CHAPTER 4 WATER RESOURCES POTENTIAL

4.1 Surface Water in Basin

Using SWAT (Soil and Water Assessment Tool), the water balance was estimated for 30 years from 1975 to 2004. The model area was 161,000 km^2, and the monthly discharge and groundwater recharge were calculated and arranged as basin's water balance. The physical processes to analyze the water balance are summarized in the following sub-sections.

(1) Catchments Delineation

Prior to modeling, the model area was partitioned into 1,269 sub-basins (Called 'catchments' in SWAT) with the use of 30-arc grids (90m) of DEM (Digital Elevation Model).

(2) Preparation of Input Information

As necessary data set for SWAT, the meteorological and hydrological information were prepared, and input information for each sub-basin was grouped into the following categories:

The actual data applied to the analysis is described in the following sub-sections.

<u>Climate</u>

In the analysis, the data from 85 stations, selected among MOWE's 135 stations and PME's eight(8) stations (Abha, Al baha, Bisha, Jizan, Khamis Mushayt, Makkah, Najran, Jeddah）were processed, and 30 years of records from 1975 to 2004 were applied to SWAT.

<u>Land Use Map and Soil Taxonomy Map</u>

The Land use map and soil characterization map were made as GIS themes as shown in Figure B.4-3. They were used to load land use and soil themes into the project areas and determine the land use/soil class combinations and distributions for the delineated watershed (s) and each respective catchments. The land use and soil themes were once imported and linked to the SWAT databases, the criteria of superficial condition was specified in determining the calculation units (hydrologic response units or HRUs) distribution. Then, one or more unique land use/soil combinations were created for each sub-basin.

<u>Hydrologic Response Units (HRUs)</u>

The calculation of the water balance was based on Hydrologic Response Unit (HRU). HRU are portions of catchments that possess unique landuse / management / soil attribute. Subdividing the watershed into areas having unique land use and soil combinations enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers/crops and soils.

Hydrologic items of groundwater recharge and runoff were predicted separately for each HRU and routed to obtain the total amount for the watershed.

4.2 Calculation of Water Balance (Model Output)

In the project area, groundwater recharge exclusively occurs during floods in the winter season. With normal precipitation, it may be intercepted and held in the vegetation canopy, fall to the soil surface, or later lost by evaporation. By the heavy rain, water flows overland as runoff and moves quickly toward a stream channel and contributes to short-term stream response. At the down reach of wadi courses, especially lain by superficial deposits or porous sedimentary rocks, water begins to be infiltrated into the subsurface. Even if held in the soil layer, the water is evapotranspiration and the rest of the water may slowly make its way to the surface-water system via underground paths.

(1) Area Rainfall

Area rainfall was calculated using with the 85 records. The area precipitation for catchments was obtained as a range from 5 mm/year to 425 mm/year in 30 years' average (1975-2004) for the basin.

(2) Potential Evapotranspiration

Potential evapotranspiration is the rate at which evapotranspiration would occur from a large area covered with growing vegetation which has access to an unlimited supply of soil water. The calculation was made with Penman-Monteith method, and a range of 660 to 4,830 mm/year was obtained.

(3) Actual Evapotranspiration

The calculated value of evapotranspiration includes evaporation from rivers and lakes, bare soil, and vegetative surfaces; evaporation from within the leaves of plants (transpiration). The model computed evaporation from soils and plants separately. Potential soil water evaporation was estimated as a function of potential evapotranspiration and leaf area index. Actual soil water evaporation was estimated by using exponential functions of soil depth and water content. Plant transpiration was simulated as a linear function of potential evapotranspiration and leaf area index. As the result of the calculations, 10 to 610 mm/year of actual evapotranspiration was taken.

(4) Soil Water Contents

Soil water content was calculated by Green-Ampt and Mein-Larson method. The method is to predict infiltration with the assumption of surface runoff occurring by rain fall. When the rainfall intensity is less than the infiltration rate, all the rainfall will infiltrate during the time period and cumulative infiltration. Inversely, when its intensity is higher than the infiltration, excess water turns to surface runoff.

As water infiltrates into the soil, the method assumes the soil above the wetting at the front, there is a sharp break in moisture content and respectively providing different hydraulic conductivity parameters.

(5) Surface Runoff (Water Yield)

The Flow in a watershed is classified as overland and channelized. The primary difference between the two flow processes is that water storage and its influence on flow rates is considered in channelized flow. Main channel processes modeled by SWAT include the movement of water in the stream network. Open channel flow is defined as channel flow with a free surface, such as flow in river or partially full pipe. SWAT uses Manning's equation to define the rate and velocity of flow. Water is routed through the channel network using valuable storage routing method. SWAT treats the volume of out flow calculated with valuable storage routing method as the net amount of water removed from the reach. As transmission is lost, evaporation and other water losses for the reach segment are calculated, the amount of outflow to the next reach segment is reduced by the amount of the loss. When outflow and all losses are summed, the total amount will equal the value obtained from valuable storage routine method.

(6) Percolation and groundwater recharge

Percolation was calculated for the soil layer in the profile. Water is allowed to percolate if the water content exceeds the field capacity water contents for that layer. Water that moves past the lowest depth of the soil profile by percolation enters and flows through the vadose zone in to the shallow aquifer. The lag between the time that water exits in the soil profile and enters the shallow aquifer will depend on the depth in the water table and the hydraulic properties of the geologic formations in the vadose zone and groundwater zones. If the time is long enough to move water into the aquifer, such as 30 years as that of the modeling, the amount of percolation water is almost the same as groundwater recharge. In the calculation, percolation amount was treated as ground amount water recharge.

(7) General Water Balance in Model Area

On average for 30 years in the model area, 120 mm/year is lost by evapotranspiration out of 130 mm/year of rainfall. Remaining 7 mm is infiltrated into shallow aquifer and stored as groundwater.

In the balance of wet years (1st of 15 years), the area of rainfall is 258 mm, and out of this, 154 mm/year is allocated to evapotranspiration. The other 16 mm/year returns to the subsurface system.

4.3 Water Balance

(1) Water Resources Potential of Region

The water balance and river discharge were estimated by SWAT model for 30 years from 1975 to 2004. The model area was 161,000 km^2 divided into 1,269 sub-basins, and the series of monthly discharge was calculated and arranged into Basin's Water Balance. As well, to secure the model accuracy, the model parameters were applied by the verification result.

(2) Water Balance of Major Wadis Basins

Prior to the estimation of water balance for major wadis, 31 outlets in basins including 21 points of Red Sea coast and 10 points of Nejd were selected to apply the basin-wide analysis. The range of the basins is shown in Figure 4-1, and the summary of water balance of basins are illustrated in Table 4-1.

Figure 4-1 Model Basin

Table 4-1 Summary of Water Balance

Moutain-Plain (Area 161,150 sqkm)							
Basin					Water Potential (MCM/year)		
No	B_ID	Basin	Area (Sqkm)	Outlet Ptn. at	ER (Mountain+Plain)	Surface Runoff	Ground-water Runoff
1	J5	Khulab	1,568	Jazan	47	1	46
2	J4	Jazan	1,862	Jazan	100	14	85
3	J3	Damad	1,376	Jazan	77	12	65
4	J2	Baysh	6,367	Jazan	98	14	84
5	J1	Itwad	1,972	Jazan	25	1	24
6	M12	Hali	5,659	makkah	99	89	11
7	M11	Yiba	3,346	makkah	91	70	21
8	M10	Yiba_N	2,416	makkah	59	38	20
9	M9	Doquah_S	1,726	makkah	53	41	13
10	M8	Doquah	1,603	makkah	24	18	6
11	M7	Doquah_N	1,578	makkah	16	26	-10
12	M6	Fagh	2,362	makkah	15	36	-21
13	M5	AlLith_Sadiyah	3,338	makkah	17	7	9
14	M4	Naaman	2,513	makkah	8	26	-18
15	M3	Fatimah	4,306	makkah	46	28	18
16	M2	Ghoran	4,916	makkah	51	25	26
17	M1	Ghoran_N	2,355	makkah	16	9	7
18	M0	Khulays	5,462	makkah	100	57	43
19	M1	Qudayd	2,207	makkah	15	7	8
20	M2	Rabigh	6,699	makkah	116	65	52
21	M3	Qahah	3,356	makkah	5	1	4
22	M1	Aqiq	15,485	makkah	47	17	30
23	M2	Turabah	7,786	makkah	154	106	48
24	M2	Ranya	7,885	makkah	144	90	54
25	A1	Bisha	22,303	asir	117	53	64
26	A2	Tathlith	17,237	asir	21	13	8
27	N1	Habana	7,186	Najran	12	1	11
28	N2	Najran	6,999	Najran	28	3	25
29	N2	Mayayn	3,128	Najran	5	1	4
30	N3	Hynah	2,262	Najran	5	0	4
31	N3	Habal	3,891	Najran	3	0	3
Total (on basins)			161,149		**1,614**	**870**	**744**

Table 4-1 shows an average value (mm/year) of 30 years for ER (Effective Rainfall) from 1975 to 2004. ER was taken by subtracting rainfall from evapotranspiration and divided into two parts of 744 MCM/year of groundwater and 870 MM of surface water.

ER refers to the same amount of replenished water as natural water resources. The Total of both of them, 1,614 MCM/year, was regarded as Water Resource Potential of the five (5) regions in the project areas.

As well, this value also implies a maximum potential to be developed in the project area. As for surface water, its potential might be exclusively be produced in the mountain areas and groundwater resources lain on the plain areas. However, in actual developmental stages, they are not all utilized simultaneously. Since they scramble for each resource, the developing potential should be evaluated based on the practical plan for the respective project plan.

(3) Estimation of Monthly Discharge

The monthly outflow was calculated for 30 years from 1975 to 2004 for major wadis as shown in Figure 4-2. In the figure, 'bottom-upper' in arranging graphs is respond to 'north-south' and the 'left-right' is similar to 'the west (Red Sea side)-east (inland side)' in basin's spatial configuration in the project area.

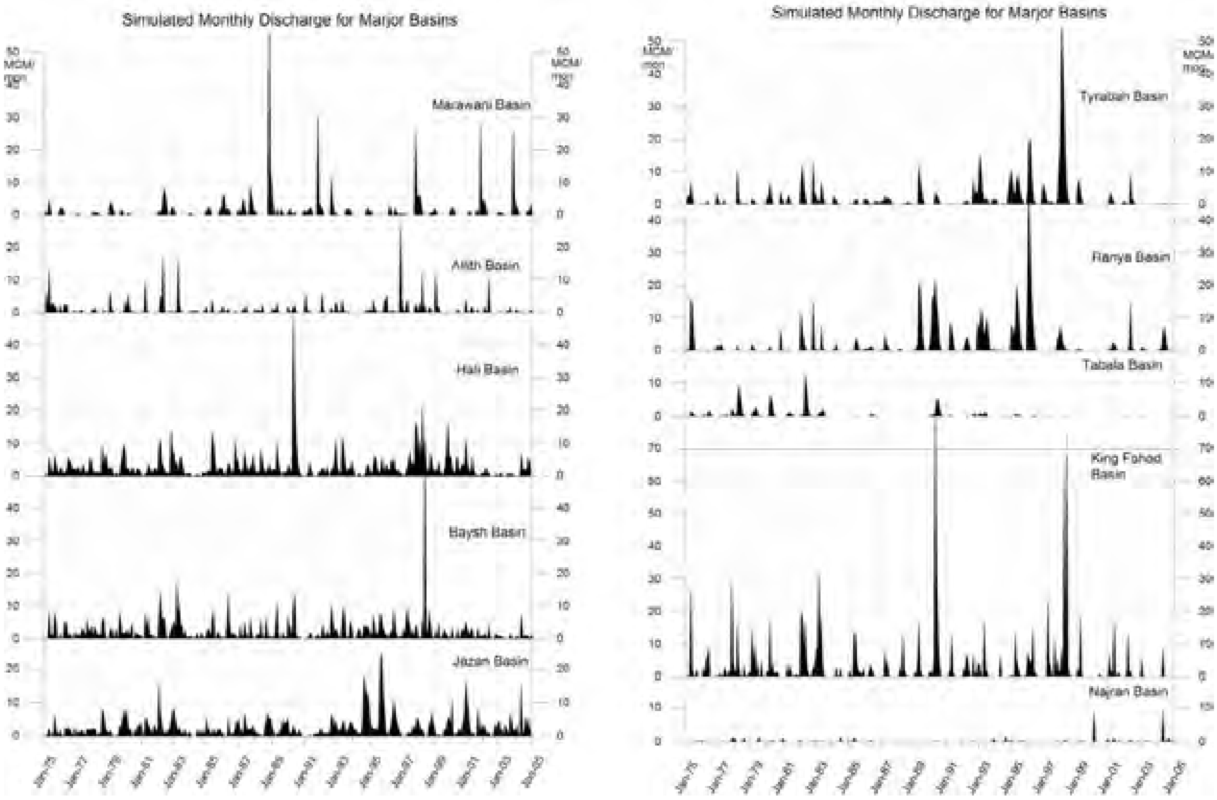
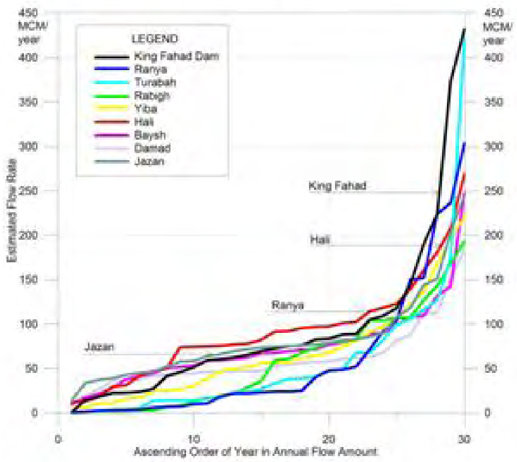


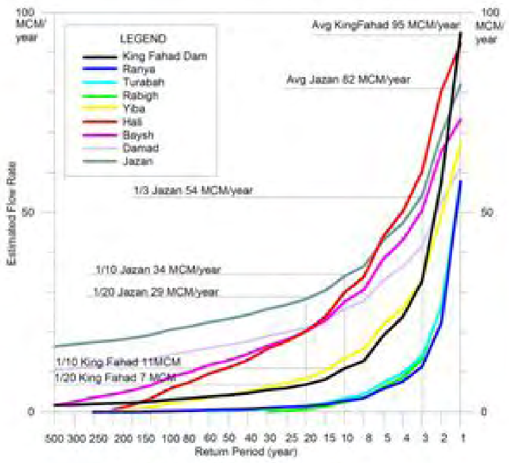
Figure 4-2 Monthly Discharge of Major Wadis

Moreover, the monthly discharge was obtained for each year, and non-exceedance probability was calculated by Iwai method for 30 years as shown in Figure 4-3. When 1/10 probability (draught year) is designated from the figure, 34 MCM (an average of 82 MCM) was taken at Jazan Dam while 11MCM (an average of 95 MCM) was obtained at King Fahd Dam.

Probability	Jazan	Damad	Baysh	Hali	Yiba	Rabigh	Turabah	Ranya	kingFahad
Average in 30yrs	82	61	73	92	67	57	56	58	95
1/2	69.4	52.8	65.2	80.4	49.1	26.4	26.1	22.2	57.4
1/3	54.1	41.5	50.3	60	32.9	13.1	14	11.3	32.6
1/4	47.2	36.3	42.9	50.1	25.9	8.6	9.7	7.6	23.7
1/5	43	33	38.3	44	21.9	6.3	7.4	5.8	19.1
1/8	36.5	27.8	30.6	33.8	15.7	3.4	4.4	3.5	12.8
1/10	34	25.8	27.6	29.9	13.5	2.5	3.5	2.8	10.9
1/15	30.4	22.9	22.9	23.8	10.3	1.3	2.2	1.9	8.2
1/20	28.3	21.1	20.1	20.2	8.4	0.7	1.6	1.4	6.9
1/25	26.9	19.9	18.1	17.7	7.2	0.3	1.2	1.2	6
1/30	25.8	19	16.6	15.8	6.3	0.1	0.9	1	5.5
1/40	24.3	17.7	14.5	13	5.1		0.5	0.7	4.7
1/50	23.3	16.8	12.9	11.1	4.3		0.3	0.6	4.2
1/60	22.5	16.1	11.8	9.6	3.7		0.1	0.5	3.9
1/80	21.4	15.1	10	7.5	2.8			0.3	3.4
1/100	20.6	14.4	8.8	5.9	2.2			0.2	3.1
1/150	19.3	13.2	6.7	3.4	1.2			0.1	2.6
1/200	18.5	12.5	5.4	1.7	0.6			0	2.3
1/250	17.9	12	4.4	0.5	0.2			0	2.2
1/300	17.5	11.5	3.6					0	2
1/400	16.9	10.9	2.5						1.8
1/500	16.4	10.5	1.7						1.7



River Flow Rate in Asceding Order



River Flow Rate - Return Period

Title: Probability Analysis for Estimated River Flow Rate (for major wadis)		
LEGEND King Fahad Dam Ranya Turabah Rabigh Yiba Hali Baysh Damad Jazan	Date	Oct 2009
	Drawn by	JICA REWARD
	Data Source	MOWE, REWAED
	Period Analysis	1975-2004
	The Study on Master Plan on Renewable Water Resources Development in the Southwest Region in the Kingdom of Saudi Arabia	

Figure 4-3 Non-Exceedance Probability of Discharge in Major Wadis

(4) Water Balance in Region

Moreover, the schematic diagram of IN/OUT of surface/groundwater resources are delineated in Figure 4-4. In the diagram, the inner side of bundling with 'light green' indicates the water balance of mountain area and the outside with 'yellow' shows that of whole project area.

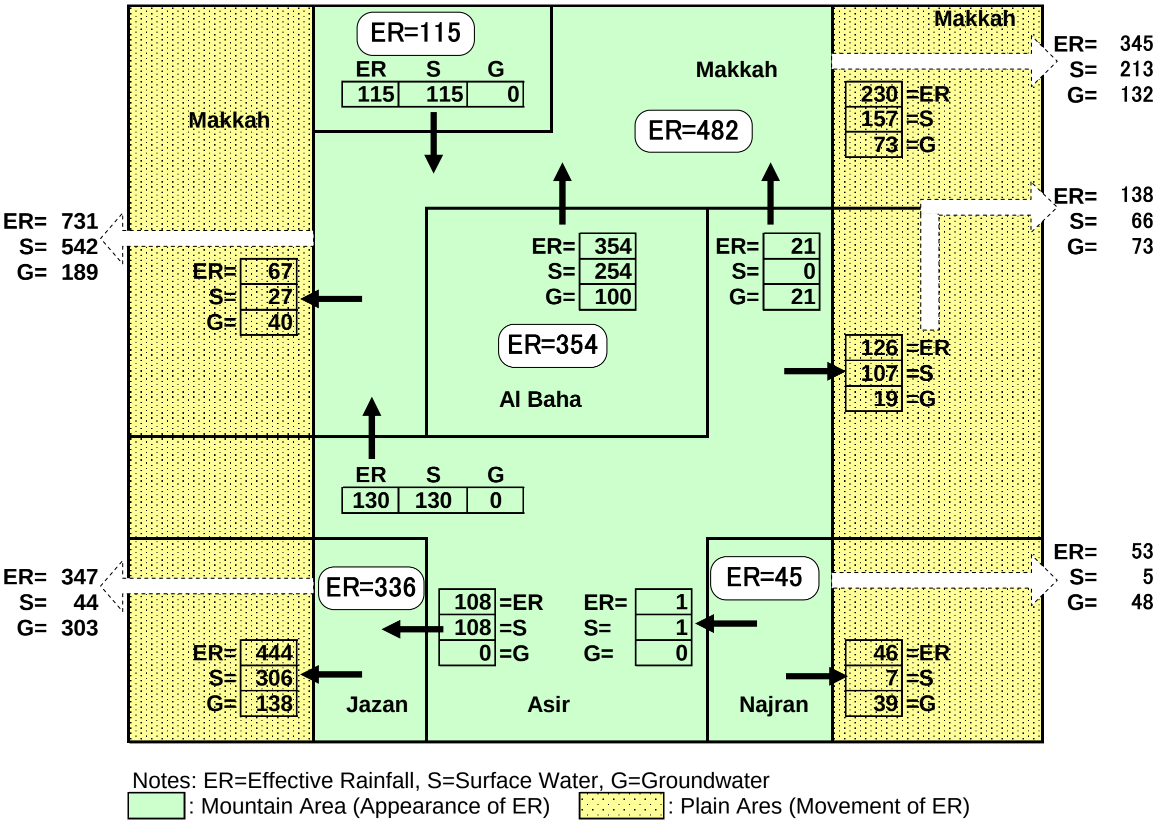


Figure 4-4 Schematic Diagram of Water Balance in Region

4.4 Storage of Shallow Aquifer

The distribution of shallow aquifers, which behaves as a storage basin for the replenishment resource, were reviewed and their capacity was estimated. The replenishment water resource, calculated as 744MCM of recharge amount, was evaluated through a comparison between available storage capacity and rechargeable water amount.

The storage capacity of the shallow aquifer was obtained as 125 BCM with 50 meters (of marginal depth), and corresponds to 150 times of the annual amount of groundwater recharge (0.8BCM, refer to Table 4-2). In Figure 4-5, the extent (wadi deposit: blue, alluvium: yellowish green, diluvium: green, and a basalt + brown) of the shallow aquifer and their groundwater recharge (only vertical recharge) are shown.

Table 4-2 Storage Capacity of Shallow Aquifer

BASIN		RECHARGE (MCM/Year)			AQUIFER STORAGE FOR TYPES (MCM up to the depth of 50m)							
No.	Basins	① Apparent GW Recharge in Basin	② ET	③ GW Runoff (①-②) Recharge (MCM/Year)	Wadi Beds	Alluvial Plain	Coastal Plain	Sand Sheets and Dunes	Pleistocene Deposit	Volcanics	Total Aquifer Capacity	Ratio: Storage Capacity / A.GW Recharge
1	KHULAB	46	0	46	38	1,160	442	0	48	0	1,688	37
2	JAZAN DAMAD	150	-0	150	29	2,320	87	0	0	83	2,518	17
3	BAYSH	90	7	84	86	3,447	87	0	451	5	4,076	45
4	ITWAD	50	26	24	38	1,514	351	0	0	0	1,903	38
5	HALI	35	24	11	95	2,449	100	0	1,402	203	4,248	122
6	YIBA	21	0	21	190	1,869	37	0	354	28	2,478	118
7	YIBA N	20	-0	20	238	1,514	0	282	209	0	2,243	111
8	DAWQAH S	13	0	13	190	387	25	78	0	0	680	54
9	DAWQAH	7	1	6	238	1,224	62	889	0	0	2,414	360
10	DAWQAH N	5	15	-10	219	1,643	112	302	0	0	2,276	484
11	FAGH	8	29	-21	29	1,160	149	0	145	0	1,483	185
12	SAADIAH L	33	24	9	86	290	117	0	0	0	493	15
13	NAAMAN	12	30	-18	0	1,095	286	0	0	0	1,382	120
14	FATIMAH	18	0	18	447	3,673	75	0	773	14	4,982	272
15	GHORAN	26	-0	26	152	2,835	125	0	242	1,281	4,634	178
16	GHORAN N	7	0	7	152	1,289	40	0	983	774	3,237	469
17	LHULAYS	43	0	43	57	644	52	0	918	2,759	4,431	103
18	QUDAYD	8	0	8	76	1,385	40	0	338	806	2,646	315
19	RABIGH	52	0	52	124	1,611	411	129	435	4,371	7,081	137
20	QANUNAH	4	0	4	38	741	53	0	451	83	1,366	360
21	AQIQ	30	0	30	656	34,287	0	2,057	628	2,847	40,475	1,331
22	TURABAH	48	0	48	618	709	0	0	0	2,745	4,072	85
23	RANYA	58	4	54	86	1,772	0	0	0	2,054	3,912	68
24	BISHA	118	54	64	770	967	0	79	564	60	2,440	21
25	TATHLITH	2	-6	8	923	1,740	0	0	451	825	3,938	1,641
26	HABAWNAH	7	-4	11	400	1,768	0	64	467	0	2,699	391
27	NAJRAN	22	-3	25	276	1,247	0	64	226	0	1,812	82
28	MAYAYN	4	0	4	105	3,550	0	738	129	0	4,522	1,190
29	HYNAH	44	0	4	76	1,964	0	0	0	0	2,040	474
30	HABAL	3	-0	3	105	1,423	0	219	773	0	2,521	813
Total		943	199	744	6,535	81,678	2,651	4,900	9,988	18,937	124,689	132

①Apparent GW Recharge is a value of including direct recharge of rainfall, recharge from surface runoff and groundwater inflow. It does not include the value of evepo-transpiaration from Basin.
②ET is a value of evepo-transpiaration from Basin.
③GW Runoff is a specific recharging value, which reducts ①ET from ②Apparent GW Recharge and refers groundwater runoff from basin.

Figure 4-5 Distribution of Shallow Aquifer and Groundwater Recharge

4.5 Available Water Resources Potential

Conventional (renewable) water resources comprising surface water and groundwater were estimated based on the hydrological water balance calculation applying the SWAT Model. For surface water, taking into consideration the safety of water use, the minimum yearly discharge was put in order for 30 years, and third (3) year (the degree of safe, 3rd/30years=1st/10years) was adopted from the minimum. While, the average discharge for 30 years was adopted for groundwater.

CHAPTER 5 WATER STRATEGY, POLICY, AND ACTION PLAN

The policy and strategy about water development management of the KSA were proposed by the World Bank (WB) as a National Water Strategy (June, 2009) based on description of a National Five Year Development Plan (8th) and the Long Term Strategy 2025. In this study, examination of the basic strategy and policy of the water about water resources development and management of five regions in the southwest area, and an action plan is prepared by considering these as a higher rank plan.

In addition, about an agricultural development plan, rational use of water for agricultural use is aimed at on the basis of Decision335 of MOA.

The examination items in this chapter are as follows.

- ◆Current condition and issues of water sectors
- ◆Balance of water demand and supply by each region
- ◆Basic policy of water resources development, utilization, and management
- ◆Water policy, strategy and action plan of five regions

5.1 Current Condition and Issues of Water Sectors

5.1.1 Current Condition of Water Use

The situation for the water supplies of the whole 5 regions (2007) which the Study Team arranged based on the data of MOWE and SWCC and interview with them is as in Table 5-1.

Table 5-1 Water Use Situation by the Water Resources and Water Sectors (MCM)

Region	Water Resource	Domestic Water (MCM) & (%)	Industrial Water (MCM) & (%)	Agricultural Water (MCM) & (%)	Total (MCM) & (%)
Makkah	Total	**388.8 (32.5%)**	**37.9 (3.2%)**	**768.2 (64.3%)**	**1,194.9 (100.0%)**
	(1) Renewable water	18.1 (2.3%)	4.2 (0.5%)	751.0 (97.1%)	773.3 (64.7%)
	- Surface water	0.0	0.0	0.0	0.0
	- Groundwater	18.1	4.2	751.0	773.3
	(2) Non-conventional Water	**370.7** (87.9%)	**33.7** (8.0%)	**17.2** (4.1%)	**421.6** (35.3%)
	- Desalinated seawater	370.7	0.0	0.0	370.7
	- Reclaimed waste water	0.0	33.7	17.2	50.9
Al Baha	Total	**14.1** (20.7%)	**0.0** (0.0%)	**54.0** (79.3%)	**68.1** (100.0%)
	(1) Renewable water	**14.1** (20.7%)	**0.0** (0.0%)	**54.0** (79.3)	**68.1** (100.0%)
	- Surface water	4.4	0.0	0.0	4.4
	- Groundwater	9.7	0.0	54.0	63.7
	(2) Non-conventional Water	**0.0** (0.0%)	**0.0** (0.0%)	**0.0** (0.0%)	**0.0** (0.0%)
	- Desalinated seawater	0.0	0.0	0.0	0.0
	- Reclaimed waste water	0.0	0.0	0.0	0.0
Asir	Total	**56.5** (16.5%)	**2.3** (0.7%)	**283.3** (82.8%)	**342.1** (100.0%)
	(1) Renewable water	**17.0** (6.0%)	**2.3** (0.8%)	**265.0** (93.2%)	**284.3** (83.1%)
	- Surface water	3.7	0.0	0.0	3.7
	- Groundwater	13.3	2.3	265.0	280.6
	(2) Non-conventional Water	**39.5** (68.3%)	**0.0** (0.0%)	**18.3** (31.7%)	**57.8** (16.9%)
	- Desalinated seawater	39.5	0.0	0.0	39.5
	- Reclaimed waste water	0.0	0.0	18.3	18.3
Jazan	Total	**15.6** (1.0%)	**0.0** (0.0%)	**1,527.0** (99.0%)	**1,542.6** (100.0%)
	(1) Renewable water	15.6 (1.0%)	0.0 (0.0%)	1,527.0 (99.0%)	1,542.6 (100.0%)
	- Surface water	0.0	0.0	25.0	25.0
	- Groundwater	15.0	0.0	1,502.0	1,517.0
	(2) Non-conventional Water	**0.6** (100.0%)	**0.0** (0.0%)	**0.0** (0.0%)	**0.6** (0.0%)
	- Desalinated seawater	0.6	0.0	0.0	0.6
	- Reclaimed waste water	0.0	0.0	0.0	0.0
Najran	Total	**11.8** (5.2%)	**0.0** (0.0%)	**217.0** (94.8%)	**228.8** (100.0%)
	(1) Renewable water	**11.8** (5.2%)	**0.0** (0.0%)	**217.0** (94.8%)	**228.8** (100.0%)
	- Surface water	0.0	0.0	0.0	0.0
	- Groundwater	11.8	0.0	217.0	228.8
	(2) Non-conventional Water	**0.0** (0.0%)	**0.0** (0.0%)	**0.0** (0.0%)	**0.0** (0.0%)
	- Desalinated seawater	0.0	0.0	0.0	0.0
	- Reclaimed waste water	0.0	0.0	0.0	0.0

[Source]Actual use for municipal & industrial water: Annual Report 2007, MOWE Agricultural water estimated by the Study Team

5.1.2 Water Sectors Issues

It arranged at the following table on the basis of Table 5-1 for the purpose of grasp of the subject of the situation for the water use of a water sector.

Table 5-2 Current Water Use in Water Sectors of Five Regions

Items	Makkah	Al-Baha	Asir	Jazan	Najran
[Domestic Water]					
• Total volume of domestic water use	389 MCM/Y	14 MCM/Y	57 MCM/Y	16 MCM/Y	12 MCM/Y
• Coverage of public potable water networks	High (96%)	Low (47%)	Low (43%)	Low (64%)	Middle (79%)
• Estimated water supply amount (LCD: Litter per capita per day)	Middle 183 LCD	Middle 149 LCD	Middle 192 LCD	Low 55 LCD	Low 93 LCD
• Percentage of desalinated seawater	High (88%)	Low (0%)	Middle (57%)	Low (4%)	Low (0%)
• Large scale seasonal change in water demand	Yes (Haji Pilgrim)	Yes (Jun-Aug)	Yes (Jun-Aug)	No	No
[Industrial Water]					
• Total volume of industrial water	38 MCM/Y	0	2 MCM	0	0
• Percentage of reuse of reclaimed waste water	Middle (59.8%)	-	Low (0%)	-	-
[Agricultural Water]					
• Total volume of agricultural water	768 MCM/Y	54 MCM/Y	283 MCM/Y	1,527 MCM/Y	229 MCM/Y
• Ratio of agricultural water in total water use	Middle (64%)	High (79%)	High (83%)	High (99%)	High (95%)
• Percentage of reuse of reclaimed waste water	Low (2%)	-	Low (6%)	-	-
• Introduction of updated facilities	Low < 50%	Low < 50%	Low < 50%	Low < 50%	Low < 50%
• Lowering of groundwater level & deterioration of water quality in agricultural wells	Yes Middle	Yes Low	Yes Low	Yes High	Yes Low
• Development of agricultural wells without proper license	Yes	Yes	Yes	Yes	Yes
• Monitoring of yield and level on agricultural water	No	No	No	No	No

From the above clarification, common issues in each region are summarized as follows:

- Coverage of Public Potable Water Network is low in Al Baha region, Asir region and Jazan region.
- Water supply amount, which is called LCD, in Al Baha region, Jazan region and Najran region is less than value used in planning for a small village whose population is not more than five thousand. These regions are classified as no desalinated seawater supplying area or small supplying are.
- There is a possibility of large scale seasonal change of water use in Makkah region, Al Baha region and Asir region.
- Total volume of industrial water use is rather small except Makkah region.
- Percentage of reuse of reclaimed waste water in Makkah region is rather high comparing to other regions. Other four regions use no or a little amount of it.
- Agricultural water is said to account for high ratio to the total water use. Actual water use for agriculture is not monitored and there are developments of agricultural wells without proper license.
- Because agriculture uses a lot of amount of water, there is a possibility to produce large amount of water by water saving. Level of introduction of modern irrigation facilities is low.
- Percentage of reuse of reclaimed waste water in agriculture is very low.

Moreover, about the issues on water in the region, it has grasped through a stakeholder meeting. If the issues which each region holds are arranged for every state, it will become as follows.

Table 5-3 Issues in each Region which Extracted from Stakeholder Meeting

Items		Makkah	Al Baha	Asir	Jazan	Najran
Water Resources	(1) Municipal water deficit	✓	✓	✓	✓	✓
	(2) Agricultural water deficit	✓		✓	✓	✓
Impact on Water Resources Environment	(1) Contamination and deterioration of water quality	✓	✓	✓	✓	✓
	(2) Groundwater drawdown	✓	✓	✓	✓	✓
	(3) Salinity due to overuse in agriculture	✓		✓	✓	✓
	(4) Issues on usage of reclaimed waste water	✓	✓		✓	✓
Water Resources Management	(1) Excavation of wells without approval		✓	✓	✓	
	(2) High leakage ratio, great loss in water conveyance	✓		✓	✓	✓
	(3) Prevalence of new irrigation method		✓			✓
	(4) Issues about management of dam/reservoir		✓	✓	✓	

From the above clarification, common issues in each region are summarized as follows:

- In water resources volume, there is concern for quantitative deficit to respond to demand.
- In water resources environmental aspect, significant groundwater drawdown and quality deterioration are seen.
- Reclaimed waste water is not reused enough for agriculture and industry.
- Excavation of wells is implemented without approval.
- In municipal water, network leakage ratio is high; in agricultural water, loss in conveyance water is great.
- In agricultural water, modern irrigation method is not spread.
- Dams are faced with problems such as sedimentation of reservoir and water quality deterioration.

5.2 Balance of Water Demand and Supply according to Region

5.2.1 Municipal Water

The amount of water development which is needed for a planned target year is examined based on the present supply capacity and demand in 2035 which is present supply capacity.

The present supply volume of water is assumed as the present supply capacity. Present supply volume is estimated by data and interviews in each region. Renewable water resources and desalinated seawater are included in the volume. Moreover, the municipal water demand in 2035 (from Table 3-5 to Table 3-9) presumed by 3.1.5 Chapter 3 was made into the target demand of a planned target year.

Here, development amount of water required by a planned target year was presumed first. It was assumed that the difference of the municipal water demand of a planned target year and the present supply capacity corresponded to it.

Next, the outline of water resources allocation to meet the necessary amount of water development was presumed. As a water resource, renewable water resources are allocated first. The quantity of renewable water resources which can be developed is the amount of water presumed from the water-resources potential analyzed in Chapter 4. And it was assumed that the insufficient quantity to required development amount of water was supplied with desalinated seawater. It is because the renewable water resources of development water value are cheaper than desalinated seawater, and desalinated seawater can secure required amount of water by extension and establishment of production plant although the quantity which can be developed is restrained on natural conditions as for renewable water resources.

In addition, the use classification of water resources classification shall be as follows.

Type of Water Resource	Water Resources		Purpose
• Non-conventional Water Resource :	Desalinated Seawater	→	Domestic, Institutional and Commercial Water
• Conventional Water Resource :	Renewable Water	→	Domestic, Institutional and Commercial Water
• Non-conventional Water Resource :	Reclaimed Waste Water	→	Landscaping and Industrial Water

Industrial water and landscaping water are included in the municipal water demand in a planned target year. Here, water quantity deducted landscaping water and 30% of industrial water from the municipal water demand in 2035 was made into the target value of a demand in the planned target year.

(1) Estimation of the Available Amount of Renewable Water

Calculation of the Available Amount of Water

Based on the water-resources potential (the numerical value of Effective Rainfall of Mountain according to wadi valley shown all over Figure B.4-11, unit MCM/year) calculated in Chapter 4, a dam site is assumed and the amount of inflow in a dam site (surface water and groundwater) is computed. This value is used as a maximum available renewable water (1).

Assumption for Calculating Available Amount of Water at Dam Site

70% of a maximum available renewable water (1) is assumed as a yearly stable available amount of water. Because about 70% of the amount of inflow can be estimated to be used stably available every year by analyzing monthly inflow data at dam site such as the Aqiq and the Baysh etc.

Water Allocation between Municipal Water Users and Vested Water Users at Downstream

Although there are vested water users downstream of dam site, the actual water use conditions are not clarified yet. The study team, considering such water users after dam construction, 30% of (2) was allocated as a quantity ((3)) to municipal water which can be used as an assumption value in the municipal water plan. The remaining 70% shall be discharged to downstream, and shall be recharged to a groundwater aquifer.

(2) Municipal Water Demand in the Planned Target Year and Available Renewable Water Resources Development

Table 5-4 shows the estimation of amount of water resources which should be developed by a planned target year. Present water supply capacity and demand in planned target year are summarized based on the above-mentioned view. The balance of Table 5-4 serve as a target value of the amount of water resources which should be developed by a planned target year.

Table 5-4 Water Supply Capacity which should be Developed for the Municipal Water Demand in 2035 (MCM/year,1000m^3/day)

Region	(1)Current Water Supply Capacity (MCM/Y)	(2)Future(2035) Water Demand (MCM/Y)	Balance (MCM/Y) (3)=(2)-(1)	Balance (1000 m^3/d)
Makkah	748	845	-97	-266
Al Baha	10	38	-28	-77
Asir	44	208	-164	-449
Jazan	53	148	-95	-260
Najran	24	62	-38	-104
[Total]	879	1,301	-422	-1,156

*) 30% x Industrial Water and 5% x Municipal Water are to be supplied by Reclaimed Waste Water.

<Makkah Region>

The quantity of the renewable water which can be developed and its allocation to municipal water in Makkah region are shown in Table 5-5. Presumption of the quantity of renewable water resources which can be developed was used based on renewable water-resources potential.

Table 5-5 Evaluation of Renewable Water Resources in Makkah Region

No.	Renewable water Resources Potential			Available Renewable Water Resources at Dam Site				
(1)	(2) Wadi Name	(3) Area (km^2) (Mt. Area)	(4) Potential (MCM/Y)	(5) Dam Name	(6) Area (km^2)	(7) Potential at Dam Site (MCM/Y) (4)*(6)/(3)	(8) Sustainably available water at Dam Site (MCM/Y) (7)*70%	(9) Allocation for Domestic Water (1000m3/d) (8)*30%
W-02	Rabigh	4,443	99	Rabigh	3,456	77	54	44
W-04	Khulago	4,390	100	Maruwani	2,762	63	44	36
W-09	Al Lith	2,641	40	Al Lith	1,838	28	19	16
W-10	Fagh	1,706	44	Qanunah	2,242	35	25	30
W-15	Yiba	2,812	81	Yiba		65	45	37
W-16	Hali	4,850	123	Hali	4,843	123	86	(35)+35
	<Total>		599			391		161

notes 1) The quantity which can be developed is assumed as 70% of water resources potentioal.
* The development amount of water by the dam which has already worked is summarized separately. Therefore, the upper table shows water to be developed by underconstruction/planning dam from now on.
* The column (9) is converting into the amount unit of daily supply (1000m^3/d) from the amount of yearly supply (MCM/Y) using column (8).
* Although the dam site of a Hali dam is the Makkah Region, a basin extends to the Asir Region. For this reason, in this table, it was assumed that a half of developed water is allocated to the Makkah Region. (35) is not appropriated for the sum total.

Future development quantity required to supply the municipal water in the planned target year of Makkah Region is an about 266,000m^3/day from Table 5-4. On the other hand, the renewable water resources which can be exploited in the Makkah Region are presumed to be a 161,000m^3/day from Table B.5-5. In the Makkah Region, shortage will arise to the demand of the municipal water of a planned target year only by development of renewable water resources.

<Al Baha Region>

The quantity of the renewable water which can be developed and its allocation to municipal water in Al Baha region are shown in Table 5-6.

Table 5-6 Evaluation of Renewable Water Resources in Al Baha Region

No.	Renewable water Resources Potential			Available Renewable Water Resources at Dam Site				
(1)	(2) Wadi Name	(3) Area (km^2) (Mt. Area)	(4) Potential (MCM/Y)	(5) Dam Name	(6) Area (km^2)	(7) Potential at Dam Site (MCM/Y) (4)*(6)/(3)	(8) Sustainably available water at Dam Site (MCM/Y) (7)*70%	(9) Allocation for Domestic Water (1000m3/d) (8)*30%
W-15	Yiba	2,812	81	Niala Qilwa	361 302	10 9	7 6	6 5
E-03	Ranya	3,503	80	Al Janabin	380	9	6	5
	<Total>		161					16

notes 1) The quantity which can be developed is assumed as 70% of water resources potentioal.
* The development amount of water by the dam which has already worked is summarized separately. Therefore, the upper table shows water to be developed by underconstruction/planning dam from now on.
* The column (9) is converting into the amount unit of daily supply (1000m^3/d) from the amount of yearly supply (MCM/Y) using column (8).

Future development quantity required to supply the municipal water in the planned target year of Al Baha Region is an about 77,000m^3/day from Table 5-4. On the other hand, the renewable water resources which can be exploited in the Al Baha Region are presumed to be a 16,000m^3/day from Table 5-6. In the Al Baha Region, shortage will arise to the demand of the municipal water of a planned target year only by development of renewable water resources.

<Asir Region>

The quantity of the renewable water which can be developed and its allocation to municipal water in Asir region are shown in Table 5-7.

Table 5-7 Evaluation of Renewable Water Resources in Asir Region

No.	Renewable water Resources Potential			Available Renewable Water Resources at Dam Site				
(1)	(2) Wadi Name	(3) Area (km^2) (Mt. Area)	(4) Potential (MCM/Y)	(5) Dam Name	(6) Area (km^2)	(7) Potential at Dam Site (MCM/Y) (4)*(6)/(3)	(8) Sustainably available water at Dam Site (MCM/Y) (7)*70%	(9) Allocation for Domestic Water (1000m3/d) (8)*30%
W-16	Hali	4,850	123	Hali	4,843	123	86	(35)+35
E-04	Bisha	10,777	111	Tabalah Hirjab	863 600	9 6	6 4	16 9
	<Total>		234					60

notes 1) The quantity which can be developed is assumed as 70% of water resources potentioal.
* The development amount of water by the dam which has already worked is summarized separately. Therefore, the upper table shows water to be developed by underconstruction/planning dam from now on.
* The column (9) is converting into the amount unit of daily supply (1000m^3/d) from the amount of yearly supply (MCM/Y) using column (8).
* Although the dam site of a Hali dam is the Makkah Region, a basin extends to the Asir Region. For this reason, in this table, it was assumed that a half of developed water is allocated to the Asir Region. (35) is not appropriated for the sum total.

Future development quantity required to supply the municipal water in the planned target year of Asir Region is about 449,000m^3/day from Table 5-4. On the other hand, the renewable water resources which can be exploited in the Asir Region are presumed to be a 60,000m^3/day from Table 5-7. In the Asir Region, shortage will arise to the demand of the municipal water of a planned target year only by development of renewable water resources.

<Jazan Region>

The quantity of the renewable water which can be developed and its allocation to municipal water in Jazan region are shown in Table 5-8.

Table 5-8 Evaluation of Renewable Water Resources in Jazan Region

No.	Renewable water Resources Potential			Available Renewable Water Resources at Dam Site				
(1)	(2) Wadi Name	(3) Area (km^2) (Mt. Area)	(4) Potential (MCM/Y)	(5) Dam Name	(6) Area (km^2)	(7) Potential at Dam Site (MCM/Y) (4)*(6)/(3)	(8) Sustainably available water at Dam Site (MCM/Y) (7)*70%	(9) Allocation for Domestic Water (1000m^3/d) (8)*30%
W-18	Baysh	4,767	105	Baysh	4,600	101	71	58
W-19	Damad	1,064	72	Damad Qissi	903	61	42	36 9
	<Total>		177					103

notes 1) The quantity which can be developed is assumed as 70% of water resources potentioal.
* The development amount of water by the dam which has already worked is summarized separately. Therefore, the upper table shows water to be developed by underconstruction/planning dam from now on.
* The column (9) is converting into the amount unit of daily supply (1000m^3/d) from the amount of yearly supply (MCM/Y) using column (8).

Future development quantity required to supply the municipal water in the planned target year of Jazan Region is about 260,000m^3/day from Table 5-4. On the other hand, the renewable water resources which can be exploited in the Jazan Region are presumed to be a 103,000m^3/day from Table 5-8. In the Jazan Region, shortage will arise to the demand of the municipal water of a planned target year only by development of renewable water resources.

<Najran Region>

The quantity of the renewable water which can be developed and its allocation to municipal water in Najran region are shown in Table 5-9. On the other hand, since the Najran region does not have a promising dam site, the amount of water by a new dam cannot be expected. In the Najran region, it is necessary to secure water resources required except renewable water resources.

The above result was summarized in Table 5-9. In order to supply the municipal water of a planned target year, by development of renewable water resources accounts for about 30% of the target. The water development by renewable water resource and water resources other than renewable water resources should be examined in the water resources development plan in the study area.

Table 5-9 Balance between Municipal Water Demand in 2035 and Water Supply(1000m^3/day)

Region	Demand	Supply	Balance	Note
Makkah	266	161	-105	
Al Baha	77	16	-61	
Asir	449	60	-389	
Jazan	260	103	-157	
Najran	104	0	-104	no water development by new dam construction
[Total]	1,156	340	-816	

5.2.2 Water for Agricultural Use

Since the withdrawal from wells for agriculture is not grasped, the present supply capacity of water for agricultural use is unknown. For this reason, about water for agricultural use, such examination as to water resources development done to municipal water can not be performed. For this reason, the supply possibility of water for agricultural use was examined by comparing the water resources which can be exploited and demand of water for agricultural use for a planned target year in a study area.

(1) Procedure of Examining Water Demand and Supply Balance

The following procedures perform examination of the demand-and-supply balance of water for agricultural use.

- ◆Water supply is renewable water resources, and is divided into surface water and groundwater. There are also the amount of water saving, the treated waste water reuse, and the return flow from irrigation water which are shown below as what is otherwise added to water resources.
- ◆Since the above is all the things considered as water resources, even if it uses these, when a water shortage occurs, it is necessary to take into consideration control of water for irrigation itself. Moreover, since it is water supply priority, a part for a water supply is first deducted from the renewable amount of water resources, and the remaining amounts of water resources examine the area which can be irrigated.
- ◆About a future agricultural development plan, rational use of water for agricultural use shall be aimed at on the basis of Decision335, and the planted area shall not be increased. However, from a viewpoint of reservation of a food self-sufficiency ratio, and small-scale farmhouse protection, cultivation of the vegetables centering on the city suburbs and a fruit tree is continued. The planted area of vegetables is considered as redoubling in 2007, and a fruit tree is considered as the maintenance of the status quo in 2007.

(2) Renewable Water Resources (Surface Water and Groundwater)

The water-resources potential according to governorate is calculated by a basin area ratio using the water-resources potential calculated according to the basin. The potential according to region which is basic data is shown.

Table 5-10 Surface Water and Groundwater Potential for Demand and Supply Plan (MCM/Year)

Item (Administration area km^2)	Makkah (144,292km^2)	Al Baha (12,033km^2)	Asir (71,426km^2)	Jazan (11,952km^2)	Najran (68,776km^2)	Total (308,478km^2)
Total Potential	782.1	99.4	380.5	322.9	401.1	1,985.9
Surface Water	216.8	23.3	146.0	247.8	68.9	702.8
Groundwater	565.3	76.1	234.5	75.1	332.2	1,283.1

Note 1: Using the discharge calculation result for 30 years by a SWAT model, about the amount of surface water, yearly discharge is put in order from the minimum to maximum for 30 years, and the third discharge is adopted for surface water (return period: 10years) and 30 year's average discharge is adopted for groundwater.
Note 2: The whole 5 regions; 308,478 Km^2

<u>Conversion of Crops</u>

Agricultural Development Plan shall be prepared based on the Decision 335. The planted area shall not be increased, although rational use of water for agricultural use is promoted. In addition, planting conversion should specialize in vegetables and fruit growing centering on the city suburbs from a viewpoint of reservation of food self-sufficiency, and small-scale farmhouse protection, and, as for vegetables, redoubling and a fruit tree shall maintain the quantity of production in 2007 to 2007. Therefore, a part for the fixture of vegetables to have increased is taken as a plan to decrease the planted area of cereals and fodders.

Amount of Water Saving

Though the irrigation method of a fruit tree and vegetables has main traditional method such as furrow irrigation, water can be saved by introducing modernistic irrigation systems, such as a sprinkler and a drip, in the future. Although the maintenance rate (the traditional irrigation method and the modernistic irrigation method) of present condition is assumed to be 50% by the result of hearing from the agriculture office and irrigation efficiency is made into 70% (= (55% +85%) *50%), future plan considers promoting the modern irrigation method and raising irrigation efficiency to 85%.

Reuse of Reclaimed Waste Water

In the KSA, National Irrigation Authority (NIA) built the large-scale irrigation institution which reused treated waste water in the suburb of Riyadh, and reuse of the treated waste water is performed from 1982. However, although the reuse of treated waste water is limited to the cereals crop, a fruit tree and a fodder crop part by the standard of a country and application to vegetables is not performed, it is necessary to aim at use expansion to the water for irrigation of reuse of treated waste water positively for effective use of water resources. Since ITAL CONSULT has established upon the development plan[1] in the whole KSA about the reuse plan of treated waste water in 2009, this report is referred to the study.

Use of Return Flow of Irrigation Water

Although parts for a net water requirement is absorbed by the plant among water for irrigation (gross water requirement), since it is thought that a part for an irrigation loss returns into the ground, and recharge the groundwater, this is counted to a head indirect as return flow. The net water requirement in the southwest area in 2007 is 1,675MCM, and the gross water requirement is 2,791MCM. Therefore, 40% (= (2,791-1675) /2791)) of gross water requirement can be reused to irrigation as return flow.

(3) The Agricultural Water Balance and the Planted Area for each Region

A demand and supply balance result when the renewable water is used according to the above-mentioned procedure in five regions is shown in Table 5-11. In a planned target year, balance will become plus in four regions except Jazan region. However, since water-resources potential, use of reclaimed waste water, and an agricultural area are unevenly distributed in a region, it is necessary to check them according to the /governorate classified by basin.

Table 5-11 Balance o f Demand and Supply of Agricultural Water for each Region

（Unit：MCM）

Region	Renewable Water Resource	Munici-pal Water Use	Avail-able for Agricul-tural Use	Agricul-tural Water Demand	Balance 1	Water Saving	Use of Re-claimed Waste-water	Return Flow	Balance 2
Makkah	782.0	108.2	673.8	750.5	-76.7	168.8	96.5	247.4	300.2
Al Baha	99.4	16.4	83.0	53.9	29.1	1.7	8.4	4.2	21.6
Asir	380.5	20.4	360.1	268.4	91.7	17.4	29.8	62.1	107.4
Jazan	322.9	106.9	216.0	1,501.9	-1,285.9	21.5	28.5	20.3	600.8
Najran	401.1	72.7	328.4	216.5	111.9	32.5	27.2	28.4	86.6
Total	1,985.9	324.6	1,661.3	2,791.2	-1,129.9	241.9	190.4	362.4	1,116.5

1: Income and outgo which deducted a municipal water and water for agricultural use from the renewable water resources
2: Balance which applied the amount of water saving, sewer reuse, and the amount of return flow to (1),

[1] Investigation and Engineering Design for Treated Waste Water Reuse in the Kingdom of Saudi Arabia

As mentioned above renewable water resources is summarized, it will become as follows, and planting in about 2007 can be secured in three regions except the Jazan and the Najran regions.

Table 5-12 Reduction Ratio of Planted Area of Five Regions, and Planted Area in 2035 (2007:100%)

Region	Planted Area 2007 (ha)	Planted Area 2035 (ha)	Ratio (2035/2007,%)
Makkah	42,077	39,293	93
Al Baha	4,450	4,425	99
Asir	21,054	20,759	99
Jazan	113,558	28,559	25
Najran	11,430	8,134	71

5.2.3 Reduction Measures Against Agricultural Water by each Region and Governorate

Although only the Jazan region is insufficient, it shall check further according to the governor rate of a state.

<Makkah Region>

When the maximum of the amount of supply is assumed as renewable water-resources potential, the planting possible area in the plan 2035 year is set to 39,293ha (decrease of 7% of an area ratio).

<Al Baha Region>

When the maximum of the amount of supply is assumed as renewable water-resources potential, the planting possible area in the plan 2035 year is set to 4,425ha (decrease of 1% of an area ratio).

<Asir Region>

When the maximum of the amount of supply is assumed as renewable water-resources potential, the planting possible area in the plan 2035 year is set to 20,759ha (decrease of 1% of an area ratio).

<Jazan Region>

When the maximum of the amount of supply is assumed as renewable water-resources potential, the planting possible area in the plan 2035 year is set to 28,539ha (decrease of 75% of an area ratio).

It seems very severe to keep present level of planted area from the point of view of availability of renewable water resources. However, it is important to carry out monitoring of groundwater and planted area, analyzing and grasping relations and managing proper planted area before decreasing planted areas in the Region.

As many conditions are assumed to analyze renewable water resources potential and to estimate amount of irrigation water which is calculated based on planning standard, it is important to monitor the situation and verify the assumptions.

Following governorates have large gaps between present planted area and projected future possible planted area in 2035. It is recommended to monitor and evaluate the result carefully in these governorates to grasp relations between planted area and groundwater.

Table 5-13 Present (2007) Planted Area in 2035

Governorate	Present Planted Area	Projected Planted Area in 2035	Ratio (2035/2007,%)
Sabya	22.785ha	6,348ha	28
Abu Arith	9,395 ha	2,292ha	25
Samtah	28,175ha	1,393ha.	5
Alharth	8,452ha	171ha	3
Damad	3,797ha	1,457ha	38
Arrayth	5,839ha	3,784ha	65
Ahad Almusarihah	22,540ha	2,561ha	11
Alaridah	4,290ha	2,465ha	57

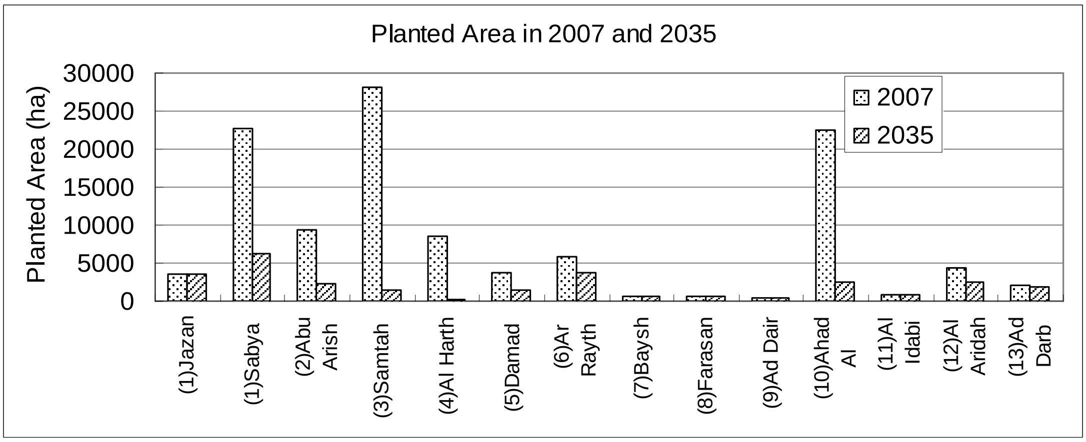


Figure 5-1 Planted Area Comparison in 2007 and 2035 in Jazan

<Najran Region>

When the maximum of the amount of supply is assumed as renewable water-resources potential, the planting possible area in the plan 2035 year is set to 28,134ha (decrease of 29% of an area ratio).

Although it is not as severe situation as the Jazan Region, if it sees from the availability of renewable water resources, it will be surmised that maintenance of the status quo of the planted area is very severe. However, before hurrying reduction in the planted area, monitoring of groundwater in a spot and a cropping situation is carried out, relation is grasped, and it is thought important to manage the scale of the planted area appropriately.

5.3 Basic Policy for Water Resources Development , Utilization and Management

5.3.1 Hydrology Handicap in the Dry Area and Actions for Securing Water

In examining the basic policy, action conditions required to utilize water resources and hydrology features are summarized.

Distinctive Hydrological Features of Five Regions

Regarding the renewable water resources development in the Study Area (The Area belongs to arid and semi-arid areas). Distinctive hydrological features (or Handicaps) are summarized as follows:

- ◆Scarcity of Renewable Water (Rainfall, Surface Water and Groundwater)
- ◆Annual and Seasonal Large Fluctuation of Rainfall and Renewable Water Resources
- ◆Large Potential Evaporation

Necessary Actions to Secure Necessary Water

To overcome the above Handicaps and to secure sufficient water for increasing demands, necessary actions should be taken. To suffice human need of water resources, three actions (Utilization, Administration, and Development) are taken based on three essential criteria (Sufficiency, Water Policy and Efficiency respectively) as below (see Figure 5-2).

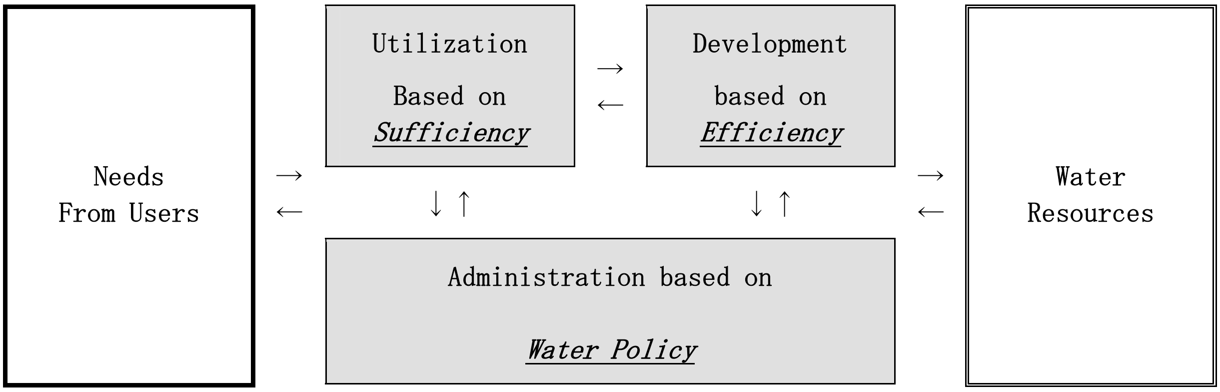


Figure 5-2 Three Criteria and Actions for Securing Water Resources

<Development>

In order to meet the future water shortage clarified in the water use plan, the act which performs water resources development is "development." Development should follow a water policy. In finalizing the water development plan, after examining the alternatives in consideration of various conditions, such as natural conditions of the water sentence characteristic, water resources, an institution and economical efficiency, and environment, it is necessary to determine the final plan.

In the study area, year change and the seasonal variation of rain and renewable water resources are large, and they become an obstacle of securing stability water use. To respond them, minimum amount of water required for maintenance of social economy is secured so that it can respond to them, and "water resources development which stresses on the stock" is taken to plan a dam with the larger storage-of-water capacity which stores a flood certainly, to use water for years and can absorb change is needed.

Variation of rainfall and renewable water resources from area to area and from basin to basin causes unstable of water use in the area. In order to perform the object for the water supplies of a fixed level as a whole to such local variation, for example, the different area and basins are connected with a pipeline, and "the mechanism in which water resources are accommodated" is needed.

It is one of the problems that the evaporation loss from the reservoir is very large in dry and semi dry area due to large potential evapotranspiration. To respond it, promotion of recharging groundwater and keep water as groundwater is thought to be advantageous. To do so, effective use of recharging facilities such as recharge dams and trenches to promote infiltration of water into aquifer is necessary to improve recharge efficiency. And surface water and groundwater should be developed and controlled as a one system. (refer to Main Report C. Chapter 2)

<Utilization>

However, in advance of development, you should decide upon the use plan beforehand.

The main irrigation persons in connection with a use plan are one waterworks (water for domestic use, water for public use, commercial city water), 2 water supply, and 3 irrigation.

If in charge of decision of an irrigation plan, based on the increase in an increase in population, a unit amount of consumption, a water supply rate, and industrial production, and future prediction of the index of irrigation area, it is necessary to fulfill irrigation persons' demand.

They need to inquire based on an irrigation person's completeness, these indices taking a water policy into consideration.

In order to aim at continuous exploitation of water resources in the scarce area concerned of water resources from water sentence conditions, you should mind the point of performing use which a maintainable quantity which is presumed from the potential of water resources, and which can be used, and balance were able to take.

For this reason, it is necessary to control use amount of water by demand management.

<Administration>

Management about use and development is performed according to a water policy. Water distribution to an irrigation person is determined based on a water policy. Moreover, it is decided also upon the preservation plan of water according to a water policy. In order for water resources to manage appropriately the water resources in the area where water receipt has been tight deficiently like an investigation area, it is important that the plan as a country is shown clearly.

Because, in order to manage precious water resources without futility effectively, fair and efficient distribution of water is very important, and adjustment between the complicated person concerned for it is needed. It is because the strong initiative and commitment of managing such water resources are required of a higher rank level in that case and the clear water policy which embodied it is needed.

5.3.2 Basic Policy of Water Resources Development, Utilization and Management

In order to arrange the view about future water development, use, and management as a water policy, the subject was arranged as follows from the examination so far about present conditions of water use, water demand and supply in the planned target year and development of renewable water resources.

Intentional Development and Utilization of Renewable Water Resources (Surface Water)

From examination of the analysis result of use renewable water-resources potential, and the dam site for using it efficiently, it is presumed that about 30% of the municipal water supply by renewable water resources is possible. However, allocation of developed water is not clarified in the plan of the dam project until now in many cases. In particular on the flood control dam, the utilization plan of the water resources stored by the flood is not defined. The development unit price of renewable water resources are cheaper than desalinated seawater and renewable water could be sustainable resource if it is managed properly. Therefore, it is important to perform development and use of these renewable water resources intentionally.

Monitoring of Renewable Water Resources (Groundwater)

The fall of the groundwater level and water quality degradation are reported in connection with the groundwater use. Such wells as MOWE uses as water resources for supplying municipal water are monitored amount of water, water quality, and a water level and controlled. However, with the agricultural sector which is the greatest user of groundwater, a use situation is not grasped but a possibility of being the cause of degradation of groundwater is pointed out. For this reason, it is necessary to perform management properly and to assure sustainable use. Therefore, while strengthening the recharge capability of groundwater, governing structures, such as monitoring of a pump discharge, need to be strengthened.

Combination of Renewable Water Resources and Desalinated Seawater in the Water Supply Plan

Although the renewable water resources are precious water resources to supply municipal water, it is difficult for only renewable water to deal with the increase demand of future municipal water. For this reason, it is necessary to examine rational water resources development plan by combining desalinated seawater and fossil groundwater with renewable water.

Effective Development and Use of Reclaimed Waste Water

Reclaimed waste water can be used as water resources supplied to some of water for agricultural use, tree planting city water, and industrial water. However, the coverage rate of a sewage system is low and, under the present circumstances, the capability of a processing institution does not enough, either. It is required to promote the spread of sewage networks, to install the processing institution for securing water quality required for use, and to use positively combining renewable water resources, desalinate seawater, etc.

Necessity of Demand Management

Available renewable water resources are restricted by natural conditions, and production of water by desalinization of seawater could be theoretically becomes huge, however, it cost much. For this reason, it is required for the sectors of domestic water, industrial water and agricultural water to put demand management into practice in exploitation of water resources, and to aim at curtailment of the amount of use. The agricultural water use sector which is the greatest user of renewable water resources needs to tackle curtailment of the amount used, such as raising use efficiency or converting into crops with little consumption amount of water.

Establishment of Effective Water Use System

A water development institution has a situation where the mechanism of it being managed independently or no effective managing system like groundwater for agriculture. The system such as legislation and organization is required for carrying out comprehensive water-resources management continuous and efficient exploitation of renewable water resources, water accommodation of water among agricultural use and municipal water use and inter-regional water use.

5.4 Water Policy, Strategy and Action Plan of Five Regions

5.4.1 Water Policy and Strategy of Five Regions

In consideration of current condition of water use and issues, gap between renewable water resources potential and water demand in planned target year, water policy which becomes common to five regions, and its strategy were adjusted as the following table. As a water policy, ten items were hung up in the following four classification.

- ◆Water Resources Development and utilization
- ◆Water Resources Conservation
- ◆Water Resources Management
- ◆Legislation for Water Resources Development, Utilization and Management

The strategy was shown below to each water policy.

Table 5-14 Water Policy and Strategy of Five Region

Items	Contents
	(1) Water Resources Development and Utilization
Policy：WP1	To Use Renewable Surface Water Effectively
Strategy	◆ To make effective use of surface water stored in reservoir together with groundwater and desalinated seawater ◆ To be given priority to domestic use of water ◆ To establish coordination body for rational allocation of surface water
Policy：WP2	To Use Renewable Groundwater Sustainably
Strategy	◆ To improve with balance between water resource development and resource conservation ◆ To develop groundwater efficiently by making use of recharge dam and underground dam ◆ To establish coordination body for rational allocation of groundwater
Policy：WP3	To Use Desalinated Seawater Properly
Strategy	◆ To make rational plan for using desalinated seawater as stable water resource to supplement renewable water ◆ To make plan for using desalinated seawater well balanced considering renewable water resources and reuse of reclaimed waste water
Policy：WP4	To Improve Reuse of Reclaimed Waste Water
Strategy	◆ To plan and construct sewerage and treatment plant to secure necessary water quality for reuse ◆ To be given priority to industrial and agricultural use so that load of renewable groundwater should be decreased ◆ To campaign for enlightenment for promoting reuse in agricultural use
	(2) Water Resources Conservation
Policy：WP5	To Conserve Groundwater
Strategy	◆ To observe and mange groundwater condition not to deplete groundwater level or degradation of water quality ◆ To strengthen monitoring system for groundwater conditions such as volume extracted and water level ◆ To strengthen inspection of registration system and its actual conditions of groundwater use

Items	Contents
Policy：WP6	To Conserve Water Quality (surface water and groundwater)
Strategy	◆ To strengthen monitoring system for reservoir conditions such as stored volume and water quality ◆ To strengthen monitoring system for groundwater condition such as water quality ◆ To strengthen inspection not to dump garbage, waste water etc. illegally
	(3) Water Use and Management
Policy：WP7	To Promote Effective Use of Municipal Water
Strategy	◆ To strengthen activities to decrease unaccounted for water ◆ To improve consciousness for water saving and strengthen action for water saving
Policy：WP8	To improve consciousness for water saving and strengthen action for water saving
Strategy	◆ To improve collecting used water in factories and its reuse ◆ To promote water saving activities in factories and to take priority over introducing more non-water-consumptive industry
Policy：WP9	To Improve Appropriate Agricultural Water Use
Strategy	◆ To improve irrigation efficiency by introducing modern irrigation facility and rehabilitation of old irrigation facilities ◆ To disseminate knowledge about efficient water use to farmers and strengthen actions for saving water ◆ To place sustainable water use as a restriction for agriculture
	(4) Legislations for Water Resources Development, Utilization and Management
Policy：WP10	To Prepare Legislative and Institutional Framework for Effective Water Resources Development and Management
Strategy	◆ To prepare legislative and institutional framework for: 1) Sustainable water resources development, 2) Effective water resources conservation, 3) Smooth and efficient water use and management

5.4.2 Action Plan - Water Resources Development

Action plan is proposed on the water policy and strategy of the following involved with water resources development.

◆Policy WP1：To Use Renewable Surface Water Effectively
◆Policy WP2：To Use Renewable Groundwater Sustainably
◆Policy WP3：To Use Desalinated Seawater properly

<Water Development by Dam>

MOWE have been constructing many dams and has some dams under construction now and a future dam plan. From investigation of the Study Team, it is judged ending with construction or that a promising large-scale storage dam is already under construction, and the new dam site is not left. In main enumeration, it was aimed at the large-scale storage dam of the following presumed that a possibility that water can be supplied stably is high by performing dam employment by the many years past storage as a main dam which develops renewable water resources. In the Najran Region since there is no planned dam site planned, development by a dam is not performed.

Table 5-15 Dams and Planed Water Supply of Water Resources Development Plan

Region	Name of Dam	Planned water supply (m^3day)
1) Makkah	Rabigh Maruwani Yiba	44,000 36,000 38,000
2) Al Baha	Nilah & Qilwah Al Janabin Hali (Makkah Region)	11,000 5,000 35,000
3) Asir	Baysh(Jazan Region) Ranya Hirjab Tabalah	25,000 68,000 9,000 16,000
4) Jazan	Baysh Qissi Damad	44,000 36,000 38,000

Note: water supply plan was set up by JICA based on the MOWE data.

<Principle of Allocation of Newly Developed Water Resources>

Principle of allocation of newly developed renewable water resources for domestic, industrial and agricultural water is as follows:

- ◆30% of Newly developed renewable water resources is assumed to allocate to municipal water and industrial water. The remaining 70% is assumed to allocate to a vested water users and agricultural water use downstream.
- ◆When municipal water demand is not satisfied by renewable water resources, allocate desalinated seawater or fossil groundwater (Najran Region and an eastern part of Asir Region) to the insufficiency.
- ◆It is assumed that reclaimed waste water is allocated to landscaping water, which is 5% of municipal water, and is allocated to 30% of industrial water as cooling water and temperature control water in the future factory. The remaining amount of water except this is supplied by renewable water resources, desalinated seawater and fossil groundwater. In addition, about use of the reclaimed waste water in industrial water, there will also be indefinite elements, such as reduction of freshwater makeup water, progress of institution maintenance of a factory, etc. accompanying improvement in the recycling rate in a factory, from now on, and the water development plan top sets 30% as the reuse target of reclaimed waste water as a safety side.
- ◆In order to maintain a social function also in unusual water shortage etc., allocate the desalinated seawater or fossil groundwater which is a stable water resources in 50% of municipal water in each state.
- ◆Allocate reclaimed waste water for agricultural use demand in the range which can be used for agricultural production.
- ◆Perform agriculture within renewable water-resources potentials by making amount of water except allocation to municipal water and industrial water into a maximum. Agricultural production shall not be performed more than it.

(1) Groundwater Development

Renewable groundwater which is the target of future large-scale development does not exist. Therefore, development and use of future renewable groundwater will increase the amount of use of groundwater by groundwater conservation (groundwater recharge).

Increase of the amount of groundwater recharge can be expectable with proper dam operation of not only existing recharge dam and irrigation dam but also flood control dam. Regarding fossil groundwater, the potential of the Wajid Aquifer which exists in the desert area of Najran region is identified by investigation of GTZ.

MOWE has been planning for a water conveyance from the Wajid aquifer to the Tathlith city and Bisha city of the northern part of Asir region and western part of Najran region (Najran city) by the following two pipelines. In the area where located far away from the desalinization-of-seawater facility, since transportation cost becomes large in order to supply water of seawater desalination, an economical burden increases in use of desalinization-of-seawater water.

(2) Construction of New Desalination Plant

As a large-scale of an established desalination plant, there are a Shuaiba plant near the Jeddah (Makkah region), and a Shuqaiq plant of Jazan region. Since capital of the region of the Al Baha Region and the Asir Region locate in a place-between-mountains place, a vertical drop with a desalination plant becomes large, and water supply cost becomes high. For reduction of water supply cost, it is necessary to shorten water supply distance from a desalination plant as much as possible.

Two new desalination plants shall be considered for Al Baha Region and Asir Region.

(3) Inter Regional Water Use for Assuring Water Resources

A time change (year change, seasonal variation) and a change regarding the place of rain are large in an arid region like an study area. For this reason, in response to the influence of such natural uncertainty, the quantity by renewable water resources, such as front running water or groundwater, which can be used is not necessarily stable. In order to exploit renewable water resources, it is necessary to improve the stability of water supply for stability of social life.

In order to improve the stability for water supplies, there are following methods.

- ◆Constructing dam and make time deviation of rain smooth by storing temporary. This effect is limited to the basin in which a dam is installed.
- ◆Connecting basins by pipelines and water is used inter-regionally. By this system deviation of water resources could be made smooth. For the purpose, the agreement for sharing water exceeding a basin system or an administration unit is needed.

For the purpose, the agreement for sharing water exceeding a basin system or an administration unit is needed. Since a main enumeration area has the deviation of renewable water resources also in time and locally as above-mentioned, it performs inter-regional water use by the pipeline (red seawater lifeline) who combined the method of these both for stable exploitation of renewable water resources.

(refer to Figure 5-3)

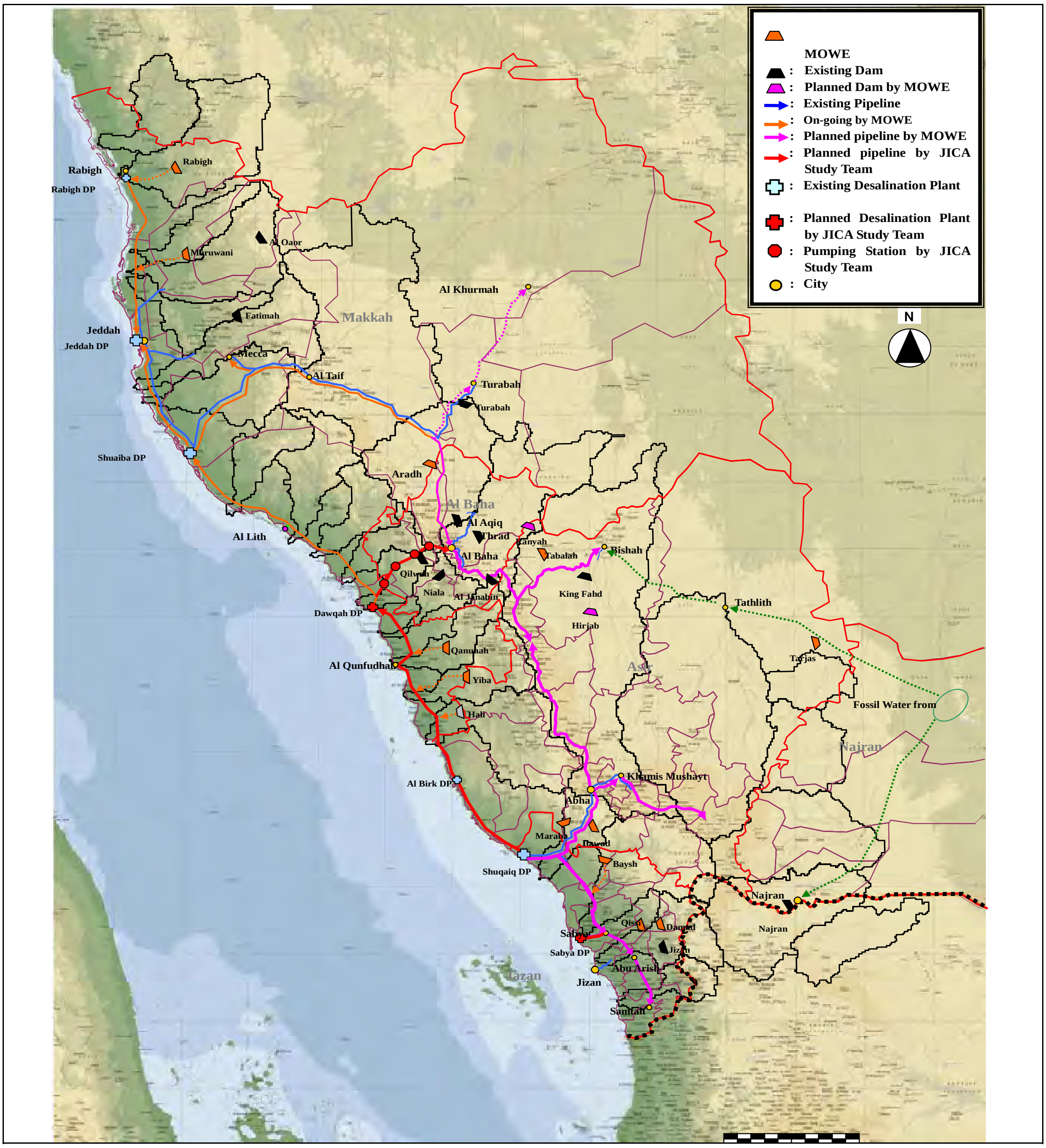


Figure 5-3 Key map of "Red Sea Water Lifeline" which Connected Facilities by Pipeline

(4) Comparison Examination of Red Sea Water Lifeline

<Comparison Cases>

Comparison of the three proposals shown in table 5-16 about a Red Sea Water Lifeline is carried out.

Alternative 1 (refer to Figure 5-4)

◆The feature of alternative 1 is that two new desalination plants, whose site is intentionally decided, are built to satisfy the future demand of municipal water.
◆Then the water supply cost to main demand area is reduced. The dams to develop renewable water resources are the same as other alternatives.
◆It is considered as the Red Sea Water Lifeline Plan which connects from Makkah region to Jazan region in the Red Sea side by a pipeline, and an exchange of broad-based water is enabled when water shortage occurs.

Alternative 2 (refer to Figure 5-5)

◆The feature of alternative 2 is that the existing major desalination plants are extended to satisfy the future demand of municipal water.
◆It is a proposal which agree with the present extension plan of desalination plants by MOWE and SWCC.
◆The dams to develop renewable water resources are the same as other alternatives.
◆It is considered as the Red Sea Water Lifeline Plan which connects from Makkah region to Jazan region in the Red Sea side by a pipeline, and an exchange of broad-based water is enabled when water shortage occurs.

Alternative 3 (refer to Figure 5-6)

◆The feature of alternative 3 is that the water utilization plan doesn't assume to exchange water among regions basically except water conveyance from Baysh dam in Jazan region to Asir region, which had already started.
◆The dams to develop renewable water resources are the same as other alternatives.
◆Two desalination plants shall be newly established like alternative 1 based on a policy of the plan that each region develop and use renewable and desalinated water independently as much as possible.
◆Moreover, it is considered as a plan not to connect between Ai Birk and Al Suffah based on a policy of the plan that each region develop and use renewable and desalinated water independently as much as possible.
◆Alternative 3 are assumed that the restrictions for the water supplies in each state are large at the time of water shortage because renewable water resources are not assumed to be shared flexibly among regions.
◆However, since the independency for the water use of each region is high, the time and effort to adjust among the states about the water use is reduced comparing to other two proposals.

<Evaluation of Comparison Cases>

An explanation Table for Alternative-1 to Alternative-3 is shown in Table 5-16.

Table 5-16 Explanation for Alternative(1) to Alternative(3)

Items	Alternative (1)	Alternative (2)	Alternative (3)
1.Water Resource (Renewable Water Resources)	1) Dams and wells under controlled by MOWE 2) Development of renewable water resources is performed preferentially.	1) Dams and wells under controlled by MOWE 2) Development of renewable water resources is performed preferentially.	1) Dams and wells under controlled by MOWE 2) Development of renewable water resources is performed preferentially.
2.Water Resource (Desalinated Seawater)	1) New desalination plants shall be proposed a) Dawqah plant for Al Baha Region b) Sabya plants for Jazan	1) The plan of SWCC is followed basically. 2)Major planned desalination plants including existing plants	1) New desalination plants shall be proposed a) Dawqah plant for Al Baha Region b) Sabya plants for Jazan

Items	Alternative (1)	Alternative (2)	Alternative (3)
	Region 2) Major planned desalination plants including existing plants are: a) Jeddah and Shuaiba desalination plants for Makkah Region b) Dawqah desalination plant for Al Baha Region c):Shuqaiq desalination plant for Asir Region d) Sabya desalination plant for Jazan Region.	to supply water to each region are: a) Jeddah and Shuaiba desalination plants for Makkah Region b) Shuaiba desalination plant for Al Baha Region c) Shuqaiq desalination plant for Asir Region d) Shuqaiq desalination plant for Jazan Region.	Region 2) Major planned desalination plants including existing plants are: a) Jeddah and Shuaiba desalination plants for Makkah Region b) Dawqah desalination plant for Al Baha Region c):Shuqaiq desalination plant for Asir Region d) Sabya desalination plant for Jazan Region.
3.Water Resource (Fossil Groundwater)	Fossil groundwater from the Wajid aquifer is supplied to the eastern part of the Asir Region	Fossil groundwater from the Wajid aquifer is supplied to the eastern part of the Asir Region	Fossil groundwater from the Wajid aquifer is supplied to the eastern part of the Asir Region
4.Water Use policy of Renewable Water Resources (Normal Conditions)	1) Water resources developed in the Region is used in the Region in which the dams were constructed 2) Water developed in Baysh dam and Hali dam is transferred and used beyond the boarder of the Region	1) Water resources developed in the Region is used in the Region in which the dams were constructed 2) Water developed in Baysh dam and Hali dam is transferred and used beyond the boarder of the Region	1) Water resources developed in the Region is used in the Region in which the dams were constructed 2) Water developed in Baysh dam is transferred and used beyond the boarder of the Region
5.Water Use policy of Renewable Water Resources (Drought Conditions)	1) Pipeline which connects between Al Birk and Al Suffah is planned 2) When water shortage is serious in Makkah Region or Al Baha, water is supplied from Jazan region or Asir Region through the pipeline, and vice versa. 3) Exchange of water is carried out according to the conditions of water shortage between Makkah Region and Al Baha Region, and between Asir Region and Jazan Region.	. 1) Pipeline which connects between Al Birk and Al Suffah is planned 2) When water shortage is serious in Makkah Region or Al Baha, water is supplied from Jazan region or Asir Region through the pipeline, and vice versa. 3) Exchange of water is carried out according to the conditions of water shortage between Makkah Region and Al Baha Region, and between Asir Region and Jazan Region.	Water shortage adjustment is fundamentally performed in each region.
5.Characteristics	1) Basic policy is water developed in each region is used its region. 2) Corresponding to the level of water shortage, a system which makes it possible to flexible water supply is planned to work. 3) Exchange of water begins between Makkah Region and Al Baha Region group and between Asir Region and Jazan Region group. 4) Diffusion of risks is attained by installing the main desalination plants 5) As the whole system, adaptability to the fluctuation of renewable water resources is higher than alternative (3).	1) A function of the system is as the same level as alternative (1). 2) Future demand is to be supplied by extension of existing Shuaiba desalination plant and Shuqaiq desalination plant. 3) Comparing to the alternative (1), the independency for each Region is not clear as to the desalinated seawater use. 4) As the whole system, adaptability to the fluctuation of renewable water resources is higher than alternative (3).	1) It becomes a system which performs independently for the water supplies of each region. 2) In case of drought or stoppage due to accident in the desalination plant, adjustment of water supply is to be carried out within each region. 3) The time and labor for adjusting the water use between regions become smallest among three alternatives.

As for the comparison on alternatives, unit price for development of renewable water, production price for desalinated seawater and conveyance price are used.

Since the location of dams are common to alternative 1 to alternative 3, the water supply system is considered to be almost the same and it is thought that the facilities cost is also equivalent.

Although the length for the water supply route shall be changed depending on the case of extension and new construction of the desalination plant, by shorting the water supply route, the conveyance cost becomes cheap, and the construction cost also becomes more advantageous.

Hence, excluding the comparison with construction cost, an economic advantage among the alternatives can be identified so that water unit price and conveyance price are adopted for the evaluation.

"The water unit price of m^3" used when comparing becomes as follows.

Table 5-17 Water Unit Price used in Evaluation of Red Sea Water Lifeline and Alternatives (Production, Development, Conveyance)

Water Resources	Place/Rout	Production/ Development Price(SR/ m^3)	Conveyance Price (SR/ m^3)	Total Unit Price (SR/ m^3)
Desalination Plant	1)Suaiba-Makkah	2.78	1.21	3.99
	2)Shuaiba-Al Baha	2.95	7.63	10.58
	3)Dawqah-Al Baha	2.78	3.28	6.06
	4)Shuqaiq-Abha	2.43	5.18	7.61
	5)Sabya-Jizan	2.84	0.60	3.44
Renewable Water	1)Qanunah-Makkah	0.31	5.79	6.10
	2)Yiba-Makkah	0.31	5.79	6.10
	3)Hali-Makkah	0.31	5.79	6.10
	4)Qanunah-Al Alayah	0.31	5.66	5.97
	5)Hali- Al Alayah	0.31	5.66	5.97

Source: Estimation by the Study Team and Material from MOWE, SWCC(annual report)

Table 5-18 Outline of Red Sea Lifeline and its Alternatives Comparison (Amount of Money Unit: MSR)

Evaluation Items		Alternative 1	Alternative 2	Alternative 3	Comprehensive Evaluation
Economy	**Desalination**	**1,319.9**	**1,484.9**	**1,444.7**	Although a difference is not looked at by alternatives in renewable water development, about the cost of freshening water, alternative-1 cost is small. Alternative-1 is synthetically excellent.
	1)Suaiba-Makkah (DS)	95.4	95.4	29.4	
	(P)	41.5	41.5	12.8	
	2)Shuaiba-Al Baha (DS)		107.7	12.8	
	(P)		278.5		
	3)Dawqah-Al Baha (DS)	101.5		101.5	
	(P)	119.7		119.7	
	4)Shuqaiq-Abha (DS)	221.7	221.7	291.8	
	(P)	472.7	472.7	622.0	
	5)Sabya-Jizan (DS)	220.8	220.8	220.8	
	(P)	46.6	46.6	46.6	
	Renewable	**226.3**	**226.3**	**229.4**	
	1)Qanunah-Makkah (DM)			3.4	
	(P)			63.4	
	2)Yiba-Makkah (DM)	4.3	4.3	4.3	
	(P)	80.3	80.3	80.3	
	3)Hali-Makkah (DM)			4.0	
	(P)			74.0	
	4)Qanunah-Al Alayah (DM)	3.4	3.4		
	(P)	62.0	62.0		
	5)Hali- Al alayah (DM)	4.0	4.0		
	(P)	72.3	72.3		
	Total	**1,546.2**	**1,711.2**	**1,674.0**	
	Index of Cost (%)	**(100)**	**(111)**	**(108)**	
Technical		There are few technical task.			There is no difference of alternatives with few technical subjects.
Control of maintenance and a management side		There is watering of renewable water resources between the Makkah Region and the Asir		There is no watering between states to be adjusted, and	Alternative-3 is predominance.

Evaluation Items		Alternative 1	Alternative 2	Alternative 3	Comprehensive Evaluation
		Region, there is no watering between states to be adjusted, and alternative-3 with few adjustment matters is predominance.		alternative-3 with few adjustment matters is predominance.	
Environmental impact		About a dam, it has the influence on water pollution about flow, groundwater, and a pipeline in the influence on an ecosystem, and a desalination plant. It is the comprehensive evaluation which the difference about an environmental side does not have.			It is the comprehensive evaluation which the difference about an environmental side does not have.
Comprehensive evaluation					In respect of control-of-maintenance management, alternative-1 is excellent in the economical efficiency of that whose alternative-3 is predominance.

Note) DS:Desalination Plant, P:Pipeline, DM:Dam

If explanation is added to above table, it will become as follows.

- ◆ Economical efficiency : in an economical comparison of an outline, it is the order of Alternative-1, Alternateive-3, and Alternative-2 from the smaller one of cost.
- ◆ Technical side : it is equivalent from building the institution of the same facilities, and a difference is not seen.
- ◆ Control of maintenance and a management side : about control of maintenance, in order to carry out so much to the institution of the same faciliites, it is judged that it is equivalent.
- ◆ Environmental impact side : about a dam, it has the influence on water pollution about flow case, groundwater, and a pipeline in the influence on an ecosystem, and a desalination plant. About "the influence of negative" in an environmental impact, it is possible to ease the influence on environment by enforcement of the layout planning, a detailed examination, and the various environmental relief measures of institutions.

Although a big difference is not seen to each proposal, finally economical efficiency is thought as important and "alternative-1" is adopted. The action plan of each following state shall be proposed based on this red seawater lifeline proposal (alternative-1).

About the economical predominancy of a red sea water lifeline proposal (alternative-1), comparison of the water supply cost of the desalinated seawater to the Al Baha Region which will be needed in the future also shows as follows.

- ◆The water unit price of about 10.58SR/m^3 and the seawater fresh water pile line of Dawqah-Al Baha of the water unit price (production cost + transportation cost) of the seawater fresh water pipeline of Shuaiba-Al Baha is 6.06SR/m^3.The 100 yen water unit price per m^3 becomes cheap. By using a cheap Dawqah-Al Baha line, at least desalinization-of-seawater moisture becomes an about 2,700 million yen reduction of incidence per year.
- ◆A Dawqah-Al Baha pipeline's purpose is to supply renewable water did not stop at supplying cheap desalinated seawater to Al Baha region, but was developed on the dam cheaper than desalinated seawater to Al Baha region, or Asir region. A Dawqah-Al Baha pipeline's purpose is to supply renewable water rich did not stop at supplying cheap desalinization water to Al Baha region, but was developed on the dam cheaper than desalinization water to Al Baha region, or Asir region again.

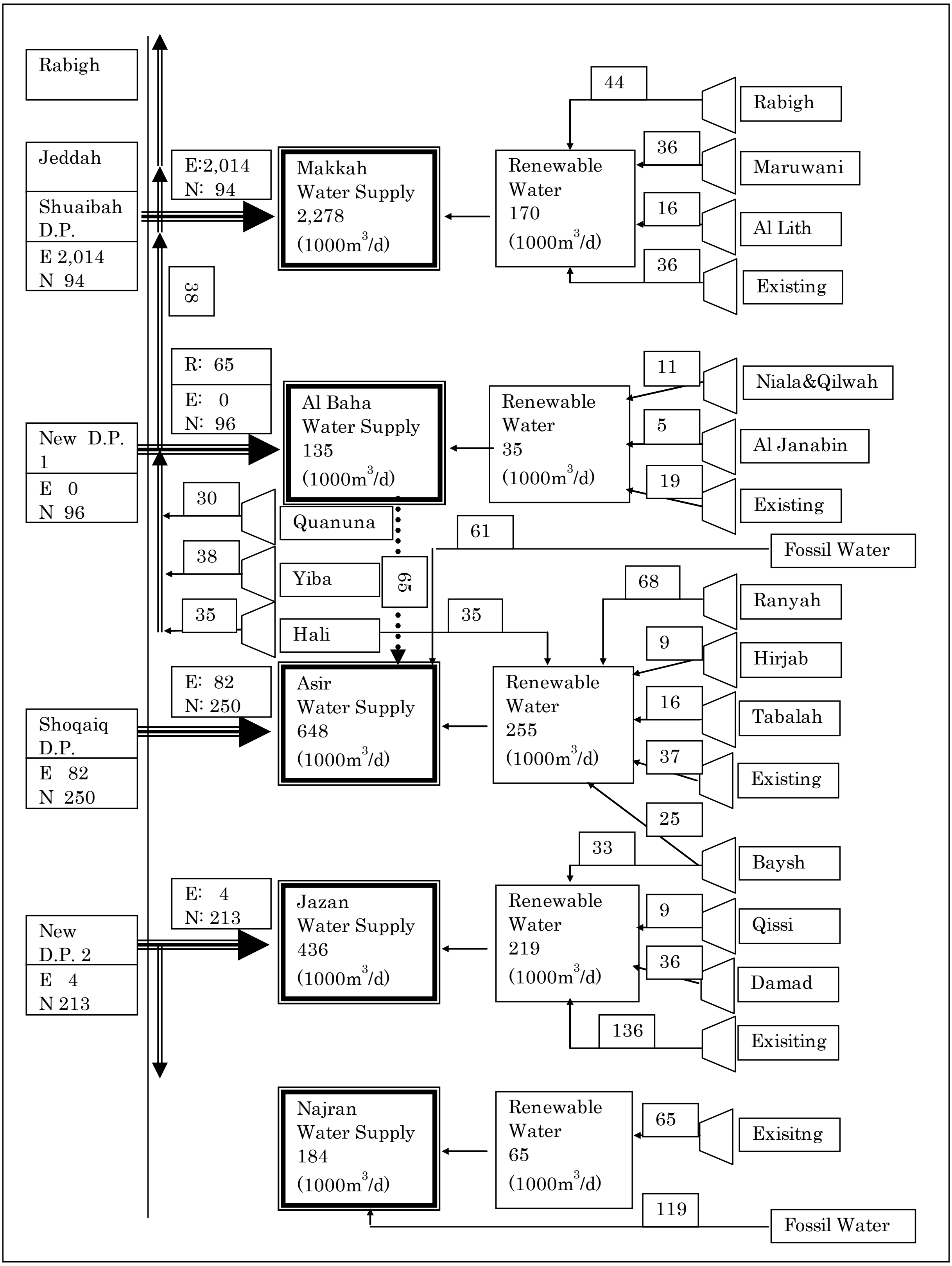


Figure 5-4 Water Supply by Facilities in Alternative-1

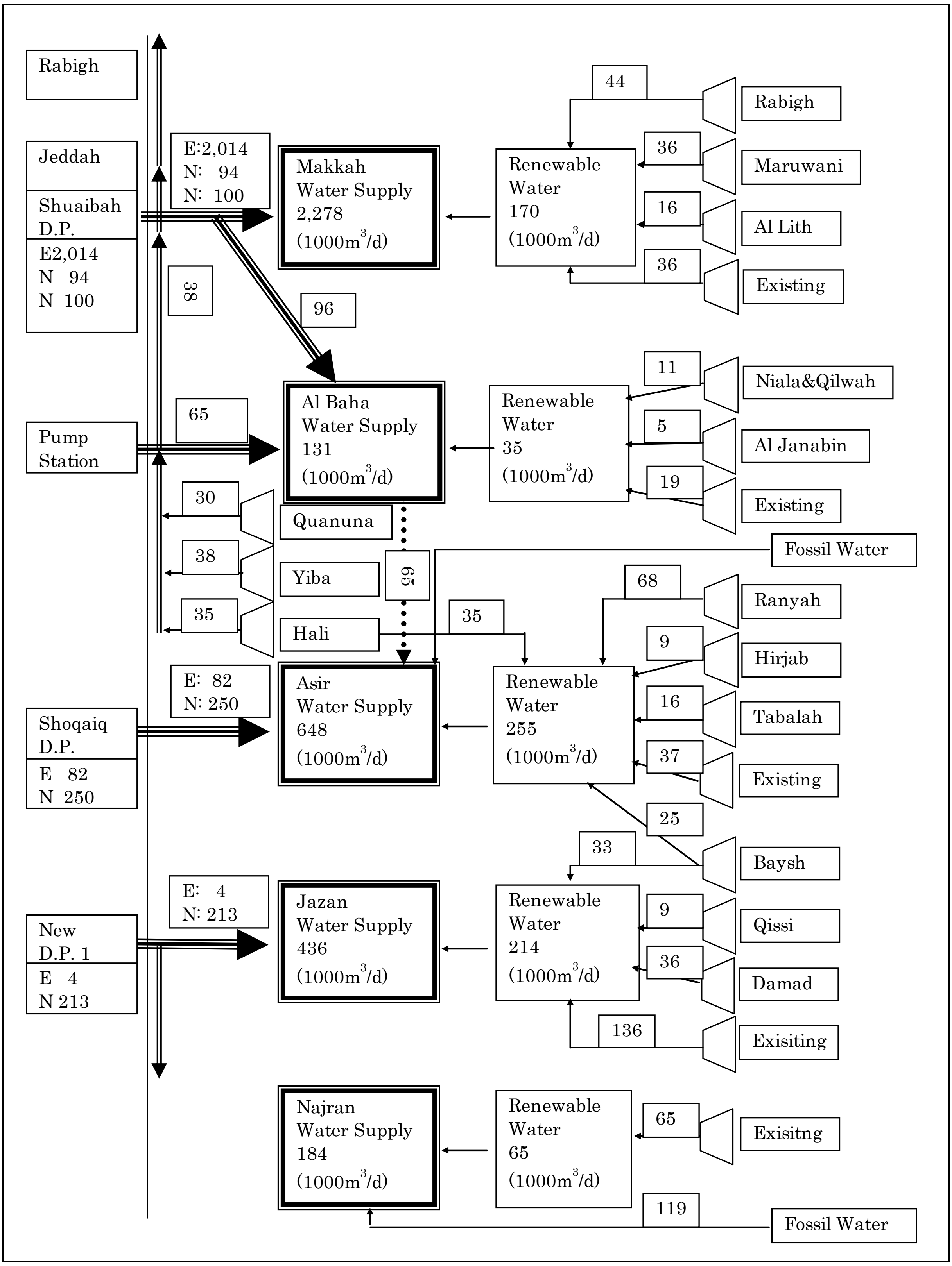


Figure 5-5 Water Supply by Facilities in Alternative-2

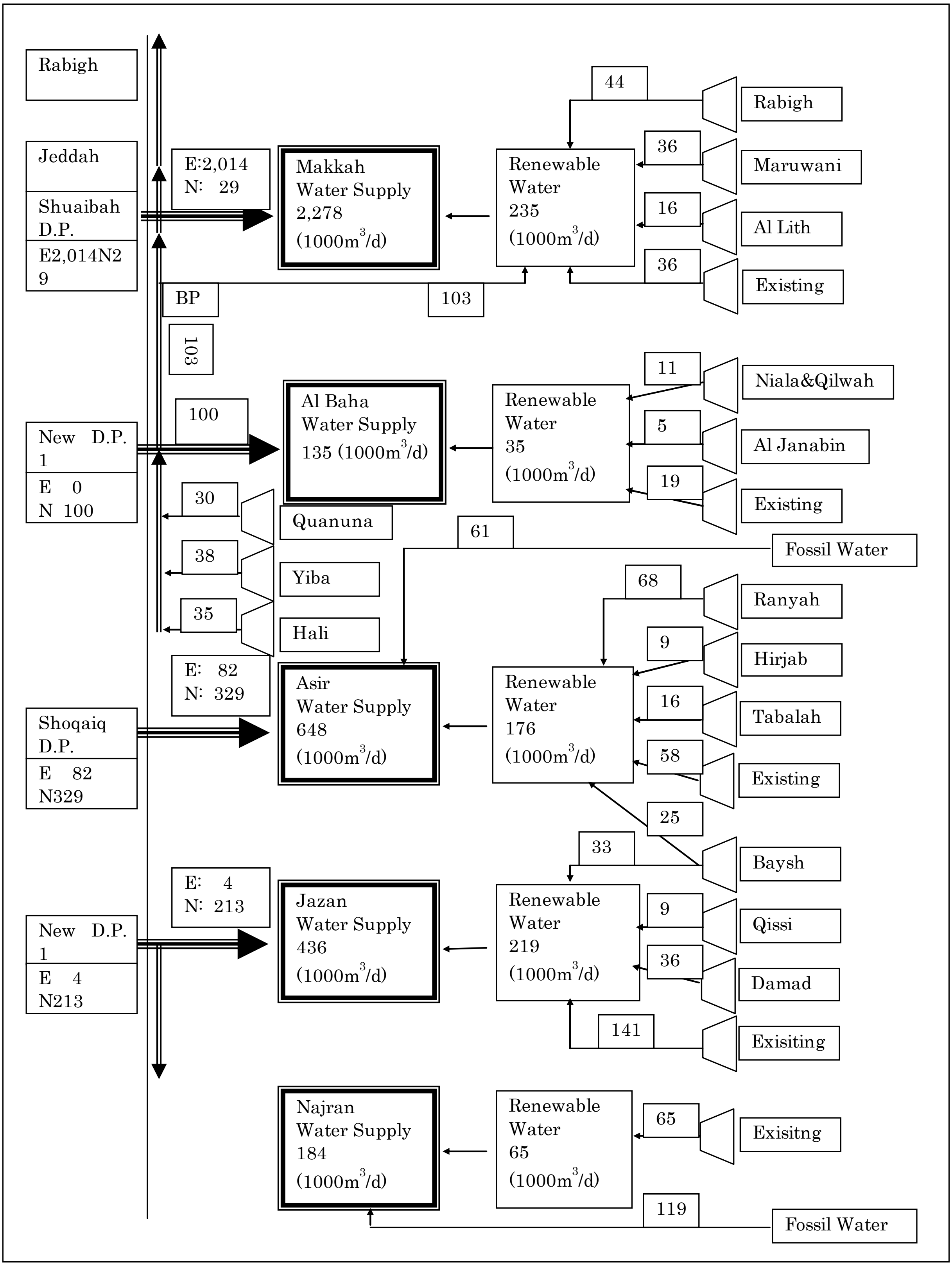


Figure 5-6 Water Supply by Facilities in Alternative-3

(5) Municipal Water Development Project and Rough Cost of Each Region

2020 and 2035 will be examined about the development project of the municipal water of each state.
About rough cost, the institution under the existing institution and construction is not appropriated for a construction cost, but adds up only a newly developed institution.

The water development plan for fulfilling the demand in the target year of the 5 Region is as follows.

Table 5-19 Demand and Supply of Planned Target Year (5 Region)

Region	Target Year	Name of facility	Volume of Water Resources Development (1000m^3/d)	Water Demand in Target Year (1000m^3/d)	Balance (1000m^3/d)	Rough Estimation of Construction Cost (MSR)
Makkah	2020	Renewable Water Resource（Existing）	36			-
		Desalinated Seawater（Existing）	2,014			-
		Renewable Water Resource（Rabigh Dam）	44			-
		Renewable Water Resource（MaruwaniDam）	36			-
		Renewable Water Resource(Al Lith Dam）	16			-
		Renewable Water Resource（Yiba Dam）	38			-
		Subtotal（by 2020）	**2,184**	**1,733**	**451**	**0**
	2035	Desalinated Seawater（Expansion）	94			132
		Subtotal（2020～2035）	**94**			**132**
		Total（by 2035）	**2,278**	**2,278**	**0**	**132**
Al Baha	2020	Renewable Water Resource (Existing)	19			-
		Desalinated Seawater (Existing)				-
		Renewable Water Resource（Nilah＆Qilwah Dam）	11			-
		Renewable Water Resource（Al Janabin Dam）	5			-
		Desalinated Seawater（New）	75			105
		Subtotal（by 2020）	**110**	**83**	**27**	**105**
	2035	Desalinated Seawater（Extension）	25			35
		Subtotal（2020～2035）	**25**			**35**
		Total（by 2035）	**135**	**135**	**0**	**140**
Asir	2020	Renewable Water Resource (Existing)	37			-
		Desalinated Seawater (Existing)	82			-
		Renewable Water Resource（Qanunah Dam）	30			-
		Renewable Water Resource（Hali Dam）	35			-
		Renewable Water Resource（Ranyah Dam）	68			71
		Renewable Water Resource（Hirjab Dam）	9			9
		Renewable Water Resource（Tabalah Dam）	16			-
		Renewable Water Resource（Baysh Dam）	25			-
		Fossil Groundwater（Wajid）	29			420
		Desalinated Seawater（Extension）	146			204
		Subtotal（by 2020）	**477**	**432**	**45**	**704**
	2035	Renewable Water Resource（Hali Dam）	35			-
		Fossil Groundwater（Wajid）	37			-
		Desalinated Seawater（Extension）	99			139
		Subtotal（2020～2035）	**166**			**139**
		Total（by 2035）	**648**	**648**	**0**	**843**
Jazan	2020	Renewable Water Resource (Existing)	141			-
		Desalinated Seawater (Existing)	4			-
		Renewable Water Resource（Baysh Dam）	33			-
		Renewable Water Resource（Qissi Dam）	9			-
		Renewable Water Resource（Damad Dam）	36			-
		Desalinated Seawater（Extension）	80			112
		Desalinated Seawater（New）	35			49
		Subtotal（by 2020）	**338**	**286**	**52**	**161**
	2035	Desalinated Seawater（Extension）	98			137
		Subtotal（2020～2035）	**98**			**137**
		Total（by 2035）	**436**	**436**	**0**	**298**
Najran	2020	Renewable Water Resource（Existing）	65			
		Fossil Groundwater（Wajid）	70			400
		Subtotal（by 2020）	**135**	**135**	**0**	**400**
	2035	Fossil Groundwater（Wajid）	49			
		Subtotal（2020～2035）	**49**			**0**
		Total（by 2035）	**184**	**184**	**0**	**400**

Action plan is proposed on the water policy and strategy of the following involved with water resources development.

◆Policy WP4：To Improve Reuse of Reclaimed Waste Water

(6) Use of Reclaimed Waste Water

Since Renewable water resources are restricted and production cost of desalinated seawater is high, it is necessary to encourage reuse of reclaimed waste water to supplement above water resources.

Improvement in sewage disposal capability

- A low sewer coverage level in the study area except some cities is intentionally raised.
- The sewage disposal capability is raised intentionally.

Promotion of utilization of reclaimed waste water

Reclaimed waste water has social and legal restrictions in the purpose of use from a viewpoint of safety and hygiene. From now on, the promising purposes to use reclaimed waste water are, for example, cooling water in the industrial water, greening water for street trees and irrigation water for fruit trees. Prudent correspondence is called for in respect of safety and hygiene so that health impairment may not occur in case of irrigation. However, since water for irrigation serves as big load in groundwater use, it is necessary for irrigation to promote reuse of reclaimed waste water.

- In order to use it as industrial water, greening water and agricultural water, introducing treatment plant which assure safe and stable water quality and its management technology should be promoted.
- In order to secure the safety of agricultural products so that use in agriculture may be promoted, introduction of the irrigation equipment for use of reclaimed waste water is promoted.
- In the mountain area where the small farmland is scattered, introduction of distributed type sewage treatment equipment which is easy to supply reclaimed waste water to farmland is considered.
- The educational campaign to a farmhouse and consumers about safe of the agricultural products using for which reclaimed waste water is promoted.

5.4.3 Action Plan - Water Resources Conservation

Action plan is proposed on the water policy and strategy of the following involved with water resources development.

◆Policy WP5：To Conserve Groundwater ◆Policy WP6：To Conserve Water Quality (surface water and groundwater)

(1) Groundwater Conservation by Dam

Groundwater is recharged into aquifer through wadi bed. Therefore, it is possible to conserve groundwater by controlling wadi discharge from recharge dam. Optimum dam operation method will be proposed to promote groundwater recharge, considering items below:

- To reduce ineffective discharge into Red Sea in wadi basins in the west of Shield.
- To reduce ineffective discharge into lower reaches of the area where groundwater is used in wadi basins of the east of Shield.
- Amount of groundwater recharge can be maximized by controlling discharge through dam.
- Optimum discharge should be decided for each dam site because it is different dam by dam.

(2) Monitoring Plan

Rainfall

Precipitation distribution should be precisely observed to analyze potential of water resources development for formulation of development plan. Currently, there are several rain gauge stations in the study area. However, observation system is not properly managed, causing lack of necessary data. This interrupts formulation of proper development plan. Activities below should be implemented to improve monitoring system.

- To establish monitoring network
- To collect observed data properly
- To analyze data exactly.

Monitoring of Wadi Discharge

In the study area, surface water is flowing within wadi course. On the other hand, groundwater is recharged into aquifer though wadi bed and flowing within aquifer under wadi beds. Consequently, the entire water resources are strongly connected to wadi discharge in the study area. Therefore, monitoring of wadi discharge must be strengthened for water resources development and conservation. Activities below are proposed.

- To improve observation accuracy (by use of water level recorders and current meters)
- To strengthen monitoring system
- To analyze data exactly

Groundwater observation

Large amount of groundwater is currently being pumped from Quaternary aquifer along the Red Sea. It is pointed out that groundwater level is currently going down, and seawater is intruding into the aquifer due to over pumping. It is proposed to know the current situation of groundwater environment to formulate measures against above problems by strengthening of monitoring system. Activities to be implemented are as follows:

- To predict area where serious draw down of groundwater level will happen
- To identify area to be monitored
- To establish monitoring system of groundwater level
- To establish monitoring system of water quality
- To strengthen monitoring system

5.4.4 Action Plan - Water Use Management

Action plan is proposed on the water policy and strategy of the following involved with water use management.

◆Policy WP7：To Promote Effective Use of Municipal Water
◆Policy WP8：To improve consciousness for water saving and strengthen action for water saving
◆Policy WP9：To Improve Appropriate Agricultural Water Use

(1) Demand Management

The national water strategy has described that "water management of supply to water demand management" and a paradigm need to be converted. From the presumed result of renewable water-resources potential, it is expected that it is not easy to fill the amount demanded of future municipal water and industrial water with renewable water resources. For this reason, it is very important to control an amount demanded by the measure of water demand management. The measure for water demand management is as follows.

Introduction of Pricing

A pricing system is a effective method for control of water demand. Pricing lets the price of water pass, asks users for a suitable burden, pushes it in a price, and expects control of an amount of consumption. In the KSA, municipal water and water for agricultural use can use water very cheaply by assistance of the government. Therefore, it is said that water-saving consciousness does not grow up and the demand management by introduction of a suitable charge system is required.

Enlightenment about water saving and water preservation

<u>Enlightenment about Water Saving and Water Preservation</u>

As one of the methods of raising the concern about water preservation ""3R" campaign (reduce of the amount used, re-use of the water used once, and the water used once are processed appropriately, and recycle is proposed. It becomes possible not only to reduce the expense concerning production of water, but to decrease reduction of the expense which processing of drainage takes, and addition by the environment by drainage of decreasing the amount of water supply by water saving. This 3R campaign can contribute not only to water saving but to environmental preservation.

(2) Water Demand Management of Agricultural Water Use

From a viewpoint of water demand management of agricultural use, crop conversion consisting mainly of vegetables and fruit tree from cereals and feed crop can be considered. Moreover, water saving in irrigation of fruit tree and vegetable cultivation is possible in the southwest area.

<u>Crop Conversion</u>

Regarding an agricultural development plan, rational use of water for agricultural use based on the Decision335 is considered. Crop conversion shall be performed. However, the planted area shall not be increased. Crop conversion is specialized in vegetables and fruit growing of city suburbs from a viewpoint of reservation of food self-sufficiency, and small-scale farmhouse protection. Crop conversion to vegetables with small water requirement and fruit tree which can expect increased demand from fodder crop and cereals with large water requirement is considered to be the most realistic measure.

<u>Water Saving</u>

Traditional furrow irrigation method is generally used in the southwest area for fruit tree and vegetable cultivation. However, water can be saved by adopting the modernistic irrigation methods, such as sprinkler and drip.

5.4.5 Action Plan - Adjustment of Organization and Institution

Action plan is proposed on the water policy and strategy of the following involved with adjustment of organization and institution.

◆Policy WP10 : To Prepare Legislative and Institutional Framework for Effective Water Resources Development and Management

The measure about an organization and capability strengthening shall be as follows.

<u>Introduction of Integrated Water Resources Management (IWRM)</u>

Since water resources have been tight in the study area, it is necessary to exploit efficiently various water resources such as renewable water resources (surface water, groundwater), desalinated seawater, fossil groundwater and reclaimed waste water. Moreover, while sharing of the information about two or more regions and basin systems is needed for that purpose, the range of the person concerned becomes large, therefore the manpower which the adjustment concerning water supplies takes also becomes large.

Surface water, groundwater, and in order to manage management of the other exploitation of water resources in one and to adjust a person-concerned pipe, The principle of comprehensive water-resources management (IWRM) is introduced as proposed also by the national water strategy to manage every kind of water resources comprehensively such as surface water, groundwater and other resources and to adjust interests among stakeholders.

<u>Information Sharing and Adjustment among Sectors</u>

The farmers who are the greatest user of the renewable water resources have drawn water from a well individually and freely, if well installation is once approved and a well is installed. Since amount of water use for agriculture cannot be grasped, if it is going to manage renewable water resources, it will become an obstacle and so on.

Many dams have so far been built for exploitation of renewable water resources, or flood damage prevention. Although the pondage of which is in what dam of which and the information how it was used was reported to main office of a ministry as information on each dam by management of these dams, management of the information that it manages synthetically with storage of water of other dams is not performed.

Management of Water Resources Facilities and Organization

The MOWE local office has been performing monitoring of a water development institution, and water supply in rural areas. It is in the situation where it is outsourced to most daily facility management, judging from listening comprehension by the spot, contractors, such as a consultant, arrange and manage information fundamentally, and the report data to main office of a ministry etc. are created with directions of a MOWE local office.

The reservoir and groundwater management by such a practical administrative task and a water development institution propose the organization which MOWE like NWC which has already functioned superintends and utilizes private capability for business for an enterprise efficiency rise.

Systematization of a water-for-agricultural-use sector

Systematization of Agricultural Water Use Sectors

In an investigation area, in order that the amount of water-resources use of a water-for-agricultural-use sector may occupy most, in order to perform water supply in this area continuously and efficiently, it is indispensable that a agricultural water sector participates in the framework of IWRM.

Now, systematization as a agricultural water sector has not been organized, but each farmhouse has secured each necessary water from wells etc. In a broader-based water feed system, RWPC to propose, MOWE, and MOA are actually unable to adjust with each irrigation person who is in a agricultural water sector. Therefore, an agricultural water sector is adjusted and it is thought required to establish the organization which becomes a window of adjustment toward the exterior.

For this reason, organization strengthening of the agricultural market syndicate established now is carried out expansively. While considering it as an agricultural cooperative association (ACA: Agricultural Cooperative Association) and performing farming support and technical guidance of a farmhouse, it proposes giving this a role of a window of a water-for-agricultural-use sector.

If ACA goes to the inside of a agricultural water sector while serving as an adjusting window mouth about the object for water supplies as a representative of a agricultural water sector, it needs to give the legal force which makes farmers observe an adjustment result.

Capability Building of MOWE

In order to perform efficiently and impartially continuous exploitation of water resources and management, MOWE which is a public institution needs to be a supervisor and to give instructions. Therefore, it is necessary to aim at improvement in practical capability about IWRM of the personnel of the water resources section of MOWE by training, local inspection of an advanced place, etc. Moreover, it is necessary for all related staff to improve their capacity and managing function in the regions should be improved.

MOWE should act as a leader (main office, rural areas), and it is necessary to bear adjustment between stakeholders especially. While deepening an understanding of the role of an organization by selecting the personnel related to it etc. and making them participate from the preparatory step of an organization to be strengthened from now on, capability required from the viewpoint of business is made to be learned.

5.4.6 Summary of Action Plan of Each Region

Based on the above examination result, the summary of the action plan about the adjustment matter which is in charge of supply of the city water of each state, use of water for agricultural use, water development, and use is shown below.

(1) Makkah Region
Supply of Municipal Water
◆ Water resources for municipal water by development of desalinated seawater including Shuaibah and Jeddah plant are secured. ◆ Construction of the dams present ordered is finished by 2020, promotion of utilization of renewable water resources is planned, and it will correspond by extension of desalination plants to shortage of the municipal water after it.
Utilization of Agricultural Water
◆ From water-resources potential, the agriculture of the Makkah Region estimates the planted area in 2007 that continuation is in general possible. ◆ It is expected that the demand of fresh fruits or vegetables increases from holding big cities, such as Makkah and Jeddah, from now on, and adjust a fixture system so that emphasis may be put on production of a fruit tree and vegetables. ◆ It is apprehensive about the fall of the groundwater level, or the further advance of degradation of the water quality accompanying them, and strive for water saving further from now on, and reduce the amount of the water used, securing the quantity of production. ◆ Promote introduction of efficient irrigation like drip irrigation by improving a fruit tree from grain and improving crops to vegetables for water saving. ◆ In big cities, such as Jeddah and Makkah, for a planned target year, a lot of sewers are generated and are processed. In order to use these as water for agricultural use, the demand area of water for agricultural use will be pinpointed from now on, and it will decide upon the electric supply plan from a disposal plant. ◆ For the reclaimed waste water use at farmhouse level and security of agricultural products which promote use, the dedicated irrigated facilities for the use of the reclaimed waste water shall be introduced.
Adjustment Issues on Development
◆ Among the dams built in Makkah region, on a Qanunah dam or a Hali dam, the amount of water developed is considering it as a plan to be used in Asir region, and by the time the dam of now under construction is completed, the details of the rule for water supplies shall be agreed among both states. ◆ Agree details by completion on the employment method of an establishment dam, and the rule of water distribution. ◆ Also about the main established dams which are not clear, the rule for water supplies examines the rule for water supplies from the efficiency of renewable water resources, and a viewpoint of fair use. ◆ When examining the operation method of the new dams and the existing dams, and the examination on rule of water allocation, while grasping the actual condition for the existing irrigation user and actual water use, it is necessary to consider so that trouble may not appear in the water use.
(2) Al Baha Region
Supply of Municipal Water
◆ Due to the no suitable dam sites for construction, it reinforces supply by desalinization of seawater rather than development of renewable water resources about supply of municipal water from now on. ◆ While completing the ordered dam by 2020 already, build a new desalination plant at a Dawqah point, and compensate shortage of renewable water resources. A Dawqah desalination plant is extended to shortage of the municipal water after it.
Utilization of Agricultural Water
◆ Reduce water consumption by adjusting a fixture system as an object for water supplies, so that emphasis may be put on production of a fruit tree and vegetables. ◆ Promote introduction of efficient irrigation like drip irrigation by improving a fruit tree from grain and improving crops to vegetables for water saving. ◆ From a view point of the safe reservation of the agricultural products, the irrigation facilities which use reclaimed waster water shall be introduced. In sewer reuse, the Al Baha Region is located in a place-between-mountains area, it is difficult to install the drain pipe way of a fixed slope in a wide area, since ups and downs of geographical feature are large, and since agriculture is also small-scale and is distributed, it is thought that it becomes easy to use distributing a disposal plant from the field of use of treated water. Therefore, introduction of a distributed processing system is aimed at rather than a broad-based concentrated type sewage disposal system. ◆ For the reclaimed waste water use at farmhouse level and security of agricultural products which promote use, the dedicated irrigated facilities for the use of the reclaimed waste water shall be introduced. ◆ Since signs are seen, the fall of the groundwater level and degradation of the water quality accompanying them also strive for water saving further from now on.
Adjustment Issues on Development
◆ Assume the system which can use on a pipeline development water, such as a Qanunah dam built in Makkah region.

By completion of these institutions, an overall community examines the rule for water supplies in emergencies, such as unusual water shortage.

- ◆ Agree details by completion on the employment method of an establishment dam, and the rule of water distribution.
- ◆ Also about the main established dams which are not clear, the rule for water supplies examines the rule for water supplies from the efficiency of renewable water resources, and a viewpoint of fair use.
- ◆ When examining the operation method of the new dams and the existing dams, and the examination on rule of water allocation, while grasping the actual condition for the existing irrigation user and actual water use, it is necessary to consider so that trouble may not appear in the water use.

(3) Asir Region

Supply of Municipal Water

- ◆ Supply the Asir Region from the Baysh dam which newly carries out a Ranyah dam etc. succeedingly, and will further development of renewable water resources by 2020, and is installed in the Jazan Region in the Makkah Region, such as an Qanunah dam, besides an ordered Tabalah dam already.
- ◆ For the shortage of water developed by dams, municipal water by the expansion of Shuqaiq desalination plants shall be supplied.
- ◆ Municipal water in the eastern part area (Tath Lith) of Asir Region is taken from the fossil water of the Wajid Aquifer.

Utilization of Agricultural Water

- ◆ Reduce water consumption by adjusting a fixture system as an object for water supplies, so that emphasis may be put on production of a fruit tree and vegetables.
- ◆ Promote introduction of efficient irrigation like drip irrigation by improving a fruit tree from grain and improving crops to vegetables for water saving.
- ◆ From a view point of the safe reservation of the agricultural products, the irrigation facilities which use reclaimed waster water shall be introduced. In sewer reuse, the Al Baha Region is located in a place-between-mountains area, it is difficult to install the drain pipe way of a fixed slope in a wide area, since ups and downs of geographical feature are large, and since agriculture is also small-scale and is distributed, it is thought that it becomes easy to use distributing a disposal plant from the field of use of treated water. Therefore, introduction of a distributed processing system is aimed at rather than a broad-based concentrated type sewage disposal system.
- ◆ For the reclaimed waste water use at farmhouse level and security of agricultural products which promote use, the dedicated irrigated facilities for the use of the reclaimed waste water shall be introduced.
- ◆ Since signs are seen, the fall of the groundwater level and degradation of the water quality accompanying them also strive for water saving further from now on.

Adjustment Issues on Development

- ◆ The Asir region is taken as a plan for renewable water resources to be supplied from the Baysh dam currently built among the dams built in Makkah region, Jazan region, such as a Qanunah dam.
- ◆ By the time the dam of now under construction is completed, the details of the rule for water supplies will be agreed among both Regions.
- ◆ Agree details by completion on the employment method of an establishment dam, and the rule of water distribution.
- ◆ Also about the main established dams which are not clear, the rule for water supplies examines the rule for water supplies from the efficiency of renewable water resources, and a viewpoint of fair use.
- ◆ When examining the operation method of the new dams and the existing dams, and the examination on rule of water allocation, while grasping the actual condition for the existing irrigation user and actual water use, it is necessary to consider so that trouble may not appear in the water use.

(4) Jazan Region

Supply of Municipal Water

- ◆ Although most municipal water has so far been supplied by renewable water resources in Jazan region, it needs to be parallel to development of renewable water resources from now on, and it is necessary to also perform water development by desalinization of seawater.
- ◆ While completing the ordered Baysh dam by 2020 already etc., perform establishment of a desalination plant with the pipelines, and extension at a Sabya point.
- ◆ Shortage of the municipal water in 2020 and afterwards corresponds by extension of the desalination plant established newly.

Utilization of Agricultural Water

- ◆ Surmise that it is difficult to maintain the agriculture of the present condition of Jazan region from water resources potential.
- ◆ Since it is apprehensive about the fall of the groundwater level, or the further advance of aggravation of the water quality accompanying them, reduce the amount of the groundwater used.
- ◆ While adjusting a fixture system so that emphasis may be put from now on production of a fruit tree with little water

consumption besides examination of curtailment of the planted area, and vegetables, promote introduction of efficient irrigation like drip irrigation.

- Reuse of reclaimed waste water shall be prompted especially, around Jizan City areas, the water treatment plan and distribution plan on waste water shall be formulated.
- For the reclaimed waste water use at farmhouse level and security of agricultural products which promote use, the dedicated irrigated facilities for the use of the reclaimed waste water shall be introduced.

Adjustment Issues on Development

- Since the Baysh dam currently installed in the State of Jazan is considered as a plan to perform water supply also in the State of Asir, it agrees the details of the rule for water supplies among both regions.
- Agree details by completion on the employment method of an establishment dam, and the rule of water distribution.
- Also about the main established dams which are not clear, the rule for water supplies examines the rule for water supplies from the efficiency of renewable water resources, and a viewpoint of fair use.
- When examining the operation method of new dams and the existing dams, and the examination on rule of water allocation, while grasping the actual condition for the existing irrigation user and actual water use, it is necessary to consider so that trouble may not appear in the water use.
- In the planning of water reduction for agricultural water, the future agricultural plan at Region level shall be also considered.

(5) Najran Region

Supply of Municipal Water

- In the Najran Region, it is considered as a plan not to continue not to introduce desalination water.
- Water will be conducted in fossil aquifer of a Wajid aquifer by 2020, and insufficient amount of water will be secured.
- In 2020 or subsequent ones, shortage of municipal water is secured with fossil aquifer.

Utilization of Agricultural Water

- Cut down the agriculture of the Najran Region from water resources potential about 30% in general from the planted area in 2007.
- While adjusting a fixture system so that emphasis may be put on production of a fruit tree with little amount of the water used, and vegetables, promote introduction of efficient irrigation like drip irrigation.
- It is apprehensive about the descending of the groundwater level, or the further advance of degradation of the water quality accompanying them, and strive for water saving further from now on, and reduce the amount of the water used, securing the quantity of production.
- Population is concentrating on the state capital and generating of reclaimed waste water concentrates the Najran Region. Since the renewable water resources which can be exploited as water for agricultural use are insufficient, near the state capital, use to the water for agricultural use of sewage disposal water is promoted.
- For the reclaimed waste water use at farmhouse level and security of agricultural products which promote use, the dedicated irrigated facilities for the use of the reclaimed waste water shall be introduced.

Adjustment Issues on Development

- Due to no connection with the water supply systems among other Regions, the water supplies in Najran Region is independent so that efficient and comprehensive rule on water use shall be introduced and formulated.
- Since fossil water in Wajid Aquifer is defined as non-circulating water resources, the rule of water use by putting into the view to save the water use shall be taken into consideration.

CHAPTER 6 OUTLINE OF WATER MASTER PLAN (M/P)

6.1 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 now. The target areas of the plan are 3 Regions: Al Baha Region, Asir Region and Jazan Region.

(2) Components of Water Master Plan

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 Seawater 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

6.2 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/use and management upon which it was decided in Part B of Chapter 5.

(1) Target Water Resources Development

Table 6-1 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 6-1 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 Seawater	• Production by Desalinated Plant	• Municipal Water • Industrial Water
	◆ Reclaimed Waste Water	• Production by Sewerage Treatment Plant (Tertiary)	• Part of Municipal Water (Greening) • Part of Industrial Water • Agricultural Water

(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 urban 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.

(3) Management of Water Demand

Urban Water

In order to decrease the water consumption of urban water by 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 urban water. The evaluation case was carried out as follows. 1) 10% reduction of the water supply source unit, 2) Demand by the present water supply unit, 3) 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

6.3 Water Resources Development

6.3.1 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.

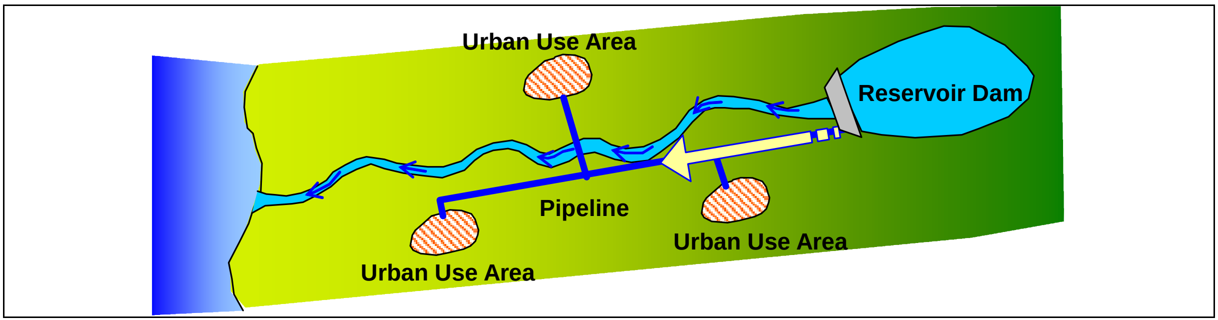


Figure 6-1 Surface Water Development by Large Dam

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.

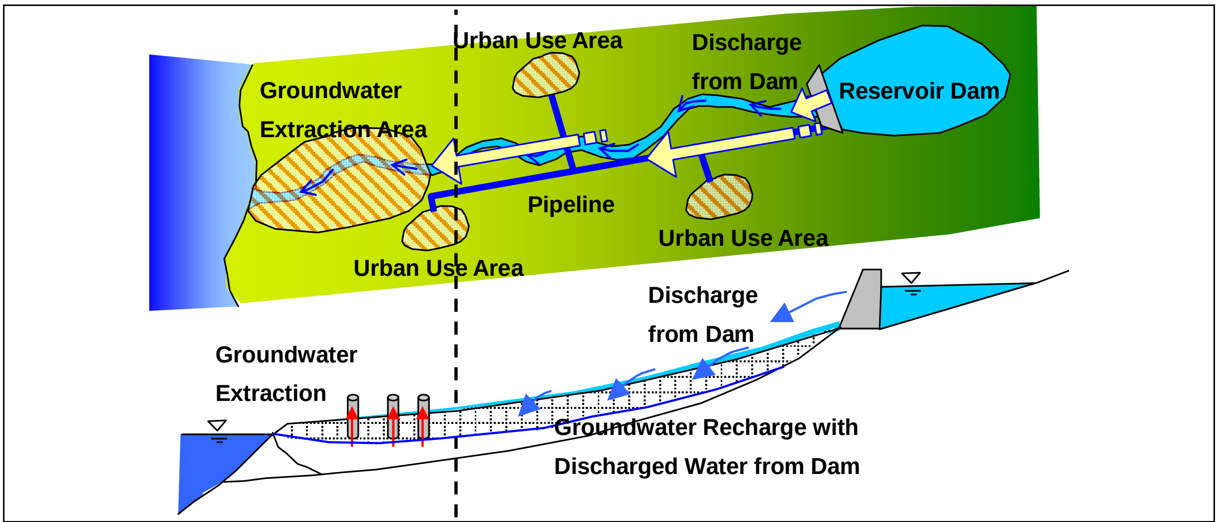


Figure 6-2 Surface Water & Groundwater Development by Combination with Large Dam and Aquifer

Groundwater Development by the Recharge Dams

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

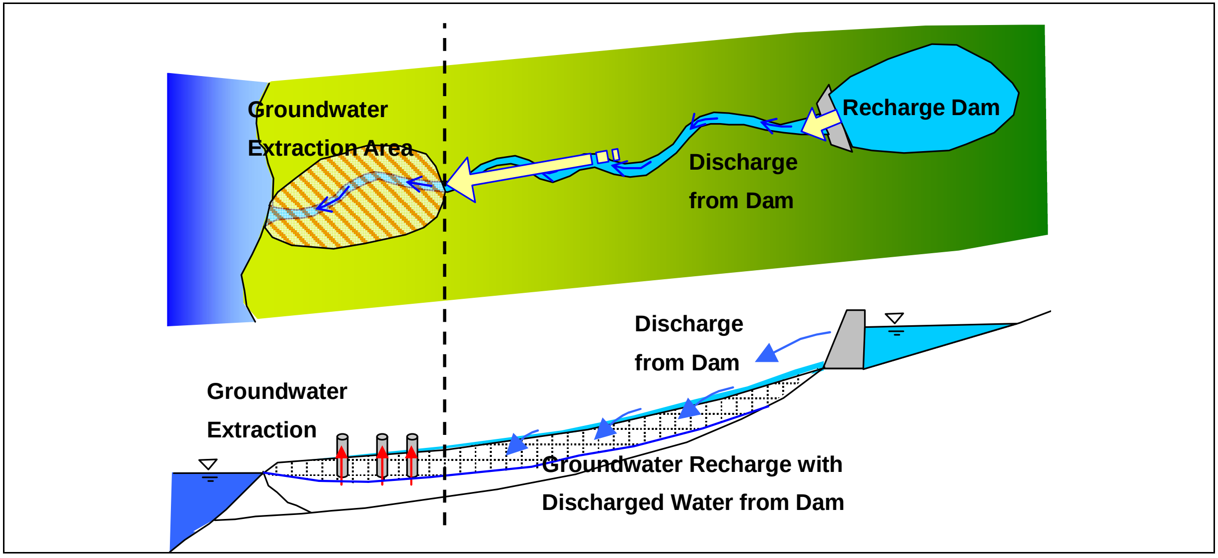


Figure 6-3 Groundwater Development by the Recharge Dams

(1) Target Development Discharge of Dam of Future Water Supply Plan and Irrigation Plan

The target dam of the future water supply plan of project areas and irrigation is as shown in Table 6-2.

Table 6-2 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
合計				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

(2) Calculated Method Development Volumes

As shown in Table 6-2, 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 Bash dam and a Hali dam are shown as a calculation case.

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.

(3) Calculated Result Development Volumes

The calculated development volumes of the main dams and dams planned for the water supply are tabulated in Table 6-3 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 6-3 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 (1000m³/d)	Development Ratio*3 (α)	Development Discharge (MCM/Y)	Development Volume (1000m³/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%
Jizan	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

6.3.2 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

(1) Desalinated Seawater

<u>Current Situation of Desalinated Seawater in Target Year</u>

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 Shuaibah 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.

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) Reclaimed Waste Water

The Reclaimed waste water production volume in the Target Area is planned as shown in Table 6-4 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 waste 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.

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 6-4.

Table 6-4 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 %

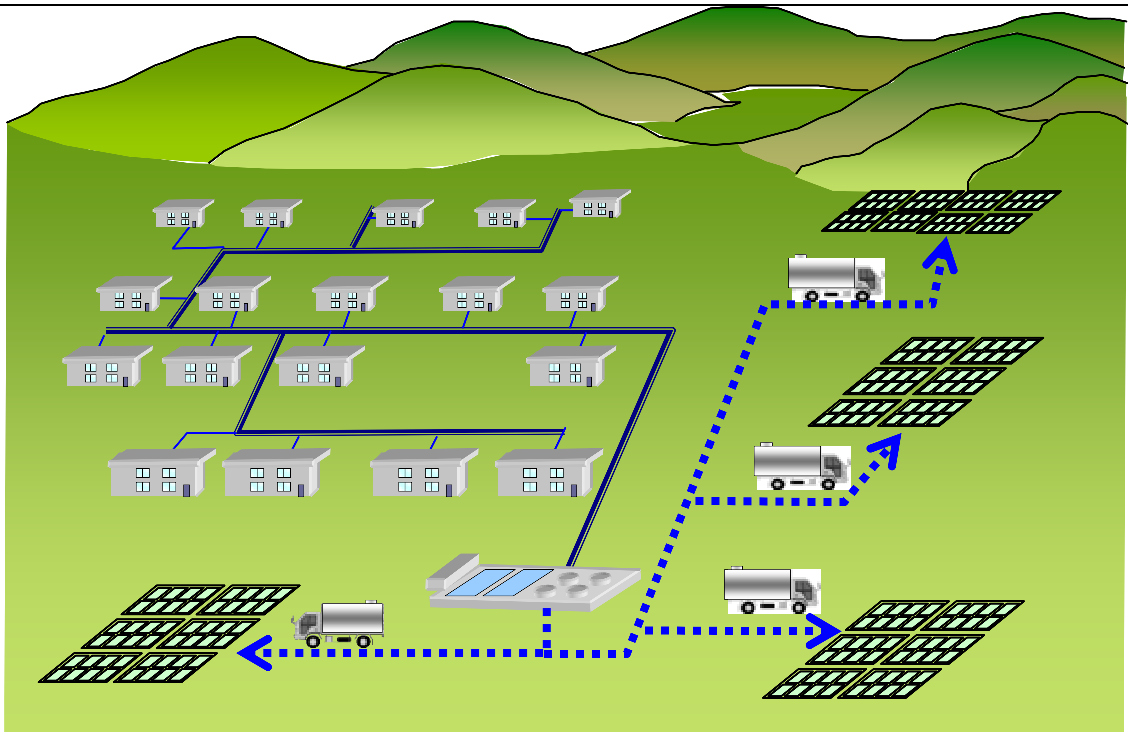
As shown in the table above regarding the recycle use of reclaimed waste water, utilization for municipal water and industrial water is limited and relatively small but for agricultural water is large. In the Al Baha Region and the Asir Region, the rates of agricultural use (Available Reclaimed Waste 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>

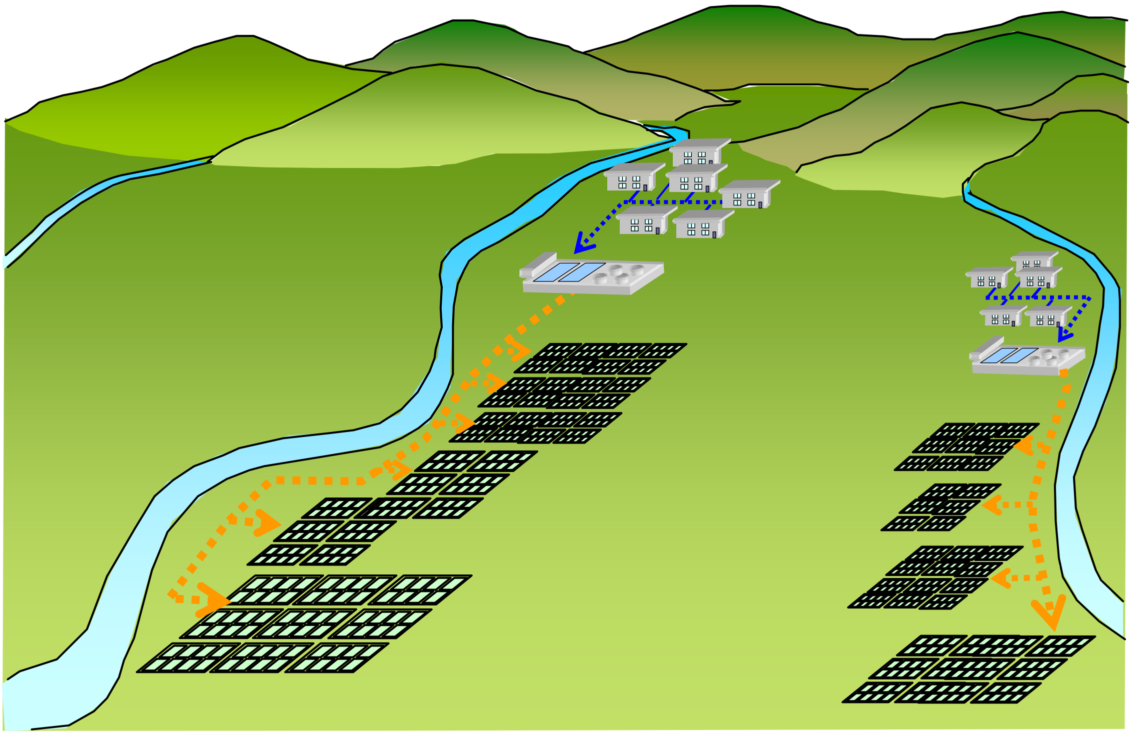
If 5% of the municipal water is replaced with reclaimed waste water, consequently the municipal water demand will decrease by 5%. According to SWCC Annual Report 2008, the water unit price (production cost and a transportation cost) of desalinated seawater is 8.0 SR/m^3 from 3.5 SR/m^3. In particular,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

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

As shown in Table 6-4, 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 6-4).



Sewage Treatment and Recycle Use 【Intensive System】



Sewage Treatment and Recycle Use【Distributed System】

Figure 6-4 System of Sewage Treatment and Recycle Use

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

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.

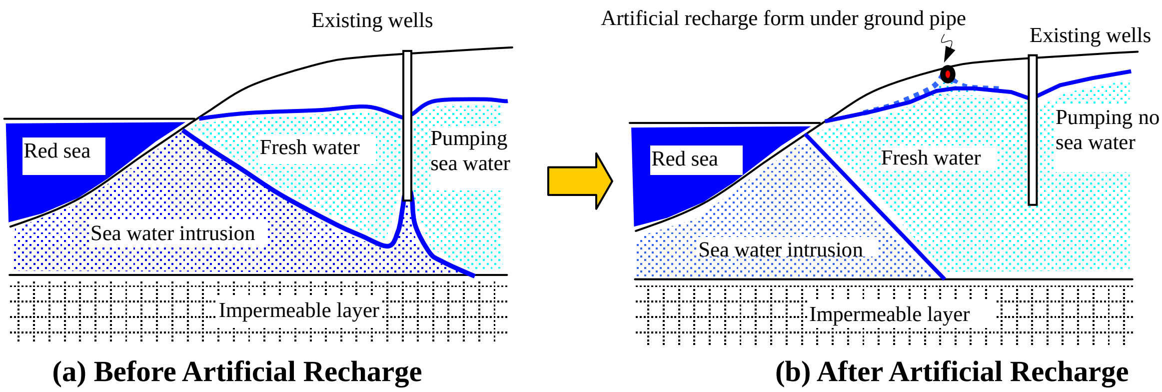


Figure 6-5 Measures against Seawater Intrusion by Treated Sewage

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

6.4 Water Supply Plan

6.4.1 Basic Condition of Water Supply Planning

(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.

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.

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.

(2) Current Water Source and Water Supply Amount

Current water sources and water supply amount in the targeted regions are summarized in Table 6-5.

Table 6-5 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**	
		Shugaiq	*(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)*	

Region	Resources	Name of Facility	Volume(1000m^3/d)	Remarks
		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**	

(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 6-6. The planned amounts of supply was planned by MOWE, but as that of Tabalah and Qanuna dam is higher than the planned production capacity, planned amounts of supply will be applied for the planned production capacity.

Table 6-6 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	
Qanuna	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)

(4) 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 6-7.

Table 6-7 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
			Niala 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	

Name of Region	Targeted Year	Development Resources	Dam/Governorate	Development Volume (m^3/d)	Remarks
	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	
			Shuqaiq	72,000	Extension
		Desalination Plants	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

6.4.2 Proposed Water Supply Plan

(1) AL Baha Region

<u>Plan for Water Demand and Water Supply</u>

The water demand and water supply of Al Baha and Asir Regions are shown in Table 6-8, Figure 6-6.

Table 6-8 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	14,000	14,000	14,000	14,000	14,000
Al Aqiq Dam (B)	4,000					
Wadi Thrad Dam (B)	5,000					
Qilwah Well (B)	2,000	5,000	5,000	5,000	5,000	5,000
Mukwah Well (B)	**1,000**					
Al Aqiq Well (B)	**1,000**					
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

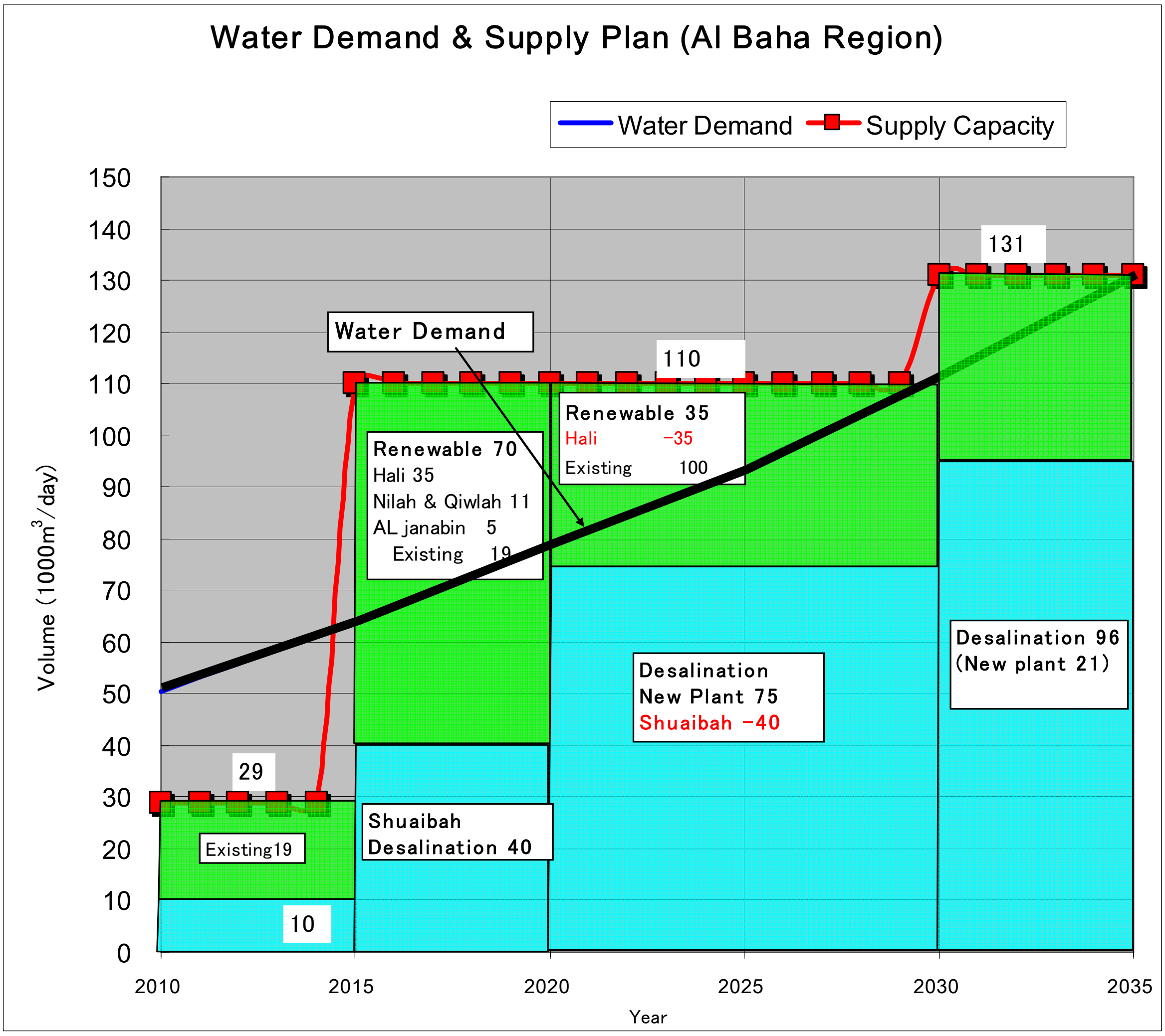


Figure 6-6 Projection of Water Demand and Water Production in AL Baha (2011-2035)

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.

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.

<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%).

<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 2030. 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.

(2) Asir Region

<u>Plan for Water Demand and Water Supply</u>

The water demand and water supply in the Asir Region are shown in Table 6-9, Figure 6-7.

Table 6-9 Water Production Plan in Asir Region

Water Resource	-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

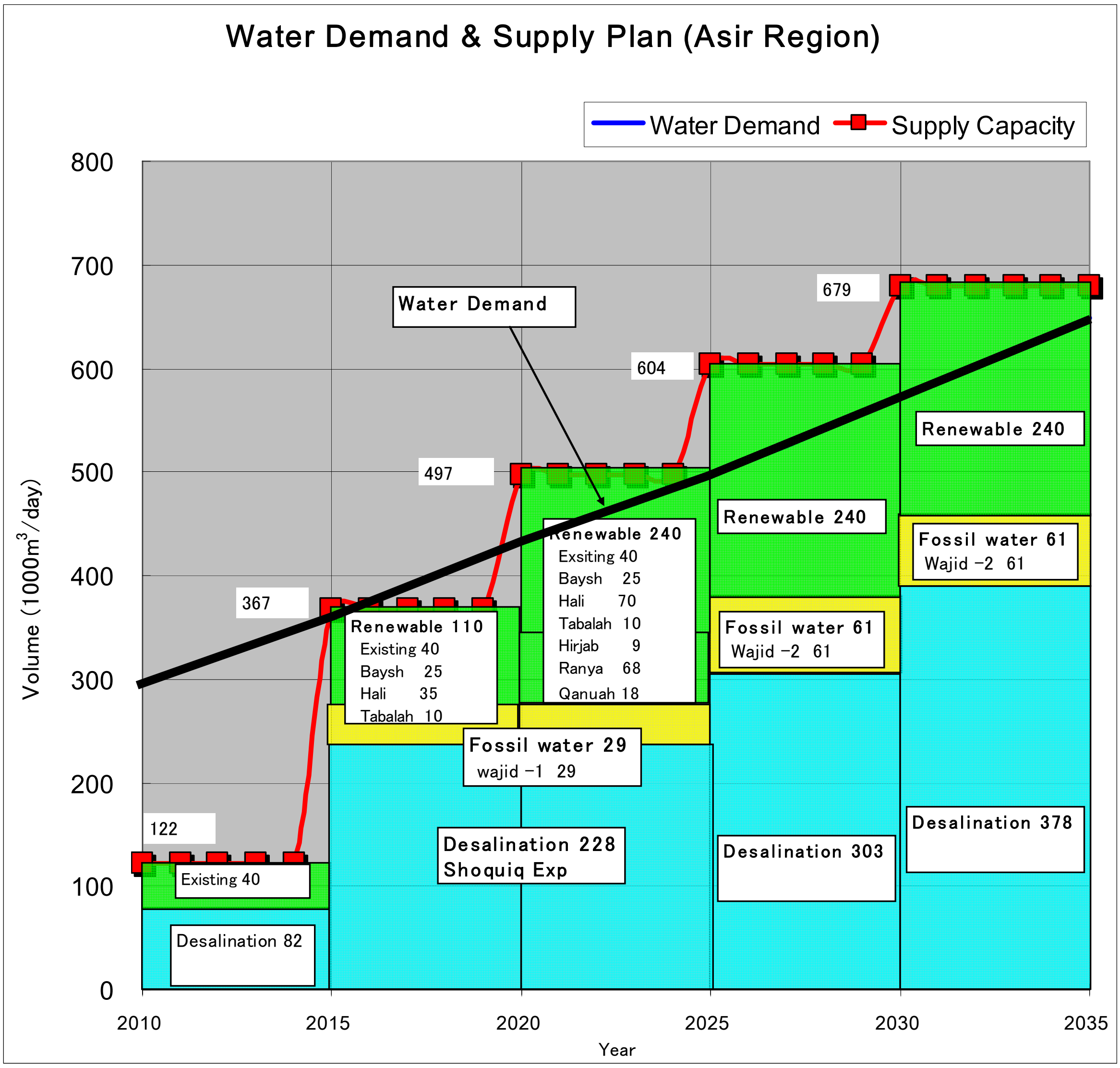


Figure 6-7 Projection of Water Demand and Water Production in Asir (2011-2035)

<u>Production of Plant for the Five Years</u>

<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.

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 2010.

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

<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 Ranayah 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.

<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.

<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.

(3) Jazan Region

<u>Plan for Water Demand and Water Supply</u>

The water demand and water supply of Jazan region is shown in Table 6-10, Figure 6-8.

Table 6-10 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**
Bayash 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

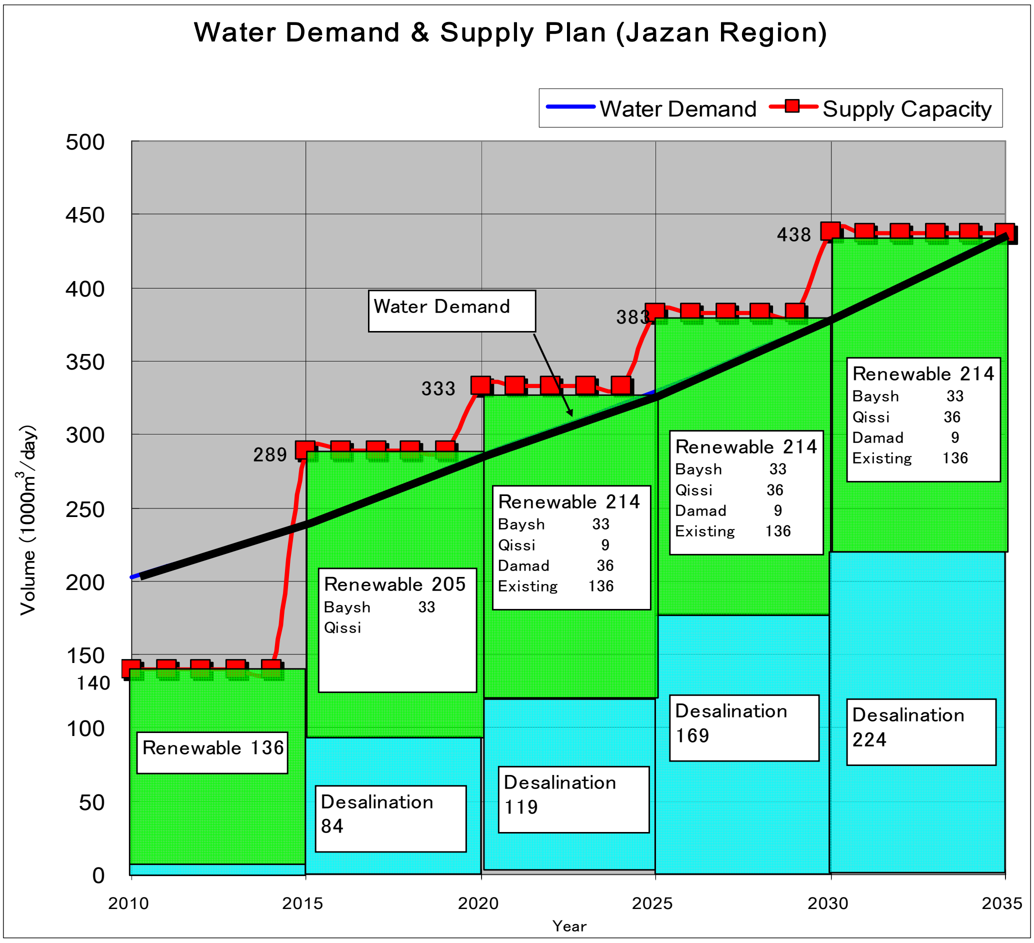


Figure 6-8 Projection of Water Demand and Water Production in Jazan (2011-2035)

<u>Production of Plant for the Five Years</u>

<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.

<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.

<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.

<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%).

Renewable water in 2035 amounts to 214,000m^3/day including water production of 78,000m^3/day provided from Baysh, Qissi and Damad Dam, and 136,000m^3/day from wells. While, desalination water production amounts to 224,000m^3/day provided from Farasan and Sabya plants. The total water production amounts to 438,000m^3/day, which meets water demand of 436,000m^3/day for the year 2035.

6.5 Management of Water Demand

6.5.1 Municipal Water

(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.

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.

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.

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.

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.

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.

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.

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, 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.

(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.

<u>The Effect in the Financial Aspect by 10% of LCD Reduction</u>

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 6-11 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^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) The State of Najran 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 6-11 in amount of money. In the five regions, the sum total of 575,700,000 SR can save in one year.

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 water will turn into mitigation of a fiscal burden after all.

<u>The Effect in the Financial Aspects in the Case of Continuing the Present LCD Level</u>

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 6-12 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	212	13	65	44	18

	Makkah Region	Al Baha Region	Asir Region	Jazan Region	Najran Region
retrenchment(1000m^3/day)					
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^{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).
*3) The State of Najran 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 6-12 in amount of money. In the five regions, the sum total of 565,100,000 SR can save in one year.

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.

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 6-13 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^{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) The State of Najran 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 6-13 in amount of money. In the five regions, the sum total of 298,300,000 SR can save in one year.

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) 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.

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 the State of Makkah, and the State of Asir.

Since an industrial expansion is expected, a measure is required in the State of Makkah, or the State of Asir.

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

<u>Planned renewal of a decrepit pipeline</u>

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.

<u>Checking and verifying the amount of supply by a flow meter and actual amount of water supply to users</u>

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.

<u>Introduction of leakage-of-water diagnostic technology</u>

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) Management of Agricultural Water Demand

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.

2) 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;

<u>The amount of the present water use for agriculture</u>

- 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.

<u>The prediction conditions for future agricultural water demand</u>

- 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.

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

- 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.

3) 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)

<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.

<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 44 MCM, when this is converted into vegetable cultivation, it is only about 6,200ha.

Based on the result of water balance simulation with the 3 regions mentioned above, in the 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 7,164ha 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.

(5) 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 the 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 Quassim (Buraidah) 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 the 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 the 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.

6.6 Operation and Maintenance, and Management Plans

6.6.1 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 master plan 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.

(3) Basic of Water Service Management

Basic of water service management are carried out as follows.

- Perform efficient and economical management combining different water resources, such as renewable water resources, desalinated seawater, reclaimed waste water, and fossil groundwater.
- Each state usually manages in principle the water resources assumed for every state at the time.
- By the local misdistribution of rain, yearly fluctuation, and a seasonal variation, when water shortage with unusual the water supply and demand of a specific area being tight etc. arises, carry out water accommodation across a state.

(4) Layout Planning of the Control Office for Water Service 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.

<u>Attachment of a Management Office to a Operation Office of an Important Facility</u>

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.

<u>Selection of a Place of the Management Office for Broader-based Water Supply System</u>

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 Conditions

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.

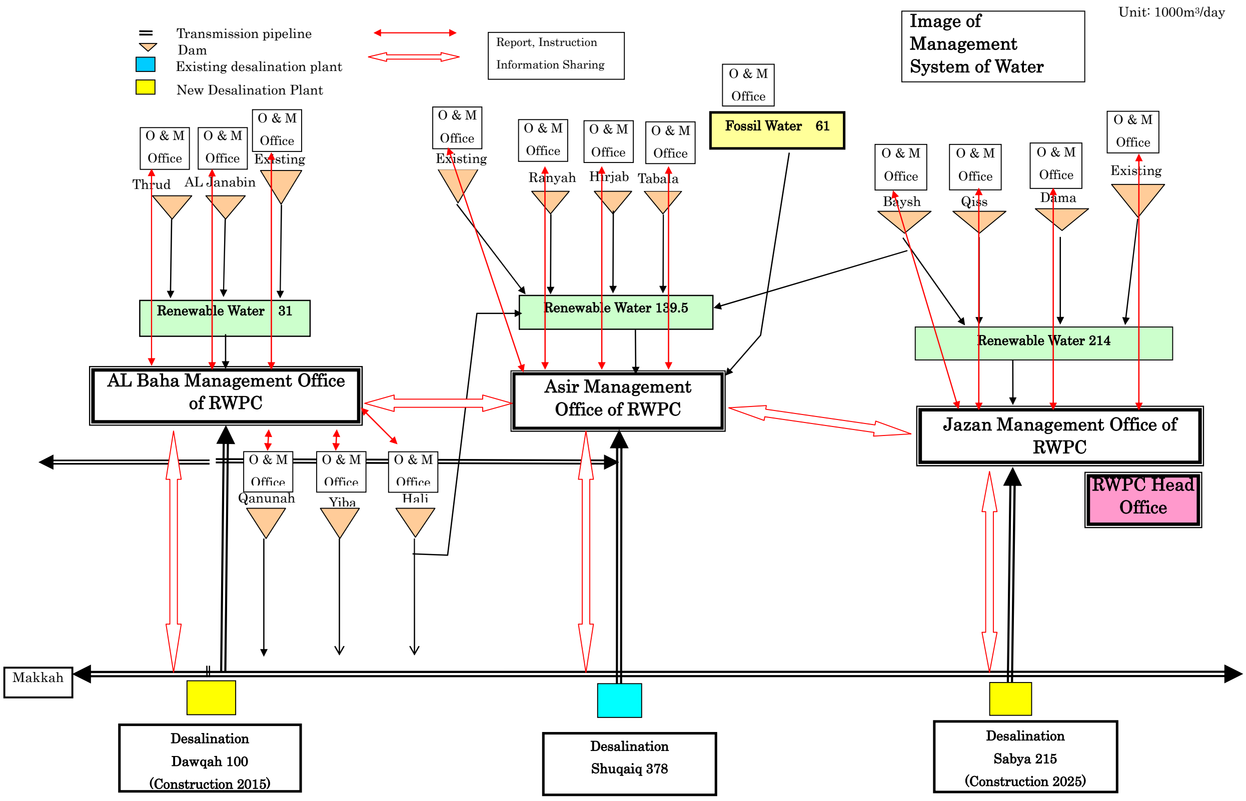


Figure 6-9 Image Figure of Water Resources Management

6.6.2 Groundwater Recharge by Dams

(1) Surface Water Development in Combination with Dam and Groundwater Aquifer

As shown in Table 6-14, 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.

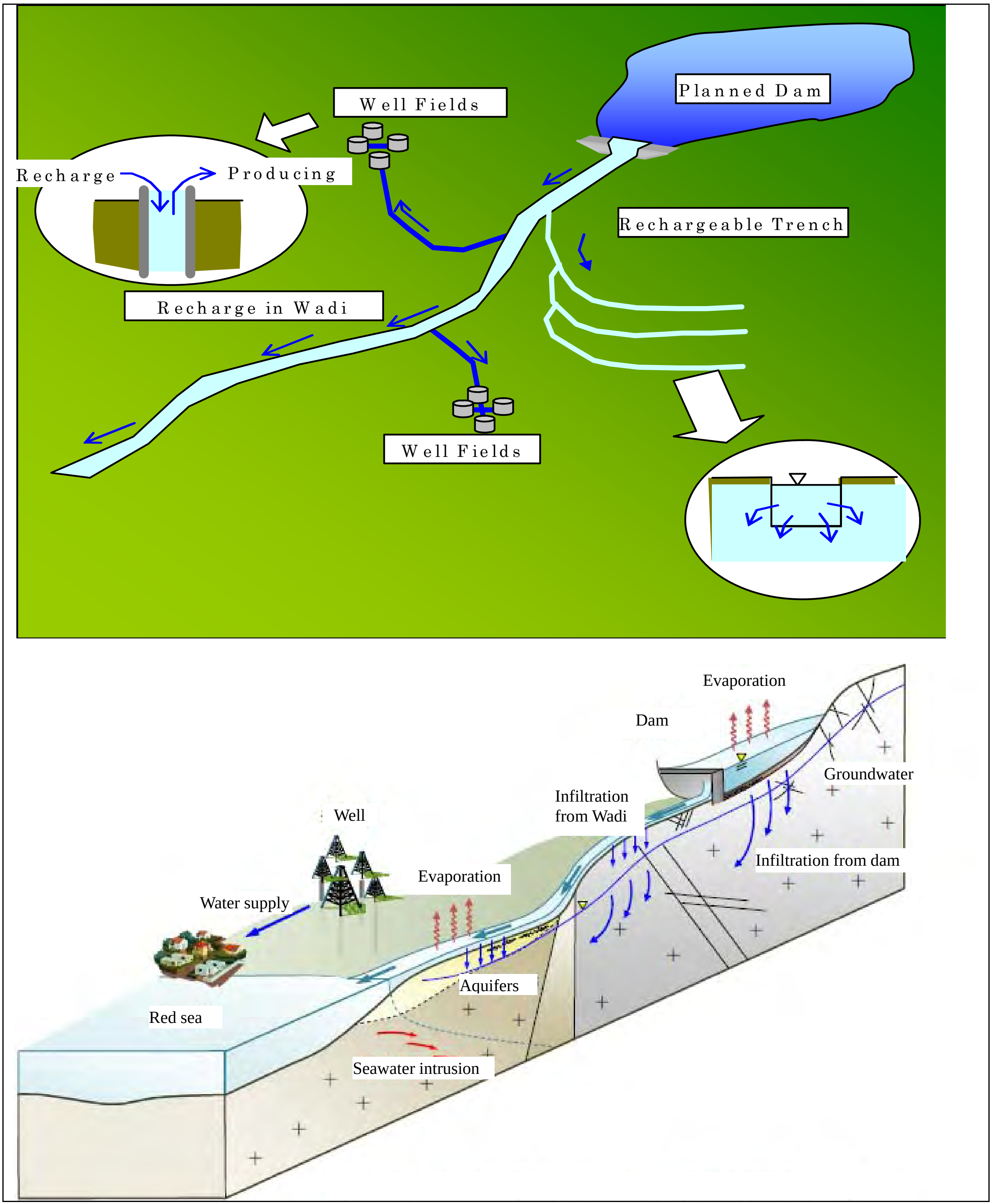


Figure 6-10 Recharge of Water from Dam into Aquifer

(2) 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.

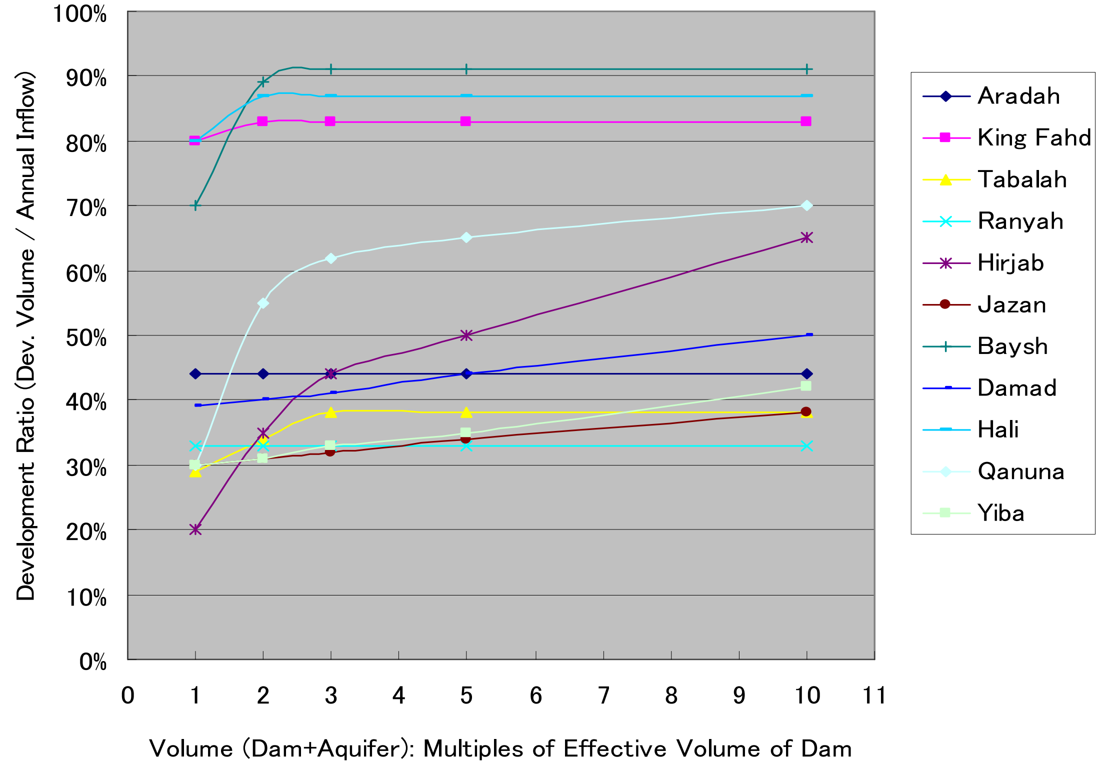
(3) Result of Development Volume

Table 6-14 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 6-14 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 6-11 Variation of Dam Development Volume in Combination with Aquifer

(4) 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. 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. 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.

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 6-15. 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 6-15 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 (Makka 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.

$Vx=Vo\times(1-a)^x$ (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 6-12.

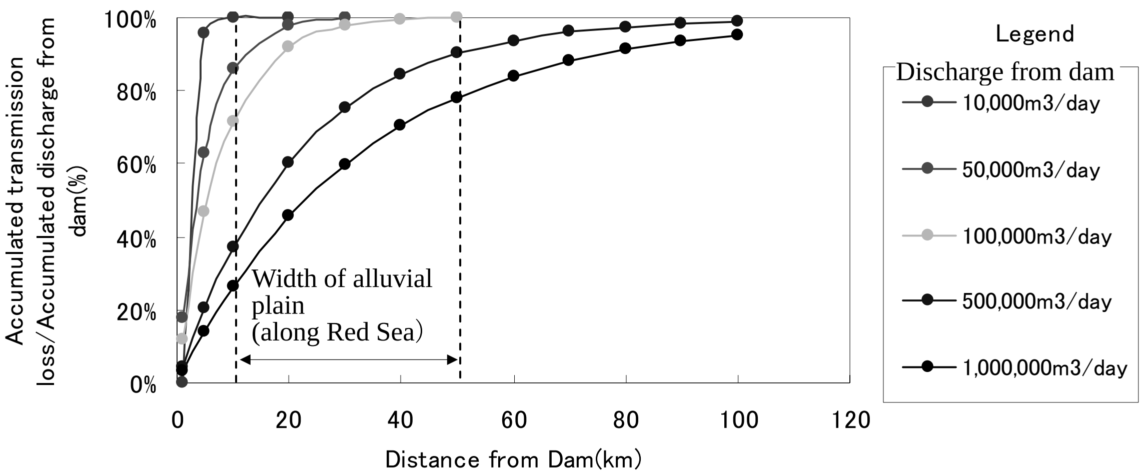


Figure 6-12 Example of Transmission Losses and Flow Distance (by Wheater Equation)

According to the example in Figure 6-12, 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.

<u>Interval of Discharge</u>

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 ($\times10^6 m^3$/day)

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

T : Interval after the previous discharge (day)

As shown in Figure 6-13, 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.

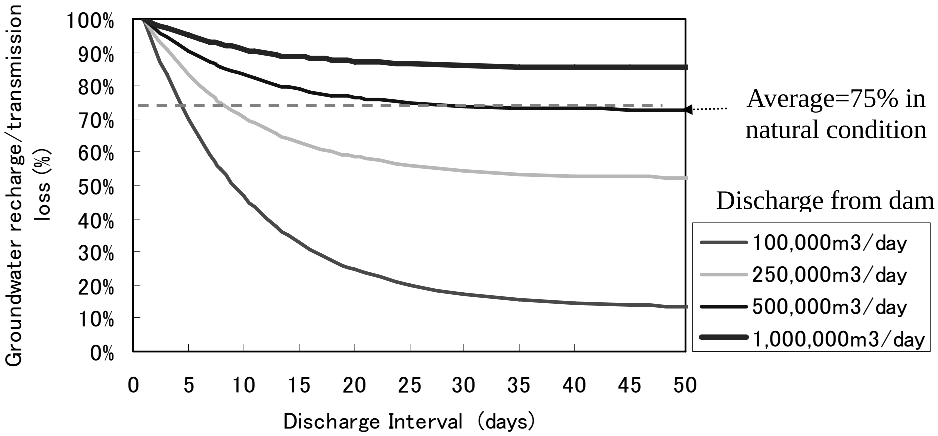


Figure 6-13 Relation between Interval of Discharge and Groundwater Recharge

(5) 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 6-16. 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 6-16 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%

(6) Increase of Transmission Loss by Recharge Dam

Increase of transmission loss depends on improvement of flow regime by recharge dam. Several representing dams in the Study Area were selected, and increase of transmission by those dams was calculated.

<Method for calculation>

Increase of transmission loss by improvement of flow regime through recharge dam was calculated. Transmission loss will increase by 17 to 40% as shown in Table 6-17. 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)".
- 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). 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 6-17 Estimated Maximum Transmission Loss Corresponding to each Dam

Dam	Width of wadi (m)	Infiltration capacity of wadi bed (mm/hour)	Maximum Transmission Loss			Increase in transmission loss (%)
			West of Shield	East of Shield	Maximum transmission loss (×1,000m^3/day)	
			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%
Ardah	50		-	7	420	34%
Tanduhah	50		-	20	1,200	20%
King Fahad	150		-	42	7,560	27%
Tabalah	100		-	66	7,920	17%
Jisan	100		45	-	5,400	23%
Baysh	150		73	-	13,140	16%
Najiran	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 (F/S) study.

6.6.3 Monitoring Plan

(1) Observation of Rainfall

There are 115 rainfall monitoring precipitation stations (MOWE: 105, PME:10) in the Study Area. 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).

(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 6-18 and Table 6-19.

Table 6-18 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 6-19 Monitoring for Discharge in Wadi

Monitoring	Method	Instruments	Remarks
Water level	Water level recording	Automatic water level recorder	
Flow Velocity	Reading of water level Monitoring of flow velocity	Staff gauge 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.

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 6-14)

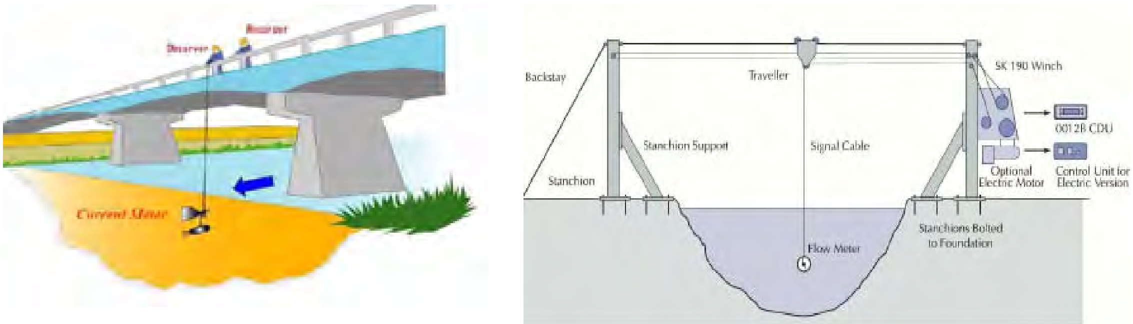


Figure 6-14 Current Meter Measuring at Bridge (Left) and Cable-way Type Current Meter (Right)

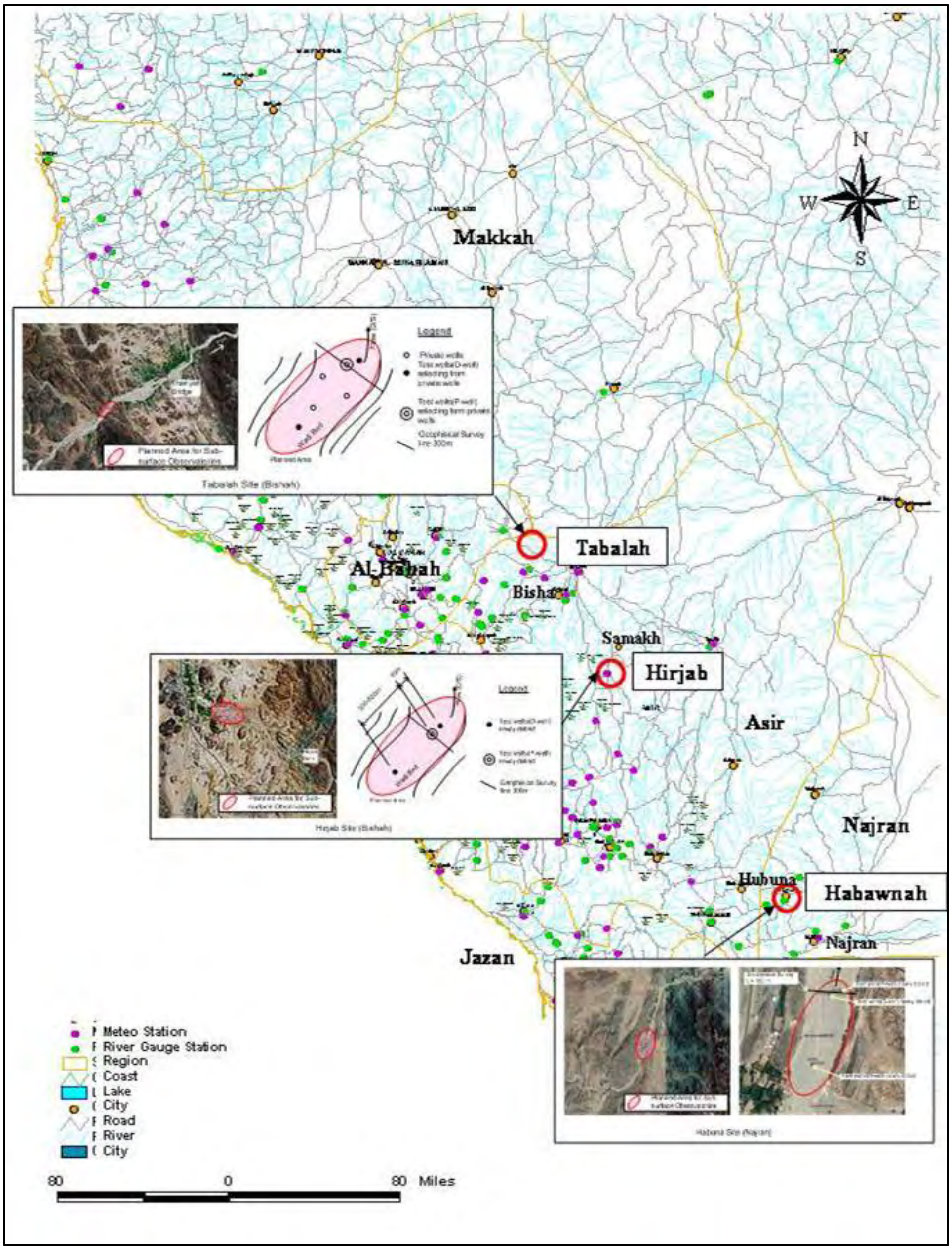


Figure 6-15 Location of Monitoring Stations for Water Level and Discharge

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.

(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.

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

In groundwater management, two points below are important.

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.

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.

6.6.4 Conservation of Water Resources

(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.

(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

6.6.5 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 6-16, 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.

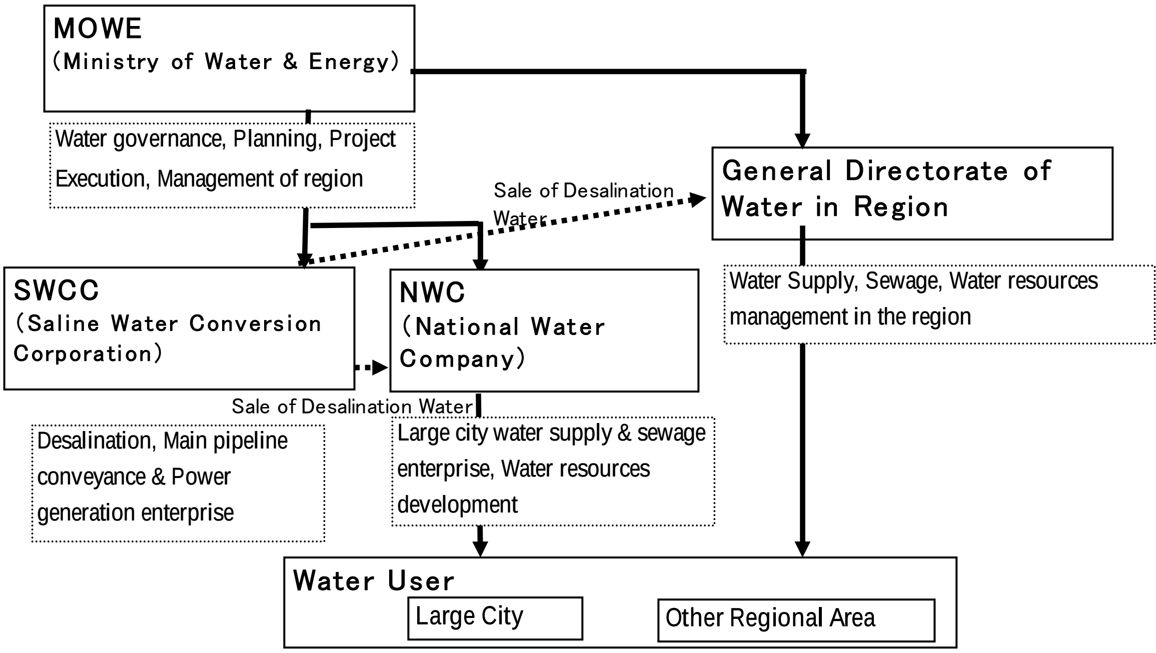


Figure 6-16 Water Management Organizations (Present)

(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 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.

<u>Renewable Water Production Corporation (RWPC)</u>

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

(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 master plan 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 master plan, 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.

< 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.

6.6.6 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..

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.

6.6.7 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.

- 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

6.7 Cost Estimate and Implementation Plan

6.7.1 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 6-20.

Table 6-20 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

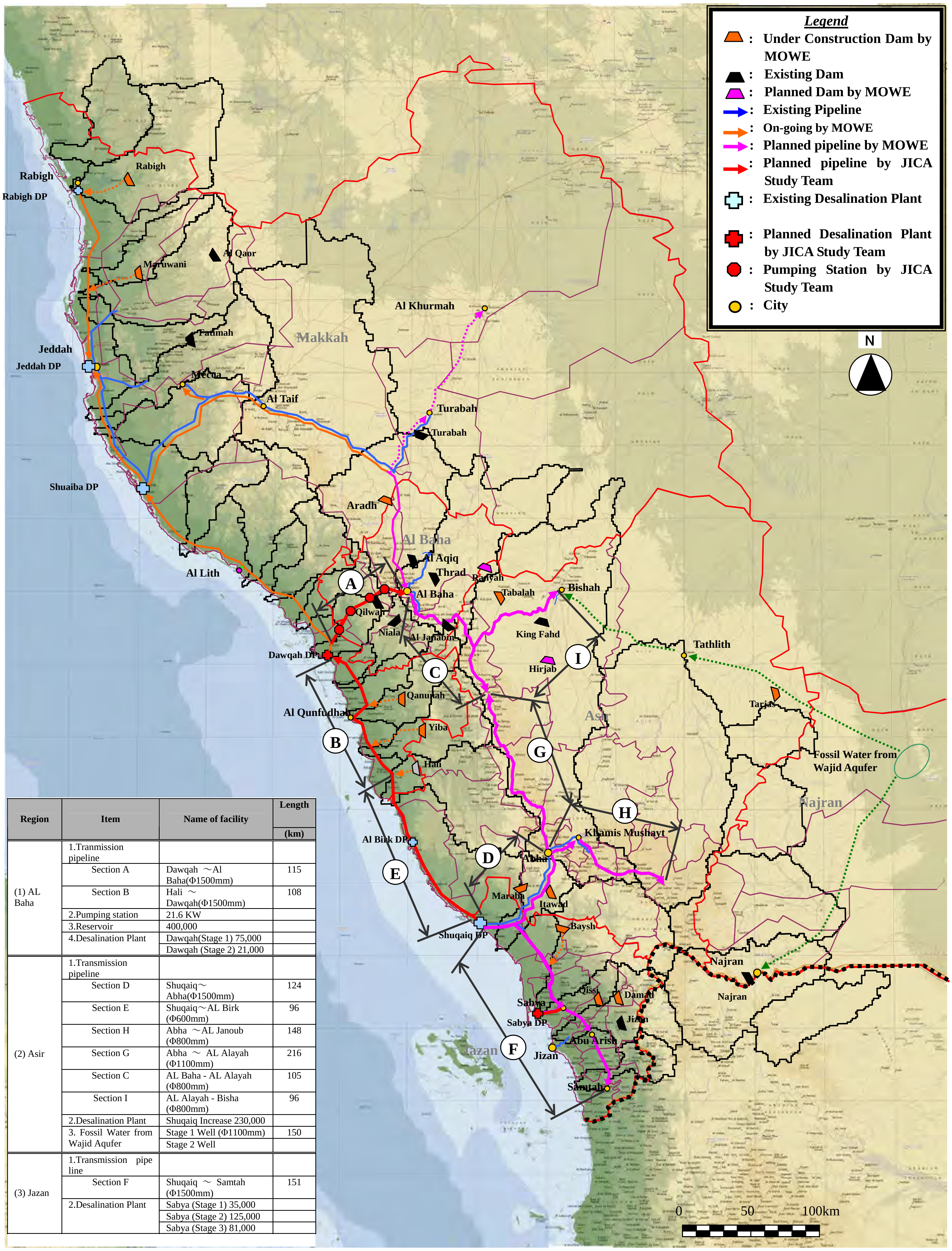
Note).Section “A～Ｉ” shows section (A) –(I) in Figure 6-17.

Dimensions of dams including under construction are also shown in Table 6-21.

Table 6-21 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
	Niala-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 6-17.



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 Janoub (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 ～ Samtah (Φ1500mm)	151
	2.Desalination Plant	Sabya (Stage 1) 35,000	
		Sabya (Stage 2) 125,000	
		Sabya (Stage 3) 81,000	

Figure 6-17 Water Supply Facility Plan in Al Baha, Asir and Jazan

6.7.2 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 Dam and Hirjab Dam, cost estimate were excluded from construction cost.

Table 6-22 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

Operation and maintenance cost from Year of 2010 to Year of 2035 is shows as follows.

Table 6-23 Operation and Maintenance Cost(Million SR/Year)

Region	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	Total
Al Baha	17	43	43	43	43	43
Asir	81	120	131	138	138	138
Jazan	102	114	158	187	*187*	187
Total	130	207	262	298	298	290

6.7.3 Implementation Program of the M/P

Implementation Plan for every five years on major facilities in the water M/P is shown in Table 6-24.

Table 6-24 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
		Dawqa 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					
		Niala& 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 - Bishah	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..

6.8 Evaluation for Water Master Plan

6.8.1 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 master plan can be technically evaluated as feasible.

- 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 master plan. The standard or criterion, which the government defined, was also used for planning, designing and cost estimating for the master plan.
- 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.
- Basic scenario for water demand projection as shown in Chapter 3, 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
- 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.
- 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.
- 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.
- 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.
- 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.

- 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.

6.8.2 Economic and Financial Evaluation

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.

(1) Basic Conditions of the Analyses

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

Table 6-25 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

<u>Adjustment of the Inflation</u>

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.

<u>Standard Conversion Factor</u>

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

[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

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.

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.

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.

(2) Water Value of the Water Supply Plan

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 World Bank (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.

Table 6-26 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

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

[3] Table of Remaining Life Time for SWCC Plants

economic value of water in the economic analysis.

Table 6-27 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 6-28 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

(3) Cost of the Water Supply Plan

<u>Summary of the Project Cost</u>

Necessary facility plan for the water supply was formulated, shown in the Table 6-29 and 6-30, 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 6-29 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 6-30 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

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.

(4) Results of the Financial and Economic Analysis

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.

Result of the Economic Analysis

Table 6-31 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.

6.8.3 Evaluation from Socio-Environmental Aspect

Contribution to the Socio-Economic Activity

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

Location of the Natural Conservation Areas and the Facilities Planned Areas

The location of the natural conservation areas and the facilities planned to construct under this master plan. 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.

Impact on the Natural Environment and Mitigation Programme

Integrated water resources development and maintenance in the master plan 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.

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.

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)

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.

Recommendations

The concrete construction locations or scale of the proposing facilities are not precisely identified yet at the master plan phase. Additionally, due to limitation of the information, the projection was conducted at Initial Environmental Examination (IEE) level. The degree of the projection and the effects of the countermeasures embrace uncertainty. Therefore, the KSA 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 F/S 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.

CHAPTER 7 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 (F/S) Study on reuse of reclaimed waste water is recommendable.

(4) Further Study on Two New Desalination Plant 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 seawater.

Desalinated seawater becomes the most useful water resources at the time of sever drought. Currently SWCC is supplying desalinated seawater 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 seawater 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 Master Plan 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 Master Plan 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) F/S 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, operation & maintenance 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 project 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 feasibility study on this very important project to realize soon for the regions and KSA.