社会開発調査部報告書

No. 52

KINGDOM OF MOROCCO
MINISTRY OF PUBLIC WORKS
GENERAL DIRECTORATE OF
HYDRAULICS

JAPAN INTERNATIONAL
COOPERATION AGENCY
(JICA)

THE STUDY
ON
RURAL WATER SUPPLY IN THE PRE-RIF REGION
IN
MOROCCO

FINAL REPORT

VOLUME II MAIN REPORT

AUGUST 1996

NIPPON KOEI CO., LTD.

KINGDOM OF MOROCCO
MINISTRY OF PUBLIC WORKS
GENERAL DIRECTORATE OF
HYDRAULICS

JAPAN INTERNATIONAL
COOPERATION AGENCY
(JICA)

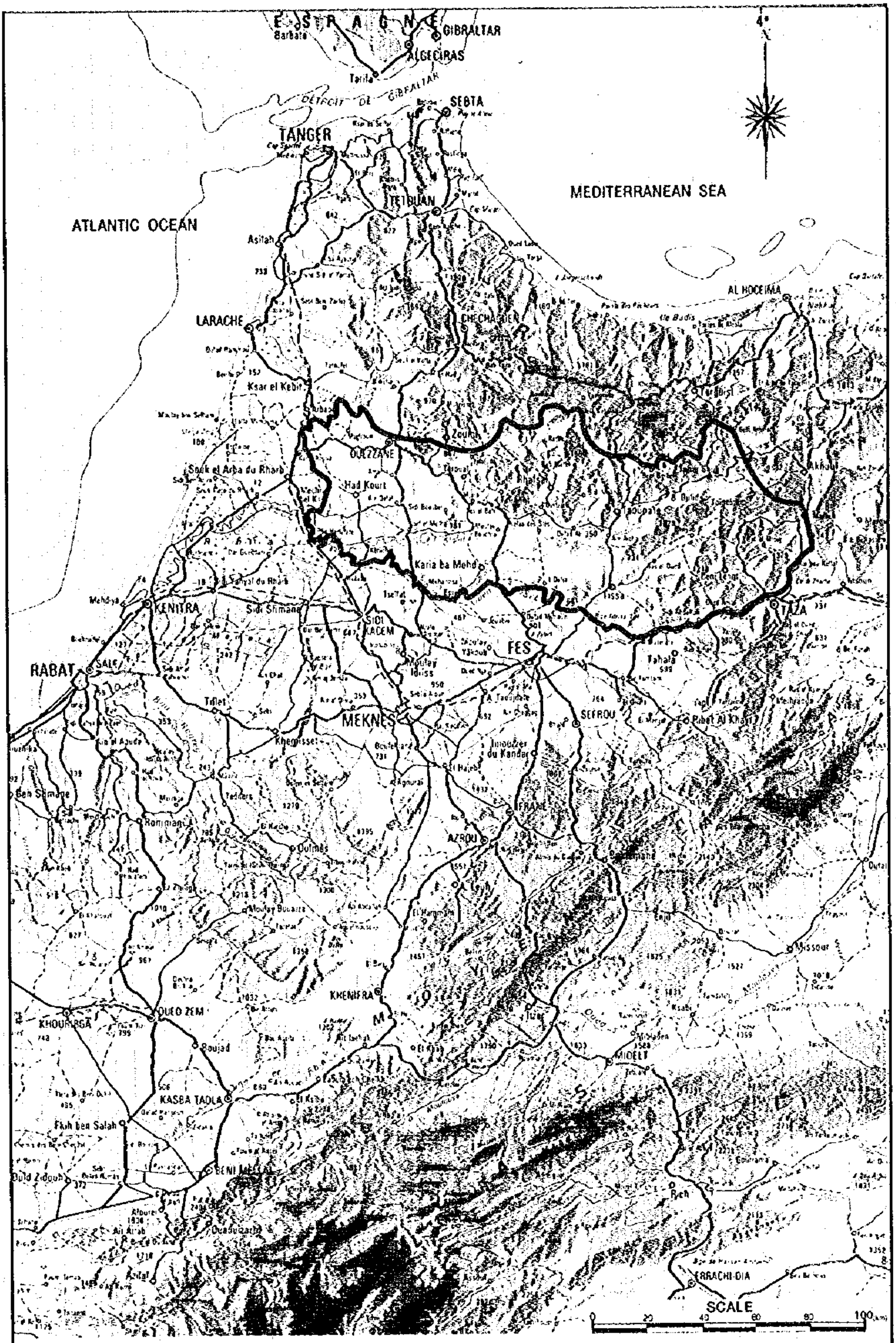
THE STUDY ON RURAL WATER SUPPLY IN THE PRE-RIF REGION IN MOROCCO

FINAL REPORT

VOLUME II MAIN REPORT

AUGUST 1996

NIPPON KOEI CO., LTD.



LOCATION MAP OF THE STUDY AREA

THE STUDY
ON
RURAL WATER SUPPLY
IN
THE PRE-RIF REGION
IN
MOROCCO

VOLUME I

MAIN REPORT

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

(Organizations)

JICA	Japan International Cooperation Agency
AH	Administration of Hydraulics
ONEP	The Office of Portable Water
DRPE	Directorate of Research and Planning of Water
DRH	Directorate of Regional Hydraulics
CERED	Research Center of Demographic Studies
FEC	Funds for Commune Equipment
UNDP	United Nation Development Program
WHO	World Health Organization
WB	World Bank
IBRD	International Bank Reconstruction Development

(Terms)

S/W	Scope of Works
IEE	Initial Environmental Examination
EIA	Environmental Impact Assessment
SBO	The Integrated Master Plan on Water Resource Development in Sebou, Bou Regreg and Oum Er Rbia Basins
MSL	Mean Sea Level
VES	Vertical Electric Sounding
VLF	Very Low Frequency
MODFLOW	Modular Three Dimensional Finite Difference Groundwater Flow Model
FDM	Finite Difference Method
O&M	Operation and Maintenance
FC	Foreign Currency
LC	Local Currency
VAT	Value Added Tax
FIRR	Financial Internal Rate of Return
EIRR	Economic Internal Rate of Return
WID	Women in Development
DH	Dirham
US$	United States Dollar
LS	Lump sum
ODA	Official Development Assistance

(Measurements)

mm	milimeter
cm	centimeter
m	meter
km	kilometer
m^2	square meter
Ha	hectare
km^2	square kilometer
m^3	cubic meter
MCM	million cubic meter
m^2/s	square meter per second
m/s	meter per second
m^3/s	cubic meter per second
m^3/d	cubic meter per day
$m^3/year$	cubic meter per year
l/d/c	liter per day per capita
l/d/head	liter per day per head
l/s	liter per second
°C	Celsius
kW	kilowatt
GWh	gigawatt hour
KHz	kilohertz
ohm-m	ohmmeter

CHAPTER I INTRODUCTION

1.1 Authorization

On the basis of the Scope of work agreed upon the Administration of Hydraulic of the Ministry of Public Works, Vocational Training and Management Training (hereinafter referred to as "AH") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") on January 14, 1994 in Rabat, JICA made a contract with Nippon Koei Co. Ltd., on September 26 1994 to conduct a Master Plan Study on Rural Water Supply in the Pre-Rif Region in Morocco.

1.2 Background

The Government of Kingdom of Morocco (hereinafter referred to as "the Government of Morocco") requested the Government of Japan to conduct a Study on Rural Water Supply in the Pre-Rif Region in Morocco (hereinafter referred to as "the Study") in February 1993.

The region so called "Pre-Rif" is identified as one of the most important areas in the Study on "Master Plan Study on National Rural Water Supply" made by UNDP through 1990 to 1993. In the report, it is recommended that the rural water supply system should be implemented in view of improvement of the level of living of this region. At present, the water supply for the area is mainly depending on surface water of rivers flowing nearby and shallow groundwater including spring water. It has been recorded that serious water shortage happened from time to time in the dry season. Then the groundwater development is deemed as an urgent requirement together with surface water development for this region, where water supply facilities equipped and distributed are rather small.

The Government of Japan decided to accept the request of the Government of Morocco to conduct the Study in accordance with the relevant laws and regulation in force in Japan. The Government of Japan entrusted JICA, the official agency responsible for the implementation of the technical cooperation programs on the Government of Japan to conduct the Study.

The JICA S/W Mission headed by Mr. K. Iwaguchi visited the site in January 1994 to discuss the scope of works with the authorities concerned of the Government of Morocco. The counterpart agency of the Government of Morocco is the AH, and both parties discussed and exchanged their views how to operate the Study and finally determined the scope of works. The JICA S/W Mission agreed to commence the work as soon as the JICA Head Office in Tokyo completes the necessary procedure.

The JICA Study Team (hereinafter referred to as "the Study Team") arrived at the site on October 11, 1994, and submitted the Inception Report to the AH. The Study Team explained the contents of the Inception Report to staff concerned of the AH, and both parties between the JICA S/W Mission and the AH. The Study Team moved to the site on October 19, 1994, and commenced the field works together with counterpart personnel of the AH.

1.3 Objective of the Study

The objective of the Study are summarized in the following three items:

1) to formulate development strategy for rural water supply in the whole Study Area,
2) to formulate a water supply plan for the model areas selected from the above strategy, and
3) to formulate a rural water supply master plan in the Pre-Rif region.

1.4 Study Area

The JICA S/W mission and the AH were mutually agreed to define the boundary of the Study Area in view of study results brought by UNDP's Master Plan and the Study to be made this time by the Study Team. The Study area defined is about 10,000 km^2 extending from east to west by 160 km and from north to south 60 km. The outline of the area is described as follows:

1) Excluding alluvial plain along the Sebou river, extending west of Sidi Kacem.
2) Southern boundary is demarcated by the main stream of the Sebou river which runs from east to west and gathering the tributaries such as the Abiad river and the Inaouen river.
3) Northern and other boundaries are determined by the water-divide of the catchment areas, or the administrative boundaries, which distribute within and along the boundaries proposed by the AH.

The Study area covers one part of the provinces of Sidi Kacem and Taza, and of almost entire part of the province of Taounate. There exist in those three provinces plenty of circles and communes, some of which were newly registered by dividing old communes. For example, the commune named Mzefroun in the province of Sidi Kacem were divided into three new communes, Mzefroun, Masmouda, and Ouazzane. The number of circles and communes of each province in the Study area is summarized below:

Number of Circle / Commune in the Study Area

(Unit: Nos.)

Province	Circle	Commune	
		Old	New
Sidi Kacem	2	10	24
Taounate	3	30	38
Taza	4	9	23
Total	9	49	85

1.5 Design Year

The design year set forth in the Scope of Work in this Study is 2010.

1.6 Organization of the Study

The organization of the Study which gives the relation between the JICA Study Team, the AH including governmental and non-governmental agencies concerned is shown in Figure 1.1.

The members of the Study Team are as follows:

Mr. Kiyohiro Inoue	Team Leader
Mr. Mohammed Naaman Ajam	Hydrogeologist
Mr. Masayuki Ogino	Hydrologist
Mr. Ravi V. Sundaram	Environmentalist
Mr. Hassan El Ramly	Boring Expert
Mr. Keisuke Okazaki	Water Supply Engineer
Mr. Mohamed Mahdi	Sociologist/WID Expert
Mr. Toshihisa Ishibashi	Geophysicist
Mr. Munenori Tada	Socio-economist
Mr. Kiyoto Yamazaki	Cost Estimator
Mr. Elie M. Icho	Interpreter/Translator

The principal members of the counterpart team of the AH are as follows:

(AH Rabat)

Mr. Mohammed Jellali	General Director of the Administration of Hydraulics
Mr. Mokhtar Bzioui	Director of Research and Planning of Water Resources
Mr. Benbiba Majid	Chief, Division of Water Resources

Mr. Zerouali Abdelaziz	Chief, Division of Hydrology

(DRH Fes)

Mr. Genah Mustapha	Director, Regional Directorate of Hydraulics of Sebou
Mr. Abdelwahab Serghini	Deputy Director, Regional Directorate of Hydraulics of Sebou
Mr. Tika Jamel Eddine	Engineer, Water Resources Planning and Management
Mr. Abou Mohamed	Chief, Services Water Resources
Mr. Mohamed Faskaoui	Chief, Service of Hydrogeology
Mr. Samir Rhaouti	Chief, Service of Hydrology
Mr. Abdelaziz Naimi	Engineer, Geology
Mr. Kamal Hassan	Engineer, Hydrogeology
Mr. Omar Fassi	Engineer, Hydrogeology

1.7 Organization of Report

The Study Report prepared are as follows:

Summary Report	Volume I
Main Report	Volume II
Supporting Report	Volume III
Drawings	Volume IV

The Summary Report presents the essential results of the whole Study which is extracted from the Main Report. The Main Report consists four Chapters as follows:

Chapter I: gives the general introduction of the Study comprising authorization, background, objective, general configuration of the Study Area and organizations of both Japanese and Moroccan teams.

Chapter II: gives the general condition and differentiation of the Study Area. This Chapter includes existing overall aspects on natural and socio-economic conditions, water resources, water supply conditions and environmental aspects pertaining to different topographic conditions. On the basis of full understanding of these conditions selection of model areas is made.

Chapter III: focuses on the development study of the model areas selected in Chapter II. In compliance with the analysis on natural and socio-economic conditions, surface and groundwater resources and exploitation of test wells in the model areas, preliminary designing of water supply facilities and subsequent cost estimate and project evaluation were carried out. In the course of establishment of water supply system in the model areas, Women In Development (WID) issue is taken into consideration.

Chapter IV: gives the establishment of Master Plan on the Study Area for the target year of 2010 consisting of assessment of future surface and groundwater resources potential and establishment of future water supply system. Further, implementation program by the target year and project evaluation are also given. Guidelines for establishment and implementation on operation and maintenance for rural water supply system, environmental aspects and WID issue are proposed.

CHAPTER II GENERAL CONDITION AND DIFFERENTIATION OF THE STUDY AREA

2.1 Natural Conditions

2.1.1 Topography

The Study Area is located at the north-west of Morocco occupying the area of about 10,000 km^2 which runs about 160 km from east to west and about 60 km from north to south. The Study Area occupies the central part of the area between the Rif Mountains facing with the Mediterranean Sea and the Atlas Mountains running from north-east to south-west.

As for the topography, the Pre-Rif region is surrounded by the mountains at its north, east and south, and reaches the Atlantic Ocean at its far end of west. Excepting the right side of the Ouergha river where the peak of the Rif Mountains is located near, the region is dominated by gradual mountain areas with small reliefs and hilly land shape. There is a clear tendency that altitude is higher at east and north parts, and becomes lower towards the south and west. While the altitude is around 400 m at flat lands and about 1,000 to 1,600 m at mountain areas in the east, but only around 600 m even at mountain areas near Ouazzane.

Two major rivers, the Sebou river and the Ouergha river, are running across the Study Area from east to west. Both rivers are meandering gradually towards the west, and join each other at the north of Sidi Kacem, and eventually flow into to the Atlantic Ocean. Main stream of the Sebou River which forms the south rim of the Study Area has the watershed at around Taza in the north part of the area, and its catchment expands over the most of the Pre-Rif region and also at the north side slope of the Atlas Mountains. The Ouergha river which runs through the north part of the Study Area has the watershed at around Boured in the north part of the mountain area, and its main catchment is south side slope of the Rif Mountains. Both of rivers do not form large scaled flat land in the Study Area, but only small scaled flat lands which are observed along the river courses.

2.1.2 Meteorology

The regional distribution of rainfall in the Study Area is illustrated in Figure 2.1.1 indicating the isohyetal map of annual rainfall. The locations of meteorological stations are shown in Figure 2.1.2. The meteorological records are complied on Table 2.1.1 by region according to the observation records at the 6 principle meteorological stations within the Study Area. At the stations such as M'Jaara, Ourtzagh, and Bab Merzouka, the records cover relatively long periods for some observation items. Of them, the records are available for the most of observation items at Ourtzagh. The records at Ourtzagh are therefore summarized on Figure 2.1.3 to indicate the seasonal changes of climate in the Study Area. With reference to the said records, general features of meteorology in the Study Area is presented as follows.

(1) Rainfall

As shown in the isohyetal map, the average annual rainfall varies from 500 to 700 mm in the area along the Sebou river mainstream (Had Kourt - Karia - Tissa), from 700 to 800 mm in the in the upstream of the Inaouen and Lebene river (Tissa - Taza / Tainaste), and 700 to 1,200 mm or more in the north of the Ouergha river (Ouazzane - Rhafsai - Taounate - Thar Souk). The seasonal variation of rainfall clearly shows the dry season from June to September. The rainfall is in general very little during the months of July and August.

(2) Air Temperature

The annual average temperature varies little by locations with a range of 18.4°C to 20.3°C, while the seasonal variation differs extremely from 10°C in January to 30°C in July and August. The average daily maximum and minimum air temperatures are 36.8°C and 4.2°C at Bab Merzouka, 37.3°C and 6.6°C at M'Jaara, and 36.8°C and 6.1°C at Ourtzagh, respectively.

(3) Evaporation

The evaporation records observed by "COROLAD" pan is available at Ourtzagh. The annual evaporation amounts to 1,718 mm. The monthly evaporation becomes highest in July and lowest in December and exceeds the monthly rainfall during April to November.

(4) Relative Humidity

The annual average relative humidity varies from 50 to 70 % by region. In general, variation of the average monthly shows that the highest takes place in December and the lowest is observed in July.

(5) Solar Radiation

The records of solar radiation are available only at Ouled Yaacoub. The average annual solar radiation is 2,634 hours. The monthly average varies from 159 hours in January to 324 hours in July.

(6) Wind Velocity

The wind velocity by region ranges from 1.1 to 2.1 m/sec on the annual average and from 3.6 to 5.5 m/sec on the average daily maximum. The wind velocity becomes higher in dry season and lower in wet season, but seasonal variation is not conspicuous.

2.1.3 Hydrology

(1) River System

The hydrology in the Study Area is subject to the two major rivers, the Sebou river and the Ouergha river.

The Sebou river system covers the catchment area of approximately 39,000 km^2 and extends to the Rif mountains range in the north, the Atlas mountains range in the south and hilly watershed in the east of Taza. The Sebou river collects water from the tributaries and runs to the west and eventually flows into the Atlantic Ocean near the city of Kenitra.

The Ouergha river is the largest tributary in the Sebou river system with a catchment area of 7,300 km^2. The mainstream of the Ouergha river originates in the mountains east of Thar Souk and runs to the west along the foot of the Rif mountains. The tributaries of the Ouergha river flow from the north down to the south forming a gorge at the foot of the Rif mountains. The Ouergha river joins the mainstream of the Sebou river in the vicinity of Khnichet.

(2) Stream Flow Condition

The location of stream gauging station is shown in Figure 2.1.4. Based on the mean monthly flow records observed in the Study Area, the analysis was made using the flow duration curves as shown in Figure 2.1.5. Consequent to the results of analysis, the stream flow condition in the Study Area shows that the most of runoff is likely to be direct runoff and a rate of baseflow is quite low and that the seasonal fluctuation of stream flow is significantly large. On the other hand, the Sebou river shows the quite different flow condition from the other rivers in the Study Area. Baseflow of the rivers are compared based on a rate of 90 percent dependable discharge to average discharge. As shown in Table 2.1.2, a rate of baseflow of the Sebou river is much higher than those of the other rivers.

Table 2.1.2 Comparison of Baseflow

River System	Gauging Station	Catchment Area (km^2)	Average Discharge (m^3/sec)	90% Dependable Discharge (m^3/sec)	Rate of Baseflow
Sebou	Dar El Arsa	7620	24.43	7.53	30.8%
Ouergha	M'Jaara	6190	81.99	1.42	1.7%
Lebene	Tissa	792	6.01	0.06	1.0%
Inaouen	Bab Merzouka	1500	6.84	0.21	3.1%
Rdat	Had Kourt	673	2.74	0.00	0.0%

(3) Runoff Rate

Using runoff record and basin rainfall of the catchment area of the 10 hydrological gauging stations, runoff rate was estimated for the case of average for 37 years (1957/58 - 1993/94), the 10-year drought as listed on Table 2.1.3. The runoff rate in the Study Area varies significantly depending on the amount of basin rainfall. As shown in the table, a large difference is found between the runoff rate on average and for the 10-year drought.

The Study Area can be generally classified in the 4 regions in consideration of basin hydrology and rainfall distribution. The rainfall and runoff for the average 37 years and the 10-year drought are summarized by region as shown in Table 2.1.4. In the 10-year drought, the annual rainfall reduces to some 65 percent of the average, while the reduction of annual surface runoff is significant, 25 and 21 percent in the upper Ouergha, the Inaouen and the Lebene basins, and only around 10 percent in the Rdat, the lower Ouergha basin and the middle Sebou sub-basins. The results show that variation of surface runoff is much larger than that of rainfall in the Study Area in drought years.

Table 2.1.4 Rainfall and Surface Runoff by Region

Region	Average 37 Years		10-Year Drought			
	Rainfall (mm)	Runoff (MCM)	Rainfall (mm)	Runoff (MCM)	Ratio to Average	
					Rainfall	Runoff
Ouergha, Upstream M'Jaara	930	2657	583	653	63%	25%
Lebene and Inaouen	651	738	432	154	66%	21%
Rdat and Lower Ouergha	611	218	408	21	67%	10%
Middle Sebou	540	152	365	15	68%	10%

2.1.4 Geology

(1) Historical Geology

The baseplates of Africa, America and Europe constituted one continent called Pangée surrounded by one ocean named Tethys. The dynamic evolution of this ocean during the Alpine cycle in the late Triassic till a recent period, reflected a particular character on the Alpine chains of Morocco; that is the chains of Middle and High Atlas originating in the baseplate of Africa (Autochthone) and the Rif chain formed beside the north baseplate of Africa (Allochthone).

The fragmentation of the Pangée during the Triassic epoch led to the formation of the Protoatlantic sea between Africa and America and the Ligure sea between Africa and Europe which are linked by a major transforming fault named Asores Gibraltar. The Protoatlantic sea expanded until it reached its present form; whereas the Ligure sea contracted during the disturbance Alpine phase thus giving rise to the future Rif chain of north Morocco and to the Iberian chain of south Spain .

The sliding of the baseplate of Africa from those of Iberia and Europe (Micro baseplate of Alboran) along the fault of Asores Gibraltar affected the massive deposits of the middle upper Jurassic. The paleogeography of the Cretaceous was characterized by two geosynclinal basins separated by a ridge with the external basin experiencing sedimentation of the flyshs type. At the beginning of the Tertiary period, during the Eocene-Oligocene epoch, the progressive advancement of the Alboran micro baseplate towards Africa baseplate was at the origin of the erection of the Rif chain. The lower-middle Miocene epoch witnessed the collision between the bloc of Alboran micro baseplate and the baseplate of Africa thus giving the Rif chain the crescent form with an overthrust towards the south.

The different units of Rif that used to be paleogeographically adjacent were superposed during this disturbance phase. The intra-Rif units are above the Meso-Rif and Pre-Rif units thus creating a disordered stratigraphyal classification.

Sedimentation continued within intramountains basins called post orogenic basins that constitute the southern boundary of the Rif chain and correspond to the great basins of Tafrant, Taounate, Ain Aicha and Thar Souk. In the course of their evolution, these basins were subject to thick sedimentation exceeding 2,000 m. and consisting of marl deposits disconnected by detritic fluviodeltaic deposits.

(2) Geomorphology

The Rif chain of northern Morocco represents the southern limb of the western edge of the Alpian chain. It is united to the northern branch of Europe, represented by the betic cordillera, through the Gibraltar arch. Towards the east, it is linked to the Tell chain in Algeria to form the Betico-Rif Telleen arch. The Rif constitutes an average mountain chain that rarely exceeds MSL 2,000 m. The highest summit is Jbel Tidghine which is situated in the Meso-Rif in the Ketama area where the highest point reaches MSL 2,452 m. The existing contrast between the southern and northern domain allows the distinction of two different zones:

i) The Rif chain which is characterized by its deep valleys and its rocky crests thus giving it a mountainous aspect.

ii) The Pre-Rif in the south which is known as lowland or land of hills with marl sedimentation that rarely exceeds MSL 1,400 m.

Geomorphologically, the geological structures of the Pre-Rif are orientated towards the plain of Gharb, thus directing the flows of the two large rivers, the Sebou and the Ouergha, towards the west. Most of the tributaries of these rivers are oriented in the north-south and the northeast-southwest directions.

(3) Geological Structures of Rif

The Rif chain is formed of deeply rooted units and thrusting formations having a crescent shape arched towards the interior of the chain. These units and formations derive from three major domains that are from north to south:

i) Internal domain or median ridges

ii) Flyshs domain

iii) External domain or external Rif (Study Area)

Several geological studies were carried out on the Rif basin ever since the discovery of the first thrusting formation. The most recent study undertaken in 1980 confirmed the aforementioned findings.

(4) Geological Stratigraphy

The geological complexity of the Pre-Rif labels it as one of the most challenging regions with overlapping stratigraphy where old age formations are situated on top of recent ones with confusing stratifications. The structural geology is formed of allochton formations, units, flyschs, of various ages extending from the paroxysmal cycle of the Paleozoic era to the late Tertiary period as summarized in the subsequent paragraphs.

1) Paleozoic Era

The Paleozoic era forms the bedrock of the Alboran micro baseplate and consists of deformed schist-sandstone formations. The series of the Paleozoic era are considered to be the substratum of the Mesozoic epoch of the internal Rif.

2) Triassic Period

The series of this period present variable facies depending on their location in the Rif area. In the internal Rif domain, the middle-upper Triassic series consist of dolometic and nodulus limestone deposits corresponding to the alboran baseplate. Whereas in the external Rif domain, the same series consist of continental sandstone conglomerates followed by red clays with evaporites.

3) Jurassic Period

The Jurassic period of the Rif is marked with a number of stages or ages:

i) The Hettangian outcropping in the form of calcareous ridges and sofsline in the internal and external Rif domain respectively and consisting of calcareous dolomite and limestone alternations of the alboran baseplate as well as of massive grey dolomite and limestone deposits of 100 m thick.

ii) The Sinemurian formed of nodulus dolomite deposits present on summits of sofsline.

iii) The Toarcian having marlo calcareous facies rich in ammonite fossiles.

iv) The Dogger-Malm of the middle-upper Jurassic epoch includes the Bajocian stage which consists of clayey limestone deposits and nodulus red limestone marking the end of the sedimentary cycle. Sandy and silty detretic clay and schist (ferryschs) deposits become more dominant in the upper Jurassic with a thickness extending to 1,000 m.

v) The Tithonian consisting of massive limestone formations of 400 m thick followed by sandy marl deposits of the lower Cretaceous period.

4) Cretaceous Period

The constituent stages of the Cretaceous period of the Rif include:

i) The Berriasian consisting of sandy and silty marl deposits.

ii) The Aptian-Albian comprising sandy flyschs deposits of 800 m thick with quartzites intercalations and limestone with flint modules.

iii) The Turonian having mainly marl deposits.

iv) The Senonian characterized by alternating marl and marly limestone deposits (flyschs) exceeding 200 m and marking the end of the Mesozoic era.

5) Tertiary Period

The Tertiary period of the Rif is marked with a number of series:

i) The Paleocene consisting of grey limestone not exceeding 100 m thick that change to marl deposits.

ii) The Eocene corresponding to thin layers of grey marl and marly limestone.

iii) The Oligocene composed of detritic and sometimes massive sandy marlstone deposits.

iv) The Miocene, encountered in the external Rif, composed of calcareous marl and silty clay intercalations forming the base of the Meso-Rif and Intra-Rif, as well as of loose conglomerate followed by sandstone changing to grey marl deposits representing the texture of the synclines of the Rif with an overall thickness exceeding 1,500 m. The upper Miocene marks the retrieval of the sea and the beginning of the erosion cycle.

6) Quaternary Period

The Quaternary period is characterized by the Villafranchian stage which consists of marl, boulders, gravel, silt and sand deposits of various ages that fill up the synclines and flat basins of the Pre-Rif region.

2.1.5 Hydrogeology

(1) Hydrogeological Features of the Study Area

The hydrogeological units of the Study Area are very limited due to the absence of potential aquifers as a result of the geological complexity of the Pre-Rif region. The most part of the region is characterized with aquiclude formations and only limited structures offering adequate ground water potentials. The geographic distribution of ground water in these structures are determined on the basis of the available water resources of each geological formation.

According to their lithological consistency and the water bearing potentiality, the hydrogeological formations of the Study Area are classified as follows:

1) Formations of Poor Water Potential

i) Triassic formations composed of red marl with evaporite and halite intercalations.

ii) Jurassic formations belonging to the upper Lias and upper Jurassic and consisting of schist, silty schist and marl.

iii) Cretaceous formations comprising silty schists with marl stone with very thin intercalations of marly limestone.

iv) Eocene and Miocene formations of the Tertiary period consisting of red marl and silty marl and schists respectively.

2) Formations of Fair Water Potential

i) Oligocene formations composed of sandy marly limestone marked with karsts, fissures and well developed joints.

ii) Upper Miocene formations comprising conglomerates with marl matrix karstified by fault activities

iii) Recent Quaternary Villafranchian formations containing conglomerates with loose marl matrix.

3) Formations of Fair to Good Water Potential

Middle Lias formations of the lower Jurassic period composed of limestone and dolomite either outcropping in the form of allochton structures on the crest of monoclines and flexures or deep-seated autochton structures.

The lithological consistency of the outcropping formations and the dispersed geological stratigraphy label the Pre-Rif as a region of poor to fair ground water potential with the absence of shallow favorable aquifers. The examination of satellite image and aero-photos together with field hydrogeological reconnaissance covering the entire Study Area led to the identification of promising hydrogeological structures with suitable ground water potential. The locations of these groundwater potential structures are shown in Figure 2.1 6; whereas their corresponding geological cross sections are presented in Figures 4.1.2 to 4.1.14 of Supporting Report. Table 2.1.5 recapitulates their hydrogeological characteristics.

(2) Mountainous Water Potential Structures

1) Taineste Flexure

An allochton structure covering an area of 3 km^2 and pertaining to the upper and middle Lias of the lower Jurassic. It is composed of karstified limestone, marly limestone and dolomite formations outcropping on the top of the flexure from which originate 5 existing springs with flows ranging between 15 and 85 m^3/d.

2) Jbel Khamise Monocline

An allochton flysch consisting mainly of limestone and cemented conglomerate formations karstified and fractured along the fault lines of the structure which belong to the Lias series of the Jurassic epoch. The monocline covers an area of 8 km^2 and has 5 existing springs issuing between 15 and 500 m^3/d.

3) Jbel Keil Monocline

An allochton flysch type overlaying an impervious Miocene layer and comprising primarily of limestone, grey marl and conglomerate formations pertaining to the Lias, Dogger-Malm series of the Jurassic period. The structure spreads over 40 km^2 and is stricken by numerous faults from which flow 8 existing springs with capacities ranging from 15 to more than 19,000 m^3/d.

4) Jbel Berda Monocline

An allochton of the Meso-Rif stricken by major faults and mostly composed of limestone, dolomite, marly limestone, schist and silty schist of the Lias, Dogger and Malm series of the Jurassic epoch. The monocline has an area of 6.3 km^2 and is being exploited through 4 springs with flow ranging between 20 and 700 m^3/d.

5) Thar Souk Syncline

A basin marked with massive water bearing conglomerate formations overlaying impervious fine marl deposits of the Miocene epoch. The area of the structure is about 12 km^2 with an estimated productive layer of about 100 m thick.

(3) Hilly Water Potential Structures

1) Teroual Syncline

The outcropping formation of the syncline pertains to the Miocene epoch and consists of impervious marl and silty marl deposits overlaying a water bearing sandy marly limestone formation of Oligocene with approximate thickness of 100 m. The subsequent formation belongs to Eocene and comprises an impervious marly layer followed by a second water bearing formation of marl with limestone intercalations. The area of the syncline is 6.5 km^2 and is marked with 2 springs issuing 20 and 70 m^3/d and 1 existing well intercepting only the upper most layer of Oligocene.

2) Ourtzagh Syncline

Situated in the Ouergha valley, the 15 km^2 structure is marked with the Quaternary conglomerate and fine marl deposits overlaying a massive impervious Miocene formation. The water bearing formation consisting of conglomerates with marl matrix is located at about 300 m deep along the fault line of the syncline. The existing 5 springs issue at the eastern flank of the syncline with flows ranging between 1 and 7 m^3/d. One borehole, partially penetrating the Miocene, was drilled by the AH to a depth of 250 m with a flow of 216 m^3/d. The Ouergha river acts as a recharge source to the Quaternary deposits of the syncline.

3) Ain Saddine Syncline

The stratigraphical column of the structure consists of an outcropping Quaternary alluvium and conglomerate deposits overlaying solidified conglomerate with marl matrix of Pliocene and marl deposits of Miocene. The water bearing formation is over a 100 m thick. The syncline is recharged from the Rdat river and has an area of 15 km^2 including one spring having a capacity of 90 m^3/d.

4) Taounate Syncline

Located along the Sra river, the syncline comprises the recent alluvium Quaternary deposits outcropping at the edge of the structure and impervious marl and silty clay deposits at the center. The deep water bearing formation is composed of fractured marlstone with solidified conglomerate located along the developed fractures. The structure is presently being exploited through 4 dugholes with flows ranging between 60 and 90 m^3/d. The area of the syncline extends over 4 km^2 and is recharged from the Sra river.

5) Tissa Syncline

The outcropping formation of the syncline consists of the Quatemary fine silty marl and conglomerate overlaying water bearing sandy marly limestone deposits of Oligocene which are followed by impervious a grey marl formation of Eocene. The structure covers an area of 5 km^2 and supply water to the town of Tissa through an existing dughole with a flow of 390 m^3/d.

(4) Flat Plain Water Potential Structures

1) Jorf El Melha Syncline

Located south of Jorf El Melha in the flat plain north of the Ouergha river, the syncline structure consists of the outcropping Quaternary loose conglomerate deposits situated along the fault lines and overlaying conglomerate and marl formation of middle Miocene. The area of the syncline covers about 10 km^2 with water bearing formation of about 100 m thick.

2) Ain Defali Syncline

The syncline is situated north of Ain Defali to the west of the Rdat river. It is marked with the outcropping Quaternary alluvium and conglomerate deposits overlaying the Miocene conglomerate and marl formations located along the fault line of the structure. The syncline extends over an area of 12 km^2 and supplies water to Ain Defali from an existing dughole producing 390 m^3/d. the thickness of the productive layers exceed 100 m thick which the upper part being recharged, during wet the season, from the Rdat river.

3) Had Kourt Basin

Bordering Had Kourt from the south and east, the structure is composed of the outcropping Quaternary recent alluvium and conglomerate deposits filling up the basin and the overlaying Miocene formations of conglomerate and marl matrix. The catchment area of the basin covers about 6 km^2 with a water producing stratum of about 100 m thick.

2.2 Socio-economic Conditions

2.2.1 Administration and Population

The country of Morocco is largely divided into seven economic regions. The administration in Morocco consists of hierarchical structures comprising provinces, circles and communes. A commune is the smallest administrative unit where various ethnic and tribes co-exist in the form of douars. The non-English term "douar" originating in the Arabic corresponds to hamlet. Morocco comprises 65 provinces, 159 circles and 1,545 communes. The provinces relating to the Study Area are Sidi Kacem, Taounate and Taza. The province of Sidi Kacem is included in north-west economic region, whereas both provinces of Taounate and Taza in north central economic region. The Study Area consists of 9 circles and 85 communes. The details of administrative structure in the Study Area is shown in Table 2.2.1.

Table 2.2.1 Administrative Structure in the Study Area

Province	Circle	Commune		
		Urban	Rural	Total
Sidi Kacem	Ouazzane	1	10	11
	Had Kourt	2	11	13
Taounate	Taounate	2	11	13
	Rhafsai	1	12	13
	Tissa	1	11	12
	Karia Ba Mohamed	1	9	10
Taza	Tainaste	0	8	8
	Taza	0	2	2
	O. Amlil	0	3	3
Total:		8	77	85

Source: CERED

The Study Area covers about 10,000 km^2. The national census survey was executed in September 1994. The total population in the Study Area was about 1.1 million, which is 4.2 percent of the country's population (26.1 million). Urban population was about 0.1 million while the remaining (1.0 million) was distributed in rural area. The population ratio of urban to total is just 11 percent in the Study Area which is far lower than the same ratio (about 50 percent) nationwide. The population density was about 110 per km^2 in the Study Area while the national average was about 40 per km^2. Area, population and population density are shown in Table 2.2.2.

Table 2.2.2 Area, Population and Population Density

	Population (thousands)			Area	Density
	Urban	Rural	Total	(km^2)	(per km^2)
Study Area	128	1,013	1,141	10,000	110
Nation	13,149	12,920	26,069	710,850	37

Source: CERED

2.2.2 Topography and Land Use

Elevation in the Study Area is high at east and north parts and becomes lower towards the south and west. Elevation is around 400 m in the area of flat lands, in the range from 1,000 m to 1,600 m in mountain areas in the east, but only around 600 m near Ouazzane in the west.

Flat lands and depressions along the valleys are extensively distributed under the elevation of 400 m. Most of flat lands consist of marl and areas along the river course of Ouergha and Sebou are basically fertile due to the alluvium deposits. Habitant area is scattered with a small number of residences mainly because the lack of potable water resources prevents habitant from dwelling in such dry land.

Land use is basically suitable for cultivation of cereals and orchard. The distribution of agricultural field and orchard is observed in hilly area where sand stone and limestone are extended. A large scale of habitant area is generally located in gentle slopes and hilly ridges. Residences are located near water sources such as spring water. Agricultural land is scarcely observed in rocky mountainous areas. Habitat normally takes the form of a small-scale residential community.

The land use employed in Morocco is divided into the following categories :

i) Agricultural land
ii) Pasture
iii) Uncultivated land
iv) Forest

The pattern of land use by province is attributed to the difference in topographic conditions. Agricultural land is prominent and distributed extensively in Sidi Kacem characterized by flat and hilly lands, whereas both forest and uncultivated land are outstanding in Taza where mountainous area is dominant. Irrigated land is merely one percent of total area. The typical cash crops cultivated in dry land are cereals such as wheat and barely, legumes such as broad beans, chickpeas and peas. Crop yield is substantially low due to less rainfall. Livestock breeding in pasture is another source of income for rural people.

Table 2.2.3 Land Use in the Study Area

(Unit : Ha)

Province	Agricultural land		Forest	Pasture	Uncultivated	Total
	Dry land	Irrigated				
Sidi Kacem	181,359 (86.7)	695 (0.4)	6,737 (3.2)	9,465 (4.5)	10,945 (5.2)	209,201 (100.0)
Taounate	389,000 (69.3)	4,000 (0.7)	51,700 (9.2)	65,600 (11.7)	51,300 (9.1)	561,600 (100.0)
Taza	310,700 (18.7)	18,300 (1.1)	467,970 (28.1)	329,000 (19.8)	537,130 (32.3)	1,663,100 (100.0)
Total:	881,059 (36.2)	22,995 (1.0)	526,407 (21.6)	404,065 (16.6)	599,375 (24.6)	2,433,901 (100.0)

Remarks : Sidi Kacem includes area of two circles, Ouazzane and Had Kourt only.
Taounate and Taza include the whole area of each province.

Source : Provincial Directorate of Agriculture.

2.2.3 Economic Activities

The statistical data on economically active population are only available on the regional bases and for 1986-1987. The data are somewhat old and broad, but indicates the pattern of labor force by economic sector. Table 2.2.4 shows the proportion of economically active population by sector.

The labor force engaged in farming activities is dominant, about 83 percent in north-west region and 87 percent in north-central region. Taking into account the above figure, agricultural sector is assumed to dominant in terms of economic activity in the Study Area. The proportion of agricultural labors without own farm land is substantial. Labors use farm land as tenant and earn a livelihood by receiving one-third to one fifth of crop yields from land owners.

Table 2.2.4 Proportion of Labor Force by Sector in Rural Area

(Unit : Ha)

Type of Occupation	North - West	North - Central
1) Professional, Government, Technical	1.5	1.2
2) Commercial services	2.0	2.5
3) Public services	1.0	0.5
4) Agricultural farmers	18.9	22.4
5) Agricultural labors	64.2	64.3
6) Forestation, Fisheries	1.3	0.6
7) Non-agricultural labors	11.0	8.4
8) Others	0.1	0.1
Total:	100.0	100.0

Source : Rural Active Population 1986/87, Statistical Office

The distribution of farms by size of farm land is concentrated on small scale farming. Table 2.2.5 shows the proportion of farms by scale in the provinces relating to the Study Area.

Table 2.2.5 Proportion of Farms by Size of Farm Land

(Unit : percent)

Province	0 - 5 ha	5 - 10 ha	10 - 20 ha	20 - 50 ha	over 50 ha	Total
Taounate	71.2	18.2	6.8	3.3	0.5	100.0
Taza	86.1	9.0	4.2	0.7	-	100.0
Sidi Kacem	78.5	11.6	6.3	3.6	-	100.0

Source : Provincial Directorate of Agriculture

In particular a small-scale farmer tend to consume cereals produced prior to sales of cereals to the nearby market. Olive market is mostly monopolized by contractual cultivation between olive oil industry and large-scale farmers. Olive production cultivated by small-scale farmers is not so large that they get small income by selling olive to the market through brokers.

It is reported by the Provincial Directorate of Agriculture that an average gross income per farm household and hectare in Sidi Kacem in 1990-1991 was about DH19,940 and DH3,680. The same source also says that an average net income per farm household and hectare was about DH18,390 and DH3,340, respectively. Net income is assumed to be equivalent to annual household expenditures. According to household consumption and expenditures in 1984-85 published by the Statistical Office, an annual average household expenditures were reported to be about DH16,000 in north-west region and DH18,670 in north-central region. The difference between net income (DH18,390) and expenditure (DH18,670) in the north-central region is marginal, indicating almost no income growth since the years of 1984 and 1985.

2.2.4 Population Projection in the Study Area

The population projection carried out in a preliminary level was revised in compliance with the national census survey executed in September 1994. The number of rural commune which was counted at forty nine as of 1986 further increased up to eighty five during last eight years. The eighty five communes include seventy seven rural communes and eight urban communes due to the national policy.

On June 1995, the CERED on the basis of the national census survey proposed the annual average population growth rates for urban and rural areas at 3.6 percent and 0.7 percent, respectively. In the report presented by the CERED, it was clearly pointed out that the trend of population growth in urban areas in recent years is substantially high compared to that in rural areas.

For this tendency, two major reasons were pointed out in the report. The one is mobilization from rural areas to urban areas including Rabat, the capital city, and Casablanca, the commercial and industrial center of Morocco. The second reason is the difference of rate of birth and mortality. Although the rate of birth in rural areas is higher than in urban areas, the mortality for the former is much larger than the latter, bringing about less population increase in rural areas as a result. These tendencies were also pointed out by the National Master Plan for Potable Water Supply for Rural Population in 1994.

Taking into account of these tendencies and rates of increase, future population in respect to each commune in the Study Area was projected up to the year 2010 with five years interval in this Master Plan Study as given in Table 2.2.6.

2.3 Water Resources

2.3.1 Groundwater Resources

(1) Existing Conditions of Groundwater Use

The existing ground water resources in the Pre-Rif region are scarce, mainly, due to the peculiar geologic character which is dominated with aquiclude formations covered by the impervious Miocene marl deposits preventing accumulation of water in the sub-strata. Nonetheless, the majority of the rural localities which is either located away from water courses or not supplied with public water facilities has to depend on the existing unreliable groundwater sources and seasonal springs for their domestic water needs. Many dugholes and few wells were drilled either by the communes, the AH or the ONEP to remedy the problem of water shortage.

Some of the springs issue from the conglomerate Miocene formations with low yield ranging between 0.5 and 2 l/sec. Others, located at the foot hill of ridges and allochton Jurassic structures, produce between 0.5 and 5 l/sec. Only the springs of Bou Adel, Tazrhadra and Ain Khamisse located in the communes of Ain Mediouna, El Bibane and Rbaa Fouki are considered as the three major water sources in the Study Area with flows of 220, 10 and 6 l/sec.

(2) Existing Capacity of Groundwater Production

The number of dugholes has been increasing gradually in the Study Area, particularly during the recent drought period, in order to provide the necessary daily water needs. The depth of the dugholes ranges between 5 and 25 m depending on the level of the accumulated groundwater in the Quaternary deposits.

According to available records, the number of dugholes drilled by the AH adds up to 410 having an average individual yield of 0.8 l/sec or a total of 28,000 m^3/d. Privately owned dugholes amount to 85 with an average individual yield of 0.3 l/sec equivalent to a total of 2,200 m^3/d. Thus, the total productive capacity of existing, hand operated, dugholes in the Study Area is about 30,000 m^3/d.

The number of wells drilled and registered by the AH adds up to 118 having various depths ranging from 10 to 100 m, with only one extending to 250 m. Ninety one or 77 percent of these wells are dry, mainly due to incorrect location, and the remaining produce between 0.05 and 2 l/sec with the exception to the three, not fully exploited, wells of Jorf El Melha, Sidi Abdel Aziz and Teroual, that yielded 10, 2.5 and 13.3 l/sec during the pumping test respectively. As such, the current capacity of groundwater production in the Study Area is calculated to be in the order of 30,000 m^3/d. The locations of the existing groundwater sources in the Study Area are shown in Figure 2.3.1 and the inventory of existing groundwater sources are summarized in Tables 4.3.1 to 4.3.3 of Supporting Report.

2.3.2 Surface Water Resources

(1) General

The Sebou river system including the Study Area is the region with the most promising surface water resources in the country. The Sebou river mainstream has a relatively stable baseflow in the dry season so that water of the river has been developed mainly for the irrigation development in the Gharb plain and has also been utilized recently for the potable and industrial water supply. On the other hand, stream flow of the other rivers in the Study Area varies significantly between wet and dry season. Thus, these rivers are not reliable water resources in the present situation even though the annual precipitation is the most abundant in the county.

Under the above-mentioned conditions, the Government of Morocco is proceeding the water resources development of the Sebou river system with the following two principles:

i) Construction of large scale dams for the integrated water resource development of the national level, and

ii) Construction of middle and small scale dams for socio-economic development of rural areas and conservation of watershed.

The outline of the surface water resources development are described below.

(2) Existing Facilities and Structures

1) Idriss No.1 and Allal Fassi Dam

The Idriss No.1 dam is located on the Inaouen river about 20 km to the north east from the city of Fes. The storage capacity of the reservoir is 1,186 million m^3. The reservoir of the Idriss No.1 is connected by the Matmata diversion tunnel with the reservoir of the Allal Fassi dam which is located on the Sebou river about 40 km to south east from the city of Fes. The purposes of this project are domestic water supply, irrigation and hydropower. The project contributes to irrigation water supply for an area of 96,900 ha in the downstream reaches. The installed capacity of hydropower is 280 MW in total including 40 MW at the Idriss No.1 dam site and 240 MW at the outlet of the Matmata diversion tunnel by using the head between both reservoirs.

2) El Kansera Dam

The El Kansera dam is located on the Beht river in the Khemisset province. The dam was constructed for the purposes of domestic water supply, hydropower and irrigation with the reservoir storage capacity of 266 million m^3. It supplies irrigation water for an area of 28,750 ha to the Gharb plain in downstream. The installed capacity of hydropower is 14 MW.

3) Sahela Dam

Construction of the Sahela dam was completed in 1994. It is located near the city of Taounate on the Sahela river which is a tributary of the Ouergha river. The reservoir storage capacity is 62 million m^3. Main purpose of this project is the irrigation development with an area of 4,230 ha in the downstream.

4) Al Wahda Dam

The Al Wahda dam is being constructed at M'Jaara on the Ouergha river mainstream. Completion of the dam construction is scheduled in 1996. The objective of this project is to effectively use the abundant water resources of the Ouergha river with the reservoir storage capacity of 3,800 million m^3, aiming the achievement of the following purposes:

i) Irrigation for the Gharb plain with an area of 100,000 ha,

ii) Flood control for the Gharb plain with an area of 150,000 ha,

iii) Hydropower generation with an installed capacity of 240 MW, and

iv) Transbasin water conveyance to the regions of the Atlantic coast for future increase of water demand.

5) Sidi Echahed Dam

The Sidi Ehahed dam is under construction on the Mikkes river which is a tributary of the Sebou river. The reservoir storage capacity is planned at 170 million m^3 for use of domestic and irrigation water supply.

6) Medium and Small Scale Dams

As mentioned above, the development of medium and small scale dams is the one of the important policy of the country in terms of water resources and socio-economical development for rural areas. The purposes of this project are 1) water supply for domestic and livestock use, 2) irrigation and 3) conservation of watershed. As of the year 1995, one middle scale dam, two small scale dams and 14 'hill' dams (Lacs Collinaires) have been completed as shown in Table 2.3.1.

(3) Existing Surface Water Potential

The surface water potential in the present condition was evaluated based on the stream flow records observed at the stream gauging stations in and around the Study Area. The evaluation was carried out on the basis of average discharge and baseflow which flows almost constantly at a objective location. The baseflow was estimated using the flow duration curve which indicates frequency of discharge exceeding a specific value within a certain period of years. In this analysis, the monthly stream flow records for the period from the hydrological year 1957/58 to 1993/94 (37 years) were used. The baseflow was evaluated for the case of a deficit frequency of 5 percent, which means that river discharge less than the baseflow may occur for 22 months in 37 years. It corresponds with 95 percent dependable discharge on the flow duration curve.

The estimated baseflow were shown in Table 2.3.2 at the stream gauging stations. As seen in the table, the Sebou river flow is the most stable water resource with an abundant quantity. The baseflow at Dar El Arsa and Azib Soltane were obtained at 5.86 and 10.92 m^3/sec, which are equivalent to 185 and 344 million m^3/year, respectively. On the other hand, the other rivers do not contribute to use of surface water in general because their baseflow are very small. Since the seasonal fluctuation of stream flow is quite large in these rivers, the surface water resource development requires a storage dam in order to increase the baseflow regulated by a rather large capacity of reservoir.

(4) Ongoing and Proposed Surface Water Development Programs

1) The Integrated Master Plan on Water Resource Development in the Sebou, Bou Regreg and Oum Er Rbia Basins (SBO Master Plan)

The SBO Master Plan was executed in 1992 for the development of water supply until the target year of 2020 in the Sebou, Bou Regreg and Oum Er Rbia river basins extending the coastal areas of Atlantic Ocean such as Kenitra, Rabat, Casablanca and El Jadia.

The Sebou river basin is considered as the most important water source in the country. The average surface water flow of the entire Sebou river basin is estimated at 5,600 million m^3/year. In order to develop the water resource, the surface water development plan of the Sebou basin is going to be implemented comprising 18 dams as listed on Table 2.3.3.

On the other hand, the Gharb, Maamoura and Fes-Meknes plains are identified as the major groundwater potential regions. Potential of the groundwater resource of these regions is estimated at 707 million m^3/year in total.

The SBO Master Plan concluded that the available water resource in the Sebou basin is estimated at 4,889 million m^3/year in 2020 by achieving the proposed development program. The general feature of the master plan for the Sebou basin is illustrated in Figure 2.3.2. Out of this amount of resource, 4,061 million m^3/year will be utilized to meet with the water demand within the Sebou basin, 60 million m^3/year will be preserved for environmental flow at the downstream end of the river, and 768 million m^3/year will be transferred to the coastal region mainly for future water supply to Casablanca. Table 2.3.4 shows the allocation of the water resource of the Sebou basin, which will satisfy the respective water demands in the year 2020.

Table 2.3.4 Allocation of Water Resources of the Sebou River Basin in 2020

(Unit : million m^3)

Sub-basin	Potable Water		Industrial Water	Irrigation		Total Sub-basin
	Urban	Rural		GH *1	PMH *2	
Upper Sebou	25.0	10.9	20.0		171.4	227.3
Ouergha	5.7	16.1			49.0	70.8
Middle Sebou	324.7	19.1	1.8		352.8	698.4
Beht	38.6	2.8			52.3	93.7
Lower Sebou	137.8	20.2	40.0	2,506	266.8	2,970.8
Total	531.8	69.1	61.8	2,506	892.3	4,061.0
Environmental Flow						60.0
Total - Sebou Basin						4,121.0
Potable and Industrial Water Supply for Casablanca						468.0
Medium/Small Scale Irrigation for Coastal Area						300.0
Grand Total						4,889.0

Note : *1 - Large Scale Irrigation
*2 - Medium and Small Scale Irrigation

Source : The Integrated Master Plan on Water Resource Development in the Sebou, Bou Regreg and Oum Er Rbia Basins, 1992, AH

2) Agricultural Development Project of the Ouergha River Basin

The study was achieved in 1992 for the purpose of establishing the master plan of the water resource development of the Ouergha river basin including the catchment area of the Al Wahda dam. The project comprises the following items :

i) Preparation of inventory of medium, small and hill dams,

ii) Pre-feasibility study on agricultural development in compliance with the selected 6 dams,

iii) Provision of development programs for rural area,

iv) Screening of inventory dams in compliance with development programs, and

v) Preparation of master plan for implementation of agricultural development in compliance with dam construction.

The dam inventory was prepared for 358 sites, which include 20 sites of medium scale dams with storage capacity from 2 to 90 million m^3, 42 sites of small scale dams from

0.2 to 2 million m^3, and 316 sites of hill dams from 0.01 to 0.2 million m^3. Subsequent to the these dam sites, the master plan concluded proposing implementation of the construction of 215 dams including 8 medium scale dams, 36 small scale dams and 171 hill dams. The primary contents of the master plan are listed on Table 2.3.5.

Table 2.3.5 Primary Contents of the Agricultural Development Project of the Ouergha River Basin

Development Program	Scale	No. of Project		Development Features
		Short Term	Long Term	
Irrigation Development	Medium	4	0	Water Resource Development : 211 million m^3
Rural Electrification	Medium	0	2	Irrigation Area : 13,990 Ha
Rural Water Supply	Medium	0	2	Hydropower : 75 GWh
	Small	12	24	Conservation of Watershed : 2,544 km^2
	Hill	53	118	
Rehabilitation of Road Network	Main Road	149.0 km	224.6 km	
Conservation of Watershed		To be provided with dam construction		

Source : Agricultural Development Project of the Ouergha River Basin, 1992, JICA

Construction of medium, small and hill dams is one of the important policy of the country in view of enhancing local development. The AH is in charge of plan and implementation of dams for the purpose of 1) water supply for domestic and livestock use, 2) irrigation, and 3) conservation of catchment basin. The AH reviewed the dam inventory of the Ouergha river basin and provided the updated inventory in 1995. Out of the inventory dams proposed, one medium scale dam, two small scale dams and 14 hill dams have already been constructed. The current implementation program of the AH indicates that 7 medium scale dams and 17 small scale dams will be implemented by the year 2001 as listed on Table 2.3.6. Other than the dam inventory of the Ouergha river basin, the AH identified 22 potential sites for construction of dams in the Lebene, Inaouen (north bank) and Rdat river basins which belong to the Study Area.

2.4 Analyses of Satellite Photos and Aero-photos

2.4.1 Analyses of Satellite Photos

Interpretation of linear patterns (joints) in the Study Area was made in order to prepare the basic materials necessary for identifying the faults, fissions, and folds in the succeeding geological survey. Since the reduced satellite photos with the smaller scale (1/250,000) were used in the present study, only a rough result was obtained. To grasp the delicate topographic features in the Study Area, it is necessary to conduct further study by using the aero-photos with the large scale of 1/100,000 or 1/40,000.

(1) Linear Patterns Identified

Linear patterns identified by satellite photos from the topographic features, vegetation disposition and gradation of soil are classified into photo-lineament which has the length of one mile or longer, and the fracture trace which has the length of less than one mile.

It is empirically said that the photo-lineament indicates the structural movement such as faults and fissions which may exert influence of the bed rocks. On the other hand, the fracture trace is said to indicate local geological structures such as the depressions extending towards the running direction of small joint, group of small joints, small faults and strata, but it does not necessarily indicate the small faults and joints themselves.

(2) Joints in the Study Area

Land shapes were identified as linear fault valleys, fault cliffs, cairncol and cairn bat, and then the photo-lineaments and fracture traces were extracted. Because of the interpretation of satellite photos with reduced scale, it was difficult to extract the minute fracture traces, but the photo-lineaments.

In the east half of the Study Area, there are relatively long lineaments running from north-east to south-west. Next long lineaments are found at east-west direction, and relatively short lineaments are extracted at the direction from north-east to south-west as well as from south-west to north-east. The photo-lineaments of north-east to south-west direction coincide with the direction of thrust fault which determines the geological structure of the Study Area. Since the main geological borders are running towards this direction, these features are considered to have been topographically reflected on the lineaments. The photo-lineaments of east-west direction are relatively short and are considered to be the borderline of geology.

In the west half of the Study Area, the photo-lineaments are scarce and most of them are short. As for the direction, north-west to south-east, and east-west are predominant in contrast to the east half of the Study Area, which is consistent with the direction of thrust faults. Also, since the main geological borders are running towards this direction, these features are considered to have been topographically reflected on the lineaments.

Distribution of lineaments is shown in Figure 2.4.1 for photo-lineament and Figure 2.4.2 for fracture trace.

2.4.2 Analyses of Aero-photos

(1) Geological Structures

The analysis of the aero-photo presents an obvious configuration of the tectonic activities that were experienced since Hercenian cycle of the Paleozoic era passing through the Alpine cycle of the Jurassic period to the late Tertiary.

On the basis of identification of the geological structures such as monoclines, anticlines and flexures, the distribution of the faults with the lineaments are identified primarily on rocky ridges and structures. The major faults lineaments appear mainly on the direction of north-east to south-west and south-east to north-west. Other faults appear along the valleys of the Ouergha and Sebou rivers including their tributaries. The inclinations of the structural bedding of the flanks which represent the type of structures are also identified.

The synclinal structures that were stricken by faulting activities are identified. The faults and lineaments are the sign of the presence of water accumulation primarily in rocky formations. The absence of faults in any structure is the sign of the presence of massive rocky formations of very low infiltration and low groundwater potential. While the presence of faults is the indications of karsts and fissures in rocky formations, and loose conglomerates with water accumulation in the depressed basins and synclinal structures.

(2) Land Form Classification

The classification of the flat plains, hills and mountainous areas are carried out. Of them, the flat plains belong to the distribution of the recent Quaternary deposition. The depressed basins and the deposition of the valleys represent the behavior of the synclinal structures. The hilly areas with their inclined edges and flanks represent the existence of the calcareous formations of the Cretaceous period. The gentle ridges and low hilly areas represent the deposition of the mioceneous marl and schists.

The north eastern area for the Pre-Rif region are identified by the massive rocky formations. The triangular shaped area situated among Taounate, Taza and Dhar Souk is characterized by deep valleys and rocky mountains. The mountains are related to the limestone and dolomitic limestone of the Jurassic period. They are located in the form of rocky ridges or anticlinal and monoclinal structures of the Jurassic sedimentation.

(3) Microland Form Interpretations

A large extension of the Pre-Rif region is covered by marl deposits of Miocene epoch series. The hilly platforms are formed of fine silty and schisty marl deposits. In a large extent of the flat areas, the basins and depressions are covered by conglomeratic depositions of various ages.

(4) Land Use

The fine recent alluvium deposits that cover most of the flat areas and depressions along the valleys constitute small scale residential areas due to lack of fresh potable water resources. In such areas, water of a number of the tributaries is polluted by salt contents due to the presence of patches of Triassic formations scattered in the form of veins or ridges along the faulted lines. This Triassic formation contains layers of halite and evaporite intercalated with the red calcareous clay.

A large extent of the land is utilized by small scale vegetation and is partly covered by pasture for livestock feeding. The gentle slopes and hilly ridges of calcareous sedimentation characterized by large scale of residential areas are primarily located near the water sources. In such hilly lands, plantations of olive trees are prevailing.

The rocky mountains seen with scattered residential areas with small scale communities yield water occasionally large or otherwise small amount depending on the geological formations. The most of the rocky ridges and mountains are covered by Lias of Jurassic karstic water bearing limestone formations which have groundwater potential.

2.5 Existing Conditions of Water Supply

2.5.1 General Aspect of Rural Water Supply in Morocco

More than 12 millions of population which correspond approximately to 52 percent of the total population presently reside in the rural area of Morocco. The rural population which occupies more than a half of the entire population engages in the agricultural sector playing a significant role of the national economy.

The AH executed the "Master Plan for the Development of Rural Potable Water Supply" which is the so called "National Master Plan" for the target year of 2010 and finalized second edition with the aid of UNDP on March 1994 following the previous edition issued in 1992. This National Master Plan has already been accepted by the Government of Morocco as the national policy and plan for rural water supply development in Morocco for coming 20 years.

It is reported in this National Master Plan that there are about 4,000 douars in total throughout the country. Each douar possesses six water sources on average ranging from none to 60 sources and one water source generally serves 60 persons (ranging from 15 to 1,000). The average distance to the existing water source is about 500 meters, however, many people travel 5 to 10 km to transport water spending more than 2 hours.

Out of 242,000 water sources in rural areas in Morocco, only 15 percent are equipped with mechanical facilities, and 20 percent of the total sources are out of order due to lack of maintenance facilities. The rest of the sources of 65 percent are non-equipped water sources.

It is also reported that an approximately 14 percent of the rural population is satisfactorily provided with public water supply facilities and the rest is supplied inadequately in quantity and quality. The latter case is by such as extracting water from unequipped private wells or springs, utilizing rain and river water and transportation from other areas beyond communal or provincial boundaries.

In the National Master Plan above said, the fundamental strategies for establishing the potable water supply system in the rural areas are flagged as follows:

i) to improve accessibility to the water sources which are satisfactorily equipped with facilities,

ii) to provide efficient facilities to the water sources, and

iii) to raise the rate of supply pervasion.

The National Master Plan also recommended to raise potable water service ratio from current 14 percent to 80 percent in 2010 as given in Table 2.5.1. The following prioritization on the development of water sources is attached to the above strategies:

1) First priority	: Spring water development
2) Second priority	: Groundwater development
3) Third priority	: Surface water development
4) Fourth priority	: Water transportation

It should be noted that Table 2.5.1 gives the classification of water supply by means of supply method, but not by supply source or the distinction between public or private supply. When speaking the difference between the public and private supply, approximately 80 percent of the population comes to obtain water from public water supply facilities. The primary importance on the rural water supply development is obviously given to the prevalence and provision of stand pipes proportionate by 40 percent compared with 10 percent for the case of house connection.

The National Master Plan also gives a great importance to institutional aspects and proposes to establish an organizational formation to ensure and enforce the implementation of water supply programs.

Table 2.5.1 Present And Future Water Supply Pervasion

Type of Service and/or Works	Water Supply Pervasion			
	Present (1990) (%)		Future (2010) (%)	
House connection	2	14	10	80
Public stand pipe with network	6		40	
Rehabilitated source	6		30	
Traditional water sources facilities	16	86	-	20
Private source	23		-	
Rain water	10		-	
Surface water	21		-	
Transport	16		-	
Total:	100	100		100
Projected population (x 10^6)	13.4		14.3	

Source : National Master Plan
Note: Traditional water source facilities are such as tanks or channels for reserving rain water or stream water.

2.5.2 Existing Water Supply System in the Study Area

Existing water supply systems in the Study Area are controlled and managed by either the ONEP, communal organizations or individuals. In the case that of controlled by the ONEP, the operation and maintenance work is carried out by the ONEP provincial offices established in the provincial centers of Taounate, Sidi Kacem and Taza. Further, planning and implementation work are also carried out comprehensively in a regional level by the ONEP Northeast Regional Center located in the city of Fes. Of them, large scale water supply systems amongst others in their magnitude, number of facilities and extension of supply networks are found in the Taounate province, whereas small scale systems are found in the Sidi Kacem and Taza provinces.

The following are concerned with the existing major surface and groundwater supply systems controlled by the ONEP.

(1) Surface Water Supply System

The surface water supply system which constitutes largest water supply system in the Taounate province as well as in the entire Study Area currently controlled by the ONEP are established at the three locations in the southern boundary along the Sebou river. They are Ain Gdah, Mekansa, and Karia Ba Mohamed water supply systems provided with intake facilities, water treatment plants, pumping stations, raw and treated water transmissions, head tanks and service reservoirs, and so forth. The location of these systems are shown in Figure 2.5.1.

Ain Gdah and Mekansa water supply systems were initially established by the Ministry of Agriculture with the financial aid by IBRD in 1985 as a part of the integrated projects comprising establishment of potable water supply system, agricultural credit bank, infrastructure works and relevant feasibility studies. Of them, the water supply system, the so called "Fes - Karia - Tissa Potable Water Supply for the Communes" was realized in the late 1980s to secure water deficiencies in rural communes. This water supply scheme was implemented with the target year of 2000. The organization of these two systems were thereafter transferred to the ONEP in 1991 in order to enforce system functions, although there was a short period that the organization was managed by the communes themselves before 1991.

The Karia Ba Mohamed water supply system was established in 1985 to enforce the potable water supply system to the town of Karia Ba Mohamed where previously suffered from saline contamination of the springs in the town.

The followings are the detail description of the facilities of these systems.

1) Ain Gdah Water Supply System

The intake facilities are located on the right bank of the Inaouen river 43 km to the east from the city of Fes. The treatment plant is situated in the neighboring site of the intake facilities. The design capacity of the treatment plant is 5,500 m^3/d and current average daily water production rate is reported to be approximately 800 m^3/d in winter and 2,000 m^3/d in summer, respectively. The technical specifications of the existing Ain Gdah water supply system is given in Table 2.5.2.

In recent years, the ONEP started pipeline extension program from the existing reservoir R2 to the new reservoir at Od Ajel in Sidi Mohamed Belacen. The proposed new system covers three supply areas including 16, 9 and 6 douars, respectively, and the facilities to be provided are such as pipe laying of 51 km and 26 public stand pipes in total. The Ain Gdah water supply douar is shown in Table 5.1 in Supporting Report.

2) Mekansa Water Supply System

The Mekansa water supply system was initiated in 1987 by the Ministry of Agriculture, and thereafter the organization was handed over the ONEP.

The intake facilities were constructed at further downstream of the Sebou river within the Study Area, approximately 70 km to the west from the Ain Gdah water treatment plant. The raw water of the Sebou river varies in quality in accordance with seasonal change of turbidity, as high as 1,000 units, large oil contents due to occasional discharge of olive oil from factories located nearby and nitrate content due to wastewater discharge from towns and villages in the upstream reaches.

The design capacity of the treatment plant is 4,800 m^3/d and current daily average water production rate is reported to be approximately 2,200 m^3/d in winter. Because of less consumption of supplied water and subsequent need of less production, the treatment plant is currently operated, as of December 1994, only 6 hours a day. The treated water at the Mekansa water treatment plant is distributed after transmission to 90 douars scattered in the Mekansa commune. The technical specifications of the existing Mekansa water supply system is also given in Table 2.5.2. The Mekansa water supply douar is given in Table 5.2 in Supporting Report.

3) Karia Ba Mohamed Water Supply System

The Karia Ba Mohamed water supply system was established in 1985 by the ONEP in order to supply water to the Karia Ba Mohamed town including 9 douars located along the transmission main. Domestic water for the town of Karia Ba Mohamed was previously supplied by two springs located in the midst of the town, however, one of them was abandoned due to high saline content. The remaining spring with the estimated yield of 14 l/s is still in use for public water supply purpose by mixing with the treated water from the aforementioned treatment plant.

The intake facilities with a capacity of 50 l/s are located on the right bank of the Sebou river in the commune of Karia Ba Mohamed. The design capacity of the treatment plant set for the target year of 2000 is 2,600 m^3/d and the current average daily production rate, as of December 1994, is reported to be 1,300 m^3/d. The technical specifications of the existing Karia Ba Mohamed water supply system is also given in Table 2.5.2. The Karia Ba Mohamed supply douar is given in Table 5.3 and Table 5.4 in Supporting Report.

(2) Groundwater Supply System and Facilities

The public water supply systems which are dependent upon groundwater have been established in many communes in the Study Area, such as Taounate, Tissa, Karia Ba Mohamed, Ain Aicha, Rhafsai, Ourtzagh and Moulay Bouchta as the major systems in the Taounate province under the control of the the ONEP. In addition, Ouazzane, Had Kourt, and Jolf El Merha are pointed out as the major systems in the Sidi Kacem province. The location of these groundwater supply systems is given in Figure 2.5.1. The technical characteristics of groundwater supply systems of Taounate, Tissa and Karia Ba Mohamed as representatives are given in Table 2.5.3.

The water supply facilities controlled and managed by communal authorities may be divided into two categories. The one is the case established by the communes by themselves, and the other is the case that wells and dug holes were initially constructed by the AH and thereafter transferred to the communal authorities in order to enforce their self-supporting capability.

The communes wish to develop wells or dug holes for potable use send application documents to the AH regional office requesting implementation of drilling. The AH in response to this request dispatch a staff to investigate the conditions whether it would be satisfactory to implement drilling works or not. The wells and dug holes executed successfully in this manner are in general handed over the communes for their own control.

Table 2.5.3 Technical Characteristics Of Groundwater Supply System

Technical Specification		Unit	Taounate	Tissa	Karia Ba Moh.
Water Source	(Wells)	no.	5	1	1
	Chamber, head tank I	m^3	100	-	500
	Chamber, head tank II	m^3	100	-	-
	Pump head I	m	193	90	-
	Pump head II	m	159	-	-
	Raw water pipe length I	m	1,180	1,590	1,187
	Raw water pipe length II	m	1,185	-	-
	Pipe material	-	A.C	A.C	A.C
	Pipe diameter	mm	200	100	200
Distribution Area		unit	7	2	6
Distribution Pipe Length		m	32,360	8,659	25,359
	Diameter	mm	-	50 - 150	60 - 200
Service Reservoir		m^3	750	150	1,000

Source: ONEP

2.5.3 Existing Conditions of Water Use and Consumption

(1) Estimated Water Consumption in the Previous Study

The National Master Plan issued in 1994 represented the existing and projected future unit water consumption as of 1990 and 2010 as given in Table 2.5.4 in compliance with the type of facilities being or to be provided in the rural areas in Morocco.

Table 2.5.4 Existing and Future Unit Water Consumption for Domestic Use

(Unit: l/c/d)

Type of Service	1990	2010
Equipped well and springs	15	15
Public stand pipes	20	30
House connection	40	50

Source: National Master Plan, 1992

In the National Master Plan report, projection is given as shown in Table 2.5.1 for the future services categorized in four types, 1) stand pipe: 40 percent, 2) house connection: 10 percent, 3) rehabilitated source: 30 percent, and 4) non-equipped or private source: 20

percent. In line with this category, the report concluded that the domestic water demand in rural areas in 2010 would be 188 million m^3/year or 36 l/c/d in average of four types, whereas water consumption for livestock feeding would be 20 /head/d.

Whereas, the National Master Plan introduced the projected water consumption by the DRPE for the target year in 1990 as shown in Table 2.5.5. At the stage of projection, the total available water in the three provinces consisting of surface and groundwater are 28 l/c/d, 27 l/c/d and 27 l/c/d, respectively.

(2) Present Water Use in the Study Area

1) Taounate Province

Table 2.5.6 shows water supply facilities provided in rural centers by the ONEP Taounate provincial office as of July 1995. Out of the rural centers, the Ain Gdah system has the largest served population followed by the Taounate, Mekansa and Karia Ba Mohamed systems. The numbers of house connection of these systems are not in proportion to the one of served population. Namely, the Ain Gdah system which includes the largest service area has less house connections as small as 9.3 percent in the rate of saved population and similarly the Mekansa system including the third largest service area has 9.8 percent. The percentage calculated is based on the rate of 8 persons per house connection as estimated in the National Master Plan. These two systems mainly supply water by stand pipes.

The available flow rate of the Taounate, Karia Ba Mohamed, Ain Gdah and Mekansa systems which are ranked on top four in the magnitude amount to 215 l/s which equivalent to 87 percent of the total. Three out of four systems other than the Taounate system, the water source is relied on the Sebou river. While, respective average water production is not in proportion to the available flow rate, namely Ain Gdah has the largest production capacity but average production volume is the third largest. In the connection, Mekansa is obviously the extreme case. This is mainly due to the rate of prevalence of house connection in the supply area.

Water production and consumption of the rural centers in the Taounate province in 1994 and first quarter in 1995 are shown in Tables 2.5.7 and 2.5.8, respectively. The relative unit water consumption including house connection and stand pipes together with unaccounted for water is calculated in the third column from the right end. The highest relative unit water consumption is seen at Karia Ba Mohamed with the amount of 63.4 l/c/d followed by 59.8 l/c/d and 43.7 l/c/d at Taounate and Tissa, respectively. It is assessed that these supply areas are rather small but provided with comparatively sufficient house connection facilities compared to others. The location of these systems are shown in Figure 2.5.1.

2) Sidi Kacem Province

In the Sidi Kacem province, three major water supply systems are controlled and managed by the ONEP Sidi Kacem. They are Ouazzane, Had Kourt and Jolf El Melha systems.

The municipality of Ouazzane is presently being supplied with water from the four boreholes located in the plain of Bouagba, 34 km to the west from the town of Ouazzane. The yield of these bore holes are estimated to be about 120 l/s. Due to topographic configuration and the difference in altitude of about 275 m between the source and the town, transmission facilities are equipped with a number of reservoirs and booster pumps. In addition, due to the hilly nature of the town, the water supply system in Ouazzane is divided into three pressure zones in the distribution network.

The average and peak flow rates of 60 l/s and 80 l/s respectively are reported by the ONEP to supply water for the municipal population of 52,200. The water from the same source is also supplied to the commune of Masmouda with an average flow of 0.5 l/s or approximately 43 m^3/d.

According to the water demand projected by the ONEP in 1993, the yield at the existing wells will be able to sufficiently meet the water demand of Ouazzane up to the year around 2005 as given in Table 2.5.9.

Table 2.5.9 Water Demand Projection in Ouazzane

(Unit: l/s)

Year	1993	1995	2000	2010	2020
Average Demand	100	103	111	129	152
Peak Demand	130	134	144	168	197

Source : ONEP Sidi Kacem Office

The water supply system in the rural center of Jolf El Melha consists of wells equipped with pump facilities, distribution network and house connections. The supply capacity in June 1995 was about 4.6 l/s, whereas water demand was estimated in the order of 10 l/s, thus water deficit of Jolf El Melha is reported by the ONEP to be around 55 percent. In order to overcome the deficit, the ONEP is presently in preparation of providing a new well with pump facilities and appurtenances. The expected new facilities with a flow rate of 16 l/s will be accomplished and in service by September 1995.

The rural center of Had Kourt is supplied with water from a well and a spring equipped with pumps feeding the network of the rural center of Had Kourt. The present water demand estimated by the ONEP is around 7 l/s, whereas average and peak flow rate in the existing facilities are 2.4 and 2.5 l/s, respectively. Due to less potential of water source. current water deficit is reported to be around 65 percent. In order to overcome the deficit, the ONEP has proposed a new project for supplying water to Had Kourt from the water source at Mechra Bel Ksiri located at 32 km to the west.

3) Taza Province

With the technical assistance and training of the personnel of the RADETA (the government owned company of distribution of water and electricity in Taza), the ONEP Taza provincial office that was created two years ago operates and maintains the water supply facilities for the municipalities of Guercif, Ouad Amlil and Tahla as well as the commune centers of Matmata and Zrarda. All these water supply systems which depend upon groundwater source are, however, out of the Study Area.

On the provincial level, the ONEP Taza is regularly receiving requests from various communes in the province, whereby the communal authorities request the ONEP to take place management of the existing water supply facilities in order to enhance. Amongst these communes, Tainaste, Oulad Zbair and Beni Lent are the ones situated within the Study Area.

(3) Existing Constraints on Water Source and Demand

1) Quantitative Constraints

The rate of surface water production in Taounate Province is as shown in Table 2.5.6, 17 percent, 25 percent and 7 percent in the Ain Gdah, Karia Ba Mohamed and Mekansa systems, respectively and these corresponds approximately to 50 percent in total. This implicates that the role of the surface water supply system in Taounate Province is indeed very large at present.

The surface water potential at the intake site is large enough, especially, at the site of Karia Ba Mohamed and Mekansa water treatment plants in the down reaches of the Sebou river. Their low flow rates estimated by the dependability of 95 percent are 7.5 m^3/s and 10.9 m^3/s or approximately equivalent to 648,000 m^3/d and 942,000 m^3/d respectively. However, the low flow rate estimated simultaneously at Ain Gdah is 0.34 m^3/s or approximately 29,000 m^3/d and this amount will be critical when considered about heavy drought periods as encountered in 1995. For instance, during the Study period in July

1995, the operation of the Ain Gdah water treatment plant was stopped for six days due to water shortage in the Inaouen river.

As for the case of groundwater sources controlled by the ONEP, it is envisaged that there would not likely to be much influence by dry periods, since the wells and dug holes are located in relatively good geophysical formations in the vicinity of rivers. Of them, the Taounate system consists of five dug holes located on the bank of the Sra river having the aquifer being constantly recharged through a preferable geophysical formation. So is the case of Ain Aicha, Rhafsai and Ourtzagh being recharged by river bed flow assisted by syncline formations. However, due to increase of population and to meet subsequent water demand in these rural centers further exploitation of groundwater source is becoming inevitably necessary.

In case of the Sidi Kacem province, the great majority of the flat plains are suffering from water shortage due to less potential of groundwater source under difficult geophysical formations which may be unable to constitute a good aquifer.

2) Qualitative Constraints

In the qualitative view point, the major constraints are pointed out on the water quality of the Sebou river and salinity of groundwater in the Triassic formations.

The contamination of the Sebou river is predominantly caused by domestic and industrial waste water discharge from the city of Fes and its suburban areas. The RADEEF has been implementing a new project for industrial wastewater disposal. The project includes the construction of lagoons for retention of olive oil and a treatment plant with mechanical treatment methods. In compliance with the completion of this disposal system, water pollution of the Sebou river due to olive oil is expected to be largely diminished in the near future.

Meanwhile, water pollution due to domestic wastewater discharge will remain for the time being until wastewater disposal system has been established in and around the city of Fes.

The problem of salinity of the groundwater is not an easy task to solve, since the problem is totally depends upon the geophysical conditions.

3) Constraints on Operation and Maintenance Works of ONEP

In the existing water supply systems by the ONEP, there is not much serious constraints on the operation and maintenance aspects as a whole. However, it should be pointed out that water leakage from the transmission pipelines are sometimes observed, for example in the Ain Gdah system, due to high pressure of more than 160 m head. Further, it is hardly accessible to the leakage site to repair during especially the rainy season, due to collapse or slippery ground conditions.

2.5.4 Proposed and Ongoing Project by ONEP

Table 2.5.10 gives the proposed and ongoing projects being and to be carried out under the ONEP in the province of Taounate. Of them, six projects including Ain Aicha, Ain Mediouna, Rhafsai, Taounate, Laghouazi and Ourtzagh were already concluded in the contracts and other three projects are in preparation of construction. The remaining projects also have already been promised in their financial aid from foreign countries. With due completion of these projects, the existing water supply systems in the Province of Taounate will be extensively improved.

2.6 Initial Environmental Examination

2.6.1 Existing Conditions of Environmental Aspects

(1) Water Quality

1) Norms or Standards

Table 2.6.1 summarizes the drinking water quality standards used in Morocco and compares them with the WHO recommended standards. Allowable water quality for livestock in Morocco is also given.

2) Groundwater Quality

The quality for drinking purposes of all groundwater sources (springs, dugholes and wells) has been studied, based on allowable salinity data characterized by measurement of electrical conductivity or total residue solids at 180°C and qualitative survey data of the National Master Plan (consumers' appreciation of the quality; qualitative observations of persons conducting the surveys), as well as by field visits conducted during Phase 1 of the Study.

Available water quality of most springs in the Study Area have been classified into five classes, namely, good, passable, average, low and saline, as shown in Figure 2.6.1. Of them, 8 springs are defined as low quality and not suitable for drinking purpose. These locations with low quality water in springs do not necessarily mean low water potential. For example, west part of the Taounate commune is well known as spring water yielding area, although saline water is found occasionally due to complicated geophysical configurations.

Table 2.6.2 presents the water quality data of selected number of dugholes in the Study Area. 14 out of 49 locations, equivalent to 29 percent, revealed to be saline water and low class water under the conductivity testing, and the dugholes defined as saline water has been mostly abandoned.

3) Surface Water Quality

Figure 2.6.2 presents major sources of pollution at various points in the Sebou river basin. The Sebou river basin is subject to regular monitoring (BOD, COD, dissolved oxygen, total nitrogen, fecal coliform) at various points along the river and its tributaries.

Figure 2.6.3 classifies the Sebou river and its tributaries in terms of its suitability for drinking use.

Extensive discharge of domestic untreated sewage into the Sebou river by urban centers worsens water quality. Simple treatment of this water is insufficient to achieve drinking water quality standards. Concentrations of bacteriological parameters of pollution caused by sewage (total coliform, fecal coliform) are very high in areas immediately downstream of urban centers along the Sebou river and its tributaries. The consumption of this polluted water has also been linked to the prevalence of major water borne diseases and occurrence of epidemics in the Sebou river basin.

(2) Sanitation and Wastewater Disposal

The National Master Plan Study has on the basis of a detailed documentary analysis and site visits to nine provinces including Taza, Taounate and Sidi Kacem has described the current situation in rural areas of Morocco, concerning sanitation, wastewater treatment and waste disposal. It has also determined causes of problems related to sanitation and wastewater disposal, and made appropriate technical and institutional recommendations.

Some features of prevailing conditions are as follows:

i) Less than 20 percent of the population in villages of the Study Area have individual latrines. In the most of the rural villages scattered mountains and hilly areas, latrines are primitive type, made of traditional locally available material (wood and mud).

ii) In general, nothing is planned for wastewater disposal. Potential pollution of water sources (springs or dugholes) is high in some locations. Housing is situated upstream of spring sources. Local ground permeability conditions would be a cause of pollution of such drinking water sources.

iii) Rural schools and markets have specific sanitation problems. In many cases schools are built without latrines due to a lack of water supply. Markets are major sources of pollution because waste disposal is scarcely managed.

iv) Pollution of the Sebou river and its tributaries by domestic sewage is a major sanitary problem.

Waste water treatment and disposal is not adequately managed or addressed by any particular institution in the Study Area. Although guidelines for building latrines are available, these are not used in rural areas.

Consequent to the conditions above, there are high prevalence of water-borne diseases (cholera, typhoid, diarrhea) in the Study Area. Typhoid occurs frequently in some villages in the mountain areas where natural springs or dugholes are used without any disinfection. This can perhaps be linked to the pollution of the water sources by waste water percolating from ground surface. In the Sebou river basin, the use of sewage contaminated water has been linked to occurrences of cholera .

Data on agricultural pollution are not available. However, this is not perceived as an important factor in the Pre-Rif region concerning to ground or surface water pollution.

(3) Health and Water Borne Diseases

A number of inter-related factors like water quality, water quantity, accessibility to safe water, reliability of supply, adequate sanitation, and health education programs, provide health benefits of water supply. Health benefits are particularly difficult to evaluate and perceive in the short term. Improved water supply is generally only a starting point towards improved public health. To gain the full potential health benefits of water supply projects, corollary inputs such as hygiene and sanitation are necessary.

Planning water supply requires an understanding of the water related diseases. Table 2.6.3 gives a classification of the provinces on the basis of incidence of cholera, typhoid and diarrhea in 1990 (Cholera also 1993). The Taza and Sidi Kacem provinces can be classified in group 1 of the maximum incidence along with four other provinces outside the Study Area. Taounate can be classified in group 2 of incidence following group 1.

In particular, communes of the Taza province within the Study Area and falling in homogenous zone 7 as defined in the National Master Plan reported high incidence of water related diseases. The Taounate commune reported several cholera cases in 1993. Communes of Chabanate, Tihili, Sidi Redouane, Jemaat El Houafate, Zirara, Had Tekna, Bir Taleb, Dar Laaslouj and Sidi Kacem in Sidi Kacem province together reported 38 cases of cholera in 1993. The number of cases were much higher in each of these provinces in 1990.

Intestinal parasitic diseases (helminthiasis, ambiosis) are also reported frequently in the three provinces of the Study Area.

(4) Institution and Management

Many institutions are involved in provision of rural water supply. These include the Ministry of Interior, the Ministry of Public Works, the Ministry of Agriculture and Agrarian Reform, the Ministry of Public Health and the National Office of Potable Water.

The Ministry of Public Health is the primary organization related to environmental matters concerning potable water supply. It is responsible for disinfection of water source, control of water quality, sanitation, control of waste water treatment and for providing sanitary education. However, its activities concerning sanitation and wastewater treatment are not fully realized.

The Department of Epidemiology and Sanitary Programmes under the Ministry of Public Health has a decentralized structure. There are over 220 rural sanitary departmental units for the entire country. In general, 1 to 3 communes are covered by each units. These sanitary department units are in turn divided into sections that are led by itinerant nurses. These itinerant nurses are responsible for effecting disinfection action of water sources as well as for providing people with sanitary education. The program of disinfection concerns principally the collective wells. Private wells are only covered in general in the case of an epidemic outbreak.

Other than the Sidi Kacem province coming under zone 5, number of private water sources (69 to 82 percent) is more than collective water source points. Thus, the disinfecting action does not cover the majority of water sources. It is hardly effective for satisfying the microbiological potable water standards. More decentralized and effective way of disinfection covering all water sources is necessary in the Study Area.

Almost half of equipped water sources in the Study Area are under private management. The rest of the water sources are under management of villages or communes. However, the villages or communes are hardly ever involved in the disinfection. This is a major institutional problem obstructing adequate or proper disinfection of water sources.

The province of Taounate has initiated an interesting institutional set-up for disinfection of water sources. Meetings are held at the level of circles with the medical chief of the rural sanitation unit. The Mokadems, low level officers appointed by the Ministry of Interior for several number of douars collectively, also attend these meetings. They are responsible for designating a person in charge of a particular collective water point. This designated person ensures that adequate disinfection is carried out. Initial results indicate that this decentralized coordinated institutional mechanism seems very effective.

Although private water points are large in number, they serve only a low percentage of the rural population. Proper education concerning needs and merits of disinfection is necessary to ensure their safety.

(5) Sociological Aspects

1) Access to Water Sources

In homogenous zone 6 - the Central-Rif region, the population does not use surface water for drinking. There are no reservoirs or ponds for water storage. The villages are located on the flanks of mountains or on the crests. The population of 31 percent has to go for accessing to potable water sources which are springs in general. The average covered distance is 3.1 km. The sources are not all everlasting, which results in severe water shortages in summer and especially in dry seasons.

In homogenous zone 7, the Pre-Rif region constituting over 2,632 villages (douars), 14 percent of the localities use surface water for drinking purposes. All rivers in this region, the Sebou river basin, are more or less suffering from water pollution. There are a few reservoirs. 48 percent of the localities have to bring water from far away with an average covered distance of 5.8 km. When the springs dry up, the rivers are used.

2) Position of Women and Children in Water Supply

Survey data of various earlier studies indicate that in the Pre-Rif and the Central Rif region, the task of bringing water is generally carried out by women and children even in long distances and scattered housing cases. It takes them 1.5 hours to 2 hours per trip on the average and two or three trips are needed in a day. Time for bringing water is much higher in some localities, especially in summer or in dry years, since the distance to suitable water sources becomes longer due to a lack of water at their water sources normally used.

The women and children spend much time for bringing water. They suffer from problems including inadequate care of infants and inability to attend schools. As a result, sanitation and hygiene practices are not provided adequately. This has been related to prevalence of water-borne diseases .

3) Service Conditions and Socio-demographic Behavior

The factors of water supply difficulty and the dominating position of women and children in the execution of this task have serious effects on the health condition as well as on living and welfare conditions. These include:

i) Areas with high prevalence of water borne diseases also have very high female illiteracy rates (about 90 percent).

ii) Female activities outside home i.e. bringing water results in high prevalence of water borne diseases, especially infant diarrhea resulting in high infant mortality rates.

iii) Difficult water supply conditions have resulted in high migration rates.

iv) Low incomes added to difficult service conditions and poor hygiene practices are also recognized as factors leading to existence of water borne diseases.

v) Effects of the disinfection are not understood or neglected. For example, many coffee shops in rural towns use non-disinfected water since people does not like disinfected water.

vi) Indigenous ownership claims water sources to forbid development and/or sharing with another area. This problem is reported in some mountain localities of the Study Area.

2.6.2 Environmental Impacts and Intervention Measures

A three step methodology is used:

(1) Relating basic data to drinking water / sanitation and health sectors,
(2) Determining source of problem and type of project intervention, and
(3) Determining complexity of interventions.

Each of these steps is enumerated upon below:

(1) Relating Basic Data to Drinking Water/Sanitation and Health Sectors

The National Master Plan has established a relation between the prevalence of water-borne diseases and a certain number of parameters characterizing water supply in rural areas of Morocco.

Areas with high incidence of water related diseases are characterized by the following:

i) There are less disinfecting operations.

ii) Less than 8 percent of water sources are properly equipped.

iii) More than 80 percent of water source intake points are in a bad condition (hygiene, cleanliness, operation and maintenance).

iv) There is a large number of non-equipped water resources (mostly private shallow wells).

v) Mother and children particularly girls, have the role of bringing water from the sources to their house. The average time required ranges from 1.5 to 2 hours (round trip) in many hilly and mountainous areas. This in turn results in low education level of mothers and children as well as neglect or inadequate case of infants.

vi) Less than 5 percent of localities possess latrines or less than 20 percent of the population utilizes latrines.

Table 2.6.4 classifies the seriousness of prevalence of four most common water borne diseases in the Study Area

(2) Determining Source of Problem and Type of Project Intervention

Based on the above step and earlier presentation of existing conditions in the Study Area, the main sources of the problem and the focal points of intervention are identified. The source of problem is indicated on a scale of 0 (negligible / not applicable), 1 (low), 2 (medium), and 3 (high). An explanation of terms in Table 2.6.5 is as follows:

1) Main Source of Disease

i) Water quality : biological and chemical quality of drinking water.

ii) Water quantity : amount and accessibility of water for domestic use.

iii) Excreta disposal : disposal of human and animal feces.

iv) Waste disposal : sullage, gray water, waste water, solid waste and the adequacy of drainage. Waste disposal can also refer to provision of potable water without adequate drainage.

v) Housing : the overall living environment inside the home and its immediate surroundings.

vi) Education : refers to overall educational level of population, and in particular, to the understanding and practice of personal and domestic hygiene. Since all programs theoretically require education, ranking implies its potential efficacy.

2) Focal point of intervention identifies main thrust of program of intervention; may be more than one category . A rank of 3 indicates that the intervention is potentially important in reducing transmission.

i) Water supply : adequate supply of potable water.

ii) Excreta disposal : sanitation, sewerage, excreta disposal.

iii) Waste disposal : sullage, drainage, waste water, solid waste.

iv) Housing : overall improvement of the home and the immediate surrounding areas, with appropriate consideration given to sunlight and air circulation.

v) Health care : preventive measures; does not refer to general health care; reflects curative interventions, e.g., epidemics or rapid dehydration, only when they pertain to interrupting transmission; and

vi) Education : general education, especially in personal and domestic hygiene

(3) Determining Complexity of Interventions

Having determined the main problems and potential interventions, the next and perhaps the most important step is to determine the complexity of interventions and whether they are appropriate within the project. Complexity in this case refers to the number of separate factors requiring coordination in component administration . Table 2.6.5 indicates this step on a ranking scale: 3 (High), 2 (Medium), 1 (Low) importance or complexity . An explanation of terms in this table is as follows.

1) Area of focus: indicates the overall focus or cast of characters necessary for an intervention program;

i) User : people rather than physical or environmental changes. A rank of 3 implies that a high level of education will be needed requiring preparation of the community and time for behavioral habits to change;

ii) Living environment: the physical environment where people spend most of their time. A rank of 3 implies high level of physical intervention is required, e.g., vector control, requiring inter-agency cooperation .

iii) Health system : collaboration of health care delivery system rather than education or environmental changes. A rank of 3 implies a high level of collaboration;

2) Time span: gives a rough idea of the time range for an intervention program;

i) Short/long : indicates how long it takes to conduct a program. A rank of 3 indicates a long program, such as a malaria campaign; a rank of 1 implies a short program, such as an immunization program without follow-up .

ii) Recurrent : indicates the necessity of a follow-up program or special budget.

iii) Initiate : indicates the level of organization required to initiate the program. A rank of 3 implies a long period.

iv) Impact : indicates period needed to have impact. A rank of 3 implies long term.

3) Integration: implies other programs can be combined together in an intervention program .i.e. using the same resources. A rank of 3 implies that it is hard to integrate with other programs and therefore requires separate efforts.

4) Critical Mass: indicates whether a major campaign is necessary for an effective intervention. A rank of 1 indicates that the campaign can be conducted by existing health care delivery service or that no major campaign is necessary.

5) Inputs: measures the difficulty of securing adequate staff and material;

i) Labor : identifies sources as skilled or unskilled. A rank of 3 indicates the need for skilled labor.

ii) Material : identifies sources as local or outside. A rank of 3 implies materials that are expensive or hard to get;

6) Perceived priority: another indicator of the extent of community involvement and change of personal habits;

7) Need: refers to the disease itself. A rank of 3 implies local people do not consider the disease important or that they do not know they can combat it.

8) Program: refers to the need of a program and the capacity of the local government to back one. A rank of 3 implies the difficulty of initiating the program.

It is clear from Table 2.6.5 and 2.6.6 that provision of drinking water supply to rural communities in the Study Area entails consideration of various environmental aspects. The bacteriological quality of water, low available water quantities, lack or inefficient disposal of excreta and waste water and the educational level especially of women are important problem areas. Interventions are necessary by not only providing adequate, good and safe water supply, but simultaneously implementing actions related to excreta disposal, wastewater disposal, improved health care (disinfection of water supply and preparedness to tackle epidemics) and education related to personal and domestic hygiene. These actions need to be focused to varying degrees on the user, the living environment and the health care system (i.e. disinfection of water supply).

The time span of various actions are necessarily long term and coordination by various ministries and their action programs is necessary. Improved water supply needs to be complemented by improved health status of the population in order to lead to an improved quality of life of the beneficiaries. Health improvements depend not on one (say providing adequate water of good quality) but on many inter-related factors, covering abroad spectrum of interventions ranging from individual hygiene to sanitary living quarters, from health care delivery to adequate diet. The following important actions need to be considered in formulating interventions:

i) Increased disinfection of water sources.

ii) Increased community and local participation in management, operation and maintenance of water sources.

iii) Necessity to impart education related to sanitation and personal hygiene.

iv) Improvement of the institutional set up for managing various aspects related to water supply and improved coordination among various organizations for water management.

v) Need for provision of sanitary latrines and waste water drainage and disposal in addition to providing water supply. This is very important since in the absence of such measures the potential for pollution of existing water sources could be high or with the provision of increased water quantities, without adequate waste water drainage facilities, the risk of outbreak of water-borne diseases could increase.

vi) Focus on women to impart sanitary education because of their dominant role and promote compulsory education of children.

2.7 Geophysical Prospecting

Goephysical prospecting by electrical sounding was conducted on the seven geologic structures of Jorf El Melha, Ain Defali, Teroual, Ourtzagh, Ain Berda, Taounate, and J. Keil, shown in Figure 4.2.1 of Supporting Report, in order to identify the detailed configuration of their hydrogeological features. In addition electromagnetic sounding was performed on the structure of Ain Berda to detect the cracked and fissured consolidated formations therein.

2.7.1 Electric Sounding

(1) Field Work

Vertical electrical sounding (VES) consisting of the Schlumberger electrode array shown in Figure 2.7.1 was used to specify the stratigraphical column of the aforementioned geological structures and to determine the exact thickness of the various water bearing formations.

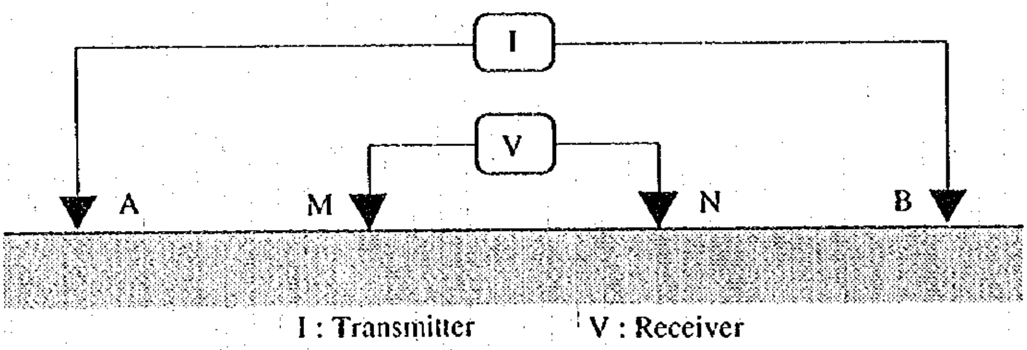


Figure 2.7.1 Arrangement of Schlumberger Electrode Array

The technique serves to measure the resistivity in various strata assuming horizontal layer distribution. The measured quantities are the electric current emitted through the electrodes (A,B) and the voltage difference detected between the potential electrodes (M,N). The apparent resistivity is calculated from the following equation for Schlumberger array.

$\rho_a = \pi (L^2 - l^2) / 2l \times V / I \quad ; L \geq 5l$

where;

r_a = Apparent resistivity in ohm-meter

L = Spacing of current electrodes (AB / 2) in meter

l = Spacing of potential electrodes (MN / 2) in meter

V = Voltage difference in volt

I = Electric intensity in ampere

The instruments used in the prospecting work consisted of a resistivity meter of the type OYO McOHM model 2115, a power booster OYO McOHM model 2917 and a 12 volt battery for power supply. Stainless steel sticks and porous pots filled with copper sulfate solution were used as current and potential electrodes respectively. Current and voltage values are displayed on the resistivity meter as illustrated in Figure 2.7.2. Spacing of electrodes is increased gradually from 2 to 500 m in order to obtain the information and characteristics of successive layers of the substratum for each of the seven potential structures.

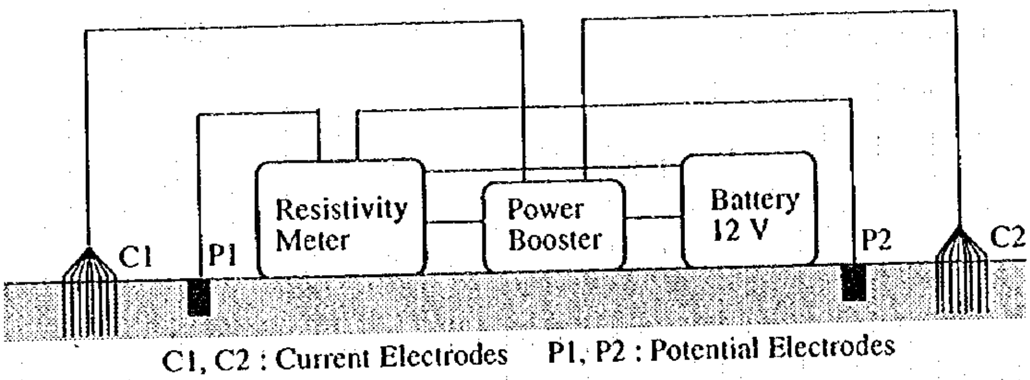


Figure 2.7.2 Installation of Instruments for Electric Sounding

(2) Data Analysis

Analysis of the vertical electric sounding (VES) data was performed by one dimensional Schlumberger inversion method based on the direct modeling of the nonlinear least square method. A personal computer IBM 2437-YMS (CPU: 486, Slc-25 MHz) was used for the calculation. The results of the analysis of all the electric sounding are presented in Figure 4.2.2 of Supporting Report where the solid line represents theoretical resistivity values computed with final resistivity model and the dots indicate measured resistivity values.

The resistivity profiles derived from the electric sounding are shown in Figures 4.2.3 and 4.2.4 of Supporting Report. In general, the recorded values indicate that the profiles can be divided into three categories of low, medium and high resistivity zones. According to the available data and the geological character of the Study Area, these three zones correspond to marl, conglomerate and limestone formations.

2.7.2 Electromagnetic Sounding

(1) Field Work

Electromagnetic sounding was carried out by VLF (very low frequency, 3 to 30 Khz) MT (Magnetotelluric) resistivity measuring system in order to confirm the locations of faults and fractures within the geological structures. In this technique the apparent resistivity of the strata is determined by magnetotelluric measurement of the radiated field from a remote radio transmitter operating for communications with submarines. The measured quantities are the horizontal component of the radial electric field (Ex), the tangential magnetic field (Hy) and the phase angle between Ex and Hy as illustrated in Figure 2.7.3

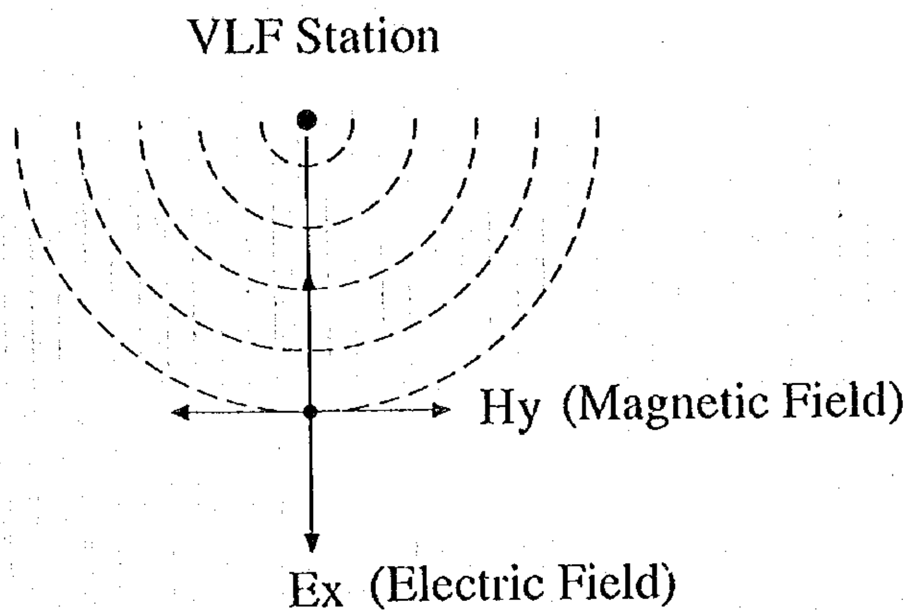


Figure 2.7.3 Schematic View of VLF - MT Measurement

The apparent resistivity is derived from the following expression:

$\rho a = 0.2\ (T\ Ex / Hy)^2$

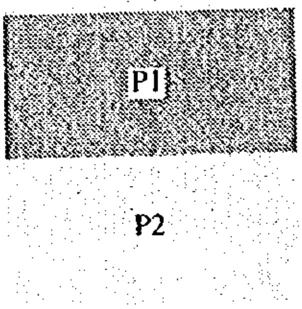
Where;

T = Period of the signal in seconds

Ex = Electric field in millivolt per kilometer

Hy = Magnetic field in nanotesla

The measuring device is moved progressively along the structure so as to detect the resistivity changes along the profile line. The phase angle is 45° for homogenous conditions and is inversely proportional to the resistivity of the ground layer as shown in Figure 2.7.4



P1 > P2 : $\Phi > 45°$

P1 = P2 : $\Phi = 45°$

P1 < P2 : $\Phi < 45°$

P1 : Resistivity of Upper Layer
P2 : Resistivity of Lower Layer
Φ : Phase Angle

Figure 2.7.4 Relation between Phase Angle and Resistivities of Two Layer Model

An electromagnetic instrument of the type Geonics EM 16/16R operating at very low frequency (VLF) and a resistivity measuring device Magnetotelluric MT were utilized for the detection of radio waves and resistivity as illustrated in Figure 2.7.5. The transmitting signal used is that of GRB, Rugby, Great Britain operating with a frequency of 16 KHz.

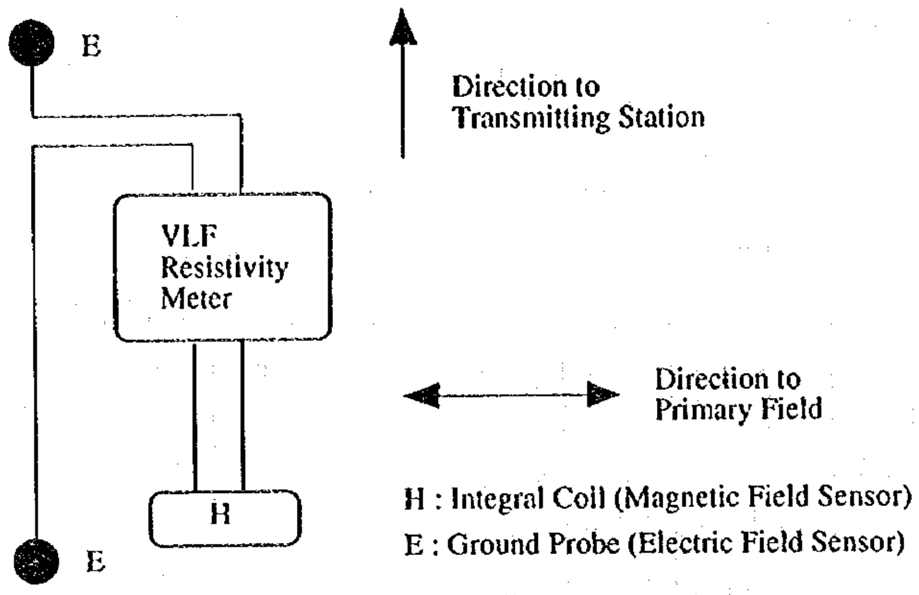


Figure 2.7.5 Configuration of Instruments in VLF - MT Measurement

(2) Data Analysis

The effective depth of penetration or "skin depth" is a function of the electric resistivity and the frequency of the signal and is calculated from the following equation:

$d = 503 (r / f)^{1/2}$

where;

- d = skin depth in meter
- r = Resistivity of earth layer in ohm-meter
- f = Frequency of signal in hertz

Apparent resistivity and phase angle profiles obtained along the 3 surveyed lines at Jbel Berda are shown in Figures 4.2.5 and 4.2.6 of Supporting Report where the solid line represents the apparent resistivity and the dots indicate the phase angle. Normally, water confined within fault lines and fractures in rock formations produces distinct low resistivity readings against that of the rock. Most of the apparent resistivity values obtained along the examined profiles are less than 50 ohm-m, thus indicating weathered material. The high resistivity reading at 160 m interval along line 1 corresponds to the outcropping limestone formation.

2.7.3 Survey Results

The resistivity profiles of the seven examined structures are shown in Figures 4.2.3 and 4.2.4 of Supporting Report. The description of the findings of the geophysical prospecting is presented in the subsequent paragraphs.

(1) Jorf El Melha Structure

Resistivity readings at the structure of Jorf El Melha range between 160 and 430 ohm-m for the upper layer composed of fine alluvium and conglomerate and extending between 10 and 30 m deep. The lower layer has very low resistivity readings of 0.8 to 7 ohm-m which correspond to impervious marl deposits.

(2) Ain Defali Structure

Electric soundings carried out in the N-S and E-W directions confirm the presence of a water bearing formation consisting of conglomerate and marl matrix with resistivity readings ranging from 15 to 100 ohm-m in the E-W direction and 60 to 300 in the N-S direction and extending about 150 m deep. Beyond this depth, the resistivity drops to less than 10 ohm-m indicating the presence of an impervious marl layer of more than 100 deep.

(3) Teroual Structure

The results indicated the presence of a water bearing silt stone formation with resistivity in the order of 100 ohm-m along the the western edge of the syncline structure. According to VES line A, the productive layer extends from 30 to 150 m below ground level. At VES points 6 and 7 of line B, the survey revealed the presence of another water bearing formation, with resistivity ranging between 40 to 100 ohm-m, outcropping along the eastern flank of the syncline and dipping towards the west to a depth exceeding 250 m from ground level. The two layers are separated with impervious deposits of about 125 m thick having a resistivity of 10 to 20 ohm-m.

(4) Ourtzagh Structure

The survey indicated that the flanks of the syncline are dipping towards its axis at VES point 10 where the top of the conglomerate formation is about 300 m below ground level. Resistivity readings of 50 ohm-m characterize this formation as a water bearing stratum. The overlaying layers consist of impervious marl deposits having a resistivity range of 2 to 4 ohm-m. The shallow surface of the syncline is covered, up to about 25 m deep, with conglomerate formation having resistivity readings of 20 to 187 ohm-m indicating the presence of water accumulation.

(5) Ain Berda Structure

The survey was carried out along the fault line of the structure as inaccessibility prevented from investigating the top of the monocline. The resistivity profile along the survey lines indicated the presence of water bearing formation with readings ranging from 30 to 360 ohm-m and extending between 70 and 150 m from ground level and about 35 m below the level of the existing spring of Tazghadra. The underlying formation is marked with low resistivity of 10 to 20 ohm-m revealing the presence of impervious deposits. The electromagnetic sounding carried out on the top of the structure registered a constant resistivity of 50 ohm-m indicating the presence of water bearing formations.

(6) Taounate Structure

The survey confirmed the presence of two syncline structures located along the Sra river. The first structure stretches north south in the direction of VES line B and includes two water bearing formations. A shallow one with resistivity readings of 30 to 56 ohm-m and a thickness ranging from 20 to 70 m at VES points 16 and 12 respectively, and a deep formation located some 250 m below ground level having a thickness of 125 m and resistivity ranging from 20 to 50 ohm-m. The second syncline lies in the east west direction along VES line C and is composed of an upper water bearing formation extending between 175 and 250 m below ground level with resistivity readings ranging from 10 to 89 ohm-m. The lower formation consists of impervious stratum having a resistivity of 1 ohm-m.

(7) Jbel Keil Structure

The survey confirmed the presence of large limestone boulders and conglomerate formation extending about 25 m below the level of the existing spring of Bouadel and identified as the water bearing stratum of the monocline. The resistivity readings of the section above the spring range from 50 to 1500 ohm-m, whereas those of the area around the spring vary between 850 and 1200 ohm-m. The base formation below the structure consists of impervious marl with resistivity of 61 ohm-m indicating the presence of schist and consolidated marl stone.

2.8 Recommendation of Model Area

2.8.1 Conditions of Selecting Model Area

In the course of executing the study in the first stage, selection of model areas in a preliminary level was made in compliance with the results of 1) topographic analysis, 2) geological and hydrogeological analysis, 3) satellite and aero-photos analysis, 4) site inspecting and reconnaissance survey, 5) inventories of existing rural water supply facilities, 6) prevalence of infrastructure and 7) socio-economic survey and analysis.

The primary conditions considered in selecting model areas are given as follows. They are:

i) The model areas shall be rich in hydrogeological and structural potential for reserving groundwater.

ii) The model areas shall be in each condition as frequently and severely, especially during dry season, suffered from water shortage in recent years, and subsequently people have to travel several kilometers spending a couple of hours to acquire water.

iii) The model areas shall be such as the rural center of the commune having large population, and the results of water supply development would assert much influence and impacts on socio-economic aspects.

iv) The model areas can be representatives among others in the Study Area in topographic, socio-economic and water sources conditions. In this regard, the areas shall be representatives of mountainous, hilly and flat zones which constitute general topographic configuration of the Study Area.

2.8.2 Selection of Model Area

In line with above conditions, especially in physical aspects, the following thirteen water potential structures containing abundant groundwater were selected as candidates for model areas. The location of these potential structures are given in Figure 2.1.6.

1) Mountainous area

i)	Taineste	Taounate Province
ii)	J. Khamise	Taza Province
iii)	J. Keil	Taounate Province
iv)	J. Berda	Taounate Province
v)	Dhar Souk	Taounate Province

2) Hilly area

i)	Teroual	Sidi Kacem Province
ii)	Ourtzarh	Taounate Province
iii)	Ain Saddine	Sidi Kacem Province
iv)	Taounate	Taounate Province
v)	Tissa	Taounate Province

3) Flat plain area

i)	Jolf El Melha	Sidi Kacem Province
ii)	Ain Defali	Sidi Kacem Province
iii)	Had Kourt	Sidi Kacem Province

Out of these candidates, seven were selected as high prioritized areas for implementing geophysical prospecting. They are:

i) Jorf El Melha
ii) Ain Defali
iii) Teroual
iv) Ourtzagh
v) Ain Berda
vi) Taounate
vii) J. Keil

The results of geophysical prospecting are given in the previous section in detail. Taking into account of the priority in the physical conditions among these, current condition of water shortage and socio-economic impacts after provision of water supply facilities were incorporated.

As a conclusion, the mode areas were selected as Ain Defali; the rural center of Ain Defali commune, Teroual; the rural center of Teroual commune and Ain Berda; the rural center of El Bibane commune.

2.9 Formulation of Development Strategy

2.9.1 Basic Conditions

On the basis of the study results on general conditions for the Study Area, the development strategy of rural water supply was formulated in compliance with the following conditions:

i) Because of the scarce potentiality of source waters in the Study Area, both of surface water and groundwater are indispensable for the future water supply development. As for the groundwater sources, thirteen high potential areas for groundwater yield have been identified, and in addition medium and low potential areas. Those groundwater potential areas are and will be applicable with high probability for rural water supply purpose, although the magnitude of them are not so large compared with surface water, immediately after exploitation of wells and dugholes.

ii) The National Master Plan which was accepted as one of the national policies for the development of rural water supply shall be the primary strategy in the course of water supply development of the Pre-Rif region. As is proposed in this National Master Plan, the surface water supply scheme is allocated on the third priority in the rural water supply development programs.

iii) According to the National Master Plan, existing public water supply pervasion of 14 percent is planned to raise 80 percent by the target year of 2010. However, this figure of 80 percent is not approachable unless surface water supply system including existing ongoing programs being carried out by the ONEP is further promoted.

iv) While, as for the surface water resources, several plans and programs for utilization for water supply system have been established by the AH on a hydraulically quantitative view point, however, facilities planning has not been completed yet or still in a level of premature against the target year of 2010.

v) The ONEP has planned and been carrying out improvement and expansion programs of the existing three surface water supply systems including treatment plants, pipelines, pumping stations and other appurtenant facilities. These ongoing schemes can be applicable for the system required in 2010.

vi) Establishment of the system of water supply based on either surface water or groundwater shall be completed within fifteen years by the target year of 2010. In view of the supply area, one third of the Study Area, which correspond to approximately 50 percent of the people, will be supplied by the surface water according to the ongoing programs by the ONEP.

2.9.2 Impact on Establishment of Rural Water Supply

The existing rural water supply system in the Pre-Rif region is largely divided into three types. The first is the supply system to the large towns such as Ourzzane in Sidi Kacem province with the population of more than 50,000 and Taounate in Taounate province with the population of more than 20,000. This type of system has comparatively sufficient supply amount with large number of wells and abundant source water.

The second is the type which is supplied with surface water such as Ain Gdah, Karia Ba Mohamed and Mekansa. This type of the system has also comparatively sufficient supply amount depending on the source water from the Sebou river.

The third is the type which is supplied with water from dug holes and springs which are very rarely equipped with facilities. This type of the system has very poor amount of source water and brings constraints to the rural people of traveling a long distance for carrying water. The great majority of the people in the Study Area belongs to this group.

The impacts on establishment of rural water supply system may differ in magnitude depending on current condition of each type of water supply and subsequent constraints. However, common impacts will be envisaged to be brought on the view point of socio-economy, uprating of rural economy and individual living standard, opportunity for job acquisition, and development of women and children.

2.9.3 Set up of Development Scenario

According to the ongoing programs on surface water supply system established by the ONEP as mentioned above, approximately 50 percent of the people will be able to acquire water by this system by the target year of 2010. The rest of the population may be supplied water either surface water supply system on the basis of probable new water supply system including new water treatment plant, pumping stations and pipelines or the groundwater supply system which will be exploited from now on by the target year.

The unit construction cost of water supply facilities per capita, groundwater exploitation is, in general, more economic, because that groundwater, as far as the Study Area is concerned, does not need treatment. Further, the water source from the supply area can be found much nearer than the case of surface water resulting in saving of pipeline and pumping costs.

In view of operation and maintenance aspect, groundwater supply system is much less complicated compared to the case of surface water due to experiences in the arid area such as the Pre-Rif region.

Taking into aforementioned conditions, the following scenarios as the basic strategy will be proposed.

i) The development of water supply systems in the Study Area for the target year of 2010 shall be established based on groundwater sources in cooperation with surface water sources, and the rate of supply pervasion will be 80 percent in compliance with national policy.

ii) In principle, groundwater will be fully utilized from the above mentioned advantages for establishing potable water supply system in the rural area. Consequently, the thirteen groundwater potential structures, which are identified by this Study, will be developed with the highest priority.

iii) Development of potable water supply system using surface water will be proceeded firstly from the existing program proposed by the ONEP. Other succeeding plan will be prepared after confirming progress of groundwater development and future plan of water usage by implementing the proposed surface water development program.

CHAPTER III STUDY ON WATER SUPPLY IN MODEL AREAS

3.1 Natural Conditions

3.1.1 Topography

The three model areas for the detail investigations were selected, Ain Defali, Teroual and El Bibane communes. Location of each commune is shown in Figure 3.1.1.

(1) Ain Defali

The Ain Defali commune is located in the west of the Study Area, covering an area of 250 km^2 belonging to the Sidi Kacem province. Topography of Ain Defali is generally flat with the low hills showing a gentle slope which is a particular topography in this region. The ground elevation varies from 80 m along the Rdat river to 250 m in the north-western part. The ground water potential structure exists in the north of the Ain Defali town located in the center of the commune. The area of this structure is 12 km^2 with the hills ranging on north-west and the Rdat river running on the south-east.

(2) Teroual

The Teroual commune belongs to the Sidi Kacem province and covers an area of 90 km^2 with the town of Teroual which is located around 10 km north-west from the Al Wahda dam site. Topography is obviously changing around the commune between the flat area in the south-west and the mountainous area in the north-east. The ground water potential structure extends with an area of 6 km^2 from the Teroual town to the north-east. The elevation of the Teroual town is 250 m with the topography showing an outlet of the basin. The steep mountains ranging on the north to east is the watershed boundary with an elevation of 500 to 600 m.

(3) El Bibane

The El Bibane commune belonging to the Taounate province is located near the town of Rhafsai which is situated 10 km north from Ourtzagh along the Ouergha river. The area of El Bibane is 50 km^2. The location of the commune corresponds to the watershed between two rivers, the Aoulai river and the Amzaz river, running through the steep gorge in the mountainous area. The groundwater potential structure covers an area of 6 km^2. The mountainous area is called Jbel Berda having the two steep mountains with the elevations of 900 m and 1,000 m at their summits. The relatively flat area is limited around the south-east to west along the foot of the mountains with an elevation of 500 to 600 m.

3.1.2 Hydrology

(1) Ain Defali

The average annual rainfall is 600 mm. The Rdat river running though the commune has a relatively wide catchment area. However, the mountainous area, which is the water source of the Rdat river, is so small that the river almost dries up in the dry season and the runoff rate is smaller than the other major rivers in the Study Area. The small streams running through the low hills shows runoff with in a short period only after rainfall. On the other hand, some part of area along the Rdat river has a good recharging capacity for groundwater, judging from the existence of the two groundwater potential structures, the Ain Defali structure in the center of the commune and the Ain Saddine structure on the northern boundary of the commune.

(2) Teroual

The average annual rainfall is 800 mm around the Teroual town and 1,000 to 1,200 mm from the north of the watershed. Around the Teroual commune, only a small tributary of the Ouergha river runs from north to south on the west of the commune. Recharging area of groundwater is supposed to extend along the foot of the watershed mountains surrounding the basin of Teroual.

(3) El Bibane

The average annual rainfall is 1,000 mm. Since the commune is located on the watershed with the steep mountains, the most of runoff is supposed to flow into the Aoulai and the Amzaz rivers through small gorges in a short period. Recharge may occur through gap of rock and boulder on the slope of the mountains.

3.1.3 Geology

The selection of the model areas of Ain Defali, Teroual and El Bibane among the structures of the flat plains, the hilly areas and the mountainous regions, is based on the type of their geological structures, their lithological character and their ability for water accumulation. The detailed examination of the stratigraphical column of the geological structures of the model areas selected for groundwater development was undertaken in order to establish precise and comprehensive understanding of the composition of their sub-strata as shown in Figures 3.1.2, 3.1.3 and 3.1.4. The geological characteristics of each structure are discussed in the following paragraphs.

(1) Ain Defali

The geological features of the syncline structure of Ain Defali enclose the deposits of two main epochs the Pleistocene of the Quaternary period and the middle Miocene of the Tertiary period. The former consists of a surface layer of recent alluvium composed of silty marl and gravels having an average depth of 15 m below ground level. The underlying layer is the Quaternary ancient (Villafranchian) composed of conglomerate and marl matrix deposits with an average thickness of 125 m. The terminal layer of the syncline belongs to the Tortonian age of the middle Miocene epoch consisting of marl and silty marl deposits dipping towards the center of the structure with an inclination angle of 10 to 20° and having a thickness of several hundred meters.

(2) Teroual

The general configuration of the outcropping formations along the flanks of the structure of Teroual indicates that the successive underlying layers of the syncline are dipping at an angle of 15 to 30° towards the center of the basin which was affected by two major faults passing through its center in the NS and EW directions. The outcropping formations mark the base of the overthrusting nap of Ouazzane.

The study of the stratigraphical column reveals the presence of various geological epochs belonging to the Tertiary period with the upper most layer consisting of the Tortonian marl and silty marl of the upper Miocene and extending around 30 m below ground level. The subsequent layer, comprising siltstone, sandstone and conglomerate with marl matrix of the Oligocene epoch, has an average thickness of about 150 m. The lower formation encloses limestone, marly limestone and marl deposits of the Eocene epoch and extends around 200 m.

(3) El Bibane

The geological configuration of the model area indicates that the depositions located on the summit of the monocline of Jbel Berda consist of limestone, marly limestone dolomite and schist formations of the middle Jurassic epoch dipping in the east west direction with an inclination angle of 35° and flattens out in the south west direction. The monocline overlays an impervious marlstone and schist formation of the upper

Cretaceous that extends over a 100 m deep. This lithological arrangement confirms the allochton nature of the structure which has the following composition:

i) Middle Lias formation of limestone and dolomite

ii) Upper Lias formation of the Bajocian age consisting of interbedded layers of marly limestone

iii) Middle Dogger-lower Malm formations of the Callovian-Lusitanian age composed of schist and silty schist

iv) Kimmeridgian and Tithonian formations of limestone of the upper Jurassic period.

3.1.4 Hydrogeology

The hydrogeological characteristics and the groundwater reserves of each of the selected model areas are determined according to the type of the geological structure, the results of the geophysical prospecting survey and technical data made available to the Study Team. The analysis of the hydrogeological potential of each model area is presented in the following paragraphs.

(1) Ain Defali

The syncline structure of Ain Defali resembles a closed basin stretching 4 km from east to west and 3 km from north to south with an area of 12 km^2, and is filled with water bearing conglomerate with marl matrix of the Quaternary deposits up to a depth of 150 m below ground level. The basin is stricken by two major faults oriented in the NE - SW and SE - NW directions causing cracks and fissures in the conglomerate matrix which facilitates groundwater accumulation. The upper part of the conglomerate layer is recharged, during the wet season, from the Rdat river located to the east of the syncline.

The two existing springs at the southern side issue water from the shallow conglomerate formations of higher recharge sources and are independent from the actual water bearing formation of the syncline structure. The existing dugholes spread around the structure are of shallow depth averaging around 15 m. As such these water facilities exploit only the superficial groundwater of the conglomerate surface layer. For normal meteorological conditions with average annual precipitation of 600 mm, the groundwater recharge of the syncline alone is estimated at about 0.6×10^6 m^3/ year.

(2) Teroual

The syncline structure of Teroual is roughly a closed basin oriented in the SE - NW direction and stretching 3 km along its major axis and 2.2 km along the minor axis, thus covering an area of 6 km^2. The upper water bearing formation of the syncline belongs to the Oligocene epoch and consist of siltstone with marl matrix having a thickness of about 100 m with flat base of marl deposition. The second water bearing formation is separated from the upper one by an impervious marl layer of the Oligocene epoch. It consists of sandy marly limestone with fair porosity and secondary permeability having a thickness of around 100 m. The two faults striking the syncline in the NE - SW and N - S directions induced fractures into the formations of the basin and gave rise to the existing springs at the east side with flow rates ranging between 20 and 70 m^3/d. The existing well, drilled at the eastern flank of the structure, penetrates the same formation of the existing springs and, when it becomes operational, it will affect the capacity of spring. For average normal hydrologic year with annual precipitation of 800 mm, the groundwater recharge from the syncline area alone is estimated at 0.4×10^6 m^3 / year.

(3) El Bibane

The monocline of Jbel Berda is an allochton structure of the Meso-Rif origin composed of limestone and dolomite formations of the Jurassic period that is placed over a base layer of the upper Cretaceous consisting mainly of impervious bed of marl. The structure is oriented in the SE - NW direction at an altitude of about 1000 m and covers an area of 6.3 km^2. It is stricken with two major faults oriented SE - NW that formed a syncline with deposits of the upper Tortonian age of the Miocene epoch having a water bearing conglomerate formation.

The existing four springs, with flows ranging from 1 to 700 m^3/d, issue water from the structure at the contact line between the Jurassic schisty formation and the underlying Cretaceous impervious marl base. For an average normal hydrologic year with annual precipitation of 1,000 mm, the groundwater recharge of the monocline structure is estimated at about 0.7×10^6 m^3 / year.

3.2 Socio-economic Conditions

3.2.1 Administration and Population

The three model areas comprise the rural communes of Ain Defali, Teroual and El Bibane. The former two are located in the circles of Had Kourt and Ouazzane in the province of Sidi Kacem, whereas the latter located in the circle of Rhafsai in the province of Taounate. The administration and population surveyed in each of the model areas are shown in Table 3.2.1.

Table 3.2.1 Administration and Population in Areas Surveyed

Province	Circle	Commune	Nos. of douars	Population	Pop./douar
Sidi Kacem	Had Kourt	Ain Defali	60	25,116	420
	Ouazzane	Teroual	29	12,096	420
Taounate	Rhafsai	El Bibane	10	6,511	650
Total/Average			99	43,723	440

Source: CERED

The number of douars in the model areas is 99 in total. The population in the three communes was about 43,700 as of 1995. The population per douar is 440 on an average.

3.2.2 Land Use

Farming activities are the essential way of making a livelihood for local people in the Study Area. This circumstance is also true of the three communes. Table 3.2.2 shows the types of crops and cultivated areas in the three communes.

A wide variety of crops is cultivated in Ain Defali. Some of crops such as vegetables, tabacco and fruit trees requiring water are planted in the valley along the Rdat river. Dry farming yields mainly cereals and covers vast areas of agricultural land from Had Kourt to Ain Defali. Hilly areas are utilized for olive tree growing.

The topography in Teroual is basically featured by hilly lands. The cultivated areas of cereals and legumes are less extensive than those in Ain Defali. A mixed plantation of olive and vine trees is observed on slopes of hilly lands. The cultivation in El Bibane is constrained due to mountainous area. The cultivated areas by crop is far smaller than those in Ain Defali.

The plantation of some cash crops have been abandoned in the three communes. The proliferation of phylloxera is a serious cause of damage to vine trees in Teroual. Sparrow attack on legumes causes a obstacle to the cultivation of them in Ain Defali and Teroual. Water shortage is also a serious constraint to the cultivation of vegetables in Ain Defali.

The species of livestock breeding are oxen, cow and sheep in three communes. Mules and donkeys are utilized for agricultural works. Traditional style of breeding for poultry, rabbit and bee is still envisaged in the three communes.

Table 3.2.2 Land Use by Agricultural Crops in Model Area

(Unit : Ha)

Crops	Ain Defali	Teroual	El Bibane
Crops			
Hard wheat	4,500	1,100	470
Soft wheat	7,000	1,650	570
Barley	2,000	550	200
Vegetable	10	60	50
Legume	1,850	1,000	26
Beet	20	---	---
Sunflower	300	50	---
Tobacco	350	150	---
Fodder	---	240	10
Plantation			
Forest	462	---	---
Fig	---	---	450
Olive	1,030	660	520
Citrus fruits	99	30	---
Pomegranate	9	---	---
Grape	---	90	---
Pasture	120	900	---
Uncultivated	---	---	600
Total:	17,750	6,480	2,296

Source: Provincial Directorate of Agriculture

3.2.3 Household Sector

The household income in the three communes is entirely owed to agricultural income. Crop yield is not always constant as it depends on prevailing climatic conditions. Agricultural net income is defined as gross income minus production cost. According to the Provincial Directorate of Agriculture, annual net income generated from agricultural activities such as vegetation, livestock breeding and forestation was reported to be DH3,000 per person in Taounate in 1993-94, and DH19,944 per farm or DH3,680 per ha in Sidi Kacem in 1990-91.

Household expenditures are another method of evaluating purchasing power of rural households. Table 3.2.3 shows per capita expenditures per month by income class.

Table 3.2.3 Expenditure per Capita and Month by Income Class

(Unit: DH)

Commune	Rich	Middle	Poor	Average
Ain Defali	316	295	171	260
Teroual	288	256	147	230
El Bibane	490	276	156	308

The above figures are the results obtained from the extensive sample survey. The average expenditures are simply multiplied by twelve months to estimate annual average expenditure per person, resulting in DH3,120 in Ain Defali, DH2,760 in Teroual and DH3,700 in El Bibane.

The majority of economically active population in three communes are those engaged in traditional dry farming activities. Agricultural labors without own lands tend to migrate to cities in order to earn petty cash. Labors also move from a farm to another in order to make a livelihood. Urban migration is also envisaged in small-scale farmers because of agricultural income at survival level. The rates of migration in terms of households for the last five years is 16 percent in Ain Defali, 7 percent in Teroual and 7 percent in El Bibane.

The continuous exodus of men as work force from rural communes to other areas is really a burden to women as women left are forced to do a lot of daily works such as farming, livestock breeding, water collection and transportation.

3.2.4 Social Infrastructure

Ain Defali is relatively well equipped with social facilities and services. El Bibane is envisaged to be the least developed rural commune. The development of Teroual is in the middle between Ain Defali and El Bibane in terms of social infrastructure.

Infrastructural facilities and social services are mostly observed at rural centers of communes. At douar level those are limited to one or two mosques and a primary school. Local people dwelling at douars are forced to move to rural centers for utilization of social infrastructure. Long distance between rural center and douar is a heavy burden on women in case sick children have to be transported to clinic at rural center.

The classes of roads consist of principal, secondary, provincial and commune roads. The access to the rural center of Ain Defali is relatively easy as both principal and secondary roads are linked to Ain Defali. Whereas accessibility to Teroual and El Bibane is somewhat constrained by availability of common roads only. Public services such as electricity and telephone concentrate the rural center in three communes. The inventory of social infrastructure is shown in Table 3.2.4.

Table 3.2.4 Inventory of Social Infrastructure in Model Areas

Items	Ain Defali	Teroual	El Bibane
Facilities			
1) Kindergarten	2	0	0
2) Primary schools	4	1	1
3) Secondary schools	1	1	0
4) Prefabricated school facility	17	6	3
5) Mosque	56	20	14
6) Post office	1	1	0
7) Agricultural office	1	1	0
8) forestry office	1	1	0
9) Vocational center	1	1	0
10) Cooperative (agriculture)	5	0	0
11) Cooperative (milk)	0	0	0
12) Rural clinic	1	1	0
Public services	Rural center	Rural center	Rural center 2 douars
1) Electricity	-do-	-do-	-do-
2) Telephone			
Transportation			
1) Principal road	1	0	0
2) Secondary road	1	0	0
3) Provincial road	0	0	0
4) Commune road	0	1	1

Source: Provincial Directorate of Public Works