4.2 Calculation of Water Balance (Model Output)

In the study 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. Along with the potential pathways of water movement in the study area, flowing outputs (a)-(f) are selected and post-processed among SWAT's options.

a. Area Rainfall
b. Potential Evapotranspiration
c. Actual Evapotranspiration
d. Soil Content
e. Water Yield (Surface Runoff)
f. Percolation / groundwater Recharge

(1) Area Rainfall

Area rainfall was calculated using the 85 records. The area precipitation for catchments was obtained as a range from 15 mm/year to 425 mm/year in 30 years' average (1975-2004) for the basin, as shown in Figure B.4-6.

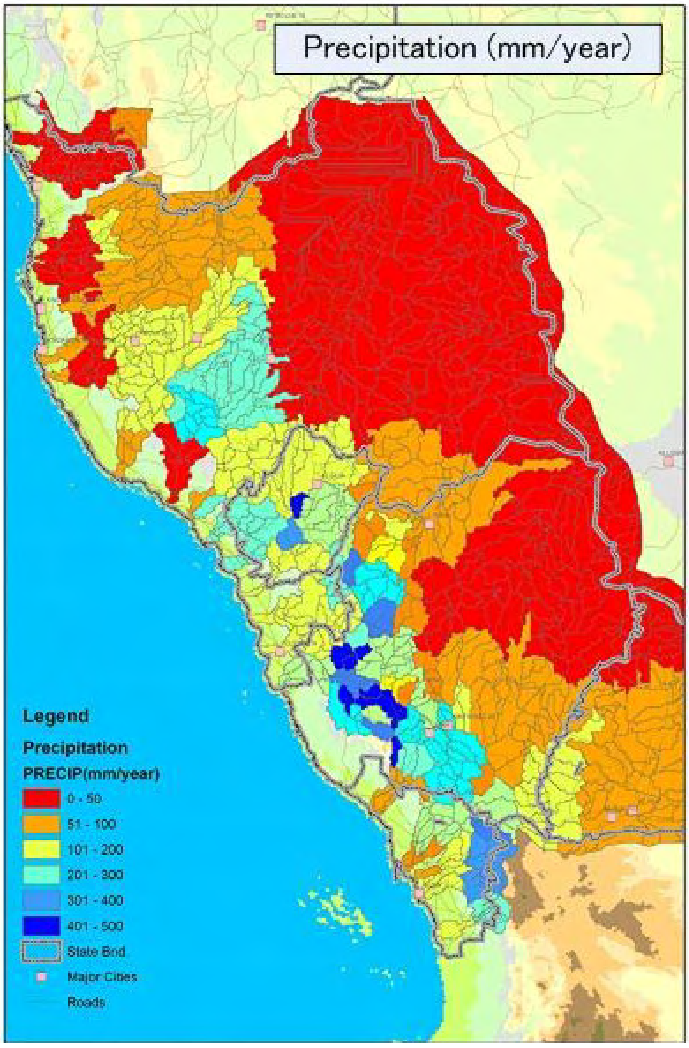


Figure B.4-6 Area Rainfall

(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, as shown in Figure B.4-7.

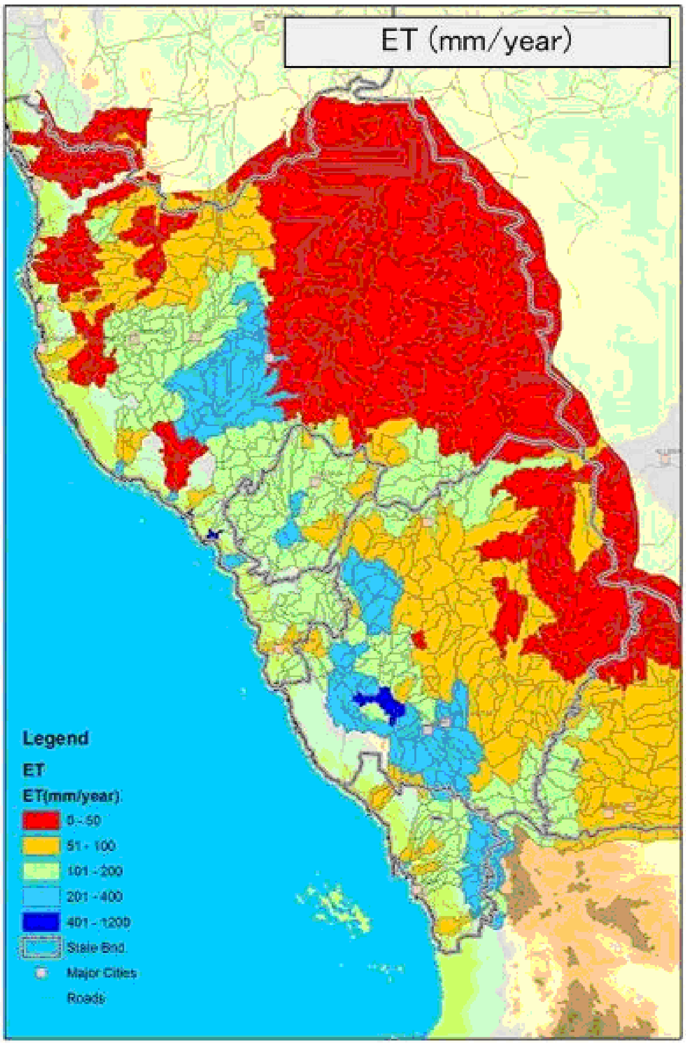


Figure B.4-7 Actual Evapotranspiration

(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. In Figure B.4-8 surface runoff (called as Water yield in SWAT as same meaning of surface runoff of individual catchments) is shown.

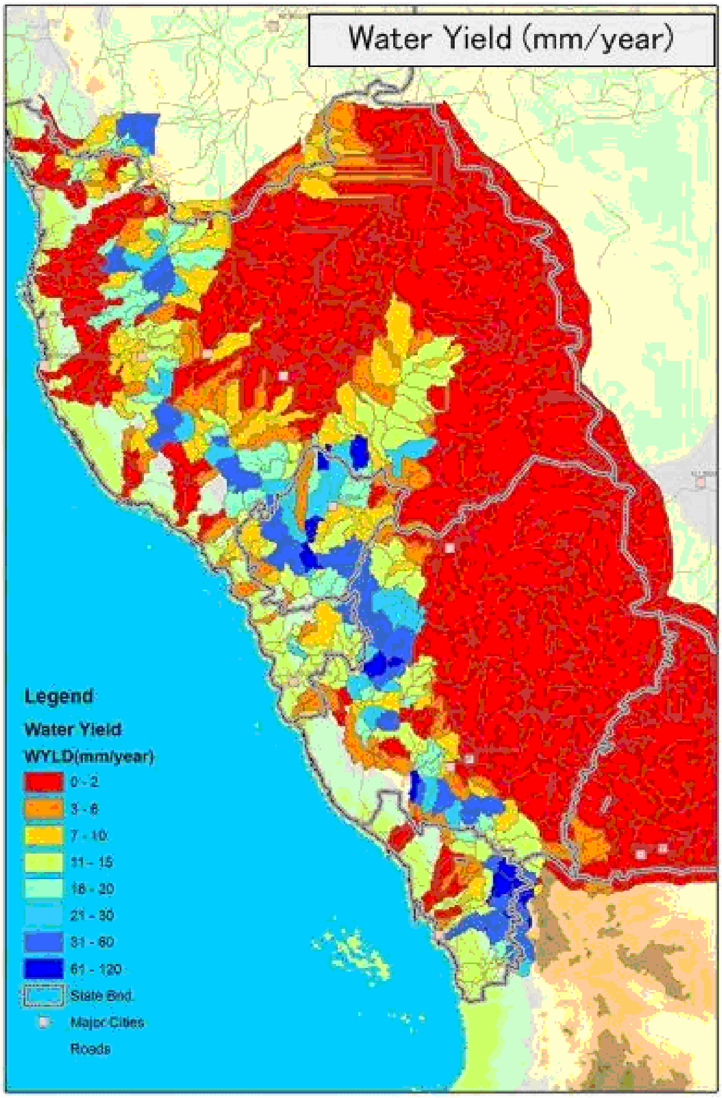


Figure B.4-8 Water Yield

(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. In Figure B.4-9 Percolation is shown.

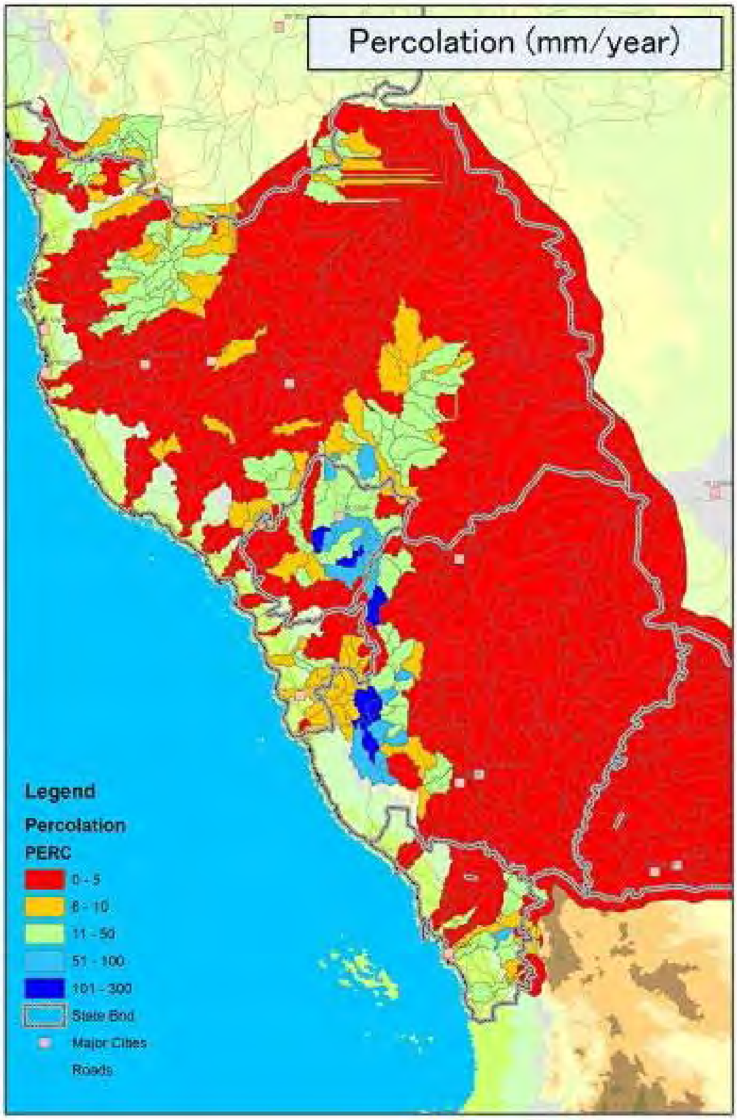


Figure B.4-9 Percolation

(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

As stated in the sub-sections of 4.1 to 4.2, 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 Najd were selected to apply the basin-wide analysis. The range of the basins is shown in Figure B.4-11, and the summary of water balance of basins are illustrated in Table B.4-2.

Figure B.4-10 Model Basin

Table B.4-2 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 B.4-2 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.

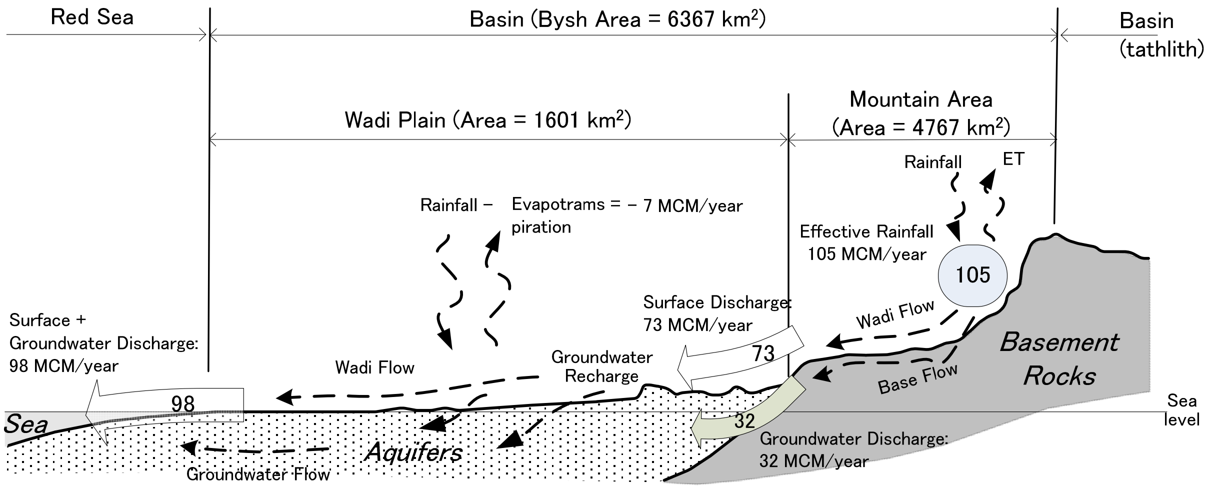
ER refers to the same amount of replenished water as natural water resources. The Total of both of them, 1,614 MCM/year, was regarded as Water Resource Potential of the five (5) regions in the study areas.

As well, this value also implies a maximum potential to be developed in the study 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) Water Balance of Mountain and Plain Areas in Major Wadi Basin

In addition to 31 outlets, internal outlets were set along the mountain border between mountains and plain areas and created a total of 64 divisions (31 plain catchments and 34 mountain catchments). For divisions, monthly discharge and water balance were calculated for 30 years. In Figure B.4-12 (1) ~ B.4-12 (6), the summary of water balance for the respective divisions is shown.

Diagram of Water Balance Item



Note： Baysh basin of B.4-11 (1) is explained to a case for the item of a balance summary. Baysh basin has the basin area of 6,367 km^2, and is sectioned into 1,601 km^2 on 4,767 km^2 and a wadi at a mountain basin. Although there are 200 mm/year of too much rainfalls in a mountain basin, a little more than 90% is lost in water loss, and remaining 22mm (105 MCM/year) flows through mountain as surface flow. The remaining 32MCM / years that 73MCM / year passes through a wadi Baysh river among 105MCM / year flow into a wadi in part as Base Flow or shallow groundwater. In the process in which the sea is reached from a mountain end, wadi flow (73 MCM/year) uses groundwater with conversion, uses it as surface water in part at the time of a flood, and is passed to the sea. Although there is rain of about 120 mm year on a wadi plain in the meantime, there is water loss exceeding this, it deducts and △-7 MCM/year is lost from surface water and groundwater.
98 MCM/year which deducted △7 MCM/yea from 105 MCM/year produced in mountain passes to the sea as surface water or groundwater.
Sources：The calculations shown by the underline were shown in the figure. (Figure B.4-11(1) ～ B.4-11(6))

1) Red Sea Coast (Jazan Area)

The Jazan area is regarded as a ‘wet area’ in the study area indicated as 180 to 300 mm/year of basin rainfall. At the southern part, Khurab, Jazan, Damad basin lain on and were calculated as high as 270 mm/year of area rainfall, annual runoff rate 32 to 57mm (Discharge 37 to 82MCM/Year) and 0.001 to 0.002m^3/sec/m^2 of specific discharge at the outlets of mountain border. However, since the rainfall record is lacking at the upper parts of their basins near/in Yemen territory, the model input had to be extrapolated by Saudi’s observatories. While in Baysh and Itwad basin, by both reasons of little rainfall and larger area of basin, they show less rainfall of 179 mm/year, annual runoff rate 19m (annual discharge 119 MCM/Year) and 0.0003 m^3/sec/m^2 of a specific discharge (Figure B.4-11 (1)).

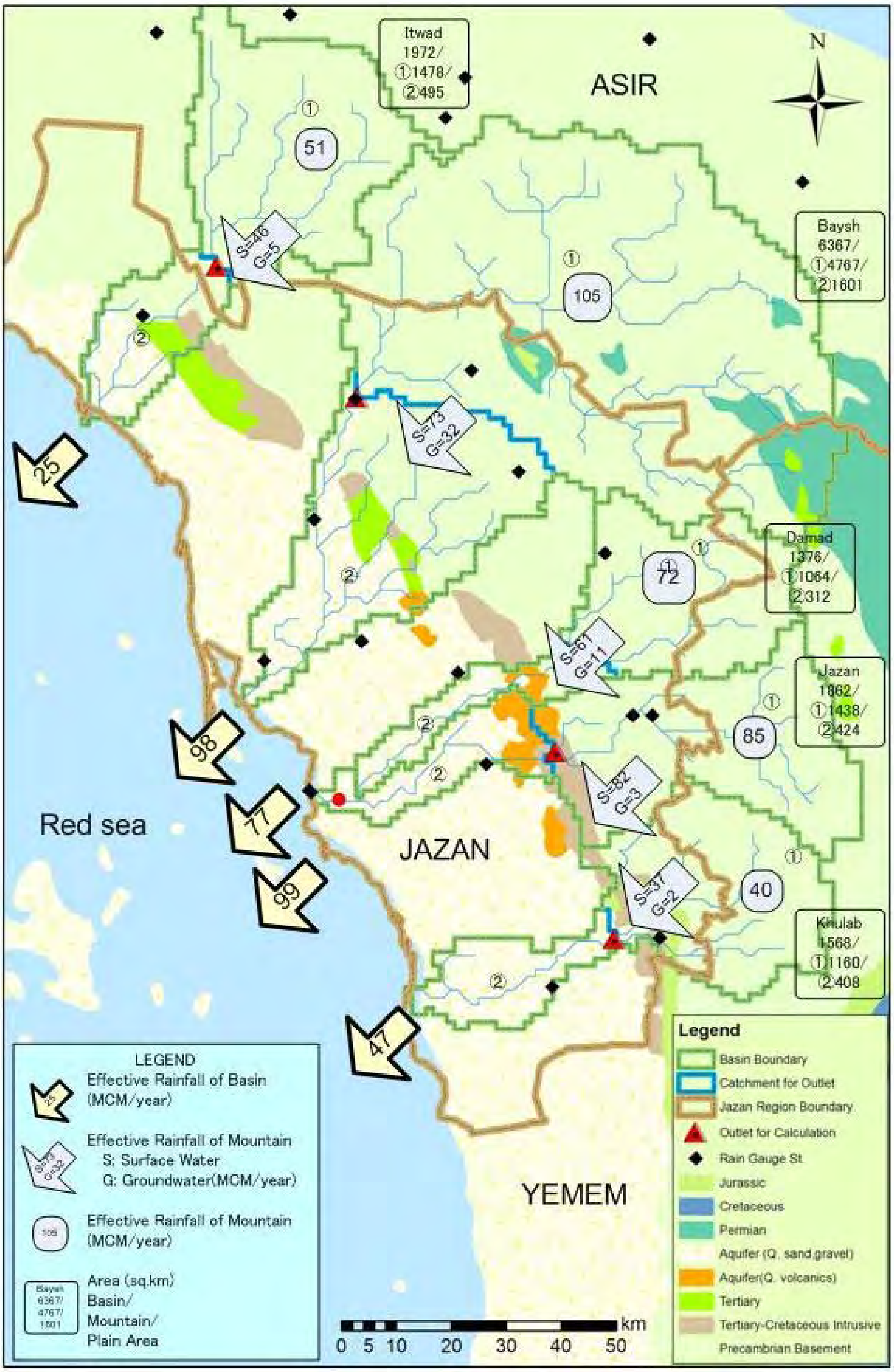


Figure B.4-11 (1) Summary of Water Balance (Red Sea Coast: Jazan Area)

2) Red Sea Coast (Asir-Makkah-Al Baha Area)

The area consisting of the Red Sea coast includes the Asir region, Itwad basin of Asir region, and Yiba basin of the Makkah region. There are Quaternary basalt and Precambrian rocks extruding nearby the Red Sea coast and forming coastal hills. Therefore, the alluvium plain limitedly develops within the narrow strip between hills. In the Hali basin, as large as 5,659 km^2 of catchment area, although it once flowed east in the mountain of the Asir region, it is barred by basaltic hills and consequently turns its flow north at the mountain foot. On the north side of a Hali, Yiba and Dawqah basins are standing parallel in a row, and flow into Alluvial plain with partial recharging into Alluvial deposit before reaching the Red Sea. The mean rainfall of the three basins was calculated as 191 mm/year, and a specific discharge was 0.025 $m^3/sec/m^2$. In the area, the groundwater is highly extracted by the shallow wells, consequently salinization is observed in some wells far from the wadi courses. As well, seawater intrusion is reported at wells located near the seashore. Hali basin conveys the largest water potential estimated as over 100 MCM/year, and Yiba basin follows as the second largest wadi (Figure B.4-11 (2)).

Figure B.4-11 (2) Summary of Water Balance (Red Sea Coast: Asir-Makkah-Al Baha Area)

3) Red Sea Coast (Al Baha−Makkah Area)

This area consists of six basins. There are three (3) Douquah basins which are located in the Al Baha region: Al Lith, Fagh and a Naaman basin in the Red Sea coast of Makkah region. In this area, the flood water produced in the mountains flashes into the plain. During flooding, a part of the surface water converts into groundwater, and the remaining is directly discharged as surface water into the Red Sea. Three (3) of Dawqah basins (in Al Baha) lie on hilly terrain, which forms Tertiary formation. Controlling by geologic conditions, their channels are in places strangulated. Moreover, the length of Alluvial plain is shorter (20 km) than the other basins. While the other three basins (in Makkah) have large alluvial plains with 30 km wide and tributaries also develop nearby the seashore. 157 mm/year of basin rainfall and 0.02 $m^3/sec/m^2$ of specific discharge were calculated. In general, aridity is higher and outflow is fewer toward the north. In this area, Dawqah basin has the highest water potential, and the amount of outflows was estimated as about 50 MCM/year (Figure B.4-11 (3)).

Figure B.4-11 (3) Summary of Water Balance (Red Sea Coast: Al Baha–Makkah Area)

4) Red Sea Coast (Makkah)

The area adjoins to the northern part of the region of Makkah and includes the southern part to Fatimah, Ghoran, and Khalays (Maruwani), Qudayd, Rabigh and Qahah basins. Among them, the mountain sections of Rabigh and Qahah basin are located in Madinah region. Tertiary basalt also spreads in the north of the area and Maruwani-Ghoran basin. The geologic feature acts as a pervious zone at the surface and accelerates the groundwater recharge even in the mountain area. To the seashore, the Alluvial plain develops between basalt hills. There is little rainfall of 74 mm/year and low specific discharge of 0.01m^3/sec/m^2 behaves as an arid zone. Since a big flood occurs at intervals of 10 years from several years ago, the amount of basin outflow that exceeds 100 MCM/year at the Maruwani and Rabigh basin is estimated. During the flood on November 26, 2009, 90 mm/4hrs of heavy rain was recorded (Figure B.4-11 (4)).

Figure B.4-11 (4) Summary of Water Balance (Red Sea Coast: Makkah Area)

5) Eastern Slope to Najd (Makkah Region)

This area lain on the eastern slope of Makkah to the Asir Region, and includes the Aqiq, Turabah, Ranya and Bisha basins from the north. All are large basins. The biggest one is Bisha basin and occupies 13,000 km^2. King Fahd Dam (biggest dam in KSA, catchment area of 7,600 km^2, storage of 325 MCM with reservoir area of 18 km^2 in Saudi Arabia) is located at the middle stream of the basin. Although the basins in the area are wide, they lie in the arid zone indicating as low as 100 mm/year of rainfall. As is the east or to the downstream of basins, evaporation rate is higher. By the actual measurement from 1975 to 1996, the pan-evaporation rate is reported as 10.1 mm/day as yearly average (MOAW, aluminum-Qahtany, 1998). Effective rainfall at the Turabah dam is as large as 150 MCM, and 117 MCM at Bisha (King Fahd Dam). The average rainfall of the area is 135 mm/year, and average specific discharge is calculated as $0.01m^3/sec/m^2$ (Figure B.4-11 (5)).

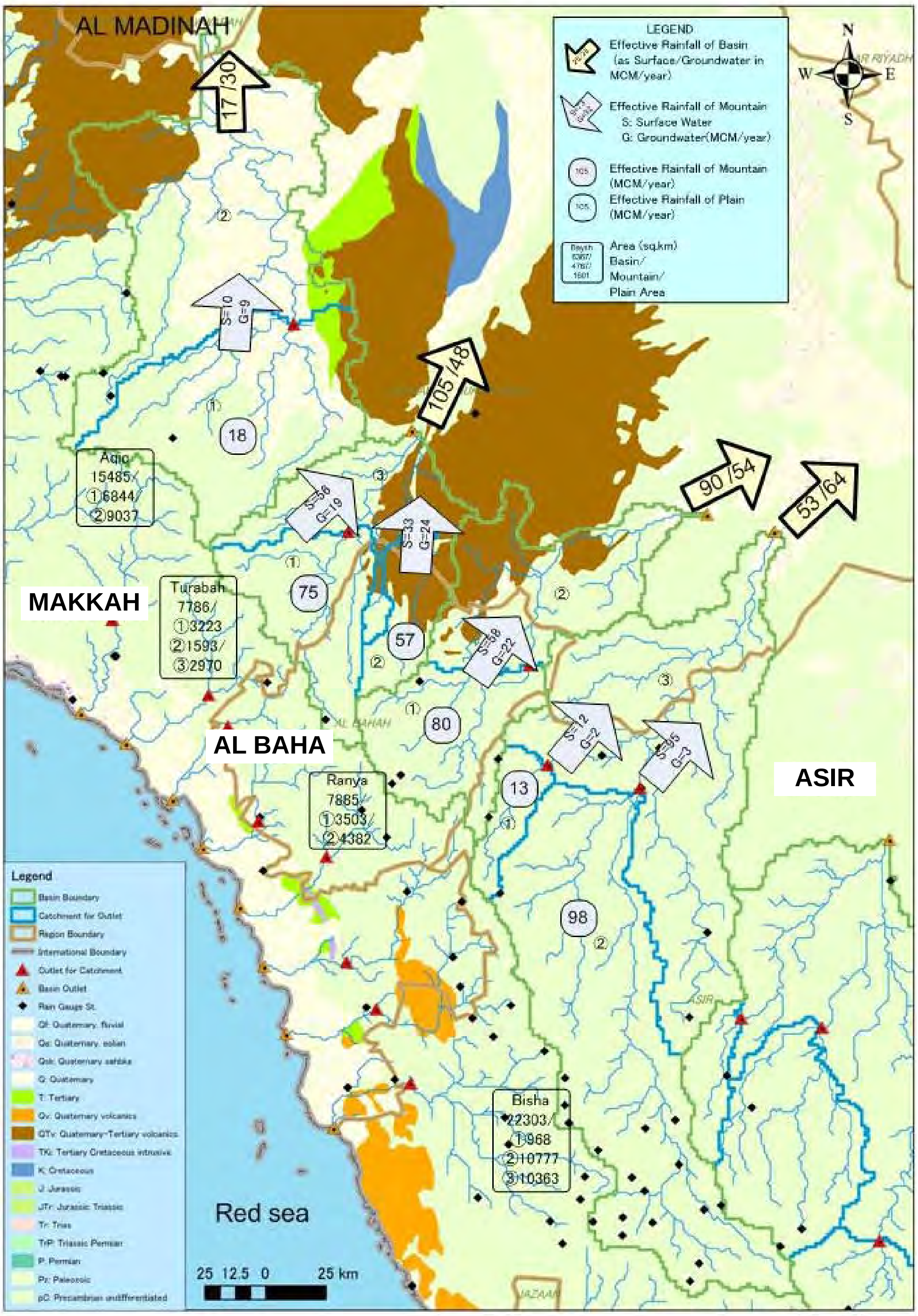


Figure B.4-11 (5) Summary of Water Balance (Najd-Ad Dahna: Makkah Area)

6) Eastern Slope to Najd (Asir-Najran Region)

This area includes the Tathlith, Habawnah, Najran, Hynah, Habal and Myayn basins. Of these, Three (3) basins (Tathlith, Habawnah and Najran) extend to the Najd-Hijaz mountain area. The other two (2) basins (Hynah and Habal) are located on Paleozoic Aquifer (mainly Permian Wajid Aquifer). At the southern end, Myayn basin adjoins to the Yemen territory. In this area, the amount of rainfall is supposed to be larger as it gets closer to Yemen, while it is fewer towards the northeast near Tathlith, Hynah and Habal basins. Although the inflow from Yemen is expected to be high at Habawnah, Najran and Mayayn basins, the calculation was not done with in-situ data due to the lack of observation data. As for the average rainfall, 99 mm/year was estimated and the specific discharge was calculated as $0.002m^3/sec/m^2$ (Figure B.4-11 (6)).

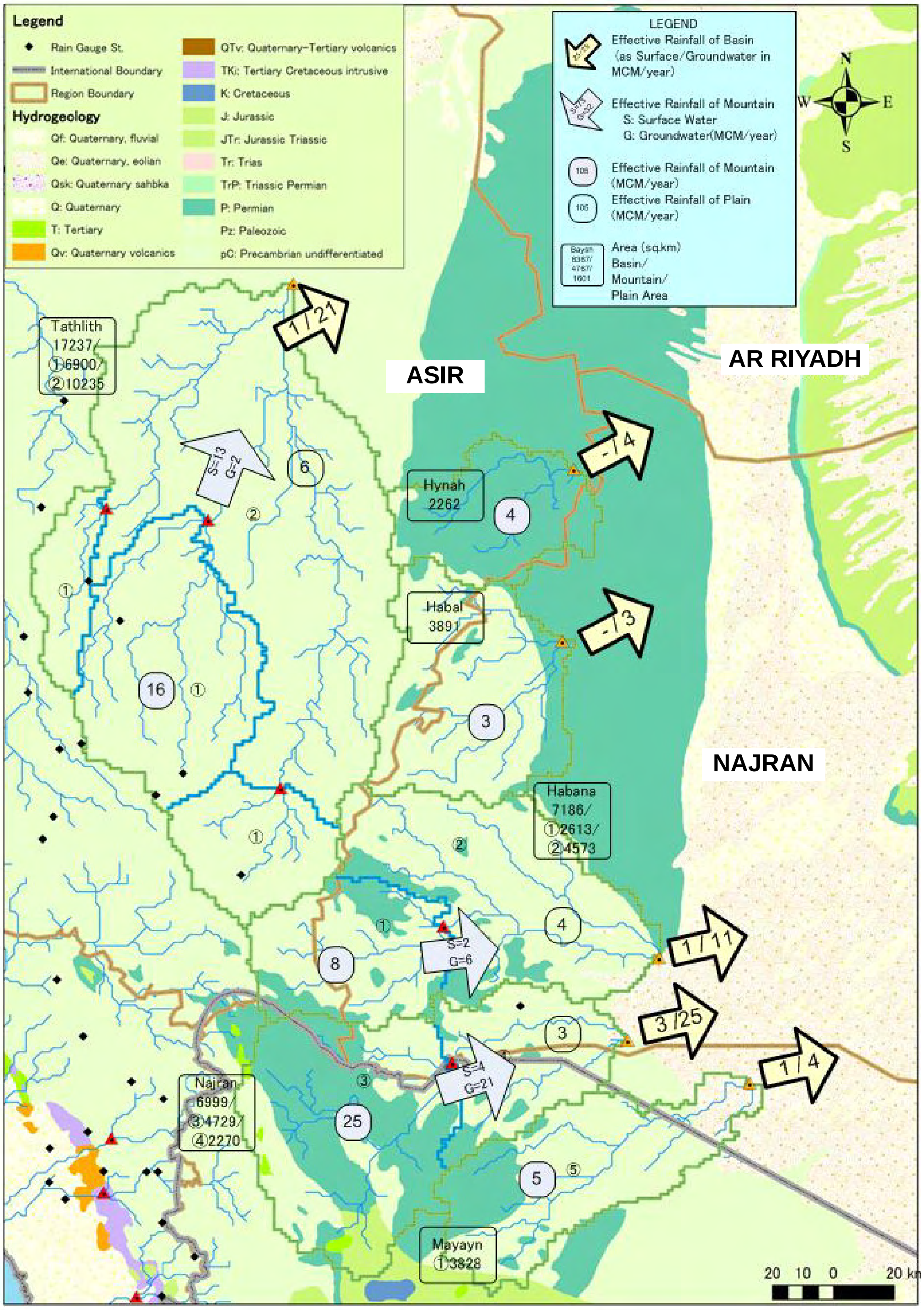


Figure B.4-11 (6) Summary of Water Balance (Najd-Ad Dahna: Asir-Najran Area)

(4) Estimation of Monthly Discharge

The monthly outflow was calculated for 30 years from 1975 to 2004 for major wadis as shown in Figure B.4-12. 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 study area.

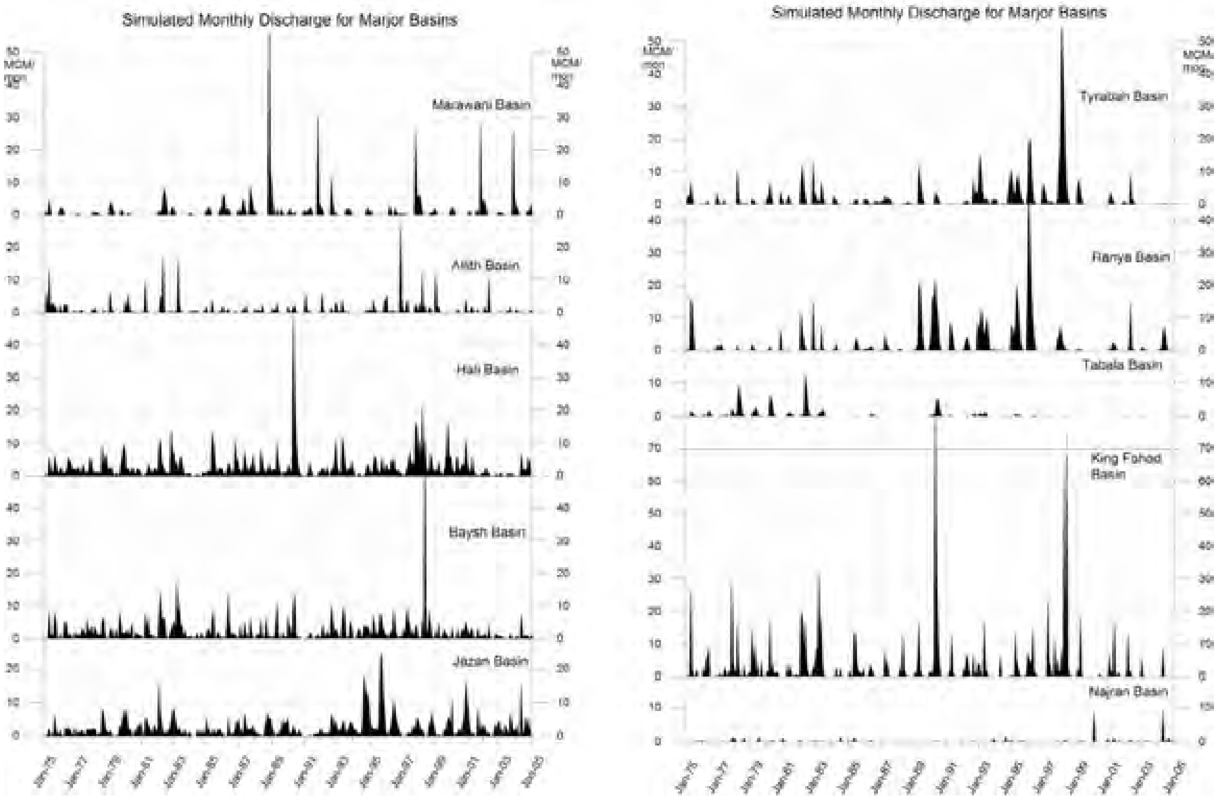


Figure B.4-12 Monthly Discharge of Major Wadis

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 B.4-13. When 1/10 probability (draught year) is designated in the figure, 34 MCM (an average of 82 MCM) was taken at Jizan Dam while 11MCM (an average of 95 MCM) was obtained at King Fahd Dam.

(5) Water Resources Potential between Major Basins

In order to investigate the actual condition of discharge in the plain area and to examine the water balance of the fore-mountain which was not contained as the model area, water potential of inter-basins (between basins) was analyzed.

As described in previous sub-sections, major basins had been already evaluated with 64 outlets located along the coastal line and at existing dams. However, minor wadis between major wadis are now developing by MOWE. Especially in the fore-mountains of Jazan and the southern part of Asir, dam plans and their constructions are progressing for collecting flood water.

With setting 20 inter-basins along the Red Sea coast as shown in Figure B.4-14, their flow rates were presumed by the specific discharge method.

The value of specific discharge was prepared based on the results of the SWAT model for both the mountains and plain parts of the above 20 inter-basins.

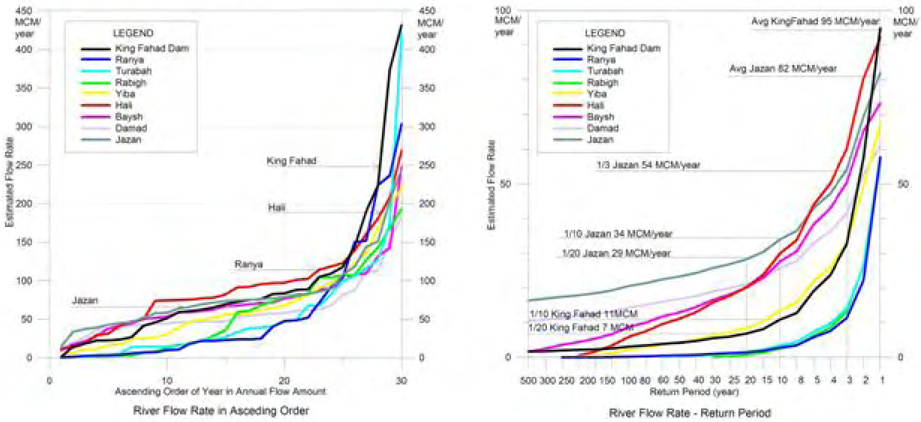
The total area of 20 inter-basins is 25,400 km^2, comprising 17,000 km^2 of Alluvial plain and 8,400 km^2 of the mountain area. With the calculation, as the most productive area, 91 MCM/year (as an average of 0.016 $m^3/sec/m^2$ of specific discharge) and 34 MCM/year (0.009 $m^3/sec/m^2$) were obtained from

Jazan (5,600 km^2) and Asir (4,200 km^2) respectively. As well, 33MCM (0.002 m^3/sec/m^2) was estimated for the northern part of the Red Sea coast covering 15,600 km^2. In the groundwater model applied in the Jazan area, the amount of outflows of 91 MCM/year was also applied as boundary condition.

(6) Water Balance in Region

The water balance calculated in each basin was re-arranged and summed up based on their outlets position in each region. In Table B.4-3(1), the summary of the water balance in the mountain area (mountain + inter-basin) is shown. As well, in Table B.4-3(2), the balance of the study area is summarized.

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



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 B.4-13 Non-Exceedance Probability of Discharge in Major Wadis

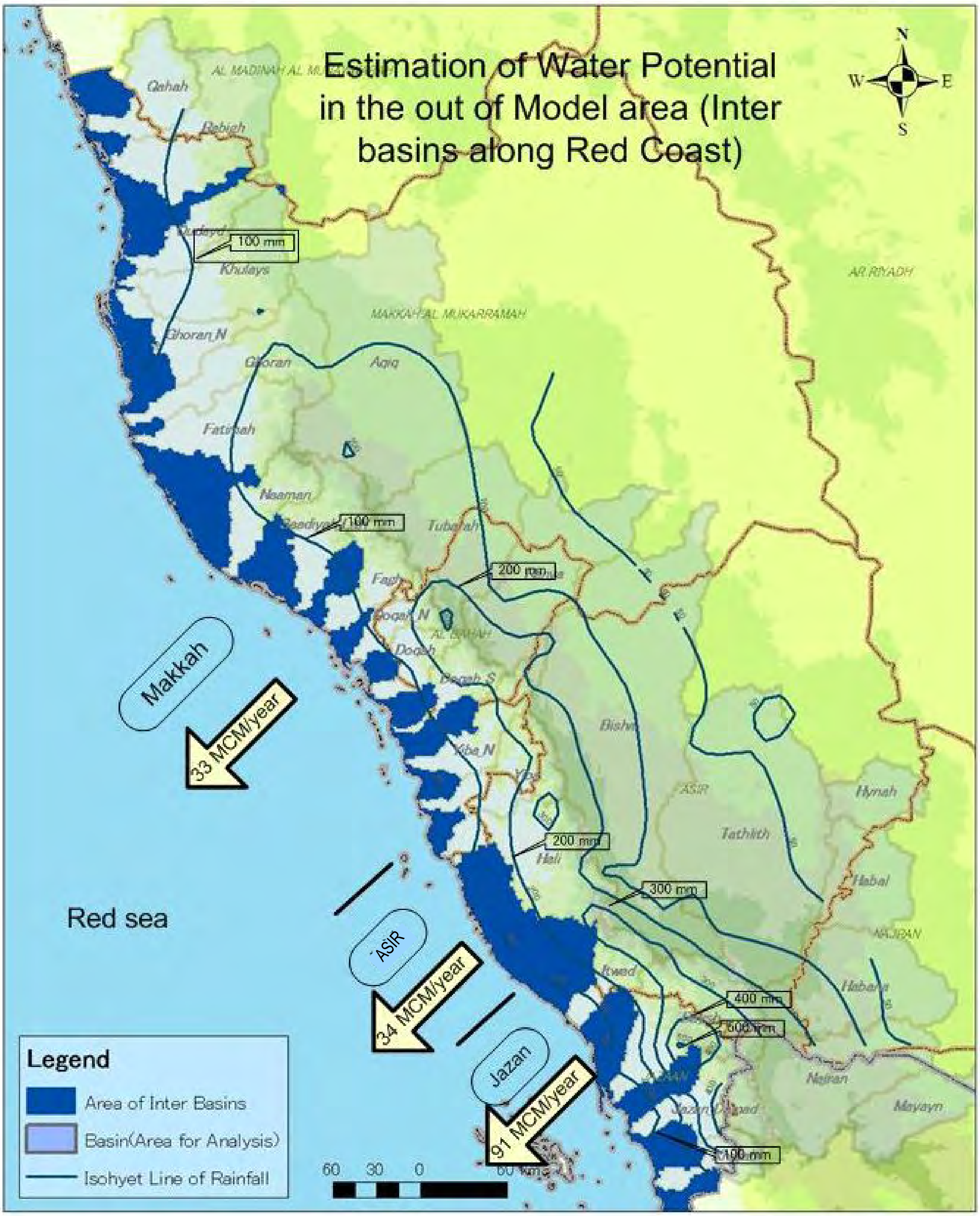


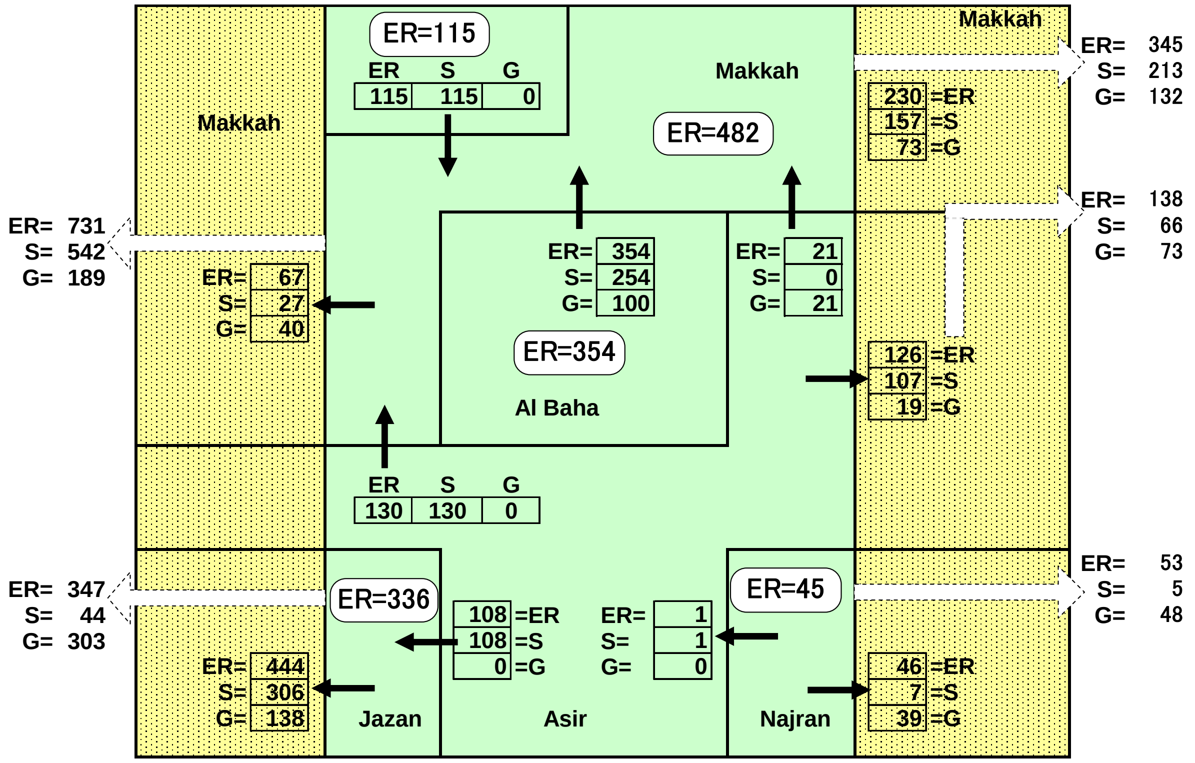
Figure B.4-14 Water Resources Potential Between Major Basins

Table B.4-3 (1) Water Balance in Region - Mountain Area -

Basin					Water Potential (MCM/year)		
No	B_ID	Basin	Area (Sqkm)	Outlet Ptn. At	ER (Moutain)	Surface Runoff	Ground-water Runoff
1	J5	Khulab	1,160	jazan	40	37	3
2	J4	Jazan	1,438	jazan	86	82	3
3	J3	Damad	1,063	jazan	72	61	11
4	J2	Baysh	4,767	jazan	105	73	32
5	J1	Itwad	1,478	jazan	51	46	5
		interBasin			91	6	85
				Jazan	**444**	**306**	**139**
6	M12	Hali	4,850	makkah	123	92	31
7	M11	Yiba	2,812	makkah	81	67	14
8	M10	Yiba_N	1,640	makkah	45	32	13
9	M9	Doquah_S	1,496	makkah	52	45	7
10	M8	Doquah	1,080	makkah	25	18	7
11	M7	Doquah_N	960	makkah	31	28	3
12	M6	Fagh	1,706	makkah	44	38	6
13	M5	AlLith_Sadiyah	2,641	makkah	40	29	12
14	M4	Naaman	1,351	makkah	38	30	8
15	M3	Fatimah	2,756	makkah	42	32	10
16	M2	Ghoran	3,807	makkah	51	30	21
17	M1	Ghoran_N	1,016	makkah	15	10	5
18	M0	Khulays	4,390	makkah	100	67	33
19	M1	Qudayd	1,341	makkah	15	9	6
20	M2	Rabigh	4,433	makkah	99	72	27
21	M3	Qahah	2,842	makkah	5	2	3
		interBasin(via.Ashir)			34	9	25
		interBasin(via.Ashir)			33	3	30
				Makkah(red coast)	**872**	**613**	**259**
22	M1	Aqiq	6,448	makkah	18	10	9
23	M2	Turabah	4,816	makkah	133	90	43
23	M2	Mountain:Turabah Dam		makkah	(75.3)	(56.2)	(19.2)
23	M2	Mountain:kara Al Qawamah Dam		makkah	(57.4)	(33.4)	(24)
24	M2	Ranya	3,503	makkah	80	58	22
				Makkah(njed)	**230**	**157**	**73**
25	A1	Bisha	12,908	asir	111	107	4
25	A1	Mountain:King Fahad Dam		asir	(97.6)	(94.9)	(2.7)
25	A1	Mountain:Tabalah Dam		asir	(13.4)	(11.8)	(1.5)
26	A2	Tathlith	6,900	asir	15	1	15
				Asir	**126**	**107**	**19**
27	N1	Habana	2,613	Najran	8	2	6
28	N2	Najran	4,729	Najran	25	4	21
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
				Najran	**46**	**7**	**39**
		Ground Total	100,225		**1,718**	**1,189**	**529**

Table B.4-3 (2) Water Balance in Region - Basin -

Moutain-Plain (Area 161,150 sqkm)+Inter Basins(Area 25,353 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
				Jazan	**347**	**44**	**303**
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
				Makkah(red coast)	**731**	**542**	**188**
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
				Makkah(njed)	**345**	**213**	**132**
25	A1	Bisha	22,303	asir	117	53	64
26	A2	Tathlith	17,237	asir	21	13	8
				Asir	**139**	**66**	**73**
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
				Najran	**53**	**5**	**48**
Total (on basins)			161,149		**1,614**	**870**	**744**
Total (Inter basins)			25,353	red coast	158	18	140
Ground Total			186,502		1,772	888	884



Notes: ER=Effective Rainfall, S=Surface Water, G=Groundwater
: Mountain Area (Appearance of ER) : Plain Ares (Movement of ER)

Figure B.4-15 Schematic Diagram of Water Balance in Region

Moreover, the schematic diagram of IN/OUT of surface/groundwater resources are delineated in Figure B.4-15. In the diagram, the inner side of bundling with 'light green' indicates the water balance of the mountain area and the outside with 'yellow' shows that of the whole study area.

4.4 Groundwater

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 B.4-4).

In Figure B.4-16, 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 B.4-4 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.

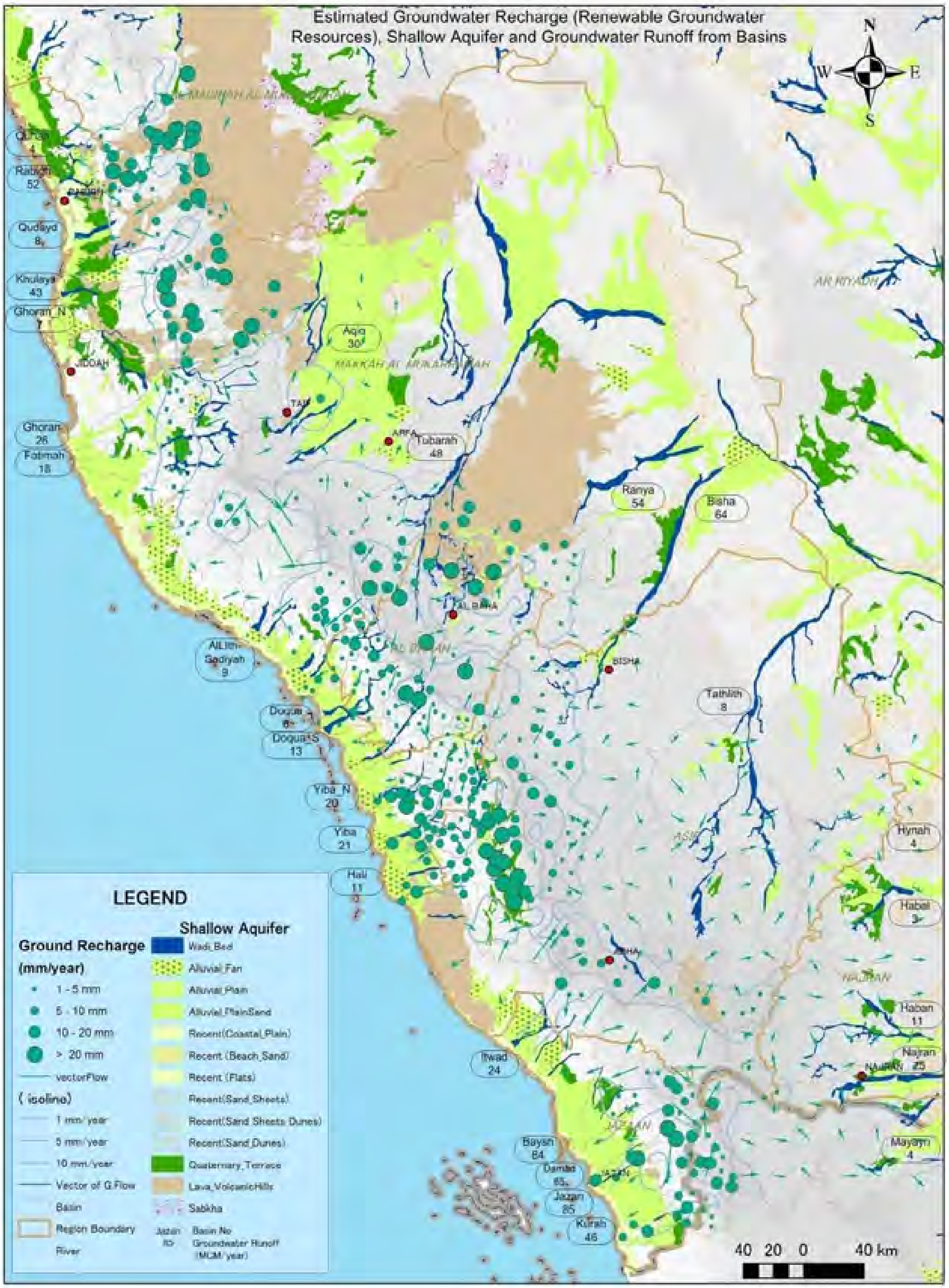


Figure B.4-16 Distribution of Shallow Aquifer and Groundwater Recharge

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.

Specific discharge for each catchment was calculated by dividing the amount of discharge by catchement area. Discharge for each governorate was calculated by multiplying specific discharge by governorate administration area. Conventional water resources potential was summarized and shown in Table B.4-5.

Table B.4-5 Conventional Water Resources Potential for Demand and Supply Plan for each Region

(MCM/Year)

Items (Administrative 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	782.0	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	565.2	76.1	234.5	75.1	332.2	1,283.1

Note)Total Area for 5 Regions: $308,478Km^2$

CHAPTER 5 WATER STRATEGY, POLICY, AND ACTION PLAN

5.1 Outline

The policy and strategy about water development management of the KSA were proposed by the World Bank (WB) as a National Water Strategy (NWS) (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
  - Water policy and strategy
  - Action plan – Water resources development
  - Action plan – Water resources conservation
  - Action plan – Water use management
  - Action plan – Adjustment of organization and institution
  - Summary of action plan of each region

Target year of action plan in five regions is set to 2035. The goal of action plan is to carry out action plan prepared based on the water policy and strategy, carries out development in which socioeconomic sustenance of target area is possible, and can lead the life in which people are rich and comfortable.

5.2 Current Condition and Issues of Water Sectors

5.2.1 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 B.5-1.

The total amount for water use

Total water use in the study area is ranked first in Jazan Region, 1,542 MCM; second in Makkah Region, 1.195 MCM; third in Asir Region, 342 MCM; forth in Najran Region, 229 MCM; and fifth in Al Baha Region, 68 MCM. The amount of the water for agricultural use used which occupies 99% has projected the Jazan Region in five states.

Water Use By the Sector

In the whole study area, water for agricultural use accounts for 84.4%, the following municipal water accounts for 14.4%, and industrial water accounts for 1.2%. Water for agricultural use serves as the almost same rate as 86.5% (the 8th Five Year Development Plan) of the national average.

In Makkah Region, it is 33%, followed by Al Baha 21%, Asir 17% , Jazan and Najran accounts for 10% or less rate of occupying to the whole municipal water consumption.

The amount of the water for agricultural use used accounts for 90% or more in the Jazan Region, and the Najran Region, and accounts for 80% or more is occupied in the Asir Region.

Ration of Renewable Water Resource and Non-conventional Water Resource

In Al Baha Region, Jazan Region, and Najran Region, renewable water resource is 100% available for water resource. The ratio of it is 65% in Makkah Region and 83% in Asir Region.

The two Regions have a high ratio in non-conventional water resource (desalinated seawater and reclaimed wastewater), 35% and 17% respectively. If it restricts to a municipal water, in Makkah Region, it will depend on for about 68% on a non-common type (freshening water) about 88% also in the Asir Region.

Table B.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 sea water	370.7	0.0	0.0	370.7
	- Reclaimed wastewater	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 sea water	0.0	0.0	0.0	0.0
	- Reclaimed wastewater	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 sea water	39.5	0.0	0.0	39.5
	- Reclaimed wastewater	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 sea water	0.6	0.0	0.0	0.6
	- Reclaimed wastewater	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 sea water	0.0	0.0	0.0	0.0
	- Reclaimed wastewater	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

5.2.2 Water Sectors Issues

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

Table B.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 sea water	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 wastewater	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 wastewater	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 sea water 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 wastewater 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 wastewater 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 B.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 wastewater	✓	✓		✓	✓
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 wastewater 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.

5.3 Balance of Water Demand and Supply according to Region

5.3.1 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 sea water are included in the volume. Moreover, the municipal water demand in 2035 (from Table B.3-23 to Table B.3-27) presumed by 3.1.6 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 sea water. It is because the renewable water resources of development water value are cheaper than desalinated sea water, and desalinated sea water 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 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 Fig. 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 used by vested water users and recharged to a groundwater aquifer.

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

Table B.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 B.5-4 serve as a target value of the amount of water resources which should be developed by a planned target year.

Table B.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 Wastewater.

Next, it was examined that how much renewable water resources can be developed, and the amount of water of which to develop in water resources other than renewable water resources for each region. The situation of each region was shown in Table B.5-9 from Table B.5-5.

In this examination, it was assumed that the region where dam is constructed use exploited the renewable water resources fundamentally. However, when the rule for water allocation is already formed among regions, the rule of the allocation is applied. Allocation of the renewable water resources by a dam is examined in Chapter 4.

It is assumed that development of renewable water resources was achieved by dam construction. Potential at dam site which is shown in Table B.5-5 to the Table B.5-9 is development potential at dam site and it is derived from calculated water resources potentials in each basin. As mentioned above, it is 70% of the dam point potential which the Study Team uses as a quantity which can actually be used, and it supposes that the 30% is assigned to municipal water.

The dam site was assumed through a map, the information from Google Earth, and exchange of opinions with MOWE. The study team found that dams have been constructed, are under construction and the future dam plan are also drawn up at sites where it is promising for dam construction. It is judged that a promising large-scale storage dam is already in ending with construction or a construction phase, and the new promising dam site is not left behind. Therefore, all dams here for water resources development are dams which are under construction or under planning stage by MOWE.

<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 B.5-5. Presumption of the quantity of renewable water resources which can be developed was used based on renewable water-resources potential (Table B.4-3 (1)).

Table B.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 ($1000m^3/d$) (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	1,383	35	25	30
W-15	Yiba	2,812	81	Yiba	2,242	65	45	38
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 potential.
* 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 B.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 B.5-6.

Table B.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 (1000m^3/d) (8)*30%
W-15	Yiba	2,812	81	Nilah Qilwah	361 302	10 9	7 6	6 5
E-03	Ranya	3503	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 potential.
* 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 B.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 B.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 B.5-7.

Table B.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 (1000m^3/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 potential.
* 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 B.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 B.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 B.5-8.

Table B.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 potential.
* 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 B.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 B.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 B.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 B.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 B.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	

5.3.2 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.

A case 3 (planting area at the 2007 level) was used to consider water demand-and-supply balance examination of water for agricultural use like B Chapter 3 3.2 .4 sensitivity analysis.

(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 wastewater 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 B.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

Conversion of Crops

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 Wastewater

In the KSA, National Irrigation Authority (NIA) built the large-scale irrigation institution which reused treated wastewater in the suburb of Riyadh, and reuse of the treated wastewater is performed from 1982. However, although the reuse of treated wastewater 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 wastewater 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 wastewater 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 B.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 wastewater, and an agricultural area are unevenly distributed in a region, it is necessary to check them according to the /governorate classified by basin.

Table B.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),

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 B.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

5.3.3 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). The possible planting area of the present condition and in 2035 for every governorate is shown in Figure B.5-1. That the planted area of present condition is continuable in general is surmised.

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

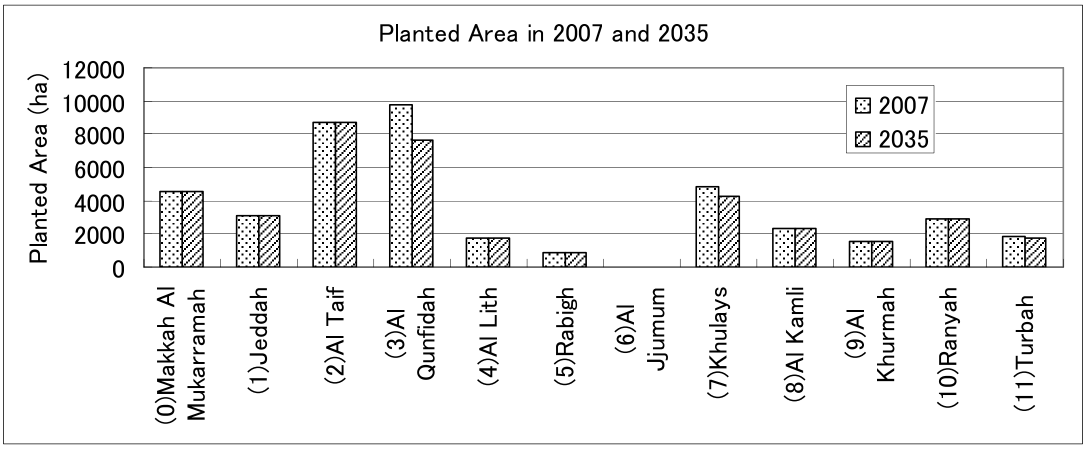


Figure B.5-1 Planted Area Comparison in 2007 and 2035 in Makkah Region

<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 a% of an area ratio). The possible planting area of the present condition and in 2035 for every governorate is shown in Figure B.5-2. That the planted area of present condition is continuable in general is surmised.

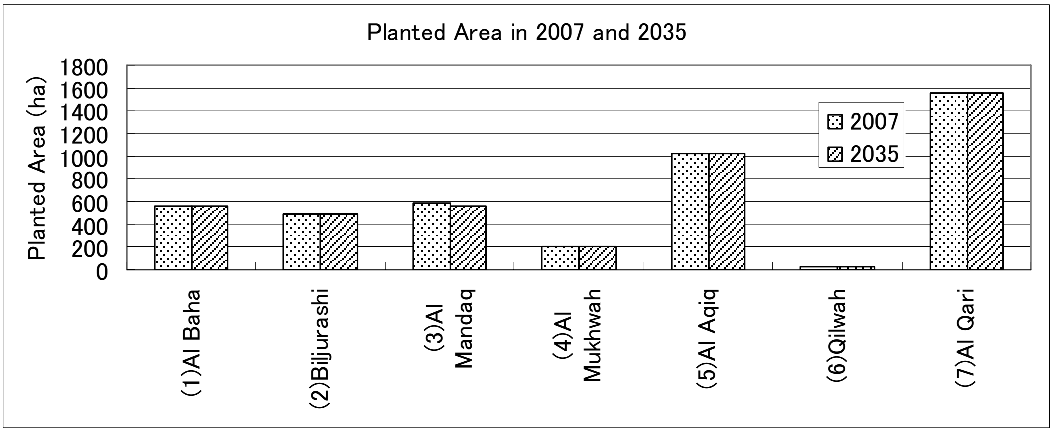


Figure B.5-2 Planted Area Comparison in 2007 and 2035 in Al Baha Region

<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). The possible planting area of the present condition and in 2035 for every governorate is shown in Figure B.5-3. That the planted area of present condition is continuable in general is surmised.

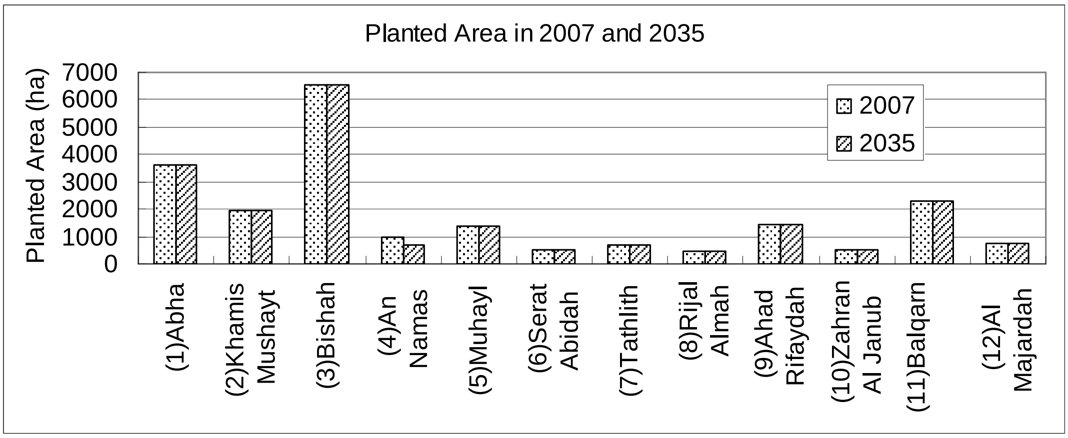


Figure B.5-3 Planted Area Comparison in 2007 and 2035 in Asir Region

<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). The possible planting area of the present condition and in 2035 for every governorate is shown in Figure B.5-4.

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. It is recommended to monitor and evaluate the result carefully in these governorates to grasp relations between planted area and groundwater.

Table B.5-13 Present (2007) Planted Area and Projected 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
Samatah	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

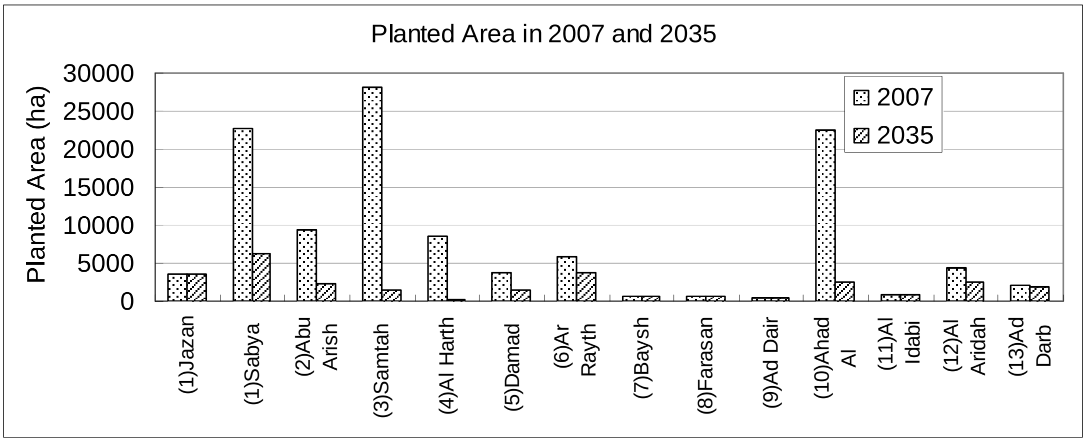


Figure B.5-4 Planted Area Comparison in 2007 and 2035 in Jazan

<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). The possible planting area of the present condition and in 2035 for every governorate is shown in Fig. B.5-5.

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.

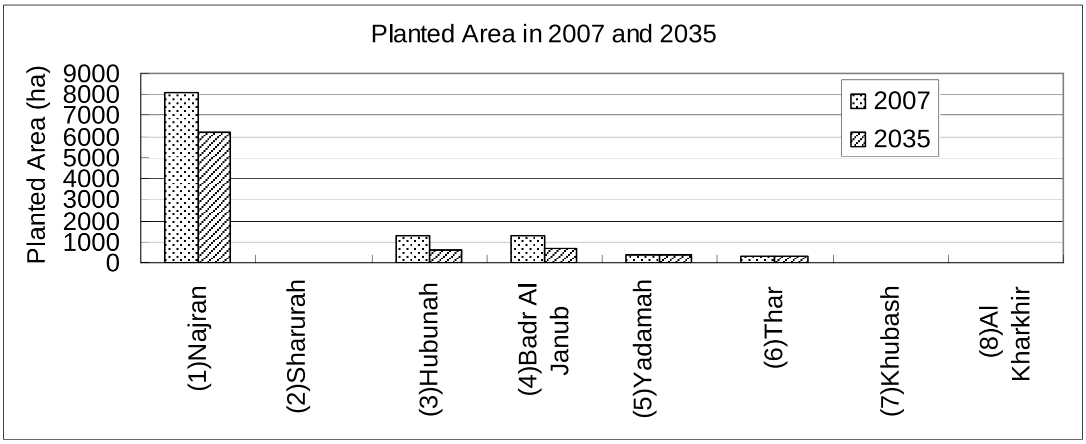


Figure B.5-5 Planted Area Comparison in 2007 and 2035 in Najran

5.4 Basic Policy for Water Resources Development , Utilization and Management

5.4.1 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.

(1) 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

(2) 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 B.5-6).

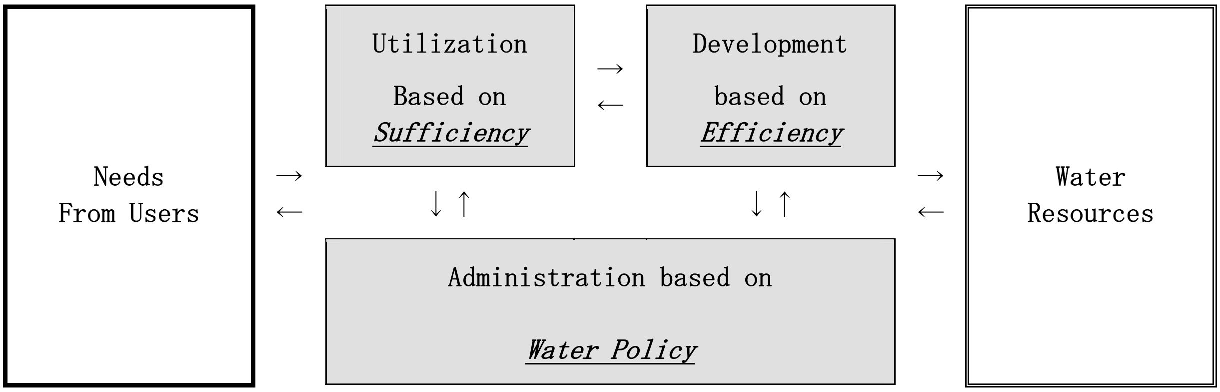


Figure B.5-6 Three Criteria and Actions for Securing Water Resources

<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 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.

5.4.2 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.

(1) 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 sea water 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.

(2) 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.

(3) Combination of Renewable Water Resources and Desalinated Sea Water 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 sea water and fossil groundwater with renewable water.

(4) Effective Development and Use of Reclaimed Wastewater

Reclaimed wastewater 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 sea water, etc.

(5) Necessity of Demand Management

Available renewable water resources are restricted by natural conditions, and production of water by desalinization of sea water 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.

(6) 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.

5.5 Water Policy, Strategy and Action Plan of Five Regions

5.5.1 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 B.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 sea water ◆ 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 Sea Water properly
Strategy	◆ To make rational plan for using desalinated sea water as stable water resource to supplement renewable water ◆ To make plan for using desalinated sea water well balanced considering renewable water resources and reuse of reclaimed wastewater
Policy : WP4	To Improve Reuse of Reclaimed Wastewater
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

Items	Contents
	(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
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, wastewater 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

5.5.2 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 Sea Water properly

(1) Water Resources Development of Each Region

<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. (About a dam position, refer to Figure B.5-7)

Table B.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

Notes: planned water supply is basically calculated using renewable water potential estimated by the study team.

<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 sea water or fossil groundwater (Najran Region and an eastern part of Asir Region) to the insufficiency.
- It is assumed that reclaimed wastewater 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 sea water and fossil groundwater. In addition, about use of the reclaimed wastewater 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 wastewater as a safety side.
- In order to maintain a social function also in unusual water shortage etc., allocate the desalinated sea water or fossil groundwater which is a stable water resources in 50% of municipal water in each state.
- Allocate reclaimed wastewater 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.

(2) 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-sea-water facility, since transportation cost becomes large in order to supply water of seawater desalination, an economical burden increases in use of desalinization-of-sea-water water.

For this reason, Tathlith and Bisha in the eastern part of Asir region and Najran region which located in inland, a plan to supply the insufficiency of renewable water resource to demand with fossil aquifer is formed. The premises of this study are these plans made by MOWE. The watering pipe plan of fossil water is as follows.

- West Najran Wajid Well Field ～Tath Lith～Bisha
- West Najran Wajid Well Field ～Najran

Fossil aquifer is utilized as municipal water, and it does not utilize for water for agricultural use. Fossil aquifer is the water resources stabilized in order to nearly be influenced by natural conditions, such as rain. So, it shall be positioned as desalination water for a stable watershed which raises irrigation safety.

(3) Construction of New Desalination Plant

From the potential examination result of renewable water resources, only development of renewable water resources cannot satisfy increased future demand of municipal and industrial water in all five regions. The difference of a future demand of municipal water and water development quantity shall be fundamentally supplied with desalinated sea water. However, MOWE is planning supplying fossil groundwater instead of desalinated sea water in the area such as Najran region and Tathlith in the east part of Asir region. And some of the plan has already started, then, in this plan, no desalinated sea water shall be supplied in the area.

The Shuaiba plant (Makkah region) located in the south of Jeddah and the Shuqaiq plant (Jazan region) located in the north of Jizan are one of large-scale existing desalination plants. Al Baha which is a capital of Al Baha region, Abha which is a capital of Asir region, etc. are on a mountain place. Desalinated sea water is supplied to Abha from the Shuqaiq plant and to Al Baha from the Shuaiba plant. These cities have high altitude, and the rate of the transportation cost occupied in supply cost of desalinated sea water is large. Because the altitude of the cities cannot be changed, for reduction of water supply cost, it is necessary to shorten transportation distance from a desalination plant to the destination as much as possible. Moreover, it is required also for the transportation cost reduction of the desalinated sea water in a plain part to shorten transportation distance as much as possible.

Although it is a almost linear transportation route from the Shuqaiq plant to Abha, water is conveyed for about 400km from the Shuaiba plant to Al Baha via Taif. In the future, the quantity of the desalinated sea water supplied to Al Baha will be increased. For this reason, it is required to establish a desalination plant in the point where water can be conveyed by the shortest route to Al Baha newly so that the supply cost is cut down.

Moreover, supply cost of desalinated sea water to Jizan city and outskirts of the city, where the quantity of water is sharply increased in a planned target year, can be cut down by conveying water not from Shuqaiq plant but from newly constructed plant in Sabya because the conveyance distance is reduced.

In order to reduce water supply cost, establishment of the following two new plants is proposed on the Red Sea coast. (Refer to Figure B.5-7)

- Southern Dawqah point of the Makkah Region: While the water supply distance to Al Baha is about 400km via Taif from Shoaiba, the water supply distance from Dawqah to Al Baha is about 110km, and distance is shortened by 290km.
- State central part Sabya point of the Jazan Region: While the water supply distance to Jizan is about 140km from Shuqaiq, the water supply distance from Sabya to Jizan is about 40km, and distance is shortened by 100km.

For the pipeline for water supply, the route of Shuaiba – Taif - Al Baha, the route of Shuqaiq – Abha - Khamus Mushayt, and the route to Shuqaiq - Ad Darb have already constructed.

The pipeline about the following routes is planned in main enumeration. (refer to Figure B.5-7)

- The southern State Dawqah point of the Makkah Region - Al Baha of Al Baha Region
- The State central part Sabya point of Jazan – Jizan - Samtah

(4) 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.

The MOWE and the SWCC have a plan to connect by pipeline along the Red Sea coast from the Hali dam to Jeddah in Makkah region and from Samtah in Jazan region to Al Birk in Makkah region. Here, it is proposed that these pipelines are connected into a continuous pipeline from the Jazan region to Makkah region along the Red Sea coast. By this connection, an exchange of the mutual water of the Hali dam and Baysh dam which have large potential of renewable water resources is attained. As a result, it becomes possible to raise the degree of safe for system-wide water supplies.

The amount of water assumed here to be above to supply as municipal water from dams is nearly equivalent to the amount of water examined in Part C 2.1.2 of this report, which means that water supply is reduced by 30% into three years out of 30 years. Although it may be a little severe assumption, water shortage arises about once in ten years temporarily, and it assumes that the amount of supply becomes about 50% in consideration of a future climate change. Moreover, although the period of the rainy season and the dry season is not clear in the KSA, it is assumed that the rainy season and the dry season continue for six months each. And it is assumed that water shortage continues from the middle of the rainy season to the middle of the next rainy season, and the periods of water shortage for six months is assumed. If the water shortage of a Hali dam and a Baysh dam does not overlap, it is presumed that water could be supplied from the dam which have average storage to the dam which is suffering from water shortage because fundamentally these dams have large potential of renewable water resources. If the amount of water accommodated mutually is calculated assuming that 3.5 times of water shortage occurs by the planned target year, 2035, based on the above-mentioned conditions, it will become as follows.

Name of dams	Amount of municipal water supply in average year (1000m^3/day)	Amount of municipal water supply in drought year (1000m^3/day)	Drought term (days)	Amount of total shortage water during drought (1000m^3)	Assumed times of drought by 2035 (times)	Amount of total shortage water by 2035 (1000m^3)
Hali	70	35	180	6,300	3.5	22,050
Baysh	58	29	180	5,220	3.5	18,270

As for the amount of water supplied to Hali dam from Baysh dam during water shortage year of Hali dam is from an upper table, 6,300,000m^3 and 5,220,000m^3 in the opposite case. The amount of water supplied at the time of water shortage is 4.2% to the water-resources potential of the normal year of a Hali dam and 6.2% to the water-resources potential of the normal year of a Baysh dam. This rate is considered not to be excessive load to the capability of a dam.

If this exchange of water cannot be done, then deficit of municipal water should be supplied by increase of desalinated water production, or managed by water saving within the group, whose members are the Makkah region, the Al Baha region and the Asir region, or the Jazan region and the Asir region. If it assumes that this deficit of water is supplied by increased production of desalinated sea water, cost is calculated as about 99Million SR by target year, 2035. (average unit cost of renewable water resources is 0.31 SR/m^3 and average unit cost of production of desalinated sea water is 2.77 SR/m^3, difference of these costs is multiplied by necessary amount of production in the table above.)

On the other hand, the expense required for this connection is a construction cost of a pipeline which is about 60km from Al Birk to Suffah, which is about 96 million SR(s). (Diameter of the pipe is assumed as 550mm to convey 35,000m^3/day.) Considering following merits by target year, investment for pipeline is correspond with benefits from the connection in the long run.

Moreover, if an exchange of the water between a Hali dam and a Baysh dam can be performed, the water of a Baysh dam can be used also at the time of the water shortage of the Yiba dam and the Qanunah dam in the Makkah region, and use of the water of a Hali dam is attained at the contrary also at the time of the water shortage of the Qissi dam and the Damad dam in the Jazan region. Thus, the degree of safe for water use can be raised as the whole system by establishing the system which can perform water supply mutually between two dams with large water resources potential.

Figure B.5-7 shows the proposal which planned the pipeline in such an idea along the Red Sea coast side from the Jazan region to the Makkah region (Red Sea Water Lifeline).

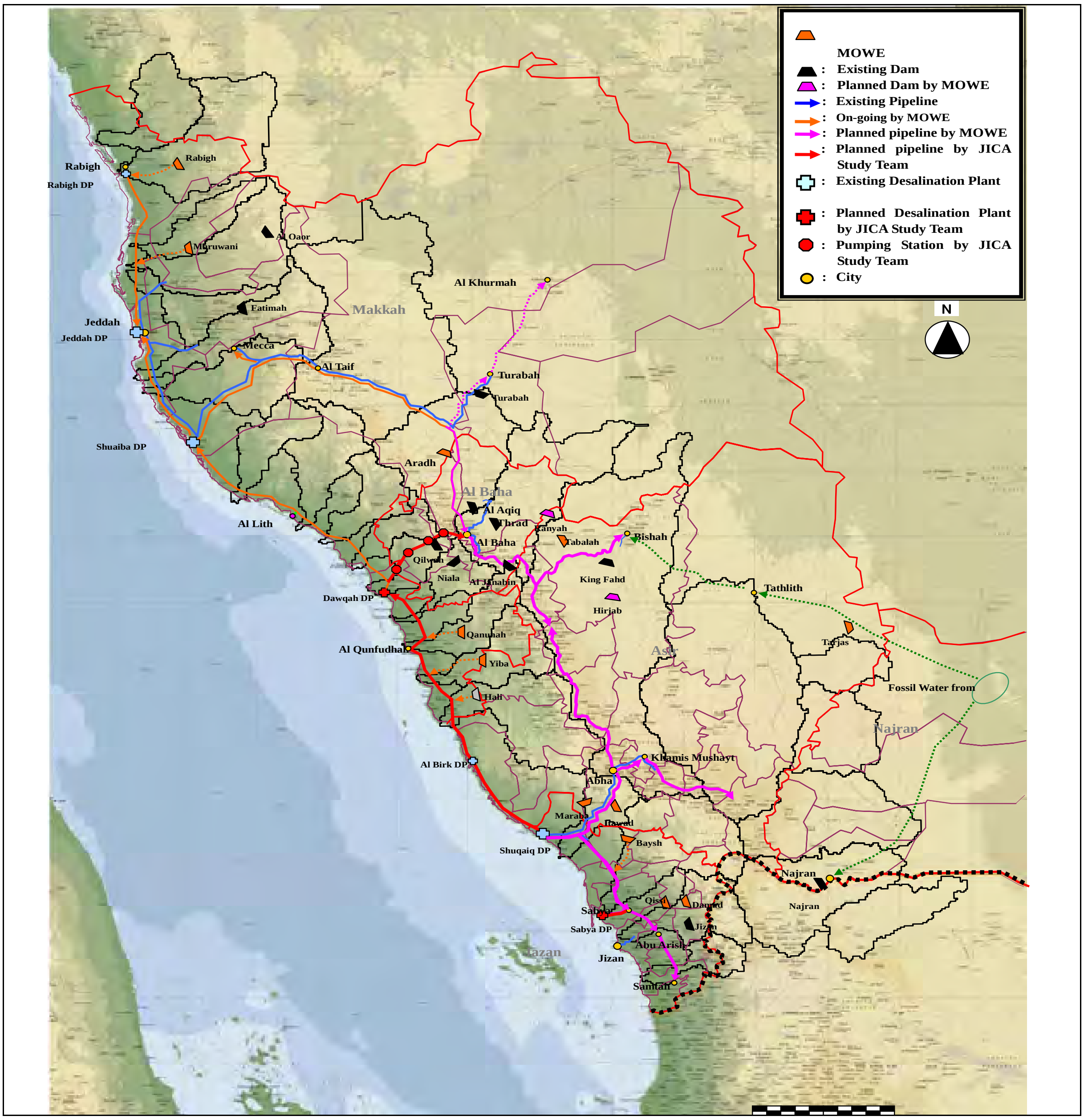


Figure B.5-7 Key map of "Red Sea Water Lifeline" which Connected Facilities by Pipeline

(5) Comparison Examination of Red Sea Water Lifeline

<u><Comparison Cases></u>

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

Alternative 1 (refer to Figure B.5-8)

The feature of alternatives 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 B.5-9)

The feature of alternatives 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 B.5-10)

The feature of alternatives 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 alternatives 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.

Alternatives 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.

Table B.5-16 Explanation of alternatives (1), (2) and (3)

Items	Alternatives (1)	Alternatives (2)	Alternatives (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 Sea Water)	1) New desalination plants shall be proposed a) Dawqah plant for Al Baha Region b) Sabya plants for Jazan 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.	1) The plan of SWCC is followed basically. 2)Major planned desalination plants including existing plants 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):aShuqaiq desalination plant for Jazan Region.	1) New desalination plants shall be proposed a) Dawqah plant for Al Baha Region b) Sabya plants for Jazan 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 from the	Fossil groundwater from the	Fossil groundwater from the

Items	Alternatives (1)	Alternatives (2)	Alternatives (3)
(Fossil Groundwater)	Wajid aquifer is supplied to the eastern part of the Asir Region	Wajid aquifer is supplied to the eastern part of the Asir Region	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 alternatives (3).	1) A function of the system is as the same level as alternatives (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 sea water use. 4) As the whole system, adaptability to the fluctuation of renewable water resources is higher than alternatives (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.

<Evaluation of Comparison Cases>

The comparison table about alternatives-1 - alternatives-3 is shown in Table B.5-16.

Comparison of outline examination was carried out based on the unit cost of water development (renewable water resources), the unit production cost (desalinated sea water) and transportation cost of water. It is because the position of a dam is common to alternatives (1) - alternatives (3), so it is assumed that the water supply system is the same and it is therefore thought that the cost for facilities is equivalent. Moreover, a water supply course changes depending on the condition that a desalination plant is extended or constructed newly. In that case, water supply cost becomes cheaper and, further more, construction cost becomes cheaper if a water supply course is shorter. That works advantageously, when establishing a plant newly. Here, since it is understand that an economic advantage can be shown if id did not include construction cost, evaluation was made with cost of production/develop water and water supply cost.

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

Table B.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)Shuaiba-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 B.5-18 Outline of Red Sea Lifeline and its Alternatives Comparison (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, alternatives-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 Region, there is no watering between states to be adjusted, and alternatives-3 with few adjustment matters is predominance.		There is no watering between states to be adjusted, and alternatives-3 with few adjustment matters is predominance.	Alternative-3 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					In respect of

Evaluation Items		Alternative 1	Alternative 2	Alternative 3	Comprehensive Evaluation
evaluation					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 : Alternative (1) proposes establishment of new desalination plants in Doqwa and Sabya, and it reduces the water supply cost to a demand area. For this reason, compared with alternative (2) which proposes extention of the existing Shuaibah desalination plant and Shuqaiq desalination plant to supply water to a demand place, Alternative (1) becomes cheaper. Altenative (3) proposes the same plan as the alternative (1) as to the establishment of new desalination plants.However, since altenative (3) assumes that developed renewable water is to be allocated within the region, the water allocated to the Asir region from Hali dam is used in the Makkah region and desalinated water is allocated to the Asir region instead. So cost for water becomes high and as Abha city is high land area and conveance cost also becomes haigh to use desalinated sea water from Shuqaiq desalination plant. Thus alternative (3) become higher than alternative (1).As the whole, it became the order of alternative (1), alternative (3) and alternative (2) from the smaller one of cost by the outline economic comparison.
- 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 sea water 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 sea water 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 sea water fresh water pile line of Dawqah-Al Baha of the water unit price (production cost + transportation cost) of the sea water fresh water pipeline of Shuaiba-Al Baha is 6.06SR/m^3.The 100 yen water unit price per m^3 becomes cheap. The 100 yen water unit price per m^3 becomes cheap. By using a cheap Dawqah-Al Baha line, at least desalinization-of-sea-water 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 sea water to Al Baha region, but was developed on the dam cheaper than desalinated sea water to Al Baha region, or Asir Region. A Dawqah-Al Baha pipeline's purpose is to supply renewable waterich 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.

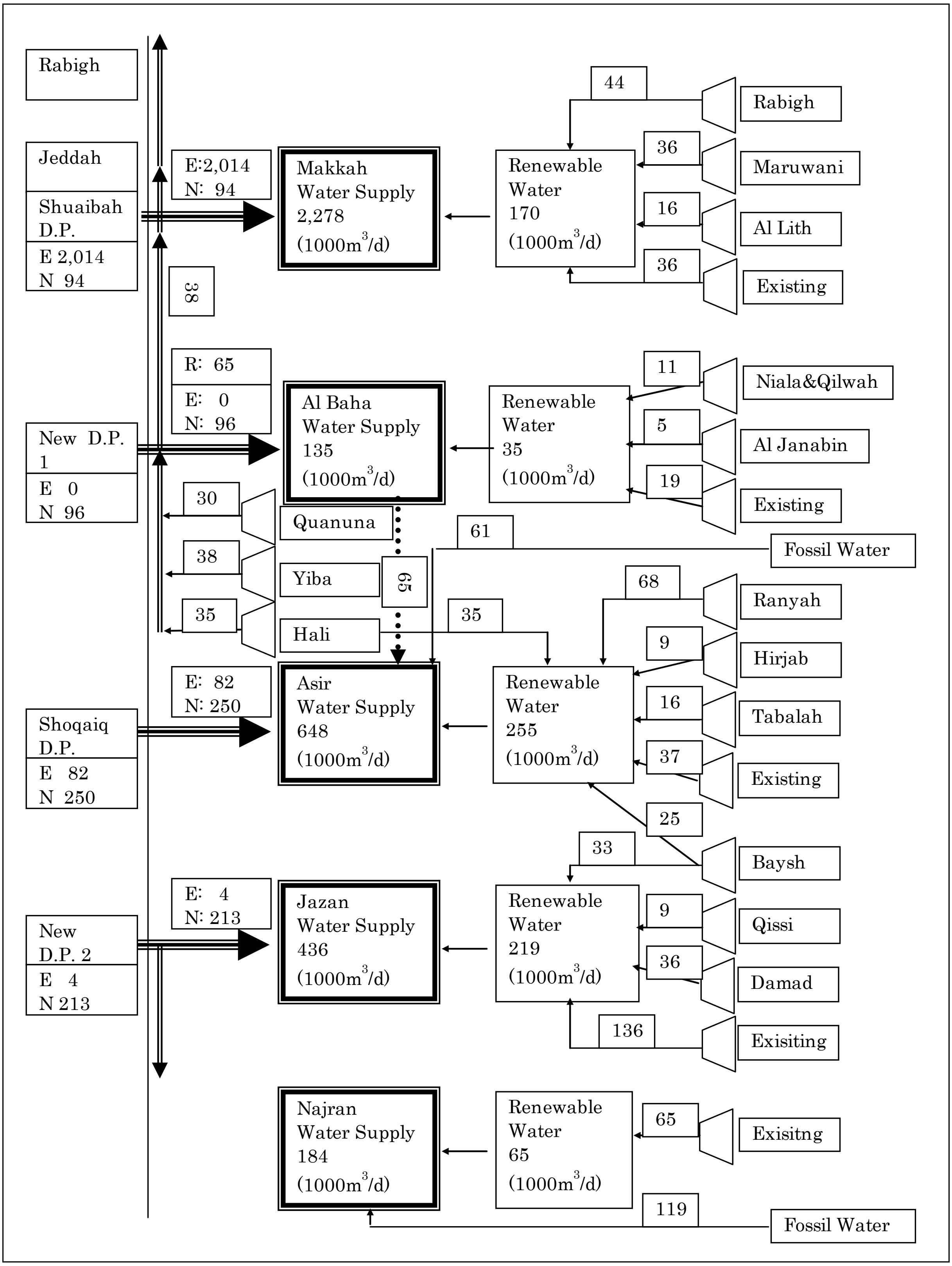


Figure B.5-8 Water Supply by Facilities in Alternative-1

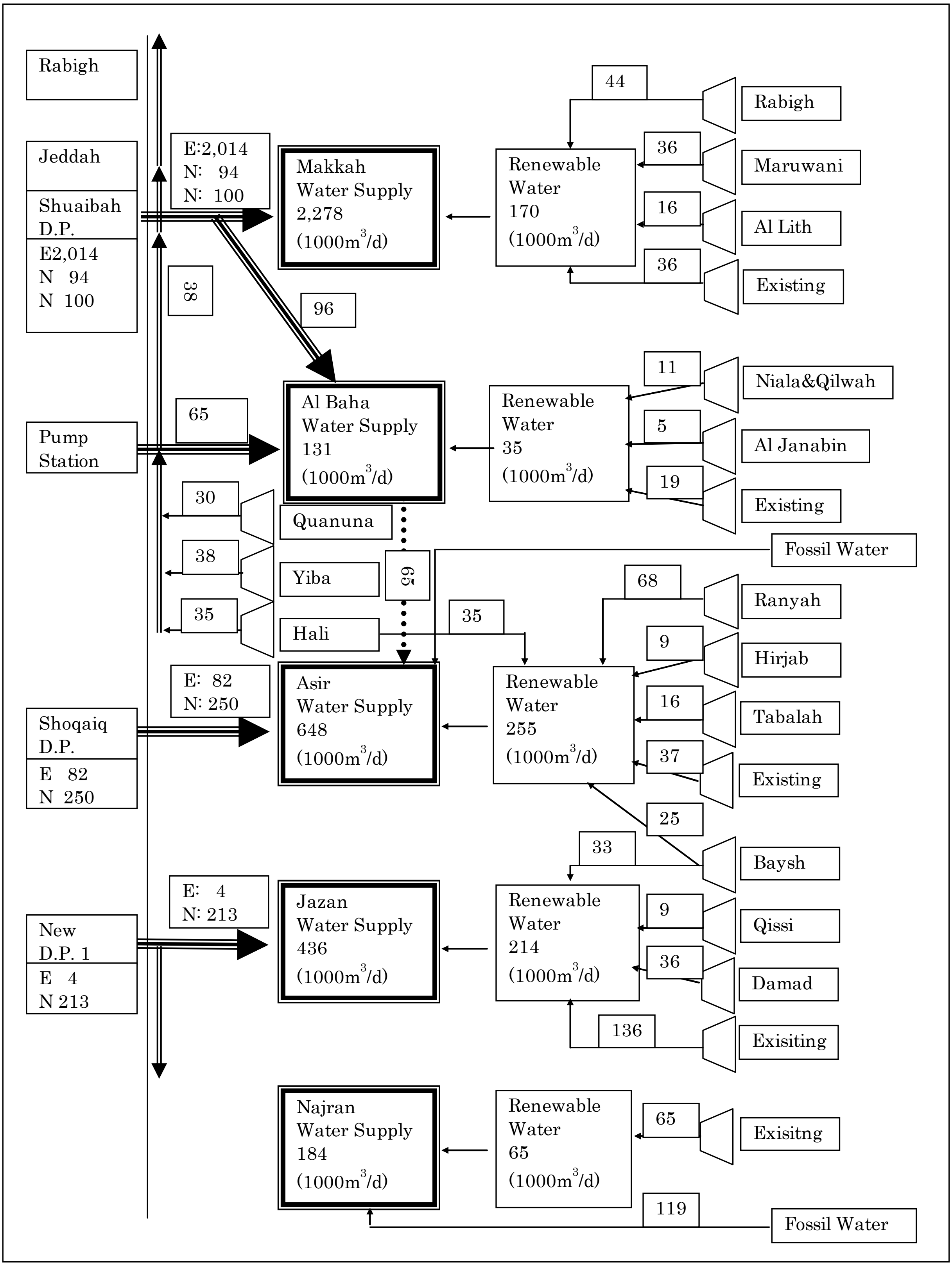


Figure B.5-9 Water Supply by Facilities in Alternative-2

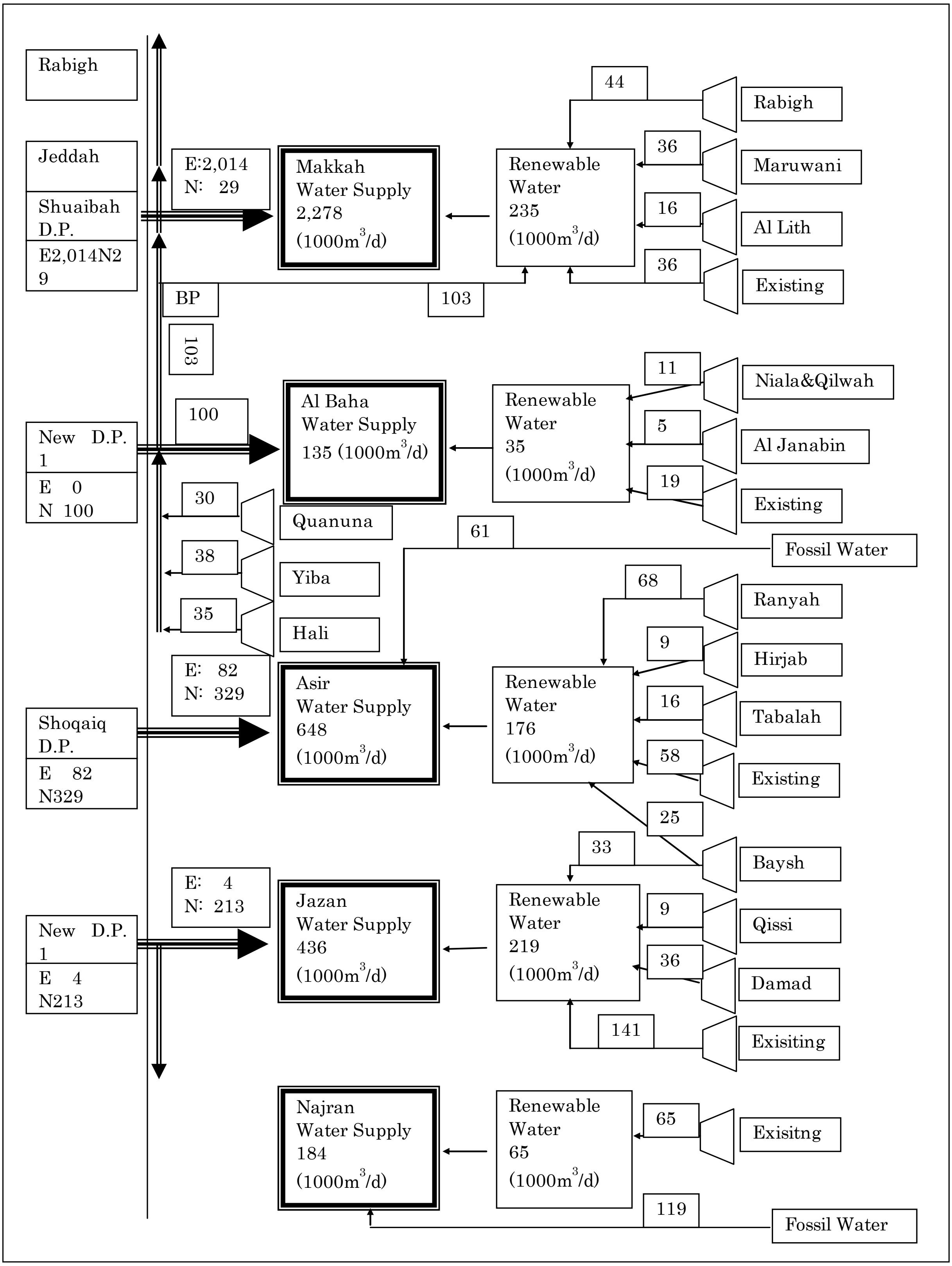


Figure B.5-10 Water Supply by Facilities in Alternative-3

(6) 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 B.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 Sea Water（Existing）	2,014			-
		Renewable Water Resource（Rabigh Dam）	44			-
		Renewable Water Resource（Maruwani Dam）	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 Sea Water（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 Sea Water (Existing)				-
		Renewable Water Resource（Nilah＆Qilwah Dam）	11			-
		Renewable Water Resource（Al Janabin Dam）	5			-
		Desalinated Sea Water（New）	75			105
		Subtotal（by 2020）	**110**	**83**	**27**	**105**
	2035	Desalinated Sea Water（Extension）	25			35
		Subtotal（2020～2035）	**25**			**35**
		Total（by 2035）	**135**	**135**	**0**	**140**
Asir	2020	Renewable Water Resource (Existing)	37			-
		Desalinated Sea Water (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 Sea Water（Extension）	146			204
		Subtotal（by 2020）	**477**	**432**	**45**	**704**
	2035	Renewable Water Resource（Hali Dam）	35			-
		Fossil Groundwater（Wajid）	37			-
		Desalinated Sea Water（Extension）	99			139
		Subtotal（2020～2035）	**166**			**139**
		Total（by 2035）	**648**	**648**	**0**	**843**
Jazan	2020	Renewable Water Resource (Existing)	141			-
		Desalinated Sea Water (Existing)	4			-
		Renewable Water Resource（Baysh Dam）	33			-
		Renewable Water Resource（Qissi Dam）	9			-
		Renewable Water Resource（Damad Dam）	36			-
		Desalinated Sea Water（Extension）	80			112
		Desalinated Sea Water（New）	35			49
		Subtotal（by 2020）	**338**	**286**	**52**	**161**
	2035	Desalinated Sea Water（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 Wastewater

(7) Use of Reclaimed Wastewater

Since Renewable water resources are restricted and production cost of desalinated sea water is high, it is necessary to encourage reuse of reclaimed wastewater 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 wastewater

Reclaimed wastewater 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 wastewater 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 wastewater.

- 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 wastewater 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 wastewater to farmland is considered.
- The educational campaign to a farmhouse and consumers about safe of the agricultural products for which reclaimed wastewater is used is promoted.

5.5.3 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.

Furthermore, dam operation method to maximize (direct water supply from dam + groundwater recharge in dawn stream area of dam) should be analyzed for conservation of groundwater.

(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 sea water 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

Monitoring result should be used to prevent deterioration in groundwater environment. At the same time, the monitoring result should be used for assessment of groundwater development potential.

5.5.4 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 an 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

Enlightenment about Water Saving and Water Preservation

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.

Crop Conversion

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.

Water Saving

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.

5.5.5 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.

Introduction of Integrated Water Resources Management (IWRM)

Since water resources have been tight in an study area, it is necessary to exploit efficiently various water resources such as renewable water resources (surface water, groundwater), desalinated sea water, fossil groundwater and reclaimed wastewater. 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.

The stakeholders assumed when managing synthetically renewable water resources (surface water, groundwater), desalinated sea water, etc. in a main enumeration area are as follows.

- MOWE and MOA (main office and local office)
- A SWCC, Independent Water and Power Project (IWPP), Water and Electric Company (WEC)
- National Water Company (NWC）
- Farmers, Agricultural company
- Local government, Governorate Offices
- Residents in the water supply area

<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.

In order to utilize renewable water resources efficiently impartially in a study area, while various information is collected, it is required to be sharable by the persons concerned.

In the water development, use, and management of this area, in order to attain the efficient and fair object for water supplies, it is required to perform adjustment as shown below in between related sectors based on the information shared.

- Adjustment of amount-demanded grasp of the sector for water supplies, and the amount demanded between sectors
- Adjustment of the allocation of supply for every water resources (amount of supply of renewable related water resources, desalinization-of-sea-water water, and reclaimed wastewater, and adjustment of source)
- Monitor the present condition of renewable water resources (surface water, groundwater), and predict future availability.
- Management and systematization of a performing-water-saving adjustment among stakeholders at the time of water shortage and generate water re-distribution adjustment water-resources institution

<u>Management of Water Resources Facilities and Organization</u>

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

<u>Systematization of Agricultural Water Use Sectors</u>

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, NNWRC 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.

5.5.6 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

- The desalination plant planned now is carried out and the water resources for municipal water is secured certainly.
- In order to promote utilization of renewable water resources, construction of the dams which are under construction and already planned at present shall be completed by 2020.Deficit of municipal water in 2020 and afterwards shall be corresponded by extension of desalination plants.

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.
- In order to encourage reuse of the reclaimed wastewater in a farmhouse level, it should be considered that introducing irrigation facilities for using reclaimed wastewater so that groundwater and reclaimed water don't mix for securing safe of agricultural products is promoted.

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 the management rule and water allocation rule of existing and newly constructed dams are examined, it is necessary to grasp the actual water use conditions of vested users and to consider not to obstacle them.

(2) Al Baha Region

Supply of Municipal Water

- Because there are few good dam sites in the Al Baha region for the future, it reinforces supply by desalinization of sea water 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 a new pipeline from Dawqah to Al Baha, and compensate shortage of renewable water resources.
- A Dawqah desalination plant is extended to shortage of the municipal water in 2020 and afterward.
- The head ratios to the 2035 amount demanded (135,000m^3) are 68% of freshwater water, and 32% of renewable water.
- There are Nilah, an Al Janabin dam, etc. as a dam for renewable water development.

Utilization of Agricultural Water

- Water consumption shall be reduced by adjusting cropping pattern so that emphasis may be further put on production of a fruit tree and vegetables from now on and, moreover, by promotion of introducing water saving facilities such as drip irrigation system.
- Promotion of reuse of reclaimed wastewater is aimed at. As the region is in the maountain area where the small farmland is scattered, introduction of distributed type sewage treatment equipment which is easy to supply reclaimed wastewater to farmland is considered.
- In order to encourage reuse of the reclaimed wastewater in a farmhouse level, it should be considered that introducing irrigation facilities for using reclaimed wastewater so that groundwater and reclaimed water don't mix for securing safe of agricultural products is promoted.
- 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

- Since development water, such as a Quanunah dam built in the Makkah region, may be used, the rule for water supplies in emergencies, such as unusual water shortage, is examined and prepared by completion of these facilities.

- 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 the management rule and water allocation rule of existing and newly constructed dams are examined, it is necessary to grasp the actual water use conditions of vested users and to consider not to obstacle them.

(3) Asir Region

<u>Supply of Municipal Water</u>

- 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.
- Deficit of municipal water after development of present planned and constructing dams shall be supplied by extension of the Shuqaiq desalination plant.
- Deficit of municipal water shall be supplied by the fossil groundwater from a Wajid aquifer in the eastern part of the Asir region (Tath Lith).

<u>Utilization of Agricultural Water</u>

- Water consumption shall be reduced by adjusting cropping pattern so that emphasis may be further put on production of a fruit tree and vegetables from now on and, moreover, by promotion of introducing water saving facilities such as drip irrigation system.
- Promotion of reuse of reclaimed wastewater is aimed at. As the region is in the mountain area where the small farmland is scattered, introduction of distributed type sewage treatment equipment which is easy to supply reclaimed wastewater to farmland is considered.
- In order to encourage reuse of the reclaimed wastewater in a farmhouse level, it should be considered that introducing irrigation facilities for using reclaimed wastewater so that groundwater and reclaimed water don't mix for securing safe of agricultural products is promoted.
- Since signs are seen, the fall of the groundwater level and aggravation of the water quality accompanying them also strive for water saving further from now on.

<u>Adjustment Issues on Development</u>

- 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 the management rule and water allocation rule of existing and newly constructed dams are examined, it is necessary to grasp the actual water use conditions of vested users and to consider not to obstacle them.

(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 sea water.
- While completing the ordered Baysh dam by 2020 already etc., perform establishment of a desalination plant, 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

- Water consumption shall be reduced by adjusting cropping pattern so that emphasis may be further put on production of a fruit tree and vegetables from now on and, moreover, by promotion of introducing water saving facilities such as drip irrigation system.
- 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.
- Reuse of reclaimed wastewater is promoted. Especially, for the agriculture in suburban areas of the Jizan city where a large amount of reclaimed wastewater is drained, demand area of agricultural water is decided and plan for supplying reclaimed wastewater is prepared.
- In order to encourage reuse of the reclaimed wastewater in a farmhouse level, it should be considered that introducing irrigation facilities for using reclaimed wastewater so that groundwater and reclaimed water don't mix for securing safe of agricultural products is promoted.

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 the management rule and water allocation rule of existing and newly constructed dams are examined, it is necessary to grasp the actual water use conditions of vested users and to consider not to obstacle them. Since a large amount of renewable water is used for agricultural use in the Jazan region, it is necessary to discuss about future agriculture plan also which ask for reduction of cultivation area in the region when water use rule is examined.

(5) Najran Region

Supply of Municipal Water

- Deficit of municipal water in the Najran region shall be supplied by fossil groundwater because there will be no dam plans and the region is at the inland from the Red Sea.
- 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.
- Water consumption shall be reduced by adjusting cropping pattern so that emphasis may be further put on production of a fruit tree and vegetables from now on and, moreover, by

promotion of introducing water saving facilities such as drip irrigation system.

- 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.
- Population is concentrating on the state capital and generating of sewage disposal water concentrates the Najran city. 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. To promote use of reclaimed wastewater, demand area shall be decided and prepare for the plan of conveying reclaimed wastewater from the treatment plant to fields.
- In order to encourage reuse of the reclaimed wastewater in a farmhouse level, it should be considered that introducing irrigation facilities for using reclaimed wastewater so that groundwater and reclaimed water don't mix for securing safe of agricultural products is promoted.

Adjustment Issues on Development

- Since the object for the water supplies of the Najran Region does not have connection with other states, either and serves as an independent system, it fixes the rule which can measure the object for water supplies efficient in a state, and fair.
- When the water use rule is examined, it should be considered that save the fossil groundwater now for the future people. Because the fossil groundwater is non-renewable water resources, it cannot be recovered once it is used up.

CHAPTER 6 SELECTION OF REGIONS FOR THE MASTER PLAN STUDY

Based on the study results, characteristics of water resources development and utilization as well as the basic policies for future development and utilization in each Region can be summarized as follows:

(1) MAKKAH REGION

- Makkah still has high dependency on desalinated seawater. In the future, it is expected that the volume of reclaimed wastewater will grow to nearly the equivalent level as desalinated seawater.
- Considering the low renewable water resource potential and the growth in regional population, industry and so forth, it is inevitable to depend heavily on unconventional water resources such as desalinated seawater and reclaimed wastewater as water supply increases the supply volume.

(2) AL BAHA REGION

- The current water resources in Al Baha are from Aqiq Dam, well fields located downstream of the dam and well fields along Wadi Aradah, a branch of Wadi Turba in the neighboring Makkah Region.
- In the future, it is expected that drinking water will be supplied in daily volume of 40,000m^3 (14.6MCM/year) by expanding the Al Shuaiba Desaliniation Plant, nearly eliminating the shortage in Al Baha and Bilijurashi.
- However, the water supply prior to such desalinated seawater can be supplied has been the problem and urgent water resource development is needed.
- The ratio of renewable water resources is the highest in the 5 Regions, and it is most suited as a renewable water resource and should be immediately developed and utilized as such.

(3) ASIR REGION

- Regarding municipal water, there is supply from Shuqaiq desalinated seawater at present. However, there is a tendency for shortage and water supply restriction by the hour. Regarding reclaimed wastewater, nearly the entire volume is utilized for agriculture and landscape.
- In the future, it is planned that the development and utilization of renewable water resources should cover about 65% and the development and utilization of desalinated seawater and reclaimed wastewater 35%.
- Regarding renewable water resources, development in Wadi Itwad has been completed, starting with storing of inflow water in Maraba Dam and Itwad Dam. Water supply from these dams can be expected in the near future. The ratio of renewable water resources is relatively high, and it is necessary to continue developing and utilizing this source of water in the future.

(4) JAZAN REGION

- The major industry is agriculture, and this industry depends entirely on groundwater (renewable water resource) as a water resource. While the supply volume for municipal water in this Region is relatively small compared to agriculture, water is supplied from Al Shuqaiq desalination plant
- The major sources of municipal water are wells, and it is expected that Baysh Dam will supply a daily volume of 80,000m^3 (29.2MCM/year) in the future.
- More than 80% of the water resources are renewable, and region-wide reduction and water saving measures in agricultural water and water resource preservation measures are necessary.
- The main focus of water resources development and utilization in Jazan Region will remain on renewable water resources, and it is necessary to formulate integrated water resources development and management plans.

(5) NAJRAN REGION

- The current water supply in Najran entirely depends on groundwater (renewable resources), and the resources are concentrated on 4 valleys in the western area of the region. There is no water network or sewage network, and water is transported or supplied by trucks.
- While agricultural water comprises more than 80% of usage, efficient utilization of water is not easily popularized and there are large losses. Lowering in groundwater is rather severe along

Wadi Najran, with land subsidence and ground fissure observed in the eastern area of Najran City caused by excessive intake. Preservation and recharging measures for groundwater are necessary.

- ◆ MOWE has been investigating the water resources potential survey in Wajid Aquifer spreading over the western and northern areas of the Region. They plan to supply water from this aquifer in the future.
- ◆ Regarding reclaimed wastewater, it is not currently recycled due to insufficient treatment facilities. In the future, it is expected that it should produce about 25% of the total water resources.
- ◆ While the rate of renewable water resources (groundwater) is relatively high, the above problems indicate that the renewable water resources should be preserved. Thus the main water resource of future development and utilization should be done in Wajid Aquifer.

Based on the above results, it is recommended for Al Baha, Asir and Jazan Region that development, utilization and management with focus on renewable water resources (surface water + ground water) will lead to benefits. These three regions are adjacent to each other, and collaborative and integrated water resources development including water transmission and supply beyond regional boundaries is also possible.

Makkah Region has high dependency on non-renewable water resources such as desalinated seawater even now. Considering the potential for renewable water resources and the sizes of the population and industry and so forth, it is inevitable that they should depend on water resources other than renewable resources including desalinated seawater to address supply volume increase.

While Najran Region has problems such as lowering of groundwater levels and land subsidence suggests that the water resources should be preserved instead of developing and utilizing. It is expected that the main water resources in the future should be developed in Wajid Aquifer.

Considering the discussion above, the following three Regions shall be selected for regions on the M/P study on renewable water resources development, utilization and management.

- ■ Al Baha Region
- ■ Asir Region
- ■ Jazan Region