwater Recharge(m)=0.0567+0.556 $\times$ $TL^{-0.099}$ $\times$ ANTEC (A.U.Sorman and M.J.Abdulrazzak, 1993)

TL : Transmission loss ($\times 10^6 m^3$/day)

ANTEC : Parameter relating discharge interval (day). ANTEC=1-0.9^T

T : Interval after the previous discharge (day)

As shown in Figure C.5-7, the more frequently water discharged, the more groundwater can be recharged. According to the existing Study in Wadi Tabalah, 75% of transmission loss will become groundwater recharge under the natural condition. Remaining 25% will become groundwater recharge under permanent flow condition.

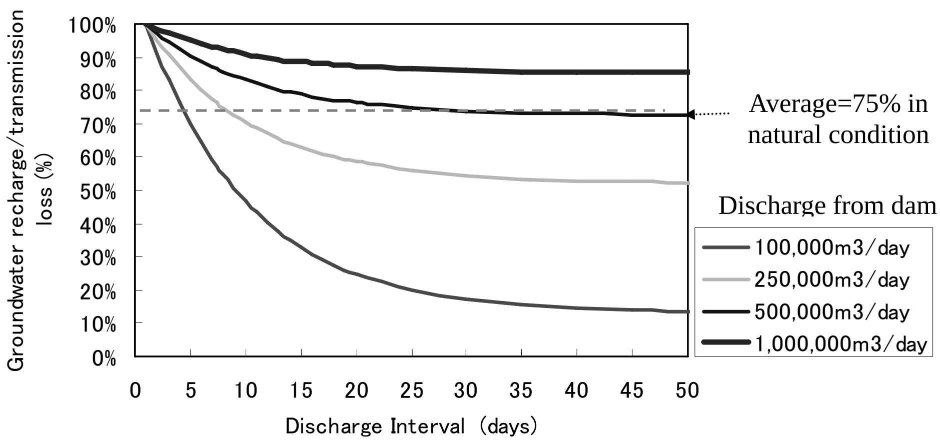


Figure C.5-7 Relation between Interval of Discharge and Groundwater Recharge

5.2.3 Groundwater Recharge in Wadi

Based on result of water balance analysis of this Study, transmission loss and ineffective discharge in the natural condition (without dams) is shown in Table C.5-4. Transmission loss of the Study Area is 67% as a whole in the natural condition. The remaining 33% of ineffective discharge will be improved by recharge dam. Except Jazan Region, transmission loss is 4% ~ 22%. Transmission loss of Jazan Region are 85%, and remaining 15% of ineffective discharge to Red Sea will be reduced by recharge dam.

Table C.5-4 Transmission Loss and Ineffective Discharge of Wadi in Natural Condition

Basin		Wadi flow from mountain to plain (MCM)	Ineffective discharge		Transmission loss	Ineffective discharge
			Discharge into Red Sea (MCM)	Discharge to inland basin (MCM)		
West side of Shield	Makkah/ Asir	613	480	—	22%	78%
	Jazan	299	44	—	85%	15%
East side of Shield	Makkah/ Asir/ Jazan/ Najran	281	—	271	4%	96%
Total		1,193	795		68%	32%

5.2.4 Increase of Transmission Loss by Recharge Dam

Increase of transmission loss depends on improvement of flow regime by recharge dam (see Figure C.5-8). Several representing dams in the Study Area were selected, and increase of transmission by those dams was calculated.

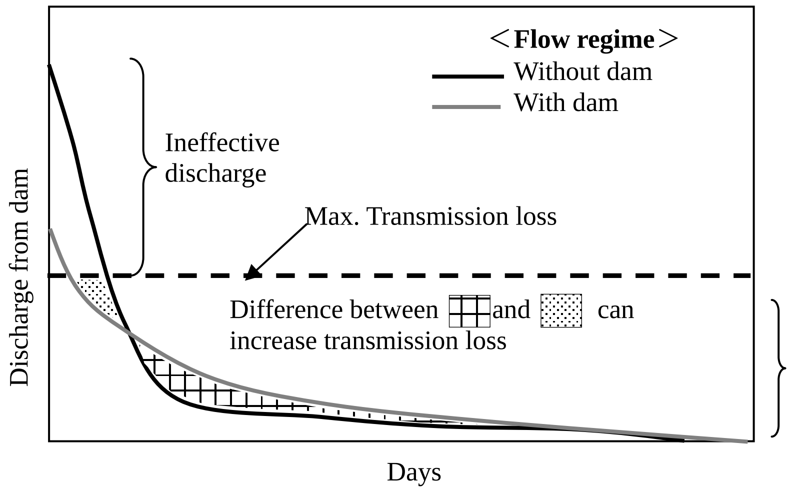


Figure C.5-8 Improvement of flow Regime and Increase of Transmission Losses

<Method for calculation>

Increase of transmission loss by improvement of flow regime through recharge dam was calculated. The result of the calculation is shown in Table C.2-8. Transmission loss will increase by 17 to 40% as shown in Table C.2-8. Method of this calculation is explained below:

- Daily discharge at each dam site was calculated by SWAT Model. This result was defined as “Daily discharge at each dam site (m^3/day)”. This calculation was conducted for 46 years from 1960 to 2006.
- Discharge to be infiltrate into river bed between dam site and the Red Sea was calculated (river basin in West of shield). On the other hand, discharge to be infiltrate into river bed between dam site and the lower most reaches of the area where water is used was calculated (inland basin in east of shield). These results were defined as “Maximum transmission loss (m^3/day)”. (see Table C.2-7)
- Responding to above calculation, discharge when it reaches Red Sea was calculated (river basin

in west of shield). On the other hand, discharge when it reaches the lower most reaches of the area where water is used was calculated (inland basin in east of shield). As seen in Table C.2-7, this discharge was analyzed using Wheaters equation explained in the previous section. The discharge was defined as “Discharge at lower most reaches (m^3/day)”.

- Transmission loss was obtained as below:
  - Transmission loss (m^3/day) = Discharge at dam site – Discharge at lower most reaches

  However, in case that transmission loss is lager than maximum transmission loss, transmission loss was set the same as maximum transmission loss (m^3/day).
- Calculation above was conducted for two cases, (i)case with dam, (ii)case without dam, each for 46 years from 1960 to 2006 in daily base. Total amount of transmission loss for 46 years was calculated for above two cases.
- Total amount of transmission loss for 46 years in case with dam was calculated changing discharge rate from the dam as 1%, 2%, 3%, 4%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%. Maximum transmission loss of different discharge rate above was defined as “transmission loss (m^3)”.
- Increase of transmission loss by improvement of flow regime was finally calculated as shown below:

  Increase of transmission loss (%)

  = (Amount of transmission loss for 46 years in case with dam – Amount of transmission loss for 46 years in case with dam)÷Amount of transmission loss for 46 years without dam)

Table C.5-5 Estimated Maximum Transmission Loss Corresponding to each Dam

Dam	Width of wadi (m)	Infiltration capacity of wadi bed (mm/hour)	Maximum Transmission Loss (see Figure-5) West of Shield	East of Shield	Maximum transmission loss (×1,000m³/day)	Increase in transmission loss (%)
			Distance to sea (km)	Distance to area of water use(km)		
	(W)	(C)	(K1)	(K2)	W×C×(K1 or K2)	
Turbah	100	50	-	30	3,600	32%
Marwani	100		59	-	7,080	38%
Aqiq	50		-	17	1,020	25%
Aradah	50		-	7	420	34%
Tanduhah	50		-	20	1,200	20%
King Fahd	150		-	42	7,560	27%
Tabalah	100		-	66	7,920	17%
Jisan	100		45	-	5,400	23%
Baysh	150		73	-	13,140	16%
Najran	50		-	66	3,960	40%

Detail analysis to find the optimum relationship between discharge from dam and ground water recharge will be done in the next study such as the feasibility study.

5.3 Monitoring Plan

5.3.1 Observation of Rainfall

There are 115 rainfall monitoring precipitation stations (MOWE: 105, PME:10) in the Study Area. (Refer to Figure B.1-10 in Chapter 1, Part B). Comments on current status on rainfall monitoring stations are summarized as follows.

- Monitoring network

  The density of a monitoring is one rainfall station in 3,000km^2 to 4,000km^2 simply. Although it is hard to say that it is enough as the number of rainfall stations, it is mostly arranged in suitable in the area of the Hijaz Asir highland area. On the other hand, it is in a situation with little number of rainfall stations in semi-arid and the desert area located in eastern area of the Study Area.

As these reasons, since the monitoring in Hijaz Asir highland area has good access to monitoring station, it is easy to manage every day. On the other hand, at the station in a desert area, it thinks because access is difficult and daily control of maintenance is also difficult. Due to density of monitoring stations, compared with the western area of the Study Area, accuracy of aerial rainfall in the eastern area serves as an inaccurate situation.

- Data collection for monitoring data

  Although monitoring using a telemetry and transmission are also carried out partly in KSA, the current condition is that monitoring usually using a rain gauge is common, and has transmitted to MOWE headquarters by fax.

  On the other hand, if there are no people for monitoring, there is information that the theft of monitoring equipment, breakage, etc. increase, and it is in the current condition that labor-saving and introduction of telemetry system do not progress.

- Data analysis and apply for runoff and water resources development

  Collection of rainfall data is a main purpose in daily hydrological activities in MOWE, and practical use to analysis or water resources development plan is seldom carried out.

As mentioned above, the proposal for the maintenance plan on rainfall monitoring and a monitoring plan is shown as follows.

- There is tendency on rainfall characteristics that the central part from Taif to Yemen border in Hijaz Asir highland area has much rain, and the desert area in an eastern part of the Study Area has little rain. Taking into account the quantitative characteristics in rainfall, it will be thought that it is necessary to add rainfall stations to Hijaz Asir highland area and its neighborhood preferentially from now on. Moreover, since there are only three rainfall stations located in Najran Region and also centers in the western part of region altogether, it is needed to be located additionally in the central part and the eastern part of the region.
- The Study Team proposes introduction of telemetry system, from the view point of advancing management, in the regional office and water supply facilities consisting of dams and well fields in future.
- The Study Team also proposes positive utilization on rainfall data based on the monitoring for the water resources development of water supply by grasping and arranging the rainfall characteristic (geographical distribution, annual quantitative change on rainfall, and aerial quantitative differences).

5.3.2 Monitoring on Water Level and Discharge in Wadi

The monitoring for discharge in Wadi (the management was transferred to MOWE in 2009) shall be performed by monitoring of the water level in Wadi, and water velocity using current meter. Three monitoring stations were constructed and monitored by the JICA Study Team from May, 2008 to May 2009. Specifications on monitoring and method of monitoring are shown Table C.5-6 and Table C.5-7.

Table C.5-6 Specifications on Monitoring Station in Wadi

Items	Wadi Hirjab	Wadi Tabalah	Wadi Habawnah
Location	42 50 02 E 19 19 59 N	42 13 47.7E 20 00 24.3N	43 53 45.76E 17 46 09.59N
Region	Asir	Asir	Najran
Width of Wadi	80m (monitoring site)	290 m (at Bridge)	84 m (at Bridge)
Catchment Area(Km^2)	778 (at Dam Site)	1,900	4,930
Town/Village	Samakh	Bisha	Habawnah
Remarks	Located Hirjab Dam site	Tabalah Dam	-

Table C.5-7 Monitoring for Discharge in Wadi

Monitoring	Method	Instruments	Remarks
Water level	Water level recording	Automatic water level recorder	
	Reading of water level	Staff gauge	
Flow Velocity	Monitoring of flow velocity	Current meter (at bridge) (by cable-way)	Monitoring shall be made at bridge in Wadi Tabalah and Habawnah. Monitoring in Wadi Hirjab shall be made by cable-way method.

Location for each monitoring station is shown in Figure C.5-9.

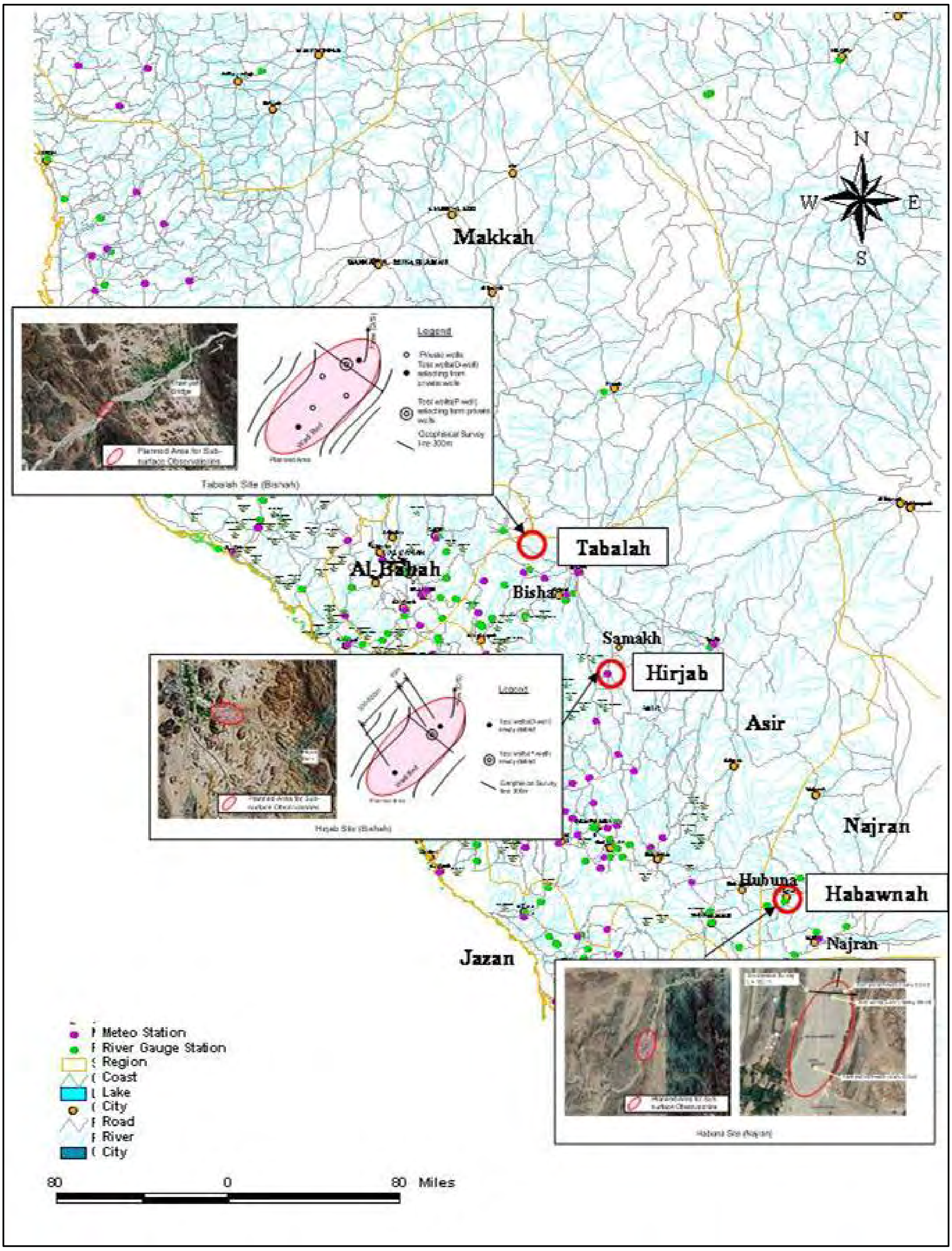


Figure C.5-9 Location of Monitoring Stations for Water Level and Discharge

Since there is no bridge for monitoring of the discharge at the dam site in Wadi Hirjab, the flow velocity monitoring with a propeller type is impossible, and the cable type current meter which stretching a cable-way between both bank of Wadi, hanging a current meter on the cable, and measuring the flow velocity was installed.(Refer to Figure C.5-10)

It is impossible to continuously observe flow amount for 24 hours over 365 days by the present condition of the skills, and thus it is required to make a stage-flow amount curve showing the correlation between flow amount and water level and convert the water level into flow amount without actually measuring the flow amount continuously. Based on the monitoring records between flow depth and discharge, stage-flow amount curve should be made up at each water level station.

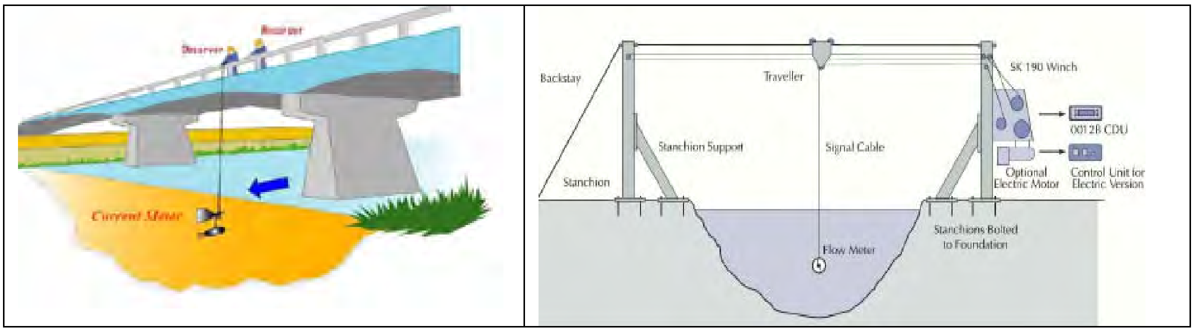


Figure C.5-10 Current Meter Measuring at Bridge (Left) and Cable-way Type Current Meter (Right)

As mentioned above, the proposal of the monitoring plan for water level and flow velocity becomes as follows.

- Since it is important to record a water level, maintenance and operation on automatic water level recorder shall be fully performed and the checking in operation shall be needed periodically.
- In an occurrence of floods, the flow velocity shall be monitored by the district water office in Bisha and Najran.
- By accumulating and analyzing data on relationship between rainfall and discharge in Wadi, this data shall be used for the planning and design for water supply and water development plan positively.

5.3.3 Groundwater Level

Lowering of groundwater level is evident in the Study Area. It is more serious in the southern part of Jazan Region.

Lowering of groundwater level will cause both drying-up of wells and reduction of yield form wells. Moreover, it will cause seawater intrusion and rising of salty groundwater from deep aquifer. Especially, seawater intrusion will give serious impact to groundwater use. It is expected that seawater intrusion will proceed further if the current water use continues (see Figure C.5-11).

Therefore, seawater intrusion must be prevented for sustainable groundwater use in Jazan Region. For this purpose, reduction of groundwater extraction is most effective.

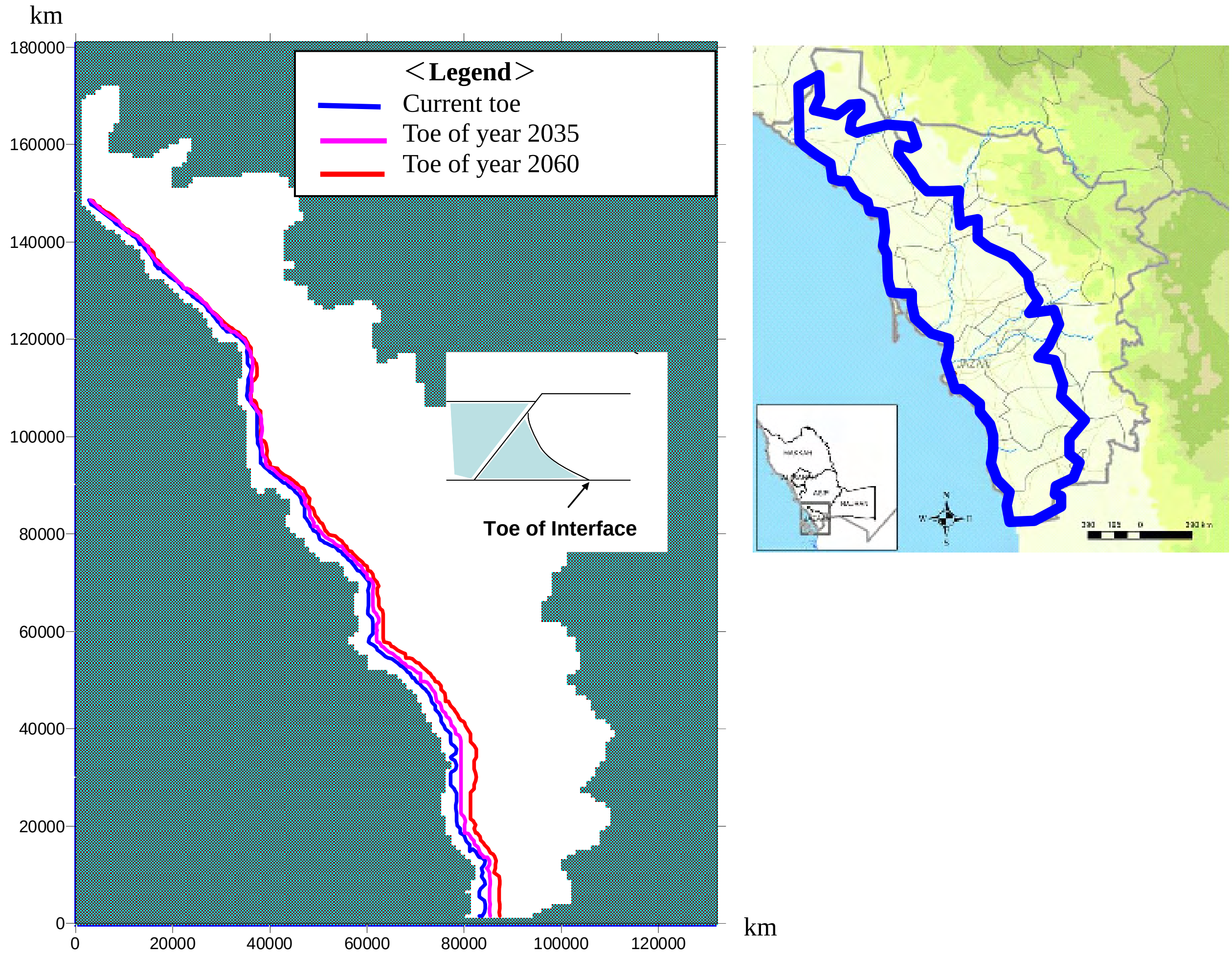


Figure C.5-11 Predicted Seawater Intrusion by Current Water Extraction (by Study Team)

In groundwater management, two points below are important.

1) Groundwater Level Should be kept Above Sea Level

If groundwater level becomes lower than sea level, seawater intrusion will occur in large scale. Salt injury will happen in area of seawater intrusion, and it will take long time to recover polluted aquifer. To prevent such disaster, groundwater level must be kept higher than sea level.

2) Reduction of Groundwater Extraction in Southern part of Jazan

Over-extraction of groundwater is taking place in the central to southern part of Jazan, in 4 governorates of Samtah, Ahad al Musarihah, Sabya and Jazan. Groundwater extraction of those 4 governorates occupies almost 70% of total extraction of Jazan Region. Groundwater extraction should be reduced in above 4 governorates.

According to result of numerical simulation, as shown in Figure C.5-12, the area of groundwater level below sea level will occupy most of Jazan Region in case that reduction of groundwater extraction is around 10-50%. However, such area will disappear from the entire Jazan Region in case that reduction of groundwater extraction is more than 60%.

Figure C.5-12 Reduction of Groundwater Extraction and Area of Groundwater Level below 0m (JICA Study Team)

Simulation result should be examined by monitoring result. If there is considerable difference between them, its reason must be made clear and simulation result must be modified. Groundwater monitoring plan was proposed in Table C.5-8, and monitoring points were proposed in Figure C.5-13.

Table C.5-8 Groundwater Monitoring Plan

Item	Frequency of monitoring	Purpose of monitoring
Groundwater level	Once/month	Groundwater level should be observed in main observation wells.
Water quality（Electric conductivity）		Salt concentration of groundwater should be observed in area where simulation result indicated deep sea intrusion/

Figure C.5-13 Proposed Groundwater Monitoring Location (Jazan Region)

5.4 Conservation of Water Resources

5.4.1 Surface Water

It seems that the injection of garbage and waste may be performed in the wadi although the number on statistics is not clear. A wadi serves as a river at the time of rain, and exhibits the function of a groundwater occurrence. The garbage and waste which were abandoned to the wadi become a cause which flows out downstream at the time of rain, and worsens environment. Moreover, a possibility that a contaminant may charged into groundwater which is precious water resources at the time of the groundwater occurrence from a wadi is also large. Once groundwater is polluted, recovery of water quality is very difficult.

A contaminant and sediment discharge cause reduction of the declining water quality of a reservoir, or the volume of a reservoir from the circumference and the upper region of a reservoir.

It is supposed that the following measures are effective because of conservation of the surface water by such a cause.

- Real dispensation and disorderly dumping are stopped for the policy for the improvement in a recovery rate of household-garbage collection.
- The recovery rate of each household effluent by the maintenance and spread of sewerage facilities etc. is raised.
- The capability to recommend maintenance of sewage treatment equipment and to process the collected drainage appropriately is raised.
- The circumference of a reservoir is specified as a conservation zone, and a house, a factory, agriculture, stock raising, etc. are restricted.
- The educational campaign for losing illegal disposal of waste is carried out.

About sewage disposal, since neither natural dilution in a wadi nor water quality improvement in downstream appearance can be performed, it is required to take the measure in which the treatment situation before sewage disposal water is discharged is checked, and treated water does not serve as a pollution source.

When continuous monitoring is carried out about a reservoir and contamination is discovered, it is required to carry the specification and the plan against a pollution source.

5.4.2 Groundwater

For conservation of groundwater resources, sound water balance must be maintained to keep normal groundwater environment. On the other hand, over-extraction of groundwater will break water balance and make groundwater environment deteriorated, which will lead to consumption of groundwater resources rapidly. Over-extraction of groundwater will give impact as listed below:

- ◆ Lowering of groundwater level.
- ◆ Seawater intrusion in the coastal aquifer due to lowering of groundwater level.
- ◆ Rising of salty groundwater from deep aquifer due to lowering of groundwater level

Methods shown in Figure C.5-14 are effective to prevent or mitigate impact above.

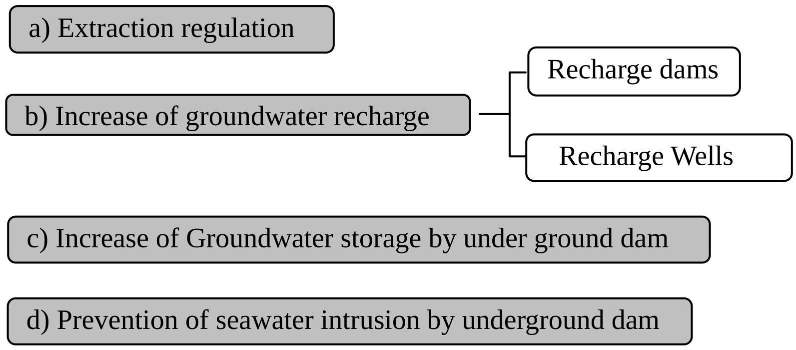


Figure C.5-14 Method for Groundwater Conservation

Above b) and c) methods have been already implemented or planned in the Study Area. Above a) method is most effective, if alternative water sources for groundwater users are prepared before its implementation. Above d) method can be applicable in coastal plain, such as in southern part of Jazan Region.

In addition to above methods, continuous groundwater monitoring (groundwater level and salt concentration) is indispensable to know groundwater environment and result of above measures.

5.5 Organization Structure and Management System

(1) The Problem of the Present Organization

The relation of the present water administrative organization and the flow of supply and use of desalination water and renewable water are shown in Figure C.5-15 and Figure C.5-16, and the following subjects occur.

- The cooperation and adjustment function between MOWE, which manages and supplies drinking and domestic water, and MOA, which manages agricultural water, are scarce. Though the both organizations mutually recognize water shortage, their intake or withdrawal is performed uniquely in each organization without restriction and connection.
- Although the situation of renewable water use for drinking and domestic water supplied by MOWE can be controlled with certain degree by monitoring of water quantity and quality, the situation of renewable water use for irrigation is not managed because that the intake and withdrawal for agricultural water use is individually performed in every area and each facility. For such occasions, it must be said that the synthetic water management is not carried out.
- The Directorate Office of MOWE is to execute collection and report of data about individual dam management in each region. However, neither the case where the report of the data from an individual dam follows a rule, nor information sharing with MOWE may be performed smoothly. Efficient management, and suitable information control and facility management are performed by SWCC which is currently managed in the public corporation. This case should be considered as reference in construction of an organization.
- The water distribution rule concerning the renewable water developed by a dam or a groundwater recharge is not defined. Therefore, intentional renewable water use has not been performed.
- The framework of organizations for the synthetic management and implementation of water demand, supply and allocation over between each province is not clarified. Therefore the integrative management and effective use of surface water and groundwater are difficult.

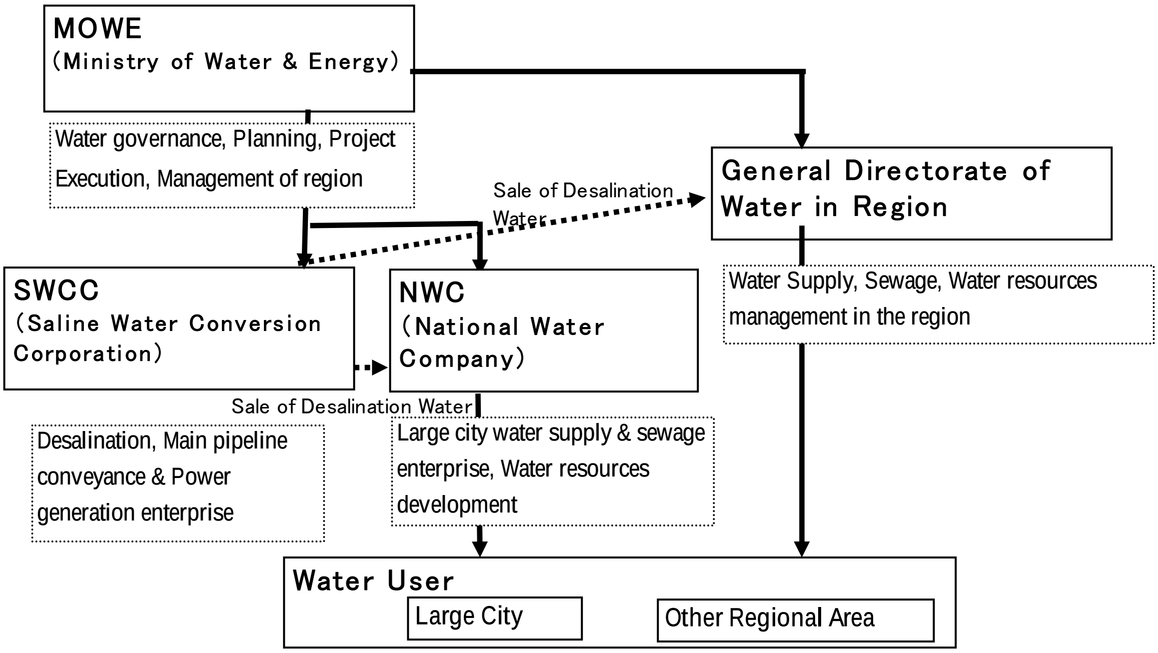


Figure C.5-15 Water Management Organizations (Present)

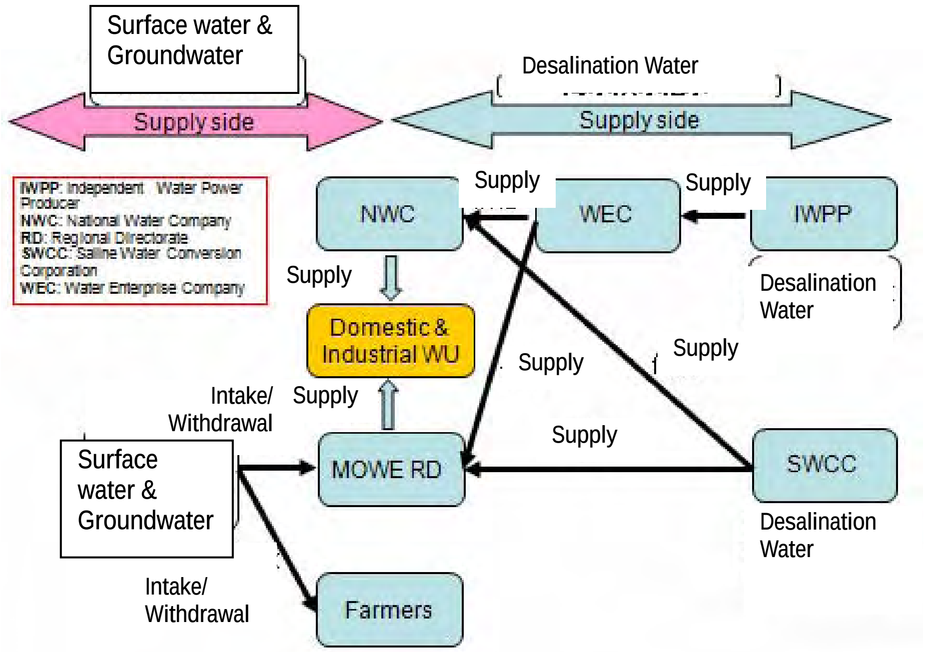


Figure C.5-16 Flow of Water Supply and Related Organizations (Present)

(2) Proposal of Organization Improvement

Since the monitoring and the function of regulation on superfluous use of agricultural water using most renewable water are insufficient in the present organization system from a viewpoint of renewable water use, the management of the water resources currently used for agricultural water is not performed enough. Moreover, the regulating function in a watershed or among watersheds for using renewable water efficiently according to the hydrological change or demand among water sectors is thought to be insufficient. In order to strengthen these organizations and to perform integrated management of renewable water resources, the improvement of organization which shows in Figure C.5-17 is proposed.

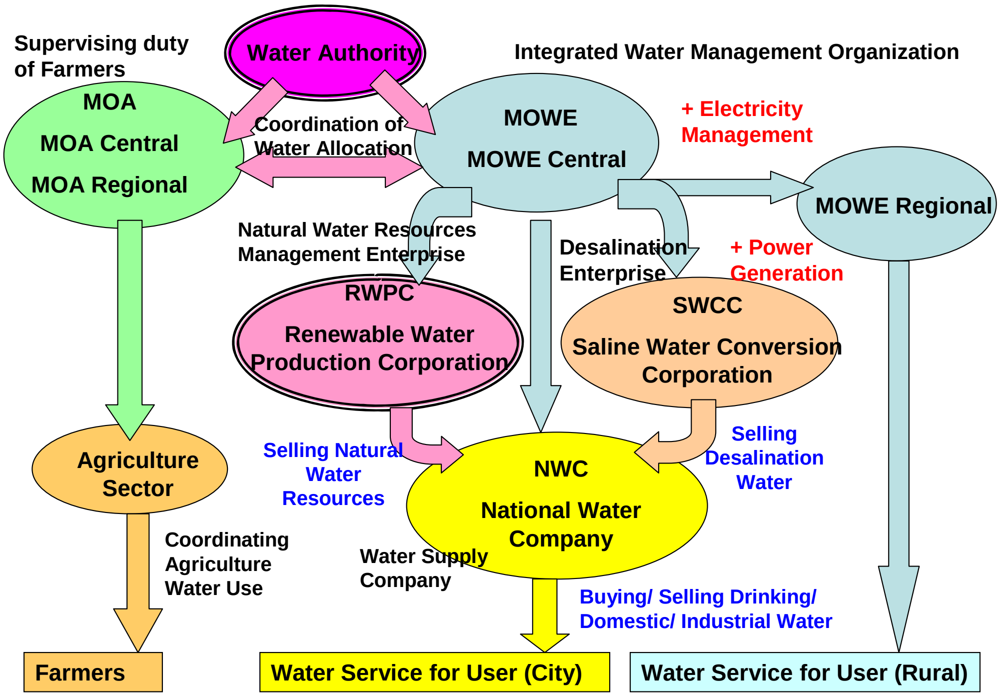


Figure C.5-17 Improvement Proposal of Water Administrative Organizations

The role of the present organization is arranged and the new organizations are added according to following directions.

- In the improvement of organizations including new organizations, the division of roles such as policy decision, regulation and supervision, and project implementation is reconsidered.
- On the level of policy decision, the function of agreement formation for the direction of water resources development and management, and for the required development administrative plan etc. is given to MOWE as a center organization and other all related ministries and agencies.
- On the level of project enforcement, according to the development administrative plan which is agreed based on the policy of the government for the water resources development and management, the organization for undertaking main projects in response to the commission from the government is established, and the function to make projects undertake efficiently is given to the organization.
- On the level of the supervision of project implementation and the operation and maintenance after project completion, The function to supervise that projects enforcement situation attain the policy objective and regulation for environmental preservation before project commencement, the conservation of water resources or the reduction of influence on environment, etc. are protected while performing execution management of projects during projects implementation, and the sustainable water management is conducted in alignment with the policy objective is given the organization.
- By clarifying the division of function, roles of the policy board, the projects enforcement organization, and the supervisor and a regulatory agency are clarified, and clarification of responsibility is attained to related organizations.

It proposes newly establishing the following organizations for achievement of the above-mentioned purpose.

<u>Water Authority and Water Council</u>

This organization is established for strengthening of a policy decision level. Water authority is constituted by the minister and secretary of each ministry and agency related to water, and the director general, and perform determination of national water policy and basic strategy of water, and adjustment between relevant ministries and agencies.

Moreover, it agrees on the water resources development and management plan of broad-based area like two or more provinces are related or important state capital by this water authority and a water council.

Especially, the future water utility of the agricultural water sector which is the largest user of renewable water resources is not only a subject of water resources but a subject interlocked with a food policy and agricultural policy. To decide a direction to the future, the argument and adjustment in which it crosses ministries and government offices are needed. Therefore, it is assumed as one of the important subjects treated by this water authority and the water council.

Water council is constituted by the deputy minister, vice-president official, and academic expert of relevant ministries and agencies as a consultative body of water policy, is deliberated to consultation of water authority, and proposes a draft doctrine etc.

Renewable Water Production Corporation (RWPC)

This organization is established for the project enforcement concerning development and management of renewable water and for assuring neutral and fair water supply. Based on the broad-based and important water development administrative plan on which it has agreed by the national policy, water authority, and water council, required projects are undertaken by the commission from the ministries and agencies to supervise.

This public corporation makes MOWE relevant authorities, and undertakes projects on the basis of supervisor instruction of MOWE.

The operation and maintenance of dams for integrated control and other large-scale important dams, the operation and maintenance of main groundwater basins which perform joint operations, the control of intake or withdrawal of main natural water resources and water supply networks are managed specially.

RWPC performs the management and maintenance of main dams which performs joint operations, and management and maintenance of main groundwater basins. And RWPC shall manage intake of main renewable water resources, and a water supply network, and shall supply renewable water. This public corporation achieves the following functions and roles.

1) Supply of renewable water to a water service enterprise etc. as raw water.
2) Operation of facilities for groundwater recharge
3) Control and maintenance of large-scale dams and middle-scale dams (flood control, intake control, control and maintenance of facilities)
4) Monitoring of main aquifers (for controlling yeild and water quality) and operation and maintenance of facilities (observation wells, production wells, pumping up facilities)
5) Main pipeline transportation (transportation control, control and maintenance of facilities) and sale of the producing water
6) The planning, investigation, design, and construction management of large-scale dams and middle-scale dams, and groundwater withdrawal facilities by commission from MOWE
7) Promotion of dissemination of rain water harvesting facilities

RWPC is a corporation which competes with SWCC, which is undertaking production and supply enterprise of desalinization water under the supervisor of MOWE, in the water production and supply enterprise field of renewable water. SWCC is accepted that efficient management is performed as a public corporation organization. It is recommended that RWPC also should be established as public corporation so that it runs efficiently.

Now, SWCC is in the state which is undertaking desalination water supply enterprise also foreseeing privatization with role as a center of water supply, and in which the competitor of water supply is not.

When RWPC performs development and supply of renewable water intentionally, by extension,

SWCC is expected to become an organization which supplies cheaper water with more efficient management

(3) The Proposal for the System Improvement of Existing Organizations

The establishment of new organization is proposed by reorganizing the role and function of the existing organizations as shown below.

< MOWE Head Office >

MOWE head office, based on the broad direction of the water policy by the water authority and the water council, carries out planning of water management, management of subordinate organizations, instruction of waterworks and sewage enterprises enforcement, and planning to construction management of large-scale facilities. Moreover, adjustment between organizations related the broad-based and important projects over provinces concerning the exploitation of water resources shall be performed. The following roles are performed.

1) Setup and management of planning of the overall plan of the water administration organizations based on the water policy and strategy and activity target of subordinate organizations. (Including decision of allocation of water resources for each water sector)
2) Planning, investigation, design and construction management of large-scale facility construction project
3) Control of the network for collection of basic data, and management of central database such as rainfall, river discharge, water level of dam reservoir, storage volume, intake volume, water quality of surface water resources, groundwater level of main aquifer and groundwater basin, groundwater storage volume, withdrawal volume, water quality of groundwater, etc.
4) Instruction of watershed conservation and management
5) Instruction of public relations and dissemination for water policy, water management plan, present condition of water supply and predicting future situation, and enforcement management
6) Introduction and management of personnel training and capacity building for related organizations
7) Management of research and technical knowledge

< General Directorate of Water in Region >

Each general directorate of water in region carries out operation and maintenance of intake facilities, water transfer and water supply network in jurisdiction territory except the big cities managed by RWPC and facilities controlled by NWC, execution of water supply and sewage enterprise of province except big cities, planning /investigation /design and construction management of small- scale facilities. Moreover, adjustment concerning the project in the province about the exploitation of water resources shall be performed. The following roles are completed.

1) Decision of the project execution plan under instruction of MOWE
2) Control of maintenance of facilities of the jurisdiction area,
3) Plan, investigation, design and construction management of small-scale facilities
4) Collection of the basic data of jurisdiction area, and information data input to network
5) Execution of water withdrawal restriction and actual crackdown in jurisdiction area
6) Implementation of the educational campaign for water supply (public relations, dissemination and education)

< Saline Water Conversion Corporation (SWCC) >

SWCC is a corporation which is undertaking the desalination water production and supply enterprise and the power generation enterprise under the supervisor of MOWE. SWCC continues succeedingly these enterprises and makes them develop. The main roles of the organization are as follows.

- Execution of desalination enterprise
- Execution of main pipeline transportation enterprise of the desalination water containing intake water from related dam group
- Execution of control and maintenance of possession facilities and plan, investigation, design and construction management of new facilities

< National Water Company (NWC) >

NWC is execution organization of the water supply enterprise and sewer enterprise of the waterworks of the big city which operated since 2008. For the moment, NWC conducts enterprise of the city zone of Makkah and Jeddah. Although it seems that the management of the water supply enterprise undertaking by the local office of MOWE is transferred to NWC even in the other major cities in the future, at present, the concrete plan in the target region of this M/P project is not released.

Although the water resources development enterprise mainly concerned with groundwater is also included, it is proposed that the part of management of water resources development enterprise is transferred to RWPC, and NWC is conducted as a specialty company of water supply enterprise and sewage enterprise in large cities. The main roles are as follows.

- Execution of water supply enterprise and sale of drinking and domestic water by purchase desalination water from SWCC and natural water from RWPC
- Control and maintenance of water purification facilities, water supply facilities, and water supply network, and design to construction management of new facilities
- Execution of a sewage enterprise, control and maintenance of sewage facilities, and design to construction management of new facilities
- Supply and sale of recycle water
- Promotion of reuse of water and recycle use of sewage

(4) Foundation of Agricultural Water Management Division and Agricultural Cooperative Association

In 3 regions which are target areas of the proposed M/P, owing to surplus withdrawal of agricultural water, there is much information that withdrawal of drinking and domestic water is suppressed. Due to no performance for effective restriction, withdrawal of drinking and domestic water not only becomes difficult, but also agricultural farms come under influence of exceed withdrawal and become severe to take agricultural water mutually. That kind of water shortage situation goes from bad to worse gradually and rapidly at part like Jazan region.

Although it is expected that the water demand for agricultural use is controlled by Decision335 of MOA, probably, water for agricultural use is the greatest user of renewable water succeedingly.

For this reason, for efficient and fair exploitation of the water resources in the region, management of resources also including water for agricultural use is indispensable.

Although the farmhouse is using the private well individually until now, the time and the labor for negotiation and adjustment for water supply condition become huge in case of selection of individual farmhouse as target for adjustment, and it is not realistic from individual request being various.

Therefore, adjustment and the regulating function as an agricultural sector is given to the new organization representing farmhouse.

In order to use sustainable agricultural water and develop continuous farming, the foundation of the following organizations is proposed. The improvement diagram of an agricultural organization is shown in Figure C.5-18.

This organization carries out necessary service under the supervision of MOA (the Ministry and its local offices) as a coordinator of agricultural water use and supply for the agriculture sector. In addition, it is expected that the MOA formulates an agricultural policy to control agricultural water demand in cooperation with MOWE.

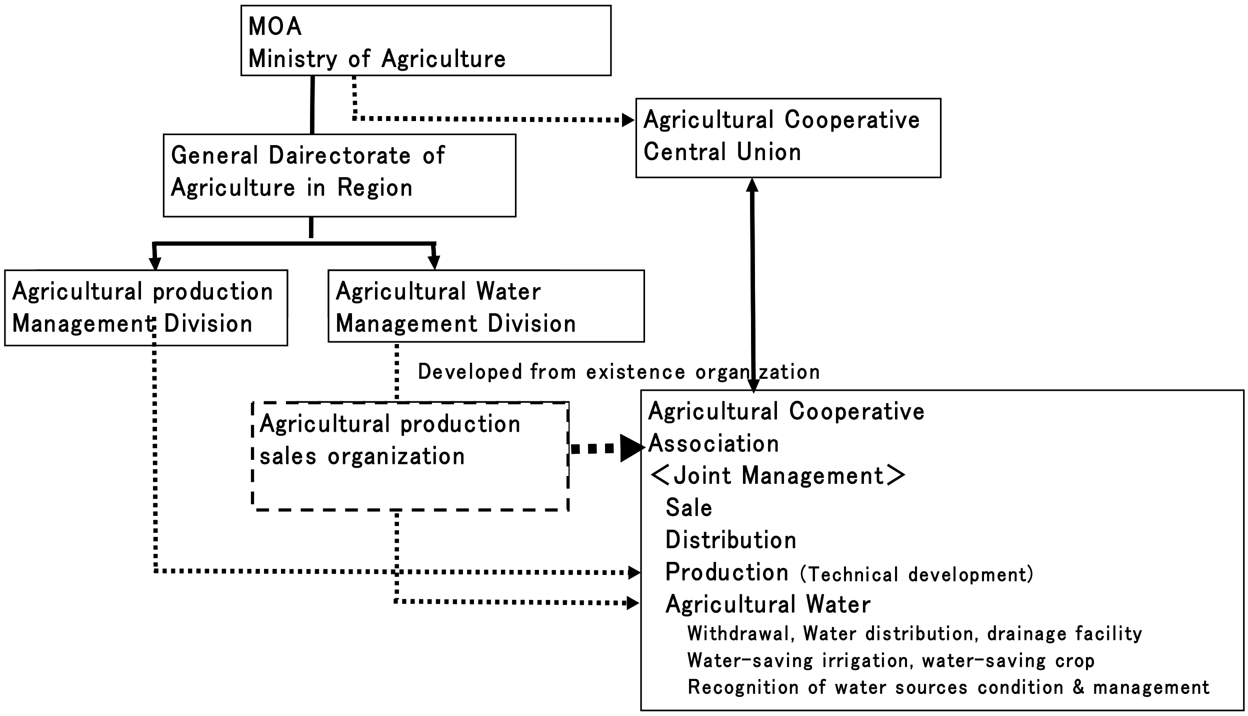


Figure C.5-18 Proposal of Improved Agricultural Organization

<Agricultural Water Management Division (Inner Organization in General Directorate of Agriculture in Region)>

The agricultural water management division is the organization for execution of agricultural water use management and adjustment between the farmers and other water basin users, and has the following functions.

- Management for agricultural water, and instruction
- Conservation of environment in the place of agricultural water use and management for operation and maintenance of intake and withdrawal facilities
- Grasp of the actual agricultural water use condition and the problem
- Water-saving technology, the reuse technology of irrigation water, instruction of recycle water use and dissemination

< Agricultural Cooperative Association >

This agricultural cooperative association is an enterprise enforcement organization of agricultural sector. The enterprise for water production and supply for agricultural use is carried out under the supervisor of MOA (Head office and local office).

The organization is established for the purpose of a farmhouse performing production of agricultural products, sale, circulation, development of agricultural technology, and introduction together. The main function is as follows.

- Execution of joint management of production of agricultural products, sale, and distribution.
- Execution of joint control of withdrawal and water supply /drainage facilities maintenance, and voluntary management for agricultural water use.
- Performance of joint development of agricultural technology, and joint introduction of technological know-how.
- Performance of joint practical study, dissemination, and educational activity for performing continuous agricultural activity together.

<Government Support System>

As governmental support, the system where government organization carries out the priority grant of support and the government subsidy preferentially is introduced into the joint enterprise and joint activity by farmer, and promoting the following enterprises is proposed.

- The joint enterprise for promoting agricultural activity activation (Establishment of the Agricultural Cooperative Association is included)
- The enterprise of decrease water use (the conversion enterprise to water-saving crops, the water-saving facilities construction enterprise, etc.)
- The enterprise for shift to joint agricultural water management

(5) Drought Adjustment

At the time of drought, the pipeline connected by network shall be utilized based on the situation of reservoir and ground water in the target whole provinces, and re-distribution of renewable water shall be performed across watersheds and provinces.

Drought adjustment is decided at the place where every representative concerned the problem is present. Since the problem is straddled across provinces, MOWE head office shall adjust countermeasure with a fair position.

The representative of the agriculture sector which proposed previously shall participate in the whole adjustment meeting after adjusting the inside of own agriculture organization, and also makes the determination matter carry out in the member inside with responsibility.

The legal force of enforcement of a drought adjustment result is exercised by MOA, and when not following, the system where required penalty can be performed is introduced.

Water service sectors carry out water supply under the supervisor of MOWE according to a plan to have been re-distributed as a result of adjustment of RWPC and SWCC.

(6) Groundwater Management

Since the range of the management of groundwater in the rejoin, in case of consideration of an aquifer, does not correspond with an administration region, MOWE head office manages it, and exercises required regulation.

The local office of MOWE has jurisdiction over permission for each water user, monitoring water use and reporting to the head office. The system which reports those information to MOWE and shares together is established.

RWPC manages utilization of a groundwater occurrence or its groundwater to control of a dam. RWPC conducts monitoring and survey of groundwater required in order to implement this service. Information sharing of monitoring and results of survey of RWPC shall be reported and done to MOWE, and it shall be referred to in decision of the water distribution which is each water sector which MOWE implements, or the plan for water supplies.

In management of this groundwater, a model for simulation is built, verification by an actual monitoring result and model is carried out in parallel, and formulation of simulation system which can examine required regulation and re-distribution of renewable water is desired.

5.6 Personnel Training and Capacity Development

MOWE head office and general directorates of water in region are necessary to demonstrate an initiative as the management and regulatory organization of water, and to attain improvement and strengthening of the personnel's temperament, to master external organizations such as consultants and contractors as hand and foot, and to raise engineers and administrators who can do supervision and instruction of subsidiary organizations. The work field and class classification of engineer and administrator are shown in Figure C.5-19.

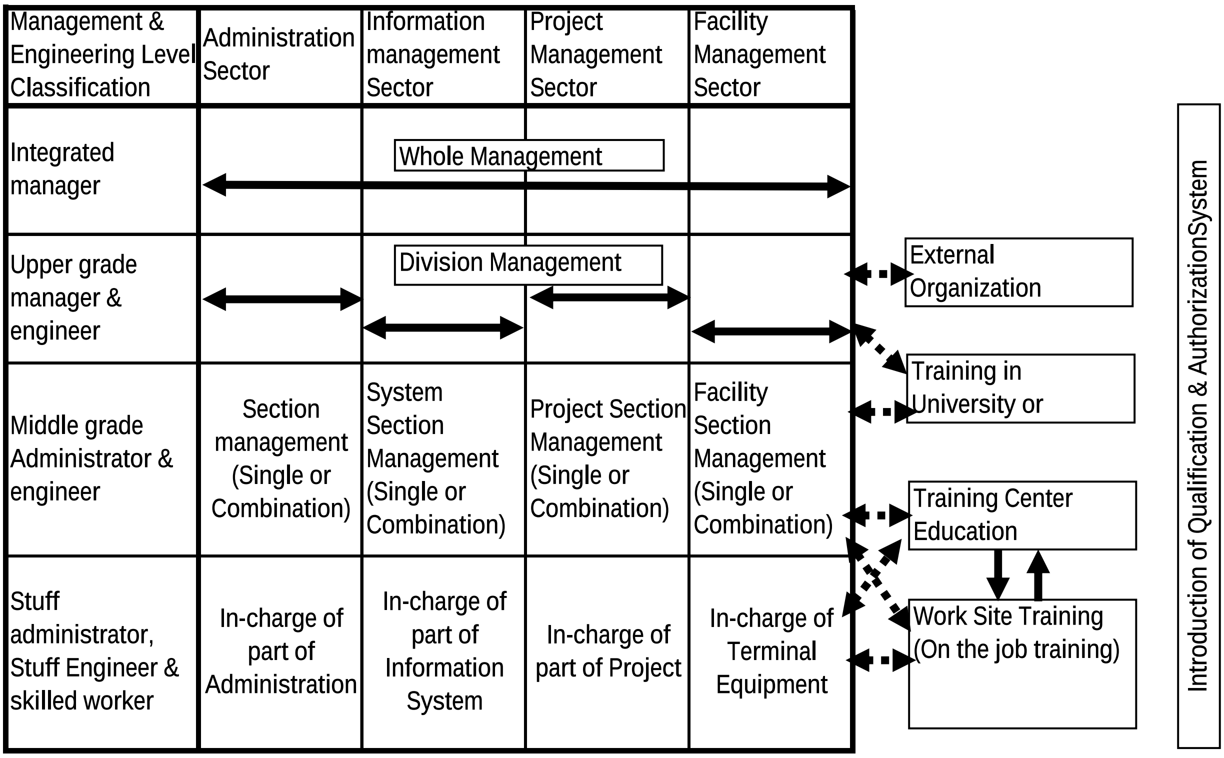


Figure C.5-19 Diagram of Education System by Sector and Work Level Classification

In order to make bottom-up of skill and technical level of workers or managers concerning terminal equipment, and in order to raise human resources who can control combined several facilities, who can manage each division of higher rank, and furthermore who can manage synthetically the whole of the organization, the improvement of the following organizations and systems are proposed.

- Establishment of a training center: In order to raise the skill and the technical level of the capable persons concerning terminal equipment and each facility, long-term and planned function training and technical education are carried out. As an organization for this, a training center is founded and instructors are stationed.
- Strengthening of on the job training: In order to apply and reflect the results of education received in the training center to each worksite, and fix it as an absolute technique, repeating site work education (on the job training) and training center education are carried out. For this reason, at each work site the system that a higher rank leader guides group constituents by making-up team organization is proposed.
- University and research institution training: The training for middle-level manager and engineer is carried out according to utilization of the university and the research institution, and more advanced management ability and technical capabilities are mastered. The creation of training program and teaching materials are requested to a university and a research institution.
- Other external training: In order that upper position manager and engineer master a broad view and make it reflected in the management work, overseas trainings and temporary transfers to external organization (for example, temporary transfer to a consultant with technical high-level capabilities, etc.) are carried out.
- Introduction of qualification and authorization system: In order to encourage the personnel's spontaneous capacity building, the qualification system for every member is introduced. Moreover, an acquisition of qualification or authorization of an external authority is also encouraged. The system that the acquisition of qualification contributes to the status promotion is required.

5.7 Promotion of Educational Campaign for Water Use

About the educational campaign for water use, the sections in charge of MOWE head office and each general directorates of water in region in its duty take out a booth in each office, and is developing water-saving campaign activity. Moreover, a water-saving campaign week (1 time and about one week per year) is set up, and televising of the TV commercial for water-saving encouragement and printing of the newspaper advertisement are performed.

Moreover, in the office of general directorate of water in Abha, the water-saving campaign room for woman is prepared with the different entrance against usual entrance.

However, the present campaign has performed only about the dissemination of water saving (the promotion of use of the water-saving instruments attached to a water facet or a toilet tank), and the object has mainly performed only for visitor of MOWE head office and general directorate offices in region except the water-saving campaign week.

In order to expand and promote the educational campaign which improves and raises the resident consciousness, performance of following activities is proposed.

The diagram of the educational campaign for water supplies is shown in Figure C.5-20.

- Activity which perform public relations of the present condition of water shortage and future situation, and recognizes strongly the necessity of water saving
- Activity which disseminate and take hold 3R (Reduce, Reuse, Recycle) of water use
- Activity which promotes rain water storage (water harvesting) and use the water at each home and public lands
- Performance of the education for fixing the action pattern for saving water use
- Development of public relations activity through media and in Mosque

Improvement of consciousness for water use	Education
Water-saving campaign (Present) ＋ Promotion of reuse & recycle of water ＋ public relations of the present water shortage and future situation	School, University, Open class, TV program & Mosque ①Present & future condition of precious water Renewable water resources (Maximum use) Fossil groundwater resouces (Negative legacy to posterity) Reuse, Recycle of water Promotion of use) Desalination water (High cost but necessary) ②Water cost Water-rate system, Production and supply cost, Government assistance, Water cost of foreign countries

Figure C.5-20 Diagram of Campaign Activity of Water Use

CHAPTER 6 COST ESTIMATE AND IMPLEMENTATION PLAN

6.1 Dimension for Water Supply Facilities

Based on the water supply plan as shown in Chapter 3, the facility plan for the municipal water supply system was conducted. Dimensions of water facilities are shown in Table C.6-1.

TableC.6-1 Dimension of Water Supply Facilities

Region	Facilities	Facilities/Quantity	Dimensions (Quantity)
Al Baha	Transmission Pipeline	Section A Desalination (Dawqah ～Al Baha)	Supply:70,000 m^3/day
		Section B Renewable (Hali ～Dawqah)	:70,000 m^3/day
	Booster Pump	4 Units	Capacity: 2.7 Kw (1), 6.9 Kw (1) 6.0 Kw (2)
	Reservoir	5 Reservoirs	Volume: 400,000 m^3 (1) Volume: 100,000 m^3 (4)
	Desalination Plants	Shuaibah (Existing)	Production:40,000 m^3/day
		Dawqah Plant (Stage 1)	:75,000
		(Stage 2)	:25,000
Asir	Transmission Pipeline	Section D (Shuqaiq～Abha)	Supply:146,000 m^3/day
		Section E (Shuqaiq～AL Birk)	10,000
		Section H (Abha ～AL Janabin)	19,000
		Section G (Abha ～ AL Alayah)	40,000
		Section C (AL Baha - AL Alayah)	65,000
		Section I (AL Alayah – Bisha)	65,000
	Desalination Plant	Shuqaiq Extension (Stage 2)	Production: 238,000 m^3/day
	Wells Fossil Water from Wajid Aqufer, Najran	Section J Stage 1 Pipeline	Supply:29,000
		Well	Production :29,000 m^3/day
		Stage 2	
		Well	Production :32,000
Jazan	Transmission Pipelines	Section F Shuqaiq(UKAD)～Samta(Jizan)	Production:160,000 m^3/day
	Desalination Plants (New)	Sabya (new) stage 1	35,000
		Stage 2	160,000
		Stage 3	55,000

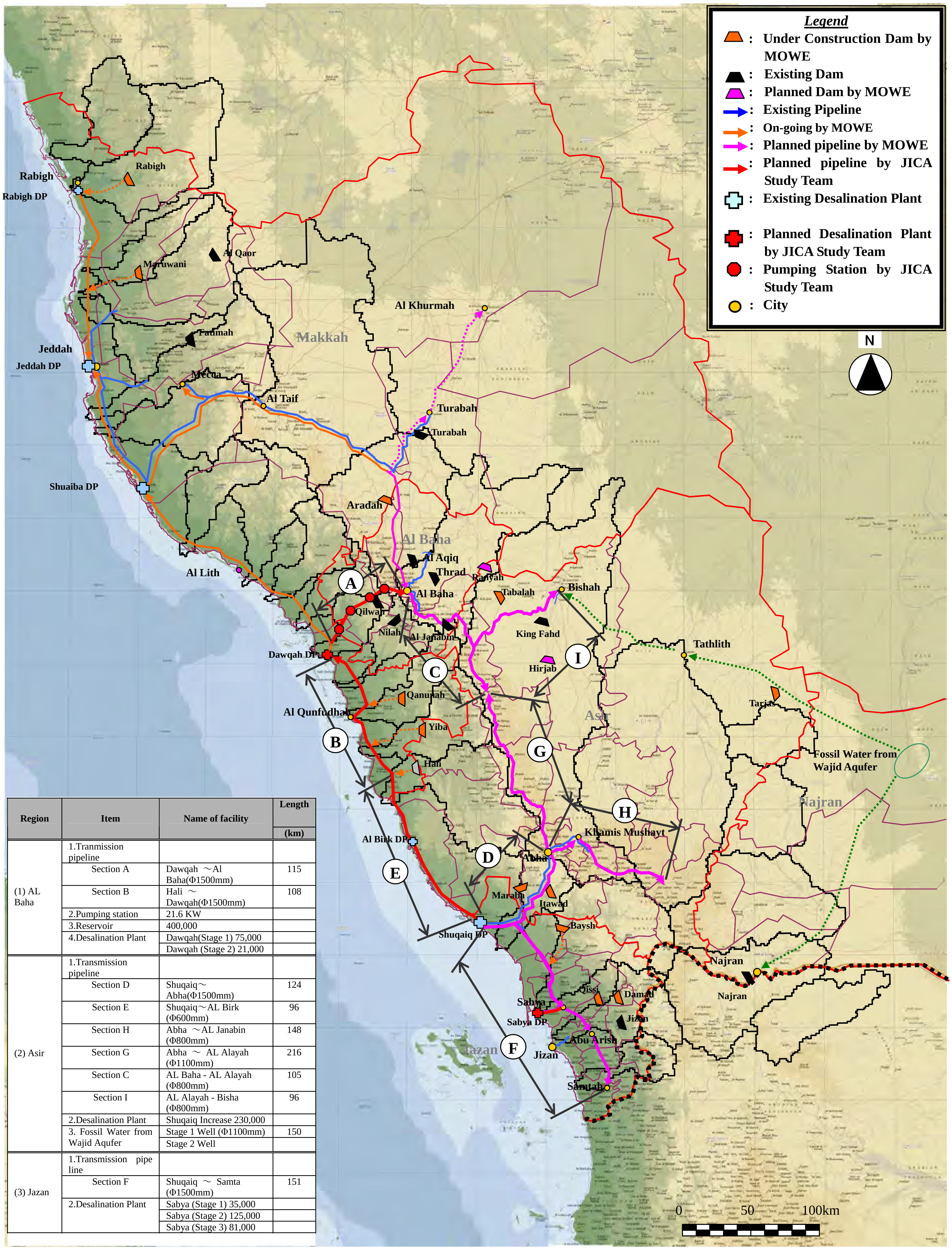
Note).Section "A～Ｉ" shows section (A) –(I) in Figure C.6-1.

Dimensions of dams including under construction are also shown in Table C.6-2.

Table C.6-2 Dimensions for Dams

Region	Name of Dam	Catchment Area	Length	Height	Capacity	Development Water
		(km^2)	(m)	(m)	(1000m^3)	(m^3/day)
Makkah	Hali	4,843	384	95	249.6	35,000
	Qanunah	2,310	385	50	79.2	30,000
	Yiba	2,242	284	64	80.9	38,000
Al Baha	Al Janabin	-	592	55	55.5	5,000
	Nilah-Qiwlah	-	-	-	-	11,000
	Tabalah	863	396	40	68,410.0	16,000
Asir	Hirjab	600	-	-	-	9,000
	Ranyah	4,375	-	-	-	68,000
Jazan	Baysh	7,600	340	106	193.6	58,000
	Damad	1,000	154	28	55.5	36,000
	Qissi	272	1044	25	151.0	9,000

Water facility plan and locations for proposed facilities is shown in Figure C.6-1.



Region	Item	Name of facility	Length (km)
(1) AL Baha	1.Tranmission pipeline		
	Section A	Dawqah ～Al Baha(Φ1500mm)	115
	Section B	Hali ～ Dawqah(Φ1500mm)	108
	2.Pumping station	21.6 KW	
	3.Reservoir	400,000	
	4.Desalination Plant	Dawqah(Stage 1) 75,000	
		Dawqah (Stage 2) 21,000	
(2) Asir	1.Transmission pipeline		
	Section D	Shuqaiq～Abha(Φ1500mm)	124
	Section E	Shuqaiq～AL Birk (Φ600mm)	96
	Section H	Abha ～AL Janabin (Φ800mm)	148
	Section G	Abha ～ AL Alayah (Φ1100mm)	216
	Section C	AL Baha - AL Alayah (Φ800mm)	105
	Section I	AL Alayah - Bisha (Φ800mm)	96
	2.Desalination Plant	Shuqaiq Increase 230,000	
	3. Fossil Water from Wajid Aqufer	Stage 1 Well (Φ1100mm)	150
		Stage 2 Well	
(3) Jazan	1.Transmission pipe line		
	Section F	Shuqaiq ～ Samta (Φ1500mm)	151
	2.Desalination Plant	Sabya (Stage 1) 35,000	
		Sabya (Stage 2) 125,000	
		Sabya (Stage 3) 81,000	

Figure C.6-1 Water Supply Facility Plan in Al Baha, Asir and Jazan

6.2 Cost Estimate for Water Supply Facilities

6.2.1 Unit Cost for Cost Estimate

Unit cost is applied based on the water supply project under executing projects and design reports of MOWE. Table C.6-3 shows unit cost for cost estimates and annual operation and maintenance cost to the construction cost. Unit cost for dams as shown in Table C.6-4 is set up based on the unit cost per dam volume from the dam which has obtained by calculation between dam volume and contract price of MOWE.

Table C.6-3 Unit Cost for Cost Estimate and Annual Operation and Maintenance Cost

Item	Unit	Unit Cost/Price	Annual Operation & Maintenance Cost (% of Const. Cost)
Expansion of Desalination Plant	SR/m^3	1,400	25.0
Dam Treatment Plant(80,000m^3/day)	SR/m^3	630	25.0
Transmission pipeline (1500 mm)	MSR/km	4.7	1.5
Transmission pipeline (1300 mm)	MSR/km	4.5	1.5
Transmission pipeline (1100 mm)	MSR/km	4.0	2.0
Transmission pipeline (800 mm)	MSR/km	1.8	3.0
Transmission pipeline (550 mm)	MSR/km	1.6	3.0
Transmission pipeline (less than 550 mm)	MSR/km	1.2	3.0
Pumping stations	SR/Kw	5,100	0.5
Reservoirs	SR/m^3	280	1.0
Drilling wells (12,000m^3/day)	SR/m^3	330	1.0
Drilling wells (6,000m^3/day)	SR/m^3	520	1.0
Drilling wells (5,000m^3/day)	SR/m^3	640	1.0
Drilling wells (3,000m^3/day)	SR/m^3	760	1.0
Drilling wells (2,000m^3/day)	SR/m^3	780	1.0
Construction of groundwater chlorination plant （12,000m^3/day）	SR/m^3	460	30.0
Construction of groundwater chlorination plant （6,000m^3/day）	SR/m^3	520	30.0
Construction of groundwater chlorination plant （3,000m^3/day）	SR/m^3	600	27.0
Construction of groundwater chlorination plant （2,000m^3/day）	SR/m^3	650	25.0
Chlorination units	SR/m^3	480	15.0
Concrete Gravity Dam	SR/m^3	350	10.0
Rockfill Dam	SR/m^3	50	10.0

Sources：Design report and project Reports executed by MOWE

Table C.6-4 Unit Cost per Dam Volume (Concrete Gravity Dam, Rock-fill Dam)

Ragions	Name of dam	Type	Purpose	Length	Height	Dam Volume(1,000m3	Storing C. (1000M3)	Contaract C.(1000 SR)	Unit Cost(m3/SR)
Makkah	Hali	Concrete	Control	384	95	651.92	249,560	226,620	347.6
	Rabig	Concrete	Control	380	80.5	555	220,350	168,900	304.3
Jazan	Baysh	Concrete	Control	340	106	680	193,644	213,186	313.5
	Damad	Concrete	Flood,irrigati	154	28	375	55,500	147,281	392.7
	Average								**339.6**
Makkah	Al Marwani	Rockfill	Control	580	101	6,000	183,600	262,321	43.7
	Al Lith	Rockfill	Control	420	79.5	2,486.00	88,570	124,296	50.0
	Average								**46.9**

Source) Progress report for each dam

6.2.2 Construction Cost and Operation and Maintenance Cost

As for the facilities proposed in the M/P, construction costs were calculated based on the construction quantity and a unit cost. Regarding construction cost for dams, except for Ranyah and Hirjab Dam, cost estimate were excluded from construction cost. Table C.6-5 shows construction cost for each implementation period.

Table C.6-5(1) Construction Cost for Major Supply Facilities (2011-2015)

Region	Item	Name of facility	Water volume	Length	Dimension	Unit Cost	Unit	Construction Cost	O&M Cost (Annual)
			(m³/day)	(km)				MSR	MSR
(1) AL Baha	1.Tranmission pipeline								
	Section A	Dawqah ～ Al Baha(renewable)	70,000	115	Φ1500mm	4.50	MSR/km	518	7.8
	Section B	Hali ～ Dawqah(renewable)	70,000	108	Φ1500mm	4.70	MSR/km	508	7.6
	2.Booster pump		21.6 KW			5,100.00	SR/KW	110	0.6
	3.Reservoir		400,000			280.00	SR/m³	112	1.1
Total								**1,247**	**17.0**
(2) Asir	1.Transmission pipeline								
	Section D	Shuqaiq～Abha	110,000	124	Φ1500mm	4.70	MSR/km	583	8.7
	2.Desalination Plant	Shuqaiq Increase	230,000			1,400.00	SR/m³	322	80.5
	3. Fossil Water from Wajid Aqufer	Stage 1		150	Φ1100mm	4.00	MSR/km	600	12.0
		Well	29,000			785.00	SR/m³	23	0.2
Total								**1,528**	**101.5**
(3) Jazan	Transmission pipe line								0.0
	Section F	Shuqaiq(UKAD) ～ Samta(Jizan)	150,000	151	Φ1500mm	4.70	MSR/km	710	10.6
Total Cost								**710**	**10.6**
Ground Total	**2010-2015**							**3,485**	**129.2**

Table C.6-5(2) Construction Cost for Major Supply Facilities (2016-2020)

Region	Item	Name of facility	Water volume	Length	Dimension	Unit Cost	Unit	Construction Cost	O&M Cost (Annual)
			(m³/day)	(km)				MSR	MSR
(1) AL Baha	1.Desalination Plant	Dawqah	75,000			1,400.00	SR/m³	105	26.3
Total								**105**	**26.3**
(2) Asir	1.Transmission pipeline								
	Section E	Shuqaiq～AL Birk	10,000	96	Φ600mm	1.60	MSR/km	154	4.6
	Section H	Abha ～ AL Janabin	19,000	148	Φ800mm	1.80	MSR/km	266	8.0
	Section G	Abha ～ AL Alayah	40,000	216	Φ1100mm	4.00	MSR/km	864	25.9
Total								**1,284**	**38.5**
(3) Jizan	1.Desalination Plant	Sabya	35,000			1,400.00	SR/m³	49	12.3
Total Cost								**49**	**12.3**
Ground Total	**2015-2020**							**1,438**	**77.0**

Table C.6-5(3) Construction Cost for Major Supply Facilities (2021-2025)

Region	Item	Name of facility	Water volume	Length	Dimension	Unit Cost	Unit	Construction Cost	O&M Cost (Annual)
			(m³/day)	(km)				MSR	MSR
(1) AL Baha								0	0.0
Total								**0**	**0.0**
(2) Asir	1.Transmission pipeline								
	Section C	AL Baha - AL Alayah	65,000	105	Φ８00mm	1.80	MSR/km	189	5.7
	Section I	AL Alayan - Bisha		96	Φ８00mm	1.80	MSR/km	173	5.2
	2. Fossil Water from Wajid Aquifer	Stage 2							
		Well	32,000			785.00	SR/m³	25	0.3
Total								**387**	**11.1**
(3) Jizan	1.Desalination Plant	Sabya	125,000			1,400.00	SR/m³	175	43.8
Total Cost								**175**	**43.8**
Ground Total	**2020-2025**							**562**	**54.9**

Table C.6-5(4) Construction Cost for Major Supply Facilities (2026-2031-2035)

Region	Item	Name of facility	Water volume	Length	Dimension	Unit Cost	Unit	Construction Cost	O&M Cost (Annual)
			(m³/day)	(km)				MSR	MSR
(1) AL Baha									
	1.Desalination Plant	Dawqah (Stage 2)	21,000			1,400.00	SR/m³	29	7.4
Total								**29**	**7.4**
(2) Asir									
Total								**0**	**0.0**

Region	Item	Name of facility	Water volume (m^3/day)	Length (km)	Dimension	Unit Cost	Unit	Construction Cost MSR	O&M Cost (Annual) MSR
(3) Jizan	1.Desalination Plant	Sabya Stage 3	81,000			1,400.00	SR/m^3	113	28.4
Total Cost								**113**	**28.4**
Ground Total	**2020-2025**							**143**	**35.7**

Construction cost is summarized as follows.

Table C.6-6 Construction Cost for each Implementation Period (Million SR)

Region	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
Al Baha	1,247	105	0	29	0	1,381
Asir	1,528	1,284	387	0	0	3,199
Jazan	710	49	175	113	0	1,048
Total	3,485	1,438	562	143	0	5,628

The Construction Cost implementation period from 2010 to 2015 shows the highest cost with SR 3,485 Million (US$ 929million), followed by period 2015 to 2020 with SR1,438 Million (US$ 383million), and period 2020 to 2035 (SR 562 Million, US$ 150 Million) and then period 2025 to 2025 with SR143 Million (US$ 38 Million).

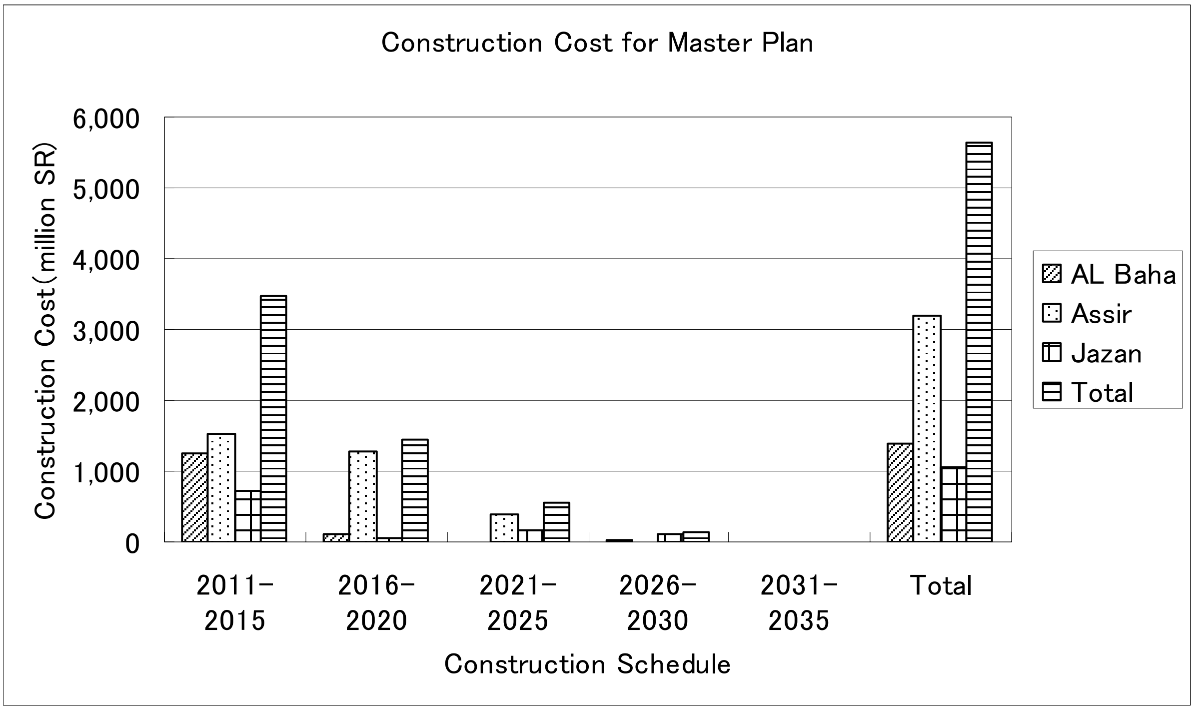


Figure C.6-2 Construction Cost for every Five Years Implementation Period

Table C.6-7 shows operation and maintenance cost from Year of 2010 to Year of 2035. The operation and maintenance cost by 2015 serves as SR130Million per every year, hereafter, increases every year and serves as per every year and SR298Milion for the targeted Year of 2035.

Table C.6-7 Operation and Maintenance Cost (Million SR/Year)

Region	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
Al Baha	17	43	43	43	43
Asir	81	120	131	138	138
Jazan	102	114	158	187	187
Total	130	207	262	298	298

6.3 Implementation Program of the M/P

Implementation Plan for every five years on major facilities in the water M/P is shown in Table C.6-8.

Table C.6-8 Implementation Plan for the Major Facilities in the Water M/P

Region	Facility	Section or Location Name	Construction Period (Water volume 10^3m^3)	2006-10	2011-15	2016-20	2021-25	2026-30	2031-35	Remarks
AL Baha	Transmission line	Dawqah - Albaha	2016-2030 (135)		70	135	135	135		
		Hali-Dawqah	2016-2015 (75)		75					
		AL Baha - AL Alayah	2016-2020 (65)			65				
	Desalination	Shuaibah	2006-2010 (40)	40	0					Return to Makkah
		Dawqah Plant	2021-2030 (96)			75	75	100		
	Renewable Water	Existing	2011-2015 (19)		19					
		Hali Dam	2011-2015 (35)		35	0				Return to Makkah
		Qanunah Dma	2011-2015 (30)		30	0				Return to Makkah
		Yiba Dam	2016-2020 (38-0)		38	0				Return to Makkah
		Al Janabin Dam	2011-2015 (5)		5					
		Nilah& Qilwah Dam	2011-2015 (11)		11					
Asir	Transmission line	Shuqaiq - Abha	2006-2025 (313)	82	238	238	313			
		Shuqaiq - AL Birk	2016-2020 (10)			10				
		Abha -Al Alayan	2016-2020 (40)			40				
		Abha -Al Janoub	2021-2025 (19)				19			
		AL Baha - AL Alayan	2021-2025 (65)			65				
		AL Alayan - Bisha	2006-2025 (65)			65				
	Desalination	Shuqaiq	2011-2025 (313)	82	238	238	313			
	Fossil water		2011-2025 (32)		29	29	61			
	Dam	Existing	2006-2010 (57)	57						
		Baysh	2011-2015 (25)		25					
		Hali	2011-2015 (35)		35					
		Tabalah	2011-2015 (16)		16					
		Hirjab	2016-2020 (9)			9				
		Ranyah	2016-2020 (68)			68				
Jizan	Transmission line	UKAD-Samtah	2011-2015 (75)		75					
	Dam	Baysh	2011-2015 (33)		33					
		Damad	2011-2015 (36)		36					
		Qissi	2011-2015 (9)			9				
	Desalination	Shuqaiq	2006-2025 (75)	3	75	75	0			No use in 2025
		Sabya	2016-2030 (206)			35	160	215		

Note) 1.Implementation period is shown by pattern coloring.
2. Number in a pattern shows the sum total water supply (quantity of production) for the target within the implementation period..

CHAPTER 7 EVALUATION FOR WATER MASTER PLAN (M/P)

7.1 Technical Evaluation

The water M/P of three regions proposed by the Study Team is drawn up according to technical data, standards and judgments, and suitable decision procedures which are described below. Therefore, this M/P can be technically evaluated as feasible.

(1) Standards and Criteria for Planning and Design

On the basis of data and information gathered from government and regions, the Study Team carefully examined pertinent information used for planning, such as social and economical conditions, natural conditions, an environmental condition and conditions for water supplies. Furthermore, in the targeted regions, the Study Team held stakeholder meetings to grasp the water issues. Opinions from stakeholders were collected and reflected on for the formulation of the M/P. The standard or criterion, which the government defined, was also used for planning, designing and cost estimating for the M/P.

(2) Projection of Population

For the projection of population in the targeted year for water demand in 3 regions, it was estimated by using the ratio of the rate of increase of each region to the annual average population growth rate (2.6%) of KSA.

(3) Demand Projection for Municipal Water

Basic scenario for water demand projection as shown in Chapter 3 in part B, is a planning value of MOEP applying in the project currently carried out by MOWE. Since the water supply service ratio varies high ratio to low ratio depending on the scale of cities and towns, it was classified and set as large scale urban area showing more than 85,000 in population, urban area showing from 5,000 to 85,000 in population, and rural community area showing less than 5,000 in population

(4) Agricultural Sector

In agricultural sector, since renewable water was quantitatively insufficient, the Study Team proposed effective use of reclaimed sewage water which categorized non-conventional water and introduction of demand management by applying modern irrigation system with saving water. By introduction of these measures, planting in the 2007 year level in targeted 2035 year became possible in Al Baha Region and Asir Region.

In Jazan Region, to the current planted area, renewable water ran short and reduction of the planted area until it balances renewable water resources potential was recommend. The amount of water resources produced by reduction of cereals and the planting stop of the feed crop was preferentially distributed to vegetables and fruit planting, and the remainder was taken as a plan to assign the sorghum cultivation which is typical crops in Jazan Region. As a result, a fruit tree will maintain the 2007 level and plant area for vegetables can secure redoubling in 2007.

(5) Connecting Pipeline System

In order to conquer the quantitative imbalance of renewable water depending on seasonal fluctuation and area for water supply of municipal water and secure of water resources, it was considered as the supply system which combined the development of renewable water by the dams and wells, and the desalinated seawater by plants. For mutual watering system to which among main demands places, connecting pipeline system including existing pipelines was adopted.

(6) Extension of Desalinated Seawater

Extension of the desalination water is planned in all regions, the ratio of desalination water for municipal water supply to the planned target in 2035 reaches as 70% in Al Baha Region, 50% in Asir Region and Jazan Region. As for a desalination plant, although a detailed examination will be required, it is advantageous to locate along the Red Sea nearest demand place from a viewpoint of the economical efficiency.

(7) Recycle Use of Reclaimed Waste Water

Although recycle use for reclaimed waste water is limited for municipal water and industrial water, it is a stage in which the reproduction processing with efficient reuse ratio as about 80% or more is possible as water for agricultural use, and positive use shall be adopted.

In particular, in the Al Baha and Abha located in plateau area, reuse efficiency shall be raised and introduction of a distributed type local sewage disposal system shall be enabled it to use effectively. In Jazan Region, since the present reuse efficiency is low, the plan of the sewage disposal system which shall be raised the efficiency in urban areas, and planning and design shall be required.

(8) Management of Water

As an executive organization, establishment of the Renewable Water Production Corporation (RWPC) which becomes a center of comprehensive water management is proposed. Comprehensive water management shall be performed efficiently and economically combining different water resources, such as renewable water resources, desalinated seawater, reclaimed waster, and fossil aquifer.

In addition, each region shall manage the water resources in region. In case of supply and demand shall be tight, this organization shall carry out water management beyond region.

(9) Demand Management of Water

As demand management, "3 R" campaign activity of saving (Reduce), reproduction use (Reuse), circulation use (Recycle), etc., introduction of proper water tariffs, introduction of water saving apparatus, the training plan for carrying campaign activities, organizational reform, etc. shall be required. Through the educational campaign and consciousness improvement activities, it is required to decrease per capita water supply consumption.

The proposed M/P for three Regions will be drawn up by the basis of the above technical bases for the purpose of 2035 based on future prediction of population and economic growth. The water M/P should be reexamined according to the actual condition of society and economy, or accumulation of hydrological information, and it should be reformulated if needed.

7.2 Economic and Financial Evaluation

7.2.1 General

Economic and financial analyses were carried out to the overall water supply plan in housing and industry in the Water M/P, which utilizes desalination plants, wells and dams. These analyses include new, planed and constructing facilities, which are necessary for the procurement of the planned water quantity. The economic/financial feasibility of the water supply plan was considered through the comparison of the benefit and the cost.

7.2.2 Basic Conditions of the Analyses

Basic conditions of the economic and financial analyses are shown in the next table.

Table C.7-1 Basic Conditions of the Economic and Financial Analyses

Items	Conditions
1. Prices	The prices as of January 2010
2. Exchange rate	SAR 1 = USD 0.2673
3. Standard conversion factor	120 %
4. Opportunity cost of capital	6.5 %
5. Evaluation period	30 years
6. Period of durability	
1) Desalination plant	25 years
2) Water transmission facility	25 years
3) Deep well	25 years
4) Dam	80 years

(1) Adjustment of the Inflation

The increase of the inflation rate during the last decade is about 21%. The cost of living declined up to 2001 and after that it rose up. The standard year of the economic/financial analysis was set in 2009 (= project starting year). The desalination costs in the past were to be converted into the current prices in 2009 by the conversion coefficient of each year.

(2) Standard Conversion Factor

International price of fuel was considered in the conversion from the financial cost of the project to the economic cost because a lot of subsidy was introduced for the restraint of oil price in the KSA. It was estimated that the fuel cost was restrained one third of the international price by the subsidy, considering the retail price of gasoline as an index. Assuming that 10% of the project cost is occupied by the fuel cost, the conversion factor from the market price to the economic price is set at 120% since the 10% of the fuel cost is tripled. (10% x 3 + 90%)

As for the subsidy of the gasoline, it was estimated double of the market price. The international price was set at 0.37$/lit, deducting 29%[1] of tax from 0.52$/lit[2] of the prince in the second quarter of 2009 in USA, which was utilized as the world index of gasoline price. The retail price at the same time in Riyadh, 0.12$/lit was applied to the market price in KSA. Therefore, it was estimated that the fuel cost in the KSA was restrained one third by the subsidy of two thirds of the international price.

(3) Opportunity Cost of Capital

The opportunity cost of capital was set at 6.5%, which was the intermediate value between 5% and 8%, because the reference standard of SWCC was 5 - 7% and NWC was 6 - 8%. The setting between 6 and 7% is considered to be appropriate since the average interest rate of the central bank in 2004 - 2008 is 4.0%, and the maximum is 5.3% in 2006.

(4) Periods of Durability of the Planned Facilities

The planned facilities in the target three districts are categorized into four types; desalination plants, water transmission facilities, deep wells for fossil water, and dams. The water volume in the future is assumed to be kept getting the planned volume up to the end of the service lives of each facility, which were shown in the above table. The service life of the desalination plants, 25 years is shown in *2008 Annual Report for Operation & Maintenance*[3] of SWCC. And the same period was applied to the service lives of the water transmission facilities and the deep wells. Regarding the service life of dams, the standard period of 50 years for fill dams and 80 years for concrete dams are decided in Japan. And 80 years was applied to the life of all proposed dams since almost all the dams were considered to be constructed by concrete.

7.2.3 Water Value of the Water Supply Plan

(1) The Financial Value of Water

The financial value of water in housing and industry is the tariff of water, which is decided in the National Water Strategy and confirmed through NWC in January 2010. It is recognized that actual tariff is about SR 0.10 – 0.15/m^3 since the volume of most water users are less than 100 $m^{3/}$month. However, the weighted mean of water tariff will be applied in the financial analysis as we can grasp the proportion of the water consumption amount in each band of the water tariff structure from the report of the WB. The next table shows the weighted mean of water tariff is SR0.40/m^3, using the proportion of each tariff band. This water price is applied to the financial water value, which can be obtained through the implementation of the water supply plan.

[1] 23.2% (individual indirect tax) + 5.7% (retail sales tax) = 29% The retail sales tax is determined in each state. 5.7% is the mean value between the maximum value of 8.5% and the minimum value of 2.9%.

[2] Source: *Energy Prices and Tax*, IEA

[3] Table of Remaining Life Time for SWCC Plants

Table C.7-2 Estimation of Weighted Mean of Water Tariff

m^3/month	Band	Price 1) (SR/m^3)	Proportion 2) (%)	Partial price (SR/m^3)
		A	b	a*b
< 50	A	0.10	60	0.06
50 – 100	B	0.15	25	0.04
100 – 200	C	2.00	15	0.30
200 – 300	D	4.00	-	-
> 300	E	6.00	-	-
Weighted mean of water tariff (Financial water price)				0.40

1) NWC, 2010
2) Estimation from Fig. Riyadh Residential Water Consumption and Tariff, *Proposal for a National Water Strategy*, June 2009, WB

(2) The Economic Value of Water

On the other hand, if the water development plan is not implemented, the most economical and realistic alternative way of developing water is the usage of desalination plants. The cost of desalinated water was estimated, using the practical data of SWCC and the conversion coefficient of inflation. The water production costs in the next table are the average of all SWCC plants in each year. In the annual report of SWCC, water transmission costs are indicated by the east coast, the west coast and the total, hence the data of the west coast were applied to the estimation.

The total cost of the desalinated water is considered the social cost of water because desalination is the most economical way to develop water in the target regions, where the usage of ground water should be limited basically though the cost is higher than that of wells. Therefore, the water price of 4.16 SR/m3 is multiplied by 120% of the conversion factor to the economic price, and applied to the economic value of water in the economic analysis.

Table C.7-3 Cost Estimation of Desalinated Water

Year	Conversion coefficient	Water production cost - SWCC plants (SR/CM)		Water transmission cost - West coast (SR/CM)		Total (SR/CM)
	a	b	c=a*b	D	e=a*d	f=c+e
2004	1.220	2.25	2.75	1.20	1.46	4.21
2005	1.212	2.35	2.85	1.19	1.44	4.29
2006	1.186	2.23	2.64	1.18	1.40	4.04
2007	1.139	2.27	2.58	1.33	1.51	4.10
2008	1.036	2.38	2.47	1.61	1.67	4.13
Average		2.30	2.66	1.30	1.50	4.16

Source: *2008 Annual Report for Operation & Maintenance,* SWCC

The grounds for the calculation of the project benefit are summarized in the next table.

Table C.7-4 Grounds for the Calculation of the Project Benefit

Project Benefit	Unit Benefit	Remark	Source
Municipal water	SR 0.40 /m^3	Financial value of water	Water tariff
Municipal water	SR 4.99 /m^3	Economic value of water, estimated by the cost of desalination	Operation and maintenance report of SWCC

7.2.4 Cost of the Water Supply Plan

(1) Summary of the Project Cost

Necessary facility plan for the water supply was formulated and the project cost including the disbursement plan was proposed. The construction costs and the annual operation and maintenance costs of each facility are summarized in the next table. More than 60% of the construction cost is occupied by the water transmission facility. Adding the construction cost of desalination plant to the cost of transmission facility, the proportion exceeds 75%. As for the operation and maintenance cost, the desalination plant occupies more than 60% of the total cost. Adding the cost of transmission facility to the cost of the desalination plant, it exceeds 92% of the total annual cost.

Table C.7-5 Summary of the Project Cost

Proposed Facilities	Al Baha (MSR)	Asir (MSR)	Jazan (MSR)	Three Regions (MSR)	Proportion (%)
Construction Cost					
Desalination plant	134.4	322.0	337.4	793.8	12.0
Transmission facility	1,247.3	2,228.6	709.7	4,185.6	63.2
Deep well	-	648	-	647.9	9.8
Dam	456	151.9	381.9	989.9	15.0
Total	1,837.8	3,350.4	1,429.0	6,617.1	100.0
Annual O&M Cost					
Desalination plant	33.6	80.5	84.4	198.5	66.4
Transmission facility	17.0	49.5	10.6	77.2	25.8
Deep well	-	18.5	-	18.5	6.2
Dam	2.3	0.8	1.9	4.9	1.6
Total	52.9	149.2	96.9	299.0	100.0

The financial and economic costs are summarized in the next table.

Table C.7-6 Financial and Economic Project Cost（MSR）

Project Cost	Construction Cost				Annual O&M Cost			
	Al Baha	Asir	Jazan	Total	Al Baha	Asir	Jazan	Total
Financial Cost	1,838	3,350	1,429	6,617	52.9	149.2	96.9	299.0
Economic Cost	2,205	4,020	1,715	7,941	63.5	179.0	116.3	358.8

(2) Disbursement Plan of the Project Cost

The construction period of proposed facilities was uniformly assumed to be five years before the commencement of the use because most existing facilities in the water development field were constructed about five years. Then one fifth of the construction cost was appropriated equally for each year of the construction period. Annual operation and maintenance cost was estimated by the types of facilities, using the experimental ratio to the construction cost, and appropriated equally for each year in the periods of the service lives.

7.2.5 Results of the Financial and Economic Analysis

(1) Result of the Financial Analysis

The financial analysis was carried out, applying the financial value of water to the benefit of the water supply plan. The B/C ratio discounted by 6.5% is 0.10. This result is caused by the low establishment of the water tariff as a matter of course. The water tariff should be raised about ten times of the current price level if it covers the whole cost in the current tariff structure.

(2) Result of the Economic Analysis

Table C.7-7 Result of the Economic Analysis

Indicators	Values
EIRR	6.8 %
B/C	1.02
Net Present Value	158 MSR

The Internal Rate of Return (IRR) was calculated at 6.8%. The standard of the discount rate in the sector of water development is considered between 6 and 7%, approximately. Hence the proposed water supply plan could be evaluated feasible from the economic aspect. This result means that the proposed water supply plan is one of the mixed models of desalinated, surface and ground water, which can be feasible even if the standard discount ratio is applied to them.

7.3 Evaluation from Socio-Environmental Aspect

1) Contribution to the Socio-Economic Activity

The objectives of the M/P is to secure the sufficient amount of water supply in correspond to the increase water demand in the future in the south-west region of the Kingdom. For this purpose, the M/P includes the activities of sustainable and integrated development of renewable water resources as well as its maintenance and operation plans.

Implementation of M/P will directly contribute to sufficient supply of portable, industrial and other water, and establishment of appropriate water right. Through such direct contribution, the M/P also positively leads to improvement of regional health and hygiene condition and regional economic growth.

2) Location of the Natural Conservation Areas and the Facilities Planned Areas

Figure C.7-1 shows the location of the natural conservation areas and the facilities planned to construct under this M/P. As shown in the same figure, there are Jabar Shada conservation area and Raydah conservation areas located in the study area near Al Baha and Abha, respectively.

However, the main facilities such as dams, pipelines and desalination plants are not designed to locate in such natural conservation areas. Therefore, significant effects on the natural conservation are not foreseen.

Figure C.7-1 Locations of the Facilities and Natural Conservation Areas.

3) Impact on the Natural Environment and Mitigation Programme

Integrated water resources development and maintenance in the M/P is based on the utilization of those facilities (dams, pipelines, etc) which have been already constructed, or currently under-planning or under-construction by MOWE. Yet, the Study Team additionally proposed construction of some facilities including dams, pipelines and desalination plants. Under this Study, the socio-environmental consideration survey was conducted at the magnitude of Initial Environmental Examination (IEE).

There are several uncertainties embraced in this socio-environmental consideration survey since the precise locations, layout and capacity have not been defined. However, it is anticipated that the newly proposed facilities including dams, pipelines and desalination plants, potentially cause some adverse impacts including temporary water pollution, noise and vibration, flora and fauna, etc. Therefore, the mitigation measures for the possible adverse impact were considered as one the activities of this M/P study. Table C.7-8 shows the main adverse impacts and mitigation measures for each environmental factor. It is considered execution of the mitigation measures will contribute to minimize the magnitude of the adverse impacts.

Table C.7-8 Mitigation Measures for Main Adverse Impacts

Item	Dam	Pipeline	Desalination	Possible Mitigation Measures
Involuntary Resettlement	D	D	D	● Selection of detour pipeline route ● Mining the pipeline ● Compensation of the land
Groundwater	**E**	C	C	● Appropriate recharge into the underground from dam site.
Hydrological condition	**E**	C	C	● Appropriate discharge from dam site
Flora and Fauna	D	**E**	D	● Understanding of the biodiversity at the project sites through biodiversity study ● Selection of detour pipeline route from the protected and high biodiversity areas ● Mining the pipeline
Air Pollution	D	D	D	● Introduction of eco-type heavy industry ● Sprinkling at the construction site ● Introduction of eco-type pump and plants
Water Pollution	**E**	C	**E**	● Extension of effluent pipeline to the offshore for desalination plant ● Surface water discharge or introduction of selective intake facility for dam
Soil Contamination	C	C	D	● Appropriate design and construction for oil and liquid storage facilities
Noise & Vibration	C	**E**	D	● Selection of appropriate site ● Compliance of the construction hours ● Install of noise barrier ● Selection of appropriate wall materials.
Sedimentation	D	C	C	● Examination of sedimentation measures at the design stage

A~E indicates likely causing A:: significant favorable impact, B: slight favorable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

4) Consideration of Alternative Scenarios

Based on the concept of the Strategic Environmental Assessment (SEA), the following three (3) scenarios were examined.

Case 1: Zero Option Scenario (Without implementation of the M/P)

Case 2: M/P Scenario (With implementation of the M/P)

Case 3: Alternative Scenario (Increase the water supply by desalination plant only)

Table C.7-9 shows the result of the examination.

Table C. 7-9 Comparison of Alternative Scenarios (Social and Environmental Consideration)

Item		Case 1	Case 2	Case 3	Projection of the Impact
Social Environment	Involuntary Resettlement	C	?	?	No involuntary resettlement is projected under the zero option scenario. Whereas, the degree of the impact is not understood due to uncertainty of the precise location, layout, number, capacity and functions of each facilities under the M/P and desalination plant scenarios at this stage.
	Local Economy	D	**A**	B	Local economy may deteriorate under the zero option scenario. Due to increase in stable and sufficient water to each region, a positive impact on local economy is expected under the M/P and desalination plant scenarios. However, the desalination plant scenario is not contribute to recovery of groundwater environment and potentially embraces possibility of deterioration of agricultural sector.
	Water Right	**E**	**A**	B	The M/P scenario will significantly contribute comprehensive water allocation for each sector and is expected to establish a systematic water right among each sector.
	Hygiene	**E**	**A**	**A**	The M/P and desalination plant scenarios are projected to contribute to improve local hygiene conditions owing to supply of sufficient amount of water. Whereas, the local hygiene condition may deteriorate due to insufficient water supply under the zero option.
Natural Environment	Groundwater	**E**	**A**	B	The zero option may lead to further extensive use of groundwater and is projected to lead to further groundwater lowering. Since some portion of desalinated water is supplied, the groundwater lowering may be eased under the desalination plant scenario. However, it may not solve the fundamental issue relating to groundwater.
	Flora and Fauna	C	D	D	The current condition remains under the zero option. On the other hand, it is projected appropriate countermeasures for protection of flora and fauna are essential under the M/P and desalination plant scenarios.
	Global Warming	C	C	**E**	Desalination plant was the one of the major sector in emission of green house gases in 1990 in the Kingdom. Although the scale of the emission of CO_2 from a single plant is limited, it is projected construction and operation of a large number of desalination plants may cause adverse impact on global warming due to complex and cumulation effect.
Pollution	Air Pollution	C	C	D	As well as the item, global warming, the impact on the environment due to emission of pollutant from a single plant is limited. However, the impact of the pollutant may be magnified due to complex and cumulation effect. Yet, the air pollution would be limited to regional environmental issue.
	Water Pollution	C	D	D	Appropriate measures are necessary for operation of dam and desalination plant under the M/P scenario and desalination plant under the desalination plant scenario. The water pollution, if caused, is projected to give adverse impact on the local environment.
	Noise and Vibration	C	D	D	Appropriate measures are necessary for operation of pipeline and desalination plant under the M/P scenario and desalination plant under the desalination plant scenario. The noise and vibration, if occurred, is projected to give adverse impact on the local environment.

A~E indicates likely causing A:: significant favorable impact, B: slight favorable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Under the zero option scenario (Case 1), nevertheless the natural environment would be reserved as present, deterioration of some social environments were projected due to shortage of water supply. Execution of the alternative scenario (Case 3) may cause local pollution such as air pollution and adverse impacts on global warming due to complex and multiple effects of the facilities.

5) Recommendations

The concrete construction locations or scale of the proposing facilities are not precisely identified yet at the M/P phase. Additionally, due to limitation of the information, the projection was conducted at IEE level. The degree of the projection and the effects of the countermeasures embrace uncertainty. Therefore, the Kingdom of Saudi Arabia shall evaluate more detail social and environmental impacts and their affected area by the proposing facilities after the completion of this study by JICA Study Team. In accordance to the Article five (5) of the General Environmental Law and Rules for Implementation (2001) and Appendix-2 of its associated regulation on the Environmental Standard, Environmental Impact Assessment (EIA) are required for all newly proposed facilities (i.e. dams, pipelines and desalination plants) at Feasibility Study Stage. It is recommended that the Kingdom shall conduct EIA and prepare social and environmental considerations not only limited to but particularly for the items that adverse impacts are possibly projected.

Table C.7-10 shows the items to be intensively examined in the EIA study and the recommended survey items.

Table C.7-10 Recommendation for Accentuated Survey in EIA

Environmental Factor	Facility	Survey Item	Season/ Frequency	Survey Location
Involuntary Resettlement	Dam	● Habitation Condition ● Land Use	Anytime	Upper and Lower basin of the dams
	Pipeline			Route + 100m in width
	Desalination Plant			Facility area + 500m
Groundwater	Dam	● Water Level ● Pumping test	Anytime	Dam position Downstream of the dam
Hydrological Condition	Dam	● Discharge Observation	Upon Flood	Reservoir entrance
Flora and Fauna	Dam	● Literature Survey ● Field Survey ● Interview with Experts	Dry Season Rainy Season	Reservoir area + 500m
	Pipeline			Pipeline route + 100m in width
	Desalination Plant			Plant area + 500m
Water Pollution	Dam	● Water Quality (pH, BOD, Do, etc)	Upon water flow Once/month	Reservoir entrance Centre of the reservoir Downstream (before conjugation with another wadi)
		● Heavy Metals and Organics	Upon water flow Twice/year	Reservoir entrance
		● Land Use	Anytime	Upstream of the dam
	Desalination Plant	● Seawater quality	Once/month	Discharge Point 500m north and south from the discharge point
		● Marine Biology	Dry Season Rainy Season	
		● Case Study	Anytime	
Noise and Vibration	Pipeline Desalination Plant	● Field Survey	Once/year	Location for booster pump facility
		● Case Study ● Inhabitation Condition ● Land Use	Anytime	Location for booster pump facility

CHAPTER 8 RECOMMENDATIONS

(1) Implementation of Projects Proposed in the Water M/P

The proposed Water M/P is prepared on the basis of the upper plans and programs such as National Five-Years Development Plan, National Water Strategy etc. to develop properly conventional water resources and non-conventional water resources and to supply municipal water and agricultural water for the areas of Al Baha, Asir and Jazan Regions so that the prosperous socio-economy and comfortable people's life are achieved in the three Regions.

The Water M/P proposes the reasonable plans of water demand and supply targeting the year of 2035 for three Regions based on the socio-economic framework by sector. To prepare the Water M/P, the opinions collected at the Stakeholder Meetings are taken into consideration.

The M/P prepared in such process proposes to solve or minimize water issues at present and in future. That is why the M/P is useful and important for the people of the regions. It is recommendable that the projects proposed in the M/P are implemented in accordance with the implementation schedule.

(2) Re-confirmation of Design Water Supply Volume from Dam

The Study team examined the new dam-projects in five Wadis (Ghoran, Naaman, Hirjab, Yiba, Khulab) based on the water balance study done in this Study. But the Study Team and MOWE concluded that these projects are not suitable for new projects judging from hydrologic, hydro-geologic and topographic conditions. Therefore, all the dams included in the M/P are the dams planned and under-constructed by MOWE.

The M/P uses the design water supply volume developed at each dam that is planned by MOWE. Before the operation of each dam, MOWE must confirm whether the design development volume covers the design volumes for municipal water supply, irrigation and compensation water of current users. Also MOWE must prepare the operation rule and manual for new dam.

For MOWE's confirmation and preparation mentioned above, the Study Team recommends the 3-Dimensional Computer Simulator to evaluate 1) sustainable water development volume and 2) effectiveness of joint operation (dam reservoir and aquifer in Wadi).

Furthermore, it shall be recommended for a preparing the data which can be used for evaluation of productive ground water potential to avoid an unrecoverable groundwater descending, and change of various environmental conditions.

(3) Promotion of Reclaimed Waste Water Reuse

At the main cities in the target regions covered by the M/P, the reclaimed waste water projects are being implemented by MOWE. The M/P proposed municipal greening water, industrial cooling water and irrigation water as a target of reuse of reclaimed waste water. Irrigation is the largest user for the reclaimed waste water. In Al Baha Region and Asir Region, each region's coverage of reclaimed waste water is respectively 20% and 25% of total irrigation water volume.

In these highland mountainous areas, the Study Team recommends the Distributed Waste Water Treatment System suitable for this kind of topography for targeting the promotion of reuse of reclaimed waste water. Also protection project of the seawater intrusion by recharging reclaimed waste water is recommendable in Jazan Region. Before starting the project operation of waste water treatment, feasibility study (F/S) on reuse of reclaimed waste water is recommendable.

(4) Further Study on Two New Desalination Plants in Water Supply Plan

The water supply plan proposed in the M/P targets municipal water use and industrial water use. The water resources of the water supply are surface water, renewable groundwater, fossil groundwater and desalinated sea water.

Desalinated sea water becomes the most useful water resources at the time of sever drought. Currently SWCC is supplying desalinated sea water for the areas of 3 Regions, and expanding the capacities of production and distribution.

The M/P Study clarified the renewable water resources potential and projected future water demand, and concluded that the renewable water resources potential is not sufficient to cover all the demand. It is indispensable for SWCC to continue and expand the desalination project to meet future water demand of municipal water and industrial water. However production cost of desalinated sea water is still 3 – 4 times higher than that of renewable water. As the cost of water conveyance is also high, new desalination plants should be constructed near the consumer areas to minimize water conveyance distance and cost.

The M/P proposes two new desalination plants at Dawqah in Makkah Region and Sabya in Jazan Region. Implementation of F/S Study on these projects is recommendable.

(5) Demand Management for Municipal Water

For the demand management of municipal water supply, the M/P proposes such promotion measures to decrease LCD (or daily water consumption per capita) as 1) Introduction of Water Saving Type Apparatus Up-dated, 2) Review of Proper Water Charge and Its Collecting System, 3) Renewal of Institution for Improvement in Water Recycling Rate of in Factory, and 4) Recognition of Importance of Water Saving by Education and Enlightenment. Also the M/P proposes such promotion measures to decrease leakage ratio of pipelines as 1) Planned Renewal of Decrepit Pipelines 2) Improvement of Flow Measurement, and 3) Introduction of Diagnostic Technology for Water Leakage.

Although the measures mentioned above need some amount of financial investment, the investment is effective in financial aspect that same amount of the investment save several dam construction for water supply. Therefore it is recommendable for water related organization to implement demand control measures to decrease LCD.

(6) Demand Management for Irrigation Water

The water sources of irrigation water are renewable water resources and reclaimed waste water. The examination done in the M/P shows that the agriculture of 2007-year level in Al Baha and Asir Region will be sustainable in 2035 by using renewable water and reclaimed waste water in each region, and that the agriculture in Jazan (National Top-3 Agricultural Region) will not be sustainable even in 2035 by using renewable water and reclaimed waste water in the region.

For Jazan Region specially, the demand management of irrigation water is recommended including 1) Popularization of Modern Irrigation System, 2) Conversion to Crops with Small Water Requirement Based on MOA-Decision335, and 3) Promotion of Utilization of Reclaimed Waste Water. Therefore, if the agricultural issues are not solved, industrial structure should be transformed and the surplus farmer should be assigned to the other industries such as Jazan Economic City - Project. In addition, when carrying out industrial structure conversion, political consideration is necessary to the small-scale farmer which has made its living by traditional agriculture.

(7) Feasibility Study on Establishment of RWPC

As basics of the total water service management, the Water M/P proposes recommendation such as to perform efficient and economical management combining different water resources by integrated network system.

The M/P proposes a new organization of RWPC (Renewable Water Production Corporation as a core of the total water service management. The objectives of RWPC are to implement development, O&M of renewable water resources, and coordination with organizations concerned.

Also the M/P clarifies the mandates and activities on water resources management for water related organizations such as MOWE and MOWE Regional Office (General Directorate of Water, GDW), other ministries, SWCC, NWC and so on. Further study (F/S Study) on the establishment of RWPC is quite recommendable to realize good water management in the study area.

(8) Feasibility Study on Establishment of REWLIP (Red-Sea Water Lifeline Project)

The Study Team proposes REWLIP based on the two important aspects: 1) Economic Aspect to Secure Less Expensive Water, and 2) Technical Aspect to Secure Necessary Water Sufficiently in Wide Area by Different Water Sources and Well Connected Water Conveyance Systems.

This large project (which produces desalinated seawater and renewable water and distributes water in 4 Regions) is the first and very important project for the area and for KSA. The Study Team recommends the F/S Study on this very important project to realize soon for the regions and KSA.