The Kingdom of Saudi Arabia

The Ministry of Water and Electricity (MOWE)

THE STUDY ON MASTER PLAN

ON

RENEWABLE WATER RESOURCES DEVELOPMENT IN THE SOUTHWEST REGION

IN

THE KINGDOM OF SAUDI ARABIA

FINAL REPORT

(SUMMARY REPORT)

OCTOBER 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.

SANYU CONSULTANTS INC.

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Foreign Exchange Rate

1.00 US Dollar=3.74 Saudi Arabia Riyal=¥89.0

(WEB：1st March, 2010 US Dollar/Saudi Arabia Riyal)

PREFACE

In response to a request from the Kingdom of the Saudi Arabia, the Government of Japan decided to conduct a study concerning the Master Plan Study on Renewable Water Resources Development in the Southwest Region, and entrusted the study to the Japan International Cooperation Agency.

JICA selected and dispatched a study team headed by Mr. Masatomo WATANABE of Yachiyo Engineering Co., Ltd. to the Kingdom of Saudi Arabia between June 2007 and June 2010.

The team held a series of discussions with the officials concerned in the Government of Saudi Arabia and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of further friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned in the Government of the Kingdom of Saudi Arabia for their close cooperation extended to the study.

October 2010

Mr. Izumi Takashima
Vice President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

October, 2010

Mr. Izumi Takashima,
Vice President
Japan International Cooperation Agency

Dear Sir

We are pleased to submit to you the final report of the Master Plan Study on Renewable Water Resources Development in the Southwest Region in the Kingdom of Saudi Arabia (KSA).

The final report deals with the basic policy, strategy and action plan for sustainable water resources development, utilization and management in the five regions (Makkah, Al Baha, Asir, Jazan and Najran Region) located in the southwest region in KSA and the Water Master Plan on renewable water resources development targeting the year of 2035, focusing for only the three regions (Al Baha, Asir and Jazan Region). In elaboration of the final report, the Study Team has taken into account the advices and suggestions of your Agency and the comments on draft final report made by the Ministry of Water and Electricity (MOWE).

The Water Master Plan proposes the water resources development facilities such as dams and wells which meet the water demand to the year of 2035. In order to overcome hydrological handicaps (scarcity of rainfall, annual and regional large fluctuation gap of rainfall, large potential evaporation) in the study area belonging to arid and semi-arid areas, the Water Master Plan also proposes the renewable water resources development by combining operations between large dams and aquifers in Wadi. It finally proposes the extension and construction of desalination plant hence water demand cannot be obtainable by only developing the renewable water resources in the three regions.

Based on economic and technical aspects it was taken into consideration the development of different water resources such as renewable water resources as well as desalinated seawater in three regions in order to secure less expensive water and necessary water sufficiency. Therefore, the Study Team planned the Red Sea Water Lifeline Project (REWLIP) that widely connects water resources with pipelines and supplies water to the mentioned three regions' major cities. As part of the water demand management plan, the Study Team promoted the reuse of reclaimed waste water for municipal greening, industrial cooling and agricultural water.

The proposed project components in the master plan can be evaluated as feasible from the viewpoints of technology, economy, and finance, and socio-environment. By the implementation of these projects proposed in the Water Master Plan, we are convinced that it will contribute to the socio-economic development of three regions and will achieve comfortable life for people.

We wish to take this opportunity to express our sincere gratitude to your Agency and the Ministry of Foreign Affairs. We also wish to express our deep gratitude to the MOWE and the related organizations for their close cooperation and extended assistance to us during the study period.

Very truly yours,

Masatomo WATANABE
Team Leader
The Master Plan Study on the Study on Renewable Water Resources Development in the Southwest Region in the Kingdom of Saudi Arabia

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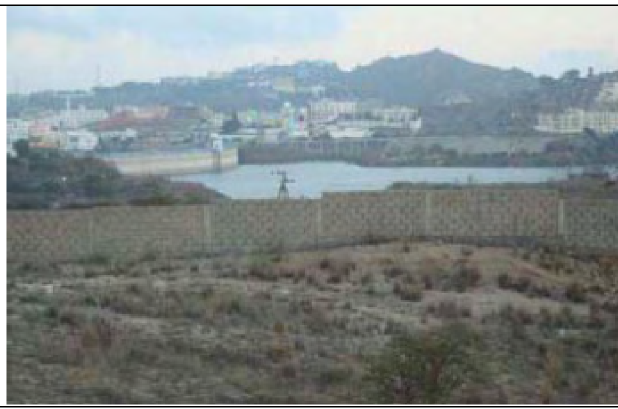

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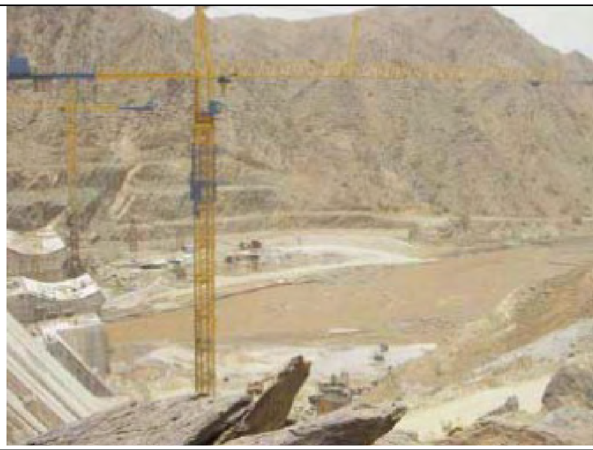

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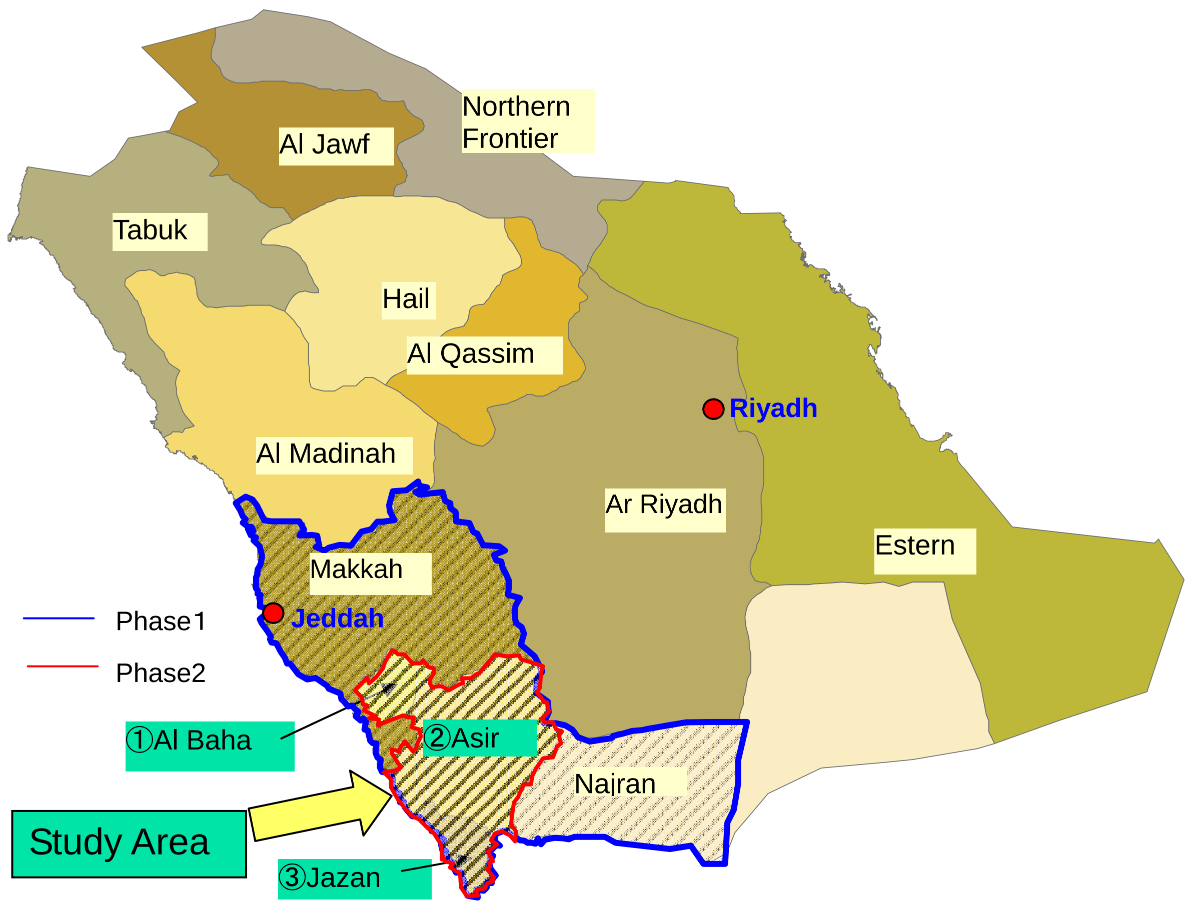

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List of Abbreviations

Abbreviation and Acronym	English	Arabic (عربي)	Japanese (日本語)
BCM	Billion Cubic Meters	مليار متر مكعب	10 億立法メーター
CBD	Convention on Biological Diversity	اتفاقية التنوع البيولوجي	生物多様性保全条約
C/P	Counterpart	النظير	カウンターパート
EIA	Environment Impact Assessment	تقييم الأثر البيئي	環境アセスメント
ER	Effective Rainfall	الأمطار الفعالة	有効雨量
ET	Evapotranspiration	التبخر	蒸発散
FAO	Food and Agriculture Organization, United Nations	منظمة الأغذية والزراعة للأمم المتحدة	国連食料農業機関
GIS	Geographic Information System	نظام المعلومات الجغرافية	地理情報システム
GPS	Global Positioning System	نظام تحديد المواقع العالمي	グローバル・ポジショニング・システム
GDP	Gross Domestic Product	الانتاج المحلي الإجمالي	国内総生産
GNI	Gross National Income	الدخل القومي الإجمالي	国民総所得
GSMO	Grain Silos and Flour Mills Organization	صوامع الحبوب ومطاحن الدقيق	サイロ・製粉公団
GTZ	Deutsche Gesellschaft fur Technical Zusammenarbeit GmbH	الجمعية الألمانية للتعاون التقني المحدودة	ドイツ技術協力公社
IC/R	Inception Report	تقرير الإنشاء	インセプション・レポート
IEE	Initial Environmental Examination	الفحص البيئي الأولي	初期環境調査
IUCN	World Conversion Union	اتحاد التحويل العالمي	国際自然保護連合
IWPP	Independent Water and Power Project	المياه المستقلة وطاقة المشروع	独立水道・発電事業
IWRP	Integrated Water Resources Planning	التخطيط المتكامل للموارد المائية	総合水資源計画
JCCME	Japan Cooperation Center for Middle East	مركز التعاون الياباني للشرق الأوسط	財団法人中東協力センター
JICA	Japan International Cooperation Agency	الوكالة اليابانية للتعاون الدولي	独立行政法人国際協力機構
KSA	Kingdom of Saudi Arabia	المملكة العربية السعودية	サウジアラビア王国
LCD	Liter per Capita per Day	لتر للفرد يوميا	リッター/人/日
MOAW	Ministry of Agriculture and Water	وزارة الزراعة والمياه	水・農業省
MEPA	Meteorology and Environment Protection Administration	ادارةالأرصاد الجوية و حماية البيئة	気象環境保護庁
MCM	Million Cubic Meters	مليون متر مكعب	100 万立法メーター
M/M	Minutes of Meeting	ملخص الاجتماع	会議の議事録
MMW	Million Megawatt	مليون ميغاوات	100 万ワット
NAS	National Agriculture Strategy	استراتيجية الزراعة الوطنية	国家農業戦略
NGO	Non-Governmental Organization	المنظمات غير الحكومية	民間公益団体
NMS	National Mining Strategy	استراتيجية التعدين الوطنية	国家鉱業戦略
NSS	National Spatial Strategy	استراتيجية العمران الوطنية	国家特別戦略
NWC	National Water Cooperation	التعاون الوطني للمياه	国家水会社
MWS	National Water Strategy	الاستراتيجية الوطنية للمياه	国家水戦略
MOA	Ministry of Agriculture	وزارة الزراعة	農業省
MOEP	Ministry of Economy and Planning	وزارة الاقتصاد والتخطيط	国家経済計画省
MOF	Ministry of Finance	وزارة المالية	財務省
MOI	Ministry of Interior	وزارة الداخلية	内務省
MOMRA	Ministry of Municipal and Rural Affairs	وزارة الشؤون البلدية والقروية	地方自治省
MOWE	Ministry of Water and Electricity	وزارة المياه والكهرباء	水・電力省
M/P	Master Plan	الخطة الرئيسية	マスタープラン
MSR	Million Saudi Riyals	مليون ريال سعودي	100 万サウジリアル
NCWCD	National Commission for Wildlife Conservation and Development	اللجنة الوطنية لحماية و تطويرالحياة البرية	国立動物保護開発協会
NIA	National Irrigation Authority	السلطة الوطنية للري	国家灌漑局

Abbreviation and Acronym	English	Arabic (عربي)	Japanese (日本語)
PME	Presidency of Meteorology and Environment Protection	الرئاسة العامة للأرصاد وحماية البيئة	国家気象環境保護
P/O	Plan of Operation	خطة عملية	プラン オブ オペレーション
PPP	Public Private Partnership	شراكة القطاعين العام والخاص	官民連携
RWPC	Renewable Water Production Corporation	شركة إنتاج المياه المتجددة	再生可能水生産公社
REWLIP	Red Sea Water Lifeline Project	شريان الحياة للمياه البحر الأحمر المشروع	紅海水ライフライン事業
OJT	On the Job Training	التدريب المهني	研修
SAGIA	Governor Saudi Arabian General Investment Authority	محافظ الهيئة العامة للاستثمار العربي السعودي	サウジアラビア総合投資庁
SAMA	Saudi Arabian Monetary Agency	مؤسسة النقد العربي السعودي	サウジアラビア通貨庁
SAR	Saudi Arabian Riyal	الريال السعودي	サウジアラビアリアル
SCT	Supreme Council for Tourism	المجلس الأعلى للسياحة	最高観光委員会
SEA	Strategic Environment Assessment	التقييم البيئي الاستراتيجي	戦略的環境アセスメント
SGS	Saudi Geological Survey	هيئة المساحة الجيولوجية السعودية	サウジ地質調査
SOIETZ	Saudi Organization for Industrial Estates and Technology Zone	الهيئة السعودية للمدن الصناعية و للمنطقة التكنولوجية	サウジ産業国家技術団体
SR	Saudi Riyals	الريال السعودي	サウジリアル
STP	Strategic Transformation Plan	خطة التحول الاستراتيجي	戦略的転換計画
STP	Sewerage Treatment Plant	محطة معالجة الصرف الصحي	下水処理プラント
S/W	Scope of Works	نطاق الأشغال	業務範囲
SWAT	Soil and Water Assessment Tool	أداة تقييم التربة والمياه	土壌水アセスメントツール
SWCC	Saline Water Conversion Corporation	المؤسسة العامة لتحلية المياه المالحة	海水淡水化公社
UFW	Unaccounted For Water	مياه غير مسجلة	無収水
UNDP	United Nations Development Programme	برنامج الأمم المتحدة للتنمية	国連開発計画
UN-ESCWA	United Nations Economic and Social Commission for Western Asia	اللجنة الاقتصادية والاجتماعية للأمم المتحدة لغربي آسيا	国連西アジア経済社会委員会
WB	World Bank	البنك الدولي	世界銀行
WHO	World Health Organizations	منظمة الصحة العالمية للأمم المتحدة	世界保健機関
WMO	World Meteorological Organization	المنظمة العالمية للأرصاد الجوية	世界気象機関

SYNOPSIS

The Study on Master Plan on Renewable Water Resources Development in the Southwest Region in the Kingdom of Saudi Arabia

Study Period: June 2007 － July 2010
Recipient Agency: Ministry of Water and Electricity, the Kingdom of Saudi Arabia

1 Background of the Study

The desert or arid area extends throughout the entire land of the Kingdom of Saudi Arabia (KSA), and the acquisition of water resources is one of the top issues to sustain the people's life and domestic industries. The recent increase in population, urbanization and industrialization induces the rapid increase in water demand, and it requires that appropriate and prompt measures be taken against water scarcity.

The southwest region is comparatively rich in rainfall (with annual average amount ranging from 200 to 500mm) on a national basis in the KSA where other regions have less than 100mm. The valuable water resources originating from rainfall has not been fully utilized so far because of its direct drain-out into the sea (the Red Sea) and underground infiltration. However, water resources development projects in the region have been implemented in recent years to keep up with the rapid increase in population and actual progress of industrialization.

The Government of KSA, accordingly, requested the Japanese Government in 2000 to formulate a master study plan on renewable water resources development and management mainly for renewable water resources of surface and groundwater in the Southwest Region of KSA based on her basic policy on the restriction of water use from non-renewable water (fossil water) and the increase of the water supply from the other water sources.

2 Objectives of the Study

The objectives of the Study are shown below.

1) To formulate a basic policy, strategy and action plan for sustainable water resources development, utilization and management in 5 Regions (Makkah, Al Baha, Asir, Jazan and Najran) located in the southwest region of KSA
2) To formulate a master plan (M/P) for sustainable water resources for the selected Regions based on the action plan
3) To transfer relevant skills and technologies mainly to personnel of the MOWE

3 Water Policy, Strategy and Action Plan of Five Regions

3.1 Issues on Water Sectors

Current condition and issues on water sectors for each Region are as follows. Refer to Table 1.

(1) Municipal Water (Domestic Water)

Coverage of domestic water network is low in Al Baha region, Asir region and Jazan region. Water supply amount, which is called LCD, in Al Baha region, Jazan region and Najran region is less than value used in planning for a small village whose population is not more than five thousand. These regions are classified as no desalinated seawater supplying area or small supplying area. There is a possibility of large scale seasonal change of water use in Makkah Region, Al Baha Region and Asir Region.

(2) Industrial Water

Total volume of industrial water use is rather small except Makkah region. Percentage of reuse of reclaimed waste water in Makkah region is rather high comparing to other regions. Other four regions use no or a little amount of it.

(3) Agricultural Water

Agricultural water is said to account for high ratio to the total water use. Actual water use for agriculture is not monitored and there are developments of agricultural wells without proper license. Because agriculture uses a lot of amount of water, there is a possibility to produce large amount of water by water saving. Level of introduction of modern irrigation facilities is low. Percentage of reuse of reclaimed waste water in agriculture is very low.

Table 1 Basic Information and Issues on Water Sectors in 5 Regions

Items	Makkah	Al Baha	Asir	Jazan	Najran
[Population]Projection by MOWE (2009)					
• 2010 (x1000), Total: 10.680	6,468	411	1,895	1,404	502
• 2035 (x1000), Total: 16,302	9,785	627	2,914	2,190	786
[Renewable Water]	Reference points: points at river mouth + points in front of desert. Al Baha: Inter basin (All potentials flow into Makkah)				
• Surface Runoff (MCM/Y) Total: 870	755	(254)	66	44	5
• Groundwater (MCM/Y) Total: 744	320	(100)	73	303	48
• Total (MCM/Y) Total: 1,614	1,075	(354)	139	347	53
[Domestic Water]					
• Total volume of domestic water use	389	14	57	16	12
• Coverage of public potable water networks	96%	47%	43%	64%	79%
• Estimated water supply amount (LCD: Litter per capita per day)	183	149	192	55	93
• Percentage of desalinated seawater	High (88%)	Low (0%)	Middle (57%)	Low (4%)	Low (0%)
• Large scale seasonal change in water demand	(Haji Pilgrim)	(Jun-Aug)	(Jun-Aug)	No	No
[Industrial Water]					
• Total volume of industrial water	38	0	2	0	0
• Percentage of reuse of reclaimed waste water	Middle (59.8%)	-	Low (0%)	-	-
[Agricultural Water]					
• Total volume of agricultural water	768	54	283	1,527	229
• Ratio of agricultural water in total water use	Middle (64%)	High (79%)	High (83%)	High (99%)	High (95%)
• Percentage of reuse of reclaimed waste water	Low (2%)	-	Low (6%)	-	-
• Introduction of updated facilities	Low <50%	Low <50%	Low <50%	Low <50%	Low <50%
• Lowering of groundwater level & deterioration of water quality in agricultural wells	Yes : Middle	Yes : Low	Yes : Low	Yes : High	Yes : Low
• Development of agricultural wells without proper license	Yes	Yes	Yes	Yes	Yes
• Monitoring of yield and level on agricultural water	No	No	No	No	No

3.2 Balance on Water Supply and Demand

(1) Municipal Water

Table 2 shows the estimation of amount of water resources which should be developed by a planned target year 2035. The amount of water resources in 5 regions are estimated as 422 MCM/year (or 1.2 MCM/day). The ratio to the current water supply capacity of the future water demand in four regions other than the Makkah region is from 2 times to 4 times. The water resources should be developed and the water supply network should be expanded in the 4 regions.

Considering such water users after dam construction, 30% of renewable water resources developed by dams were allocated as available renewable water 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. As shown in Table 2, available renewable water in 5 regions is to be 340m^3/day. To meet the future water demand, the water development by water resources other than renewable water resources should be examined in the study area.

Table 2 Balance for Future Water Demand in 2035

Region	(1)Current Water Supply Capacity (MCM/Y)	(2)Future(2035) Water Demand (MCM/Y)	Balance (MCM/Y) (3)=(2)-(1)	(4) Balance (1000 m^3/d)	(5)Available Renewable water (1000 m^3/d)	(6)Balance (1000 m^3/d) (6)= -((4)+(5))
Makkah	748	845	-97	-266	161	105
Al Baha	10	38	-28	-77	16	61
Asir	44	208	-164	-449	60	389
Jazan	53	148	-95	-260	103	157
Najran	24	62	-38	-104	0	104
Total	879	1,301	-422	-1,156	340	816

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

(2) Agricultural Water

Table 3 shows water balance on agricultural water and comparison of the planted area between 2007 and 2035. Planted area in 2035 was predicted based on the [Decision 335] and irrigation water potential consists of reclaimed waster water and new developed water. A part for a water supply for municipal water is first deducted from the renewable amount of water resources, and the remaining amounts of water resources is transferred to irrigation water.

New developed irrigation water consists of water saving, reclaimed waste water and return flow of irrigation water (estimated as 40% of irrigation water).

Planted area for the target year (2035) corresponding to the new irrigation water resources developed by renewable water resources and water saving will become 53% in the whole 5 regions as compared with the planted area in 2007. However, although three regions such as Makkah, Al Baha and Asir Region can secure the planted area at 2007 level mostly, two regions such as Jazan and Najran region can not secure. Planted area will be decreased as 75% from 2007 level in Jazan region, whereas as 29% in Najran Region.

Table 3 Water Balance on Agricultural Water and Comparison of Planted Area

Region	(1)Irrigation Demand 2007 (MCM/Y)	(2) Available for Agricultural Use(MCM/Y)	(3)New Water Resources (MCM/Y)	(4)Balance (MCM/Y) =(2)+(3)+(4)-(1)	(5)Planted Area in 2007 (ha)	(6)Planted Area in 2035 (ha)	(7)Ratio (%)
Makkah	751	674	513	436	42,077	39,293	93 %
Al Baha	54	83	14	43	4,450	4,425	99 %
Asir	268	360	109	201	21,054	20,759	99 %
Jazan	1,502	216	70	-1,216	113,558	28,559	25 %
Najran	217	328	88	200	11,430	8,134	71 %
Total	2,792	1,661	795	-336	192,569	101,170	53 %

*) New Water Resources = saving water＋reuse of reclaimed water＋return flow

*) Planted area in 2035 is based on the Decision335 and irrigation potential resources (reclaimed waste water + new resources)

3.3 Basic Policy for Water Resources Development, Utilization and Management

(1) Hydrological Handicaps in the Dry Area and Actions for Securing Water

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

To overcome the above handicaps and to secure sufficient water for increasing demands, necessary actions should be taken and summarized as follows.

- ◆ To respond the annual fluctuation and the seasonal variation of rain and renewable water resources, minimum amount of water required for maintenance of social economy is secured by desalinated seawater.

- 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.
- 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. An Effective use of recharging facilities such as recharge dams and trenches to promote infiltration of water into aquifer is necessary to improve recharge efficiency.

(2) Basic Policy of Water Resources Development and Conservation

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

- From examination of the analysis result of renewable water-resources potential, and the dam site for using it efficiently, it is presumed that about 30% of the developed renewable water resources is usable for municipal water supply.
- 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 is cheaper than desalinated seawater and renewable water could be sustainable resource if it is managed properly.
- Therefore, it is important to perform development and use of these renewable water resources intentionally.

Monitoring of Renewable Water Resources (Groundwater)

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

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

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

Effective Development and Use of Reclaimed Waste Water

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

(3) Basic Policy of Water Resources Utilization and Management

Necessity of Demand Management

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

Establishment of Effective Water Use System

- ◆ A water development institution has a situation where the mechanisms 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.

3.4 Water Policy and Strategy of Five Regions

In consideration of the current condition of water use and issues, the 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 displayed in the following four classifications. The strategies to each water policy are shown in Table 4.

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

Table 4 Water Policy and Strategy of Five Region

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

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

3.5 Action Plan - Water Resources Development

(1) Water Resources Development

Action plan on water policy and strategy (WP1: Surface Water Use, WP2: Groundwater Use, WP3: Desalinated Seawater Use)

<REWLIP (Red-Seawater Lifeline Project)>

REWLIP is a project to produce and distribute municipal water to the main cities in the southwestern area (Makkah, Al Baha, Asir and Jazan Regions) of KSA. REWLIP are composed of 1) desalination plants (including new 2 plants), 2) 10 dams (constructed and under construction), and water pipelines (total length: around 1,300km). The Study Team proposes REWLIP based on the two important aspects: 1) Economic Aspect to Secure Less Expensive Water, and 2) Technical Aspect to Secure Necessary Water Sufficiently in Wide Area by Different Water Sources and Well Connected Water Conveyance Systems. Outline of REWLIP is as follows:

- ◆ The renewable water resource in the four regions (excluding Najran Region) is assumed to be developed by dams. There is no new dam plan in Najran Region.
- ◆ About desalinization plant, the Makkah Region extends a Shuaibah Plant, and the Asir Region corresponds by extension of a Shuqaiq Plant.
- ◆ New desalination plants are planned to be constructed to supply water to Al Baha Region and Jazan Region respectively. This plan is proposed by the Study Team.
- ◆ Water conveyance among regions is done by the pipelines proposed by the Study Team.

<Water Supply System of Five Regions in 2035>

Table 5 Water Demand and Supply Plan and Water Resources by percentage (%) Region according to Region in 2035

Region	Water Demand (1000m^3/day)	Water Supply (1000m^3/day)				Balance of Demand and Supply
		Total	Renewable Water	Desalinated Seawater	Fossil Groundwater	
Makkah	2,278	2,278	170	2,108	0	0
		(100%)	(7.5%)	(92.5%)		
Al Baha	135	135	35	100	0	0
		(100%)	(25.9%)	(74.1%)		
Asir	648	648	255	327	66	0
		(100%)	(39.4%)	(50.5%)	(10.1%)	
Jazan	436	436	219	217	0	0
		(100%)	(50.2%)	(49.8%)		
Najran	184	184	65	0	119	0
		(100%)	(35.3%)		(64.7%)	
Total	3,681	3,681	744	2,752	187	0

Action plan on water policy and strategy (WP4: Reuse of reclaimed waste water)

<Use of Reclaimed Waste Water>

When using sewage disposal water as a proportion of domestic water or industrial water, it is necessary to separate the water supply method completely from general water service for safe preservation. Processing of the concentration drainage generated in the processing procedure, sludge, etc. must be ensured, and secondary pollution generating must be prevented.

Within the agricultural sector, reuse of reclaimed waste water potential is considered to be very large. Under the present circumstances, farmers have resistance towards changing from groundwater use to reusing reclaimed waste water. However, it is required to promote the use of reclaimed waste water for agricultural purposes from the current situation where water supply and demand are tight.

(2) Water Resources Conservation

Action plan on water policy and strategy (WP5: Groundwater Conservation, WP6: Water Quality Conservation)

<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 by considering the items below:

- To reduce ineffective discharge into Red Sea in wadi basins of 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 of the differences from dam to dam

<Monitoring Plan>

- Rainfall
- Monitoring of Wadi Discharge and Water Quality
- Monitoring of Groundwater Level and Quality

(3) Water Use Management

Action plan on water policy and strategy (WP7: Effective Use of Municipal Water, WP8: Improvement of Water Saving, WP9: Appropriate Agricultural Water Use)

<Demand Management of Domestic Water Supply>

- Introduction of Pricing
- Educational Programs concerning Water Saving and Water Preservation

<Water Demand Management of Agricultural Water Use>

- Crop Conversion
- Water Saving

(4) Adjustment of Organization and Institution

Action plan on water policy and strategy (WP10: Institutional Framework for Effective Water Resources Development and Management)

- Introduction of Integrated Water Resources Management (IWRM)
- Information Sharing and Adjustment among Sectors
- Management of Water Resources Facilities and Organization
- Systematization of Agricultural Water Use Sectors
- Capability Building of MOWE

4 Master Plan for Three Regions

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. The three regions (Al Baha, Asir and Jazan) were selected for regions on the M/P study on renewable water resources development, utilization and management.

4.1 Water Resources Development

(1) Renewable Water Resources

To overcome the hydrological handicaps such as little rainfall, quantitative fluctuations and much evapotranspiration, and to secure sufficient water for increasing demands, the following view points shall be taken into consideration on development of renewable water resources.

- ◆ Water resources development which stresses on the stock is taken to plan a dam with the larger storage-of-water capacity which stores floods certainly
- ◆ An Effective use of recharging facilities such as recharge dams and trenches to promote infiltration of water into aquifer is necessary to improve recharge efficiency.

Methods proposed below are applicable to develop renewable water resources (surface water and shallow groundwater) in the Study Area

<u>Surface Water Development by Large Dam</u>: For the purpose of water use, surface water is developed by the large scaled dam & reservoir with double or triple volume of annual average discharge volume. Reservoir is continuously stored and used throughout the year. Developed water is conveyed to the consumer areas.

<u>Development of Surface Water and Groundwater by the Combination with Large Dam and Groundwater Aquifer</u>: In case of small sized dams or limited annual flow regime at dam sites, surface water is recharged and stored in the groundwater aquifer to increase development volume. To increase recharge volume, recharge wells and trenches are employed.

<u>Groundwater Development by the Recharge Dams</u>: Recharge dams with facilities of natural discharge are constructed to increase recharge volume in the course of Wadi by changing the flow pattern.

Table 6 shows the development volume of dams and combination development with dams and aquifers. The Study Team estimated for the volume of annual 351MCM for surface water developed by large dams.

Table 6 Development by Dams and Combination Development with Dams and Aquifers

Name of Dam	Location of River	Annual Flow (MCM/Y)	Reservoir Volume (MCM)	Development Volume *1		Development Rate*2 (α)	Design Supply Volume*3 ($1000m^3/d$)	Dams & Aquifers *4	
				(MCM/Y)	($1000m^3/d$)			(MCM/Y).	Rate (%)
Aradah	East(Desert)	15.2	68.0	6.7	18	44%	5	6.7	100%
King Fahd	East(Desert)	69.1	325.0	55.3	152	80%	-	57.3	104%
Tabalah	East(Desert)	12.3	68.4	3.6	10	29%	10	4.7	131%
Ranyah	East(Desert)	99.6	219.8	32.9	90	33%	68	32.9	100%
Hirjab	East(Desert)	16.8	4.6	3.4	9	20%	9	7.4	218%
Jizan	West(Redsea)	78.9	51.0	23.7	65	30%	-	25.4	107%
Baysh	West(Redsea)	104.6	193.6	73.2	201	70%	58	95.2	130%
Damad	West(Redsea)	61.5	55.5	24.0	66	39%	36	25.2	105%
Hali	West(Redsea)	122.3	249.9	97.8	268	80%	70	106.4	109%
Qanunah	West(Redsea)	21.3	79.2	6.4	18	30%	10	13.2	206%
Yiba	West(Redsea)	81.3	80.9	24.4	67	30%	-	26.8	110%
Total		682.9	1,395.9	351.4	964	51%		401.2	114%
Total	East(Desert)	213.0	685.8	101.9	279	48%		109.0	107%
Total	West(Redsea)	469.9	710.1	249.5	685	53%		292.2	117%

[Note] *1: Development Safe97%=30% of development volume is insufficient once in 10 years、*2: Development Safe 95%=50% of development volume is insufficient once in 10 years、*3: Development Rate(α)=Development Volume/Annual Flow, *4: Development volume by the combination of dam and aquifer with two times volume of the dam reservoir

In such cases that there are users in downstream and new irrigations, although not all of such development quantities can be used for water supply, the supply volume by dams may be larger than the planned water supply volume which MOWE planned, and may be able to increase water supply volume more.

In case of combination development with dams and aquifers (development volume in aquifer is estimated as 2 times of dam development), development volume increases greatly. In particular, this tendency is shown on Tabalah dam, Hirjab dam, Baysh dam, and Qanunah dam.

(2) Desalinated Seawater

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

- Stable and Reliable Water Source: Desalinated seawater is a stable and reliable water source to secure the expected water supply quantity comparing with renewable water resources which are affected by the annual fluctuation, the most prominent characteristics in the semi-arid areas.
- High Production Cost: Although the production cost of desalinated seawater falls by technical progress, 3 times - 4 times are still high (SWCC Annual Report 2008, 2.40SR/m^3) in comparison with the renewable water production cost by the dam. An investment capital interest rate of the dam construction is assured to be 8% a year.
- Minimum Water Transmission: As the desalinated seawater is produced near the sea, the cost of water transmission increases so that the consumption location is too far from the sea. For example, in concert with the above report, transmission cost from Shuqaiq Plan to Abha is 5.18 SR/m3. It is self-evident to plan the construction of new plants as near as possible to the consuming area to reduce transportation cost.

(3) Use of Reclaimed Waste Water

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

<Utilization Merritt for Municipal and Industrial Uses>

If 5% of the municipal water is replaced with the reclaimed waste water, consequently the municipal water demand will decrease by 5%. According to SWCC Annual Report 2008, the water unit price (production cost and a transportation cost) of the desalinated seawater is 8.0 SR/m^3 from 3.5 SR/m^3. In particular, as Transportation costs increase, the water supply to the plateau city rises as well. For example, the decrease of the government subsidy for one year reaches SR67.8 Million if 5% (25,800m^3/day) on city water demand 516,000m^3/day at 2020 in Al Baha Region and Asir Region, and government subsidy supposes with 90% (8.0SR/m^3 x 90% = 7.2SR/m^3).

<Recycle Use of Treated Waste Water for Agricultural Use>

Recycle rate of reclaimed waste water for agricultural use (more than 20%) is high in Al Baha Region and Asir Region. Therefore, to promote agricultural use of reclaimed waste water, “Distributed System of Sewage Treatment and Recycle Use“ is recommended over an “Intensive System” in Al Baha Region and Asir Region.

<Proposal of Implementation of Artificial Recharge by Treated Sewage>

For countermeasures against seawater intrusion, rising of groundwater level by artificial recharge is effective. It is recommended to use treated sewage for water source of artificial recharge. This method can be applied by using treated sewage discharge from Jizan city. The southern part of Jizan city, where seawater intrusion is taking place, should be target for this method. Feasibility Study (F/S) on the reuse of treated sewage discharge is recommended.

4.2 Water Supply

(1) Al Baha Region

Table 7 Water Production Plan in Al Baha Region

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

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

(2) Asir Region

Table 8 Water Production Plan in Asir Region

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

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

(3) Jazan Region

Table 9 Water Production Plan in Jazan Region

Water Resource	-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
1.Existing (m^3/day)	**140,000**	**140,000**	**140,000**	**137,000**	**137,000**	**137,000**
1.1 Renewable Water	**136,000**	**136,000**	**136,000**	**136,000**	**136,000**	**136,000**
Existing Wells	136,000	136,000	136,000	136,000	136,000	136,000
1.2 Desalination	**4,000**	**4,000**	**4,000**	**1,000**	**1,000**	**1,000**
Shuqaiq D.P	3,000	3,000	3,000	0	0	0
Farasan D.P	1,000	1,000	1,000	1,000	1,000	1,000
2.New (m^3/day)	**-**	**149,000**	**193,000**	**246,000**	**246,000**	**301,000**
2.1 Renewable Water	**-**	**69,000**	**78,000**	**78,000**	**78,000**	**78,000**
Bayash Dam	-	33,000	33,000	33,000	33,000	33,000
Damad Dam	-	36,000	36,000	36,000	36,000	36,000
Qissi Dam	-	-	9,000	9,000	9,000	9,000

Water Resource	-2010	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035
2.2 Desalination	**-**	**80,000**	**115,000**	**168,000**	**168,000**	**223,000**
Shuqaiq D.P	-	72,000	72,000	0	0	0
Farasan D.P	-	8,000	8,000	8,000	8,000	8,000
Sabya D.P	-	-	35,000	160,000	160,000	215,000
3.Total (m^3/day)	**140,000**	**289,000**	**333,000**	**383,000**	**383,000**	**438,000**
4.Water Demand(m^3/day)	**203,000**	**238,000**	**286,000**	**329,000**	**379,000**	**436,000**

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

4.3 Management of Water Demand

(1) Urban Water Supply - Proposal for Reduction of LCD

- Promote introduction of the water saving type apparatus according to updating time (a washing machine, a dishwasher, a flush lavatory, etc.).
- Promotion of renewal of an institution for the improvement in a recycling rate of the water in a factory
- Water rates and the water-saving motivation
- Promoting recognition of importance of water saving by education and enlightenment

(2) Urban Water Supply - Proposal for Improvement of Leakage Ratio

- Planned renewal of a decrepit pipeline
- Checking and verifying the amount of supply by a flow meter and actual amount of water supply to users
- Introduction of leakage-of-water diagnostic technology

(3) Agricultural Water Use - Future Planting Plan for Water Demand Control

- Support of the water management technology to the farmers
- Water-saving awareness to farming communities
- Crop conversion to vegetables with small water requirement and fruit tree which can expect increased demand from a fodder crop and other crops with large water requirement

4.4 Operation and Management

(1) Integrated Water Management System

The system that deliberately manages renewable water (surface water, groundwater) had not actively been managed as proposed years before. Conventionally, surface water and groundwater have been managed and used almost individually except the dams and wells which the MOWE regional office has managed for domestic water supply. For this reason, the existing agencies which are bearing managing and supplying renewable water are only MOWE regional offices.

In this M/P, governorate responsibilities are overlapped and the water management plan is proposed. A new RWPC (Renewable Water Production Corporation) is proposed as an organization to take a central role in renewable water activities. In addition, a Water Authority is proposed as a committee that carries out adjustments with the MOWE and the MOA (Ministry of Agriculture).

(2) Groundwater Recharge by Dams

Surface Water Development in Combination with Dam and Groundwater Aquifer

The development volume of each dam is decided based on the annual flow regime and scale of reservoir volume. Therefore, the surface water development in combination with dam and groundwater aquifer is necessary.

Increase of Groundwater Recharge by Facilities

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

(3) Organization Structure and Management System

<Proposal of Organization Improvement>

Water Authority and Water Council

This organization is established for strengthening policy and decision-making levels. The water authority consist of the minister, and secretary of each ministry and agency related to water, and the director general, who determines the national water policy and basic strategy of water and adjustments between relevant ministries and agencies. Moreover, the organization agrees on the water resources development and management plan of the broad-based areas like two or more provinces with related or important state capital. The water council constitutes the deputy minister, vice-president official, and academic expert of relevant ministries and agencies as a consultative body of water policy. The water council deliberates and consults with the water authority and proposes draft doctrine, etc.

Renewable Water Production Corporation (RWPC)

This organization is established to enforce projects concerning development and management of renewable water. Based on the broad-based and relevant water development administrative plan agreed on by the national policy, water authority, and water council, required projects are undertaken and supervised by the commission through the ministries and agencies. This public corporation makes MOWE relevant authorities and undertakes projects based on the supervision and instruction of MOWE.

The operation and maintenance of dams for integrated control and other large-scale vital dams, the operation and maintenance of main groundwater basins which perform joint operations, the control of intake or withdrawal of main natural water resources and water supply networks are specially managed. This public corporation achieves the following functions and roles.

- Production of renewable water and supply of the producing water to water service enterprise etc
- Control and maintenance of large-scale dams and middle-scale dams (flood control, intake control, control and maintenance of facilities)
- Control and maintenance of main groundwater basins (aquifer management, withdrawal management, water quality monitoring and supervision, control and maintenance of facilities)
- Main pipeline transportation (transportation control, control and maintenance of facilities) and sale of the producing water
- The planning, investigation, design, and construction management of large-scale dams and middle-scale dams, and groundwater withdrawal facilities by commission from MOWE
- Promotion of dissemination of rain water harvesting facilities

<System Improvement of Existing Organizations>

MOWE Head Office

MOWE head office, based on the broad direction of the water policy by the water authority and the water council, carries out planning of water management, management of subordinate organizations, instruction of waterworks and sewage enterprise enforcement, and planning of construction management of large-scale facilities. Moreover, MOWE makes adjustments between organizations related to broad-based, important projects over provinces concerning the exploitation of water resources.

General Directorate of Water in Region

Each general directorate of water in region carries out operation and maintenance of intake facilities, water transfer and water supply network in the jurisdiction territory except for big cities managed by RWPC and facilities controlled by NWC, execution of water supply and sewage enterprise of province, planning /investigation /design and construction management of small- scale facilities. Moreover, the General Directorate of Water makes adjustments concerning project in the province concerning the exploitation of water resources as well.

Saline Water Conversion Corporation (SWCC)

SWCC is a corporation responsible for undertaking desalination water production, supply enterprise and the power generation enterprise under the supervisor of MOWE. SWCC continues to support these enterprises and ensure their successful development.

National Water Company (NWC)

NWC is the execution organization of the water supply enterprise and sewer enterprise of the waterworks of big cities, which has operated since 2008. For the moment, NWC maintains oversight of the city zone of Makkah and Jeddah. Although it seems the management of the water supply enterprise is undertaking by the local office of MOWE is transferred to NWC, even in the other major cities in the future; at present, the concrete plan in the target region of this M/P project is not relinquished. Although the water resources development enterprise is mainly concerned with groundwater, it is proposed that part of the management of water resources development is transferred to RWPC, and NWC exists as a specialty company of the water supply enterprise and sewage enterprise in large cities.

<Proposal of New Institutions for Agricultural Water Management>

Agricultural Water Management Division and Agricultural Cooperative Association

Although the farmhouse is using the private well individually until now, the time and the labor for negotiation and adjustment for water supply condition become huge in case of selection of individual farmhouse as target for adjustment. Therefore, adjustment and the regulating function as an agricultural sector is given to the new organization representing farmhouse.

The agricultural water management division (Inner Organization in General Directorate of Agriculture in Region) is the organization for execution of agricultural water use management and adjustment between the farmers and other water basin users.

The agricultural cooperative association is an enterprise enforcement organization of agricultural sector. The organization is established for the purpose of a farmhouse performing production of agricultural products, sale, circulation, development and introduction of agricultural technology. Through these activities, agricultural water demand will be managed.

Government Support System

As governmental support, the system where government organizations carry out priority grants of support and government preferential subsidies is introduced into the joint enterprise and joint activities of farmers to promote the following enterprises.

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

4.5 Cost Estimate and Implementation Plan

(1) Cost Estimate for Water Supply Facilities

As for the facilities proposed in the M/P, construction costs were calculated based on the construction quantity and a unit cost. Regarding construction cost for dams, except for Ranyah Dam and Hirjab Dam, cost estimate were excluded from construction cost.

Table 10 Construction Cost for each Implementation Period (Million SR)

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

Table 8 shows operation and maintenance cost, which is the highest during Year of 2010 to Year of 2035. The operation and maintenance cost by 2015 serves as SR130Million per every year, hereafter, increases every year and serves as per every year and SR298Milion for the targeted Year of 2035.

Table 11 Operation and Maintenance Cost (Million SR/Year)

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

(2) Implementation Program

Table 12 Implementation Plan for the Major Facilities in the Water M/P

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

Note) 1.Implementation period is shown by pattern coloring.

2. Number in a pattern shows the sum total water supply (quantity of production) for the target within the implementation period..

4.6 Evaluation for Water M/P

(1) Technical Evaluation

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

(2) Economic and Financial Evaluation

<u>Result of the Financial Analysis</u>

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

Result of the Economic Analysis

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

(3) Evaluation from Socio-Environmental Aspect

Impact on the Natural Environment and Mitigation Program

In the M/P, the Study Team newly proposed construction of some facilities including dams, pipelines and desalination plants. Under this Study, the socio-environmental consideration survey was conducted at the magnitude of Initial Environmental Examination.

There are several uncertainties embraced in this socio-environmental consideration survey since the precise locations, layout and capacity have not been defined. However, it is anticipated that the newly proposed facilities including dams, pipelines and desalination plants, potentially cause some adverse impacts including temporary water pollution, noise and vibration, flora and fauna, etc. By considering and executing these mitigating measures, the minimum magnitude of adverse impact will be undertaken.

Consideration of Alternative Scenarios

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

- Case A: Zero Option Scenario (Without implementation of the M/P)
- Case B: M/P Scenario (With implementation of the M/P)
- Case C: Alternative Scenario (Increase the water supply by desalination plant only)

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

EIA at F/S Study Stage

In accordance with Environmental Law and Rules for Implementation (2001), Environmental Impact Assessment (EIA) is required for dams, pipelines and desalination plants at F/S Study Stage. It is recommended that the Kingdom shall conduct EIA and prepare social and environmental considerations not only limited to but particularly for the items that adverse impacts are possibly projected.

4.7 Recommendation

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

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

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

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

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

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

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

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

(3) Promotion of Reclaimed Waste Water Reuse

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

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

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

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

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

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

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

(5) Demand Management for Municipal Water

For the demand management of municipal water supply, the M/P proposes the promotion of measures to decrease LCD (or daily water consumption per capita), such as 1) Introduction of Water Saving Type Apparatus, 2) Review of Proper Water Charge and Its Collecting System, 3) Renewal of Institution for Improvement in Water Recycling Rate of Factories, and 4) Recognition of the

Importance of Water Saving by Education and Enlightenment. Also the M/P proposes such promotion measures to decrease leakage ratio of pipelines, such as 1) Planned Renewal of Decrepit Pipelines 2) Improvement of Flow Measurement, and 3) Introduction of Diagnostic Technology for Water Leakage.

Although the measures mentioned above requires some amount of financial investment, the investment is effective considering the financial aspect where the same amount of investment would save several dam constructions for water supply. Therefore, it is recommendable for water related organizations to implement demand control measures to decrease LCD.

(6) Demand Management for Irrigation Water

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

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

(7) F/S Study on Establishment of RWPC

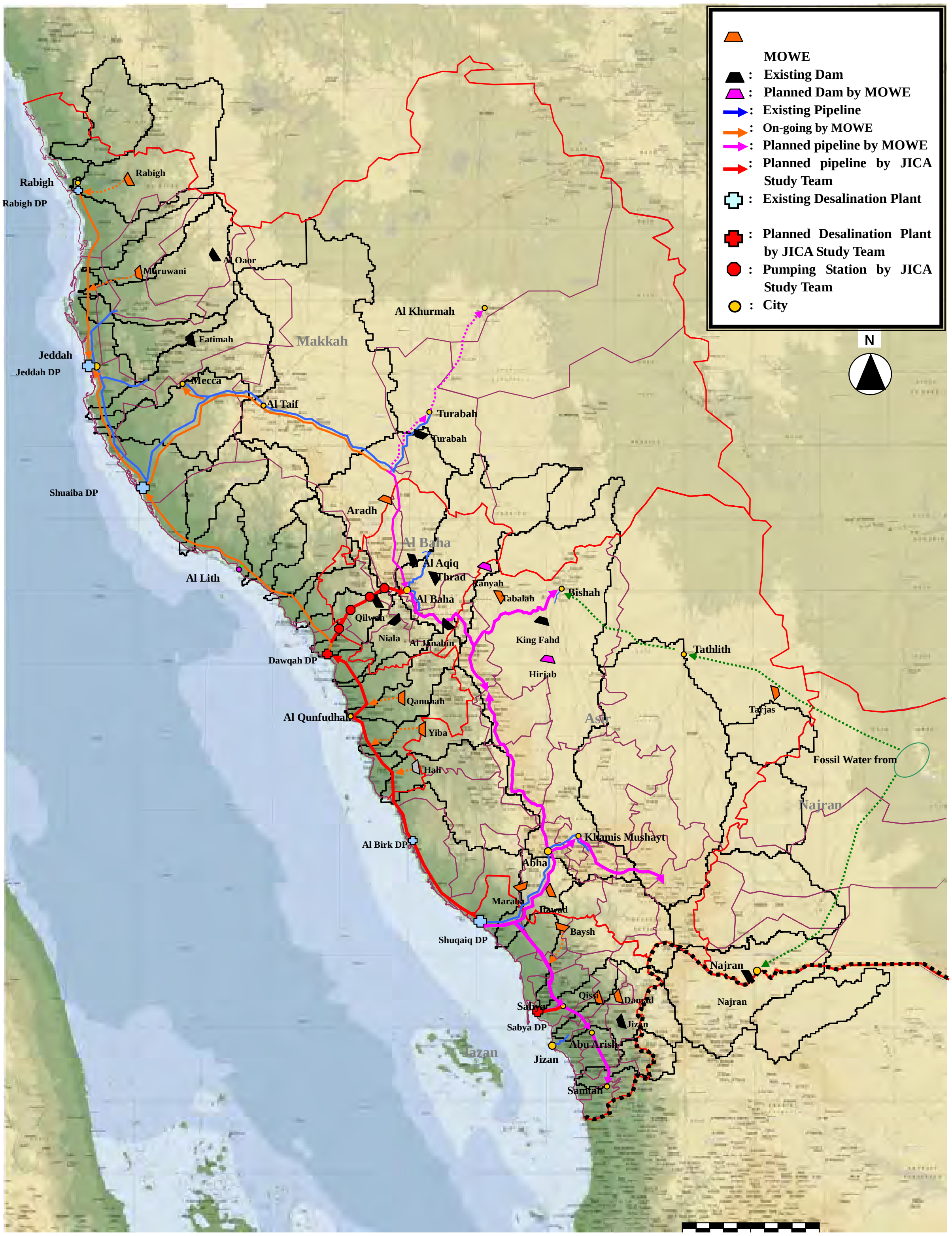
The Water M/P proposes several basic total water service management recommendations: 1) To perform efficient and economical management while combining different water resources; such as, renewable water resources, desalinated seawater, reclaimed waste water, and fossil groundwater, 2) In principle, each state usually manages the water resources assumed for every state at the current time, and 3) Water accommodation across a state should be carried out when water shortage is unusually tight due to the water supply and demand of a specific area arises (due to the local mal-distribution of rain, yearly fluctuation, and a seasonal variation).

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

Also the M/P clarifies the mandates and activities on water resources management for water related organizations such as MOWE and MOWE Regional Office (GDW), other ministries, SWCC, NWC and so on. Further study (F/S) on the establishment of RWPC is highly recommended to realize good water management in the projected areas.

(8) F/S Study on Establishment of REWLIP (Red-Seawater Lifeline Project)

The Study Team proposes REWLIP based on the following two important aspects: *1) Economic Aspect to Secure Less Expensive Water, and 2) Technical Aspect to Secure Necessary Water Sufficiently in a Wider Area by Different Water Sources and Well Connected Water Conveyance Systems*. This large project (which produces desalinated seawater, renewable water and distributes water in the 4 Regions) is the first and very important project for the area and for the KSA. The Study Team recommends the F/S Study on this very important project to be realized soon for the study regions and the KSA as a whole.



Red-Seawater Lifeline Project

CHAPTER 1 OUTLINE OF THE STUDY

1.1 Outline

(1) Background

The desert or arid area extends to the whole land of the Kingdom of Saudi Arabia (KSA), and the acquisition of water resources is one of the top issues to sustain the people's life and domestic industries. The recent increase in population, urbanization and industrialization induces the rapid increase of water demand, and it requires that appropriate and prompt measures against water scarcity be taken.

The southwest region is comparatively rich in rainfall (with annual average amount ranging from 200 to 500mm) on a national basis in KSA where other regions have less than 100mm. The valuable water resources originating rainfall has not been fully utilized so far because of its direct drain-out into the sea (the Red Sea) and the underground infiltration. However, the water resources development projects in the region have been implemented in recent years to keep up with the rapid increase of population and actual progress of industrialization.

The Government of the KSA, accordingly, requested the Japanese Government in 2000 to formulate a master plan (M/P) study on renewable water resources development and management mainly for the renewable water resources of surface and groundwater in the Southwest Region of KSA based on her basic policy on the restriction of water use from non-renewable water (fossil water) and the increase of the water supply from the other water sources. The Government of KSA expressed the request for the corporation in water resources sector to the Japanese Government in November, 1999. In response to the requests, JICA sent a Study Mission on the background of the request in April, 2000 and also sent a Mission for Project Formulation Study in October 2000 in order to conduct a project formulation on "The Renewable Water Resources Development in the Southwest Region of the Kingdom of Saudi Arabia".

As for the captioned study, the preliminary study was carried out in December, 2006 in order to reconfirm the details of the requests and the organization structure for above implementation and followed by the dispatch of the Preliminary Study Team from January 12th to February 8th, 2007. At the Preliminary Study, the discussion was carried out for confirming the scope of the full-scale study and the organization structure for above implementation between the Government of KSA and the Government of Japan. The team leader of JICA Preliminary Study Team and Deputy Minister of Ministry of Water and Electricity (MOWE) concluded an agreement and signed the S/W (Scope of Works) and M/M (Minutes of Meetings) on above full-scale study in January 21st 2007.

The JICA Study commenced in Riyadh in July, 2007, and submitted a progress report (1) based on field reconnaissance, new findings on water use and water resources, updated information was submitted on February, 2008. The interim report compiling the formulation on the basic strategy and policy for integrated water resources development and management, and selection of regions such as Al Baha Region, Asir Region and Jazan Region for the M/P study based on the water balance analysis including desalinated seawater as well as reclaimed waste water and demand projection to the Targeted Year 2035 on municipal, industrial and agricultural water was also prepared in June, 2009.

The progress report (2) describing water resources development plan for renewable water, desalinated seawater and reclaimed water including operational plan, implementation plan and cost estimate as well as economic and financial evaluation for the water M/P was submitted to MOWE, and a discussion was held in January, 2010.

The draft final report dealing with the strategy and action plans for water resources development and management plan in the 5 Regions and water M/P in the 3 Regions was prepared, and discussed in the steering committee in May, 2010.

(2) Objectives of the Study

The objectives of the Study are shown below.

1) To formulate a basic policy, strategy and action plan for sustainable water resources

development, utilization and management in the southwest region of KSA

2) To formulate a M/P for sustainable water resources for the selected Regions based on the action plan
3) To transfer relevant skills and technologies mainly to personnel of the MOWE

(3) Study Area

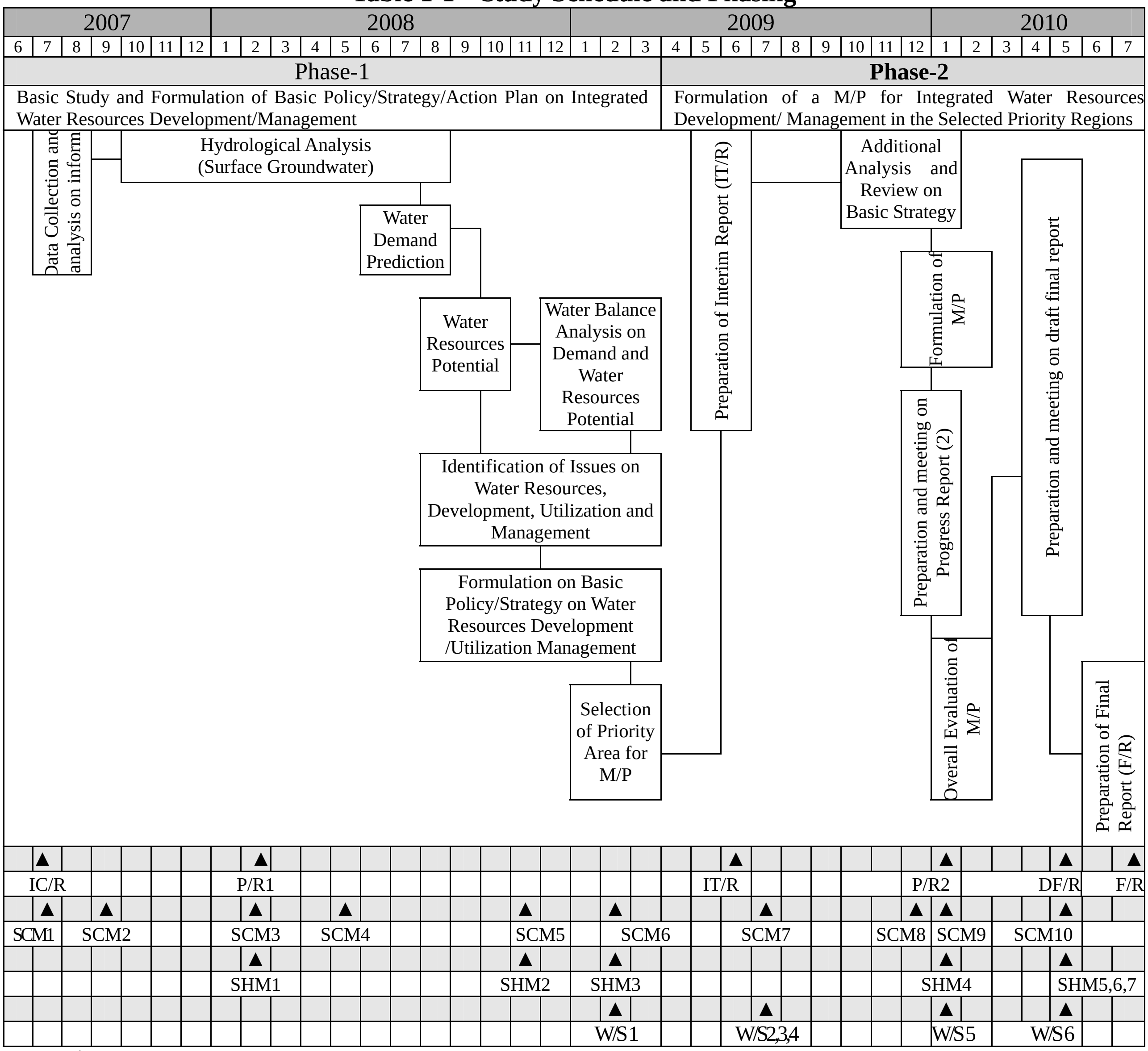
The study area for the phase 1 covered the following five (5) Regions, Makkah, Al Baha, Asir, Jazan and Najran located in the southwest area of the KSA. The study area for phase 2 focuses on Al Baha Region, Asir Region and Jazan Region.

(4) Study Schedule and Study Flow

The study consists of two (2) phases as shown below which will be allocated in the total study period of approximately 37 months.

Phase 1 : Basic study and formulation of basic policy, strategy and action plan on integrated water resources development and management
Phase 2 : Formulation of a M/P for integrated water resources development and management in the Selected Priority Regions

Table 1-1 Study Schedule and Phasing



Notes）IC/R: Inception Report, P/R1: Progress Report (1), IT/R: Interim Report, P/R2: Progress Report (2), DF/R: Draft Final Report, SCM: Stirring Committee Meeting, W/S: Workshop, SHM: Stakeholder Meeting

1.2 Study Organization

The operational organization of the study will be collaborated, finalized and decided through the discussion with MOWE and the details are shown in Figure 1-1.

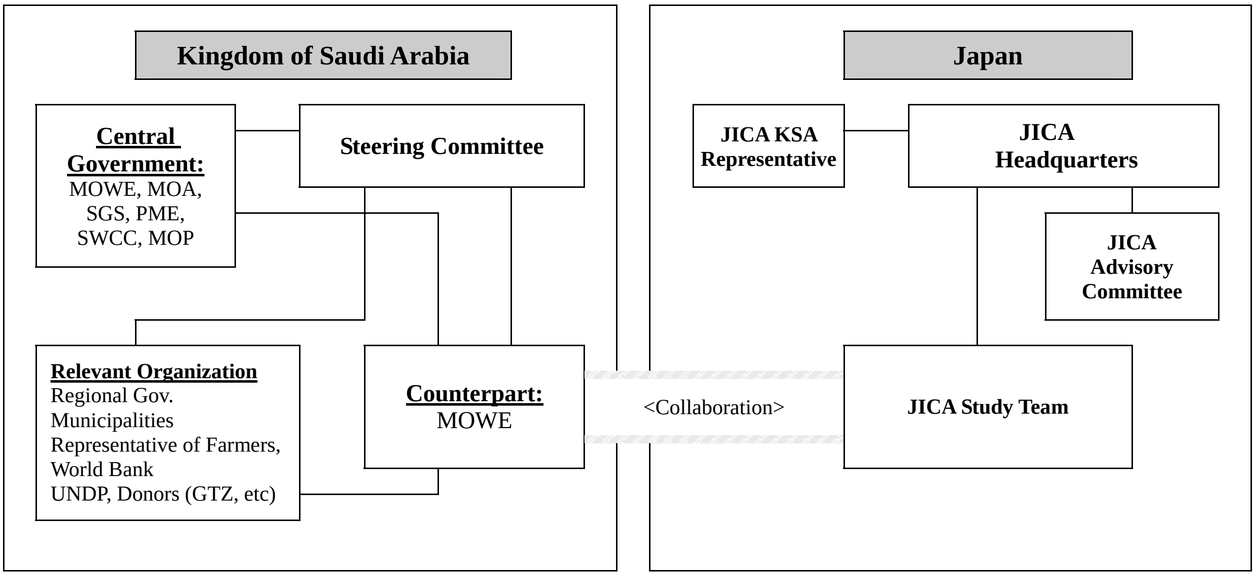


Figure 1-1 Organization of the Study

1.3 Member of Steering Committee, Counterpart Personnel and JICA Study Team

The members of the steering committee and counterpart team of MOWE and JICA Study Team are shown in Table 1-2, Table 1-3 and Table 1-4 shows the main topics discussed in the steering committee meetings.

Table 1-2 Member of the Steering Committee (Ministry of Water and Electricity)

Position	Name	Position or Job Title
Chairman	Dr. A Mohammed I.Al Saud	Deputy Minister of Water Affairs, MOWE (Phase II)
Chairman	Dr. Ali Saad Al-Tokhais	Deputy Minister of Water Affairs, MOWE (Phase I)
Member	Mr. Said Ali Al Duair	Director General for Water Resources Development Department, MOWE (Phase II)
Member	Mr.Ahmed bin Abdullah Al-Ghamdi	Director General for Water Resources Development Department, MOWE (Phase I)
Member	Mr. Abdulaziz Al-Kahlan	Director of Hydrology Division, MOWE
Member	Mr. Helal Ayedh Al-Harthi	Director of Water Research & Studies Division, MOWE
Member	Mr. Ahmed Al-Khalifa	Assistant Director of Water Research & Studies Division, MOWE
Member	Mr. Fahad Ahmed Al-Beajan	Senior Geologist, MOWE
Member	Mr. Metib Al-Khatany	Senior Geologist, MOWE
Member	Mr. Abdulaziz bin Saleh Al-Hassan	Senior Hydrogeologist, MOWE
Member	Mr.Hatim Sarin H. Ratah	Senior hydrologist
Member	Mr. Ghanem Abdulaziz Al-Ghanem	Hydrologist, MOWE
Member	Mr. Saleh Al Meeman	Engineer of Project Execution Department, MOWE

Table 1-3 Member of the Counterpart Personnel for each Region

Position	Name	Position or Job Title	Region
Member	Mr. Habib Mohammed Khayat	Senior Geologist	Makkah
Member	Mr. Hani Othman Kemrin	Senior Geologist	
Member	Mr. Jaber Al-Fifi	Senior Geologist	Al Baha
Member	Mr. Awadh Mahdi Al-Gharni	Senior Geologist	
Member	Mr. Ahmed bin Siraj	Senior Geologist	Asir
Member	Mr. Abdullah bin Ali Al-Shihri	Senior Geologist	
Member	Mr. Ahmad Hassan Nejmi	Senior Geologist	Jazan
Member	Mr. Ibrahim Souwaidi	Observer	
Member	Mr. Faris bin Mohammed Dakhil	Senior Geologist	Najran
Member	Mr. Abdullah bin Rashid Debis	Senior Geologist	

Table 1-4 Member of the JICA Study Team

Name	Position in the Study Team or Job Title
Mr. WATANABE Masatomo	Team leader
Mr. NAKAGAWA Yoshio	Project Director
Mr. TAKAHASHI Toru	Deputy Team Leader / Water Resources
Mr. SHIRAISHI Masayuki	Deputy Team Leader / Water Resources Development Management(Phase I)
Mr. OCHII Yasuhiro	Deputy Team Leader / Water Resources Development Management(Phase I & II)
Mr. KANAMURA Hidetoshi	River/Hydrology (Phase I)
Mr. NAKAMURA Hiroshi	River/Hydrology (Phase II)
Mr. KATO Izumi	Geology/Hydrogeology
Mr. NAKANO Toshinobu	Agriculture /Irrigation
Mr. FUJIYAMA Taketoshi	Water Supply (Desalination, Waste Water Reuse)
Mr. SHINGU Tamotsu	Facility Design / Cost Estimate
Mr. Pirran D. DRIVER	Environmental and Social Consideration (Phase I)
Mr. HARA Takashi	Environmental and Social Consideration (Phase II)
Mr. NAKANISHi Sampei	Social / Organization /Institution (Phase I)
Mr. OURA Hisashi	Social / Organization /Institution (Phase II)
Mr. NATSUDA Shohei	Economic and Financial Analysis
Mr. ONO Shigeru	GIS Expert
Dr. EIBO Ahmad	Interpreter（Phase II）
Mr. KATO Atsushi	Coordinator (Computer specialist)

(1) Stakeholder Meetings and Workshop

During phase 1 study, stakeholder meetings were held 3 times for the purpose of explanation of the study outline and obtaining information on water issues in Region. Outline of the water M/P for each Region was explained and discussed among stakeholders in the meeting during phase 2 study.

Workshops were carried out 6 times for the exchange of information on water resources development and water demand, opinions for the JICA study and for seminar on monitoring method of surface runoff and sub-surface water in Wadis.

(2) Survey by Sub-contract

To grasp the hydrological condition on surface runoff and sub-surface water in Wadi and groundwater level, hydrological surveys were done in the study area. The initial environmental examination (IEE) was also conducted during the phase 2 study to recognize the richness and current conditions of the fauna, flora and water quality in the targeted areas.

(3) Counterpart Training in Japan

Counterpart training in Japan was carried out 2 times, in 2008 and 2009, for the purpose of introduction to the water development plan in Japan, the management and operation for water resources development facilities such as dams and barrages through the lectures and study tours. Semi High-level official training in Japan was carried out from June to July 2009, for the purpose of introducing of the technology of the future water field, and discussing the possibility of technical cooperation. Discussion on the M/P in the JICA Study was conducted at the headquarters of JICA, and a discussion with the executives of the Ministry of Land, Infrastructure and Transport, the Ministry of Agriculture, Forestry, and Fisheries and Japan Water Agency.

The counterpart training session was done for understanding the policy of water-resources-development method, technology, and Japan, while evaluating these situations through actually inspecting dam facilities, river operation and maintenance facilities. The technology of control management of a dam, floodgate and the water quality improvement method could be applied to Saudi Arabia, and the JICA Study Team followed up after training.

Semi high level official training deepened understanding and information concerning the administrative and technology of water resources development management in Japan, and purposely showed the interest in continuous discussions in the area of sewerage treatment technology and water reuse technology.

CHAPTER 2 CURRENT SITUATION OF THE STUDY AREA

2.1 Socio-economy

2.1.1 Sub-division and Population

Table 2-1 shows population trends in the five regions and all 13 regions in the KSA from 1974 to 2004. The population of the five regions made up about 40% of the KSA's population in 2004 and increased three-fold in the 30 years from 1974 to 2004. In addition, the annual population growth rate was 6.9% from 1974 to 1992 and decreased to 2.3% from 1992 to 2004.

Table 2-1 Population Growth in the Five Regions from 1974 to 2004

Regions	1974	1992	2004	Growth Rate per Year in 1974-1992 (%)	Growth Rate per Year in 1992-2004 (%)
Makkah	1,754,108	4,467,670	5,797,971	8.1	2.3
Al Baha	185,905	332,157	377,739	4.1	1.1
Asir	681,361	1,340,168	1,688,368	5.1	2.0
Jazan	403,106	865,961	1,186,139	6.0	2.8
Najran	147,970	300,994	419,457	5.4	3.0
5 Regions total	**3,172,450**	**7,306,950**	**9,469,674**	**6.9**	**2.3**
13 Regions total	**6,729,642**	**16,948,388**	**22,673,556**	**8.0**	**2.6**

Source: The Eighth Development Plan

Note: Population growth rates were re-calculated.

2.1.2 Economy

Represents value added changes from 1999 to 2004. The average annual growth rate of the GDP in the period is 3.4%. The growth rate of the non-governmental services sector and the productive sector are higher than the average growth rate of GDP. In 2004, the share of non-governmental services sector was about 30%, the crude oil and natural gas sector was about 28%, and the productive sector was about 25% of the GDP.

The productive sector and non-governmental services sectors are divided into sub-sectors as shown in the above table. Trade, Restaurants and Hotels, Other manufacturing, Real estate, and Construction occupy more than 6.0% of the GDP. The sub-sectors whose average annual growth rates are over 5.0% are Electricity, Gas and Water (6.3%), Other Manufacturing (5.9%), Finance, insurance and business services (5.8%), and Transport and Communications (5.6%). These figures show that the manufacturing sector and non-governmental services sector are leading the growth of the national economy.

In these years, GDP per capita is increasing steadily year by year. The value is seemed to be over US$ 15,000 in 2007. The growth rate is decreasing in these five years. It came down between five and six percent in 2004 though it was nearly eight percent in 2003 in particular. However, the trend of decreasing has been eased, gradually. It is estimated that the growth rate in 2007 will maintain between four and five percent.

2.1.3 Agriculture

(1) Agricultural Area in KSA

The average planted area of the whole country in 2002 to 2007 is about 1,140,000 ha. The big 5 regions of planted area are Riyadh, Al Qasim, Jazan, Al Jawf and Hail in order, and the Jazan of the biggest planted area in the South West Area is the 3rd in KSA. In these regions except Jazan, large-scale mechanized farming is carried out and much fossil water is used as a head. In addition, the percentage of occupying the agricultural population in 2001 in whole Saudi Arabia to overall population by 1,930,000 people is 9.2%. (source: FAOSTAT).

(2) Agriculture in South West Region

Since the Makkah Region is holding the big consuming city Jeddah, agriculture in suburban type cultivation is popular in this area. Moreover, mountainous Al Baha, Asir (Abha), and Najran Regions are active in fruit trees and vegetable cultivation because of the geographical features and high elevation climate. Jazan Region shows the biggest planted area, especially cultivation of cereals occupies many, and has become percentage of 80% or more. Cereals represented by the sorghum and wheat are grown on the flat plain of Asir and Jazan Regions.

In the South West Region, although modern irrigation systems exist, such as drip irrigation and micro jet irrigation, the adopted irrigation efficiency is rather high for vegetables and fruit trees. In cultivation of cereals, such as a sorghum and wheat, traditional irrigation systems, such as flood irrigation systems, are generally adopted and irrigation efficiency is rather low.

2.1.4 Industry

(1) Current Status of Industries in Overall KSA

The total number of factories remarkably increased eight-fold in the 35 years from 1971. Currently the main industries are chemical and plastic products, building materials, glass and basic metallic. There were 1,176 factories in the five regions in 2006, making up around 30% of the national total, and its rate has almost unchanged from 1999.

(2) Number of Industries in Five Regions

The numbers of all industries in the five regions have increased. The region with the highest rate (about 3.6%) of increase is Al Baha region and the second highest rate (about 3.4%) is Asir region. On the other hand, the region with the lowest rate (about 1.2%) of increase is Jazan region.

The following table shows the breakdown of the number of operating factories classified by industrial sectors in the five regions in 2006. Food processing, chemical products, building material and base metal processing in all five regions are the main sectors, and these four sectors make up more than 70% of the total.

(3) Number of Industrial Laborers in the Five Regions

Laborers for food processing, and chemical and plastic products represent the majority in the five regions overall. In Makkah Region, laborers for food processing, and chemical and plastic products are the majority as well. In Al Baha, Jazan, Najran Regions, the number of laborers for food processing, building materials and glass, etc are more than that for all other sectors combined.

(4) Number of Labors per factory by Sector in Five Regions

The average number of laborers per factory is between 30 and 100. Of the five regions, there are the largest scale factories in the Makkah Region with the laborers per factory of about 100. The next largest scale factories are located in the Asir Region with the laborers per factory of 60. In terms of sectors in the five Regions, the average number of laborers per factory is between 40 and 60 with the exception of paper, printing and publication sector.

2.1.5 Infrastructure

(1) Roads

The road length of the targeted five regions make up about 38% of the KSA's total road network, with 80% unpaved and 20% paved, while the KSA national average is 73% unpaved and 27% paved. Asir, Riyadh, and Makkah have the highest proportions of the road network, and the proportion of road network in Najran, and Jazan is low.

(2) Electricity

The rate of electrical service coverage in 2003 was 90%, and the annual growth rate of the service coverage from 1999 to 2003 was 3.3%, with an annual growth rate of per capita consumption for electricity was 1.7%, which indicates the electricity sector is growing constantly. About 83% of customers of the electrical service were residential, with an annual increase in customer numbers of

5.8%. According to The Eighth Development Plan, the estimation of electricity service coverage in 2004 was 92% and there are plans to achieve 100% coverage by 2009. In addition, no data of the existence of a power failure etc. is obtained.

2.1.6 Employment

In 2003 about 33% of the total labor force in the private sector were Saudi nationals and 67% were foreigners. The productive sectors made up 52% of the entire labor in the private sector and the ratio of the services sectors was 46%. The Saudi labor in the services sectors was more than the Saudi labor in the productive sectors while the non-Saudi labor in the productive sectors was more than the non-Saudi labor in the services sectors.

The unemployment rates of the five target regions are arranged in the next table. Even in Makkah, that includes Jeddah, the unemployment rate is 18 %, which is higher than the average rate of 16% in the whole country. The remarkable regions whose unemployment rate is over 30 % include Al Baha (32 %) and Jazan (31 %). The unemployment rates among women in all regions are higher than that of men all over the country. The unemployment rates among women in Al Baha and Jazan are 64 % and 52 %, respectively, which means that women who can get job are less than the half of applicants for jobs.

2.1.7 Public Health

Saudi Arabia has achieved substantial improvements to its healthcare system in the past 20 years from 1984 to 2003, with infant mortality rates dropping from 85 per 1000 births to 22 per 1000 births, and average life expectancy increasing from 61 years to 72 years. Access to healthcare of pregnant women increased from 86.8% in 1999 to 98% in 2003.

2.1.8 Economic Value of Water

(1) Water Tariff

The eighth development plan mentions that the average water consumption for a family of six is estimated to be around 41 m^3/month. Such consumption falls under the first segment of the tariff structure (See Table 2-2). Consequently the price paid by most consumers is SR 0.10 per cubic meter[1].

Table 2-2 Structure of Water Tariff for Municipal Purposes

Segment	Volume (m^3)	Tariff (SR/m^3)
First	0-50	0.10
Second	51-100	0.15
Third	102-200	2.00
Fourth	201-300	4.00
Fifth	301 and Over	6.00

Source: The Eighth Development Plan

(2) Water Cost

Household water and sanitation services in Saudi Arabia: an analysis of economic, political and ecological issues[2] made a trial calculation of cost comparison between desalinated water and groundwater. It said that the cost of one cubic meter of domestic water from the New Riyadh Wells Project might be estimated at some US$ 0.36. With the addition of the opportunity cost of capital of US$ 0.18 per cubic meter the total cost becomes US$ 0.54 per cubic meter.

[1] 23.2.7 Water Cost (p. 476), The Eighth Development Plan
[2] Elie Elhadj, SOAS Water Research Group, Occasional Paper 56, SOAS/KCL Water Research Group, School of Oriental & African Studies and King's College London, University of London, May 2004

2.2 Natural Condition

2.2.1 Geography

The project area lies on the south-western part of the Kingdom that rises abruptly from the Red Sea in the west and dips gently towards the Najd in the east. In the trunk of the project area, Hijaz Asir highlands rises up to about 3,000 meters in the south near Abha, while at northern boundary of the area near Taif, the elevation is about 1,500 meters (refer to Figure 2-1).

There is a distinct coastal plain, locally known as Tihama, separated from the hills by an imposing scarp wall that runs parallel to the Red Sea along 700 km in the project area.

Toward the east forms the peak of Hijaz Asir highlands, hills peter out further east to the interior, and give way to an extensive plateau covered with lava flow (Harrat) of the area, and very thin veneer rock debris and alluvium over a basalt and crystalline basement, which is frequency outcrop as knolls and low hills. In large scale geographic view, the project area is divided into three geographic regions, as follows.(veneer rock debris: weathered and scoring debris , then debris cover; laying on older rock formation)

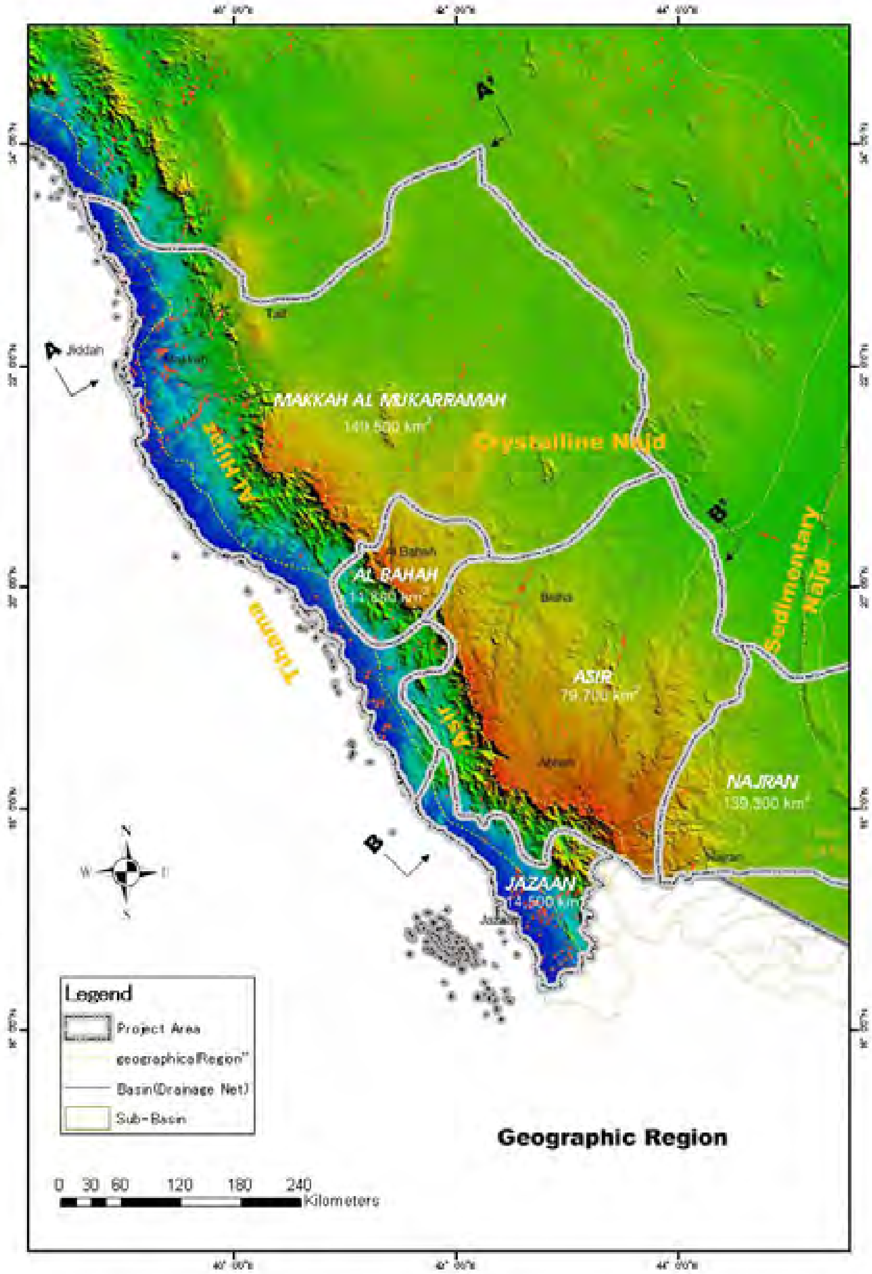


Figure 2-1 Geography of Project Area

2.2.2 Geology

Project area is underlain by tightly folded, regionally metamorphosed volcanic-clastic, and epi-clastic rocks and many mafic to felsic plutonic[3] all of late Proterozoic age. It is called as 'Arabian Shield-Nubian Shield' and is exposed with concealed by the sedimentary cover rock that dips gently toward the east. As covered rock, in the project area, Paleozoic sandstones, comprising the Cambrian-Ordovician Wajid sandstone, are found on the southeastern range of the project area and overlie Proterozoic rocks.

In the project area, several episodes of volcanism are recognized in the geologic age. Of those events, older volcanic activity occurred in Precambrian age and formed a volcano-clastics and subordinate flow rocks, complexly inter-layered with volcanically delivered and epi-clastic sedimentary rocks. While the younger rocks, Tertiary and Quaternary basalt-flows and gabbro-dikes are found in particular the north of the project area. Both are associated with Red Sea rifting: the basalt is part of a large area of a flow rocks and volcanic cones resulting from volcanic activity, whereas the gabbro dikes were intruded into tension fractures.

Overlying the bedrock are unconsidered Quaternary deposit that included wadi alluvium, fanglomerate delivered from the Red Sea escarpment, terrace gravels, coastal-plain silt and eolian sand. These formed during the period of active erosion following the uplift of the region and the opening the Red Sea, which caused the development of wadi system draining to the east and west and the erosional retreat of the Red Sea escarpment.

Typical litho-stratigraphy and geologic map of the project area is shown in Figure 2-2.

[3] Note:
Plutonic rock: Type of igneous rock formed by solidification depth beneath the earth surface
Felsic rock: Igneous rock dominated by aluminum-rich minerals.
Mafic rock: Igneous rock dominated by magnesium and ferrous iron.

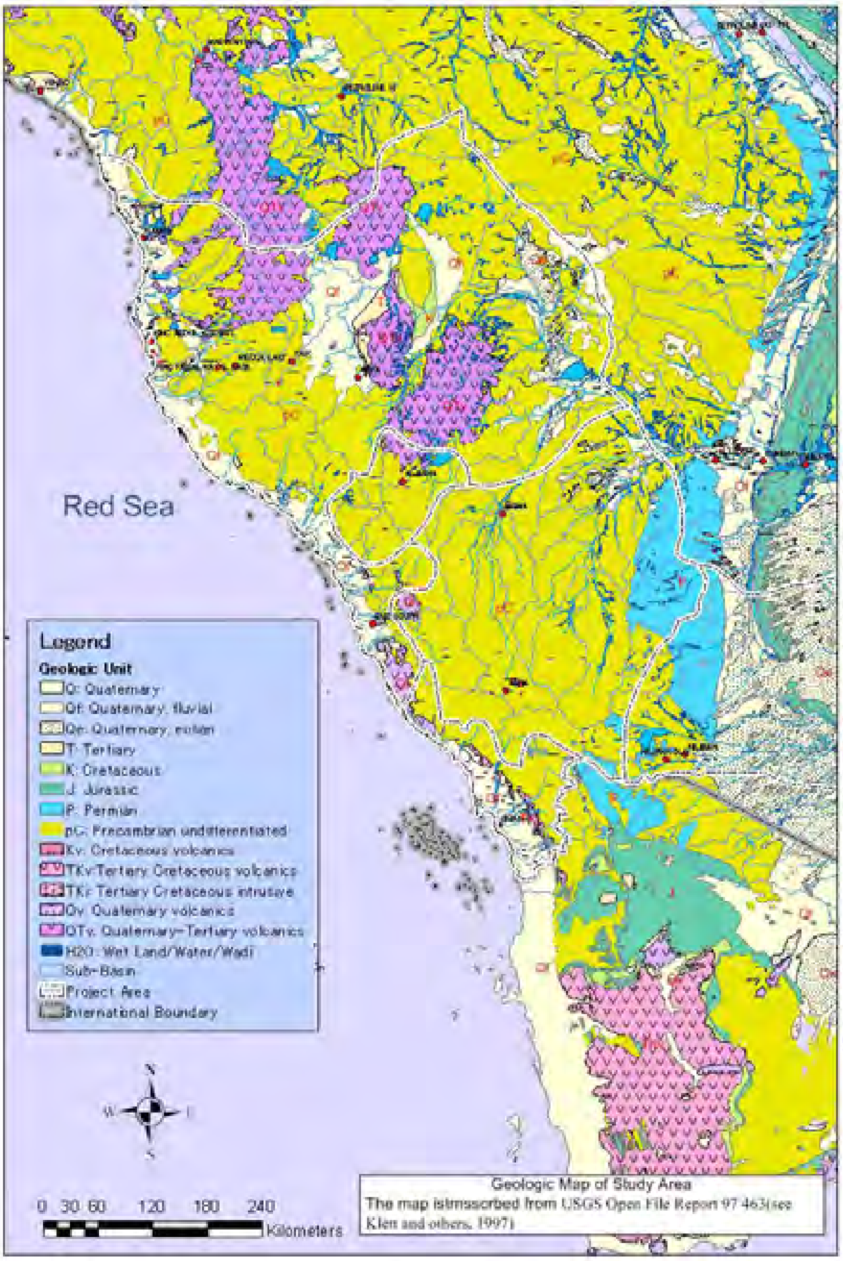


Figure 2-2 Geologic Map of the Project Area

2.2.3 Meteorology (Meteorological Stations)

The study area has 10 Meteorological Stations under the control of Presidency of Meteorological and Environment (hereinafter referred to as P.M.E) and 56 of them under the control of MOWE.

2.2.4 Hydrology (Rainfall, Runoff)

(1) Rainfall

Regarding tendency on areal rainfall, in the north areas (representing by monitoring station J140 located in north of Jeddah) in the study area, annual rainfall is 100mm or less at the maximum.

In the mountain land area (representing by A107 monitoring station) of the central part in the study area, there is comparatively much annual rainfall and it reaches from 50 mm to 250 mm.

The Jazan Region located in the south area representing by SA137 station shows largest annual rainfall from 50mm in minimum to 400mm in maximum.

(2) Tendency of Rainfall from 1968-2004

Based on the database of MOWE, the annual rainfall in 1968 - 2004 was arranged, and the amount of areal annual rainfall in 5 regions was calculated by the Thiessen dividing method.

These calculation results are shown in Figure 2-3.

The tendency for annual rainfall to decrease is remarkable in recent years. According to these figures, Jazan Region has the most rain in the five regions, and annual average rain shows 400mm or more.

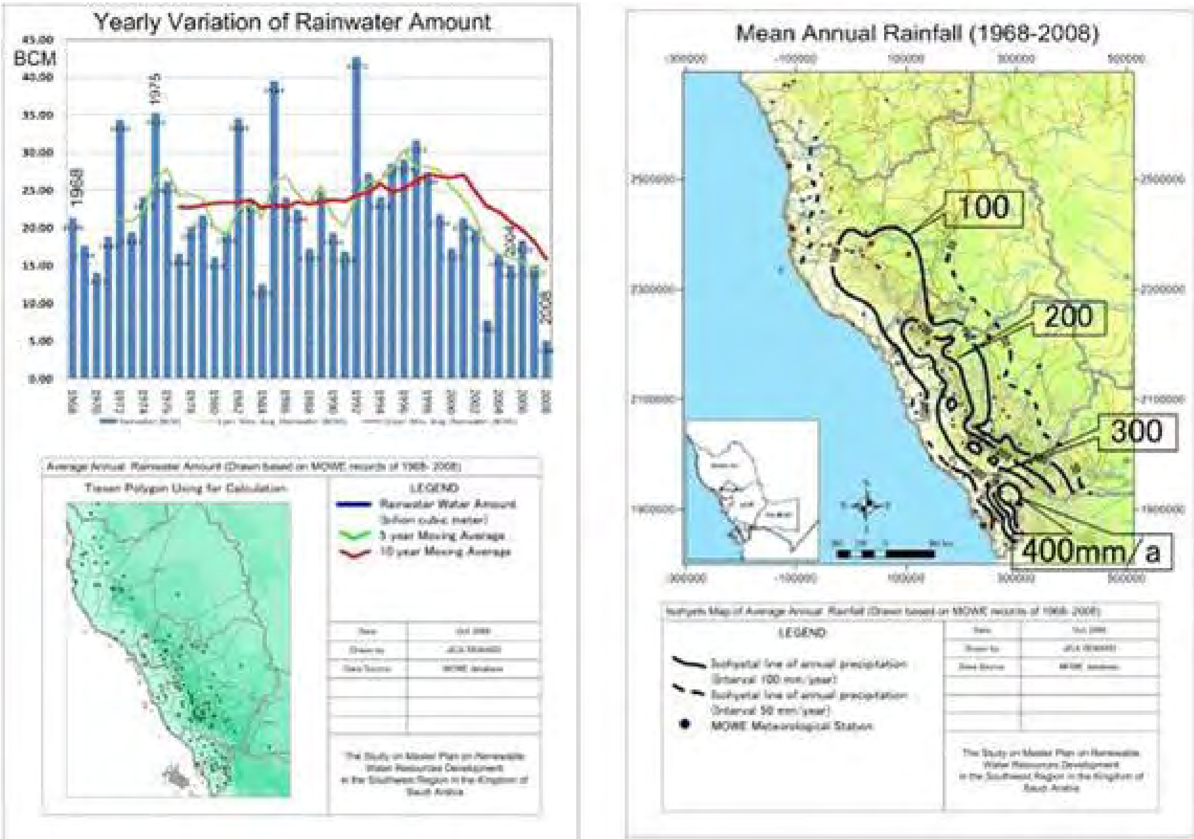


Figure 2-3 Tendency of Annual Rainfall and Areal Distribution

(3) Runoff Stations

Observation of discharge has continued until around 1985. Location of the runoff stations in each region are shown in Supporting Report.

Looking on the areal tendency of annual runoff representing by station J410 located in north of Jeddah of the Makkah Region, there is runoff of 40 MCM in 1975, however, there is little runoff for other years in the north area. In the mountain land area representing by A403 monitoring station in the central area of the Study Area, although year change of runoff is large comparatively and there is a year showing runoff with 80MCM, small runoff have been continued in 1977 and afterwards.

In the Jazan Region representing by station SA21 located in south of the study area, it shows continuous runoff, and shows the runoff of 15 MCM in minimum or more 80 MCM in maximum.

2.2.5 Hydrogeology

In the project area, the natural groundwater storage systems include aquifers from both the oldest and the youngest of he geologic ages. These are Precambrian crystalline rocks from the former age and others are of Recent alluvial deposits and eolian sands from the later age. The aquifer occurs within the sedimentary strata and volcanics overlying the Precambrian basement of the project area.

In the project area, two principal aquifers: Minjur/Dhruma, Wajid: and two secondary aquifers:

Alluvium and Basalt: are of principal groundwater resources.

1. Lower Paleozoic Clastic Rocks (Wajid Aquifer)
2. Jurassic, Triassic, and Permian Clastic Rocks (Minjur/Dhruma Aquifer)
3. Quaternary and Tertiary Volcanics (Basalt Aquifer)
4. Quaternary Sediments (Alluvium)

Four aquifers cropping out in the project area is shown in Figure 2-4.

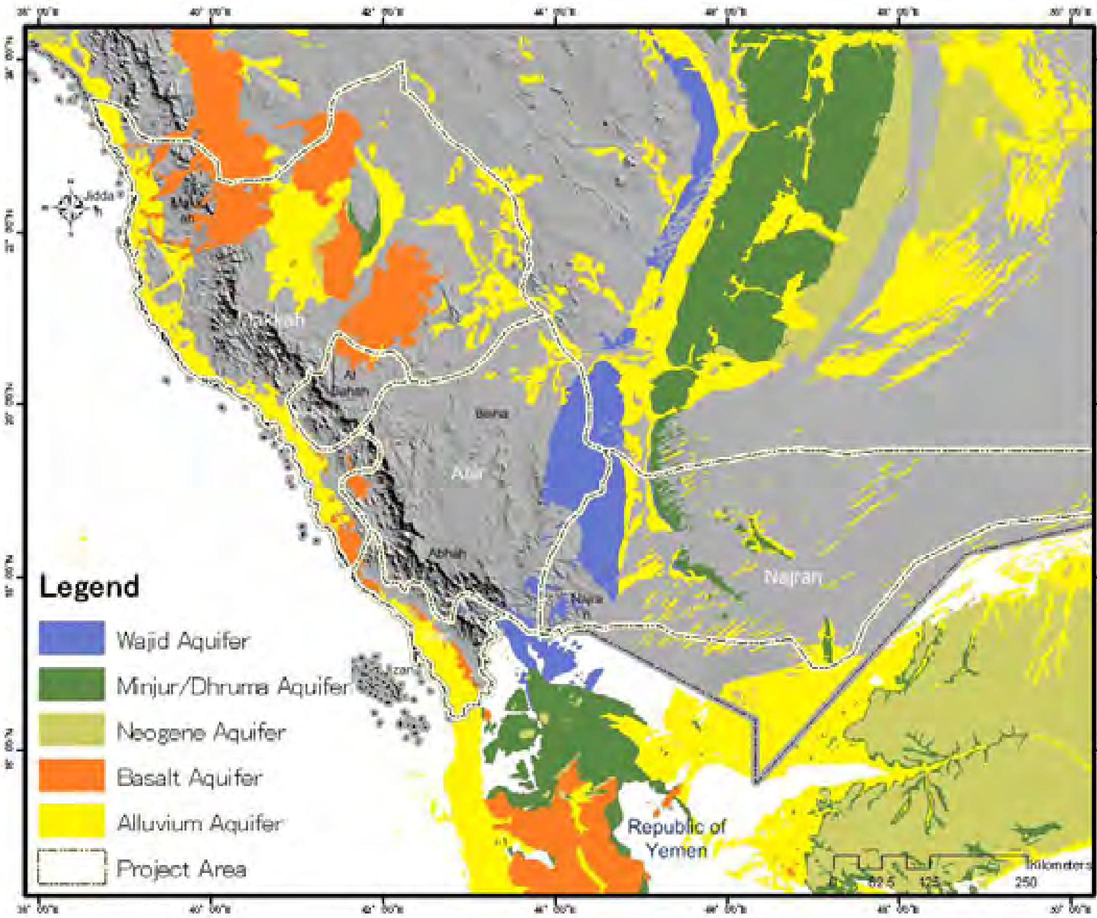


Figure 2-4 Aquifers in Project Area

2.2.6 Groundwater and Water Quality

In the project area, four layers are regarded as the productive aquifers which have enough permeability and storage to effective extraction for bulk water use. Their general hydrologic characteristics and groundwater quality are described as follows:

<u>Wajid Aquifer (Lower Paleozoic Clastic Rocks)</u>

Wajid Aquifer lies on eastern area of Asir region and Najran region which occupy a part of Wadi Dawasir basin. The water quality is generally good and the dissolved-solids concentration of water in the aquifer is generally less than 1,000 milligrams per liter. They quality of the water improves eastward toward the Rub al Khali basin, but eventually the trend reverses and mineralization increases.

<u>Minjur/Dhruma Aquifer (Jurassic, Triassic, and Permian Clastic Rocks)</u>

Minjur/Dhruma Aquifer is limitedly found in Makkah Region as remnant, and Najran Region overlaid by recent eolian sand in Rub al Khali. Water quality data has indicated that the saline increase down-gradient and with depth. The dissolved solids ranged from freshwater to saline water.

Basalt Aquifer (Quaternary and Tertiary)

Basalt Aquifer covers extensive area in the Makkah region. Mineral concentration of the water from the Basalt Aquifer was shown to be generally low. The specific concentration was reported as a range from freshwater to brackish water and Sodium and chloride were the dominant ions.

Alluvium (Quaternary and Tertiary)

Alluvium aquifer is located everywhere in extensive areas: the Red Sea coastal strip, along with wadi courses, mountainous basins and even in eolian sands in the project area. The specific conductance of this water was found to vary greatly, ranging from freshwater to saline water. The percentages of sodium and chloride were slightly higher than the other dissolved minerals. As total mineralization increased, however, the sodium and chloride concentrations became increasingly dominant.

2.2.7 Land Use

Land use map was collected from International Steering Committee of Global Mapping (ISCGM) product covering the project area at 1 km resolution in a consistent manner and its content is equivalent to conventional maps at scales of 1:1,000,000. These geographic data sets are composed of not only land-use but also elevation, vegetation, land-cover, transportation drainage systems, boundaries and population centers and the data will be updated at approximately five-year intervals to facilitate the monitoring of changes occurring in the global environment. (refer Figure 2-5)

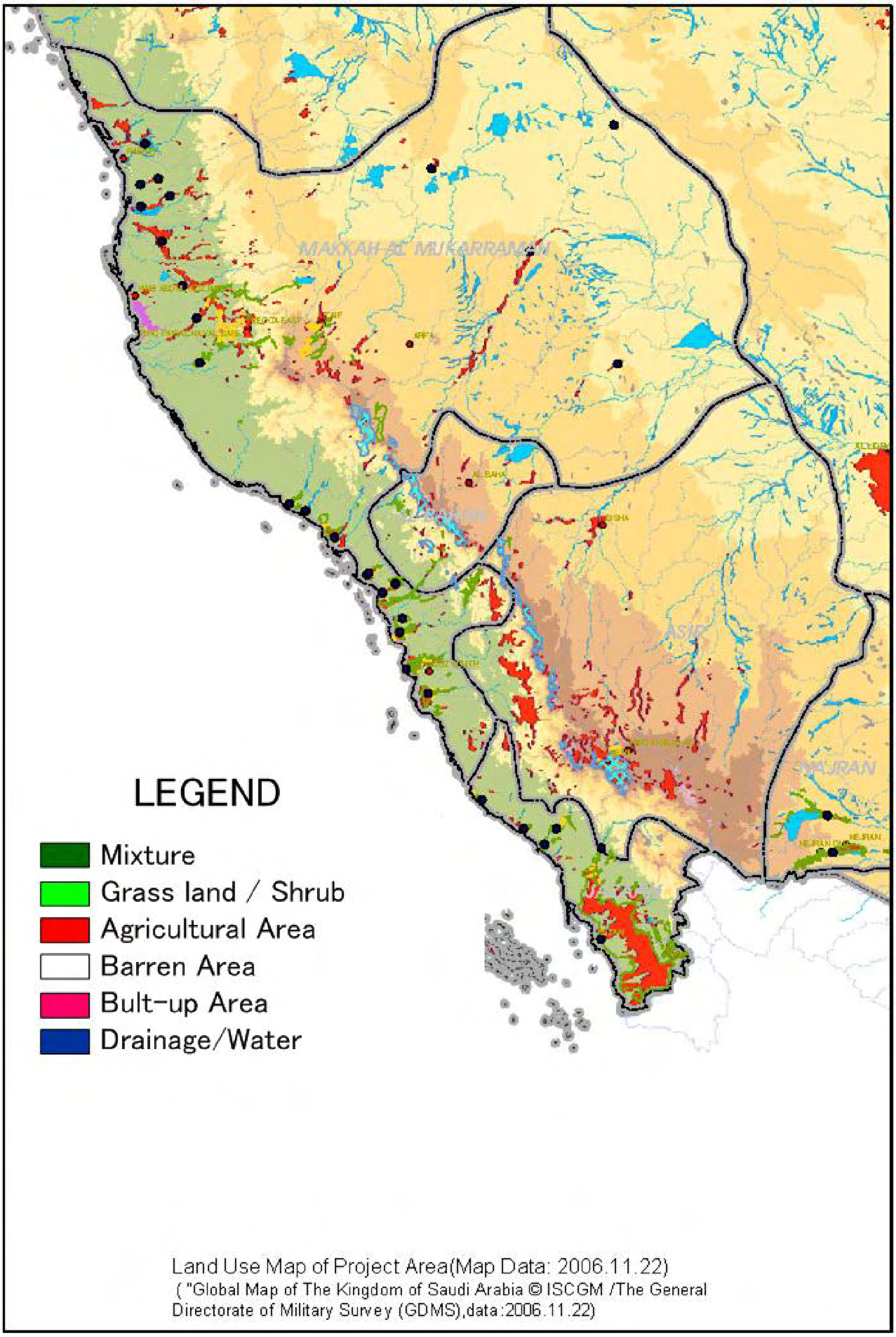


Figure 2-5 Land Use Map in the Project Area

2.2.8 Fauna and Flora

Characteristics of Habitats

The majority of the project areas are covered with the artificial environments such as agricultural land and residential land, and desert areas or wastelands. Therefore, these areas are not suitable for development of ecosystem. On the other hand, the average annual rainfall in the Al Hijaz Asir highland, which runs through the center of the project area, amounts to 300-500 mm. Such relatively high rainfall brings rich biodiversity in the area. According to the First Saudi Arabian Report on the Convention of Biodiversity, the kingdom has 10 "large" and 11 "small" areas of juniper forest, most of which fall inside the project area. These areas are some of the few forested areas in the country, and as well as being important as areas of soil formation and desertification barriers, they also host a comparatively high diversity of other plants and animals.

Endemic or Endangered Species

Due to the local conditions already described, the project area is estimated to hold around 70% of the kingdom's 3000 or so plant species, indicating that a considerable proportion of the faunal species are likely to be present in the same area. Further clarifications are needed in order to identify precisely which species of note are to be found within the project area; however the following are already identified as being important species present in the area, either due to their endemicity, rarity or as a "flagship species."

Flora:	• *Juniperus* sp. Reasonably widespread at higher elevations • *Ziziphus* sp. Christi (Christ's Thorn Jujube) Common in wadi beds and rangeland, and has many uses in Arabian culture from shade to fruit and forage, soap, timber, and honey production; • *Acacia* sp. This community is generally confined to gravelly wadi-beds and slopes of the study area; • *Olea europaea* (Olive). Generally found on slopes below Juniper communities.
Fauna:	• *Chlamydotis (undulata) macqueenii* (Houbara Bustard) ; • *Oryx leucoryx* (Arabian Oryx); • *Dendrocopos dorae* (Arabian woodpecker) – Listed by IUCN as vulnerable, and endemic to Saudi Arabia and the Yemen; • *Caracal caracal* (Caracal Lynx)

Protected Areas

To date, 15 protected areas, covering almost 4% of the country's surface conserve all the major physiographic regions, half the country's biotopes, key wetlands, marine and mountain habitats and protect viable populations of endemic, endangered and key plant and animal species.

2.2.9 Vegetation

The vegetation (land cover) map illustrates important valuables in estimating water demand and understanding water balance. The map was collected from Global Land Cover Facility (GLCF) products. It was processed with satellite images from 1981 to 1992 and composed of 1 km spatial resolution (grids) with 14 classifications.

2.3 Previous Studies and Plans for Conventional Water

2.3.1 General

Conventional water resources in KSA classified as runoff water, shallow groundwater and fossil ground water. It is classified as runoff water and shallow groundwater which are recharged by rainfall, while classifieds as fossil groundwater which is not recharged by rainfall in a short term.

2.3.2 Previous Study for Runoff Water and Groundwater

To aid in grasping the hydrological characteristics and plan for water resources development facilities as well as cost survey, Ministry of Agriculture and Water (MOAW) started the hydrological study in five Wadis: Al Lith, Tabalah, Yiba, Habawnah and Liyyah, in 1984.

Of these Wadis, proposals for the construction of dam are made in Wadi Lith, Wadi Yiba and Wadi Tabalah. In parallel to the study for 5 Wadis, the Ministry of Agriculture (MOA) started the study on water resources such as dams including well field.

Among these dams, the two dams currently in operation are Aqiq Dam and King Fahd Dam. All other dams are under construction as of 2009.

To cover the required demand 20,000 m^3/day for potable water in the area including the Cities Abha, Khamis Mushayt and Ahad-Rufeida in Asir Region, the water resources development study was carried out by MOAW in 1997. Wadi Itwad and two tributaries flowing near Ad Darb Town in the south coastal area were selected for the sites of development of water resources.

To develop water resources of Wajid and overlying aquifers located in the northern area of Najran, MOWE contracted with Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) in April, 2006. The project titled “Detailed Water Resources Studies of Wajid and Overlying Aquifers”, abbreviated “ Wajid Project”, will be executed for 3 years until April, 2009. The study is divided in two phases. Phase I includes a reconnaissance stage and a preliminary study. Phase II is the continuation of Phase I in detailed form.

2.3.3 Dams and Wells

In the KSA, as measure of surface water development, dam constructions have been introduced. 126 dams had been already constructed and 86 dams are under construction in the study area. The Number of dams in the Asir Region shows the largest number.

Many wells have been drilled in the KSA for the purposes of provision of water, monitoring of water level and water quality and agricultural use. According to a book on water resources development facilities in KSA, 824 wells are listed up during the period from 1989 to 2005 by Regions.

2.3.4 Issues on Development of Conventional Water Resources

Issue on development of conventional water resources is arranged as follows.

- The renewable resources (surface runoff) have the tendency of large changes for every year, and can be utilized as effective water resources by storing of dams. In addition, for storing in dams, it is important to take into consideration the influence of an amount of evaporation.
- The water is mainly stored in Quaternary Wadis sediments. Over abstraction is remarkable in these areas. The water levels of groundwater will need to be managed in the Quaternary areas along the Red Sea.
- The mountain areas in the west of the Study area, only wadi circumference area has the potential of groundwater development.
- According to areal distribution of rainfall, areas suitable for development of the water resources development will be limited. That is, Jazan Region has high potential of water development, followed by the circumference areas such as southern areas of Makkah Region and Asir Region.
- The northern area of Makkah Region, Al Baha Region, northern area of Asir Region near Bisha, and the Najran Region have little rain, and need large catchment areas for the development water resources by construction of dam.
- Dams in the under construction stages such as Rabigh Dam, Maruwani Dam were planned in the 1980s and started construction in accordance with the year 2000 schedule. Wadi Itwad project was started in 1997 and was completed in 2009.
- Dam sites should be designated by taking into consideration the geographical features, the viewpoint of geology, and the viewpoints of hydrology on discharge a water etc. The Study Team proposed five dam sites selected based on the topographic maps such as the Wadi Gholan and Wadi Khulab. Through meetings with MOWE, however, there were no suitable as dam site identified and therefore judged as appropriate dam sites at present.
- As for the dam operation, it remains only in operation of each dam, and cooperative operation among dams is not made. In major dams located in the Study Area, it is necessary to examine the possibility of cooperative operation.
- Regarding fossil aquifer, it is important to check the amount of Resources at first. Furthermore, in consideration of being limited resources, maintenance and preservation plan for fossil aquifer should be draw up and should be done for bare essentials of use.

2.4 Current State and Supply Plan on Desalinated Seawater and Waste Water Reuse

2.4.1 General

Non-conventional water resources in the KSA are classified as desalinated seawater and reclaimed waste water. The former carries out desalination processing by making sea water into fresh water. The latter aims at reuse of reclaimed waste water, and is used as the source for agriculture, water in the city, and industrial water.

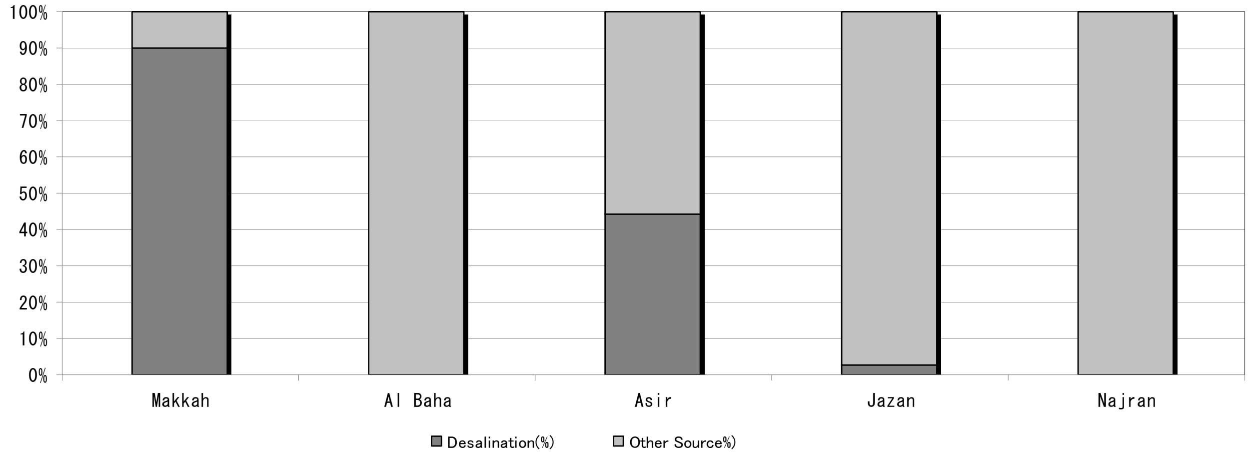
In the KSA, domestic water supply depends on the desalinated seawater. According to the National Water Strategy 2007, about 50 % of water sources used for the water supply facilities, comes from desalination plants, around 40% from groundwater, and the remaining 10% from surface and reuse water.

2.4.2 Desalinated Seawater

(1) Historical Supply of Desalinated Seawater

The Makkah region gets about 90% of its water via desalination plants, which is the highest percentage in the five regions studied. (See Figure 2-6) The SWCC (Saline Water Conversion Corporation), which is supervised by the MOWE, is engaged in desalination work. There are 11 plants on the West Coast and 3 plants on the East Coast, for a total of 14 desalination plants. In 2005, the combined total capacity of these 14 plants was approximately 2.8 million m^3 per day. The combined total capacity of the plants located in the five regions studied is 1.1 million m^3 per day, which is a little less than 40% of the combined total capacity of all the plants in the country.

Current distributed amount of water by region and amount of water to be expanded by SWCC. Asir Region and Jazan Region are supplied by desalinated seawater as of 2006



Source: Regional General Directorate, MOWE

Note: Most of others are the water that stored in recharge dam, penetrated into ground and pumped up from wells.

Figure 2-6 Occupation Ratio of Desalinated Water and Other Sources for Potable Water

2.4.3 Current Status of Reclaimed Water

About 40% of total amount of the treated waste water in the five regions is used for industries, irrigation and landscaping. Reclaimed water is used not only for irrigation and landscaping but also for construction use mainly in the Asir Region where the rate of reclaimed water use is highest of the five regions

2.4.4 Issues on Development of Non-conventional Water Resources

Issue on development of non-conventional water resources is arranged as follows.

- Although a stable supply is possible for desalinated seawater, the fall in cost will be nonexistent if a large-scale plants are not built.
- Reclaimed waste water may serve as an important future water resource. However, this future water supply resource needs restricting and network system should be developed.
- Supply of reclaimed waste water is a set with network system, and needs to give a priority to advance of network system.

The supply of reclaimed waste water should work in unison with the development of sewer networks, and the latter needs to take priority to advance development.

2.5 Current State and Supply on Water Use

2.5.1 Domestic, Institutional and Commercial Water

(1) Service Population

Facilities of water use are categorized into public and private water supply facilities. Types of water users are composed of users of network system which receive water pipelines directly and that of water trucks for public water supply. The remained users rely on individual water sources. Water supply facilities with pipelines are one of the most common types, supplying approximately 4 million people, and representing about 42% of the total population in the five regions studied.

(2) Water Use

In many areas of the KSA, since there are no water meters in most of private households, data of revenue water has systematically not developed.

On the other hand, Annual Report 2007 of MOWE shows supply amount (MCM: million m^3/year) of water of KSA. The supply amount of water includes unaccounted for water such as leakage.

2.5.2 Industrial Water

The supply amount of industrial water including leakage water of the five regions in 2007 is 150MCM (0.4million m^3/day), making up about 20% of overall industrial water (716MCM) of KSA and about 23% of municipal water (629MCM) in five regions.

2.5.3 Agricultural Water

Gross water requirement multiplies the planted area of each year by the unit net water requirement of different crops shown above is calculated. Details for these calculations are shown in the Supporting Report.

2.6 National Plans, Strategies and Laws on Water Resources Development and Management

2.6.1 Five-Year National Development Plans

The Five-Year National Development Plans have been prepared by the Ministry of Economy and Planning (MOEP).

First 5-Year National Development Plan (1970/71 – 1974/75) was formulated in 1970 and eighth 5-Year National Development Plans had been issued in 2006. The latest 5-Year National Development Plan was formulated in 2005 that will be effective up to 2009.

In previous plans, the long-term general objectives served as the point of departure for setting priorities and the areas of focus of each plan. The Eighth development plan represented the first landmark in a strategic approach for the national economy, which extends over the next twenty years and encompasses four consecutive five-year plans. As such, this approach reflected a new turn in the methodology adopted for strategic planning in KSA.

The Eighth Development Plan defined more precise targets and translated them into quantitative terms (whenever possible) and clearly spelled out implementation schedules and the responsibilities of the implementation agencies, as well as the issues they would address.

2.6.2 Review Results of Water Related Portions in the 5-Year National Development Plans

(1) Main Issues

In Second and Third development plans, wasteful practices of irrigation and severe water shortage by over-pumping were recognized as a main issue.

Up to the 1990s, increase of water consumption of non-renewable groundwater and agricultural consumption of water had become an issue. The formulation of National Water Plan had been necessitated in almost all development plans.

After the1990s, water pricing, reclaimed water, water conservation and water & waste water services have become a main issue. In the latest development plan, monitoring, follow-up and enforcement of regulation, strengthening of water legislation and administrative centralization became a main issue.

(2) Role of Private Sector

Since the Third development plan, the private sector role has been emphasized.

The MOWE is in the process of reforming the water sector in KSA. The basic idea of this reform process is to improve the overall performance of the sector in various areas through the transfer of services to a business minded environment and the involvement of the private sector. The reform program in the water sector aims at the following objectives:

a) Provide access to clean and good quality potable water for all residents
b) Provide sanitation connections to all households and safe disposal of waste water
c) Improve organization performance and customer service, with a view to gradually becoming a commercially oriented organization
d) Provide reasonably priced water and sanitation services with a view to cost recovery
e) Progress towards privatization to facilitate the enhanced performance of the sector
f) Protect the natural environment and conserve natural resources in KSA.

(3) Future Water Vision

Water vision in the future was firstly manifested in the latest Eighth development plan below:

a) Satisfying the growing demand for water for residential and industrial purposes
b) Gradually decreasing the demand for water for agricultural purposes

This water vision manifested is expected to be realized through the following measures:

a) Development of non-conventional and renewable water resources
b) Enhancing water conservation and protection of water resources
c) Applying the economic value of water
d) Administrative development

(4) Development Strategy

The development strategy including objectives and policies has clearly been indicated since the First development plan up to the latest Eighth development plan.

The development strategy in the Seventh and Eighth Five-Year National Development Plan is summarized below:

Table 2-3 Development Strategy in 8th 5-Year National Development Plan

Development Plan	Main Development Strategy
Eighth (2005/06 – 2009/10)	**Objectives** 1. Conserve and develop water resources, along with ensuring rationalized use of these resources 2. Provide water and waste water services for all segments of the population of the Kingdom at a high level of quality and reliability and at the lowest possible cost while taking into consideration the purchasing power of low income citizens 3. Provide water for industrial and agricultural purposes within the limit of what is dictated by sustainability of water resources and socio-economic effectiveness 4. Realize the integrated management of the Kingdom's water resources **Policies** 1. Intensify water rationalization and conservation techniques

Development Plan	Main Development Strategy
	2. Develop desalination and reclaimed waste water as additional non-conventional water resources 3. Apply the economic value of water approach in all uses and realize sustainable balance between water prices and the cost of production 4. Increase the efficient utilization of renewable water, and endeavor to develop such water 5. Protecting natural water resources against pollution 6. Give priority to meeting the demand for water used for drinking and municipal purposes while encourage the utilization of reclaimed waste water for agricultural , industrial and other purposes 7. Improve the standard of water sector's management 8. Encourage the private sector to invest in waste water collection and treatment facilities 9. Increase the actual capacity of water desalination and encourage private investment in the desalination sector 10. Enhance the contribution of national manpower in the water sector 11. Finalize the studies and research pertaining to the preparation of the National Water Plan 12. Review the legislation that regulates water uses 13. Establish comprehensive databases of the water sector

(5) Establishment of Ministry of Water and then Consolidation of Water and Electricity

To secure more effective water resources management and national leveled water planning and a higher level of sustainability and continuity of water development and progress of KSA, in 2002 all water agencies and authorities were merged under the Ministry of Water. The specific objectives of the new Ministry as stated in the **Royal Decree No. 125 on 16 July 2001** covers water resources development and management and water use.

a) Supervise the management, monitoring and organization of the water sector and its facilities
b) Carry out all related studies needed to assess the country's water supplies and storage volumes
c) Prepare a comprehensive water plan defining policies for water resources development, protection and conservation
d) Prepare a national program to expand the drinking water and waste water networks in all urban areas of KSA
e) Suggest the required organizations needed for water resources protection
f) Study and propose new water tariffs for all users of water
g) Determine how to improve the performance of waste water collection systems
h) Develop mechanisms, frameworks and implementation strategies for private sector involvements, operation and maintenance

(6) Water Demand and Supply Balance in 5-Year National Development Plans

Since the Second 5-Year National Development Plan (1975 – 80), the present and future water demand and supply balance was estimated as shown in Table 2-4.

The latest Eighth 5-Year Development Plan expected the low growth rate of water supply by renewable surface and groundwater and the sharp reduction of water supply by non-renewable groundwater and the high growth rate of non-conventional water as summarized below.

Table 2-4 Expected Water Demand and Annual Growth Rate in Latest Development Plan

Water Resources	Water Consumption in 2004 (MCM/year)	Expected Water Demand In 2009 (MCM/year)	Annual Growth Rate (%)
Renewable Surface and Groundwater (Arabian Shield & Continental Shelf)	6,500	6,900	1.0
Non-Renewable Groundwater	12,400	9,270	-5.0
Non-conventional water (Desalinated Water and Reclaimed Waste Water)	1,370	2,090	8.0
Total	20,270	18,260	-2.0

2.6.3 Long-Term Strategy 2025

The work on the Long-Term Strategy 2025 (LTS 2025) began with the Royal Consent on July 2, 1998 giving the responsibility to the MOEP to organize a National Symposium on the "**Future Vision for**

the Saudi Economy" held on October, 2002.

(1) Long-Term Strategy for Water Sector

Vision 2025 listed the following core set of strategic policies in water sector:

a) Issue a clear statement of water policy

b) Revive benchmarking of water utilities

c) Implement Result-oriented conservation drive

d) Increase PSP (Private Sector Participation) in water and waste water sector (including dams)

e) Tariff reform

f) Update estimates of total water resources

2.6.4 National Water Strategy

(1) Background

In 2003, the MOWE requested World Bank to support for the development of an Integrated Water Resources Management Strategy and Short/Long Term Action Plans for KSA.

The overall scope of the MOWE-WB (World Bank) Cooperation Program was agreed upon to include the following three phases:

a) Phase I: Assessment of the current water resources management situation

b) Phase II: Development of strategic water sector management policies through extensive in-country consultations

c) Phase III: Development of an action plan for implementation of the strategy

(2) Issues in the Water Sector

The World Bank Study Team identified the most pressing issues that the water sector in KSA is facing, and grouped those issues under the definition of five policy gaps as summarized below:

Table 2-5 Contents of Issues in the Water Sector of KSA

Items	Contents
(1) Water Scarcity Gap:	a) The current levels of groundwater withdrawals, mostly water for irrigation, exceed beyond its sustainable yield. b) The high subsidies which farmers have been receiving for the 25 years induced a precipitous increase in the cultivated area and discouraged water savings. The negative externality emerges due to the unrestricted access to groundwater. c) Farmers are treating groundwater as a free good, assuming that it is their right to take (and to waste) as much water as they want. There is the lack of government control and regulation of the irrigation activity.
(2) Water Conservation Gap:	a) The tariff for urban water supply provides no incentive to conserve water, yielding large per capita consumption levels. And there haven't been enough concern for reducing the excessive water losses occurring along the distribution networks. b) There is the imbalance between treated waste water supply and its reuse due to lack of a long-term plan. The benefit of such a policy is two-fold if treated waste water is recycled; as a safeguard against pollution and environmental degradation; as a way of securing additional water supplies for a variety of uses. c) The irrigation efficiency of 45% occurs despite the large investments made in the modernization of the irrigation infrastructure.
(3) Water Service Gap:	a) The quality of water supply and sanitation(WSS) service remains noticeably below internationally acceptable standards. An important portion of the population remains dependent on supply through water tankers, and waste water collection and treatment are the areas requiring the most improvement. b) SWCC provides bulk desalinated water to the regional directorates free of charge, utilities

Items	Contents
	recover on average less than 5 per cent of their O&M cost. And such a low level of cost recovery has prevented the investments necessary to keep up with service improvements.
(4) Water Governance Gap **:**	a) Past water administrators have dedicated their best efforts to building the major water infrastructure and providing water services, with little attention to base resource management. b) The MOWE should enhance coordination with water actors as well as provide the means and technical instruments for successful management. At that stage political support will be needed to establish the new organizations, build capacity and improve upon current recruitment policies.
(5) Financial Gap **:**	a) The high level of farm subsidies and the lack of cost recovery in water provision services impose a heavy burden on the government budget. Agriculture production should be examined by considering a substantial gap between the productions cost to farmers and the true cost of agriculture to the Saudi economy as a whole. b) Because irrigation overuse groundwater, domestic water cannot use groundwater and are forced to depend on desalinated sea water which costs lot. c) The lack of cost recovery hinders the WSS sector capacity to extend sewerage services to more areas and build new treatment facilities.

(3) Recognized Policy Framework for National Water Strategy (NWS)

Three premises such as Sustainability, Efficiency and Equity embody the essence of the KSA water strategy. The three premises were translated into a series of clear mandates that guided the preparation of the water strategy as listed below:

a) Declare water a national good for public use, subject to government regulation

b) Stop the devastation of the base resource and reverse the course of action

c) Shift in paradigm: from water supply management to water demand management

d) Find a balance between water development and resource protection

e) Adopt a virtual water strategy to relieve the pressure on the water resources

f) Promote high value of water so as to increase water productivity

g) Reach universal coverage of water supply and sanitation services

h) Attain cost recovery for water services

i) Provide legal protection to water users

j) Adopt integrated planning as the rationale for water allocation

k) Exercise water management at the lowest appropriate level

l) Improve public awareness and encourage water conservation

(4) Coordination of Water allocation and Interests

a) The process needs to create horizontal linkages across all water users to find the best possible solution to the water allocation problem. Technical coordination can be achieved by setting up an integrated water resources planning (IWRP) process.

b) The KSA should create an executive body to overcome sectoral interests and set the government in motion to ensure the coordination of sectoral policies. The NWS recommends the formalization of an intra-governmental and interagency coordination body to be named the Kingdom’s Water Council (KWC), to focus coordination and integrated planning in the water sector and enforce collaborative decision making.

(5) Recommendation for implementing Goals

The following are recommendations for implementing the goals in the NWS.

a) Goals shown in the NWS are water use efficiencies, water conservation, equitable and efficient water allocation, monitoring and protection of the sources, increasing the reuse of water, enhancing water productivity and expansion in the population served.

b) The new institutional structure will be founded in a modern legal and regulatory framework, supported by proper instruments, to give the MOWE the power to exercise specific water management functions.

c) Government had been absent from the basic functions of resource management. Hence a new organizational structure is in order, aimed at promoting integrated water resources management functions in the Kingdom.

2.6.5 Laws and Regulations related to Water Resources Development & Management

(1) Current State on Development of Laws & Regulations in Water Sector

Table 2-6 shows the summary on the current state on the development of the laws and regulations related to water resources development and management in KSA by focusing the categories and issues in water sector.

Table 2-6 Summary on Current State on Laws and Regulations in Water Sector

No.	Category / Issue	Corresponding Laws or Regulation
1. Water Resources Development and Management		
1.1	Middle-term Development on Water Resources Development and Management	• 8th National Development Plan • 9th National Development Plan (under preparation)
1.2	Overall Water Resources Management	• 8th National Development Plan • Royal Decree No M/34 dated 24/08/1400H (7 July 1980G) • The Council of Ministers' Resolution No. 62044 dated 07/07/1409H
2.Reuse or Reclamation of Treated Waste Water		• Royal Decree No. M/6 dated 13/02/1421H (18 May 2000G)
3. Water Right (Priority Use on Water)		• Royal Decree No M/34 :Priority Use on Water • The Council of Ministers' Resolution No. 62044 :Priority Use on Water
4. Legislation on Water Tariff		• the Council of Ministers' Resolution No. 125 dated 25/04/1422H (17 July 2001G): One of the key tasks of MOWE is to propose water tariffs for all consumers • The Council of Ministers' Resolution No.96 dated 26 Dec. 1994G
5. License for Well Digging		• Royal Decree No M/34 • The Council of Ministers' Resolution No. 62044
6. Monitoring (Water Quantity, quality, etc.)		• Royal Decree No M/34 • The Council of Ministers' Resolution No. 62044 • Royal Decree No. M/6
7. Institutional & Organizational Demarcations / Mandates of Relevant Agencies		
7.1	Set-up of Two Distinct Entities into Water and Agriculture Departments from the former Ministry of Water	• The Council of Ministers' Resolution No. 125
7.2	Delegation of Authority on Water Resources Development & Management to MOWE	• Royal Decree No 27472 dated 09/07/1423H (17 September 2002G)
7.3	Saline Water Conversion Corporation Law	• Royal Decree No M/49 dated 20/08/1394H (7 September 1974G) • Royal Decree No M/10 dated 27/02/1427H (27 March 2006G) (Revision of M/49)
7.4	The Saudi Geological Survey Regulation	• The Council of Ministers' Resolution No. 115 dated 16/07/1420H (26 October 1999G)
8. PPP (Private Public Partnerships)		
8.1	Lists of Projects to be privatized	• The Council of Ministers' Resolution No. 219 dated 16/07/1420H (26 October 1999G)

(2) Laws and Regulations relating to PPP (Private Public Partnerships)

The Council of Ministers' Resolution No. 219 dated 16/07/1420H (26 October 1999G) listed the infrastructure projects such as; Water, sewage, desalination, telecommunications, air transport, railway, etc. including construction, operation and maintenance.

2.6.6 Institutional, Organizational and Budgetary Aspect

(1) Current State on Institutional and Organization Framework

The current state on institutional and organizational framework relating to water resources development and management in KSA is shown in Figure 2-7.

MOWE is currently a core body for water resources development and management in KSA, which has the mandate to formulate a basic policy on water sector, permit well digging for well digging contractors, inspection the facilities and actual implementation on water and sewerage sector. MOA formulates an agricultural policy in the agriculture sector which currently consumes over 85 % of water resources in KSA, and MOA also authorizes permits / license for reuse of treated waste water. SWCC, an inter-agency of MOWE, operates saline water conversion plants nationwide KSA and supply its bulk desalinated water to MOWE and municipalities for their water distribution to customers. Saudi Geological Survey (SGS) has a mandate to carry out survey works to identify water resources and water storage, determine the qualities and quantities of surface and groundwater, and determine water suitability in consultation with MOWE. MOEP formulates a national development plan including water and agricultural sectors based on the data / information supplied by MOWE and MOA.

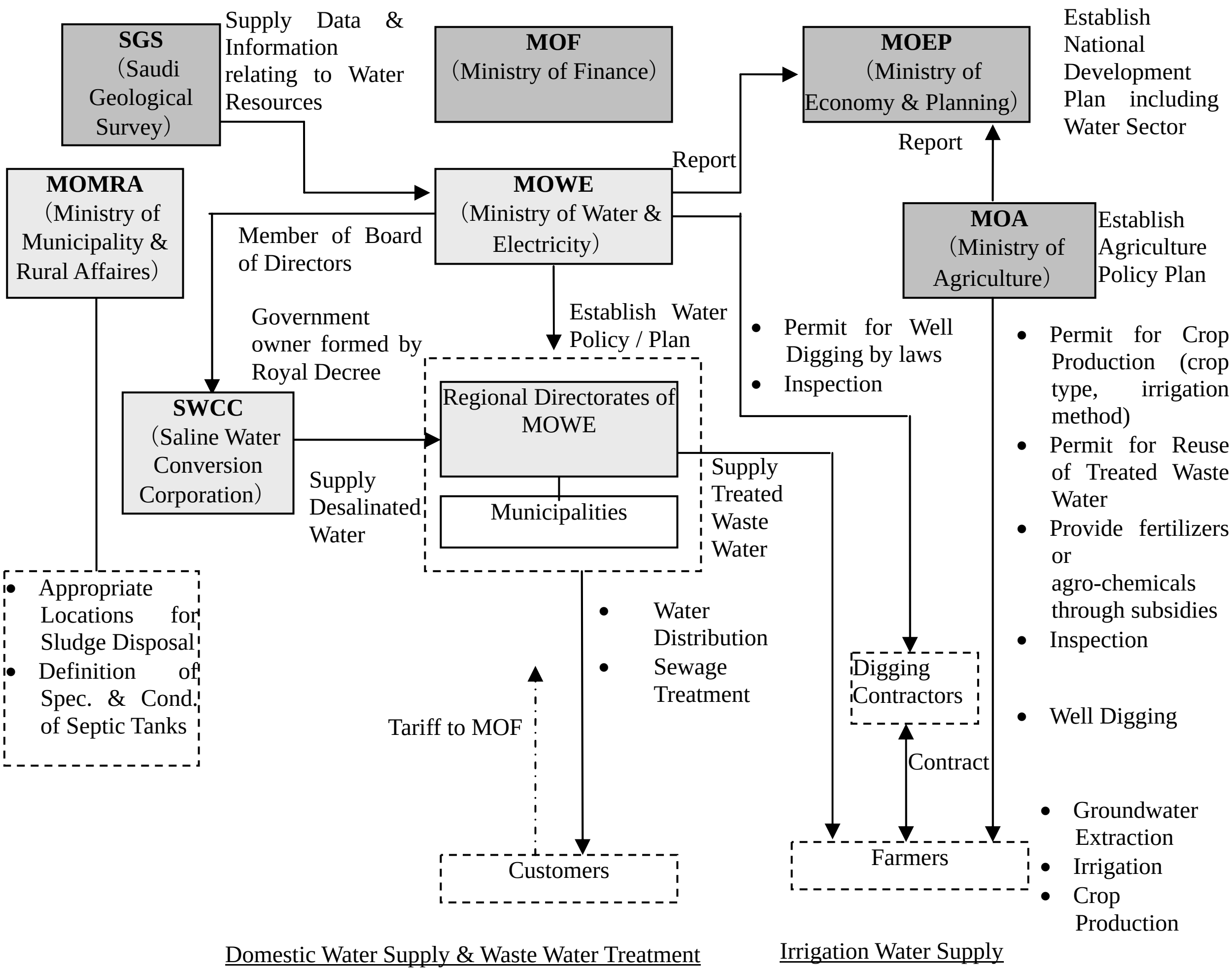


Figure 2-7 Current State on Institutional and Organizational Structures relating to Water Resources Development and Management

(2) Institutional and Organizational Reform Process in Water Sector

In order to deal with the challenges the KSA faces, the Government of the KSA has launched a reform process in the water sector. The government's overall key objectives for the reform are:

Reform 1: Centralization in Water & Sewerage Sector, Establishment of MOWE

In order to centralize and streamline roles and responsibilities within the water sector, the creation of a Ministry of Water (MOW) was authorized by the Government in July 2001. This Ministry has taken over the water-related roles from the MOWA, and Ministry of Municipal and Rural Affairs (MOMRA). In 2003, the Ministry was expanded to incorporate the electricity sector and established as the Ministry of Water and Electricity (MOWE).

Reform 2: Introduction of PPP

Public-Private Partnerships (PPP) was expected to deliver on the promise of improved water quality and customer service and visible increases in capital investment and the replacement of aging facilities, taking into account best practices, successful business models and adherence to international efficiency standards and given the projected increases in water demand in KSA. The Kingdom's Supreme Economic Council passed a Resolution (5/23), in June 2002, which established a framework for the involvement of the private sector in investing in water infrastructure.

Reform 3 : Establishment of NWC

The National Water Company (NWC) was established to improve the overall performance of the sector in various aspects. NWC is expected to start as government-owned statutory company formed by Royal Decree and registered as joint-stock-company. It will gradually integrate the operations of the other major cities. The short-term institutional structure in water sector is shown in Figure 2-8.

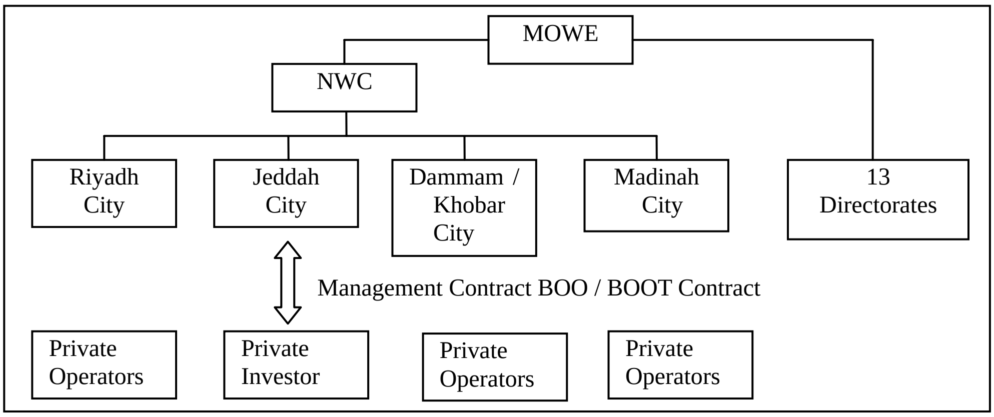


Figure 2-8 Short-term Institutional Structure in Water Sector (Under Process)

(3) Current State on Organizational Demarcations / Mandates of Relevant Authorities

Ministry of Water and Electricity (Head Quarter)

In accordance with Resolution No.125, the water directorates and departments of the MOA and the water directorates and departments of the MOMRA, came under the jurisdiction of MOWE.

Pursuant to Resolution No. 125, the key tasks of MOWE in relation to the water sector is shown in 2.1.2 (5).

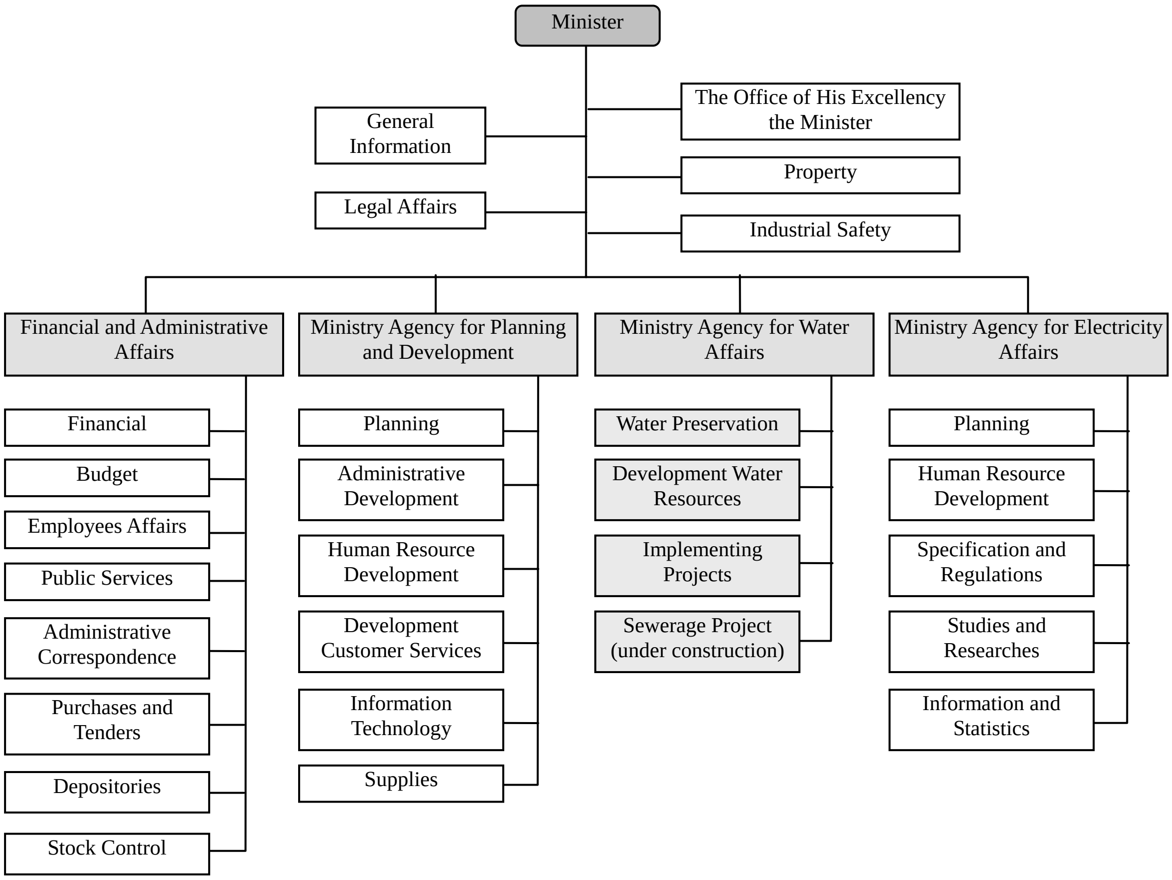


Figure 2-9 Organization Chart of MOWE

Ministry of Agriculture

MOA is the former organization body which had the mandate for water resources development and management before it came under the jurisdiction of MOWE.

The departments relating to reuse of treated waste water and irrigation water which is consuming 85% of the total water consumption in KSA is independent from the following major departments. The regional offices of MOA in 13 regions are under the direct jurisdiction of the minister.

Saline Water Conversion Corporation

SWCC is administratively related to MOWE. The organization chart of SWCC is shown in Figure 2-10. SWCC has all necessary powers to achieve its main objective, which is to support natural water resources through providing desalination in 13 regions and cities in which water sources are insufficient.

Saudi Geological Survey

The tasks and duties of the SGS are similar to those of most geological surveys worldwide, and include mapping, grass-roots mineral exploration, geo-hazard and geo-environmental studies, hydro-geological studies and services to the community. SGS has about 800 staffs and the head office in Jeddah with the staff number of about 650.

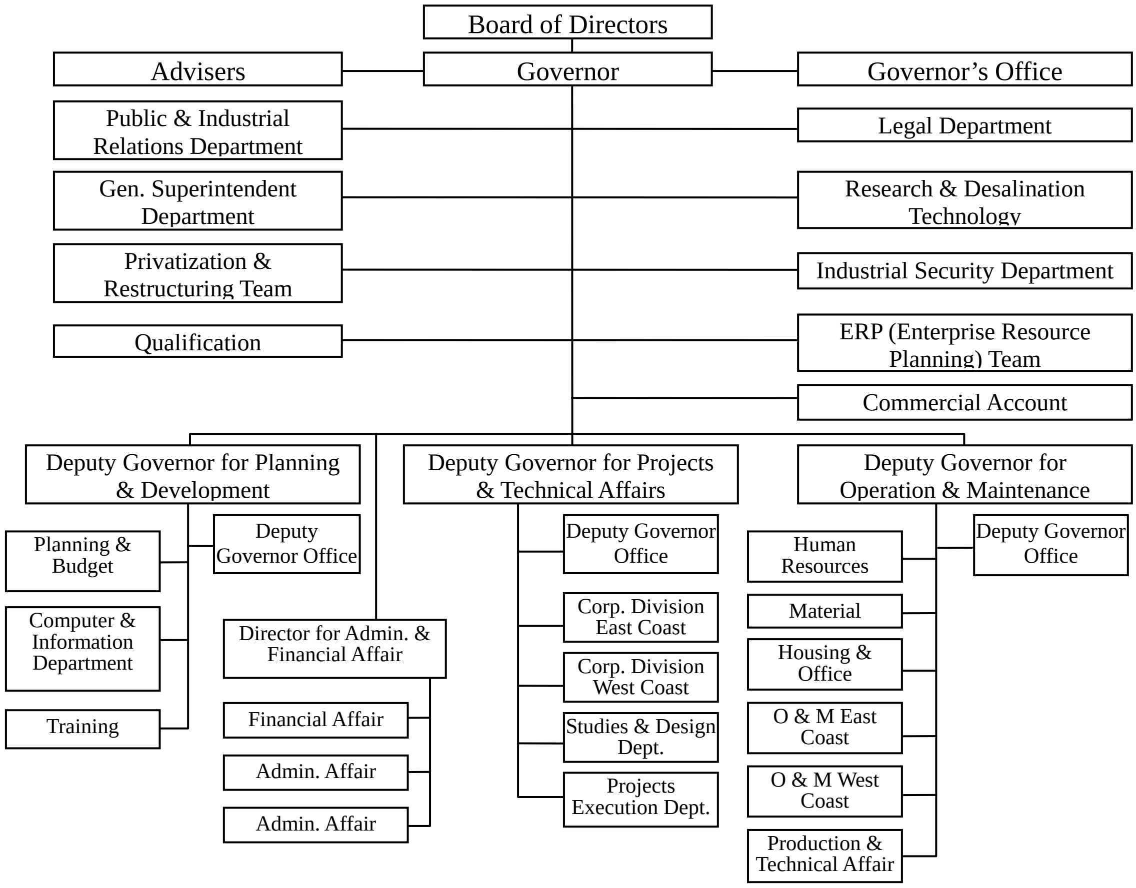


Figure 2-10 Organization Chart of SWCC

(4) Budgetary Aspect relating to Water Resources Development and Management

National Budget in Last 3 Years and Public Investment to Water Sector

The national budget consisting of revenues and expenditures for the last 3 fiscal years of 2005, 2006 and 2007 is shown in Table 2-7.

Table 2-7 National Budget in 2005, 2006 and 2007 (Performance)

Unit in Billion Saudi Riyals

Year	Revenue	Expenditure	Surplus / Deficit
2005	555	341	214
2006	655	390	265 Breakdown; Additional Development Projects: 40 Public Investment Fund: 20 Government's Reserves Account: 100 Others (incl. public debt): 105
2007	621.5	443	178.5 Breakdown; Real Estate Development Bank: 25 Government's Reserves Account: 100 Others (incl. public debt): 53.5

Source:
1) Ministry of Finance
2) http://www.saudiembassy.net/2006News/Statements

Annual Budget of MOWE

The annual budget in the past 4 years of 2004 to 2007 is shown in Table 2-8. The annual increase rate of investment for new projects is 20 % to 50% for the previous year.

Table 2-8 Annual Budget of MOWE

Unit in 1,000 Saudi Riyals

Category	Regions	2004	2005	2006	2007
Third (Operation & Maintenance)	The Public Office	2,146	2,297	1,702	328
	Riyadh and other 12 regions	5,152	3,875	7,700	9,777
	Others	0	181	0	0
	Total	7,298	6,353	9,402	10,105
Fourth (New Project)	The Public Office	10,563	11,121	10,362	9,129
	Riyadh and other 12 regions	13,061	14,365	29,725	44,222
	Others	2,955	5,441	8,765	8,086
	Total	26,579	30,927	48,852	61,437

Source: Ministry of Water & Electricity

Notes: The figures of First (Salary) and Second (Bonus) categories were not available.

(5) Problems Surrounding Institutional / Organizational Issues

The water resources development and management in KSA has been consolidated to MOWE since 2003 institutionally and is still in reform process at the present.

The institutional / organizational problems surrounding in water sector are shown as follows;

Organizational and jurisdictional problems surrounding irrigation water:

The jurisdiction of irrigation water, which is exceeding 85% of total water consumption, is not clear between MOWE and MOA. MOA has the irrigation department, while the jurisdiction of water resources including groundwater legally belongs to MOWE. There is no cross-sectional organization body or coordination institution of the two ministries for alleviating jurisdictional problems.

Law enforcement and MOWE's human resource capability:

In view of the laws and regulations concerning water resource management (Royal Decree No M/34 or Council of Ministers' Resolution No. 62044), MOWE shall grant licenses for digging wells, inspecting sights and carrying out oversight of water resource management. However, it is uncertain that MOWE has enough human resource capacity to enforce above legal provisions.

Role, demarcation and mandates among the headquarter and regional offices of MOWE:

The role, demarcation and mandates among the headquarter and regional offices of MOWE are not clear. In some instances, the regional offices have more data / information on water resources management necessary for formulating mid-term or strategic long-term plans, while the headquarter has the mandates for preparing such plans.

Private extraction of groundwater and the limits of government's involvement:

The land owner extracts groundwater privately within his land in Middle-East Countries, in which there is a limit for government organs to manage the groundwater compared to surface water.

Uncertain origins or no origins for water allocation and data gathering:

It is uncertain whether there is an origin, which controls / manages the data for water allocation and water use amount, or not. Therefore, it will be hard for the government to conduct the planned water management based on scientific data. No monitoring is done for use of irrigation water of renewable water. The provision on water right is not clear.

Free of charge for irrigation water: No estimated tariff is charged for water used for irrigation purposes at present, which is allowing the farmers to extract groundwater unimpeded and without limitations.

Educational campaign for water saving measures:

Water saving is currently carried out for municipal water. However, for irrigation water use, it is doubtful that such education including technical knowledge on irrigation methods for saving water is implemented for farmers.

Tariff issues:

The water tariff of municipal water is remarkably cheap compared with an international level. There is no water charge for irrigation water utilization. Even concerning municipal water, its water tariff is extremely lower compared to international levels or its water cost (e.g. water tariff to per capita GDP: 0.14 % in KSA in 1999 compared to that of over 0.75% in the world, and tariff to water cost: the average tariff for a family of 6 is 0.1 SR/m^3 because of its consumption of around 41 m^3/month is higher the water cost 4.0 SR/m^3 consisting of production cost 1.5 SR/m^3 plus distribution cost 2.5 SR/m^3). Furthermore, the tariff structure is the same for all domestic, institutional, commercial or industrial use.

CHAPTER 3 WATER DEMAND PREDICTION

3.1 Municipal and Industrial Water

3.1.1 Basic Frame

Municipal water includes industrial water but in this study is defined as Domestic, institutional and Commercial Water.

3.1.2 Basic Frame for Municipal Water Demand Prediction

(1) Water Supply Service Ratio

In order to establish future water supply service ratio, the population size of administrative areas such as cities, towns and rural communities shall be taken into account hence the necessity to develop a water supply system that depends on human activities. The population sizes are followed by three categories for per-capita water consumption criteria of MOWE's ministerial ordinance that MOWE applies for achieving the goal of 100%.

On the other hand, it is envisaged that current water supply service ratio and rate of development in urban areas are different from that in rural communities except large-scale urban areas.

(2) Daily Per-capita Water Consumption of Domestic (Including Institutional and Commercial Water)

The criteria for the per-capita water consumption are classified by population size. The criteria for the per-capita water consumption by size of population were established as a mandate of MOWE in 2008. All the projects being executed in MOWE are instructed to apply criteria estimates for future water demand.

The per-capita water consumption is divided into the following three categories:

- For at least 85,000 population (Large scale urban area): 250LCD
- For more than 5,000 and less than 85,000 population (Urban area): 200LCD
- For less than 5,000 population (Rural community area): 150LCD

In sensitive analysis, on the basis of current water consumption rate, the water consumption rate, which is 10% lower than that of MOWE's ordinance, applied as in other scenarios. This water consumption rate is further likely to be the current water consumption rate.

- For at least 85,000 population (Large scale urban area): 225LCD
- For more than 5,000 and less than 85,000 population (Urban area): 180LCD
- For less than 5,000 population (Rural community area): 135LCD

(3) Industrial Water

In terms of future water demand of industrial use, as there are no differences in daily per-labor water consumption by industrial sector, the daily per-labor water consumption which is applied for estimating general industrial water demand as shown in Table 3-1 shall be applied for estimating future industrial water demand.

Table 3-1 Daily Per-labor Water Consumption of Industrial Water

Industrial Sector	Daily Per-labor Water Consumption m^3/day/labor)
Food and Beverages	1.00
Textiles, readymade clothes and leather	0.43
Wood, wooden products and furniture	0.46
Paper, printing and publication	0.27
Chemical industries and plastic products	2.30
Building materials, glass, ceramic and metal basic industries	2.50
Basic Metallic	0.54
Manufactured metals, machines and equipment	2.10
Other industries (including transportation)	0.05

Source: Technical Book (Water Supply Fifth Edition)

(4) Rate of Waste Water Use

From the aspect of water use composition (about 6% of overall water consumption in KSA), the JICA Study Team proposed that the rate of reclaimed waste water be 5% and only be applied for large-scale urban areas.

According to the regulation of reclaimed use in the KSA, reclaimed waste water can be utilized for industrial purposes with exception of beverage and food processing factories.

30% of the total industrial water demand in the five (5) regions is applied for estimating reclaimed waste water. The basis of 30% was examined based on the following criteria.

- Utilize for coolant and temperature control use
- It is envisaged that about 50% of the served water is utilized for coolant and temperature control for the future because water might be recycled.
- Reclaimed waste water is not utilized for beverage and food processing factory.
- Based on Japanese Industrial Statistics (2007), rates of coolant and temperature control water which was made up in industrial water are as follows:
  - ✓ Chemical industries and plastic products: 88.5%
  - ✓ Building materials, glass, ceramic and metal basic industries: 78.9%
  - ✓ Manufactured metals, machines and equipment: 68.3%

As a result of these estimations, the rate of reclaimed waste water, which is to be utilized for industrial water in the five (5) regions, is to be 60%.

However, considering the progress of facility development for utilizing reclaimed waste water and recycled water improvement, the rate of reclaimed waste water is less than 60%. Accordingly, it is proposed that the rate of reclaimed waste water is 30% (a half of 60%) on the safe side.

(5) Leakage Ratio

In order to set up leakage ratio, Leakage ratio of about 20% which is included in MOWE' basic scenario (Ministerial Ordinance) is applied for estimating municipal water demand in this study, because current status of the existing pipe network and data of leakage ratio on pipe rehabilitation were not clarified.

Furthermore, considering the construction year of the existing pipeline system and leakage reduction through improvement of the system in each region, it is proposed that 15%, which is the lowest ratio in the KSA, is also applied as other scenarios in the sensitivity analysis.

(6) Condition of Water Demand Prediction

Condition of water demand prediction applied to development of water supply facility is summarized as follows:

Table 3-2 Basic Condition of Water Demand Prediction

Items		Basic Condition
Per-capita water Consumption (L/capita/day)		
• Large Scale Urban		250
• Urban		200
• Rural Community		150
Leakage Ratio		20%
Rate of Waste Water Use		
• Municipal Water (Landscaping)		5%
• Industrial Water		30%
Water Service Coverage		
Large Scale Urban	2010	90%
	2015	95%
	2020	100%
	2025	100%

Items		Basic Condition
	2030	100%
	2035	100%
Urban	2010	50%
	2015	60%
	2020	70%
	2025	80%
	2030	90%
	2035	100%
Rural Community	2010	40%
	2015	52%
	2020	64%
	2025	76%
	2030	88%
	2035	100%

In addition, water demand is estimated in multiple options taking into consideration that water demand fluctuation through water demand management and practical rate of water supply facility development as shown in the table above in the sensitive analysis.

3.1.3 Daily Peak Factor for Planning Capacity of Facilities

Daily maximum water demand is generally estimated based on the historical data of daily peak factor. In KSA, water consumption for tourist and pilgrim is one of the causes of increased water demand water demand in a certain period of year. Peak season for tourist and pilgrim is from June to October, and water demand also increases as it is.

In this study, it is proposed that the daily maximum factor is set to be 1.29 on the influx of tourism. Accordingly, in order to set up the capacity of each water supply facility, 29% of total water demands which was estimated above shall be taken into account.

3.1.4 Predicted Municipal Water Demand (Domestic, Institutional, Commercial Water)

(1) Future Population

Future population of the five regions shall be estimated based on the following conditions.

- Case 1: Based on the past trends of population
- Case 2: Based on future population growth rate as mentioned in the Eighth Development Plan
- Case 3: Based on future population that was officially forecasted by MOEP in 2009.

In Case 3, estimating domestic water consumption is applied based on the future population that is predicted by MOEP hence projects coordinating and planning are executed under MOWE. Table 3-3 shows the future population sum by region based on the future population by areas such as city, town and community.

Table 3-3 Future Population Prediction by Region (1000 persons)

Year	Makkah	Al Baha	Asir	Jazan	Najran	Five Regions
1974	1,754	186	681	403	148	3,172
1992	4,468	332	1,340	866	301	7,307
2004	5,798	378	1,688	1,186	419	9,469
2010	6,468	411	1,895	1,404	502	10,680
2015	7,115	449	2,090	1,572	564	11,790
2020	7,755	492	2,288	1,720	617	12,872
2025	8,379	533	2,480	1,864	669	13,925
2030	9,054	578	2,688	2,021	725	15,066
2035	9,785	627	2,914	2,190	786	16,302

Source: JICA Study Team

3.1.5 Predicted Industrial Water Demand

(1) Predicted Number of Industries

According to the economic Report 2007 (SAGIA), industries in each region increase yearly since all regions focus on industrial development. Thus these numbers of industries increase based on arithmetic way.

(2) Number Prediction of Industrial Labors

The future number of labors by sectors as shown in Table 3-4 are estimated based on the ratio of composition against the number of labors by sectors.

Table 3-4 Predicted Numbers of Labors

Region	2010	2015	2020	2025	2030	2035
Makkah	105,212	115,495	125,778	136,062	146,345	156,628
Al Baha	532	600	667	735	803	871
Asir	5,918	6,645	7,372	8,098	8,825	9,552
Jazan	1,489	1,574	1,659	1,745	1,830	1,915
Najran	670	706	742	777	813	849
Total	**113,821**	**125,020**	**136,218**	**147,417**	**158,616**	**169,815**

Source: JICA Study Team

3.1.6 Future Water Demand on Municipal and Industrial Water

Table 3-5 to 3-9 shows the overall municipal water demand for domestic, institutional and commercial, and industrial use as public water supply, and the reclaimed waste water utilized for landscaping, etc. The amounts of water which is provided with renewable water and desalinated water are estimated due to a deduction of some water amounts which can be covered by reclaimed waste water from the overall water demand.

Table 3-5 Total Water Demand (Makkah Region)

1000m^3/day

Makkah Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	1,315	1,545	1,799	1,970	2,158	2,363
Industrial Water Demand [2]	147	160	175	189	203	218
Overall Water Demand	**1,462**	**1,705**	**1,974**	**2,159**	**2,361**	**2,581**
Water covered by reclaimed waste water [3]	184	210	242	261	282	304
Total [1]+[2]-[3]	**1,277**	**1,494**	**1,733**	**1,898**	**2,080**	**2,278**

Source: JICA Study Team

Table 3-6 Total Water Demand (Al Baha Region)

1000m^3/day

Al Baha Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	51	65	80	94	112	132
Industrial Water Demand [2]	1	1	1	1	1	1
Overall Water Demand	**52**	**66**	**81**	**95**	**113**	**133**
Water covered by reclaimed waste water [3]	1	2	2	2	2	2
Total [1]+[2]-[3]	**53**	**68**	**83**	**97**	**115**	**135**

Source: JICA Study Team

Table 3-7 Total Water Demand (Asir Region)

1000m^3/day

Asir Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	298	364	436	500	577	655
Industrial Water Demand [2]	10	12	13	14	16	17
Overall Water Demand	**308**	**376**	**449**	**514**	**593**	**672**
Water covered by reclaimed waste water [3]	13	15	17	19	22	23
Total [1]+[2]-[3]	**295**	**361**	**432**	**495**	**571**	**648**

Source: JICA Study Team

Table 3-8 Total Water Demand (Jazan Region)

1000m³/day

Jazan Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	207	241	290	333	382	442
Industrial Water Demand [2]	3	3	3	3	4	4
Overall Water Demand	**210**	**244**	**293**	**336**	**386**	**446**
Water covered by reclaimed waste water [3]	7	6	7	7	8	9
Total [1]+[2]-[3]	**203**	**238**	**286**	**329**	**379**	**436**

Source: JICA Study Team

Table 3-9 Total Water Demand (Najran Region)

1000m³/day

Najran Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	85	115	135	150	166	184
Industrial Water Demand [2]	1	1	1	1	1	1
Overall Water Demand	**86**	**116**	**136**	**151**	**167**	**185**
Water covered by reclaimed waste water [3]	1	1	1	1	1	1
Total [1]+[2]-[3]	**85**	**115**	**135**	**150**	**166**	**184**

Source: JICA Study Team

3.1.7 Sensitivity Analysis of Water Demand

(1) Options

In this study, water demand is estimated in four (4) options as well as basic condition (Option -1) as shown in Table 3-2, taking into consideration that water demand fluctuation through water demand management and practical water service ratio.

Option-1: When the service coverage ratio is 100% for the year of 2035, water demand projection shall be applied for water supply facility plan in this study.

Option-2: Since urban development does not proceed as it is planned in urban areas and rural communities with the exception of large scale urban area, this option is set taking into account that water supply facilities will be developed based on practical situation

Option-3: This option is set for verifying the change in case water consumption rate is practically 15% lower than the proposed water consumption rate.

Option-4: This option is set in case leakage reduces from 20% to 15% due to pipe rehabilitation.

Option-5: This option is set in case water consumption rate is 15% lower than proposed one in addition in case leakage set at 15%.

All the conditions above are summarized as shown in Table 3-10.

Table 3-10 Criteria on Options for Sensitive Analysis

Items		Option-0 (MOWE)	Option-1	Option-2	Option-3	Option-4	Option-5
Water consumption rate (LCD)							
• Large scale urban		250	250	250	225	237	212
• Urban		200	200	200	180	190	170
• Rural community		150	150	150	135	142	127
Leakage Ratio (%)		20%	20%	20%	20%	15%	15%
Rate of reclaimed waste water to be utilized (%)							
• Municipal water		0%	5%	5%	5%	5%	5%
• Industrial water		0%	30%	30%	30%	30%	30%
Water supply service ratio (%)							
Large scale urban	2006	100%	85%	85%	85%	85%	85%
	2010		90%	90%	90%	90%	90%
	2015		95%	95%	95%	95%	95%

Items		Option-0 (MOWE)	Option-1	Option-2	Option-3	Option-4	Option-5
	2020		100%	100%	100%	100%	100%
	2025		100%				
	2030		100%				
	2035		100%				
Urban	2006	100%	45%	45%	45%	45%	45%
	2010		50%	50%	50%	50%	50%
	2015		60%	55%	60%	60%	60%
	2020		70%	60%	70%	70%	70%
	2025		80%	65%	80%	80%	80%
	2030		90%	70%	90%	90%	90%
	2035		100%	75%	100%	100%	100%
Rural community	2006	100%	35%	35%	35%	35%	35%
	2010		40%	40%	40%	40%	40%
	2015		52%	42%	52%	52%	52%
	2020		64%	44%	64%	64%	64%
	2025		76%	46%	76%	76%	76%
	2030		88%	48%	88%	88%	88%
	2035		100%	50%	100%	100%	100%

Note: Criteria that was highlighted in white-gray is applied for water supply facility plan in this study
Source: JICA Study Team

(2) Consideration in Sensitive Analysis

As results of the sensitive analysis, water demand of the year of 2020 and 2035 is summarized by region in Table 3-11.

Table 3-11 Water Demand by Option and Region (2020 and 2035) (1000m^3/day, Ratio:%)

Option	Makkah		Al Baha		Asir		Jazan		Najran	
	2020	2035	2020	2035	2020	2035	2020	2035	2020	2035
1	1,733	2,278	79	131	432	648	286	436	130	178
Standard Index (%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
2	1,707	2,197	71	106	407	575	266	380	126	167
Ratio 2/1 (%)	(98.5)	(96.4)	(89.9)	(80.9)	(94.2)	(88.7)	(93.0)	(87.2)	(93.3)	(90.8)
3	1,572	2,065	71	118	390	585	255	389	117	160
Ratio 3/1(%)	(90.7)	(90.6)	(90.0)	(90.0)	(90.3)	(90.3)	(89.2)	(89.2)	(90.0)	(89.9)
4	1,652	2,171	75	124	411	616	270	411	123	169
Ratio 4/1(%)	(95.3)	(95.3)	(94.9)	(94.7)	(95.1)	(95.1)	(94.4)	(94.3)	(94.6)	(94.9)
5	1,491	1,959	67	111	369	553	241	367	110	151
Ratio 5/1(%)	(86.0)	(86.0)	(84.8)	(84.7)	(85.4)	(85.3)	(84.3)	(84.2)	(84.6)	(84.8)

Source: JICA Study Team

Differences between water service coverage ratio of Option-2 and Option-1 is large, as urban size is small. Differences between water service coverage ratio of Option-2 and Option-1 is large, as urban size is small. Thus, there are small differences of water demand in the Makkah region where large urbanization is made up out of the five (5) regions, while there are large differences in the Al Baha region where small towns and communities are made up.

The largest decrease rate through the analysis above is Option-5, which results in 15% lower than that of Option-1. This results in decreased water consumption and improvement in the leakage ratio due to awareness improvement in water conservation, where pipeline rehabilitation respectively leads to a decrease in water demand.

For references, the water demand (as 'Option-6') for which current water consumption (see Table B.1-13) by region was applied is as follows:

Since the option 1 has set up the large water consumption rate compared with the present condition, the difference of water demand has made it to the option 6 which is the water consumption rate near the present condition. In actual supply facility plan, it is necessary to check water consumption rate and water service coverage.

Table 3-12 Water Demand of Option-1 and Option-6 by Region (2020 and 2035)

(1000m^3/day, Ratio:%)

Option	Makkah		Al Baha		Asir		Jazan		Najran	
	2020	2035	2020	2035	2020	2035	2020	2035	2020	2035
1	1,733	2,278	83	135	432	648	286	436	130	178
Standard Index (%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
6	1,676	2,111	41	52	232	302	193	251	56	71
Ratio6/1(%)	(96.7)	(92.7)	(49.4)	(38.5)	(53.7)	(46.6)	(67.5)	(57.6)	(43.0)	(39.9)

Source: JICA Study Team

There is a significant decrease in water demand in all four (4) regions with the exception of the Makkah region.

In order to save water, it is imperative that the water consumption rate be minimized and leakage be reduced. As a concrete measures, while aiming at reduction of water consumption rate by performing water-saving, by exchanging an old pipeline intentionally, the leakage-ratio will be reduced.

3.2 Agricultural Water

3.2.1 Basic Frame for Municipal Water Demand Prediction

(1) Future Frame for Demand Prediction

The future development project for agriculture is negated for developing water resources and increasing farmland area. It is about preventing exhaustion of water resources and how to reduce farmland area. For this reason, in Decision No.335 (Rules and Procedure for the Rationalization of Water Consumption and regulates its use in Agriculture Purpose in all cities and villages within Kingdom of Saudi Arabia), the following policies are examined.

- To discontinue a subsidy for a well construction and a pump purchase,
- To stop a land distribution policy,
- To eliminate import tariffs on agricultural-products,
- To promote import of fodder crops,
- To stop the encouragement price of wheat and barley through the GSMO (Grain Silos and Flour Mills Organization)

Therefore, the future planning of agricultural projects, is another way of saying, how many planted areas were produced after the above-mentioned policy was implemented?

(2) Prediction conditions for future Agricultural

Although MOA envisions a future plan for agriculture in the year 2020 based on agricultural-statistics data taken in 2007, the deviations from the actual planted areas can clearly be seen in southwest areas. Therefore, in order to raise accuracy in demand forecasting, the following three cases are examined in consideration of the future agriculture plan of MOA and both sides of agricultural-statistics data.

Case-1: Case which rectified the future agriculture plan by 2020 upon which MOA decided in 2000 to 2004 by the agricultural-statistics data in 2007.
Case-2: Case presumed in recent years using the agricultural-statistics data of 6 years (2002-2007).
Case-3: Case which the planted area in 2007 where change of the planted area settled down will

continue.

(3) Basic Frame Work for Sensitivity Analysis

So far, although 3 cases of water demand was examined such as a modified MOA plan (Case 1), 2002 to 2007 trend (Case 2), and 2007-year level (Case 3), the Case 1 which added correction to prediction of MOA can be taken for reality having deviated clearly as compared with agricultural-statistics data. On the other hand, since it can observe converging the increase and decrease of a tendency of the planted area on the value in 2007 from agricultural-statistics data, it is simple to perform examination of a demand restraint measure on a "Case 3:2007-year level", and it is intelligible (Case 3 is with the statistical data itself). Since it is judged for not processing regressive prediction etc., examination after this (water balance) is performed about a Case 3 (2007 level).

(4) Procedure of Water Demand and Supply Balance

The following procedures perform examinations on the supply-demand balance of water for agricultural use. The Water supply is part of the renewable water resources and is divided into surface water and groundwater. Shown below is the amount of water saving, treated waste water for reuse, and the return flow from irrigation water that is added as a water resources. Since the above water supply is considered as the water resource, when a water shortage occurs, it is necessary to take into consideration water control for irrigation alone even if used. Moreover, the water supply priority is to first deduct from the renewable amount of water resources and use the remaining amounts of water resources to examine the areas that can be irrigated.

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

According to each governorate, the water resources potential is calculated based on the catchment areas of 31 Wadi (21 Wadi: Red Sea side, 10 Wadi: Inland side).

(6) Crop Diversification

Although rational use of water for agricultural use is aimed at the basis of Decision335 concerning the agricultural development plan and crop diversification, the planted area shall not be increased. In addition, crop diversification should specialize in vegetables and fruit growing centering on the city suburbs from a viewpoint of preservation of food self-sufficiency, small-scale farmhouse protection, and vegetables shall double while fruit trees maintain the planted areas in 2007. Therefore, a part for the planted area of vegetables to have increased is taken as a plan to decrease the planted area of cereals and a feed crop. Therefore, as the planted area for vegetables increases, the planted areas for cereals and fodder crops will decrease.

(7) Water Saving by Modern Irrigation

The irrigation method for fruit trees and vegetables has maintained traditional methods such as furrow irrigation, and its irrigation efficiency is low in the southwest area. However, in the future, water can be saved by introducing modernistic irrigation systems, such as a sprinkler and a drip. Although the maintenance rate (the traditional irrigation method and the modernistic irrigation method) of present condition is assumed to be 50% according to the agriculture office and irrigation efficiency is made into 70% (= (55% +85%) *50%), consideration of future plans to promote modern irrigation methods and raising irrigation efficiency to 85%.

(8) Reuse of Treated Waste Water

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

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

(9) Return Flow of Irrigation Water

Although portions for net water requirement is absorbed by plants in the water for irrigation (gross water requirement), it is thought that a portion of the irrigation loss returns into the ground and recharge the groundwater. This is counted and referred to 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 for irrigation as return flow.

(10) Water Balance in 5 Regions

Water balance computational procedure uses the renewable water resources in the five regions. In a planned target year, whole balances are positive in the four regions except Jazan. However, since the water-resource potential of sewage water, and agricultural water areas are unevenly distributed in the region, it is necessary to check them according to governorates and Wadi basin classifications

Table 3-13 Water Balance in 5 Regions

(Unit: MCM)

Region	Renewable Water Resource	Water Supply	Available Water	Agriculture Demand	Balance ①	Water Saving	Reuse of Treated Water	Return Flow	Balance ②
Makkah	782.0	180.2	601.8	750.5	-148.7	80.2	28.0	300.2	287.7
Al Baha	99.4	16.4	83.0	53.9	29.1	8.2	4.1	21.6	67.1
Asir	380.5	20.4	360.1	268.4	91.7	27.2	62.1	107.4	350.5
Jazan	322.9	106.9	216.0	1,501.9	-1,285.9	24.0	28.0	600.8	-605.1
Najran	401.1	72.7	328.4	216.5	111.9	24.9	28.4	86.6	280.2
Total	1,985.9	396.6	1,589.3	2,791.2	-1,201.9	164.5	150.6	1,116.5	380.3

Balance① : Renewable Water – (Water Supply ; Agriculture Demand)
Balance② : ①+(Water Saving + Reuse of Treated Water + Return Flow)

(11) Water Demand Control Measures in 5 Regions

Although the planted area of the Southwest Region in 2007 is 192,000ha, it is necessary to decrease it from the standpoint of preservation of renewal water resources potential to 101,150 ha about half of 2007 levels. When water resources reach their potential and after deducting water supply is maximized, calculations for possible planted areas in each region and governorate are as follows.

Table 3-14 Planted Area in 2007 and Calculated Planted Area in 2035 in five Regions

Name of Region	Planted Area in 2007 (ha)	Planted Area in 2035 (ha)	Reduced Area for 2007 in percentage (%)
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