THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF WATER & IRRIGATION

JORDAN VALLEY AUTHORITY

UNITED STATES AGENCY
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Jordan Valley Preliminary Land Use Master Plan Project

Geologic Assessment, Water Resources and
Agricultural Resources

Volume 5 of 5

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Table of Contents

Planning Process and Architectrual Design Guidelines - Volume 2 of 5

Social, Transportation, and Economic Assessment - Volume 3 of 5

Environmental Assessment, Dead Sea Carrying Capacity and Archaeological Assessment - Volume 4 of 5

Geologic Assessment, Water Resources and Agricultural Resoruces - Volume 5 of 5

Annexes of Volume 5 of 5

List of Tables of Volume 5 of 5

List of Figures of Volume 5 of 5

Acronyms Or Abbreviations

AMIR	Achievement of Market Friendly Initiatives and Results Program
a.s.l	Above Sea Level
b.s.l	Below Sea Level
BMPs	Best Management Practices
CC	Consolidated Consultants Engineering & Environment
CDG	Community Development Group
CIDA	Canadian International Development Agency
CMI	Chesrown Metzger International
CSBE	Center for the Study of the Built Environment
DOA	Department of Antiquities
DOS	Department of Statistics
EA	Environmental Assessment
EIS	Environmental Impact Statement
EU	European Union
FOE	Friends of the Environment
FoEME	Friends of the Earth Middle East
FTA	Free Tourism Area
GIS	Geographic Information System
GTZ	German Aid Agency
IBA	Important Bird Area
IUCN	International Union for the Conservation of Nature
JEPAFV	Jordan Exporters and Producers Association for Fruits and Vegetables
JES	Jordan Environment Society
JIB	Jordan Investment Board
JSDCBD	Jordan Society for Desertification Control and Badia Development
JTB	Jordan Tourism Board
JVA	Jordan Valley Authority
JVA IAS	Jordan Valley Authority Irrigation Advisory Service Unit
KAC	King Abdullah Canal
KAFA’A	Knowledge and Action Fostering Advances in Agriculture
KTD	King Talal Dam
LRD	Department for Lands and Rural Development
MCM	Million Cubic Meters (water)
MJVSA	Middle Jordan Valley Study Area
MOA	Ministry of Agriculture
MOE	Ministry of Environment
MOP	Ministry of Planning
MOT	Ministry of Transport
MOTA	Ministry of Tourism and Antiquities

MPWH	Ministry of Public Works and Housing
MWI	Ministry of Water and Irrigation
NCARTT	National Center for Agricultural Research and Technology Transfer
NTSI	National Tourism Strategy Initiative
NEAP	National Environmental Action Plan
NEF	Near East Foundation
NGO	Non-governmental Organization
NJVSA	Northern Jordan Valley Study Area
QIZ	Qualified Industrial Zone
RSCN	Royal Society for the Conservation of Nature
RSDS	Red Sea to Dead Sea Canal or Pipeline Project
SJVSA	Southern Jordan Valley Study Area
SWOT	Strengths, Weaknesses, Opportunities and Threats
TFR	Total Fertility Rate
UFW	Unaccounted for Water
USAID	United States Agency for International Development
WAJ	Water Authority of Jordan
WCA	Water Conservation Association
WTO	World Tourism Organization

1 PROJECT GOALS AND OBJECTIVES

The Jordan Valley is Jordan's premier agricultural production area. The mild winters in the valley, which are due to the predominant below-sea-level (b.s.l.) elevations, provide great potential as a natural greenhouse for the production of high-value off-season fruits and vegetables. In addition to the significant agriculture, the Jordan Valley, including the Dead Sea, contains environmentally sensitive ecosystems and coastline, industrial areas, human settlements, and important cultural and natural sites which should be protected and linked for tourism development. These geographic areas are important to the creation of sustainable economic opportunities for Jordan and the region.

The Jordan Valley Authority (JVA) requested assistance to undertake work identified in the Regional Land Use Planning and Land Management Strategy for the Jordan Valley Authority. The United States Agency for International Development (USAID)/Jordan Water SO Office has indicated that it will assist the JVA in the development of a preliminary land use master plan for tourism and commercial/industrial purposes.

The main objectives of the project include:

1- Assisting Jordan Valley Authority in physical land use planning needs for the 3 identified zones in the project area; Zone 1: Yarmouk River to the Baptism Site, Zone 2: the Dead Sea area, and Zone 3: the Southern Ghors and Wadi Araba;
2- Analyzing the existing land uses including agricultural, industrial, natural and cultural sites; and
3- Providing recommendations for appropriate land uses that will allow increasing economic opportunities.

The project area covers the whole mandate of the Jordan Valley Authority, which extends from Yarmouk River in the North to Qater in the South (Wadi Araba); the eastern boundaries are contours 300 and 500 in the area north and south of the Dead Sea, respectively. It should be noted that Umm Qais, which is not within Jordan Valley Authority mandate, has been included in the study due to its importance in establishing the tourism linkages in the area.

On the 19th of February 2004, the United States Agency for International Development (USAID) retained the services of Consolidated Consultants for the Jordan Valley Preliminary Land Use Master Plan Project. The Kick off meeting was held on the 29th of February 2004.

The objective of the Consultant's services as mentioned above is to assess the existing land uses in the project area. The assignment was carried out in three phases. These project phases have been modified from those described in the scope of work so that Phase 1 represents data collection, Phase 2 analysis of existing conditions and establishment of the land use planning, and Phase 3 is related to production of final land use maps for the three zones. Thus, the three phases are as follows:

- **Phase 1** which includes:
    - collecting and disseminating background information and baseline data
    - cross referencing of existing Geographic Information System (GIS) data
    - completing photo survey of the study areas
    - conducting three Focus Groups
    - creating of draft overlay maps of baseline conditions
    - completing interviews
    - participating in the land use planning team workshop
    - presenting baseline findings to client for discussion

- **Phase 2** which includes:
  - analysing the existing conditions in the Jordan Valley
  - creating preliminary drawings (18 A-0)
  - developing design guidelines
  - preparing bibliography of data used for report
  - completing preliminary report text and send copy to project manager and land use planner for editing
- **Phase 3** which includes:
  - informing the team and clients throughout the duration of the project
  - revising text and prepare draft final report with drawings
  - presenting draft final to client
  - revising drawings/ text as necessary layout, printing, binding copies
  - producing the Final Report with overlay land use maps
  - submitting the Final Report to client

1.1 Organization of the Land Use Report

The purpose of the Final Report is to provide the complete details of all work performed, analyses made, and justification of options and recommendations proposed. The Final Report is submitted in five separate volumes which comprise the Land Use Report and the four volumes on the reports by the specialist in the fields of architecture, sociology, transportation, economy, environment, archaeology, geology, and water and agricultural resources. These five volumes are as follows:

- **Volume 1 of 5:** Land Use Report, which is prepared in both Arabic and English languages.
- **Volume 2 of 5:** Planning Process and Architectural Design Guidelines.
- **Volume 3 of 5:** Social, Transportation, and Economic Assessment. This volume also presents a preliminary framework for establishment of fish farms in the study area.
- **Volume 4 of 5:** Environmental Assessment, Dead Sea Carrying Capacity and Archaeological Assessment.
- **Volume 5 of 5:** Geologic Assessment, Water Resources and Agricultural Resources.

2 GEOLOGY OF THE JORDAN VALLEY AND GEOTECHNICAL CONSIDERATIONS

2.1 General Geology for the Study Area

Cambrian, Triassic and Cretaceous System are outcrops mainly distributed through the foothills, the escarpment and the highlands in the study area. While the Tertiary and Quaternary deposits cover most of the area, igneous rocks are of limited occurrence, but basaltic flows of the Pleistocene are distributed in many locations of the study area.

According to the information obtained from the available geological maps at scale 1:500,000 and 1:50,000 prepared by Sir F. Bender and Jordan Natural Resources Authority (NRA), respectively, the major geological units (formations) exposed along and in the vicinity of the understudy area are presented in **Table 1** and in the geologic map of **Annex 7**.

Table 1: Description of outcropping formation

Period	Epoch	Group	Formation	Symbol	Lithology
Quaternary	Holocene (recent)		Fan, talus, terrace, river		Sand, clay, gravel
	Pleistocene	Jordan valley	Lisan	J	Marl, clay, gypsum, sand, gravel
tertiary	Pliocene		Basalt Undifferentiated	B	Basalt Dolerite
	Miocene				
	Oligocene				
	Eocene	Balqa	Rijam	B4	Chert limestone
	Paleocene				
Upper cretaceous	Maestrichtion		Muwaqqar	B3	Chalk marl
	Companion		Amman	B2	Silicified limestone, chert
	Santonian		Wadi Ghudran	B1	Chalk, chalky marl
	Turonian	Ajlun	Wadi Sir	A7	Limestone
	Cenomanian		Shuaib	A5-6	Marly limestone
			Hummar	A4	Limestone
			Fuheis	A3	Marl
			Naur	A1-2	Marl, limestone
Lower cretaceous	Albian	Kurnub		K	White sandstone with dolomite and shale; varicolored sandstone with limestone, shale, dolomite and marl
	Aptain				
	Neocomian				
Jusrassic		Zarqa	Azab	Z2	Limestone, marl, dolomite, sandstone, shale
Traissic			Main	Z1	Sandstone, calcareous sandstone, limestone, shale, gypsum

Period	Epoch	Group	Formation	Symbol	Lithology
Cambrian		Ram	Umm Ishrin		Sandstone, siltstone
			Burj		
			salib		
Precambrian		Aqaba & Araba complexes		G+Sr.	Igneous, metamorphic, Conglomerate

The description of each outcropping formation is discussed in the following sections.

2.1.1 Precambrian Granitic Rocks (p€g)

Aqaba and Araba complexes are exposed along the east side of Wadi Araba (South of Dead Sea). They include igneous rocks, metamorphic rocks and Conglomerate of Sarmuj Formation. Scattered outcrops of these rocks are exposed along the study area, especially the southern part towards Wadi Gharandal.

2.1.2 Cambrian Rocks

Ram Group = €s(Bender)

It comprises the Salib Arkosic Sandstone, Burj Dolomite Shale and Umm Ishrin sandstone formations.

These formations outcrops out in the west along the Dead Sea escarpment as steep rugged cliffs and in the deep wadis to the south.

1- Salib Arkosic Sandstone

The Salib Arkosic Sandstone consists of yellow, yellow-brown, red, pink-brown, medium- to very coarse-grained arkosic and subarkosic sandstone; commonly it contains sub-rounded to round pebbles of milky and smoky quartz, pink feldspar and lithic clasts derived from the basement rocks. Conglomerates are present locally. In general, grain size decreases upwards from a conglomeratic base to medium-grained sandstone; however, lenses of pebbly fore sets occur in places throughout the formation. Thin laminae of micaceous siltstone of various colors occur at several levels. An erosional surface is recorded near the top of the formation overlain by red-brown angular mudstone and siltstone clasts.

The thickness of this formation is between 20 and 80 m. However, a maximum thickness of 200 m is recorded near the shoreline of the Dead Sea.

2- Burj Formation

The formation consists of red-brown, off white, green and buff micaceous siltstone and sandstone with ripple cross-lamination, ripple marks and sparse burrows. Thin beds of buff-brown sandstone with bimodal trough cross-bedding are also present. The carbonates are yellow or grey dolomitic limestone, dolomite and sandy dolomite, with chert, and sandstone lenses. Cross-lamination is common in the siliclastic lenses and oncolites, ooliters, peloids and bioclasts are present in the purer carbonates.

The thickness of the formation is between 80-130 m in the Dead Sea area.

3- Umm Ishrin Sandstone (IN)

It mainly consists of yellow-brown, red-brown and gray, medium-to coarse-grained, partly subarkosic massive sandstone and thin beds of red, very finely laminated micaceous siltstone with ferruginous sandstone layers. Cavernous weathering form and planar/ cross-bedding (is typical with planar forests) are the most common characteristic features specially within the successions of middle and upper parts. The thickness of this formation is between 300 and 350 m.

Umm Ishrin Formation forms distinct steep, rugged cliffs and a belt along the faulted scarps areas and along the wadis. The upper and lower boundaries of the formation are easily distinguished by lithological homogeneity, distinct joint system, massive morphology, steep cliffs, and the dense fracture system.

2.1.3 Triassic – Jurassic Rocks

Generally, Triassic- Jurassic sediments consist of Zarqa Group **(J+Tr Bender)** which are exposed at very limitted areas mainly in the eastern Jordan Valley escarpment as a narrow belt and its locally out crops in the study area near Ghor Kabid. It attains a total thickness of about 220 m and is mainly composed of alternating calcareous sandstones, oolitic marls, blue-gray shales, gray and yellow limestones, crystalline limestones, marly limestones and partly dolomitic limestones with sandy limestone and sandy marls beds. Upward, clastic components increase and coarse sandstones, sandy limestones, sandy marls and marly limestones are developed. In the upper part, clastic components decrease again and dense limestone, marls, crystalline dolomites, detrital limestones, shales and marl form this part.

2.1.4 Cretaceous Rocks

The onset of the Cretaceous succession in Jordan as in other Middle East and North Africa countries is characterized by a marine transgression. The sedimentarly sequence resulted from this major transgression attains a thickness is more than 1,000 m and consists mainly of shallow marine dolostones, limestones and marlstones at the upper part, and sandstones and clays at the lower part.

Cretaceous rocks are divided into two major parts: the lower one is the kurnub sandstone and the upper one is carbonate rocks which are divided into two groups, namely Ajlun Group and Belqa Group. The upper Cretaceous rocks disconformably overly the kurnub and cover more than 60% of Jordan.

2.1.4.1 Lower Cretaceous Rocks/ Kurnub Sandstone, (Ks Bender)

The Kurnub Sandstone group crops out along the rift margins. The group forms accessible cliffs above the steep excarpments of the harder Umm Ishrin Sandstone. Litholigically, it is mainly composed (from the bottom to top) from white, pale yellow and pink passing upwards to multicolored, medium to coarse-grained quartzitic sandstone. It attains a thickness of 200 – 300 m. The lower part of this group is distinguished by massive, friable, white - gray, pale yellow and pink, coarse - grained quartizitic sandstone with scattered rounded quartz pebbles. Planar cross - bedding within tabular sets distinguishes the lower part, with sparse channel - fills, changing upwards to through and low - angle cross - bedding. The upper part consists of thin parallel-laminated friable, grayish, brownish or greenish, ferruginous siltstone and fine-grained sandstone beds with plant fossils. The top of this formation can be easily distinguished by the lithological changes from continental clastic sediments to marine carbonate sediments of the Upper Cretaceous.

2.1.4.2 Upper Cretaceous Rocks

(a) Ajlun Group (Ks2 Bender)

1- Naur Formation (A1/2)

It has an average total thickness of about 200 m. The base of this formation is mainly composed from greenish, level-bedded, fossiliferous, glauconitic, sandy silty limestone with thin gypsum veins. This layer represents the transitional unit between the underlying Kurnub Sandstone and A1/2 Formation. This unit is overlain by a marine, massive, nodular, gray to light brown dolomitic limestone, highly burrowed with chert nodules. The dolomitic limestone is usually interbedded with marlstone, limestone, marl and clays. However, the topmost of this formation becomes more dolomitic than the lower.

The limestone and dolomitic limestone alternate with less resistant materials (e.g. marls and clays) and form relief features in term of steep slopes (cliffs).

Fracturing, widely spaced joints and potentially unstable rock blocks and non-similarities and discontinuities are the main structural features of this formation. Rock falls and landslips could occur in A1/2 formation if it is subjected to extensive excavation work especially in high cuts or if subjected to water.

2- Fuhays Formation (A3)

Generally A3 Formation has a thickness of about 60 to 80 m. It is dominated by marls and marly nodular limestone. The lower part (about 20 m) consists of yellow-gray, soft, friable, mainly calcareous and locally gypsiferous marls, intercalated with lenses of calcareous mudstone and thin beds and laminae of nodular and fossiliferous limestone. The middle part consist of about 25 m of gray to yelow gray marly, fossiliferous limestone interbedded with thin beds of marl. The upper about 20 m consists of alternating beds of yellow to yellow-gray, soft marl and marly to micritic, partly nodular limestone.

3- Hummar Formation (A4)

It has a total thickness of about 50 m. The outcropping rocks consist of pink to yellow-gray, micritic and party dolomitic limestone with thin beds of marly limestone. Shelly limestone laminae were also observed. Distinctive thin bedded clayey micrites occur at the base. The formation is highly fractured, highly cavernous and highly fossiliferous.

4- Shuayb Formation (A5/6)

It consists mainly of yellow to yellow – gray, thin to medium bedded marly limestone alternating with marls at the upper part. The total thickness is about 50 m.

5- Wadi As-Sir Formation, (A7)

It forms a prominent cliff features. The basal of the formation (about 20 m) consists of white, creamy and gray, massive micritic limestone intercalated at the top with oolitic dolomitic limestone. The succeeding about 55 m comprises massive to medium bedded dolomitic limestone interbedded with calcareous mudsotne, siltstone, micritic limestone which is locally slightly bituminous, argillaceous micrite and biomicrite. The upper part of this formation consists of gray, massive, dolomitic limestone, with layers of bioclastic dolomicrite and coquina. The upper most 20 m, consists of medium beds of white and gray dolomitic limestone interbedded with thinly bedded micritic limestone containing small chert nodules, laminated marl and chalk.

(b) Belqa Group

B1/2/ 3 (Ks3 Bender)

Along the study area limited out crops of KS3 formations are exposed.

1- Wadi Umm Ghudran Formation (B1) or (WG)

It's mainly composed from chalk with thin wavy beds of chert interbedded with massive sandstone beds, which occur as sandbank - like bodies and dolomitic micrite. This is overlain by thin wavy bedded white chert (tripolised) interbedded with partly bituminised marly limestone, silty marl and quartzite. The thickness of the formation ranges from 55 to 85 m.

2- Amman Silicified Formation (B2a) or (ASL)

It is distinguished by massive dark-weathered chert beds, which form a small cliffs above the pale weathered chalks of the Wadi Um Ghudran Formation.

In general, this formation consists of thin to medium bedded heterogeneous lithologies. These are predominantly gray, white or brown chert (exhibiting a variety of textures ranging from homogeous to brecciated), microcrystalline limestone (as beds and/or concretions), dolomitic chalky marl, chalk and silicified limestone. The thickness of this formation is about 85 m.

3- Al-Hisa Phosphorite Formation (B2b) or (AHP)

It consists of more or less silicified phosphorite; phosphorite-bearing oyster lumachelles, and phosphate layers. Varicolored chert is less when compared to the Amman silicified formation, whereas there is a distinct increase in the proportion of limestone and phosphate. Limestone within this formation varies in texture from micritic interbedded with phosphate, to chalky marl. Laminated marls of yellowish tan colored are also common at the upper parts of this formation.

4- Muaqqar Chalk - Marl Formation (B3) or (MCM)

It is mainly composed of pale yellow, tan and gray chalky marl and chalk with primary and secondary gypsum. The upper horizon is bituminous and has a dark gray color. The basal about 55 m comprise massive yellowish white, laminated marl and chalky marl. The succeeding about 55 m consists of yellowish white, buff and orange, hard chalky marl, calcareous marl, marly chalk and thin bands of light brown chert. It is overlain by about 25 m of pale red to orange, slightly bitominous marl and argillaceous marl with clay and mudstone. Obove this unit there is about 53 m of dark gray bituminous marl interbedded with chalky marl and chalk. At the top of formation is about 6m of finely laminated, dark gray, bitumous calcareous marl containing bioclastic material. The topmost part of this formation can be distinguished easily from the starting of thick chert layer (7 m) of Umm Rijam Chert – Limestone Formation.

5- Umm Rijam Chert-Limestone Formation (B4), (URC), (TK Bender)

it is exposed in the extreme northern part of the study area (adjacent Yarmouk River) and at the south of the Dead Sea near Jabal Al-Taibah (wadi Mousa). This formation is composed of a sequence of chert, limestone, chalk, chalky limestone, sandy to marly limestone, conglomeratic limestone, marls and locally nummulatic limestone. The limestone of this unit is hard to very hard but occasionally chalky and soft, it is of tabular and sometimes nodular character. The thickness of the limestone beds ranges from 0.5 to 1.2 m interbedded with chert (0.2-0.4 m) and chalk to chalky limestone layers. The thickness of this formation is about 120 m.

2.1.5 Quaternary Sediments

1- Volcanic Rocks (Basalts) (B)

Pleistocene basalt flows (up to 100 m thick).it is in composition from basanites to alkali basals.Volcanic tuffs are restricted to the Wadi Al Hidan.

Basalts and Basalt-tuffs (undifferentiated) of Quaternary-Neogene age were also observed scattering along the study area.

2- Pleistocene Sediments (QS Bender)

Lisan Formation (JV3)

The Lisan Formation of Jordan Valley Group of Quaternary Period and Pleistocene Epoch. This formation consists predominantly of millimeter-to-centimeter-laminated, very weak, friable, low density, white, calcareous mudstone with alternating white marl, greenish brown clay and evaporate. In the water saturated state they behave as soft clays. Microfaults and controlled laminations are typical. This formation was formed in brackish water of the Lisan Lake which occupied the Dead Sea basin during the Late Pleistocene.

Away from the influence of the wadis (which were discharging to the Lisan Lake), calcium carbonate and calcium sulphate were chemically precipitated by solar evaporation of the lake during the annual dry season. During the rainy season, with an increase in the fresh-water inflow, evaporation slowed down and chemical precipitation was replaced by deposition of silt and clay size material brought down in suspension by the wadis. The results was a varied sequence.

Calcium sulphate occurs within the sequence as firmly disseminated gypsum and as discrete harder beds of gypsum. Lisan Formation is very susceptible to erosion by water and the outcrop areas are always extensively gullied. Slopes also weathered quickly as a result of softening and rain splash during heavy storms. Wetting causes solution of gypsum and together with slope washing result in development of a weathered zones of very weak sequence beneath a thin slightly stronger crust.

At the central and northern areas of the Jordan Valley Graben, Lisan Formation contains 25 to 30 m thick poorly cemented gravels with red argillaceous sandy matrix with lacustrine fauna at the lower portion. This lower portion of the Lisan beds is probably time-equivalent to the fresh-water beds of the Samra Lake.

3- Holocene – Recent Alluvium

In the vicinity of the influence of the main wadis, sand, silt and clay size materials with gravel and cobbles were deposited. Depending on the distance from the main wadis, these deposits become finer or coarser. They were accumulated through the processes of weathering, erosion and sedimentation during the recent time.

At the mouths of wadis near the foot of scarps and at the rims of the Jordan Valley Depression, alluvial fans of unsorted wadi sediments have frequently developed.

Out of all formations highlighted above, only the Lisan formation (which is present in the low lands at the central and northern areas of the Jordan Valley) presents difficulties for construction of structures as presented in the geotechnical conditions section. The other formations offer stable ground for foundations of structures. Although, some of these formations give rise to problem during highway construction which requires special studies.

2.2 Soils of the Jordan Valley

Soils in the Jordan Valley are formed in lacustrine sediments, the most important of which is the Lisan Marl formation. This parent material was deposited in Lisan Lake that covered the Valley during the Middle Pleistocene. During the Upper Pleistocene the lake began to retreat towards the Dead Sea. The salinity of the lake increased. Consequently, Lisan marls which were deposited later in the central and the southern parts of the valley are more heavily impregnated with salts than ealier deposits.

As Lisan Lake continued to retreat, the Jordan River cut through the Lisan formations and formed a flood plain, the Zor. In later periods, sediments of the Jordan River, referred to as alluvial sediments, were deposited in this flood plain.

The formation of the Zor left the Ghor terrace of Lisan marl at both sides of the river. This was later covered by fluviatile colluvial sediments, originating from the bordering uplands. The cover is thickest on the Upper Ghor, thinning out towards the river. Runoff water from the Ghor terrace eroded the Ghor-Zor transition zone, the Katar, giving it its present cut-up appearance.

2.3 Geotechnical Consideration

Construction in Jordan Valley will have to meet several challenges from an engineering perspective. These are discussed below.

2.3.1 Seismic Design

Generally, the Jordan Valley is the most active seismic zone in Jordan (see geologic map presented in **Annex 7**). This will impose extra cost on any construction due to the increased forces on structures and the special detailing required to resist earthquakes. All of the Jordan Valley areas are classified within Zone 2B or Zone 3 (Seismic Zones) according to UBC (97) or the newly published Jordanian Code. These codes stipulate the forces and requirements for proper seismic design.

2.3.2 Ground Water Table Condition

In many areas in the middle and northern parts of the Valley, the water level is high and fluctuates seasonally. This will impose extra challenges and cost on construction due to the required raising of the structure levels cost of drainage system and cost of special type of foundations.

2.3.3 Soil Condition

In many parts of the middle and northern parts of the Valley, Lisan marl and layers of Gypsum are encountered. These conditions will add more difficulties to construction and in turn will add extra costs (see geological map presented in **Annex 7**). This is mainly due to the requirement for deeper foundations to reach a zone of stable moisture content to avoid changes on volume of soil. Also, these soils are characterized by low bearing capacity. Areas of Lisan marl are shown on the geologic map in **Annex 7**.

Furthermore, in some parts, soft clay (mud) is encountered which will require deep foundations to reach more stable grounds adding more difficulties. This mud was encountered in Suweimah east of the Dead Sea highway and at the northern tip of the Dead Sea.

Chemical composition of soils (sulphates and chlorides) add extra on construction to provide protection against these aggressive elements such as providing large concrete cover and protecting the reinforcement steel by coating.

Based on the above, it is recommended to avoid construction of any heavy structures in the Valley itself except following a detailed site investigation. Also, construction may be more suitable on the highlands. However, the decision can be made on a case by case basis.

2.3.4 Sinkholes

Sinkholes is a phenomenon that took place in the Valley in the area close to the Dead Sea. The reason behind this phenomenon is most probably the result of the action of fresh water in dissolving subsurface salt layers. This phenomenon was helped by the drop in the Dead Sea water level. At Ghor Hadetheh, the reason behind the sinkholes was attributed to tectonic movements (Potash company report, 1994) and an investigation of sinkholes was carried out by University of Jordan (1995). The locations of these sinkholes are shown in **Figure 1**.

In this report it is recommended to consider the area of very high risk and not to utilize it except for forests. Accordingly, no building should occur in these areas as a matter of public health, safety and welfare.

Figure 1: Sinkholes Map

3 WATER RESOURCES

3.1 Water Resources Analysis

The study area covers specifically the Jordan Valley mandate (JV), which is an important part of Jordan and has a big role regarding the water resources issue. This section will deal with Jordan water resources in total to provide a global view of the water constrains in the Jordan Valley. Through the Valley a main canal runs from the tunnel on Yarmouk River in the north to the Dead Sea Area. This canal is known as King Abdullah Canal (KAC), which is considered as the main national carrier in Jordan. The canal runs for about 110 km parallel to Jordan River, starting from the north border to the north of the Dead Sea, as shown in **Figure 2**. The canal is a lined concrete trapezoidal channel with a capacity ranging between 25 and 2.6 m^3/s from north to south respectively, and it forms the spine of the Jordan Valley System.

The water resources analysis can be tackled through demand, supply, and deficit of water use in Jordan. Water demand is presented in this section for both main uses:

- Municipal and Industrial.
- Irrigated Agriculture.

Table 2 and **Figure 3** show the historical supply for the period 1985-2001 to the different sectors with future demand forecasting up to the year 2020 according to the Ministry of Water Irrigation projections. Demand forecasting is conditioned by water availability which is in turn sensitive to rainfall conditions. The sector most affected by water availability is irrigated agriculture during dry weather years. Since agriculture has the least priority in water allocation, the supply fills up the domestic demand before irrigation and consequently the deficit concentrates in the agricultural sector. This is evident by comparing the irrigation supply during the wet years of 1992 and 1993 to the irrigation supply of the dry year of 2001. In addition, **Figure 4** matches the behaviour of irrigation supply, domestic and industrial supply and rainfall.

This matching reveals no change in the behaviour of domestic and industrial supply in response to changing rainfall conditions whereas the behaviour of the agricultural supply reveals a similar variation as that of rainfall. Water year 1991/1992 divided the rainfall record into two intervals: before and after. The rainfall trend for the period before 1991/1992 was increasing, which was reflected on irrigation water supply. For the period after 1991/1992, the decrease in both irrigation water supply and rainfall was detected. The projection for irrigation considers the average water year with growing demand and that the growing demand in irrigation cannot continue due to water shortages. This fact is considered in the 2015 and 2020 projections.

Municipal and industrial demand were increased from 21% at the year 1985 to 36% at the year 2001 out of the total demand according to MWI figures and as shown in **Figure 5**. **Table 3** shows the irrigation water supply from 1996 to 2000 according to the source and the region. Surface and groundwater supplies show a decreasing trend as compared to the increasing trend of treated wastewater reuse for irrigation. This trend is reflected in **Figure 6**.

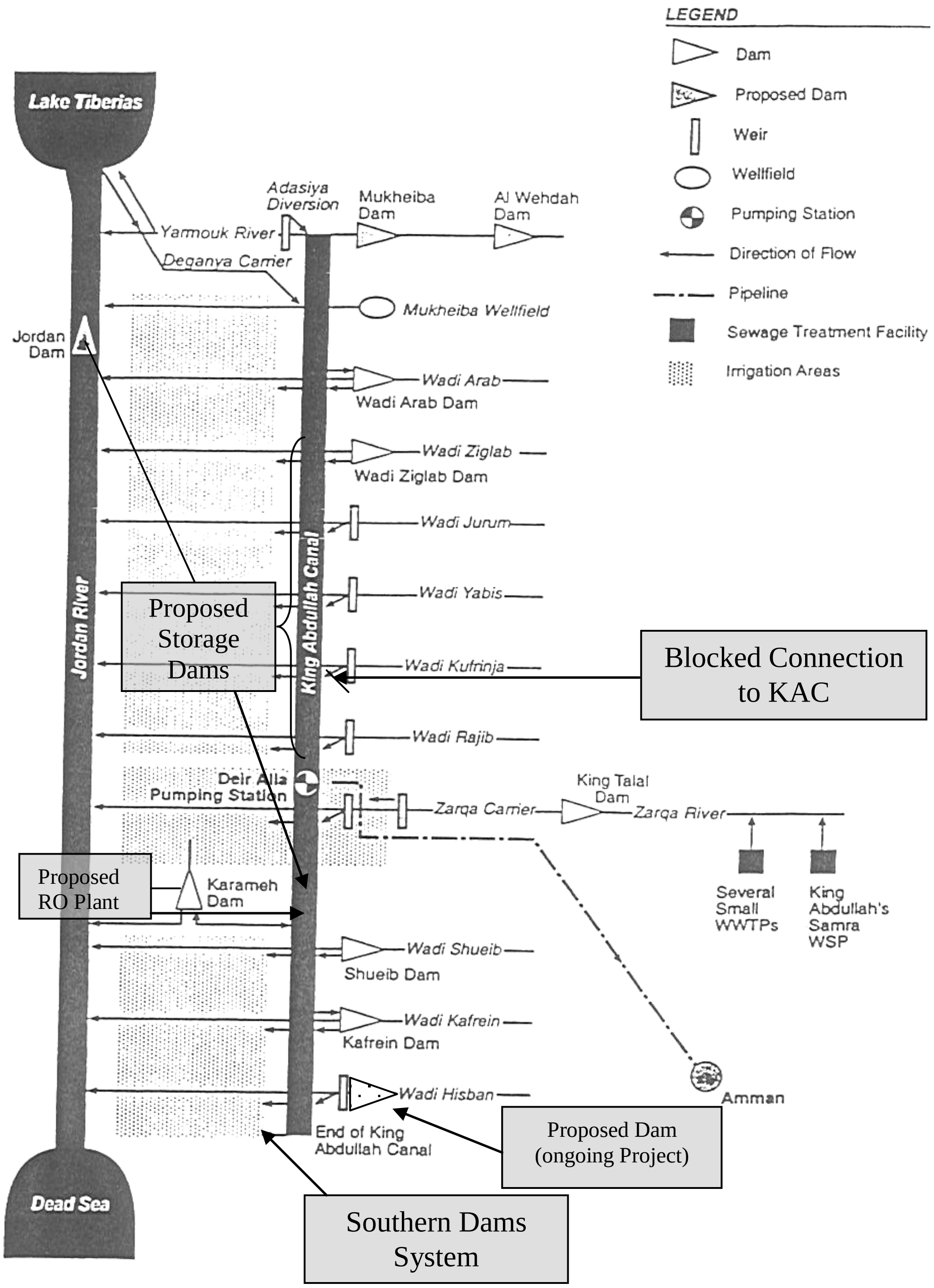


Figure 2: Schematic Plan of Jordan Valley (Source MWI-JVA)

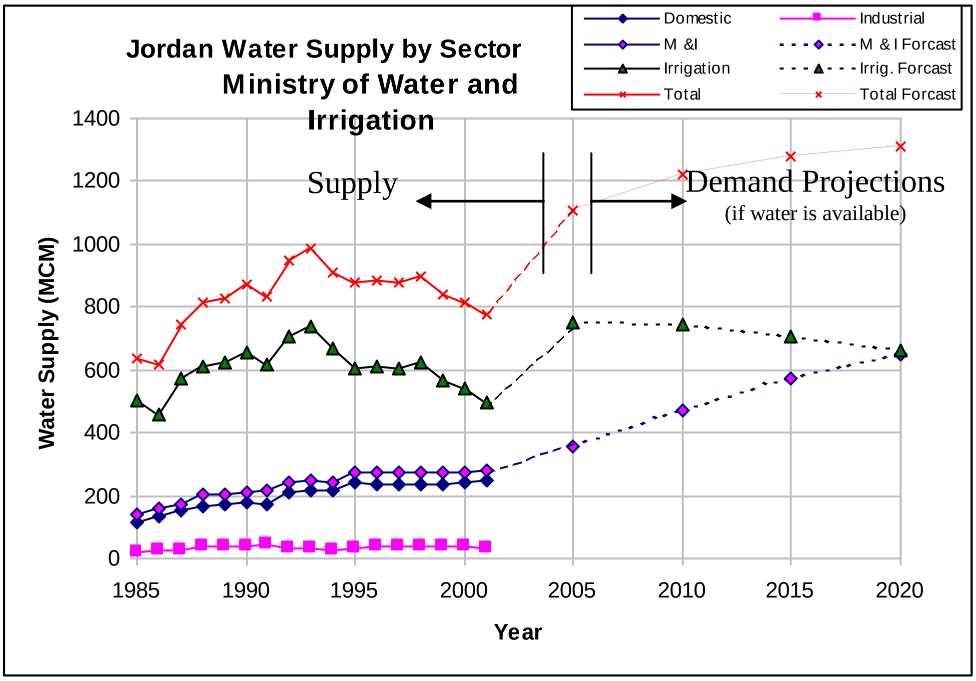


Figure 3: Jordan water supply by sector, historical and future forecasting according to MWI projection

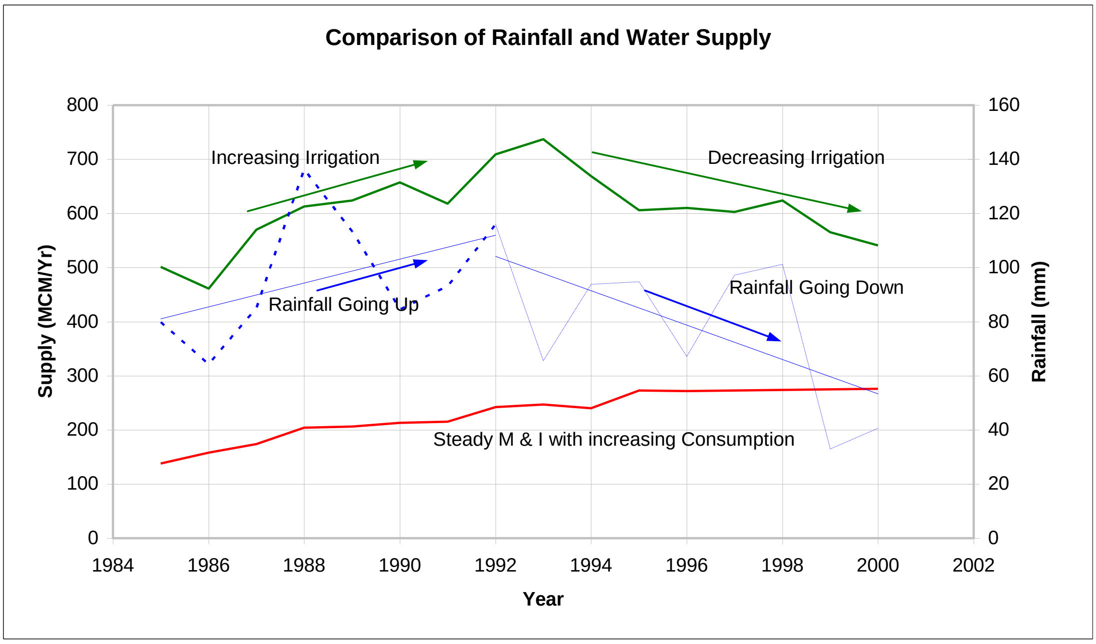


Figure 4: Irrigation and "Domestic and Industrial" Supply versus Jordan's average annual rainfall

Table 2: Jordan water supply (MCM) by sector according to the MWI

Year	Domestic	Industrial	Irrigation	Total	M&I
1985	116	22	501	639	138
1986	135	23	461	619	158
1987	150	24	570	744	174
1988	165	39	613	817	204
1989	170	36	624	830	206
1990	176	37	657	870	212
1991	173	42	618	833	215
1992	207	35	709	951	241
1993	214	33	737	984	247
1994	216	24	669	909	240
1995	240	33	606	878	272
1996	236	36	610	882	272
1997	236	37	603	876	273
1998	236	38	561	835	274
1999	232	38	532	801	207
2000	239	37	541	817	276
2001	246	33	495	774	279
2005	281	76	750	1107	357
2010	380	93	746	1219	473
2015	463	112	704	1279	575
2020	517	130	665	1312	647

Source: Ministry of Water and Irrigation (MWI, 2003)

Table 3: Irrigation water supply according to source

Item	1996	1997	1998	1999	2000	2000
Surface Water	254	272	294	239	216	39.93%
Groundwater						46.77%
Upland	237	222	209	198	195	36.04%
Midland	4	4	4	5	5	0.92%
JRV	56	44	46	53	53	9.80%
Subtotal	297	270	259	256	253	
Wastewater						13.31%
Upland	7	8	11	11	12	2.22%
JRV	52	53	60	59	60	11.09%
Subtotal	**59**	**61**	**71**	**70**	**72**	
Total	**610**	**603**	**624**	**565**	**541**	**100%**
Surface + Ground Water	**551**	**542**	**553**	**495**	**469**	

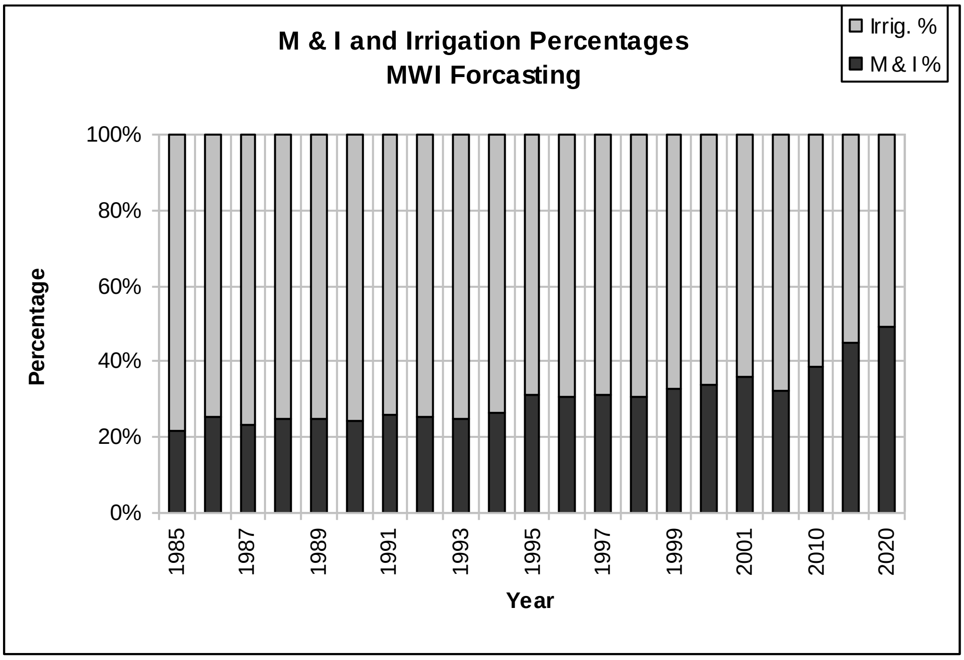


Figure 5: Municipal and industrial (M & I) percentage compared to irrigation consumption according MWI projection

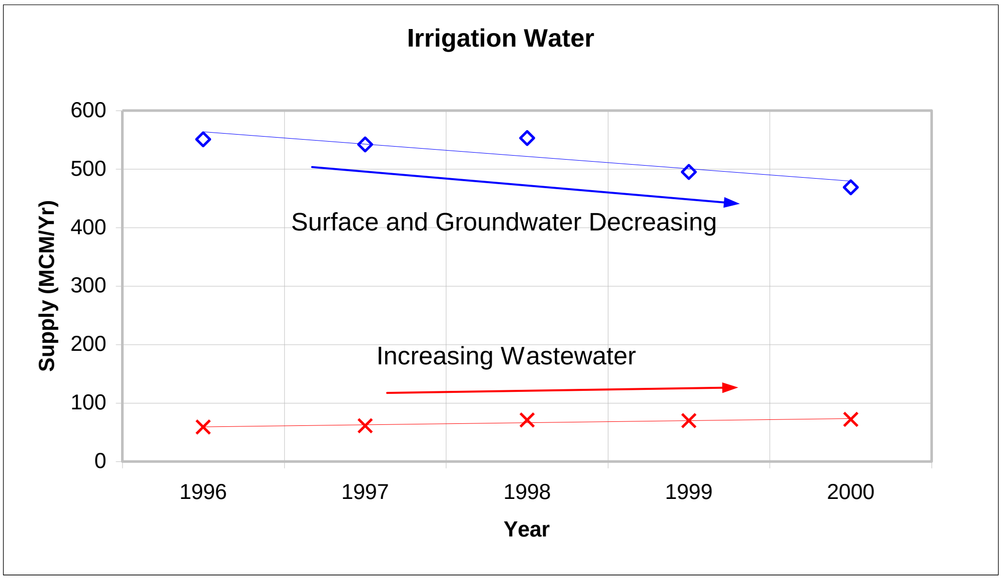


Figure 6: Irrigation Water Supply by source

The water resources are discussed at three different time scales:

- Present supply.
- Long term average with and without adjustment due to drought periods.
- Future forecasting in three time scale action:
    - Short-term.
    - Medium-term.
    - Long-term.

The forecasting discusses accordingly the GOJ framework taking into consideration the Action Plan and the Investment Program. The section integrates all water resources:

- Surface Water
- Groundwater
- Treated Wastewater
- Management
- Non-Conventional
- Regional

The climate of Jordan ranges from Mediterranean to desert. The Rift Valley and the highlands belong to the semi-arid to arid climate zone, which is largely affected by moist westerly air masses in winter. In summer, dry easterly and north-easterly desert winds affect the Kingdom. Winds are generally westerly to south-westerly.

Mediterranean climate dominates most of the highlands on both sides of the Jordan River and in the mountain chains east of the Dead Sea and Wadi Araba extending as far south as Ras El Naqeb. Dry summers with an average maximum annual temperature of 39 °C occur between April and October. In winter months, from November till March, the average minimum annual temperature is 0-1 °C. In winter, the average mean daily temperatures recorded at Amman Airport and Deir Alla were 10 °C and 17 °C, respectively, for the period 1981-1998.

The average temperature in the wet season is generally higher in the Jordan Valley than along the seashore on the west and falls again over the highlands and within the eastern plateau. The average annual evaporation rate ranges from 2,042 mm in Zarqa to 5,038 mm in Ma'an and from 2,594 mm in the Jordan Valley to 3,516 mm in the eastern hills.

Seasonal, uneven and fluctuating rainfall affects the country between October and May. Eighty percent of the annual rainfall occurs between December and March. Average annual rainfall in Jordan ranges from < 50 mm in the eastern desert to approximately 600 mm over Ajloun heights. **Table 4** presents the categories into which Jordan may be classified based on the rainfall distribution:

Table 4: Classified categories according to rainfall distribution

Zone	Annual Rainfall (mm/year)	Area (km^2)	Area as a percentage of the total area of Jordan	Rainfall Volume Fifty Years Average (MCM)
Semi-humid	500-600	620	0.7 %	425
Semi- arid	300-500	2,950	3.3 %	1,170
Marginal	200-300	2,030	2.2 %	530
Arid	100-200	20,050	22.3%	2,950
Desert	< 100	64,350	71.5 %	3,425
Total		**90,000**	**100 %**	**8,500**

Source: MWI, 2003

Rainfall is the only source of water supply in Jordan to recharge the groundwater aquifers. It is scarce and unevenly distributed over the country. The mountainous highlands along the Jordan Valley-Dead Sea-Wadi Araba depression receive the majority of total rainfall volume. Estimates of long-term records (1937/1938-2000/2001) of rainfall distribution over Jordan indicate that the average annual rainfall volume over the country is around 8,360 MCM. **Figure 7** shows the average rainfall in mm per year over Jordan with the drought periods, which are below long term average.

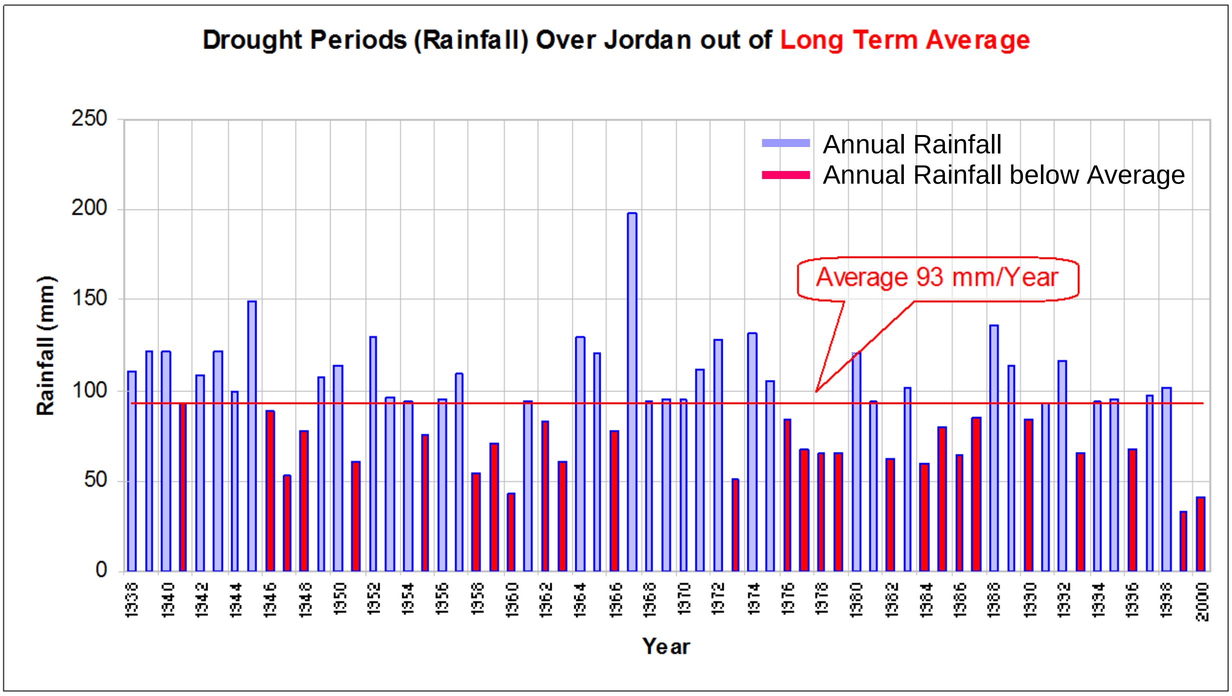


Figure 7: Average rainfall over Jordan in mm/year
(Source: MWI with development by the Consultant)

The major topographic and geomorphologic features in Jordan control the drainage pattern. The overall drainage system in Jordan consists of two main flow patterns. The first one drains rainfall towards the Jordan Rift Valley, through deeply incised wadis and rivers dissecting the Jordan Valley-Dead Sea escarpments, to ultimately discharge into the Dead Sea. The second one drains rainfall through shallow streams and washes, which generally run eastwards from the western highlands towards the internal desert depressions and mudflats.

Based on the prevailing topographic terrain, there are fifteen surface water basins in the country as shown in **Figure 8** and **Table 5**. The ten hatched basins are related to the Jordan Valley, as indicated by JVA mandate on **Figure 8**. Five basins are related directly:

- Jordan Valley Basin # 3
- Jordan Valley Side Wadis North Basin # 4
- Jordan Valley Side Wadis South Basin # 5
- Dead Sea Side Wadis Basin # 8
- North Wadi Araba Basin # 9

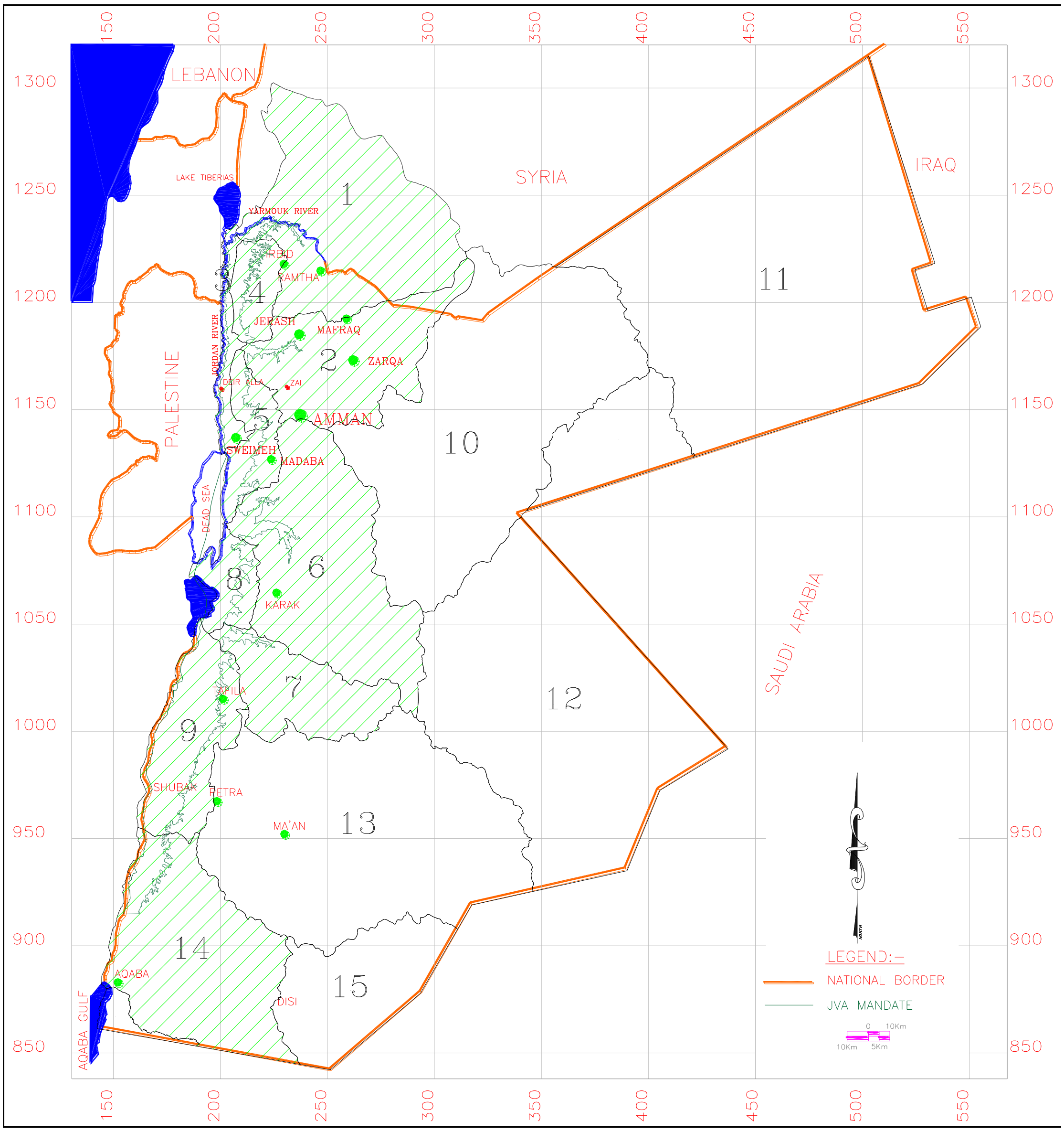


Figure 8: Major Surface Water Basins in Jordan and related basins (hatched) for Jordan Valley (Source: MWI with development by the Consultant)

Table 5: Surface water resources in Jordan[1]

No	Surface Water Basin – Region		Surface Water Basin – Name		Sy	Population (1994)**	Area (Km^2)	Average Annual Rainfall (mm)	Estimated Runoff Coeff. (%)	Long Term Rainfall Average 61 Years (MCM)	Surface Water Flows (MCM) Long-Term Av. (1937-1998)
1	DEAD SEA BASIN – JORDAN RIVER SUB BASIN	Northern Basins	Yarmouk*		AD	355,083	1,500	293	5.1	439	Base: 246 Flood: 109 Total: 355
2	DEAD SEA BASIN – JORDAN RIVER SUB BASIN	Northern Basins	Amman-Zarqa		AL	2,239,043	3,725	249	2.9	926	Base: 43.00 Flood: 25.30 Total: 68.30
3	DEAD SEA BASIN – JORDAN RIVER SUB BASIN	Northern Basins	Jordan Valley		AB	139,373	775	300	1.9	233	Base: 0.0 Flood: 2.73 Total: 2.73
4	DEAD SEA BASIN – JORDAN RIVER SUB BASIN	Northern Basins	J.V. Side Wadis	N	AE, AF, AG, AH, AJ, AK	500,024	975	599	2.9	584	Base: 37.37 Flood: 12.02 Total: 49.39
5	DEAD SEA BASIN – JORDAN RIVER SUB BASIN	Northern Basins	J.V. Side Wadis	S	AM, AN, AP	137,906	725	404	3.4	293	Base: 25.18 Flood: 7.93 Total: 33.11
6	DEAD SEA BASIN – DEAD SEA SUBBASIN	Central Basins	Mujib		CD	260,244	6,675	132	4.0	884	Base: 31.38 Flood: 33.62 Total: 65.00
7	DEAD SEA BASIN – DEAD SEA SUBBASIN	Central Basins	Hasa		CF	20,570	2,600	128	2.8	334	Base: 26.26 Flood: 5.47 Total: 31.73
8	DEAD SEA BASIN – DEAD SEA SUBBASIN	Central Basins	D.S. Side Wadis		C	196,697	1,525	178	2.5	290	Base: 33.63 Flood: 6.06 Total: 39.71
9	DEAD SEA BASIN – DEAD SEA SUBBASIN	Central Basins	N.Wadi Araba		D	79,128	2,975	135	0.7	403	Base: 8.58 Flood: 2.35 Total: 11.13
10	Eastern Desert Basins		Azraq*		F	26,031	12,200	71	2.7	866	Base: 0.0 Flood: 22.47 Total: 22.47
11	Eastern Desert Basins		Hamad*		H	9,966	18,150	112	0.7	2,050	Base: 0.0 Flood: 9.58 Total: 9.58
12	Eastern Desert Basins		Sirhan*		J	3,851	15,700	28	1.9	445	Base: 0.0 Flood: 7.49 Total: 7.5
13	Eastern Desert Basins		Jafer		G	47,783	12,450	43	1.5	545	Base: 0.0 Flood: 8.0 Total: 8.0
14	Southern Basins		S. Wadi Araba		E	89,220	3,725	37	1.3	138	Base: 0.0 Flood: 2.09 Total: 2.09
15	Southern Basins		Southern Desert*		K	958,	6,300	16	1.0	103	Base: 0.8 Flood: 1.18 Total: 1.18
T O T A L						**4,105,877**	**90,000**	**95**	**3.0**	**8,532**	**Base: 452** **Flood: 255** **Total: 706**

[1] Source of rainfall: JICA Study, 2001 & WIS/MWI * Basin area in Jordan ** DOS Population and Housing Census, 1994.

The groundwater resources are very scarce and vary widely in quantity and quality. Generally, the groundwater basins in Jordan are divided into renewable and non-renewable groundwater resources. There are twelve groundwater basins, which are subdivided according to the upper most aquifer system. Groundwater divides indicated by different groundwater flow systems separate these basins from each other. **Figure 9** presents the groundwater basins in Jordan and the general flow system in the upper aquifer. The highlighted basins are related to Jordan Valley. These basins are:

- Jordan River Valley
- Jordan River Side Wadis
- Dead Sea
- Northern Wadi Araba
- Red Sea

The safe yields of the upper aquifer systems of the different groundwater basins are shown in **Figure 10**. According to the geological succession and the different rock units occurring in the different areas of the groundwater basins, the rock formations in Jordan deposited above the basement complex which forms the base of the above sedimentary rocks of different ages. A generalized classification of the geological succession in Jordan is presented in **Table 6**. Based on the lithological characteristics of the different rock units of the geological succession, these rocks are subdivided into aquifers and aquicludes.

Table 6: Generalized geological succession in Jordan

Period	Epoch	Group	Formation	Thickness (m)		
				Amman	Mujib	Jafer
QUATERNARY	Recent	Alluvial & Aeolian Rocks				
	Pleistocene	Plateau	Azraq			
TERTIARY	Pliocene		Sirhan			
	Miocene	Volcanic	Upper Basalts			
	Oligocene		Basalt Tuff			
			Middle Basalt			
			Lower Basalt			
	Eocene	Belqa Group	Wadi Shallala (B5)			
	Palaeocene		Rijam (B4)			40-50
UPPER CRETACEOUS	Maestrichtian		Muwaqqar (B3)		100-145	20-450
	Campanian		Amman (B2)	80-115	70-200	
	Santonian		W. Ghadran (B1)	20-40	Absent	
	Turonian	Ajloun Group	Wadi Sir (A7)	65-90	70-100	
	Cenomanian		Shu'eib (A5/6)	65-100	127	
			Hummar (A4)	40-65	Absent	
			Fuheis (A3)	80	70	
			Na'ur (A1/2)	200-230	Thin	
LOWER CRETACEOUS		Kurnub	Subeihi (K2)			
			Arda (K1)			
JURASSIC		Zarqa	Azab (Z2)			
TRIASSIC			Ma'an (Z1)			
PALAEOZOIC		Khreim	(K)			
		Disi	(D)			
PRECAMBRIAN		Sarmuj	(S)			
		Basement Complex (BC)				

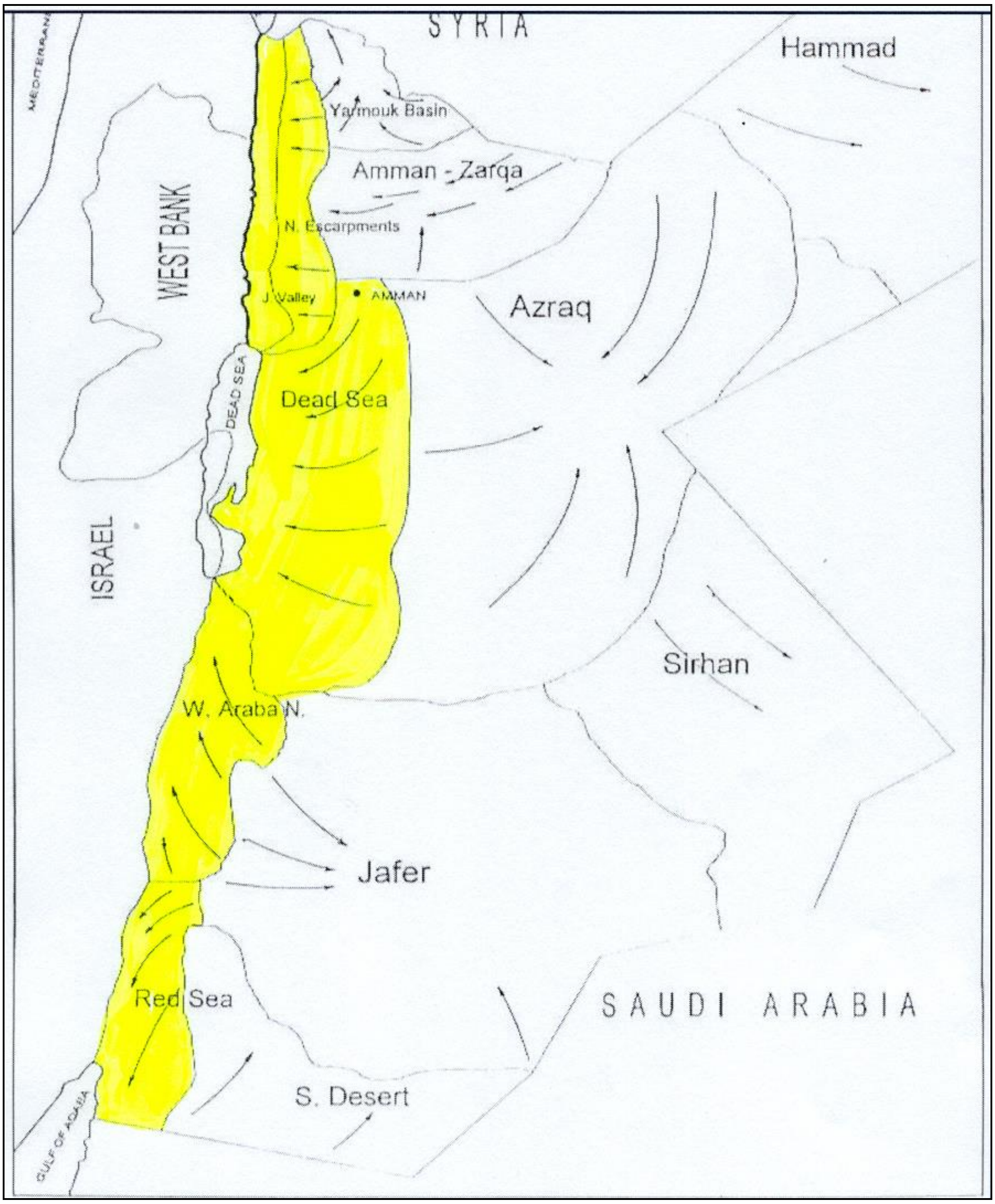
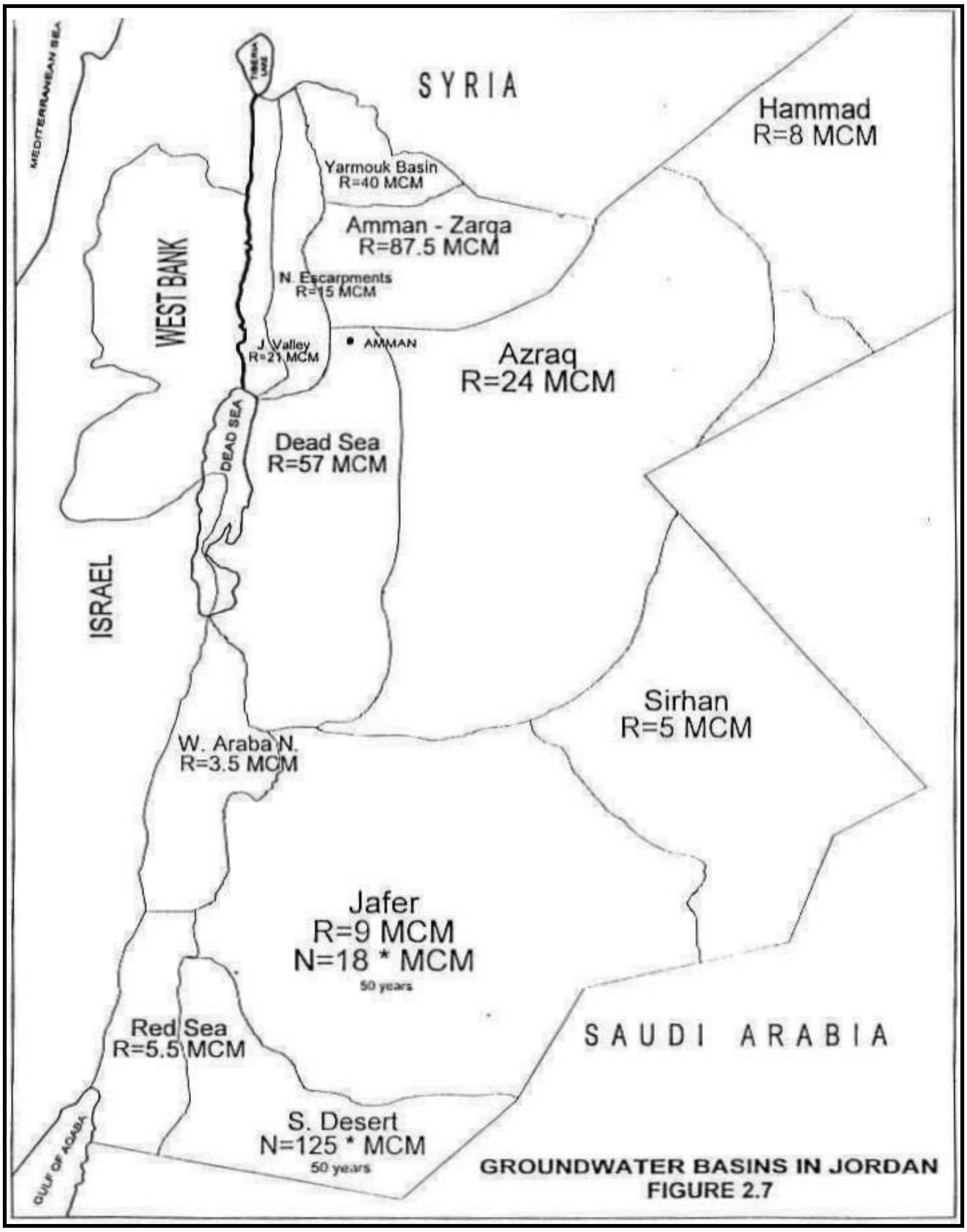


Figure 9: Groundwater basins and the general flow directions of the Upper Aquifer System in Jordan (Source: GTZ, 1996)



R: Renewable = 275 MCM/year
N: Non-Renewable = 143 MCM/year (50 years Abstraction)

Figure 10: Safe Yield of the different groundwater basins in Jordan (Source: GTZ, 1996)

All of the groundwater basins in Jordan are constituted from three main aquifer systems distributed vertically according to the geology of the basin. These aquifer systems are namely the upper aquifer system, intermediated aquifer system and deep aquifer system. According to the surface geology of each basin, the vertical distribution of each aquifer system in each basin mostly varies from one basin to another. The distributions of the upper, intermediate and deep aquifer systems in the different groundwater basins are presented in **Table 7**.

Table 7: Aquifers distribution in the different groundwater basins in Jordan

	Groundwater Basin	Upper Aquifer System	Intermediate Aquifer System	Deep Aquifer System
1	Yarmouk	Basalt Basalt + B_2/A_7 (1) B4 (2)	A_{1-2} (3) + A_4 (4)	Kurnub (K) (5) K + Rum Triassic-Jurassic (T-J) (6)
2	Azraq	Basalt Basalt + B_4 + B_5	B_2/A_7 B_2/A_7 + A_{1-2} + A_4	K K + T-J + Rum
3	Zarqa	Alluvial Alluvial + B_2/A_7 Alluvial + A_4	A_{1-2} + A_4	K + Rum + T-J K + Rum
4	Dead Sea	Alluvial B_2/A_7	A_{1-2} + A_4	K + Rum + T-J K + T-J T-J + Rum
5	Jafer	B_4 B_4 + Alluvial	B_2/A_7 A_{1-2} + A_4	K K + Rum
6	Mudawarra-Southern Desert	Rum (Disi) + Khreim		
7	Sirhan	B_4	B_2/A_7 A_{1-2} + A_4	K K+ T-J + Rum
8	Hammad	Basalt Basalt + B_4	B_2/A_7 A_{1-2} + A_4	K K+ T-J + Rum
9	Northern Wadi Araba	Alluvial	B_2/A_7 A_{1-2} + A_4	Rum K
10	Red Sea	Alluvial	B_2/A_7	Rum
11	Jordan River Side Wadis	Alluvial Alluvial + B_2/A_7	A_{1-2} + A_4	K K + T-J K+ T-J + Rum
12	Jordan River Valley	Alluvial	B_2/A_7 A_{1-2} + A_4	K K + T-J K+ T-J + Rum

(1) B_2/A_7= Amman-Wadi Sir Formation Deposits of Late Cretaceous Age (Mesozoic Rocks)
(2) B_4 = Rijam Formation Deposits of Late Cretaceous – Early Tertiary Rocks (Mesozoic-Cenozoic Rocks)
(3) A_{1-2}= Fuhais Formation Deposits of Ajlun Group of Late Cretaceous Age (Mesozoic Rocks)
(4) A_4= Hummar Formation Deposits of Ajlun Group of Late Cretaceous Age (Mesozoic Rocks)
(5) K= Kurnub Group Deposits of Early Cretaceous Age (Mesozoic Rocks)
(6) T-J= Triassic and Jurassic Rocks Deposits (Mesozoic Rocks)

The prevailing conditions of the groundwater basins according to the utilization for the different purposes are presented in **Table 8**. This table shows that most of the groundwater basins are over abstracted and, due to this, salinization had occurred for the water of the upper aquifer system.

Table 8: Water budget, safe yield and abstraction from the groundwater basins for the year 2000

No	Basin	Aquifer	Safe Yield (MCM/a)	Domestic (MCM/a)	Industrial (MCM/a)	Agriculture (MCM/a)	Sum	Sy.-Abst.	Water Quality
1	Yarmouk	B4, B2/A7, A2	40.0	22.755	0.184	32.922	56.267	-16.267	Fresh but getting partly salinized
2	Side Wadis	A+K	15.0	4.913	0.000	5.120	10.033	4.967	Fresh
3	Jordan Valley	ALL	21.0	8.369	0.160	28.206	36.735	-15.735	Salinization
4	Amman/ Zarqa	Ba, B2/A7, A4, A2, K	87.5	67.141	6.121	62.516	137.812	-50.312	Salinization
5	Dead sea	B2/A7, A4, A2	57.0	33.855	15.098	32.117	83.204	-26.204	Salinization
6	Disi - Mudawarah	D	125.0	9.720	4.483	50.920	66.259	58.741	Fresh
7	Wadi Araba - North	ALL, B2/A7, K, D	3.5	0.000	2.784	0.563	3.514	-0.014	Salinization
8	Red Sea	ALL, D	5.5	1.061	0.157	3.695	5.016	0.484	Salinization
9	Jafer	Ba, B4, ALL, B2/A7, A1, K	18.0	7.183	6.282	9.931	23.450	-14.450	Salinization
10	Azraq	Ba, B4, B2/A7, AB, K	24.0	27.202	0.208	28.694	56.657	-32.657	Salinization
11	Sarhan	B5/4, AB	5.0	0.000	0.000	1.618	1.821	3.179	Fresh-brackish
12	Hammad	B4	8.0	0.562	0.000	0.097	1.148	6.852	Fresh-brackish
		Total		**182.761**	**35.477**	**256.399**	**473.000**	**-81.416**	
		Renewable	275.5						
		Renewable & Non-Renewable	418.5						

3.1.1 Present and Future Water Demand

The total annual municipal water supply across the country maintains more or less the same level of around 240 MCM for the period between the year 1996 and the year 2001 as shown in **Table 9**. The Governorate of Amman consumed 37.5% of the total water supply as an average for the entire period, followed by the Governorate of Zarqa and Irbid with 13.2% and 12.8%, respectively.

Table 9: Municipal Water by Governorate 1996 to 2001

Governorate	Municipal Water Supply											
	1996		1997		1998		1999		2000		2001	
	MCM	lcd	MCM	lcd	MCM	lcd	MCM	lcd	MCM	lcd	MCM	lcd
Amman	89.6	145.2	88.8	139.6	85.7	131.4	88.2	131.7	91.3	133.1	93.6	133.2
Zarqa	31.7	126.9	31.5	122.4	32.0	121.2	30.1	111.1	31.8	114.5	32.7	115.2
Irbid	31.7	107.5	29.6	97.6	29.1	93.3	31.8	99.5	30.3	92.4	30.9	92.0
Mafraq	17.4	250.3	18.4	256.7	18.5	251.6	19.0	251.8	18.5	239.1	18.9	238.4
Balqa	19.2	176.7	18.9	168.8	19.1	166.4	17.9	152.2	16.3	135.4	15.2	123.3
Karak	8.5	127.6	8.7	127.6	9.4	134.0	9.2	127.3	9.2	124.8	9.4	124.4
Tafileh	2.0	83.7	2.3	92.0	2.3	89.8	2.2	83.8	2.4	89.3	2.6	94.5
Ma`an	6.8	219.5	6.8	213.5	7.3	224.7	7.2	214.3	7.5	220.6	7.7	220.5
Madaba	12.9	305.8	12.0	276.1	11.7	263.5	8.8	191.6	5.6	119.2	5.9	123.9
Aqaba	15.3	498.2	15.1	475.5	15.0	462.0	16.5	493.9	15.2	443.1	15.0	426.5
Ajloun	3.5	93.4	3.7	96.5	3.9	99.3	3.0	75.0	3.2	76.3	3.1	71.9
Jarash	3.9	79.2	4.1	82.8	5.2	100.4	3.6	67.5	4.2	78.5	3.9	71.2
Total	**242.5**	**149.6**	**239.9**	**143.7**	**239.2**	**139.7**	**237.3**	**135.1**	**235.6**	**130.8**	**239.0**	**129.6**

Source: WAJ
Notes: 1) The figures include touristic water and the water for small and medium industry.
2) The figures include physical losses.

The population grew at the average annual rate of 2.7% (for the period 1996 to 2001) and the per capita per day municipal water supply over the whole country decreased from 150 litres in 1996 to 130 litres in 2001 as shown in **Table 9**.

Table 10 presents the JV communities' centres and the present population with the domestic consumption. The domestic consumption is considered as 130 l/c/d including the losses.

Table 10: Present Domestic Consumption for Jordan Valley

Zone 1: Yarmouk River to the Baptism Site.		
Population areas	**Governorate**	**Domestic water (MCM/yr)**
Aladaseiah	Irbid	0.123
Al Baqura	Irbid	0.039
Abu Habeel	Irbid	0.053
New Shuneh	Al-Balqa	0.231
Abu Sido	Irbid	0.126
South Shuneh	Al-Balqa	0.162
Al Manshiye	Irbid	0.331
Mu'addi	Al-Balqa	0.192
Karn	Irbid	0.034
Mashara	Irbid	0.902
Waqqas & Qleat	Irbid	0.274
Suleikhat	Irbid	0.036
Al Rweha	Al-Balqa	0.143
Daharat Al Ramle	Al-Balqa	0.077
Al-Nahda (Al Rahma Al Jalad)	Al-Balqa	0.100
Dirar	Al-Balqa	0.280

Zone 1: Yarmouk River to the Baptism Site.		
Population areas	**Governorate**	**Domestic water (MCM/yr)**
West Twal	Al-Balqa	0.350
Khazma	Al-Balqa	0.126
Al Ardhah	Al-Balqa	0.098
Deir Alla	Al-Balqa	0.070
Al Maraza	Irbid	0.048
Kraymeh	Irbid	0.860
Zimalia	Irbid	0.063
Abu Ezzeghan	Al-Balqa	0.035
Damia	Al-Balqa	0.051
Karamah	Al-Balqa	0.436
Al Jofeh Al Jawasreh	Al-Balqa	0.298
Balawna	Al-Balqa	0.262
North Twal Al Rabeea	Al-Balqa	0.190
North Shuneh	Irbid	0.765
Almukheibeh Altahta	Irbid	0.122
Almukheibeh Alfouqa	Irbid	0.083
	Sub-Total	**6.962**
Zone 2: The Dead Sea Area		
Population areas	**Governorate**	**Domestic water (MCM/yr)**
Al Haditha	Al-Karak	0.161
Al Rawdhah	Al-Karak	0.384
Suweimah	Al-Balqa	0.122
	Sub-Total	**0.667**
Zone 3: The Southern Ghors and Wadi Araba		
Population areas	**Governorate**	**Domestic water (MCM/yr)**
Safi_ Ramleh	Al-Karak	0.809
Mazraa	Al-Karak	0.358
Fifa	Al-Karak	0.094
Rahmeh	Al-Aqabah	0.043
Qatar	Al-Aqabah	0.010
Al Resheh	Al-Aqabah	0.047
Fenan	Al-Aqabah	0.016
Beermathkoor	Al-Aqabah	0.022
Alselemani	At-Tafilah	0.010
Al Mamurah	At-Tafilah	0.029
	Sub-Total	1.438
	Total	9.067

Touristic water demand at Dead Sea could be the most important touristic consumption in the Jordan Valley. According to JICA Study (Dec. 2001), the growth in the next 10 years could reach 14 MCM. The growth at Suweimeh is 2.45 MCM per five years starting from year 1998 and 2.22 MCM foe Zara. **Table 11** shows the torustic demand at Balqa and Madaba Governorates for three scenarios for the period between 1998 and 2020 according to JICA Study. The sum can reach 14 MCM at year 2020.

Table 11: Projection of Touristic Water Demand by Scenario for Jordan Valley

Governorate	1998	2005	2010	2015	2020
Scenario 1					
Balqa	0.01	2.67	4.70	6.94	6.94
Madaba	0.00	2.35	4.41	6.55	6.56
Scenario 2					
Balqa	0.01	5.13	7.29	7.29	7.29
Madaba	0.00	3.29	6.56	6.57	6.60
Scenario 3					
Balqa	0.01	5.13	7.29	7.29	7.29
Madaba	0.00	3.28	6.55	6.55	6.56

The Movenpick Hotel at the Dead Sea has been considered as a typical example. **Table 12** presents the water consumption for the last four years in the hotel. The consumption ranged between 50,000 m^3 and 60,000 m^3 per year.

Table 12: Movenpick at Dead Sea Water Consumption for the Period 2000-2003

Month	Guests	No. of Employees	Year 2000		
			Water JD's		Waste Removal (Sweage)
			m^3	Total JD	Total JD
Jan-00	6974	367	4,469	4,469	815
Feb-00	6672	367	3,649	3,649	380
Mar-00	9583	367	5,329	5,329	260
Apr-00	11774	367	5,073	5,073	280
May-00	10287	367	4,539	4,539	215
Jun-00	7967	367	4,199	4,199	90
JLY 00	5475	367	4,583	4,583	450
Aug-00	7501	367	4,724	4,724	360
Sep-00	8486	367	4,987	4,987	180
Oct-00	11070	367	5,033	5,033	510
Nov-00	8085	367	4,703	4,703	165
Dec-00	4046	367	2,776	2,776	450
Total Year JD	97920	4404	54064	54064	4,155

Month	Guests	No. of Employees	Year 2001		
			Water JD's		Waste Removal (Sweage)
			m^3	Total JD	Total JD
Jan-01	2618	340	3,010	3,001	90
Feb-01	4187	340	3,379	3,405	105
Mar-01	8867	340	5,686	5,688	105
Apr-01	10667	340	5,652	5,654	135
May-01	8164	340	5,612	5,648	135
Jun-01	5245	340	4,230	4,234	90
JLY 01	5773	340	4,482	4,489	140
Aug-01	7301	340	4,985	4,986	90
Sep-01	4282	340	4,312	4,322	105
Oct-01	4668	340	3,739	3,757	150
Nov-01	2905	340	3,315	3,311	150
Dec-01	2576	340	3,114	3,128	30
Total Year JD	67253	4080	51516	51,623	1,325

Month	Guests	No. of Employees	Year 2002			
			Water JD's			Waste Removal (Sweage)
			m^3	Total JD		Total JD
Jan-02	2260	390	3,415	3,432		60
Feb-02	3470	390	3,907	3,916		75
Mar-02	5711	390	4,653	4,664		150
Apr-02	8139	390	6,081	6,085		45
May-02	8475	390	6,953	6,959		150
Jun-02	7721	390	6,427	6,431		225
JLY 02	5532	390	5,065	5,069		475
Aug-00	6576	390	5,813	5,827		150
Sep-02	5659	390	5,208	5,340		285
Oct-02	7495	390	5,391	5,397		135
Nov-02	4378	390	3,784	3,806		75
Dec-02	3840	390	3,483	3,490		30
Total Year JD	69256	4680	60180	60416		1,855

Month	Guests	No. of Employees	Year 2003			
			Water JD's			Waste Removal (Sweage)
			m^3	Total JD		Total JD
Jan-03	2702	344	3,033	3,038		60
Feb-03	2869	344	2,995	3,000		45
Mar-03	808	344	1,816	1,949		135
Apr-03	2889	344	2,393	2,438		75
May-03	4713	344	4,046	4,061		135
Jun-03	5020	344	6,653	6,682		390
JLY 03	4391	344	5,325	5,340		120
Aug-03	6630	344	6,226	6,238		75
Sep-03	5983	344	4,477	4,487		270
Oct-03	9423	344	3,304	3,309		159
Nov-03	7060	344	4,610	4,613		120
Dec-03	5201	344	4,604	4,601		0
Total Year JD	57689	4128	49482	49.754		1584

Figure 2 presented earlier, shows a schematic plan of Jordan Valley System, which is the source for any water activity in the Valley. Options to provide the additional needed water are:

- Storage Dams to facilitate water through construction of:
    - Al Wehdah Dam
    - Jordan River Storage System
    - Wadi Hisban Dam
    - Southern Dams System
- The use of RO Plant forKaramah and King Talal Reservoir to enhance water quality before mixing.

Water quality of King Talal Reservoir could be enhanced through As-Samra new wastewater treatment plant, while RO for Karamah water could be a must even after the mixing with flood water of Jordan River (ongoing project). The investment cost and the running cost for RO station with a capacity of 20 MCM (as an example) are presented in **Table 13**.

Table 13: Water cost components reference design

	45% Recovery (USD/m^3)	55% Recovery (USD/m^3)
Capital Cost	0.320	0.275
Membrane Replacement	0.050	0.037
Maintenance	0.095	0.084
Power Consumption	0.252	0.276
Chemicals and Cartridge Filters	0.060	0.050
Labour	0.050	0.040
Total Water Cost, $/m^3	0.827	0.762

Source: Wilf and Klinko, 2001

Large amount of water is consumed in the Jordan Valley by the irrigated agriculture. Two periods were considered to show the history of the agricultural water consumption for comparison and reference. These periods are four years at end of the 80's and five years in mid 90's, which can be considered of some contrasts. **Table 14** shows the average annual crop water requirements and average cultivated areas of main crop categories for two periods 1987-1990 and 1994-1998. Only the areas of fruit trees in NJV increased by 6 thousand dunums and by 3 thousand dunums in SJV, whereas the cultivated areas of vegetables are decreased in the three zones by 59.5 thousand dunums. Furthermore, the average cultivated areas in the two periods were decreased from 290.7 thousand dunums to 242.7 thousand dunums.

Table 14: Average crop water requirements and cultivated areas at JV

Crop categories	Average crop water requirements m^3/dunum	Cultivated areas (dunum)	
		1987-1990	1994-1998
NJV Fruits Trees Area	1,724	52,524	58,482
NJV Vegetable Area	404	70,960	45,207
NJV Field Crops Area	500	24,929	20,930
NJV Total Area		**148,414**	**124,619**
MJV Fruits Trees Area	1,875	9,930	9,671
MJV Vegetable Area	398	55,848	50,785
MJV Field Crops Area	624	16,629	17,218
MJV Total Area		**82,406**	**77,674**
SJV Fruits Trees Area	1,830	11,193	14,641
SJV Vegetable Area	355	45,725	17,052
SJV Field Crops Area	685	3,050	8,766
SJV Total Area		**59,968**	**40,459**
JV Total Fruits Tress Area	1,810	73,647	82,794
JV Total Vegetable Area	386	172,533	113,044
JV Total Field Crops Area	603	44,608	46,914
JV Total Area		**290,788**	**242,752**

In NJV during the 1987-1990 period, fruit trees used 90.7 MCM compared to 7.1 MCM for autumn vegetables and 22.9 MCM for summer vegetables (**Table 15**). This is mainly due to the large area planted with citrus in the northern part of Jordan Valley. Meanwhile, vegetables (70.9 thousand dunums) needed 30 MCM as a total amount for irrigation. Field crops require 8.7 MCM. As shown in **Table 15** fruits tress require about 70% of total water requirements in NJV. Due to the expansion of fruit tress areas during the period (1994-1998) fruit trees used 100.4 MCM which represent 79% of total water requirements in NJV. Vegetables used only 17.2 MCM which represent only 13.7% of total water requirements in NJV. The peak demand of water in this zone is during the period of April-July.

Table 15: Total monthly crop water requirements (MCM) of major crops cultivated in Northern JV

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1987-1990													
Fruits trees	8.2	2.8	0.0	0.0	0.0	2.4	8.9	13.4	15.4	15.8	14.1	9.7	90.7
Vegetable-Autumn	1.9	2.1	0.9	0.3	0.0	0.1	0.4	0.0	0.0	0.3	0.4	0.7	7.1
Vegetable-Summer	0.0	0.0	0.0	0.2	0.2	2.7	6.6	8.8	3.7	0.8	0.0	0.0	22.9
Field Crops	0.0	1.3	0.0	0.0	0.2	2.0	3.9	1.3	0.0	0.0	0.0	0.0	8.7
Total	10.1	6.2	0.9	0.5	0.4	7.2	19.8	23.5	19.2	16.8	14.4	10.4	129.4
1994-1998													
Fruits	9.0	3.1	0.0	0.0	0.0	2.6	9.9	14.9	17.1	17.4	15.6	10.7	100.4
Vegetable-Autumn	1.7	1.9	0.8	0.4	0.0	0.1	0.4	0.1	0.0	0.2	0.3	0.5	6.5
Vegetable-Summer	0.0	0.0	0.0	0.0	0.0	1.1	3.1	4.1	1.9	0.6	0.0	0.0	10.8
Field	0.0	1.1	0.0	0.0	0.2	1.9	3.5	1.3	0.0	0.0	0.0	0.0	8.0
Total	10.8	6.0	0.9	0.4	0.3	5.7	16.9	20.4	19.0	18.2	15.9	11.2	125.7

In MJV during the period 1987-1990, fruit trees used 18.5 MCM compared to 9.8 MCM for autumn vegetables and 12.7 MCM for summer vegetables (**Table 16**). However, vegetables (55.8 thousand dunums) required 20.5 MCM as a total amount for irrigation water, which represents about 45% of total water requirements in this zone. Field crops required 9.1 MCM, which represent about 18.1% of total water requirements as shown in **Table 16**. During the period 1994-1998 fruit trees consumed 24.6 MCM which represent 44.4% of total water requirements in MJV. Vegetables used 20.7 MCM which represent only 37.4% of total water requirements in MJV. The peak demand of water in the MJV is during October-November for autumn vegetables and April-May for summer vegetables.

Table 16: Total monthly crop irrigation water requirements (MCM) of major crops in cultivated in Middle JV

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1987-1990													
Fruits Trees	1.6	0.6	0.0	0.1	0.2	0.5	1.9	2.7	3.1	3.1	2.8	1.9	18.5
Vegetable-Autumn	2.7	3.0	1.8	0.9	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.9	9.8
Vegetable-Summer	0.0	0.0	0.0	0.3	0.4	2.0	4.2	4.4	1.1	0.3	0.0	0.0	12.7
Field Crops	0.0	1.0	0.6	0.4	1.1	1.9	3.1	1.0	0.0	0.0	0.0	0.0	9.1
Total	4.3	4.6	2.4	1.6	1.8	4.8	9.2	8.1	4.2	3.5	3.0	2.8	50.1
1994-1998													
Fruits Trees	2.1	0.8	0.0	0.1	0.2	0.7	2.6	3.7	4.1	4.2	3.7	2.5	24.6
Vegetable-Autumn	3.0	3.4	2.0	1.3	0.3	0.3	0.0	0.0	0.0	0.0	0.1	1.1	11.7
Vegetable-Summer	0.0	0.0	0.0	0.1	0.2	0.9	2.4	2.9	1.6	0.9	0.0	0.0	9.0
Field	0.0	0.9	0.5	0.4	1.3	2.3	3.5	1.0	0.0	0.0	0.0	0.0	10.1
Total	5.1	5.2	2.6	1.9	2.0	4.2	8.4	7.6	5.7	5.1	3.9	3.6	55.4

In SJV during the 1987-1990 period, fruit trees consumed 27.5 MCM compared to 21.24 MCM for autumn and summer vegetables as shown in **Table 17** the autumn vegetables (45.7 thousand dunums) required about 12.6 MCM. Field crops required 2.3 MCM. Vegetables used only 7.6 MCM which represent only 15.2% of total water requirements in SJV compared to 21.24 MCM during the 1987-1990 periods. This reduction in total crop water requirements of vegetables was due to the shrinking of vegetable-planted areas by 28.6 thousand dunums between the two periods.

Table 17: Total monthly crop irrigation water requirements (MCM) of major crops in cultivated in Southern JV

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1987-1990													
Fruits trees	2.4	1.0	0.2	0.4	0.7	1.3	2.7	3.8	4.2	4.4	3.9	2.7	27.5
Vegetable-Autumn	2.8	3.5	2.3	0.7	0.6	0.4	0.3	0.0	0.0	0.0	0.7	1.3	12.6
Vegetable-Summer	0.0	0.0	0.0	0.2	0.4	1.7	2.9	2.2	1.0	0.1	0.0	0.0	8.6
Field Crops	0.0	0.2	0.1	0.1	0.3	0.6	0.7	0.3	0.0	0.0	0.0	0.0	2.3
Total	5.2	4.6	2.7	1.5	1.9	4.0	6.6	6.3	5.3	4.4	4.6	4.0	51.1
1994-1998													
Fruits	3.2	1.3	0.3	0.6	0.9	1.7	3.6	5.0	5.6	5.8	5.2	3.6	36.7
Vegetable-Autumn	1.2	1.6	1.1	0.3	0.6	0.4	0.3	0.0	0.0	0.0	0.1	0.4	6.0
Vegetable-Summer	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.5	0.3	0.0	0.0	0.0	1.6
Field	0.0	0.5	0.4	0.4	0.8	1.4	1.8	0.5	0.0	0.0	0.0	0.0	5.8
Total	4.4	3.3	1.9	1.3	2.3	3.8	6.1	6.0	5.9	5.8	5.3	4.0	50.1

The water requirements for the whole JRV during the period 1987-1990, reached 230.7 MCM, whereas it reached to 231.2 MCM during the period 1994-1998 as shown in **Table 18**. In general, the total irrigation requirement in the JV was estimated to be around 230 MCM annually, of which 128 MCM was allocated to irrigate 124.6 thousand dunums in NJV; 55.4 MCM to irrigate 77.6 thousand dunums in the MJV and 50 MCM to irrigate 40.5 thousand dunums in SJV.

During the period of 1987-1990 it was found that, the total water demand for a total of 290.8 thousand dunums was about 230.6 MCM, and was distributed as follows: 59.2% for fruit trees, 12.8% for autumn vegetables, 19.2% for summer vegetables and only 8.8% for field crops. For the period 1994-1998 the result shows that for a total of 242.7 thousand dunums, the total water demand was about 231.2 MCM, and was distributed as follows: 70% for fruit trees, 10.4% for autumn vegetables, 9.3% for summer vegetables and 10.3% for field crops. This shows that fruit trees consumed the majority of water; therefore, it is important to consider this fact in future planning for water management in the Jordan Valley. The peak demand of water in JV is during the period of April-May as shown in **Figure 11**.

Table 18: Total monthly crop irrigation water requirements (MCM) of major crops in cultivated in JV

Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1987-1990													
Fruits trees	12.2	4.4	0.2	0.5	0.8	4.2	13.5	19.9	22.7	23.2	20.8	14.3	136.6
Vegetable-Autumn	7.4	8.6	5.0	1.9	0.8	0.8	0.7	0.0	0.0	0.3	1.2	2.8	29.6
Vegetable-Summer	0.0	0.0	0.1	0.6	1.0	6.4	13.7	15.3	5.9	1.2	0.0	0.0	44.3
Field Crops	0.0	2.4	0.7	0.6	1.5	4.6	7.7	2.6	0.0	0.0	0.0	0.0	20.2
Total	**19.5**	**15.4**	**6.0**	**3.6**	**4.2**	**16.0**	**35.6**	**37.9**	**28.6**	**24.7**	**22.0**	**17.1**	**230.7**
1994-1998													
Fruits trees	14.4	5.1	0.3	0.6	1.1	5.0	16.1	23.6	26.8	27.4	24.5	16.9	161.7
Vegetable-Autumn	5.9	6.9	4.0	2.0	0.9	0.9	0.7	0.1	0.0	0.2	0.6	1.9	24.1
Vegetable-Summer	0.0	0.0	0.0	0.2	0.2	2.2	6.0	7.5	3.8	1.5	0.0	0.0	21.4
Field crops	0.0	2.5	1.0	0.9	2.4	5.7	8.7	2.8	0.0	0.0	0.0	0.0	23.9
Total	**20.3**	**14.5**	**5.4**	**3.7**	**4.7**	**13.7**	**31.5**	**34.0**	**30.6**	**29.1**	**25.1**	**18.8**	**231.2**

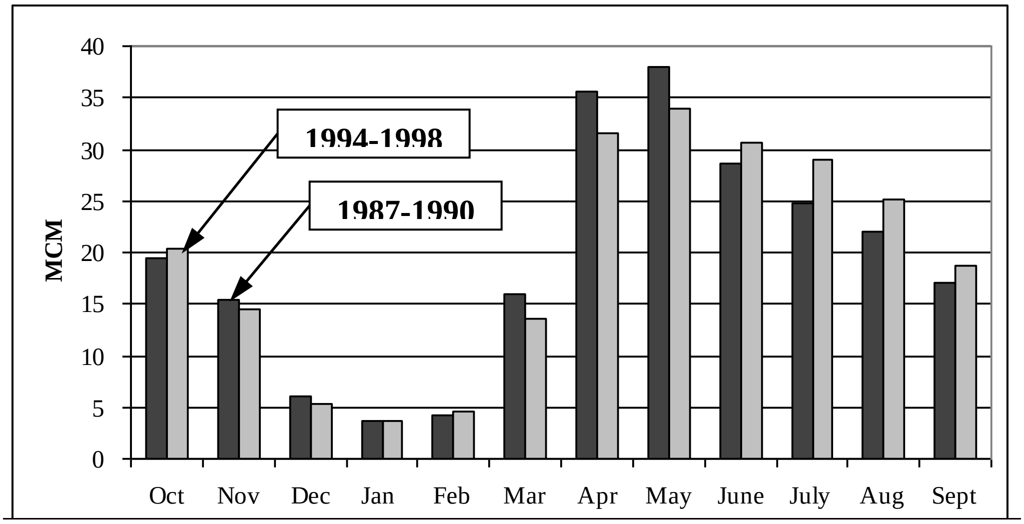


Figure 11: Monthly total crop water requirements at JV

4 AGRICULTURAL ASSESSMENT

4.1 Introduction

Jordan is a small country with an area of 90,000 km^2 that is classified as an arid to semi arid country. The country is divided into two main regions through Uplands Mountains crossing the country from the north to the south with a width of 30 km and a length of 300 km. These mountains slop gradually to the eastern direction forming the Jordanian eastern desert (Badia) (Al-Quda, 2001). While mountains slop hardly toward the western direction forming the Jordan Rift Valley. Jordan population is about 5 Millions inhabitants where 80% are concentrated on the Jordanian Bank of the Jordan River basin mostly in the cities of Amman, Zarqa, Irbid, Mafraq, Jerash and Ajloun (**Figure 12**).

The financial state of the country depends mainly on industrial, agricultural and tourism sectors. This highly accommodated by the geographical location of Jordan within the Middle East that raises the potential of being the center of trade between neighbors. However, due to the limited natural resources of Jordan, the country is facing a critical situation of water shortage, which following a strong demographic growth and an increase of the everyday needs of the population will get worse.

Agricultural sector in Jordan suffers from low productivity, due to low investments and the use of traditional methods and techniques in the farming process (Ministry of Planning and International Cooperation, Report). Despite its low direct contribution to GDP, which accounts to 5%, its indirect contribution is substantial and exceeds 29%. Agricultural exports contribute to 12.1% of total exports, of which the fruits, vegetables and citrus exports make up 61.4% of the agricultural exports. The production of fruits and vegetables account to 79% of total agricultural production in Jordan. Most of the vegetables, fruits and citrus production is concentrated in the Jordan Valley (JV) that extends from Lake Tiberias (200 m below the sea level) to the Dead Sea (410 m below sea level).

The productivity of Jordanian agricultural sector requires a proper land use planning. Under the area of study that extends from the upper north of JV south to the dead sea and along Wadi Araba (WA) to the Aqaba port, the land use planning was initially planned on the basis of land capability classification identifying irrigable and non-irrigable agricultural lands and separates areas for township development. However, due to the increase of population growth and the expanded agricultural lands in association to the dramatic deterioration of water quality, the old land use should be changed to account the new changes and stop further deterioration of the environmental resources.

Iain Grierson (2001) discussed in details the hampering situation and reasons for the failure of a new land use strategic plan. He explained such difficulties by the lack of cadastral tilting in townships and non-flexibility of water rights for farmers to adapt the new changes. As a matter of challenge, this project will give a detailed descriptive of the suitability of land uses as function of more than farmer rights but rather on environmental resources available at the current time. Hopefully, this project will help the decision-makers to right the proper legislation to enhance both land resources as an agro-socio-economics and the farmer living standards.

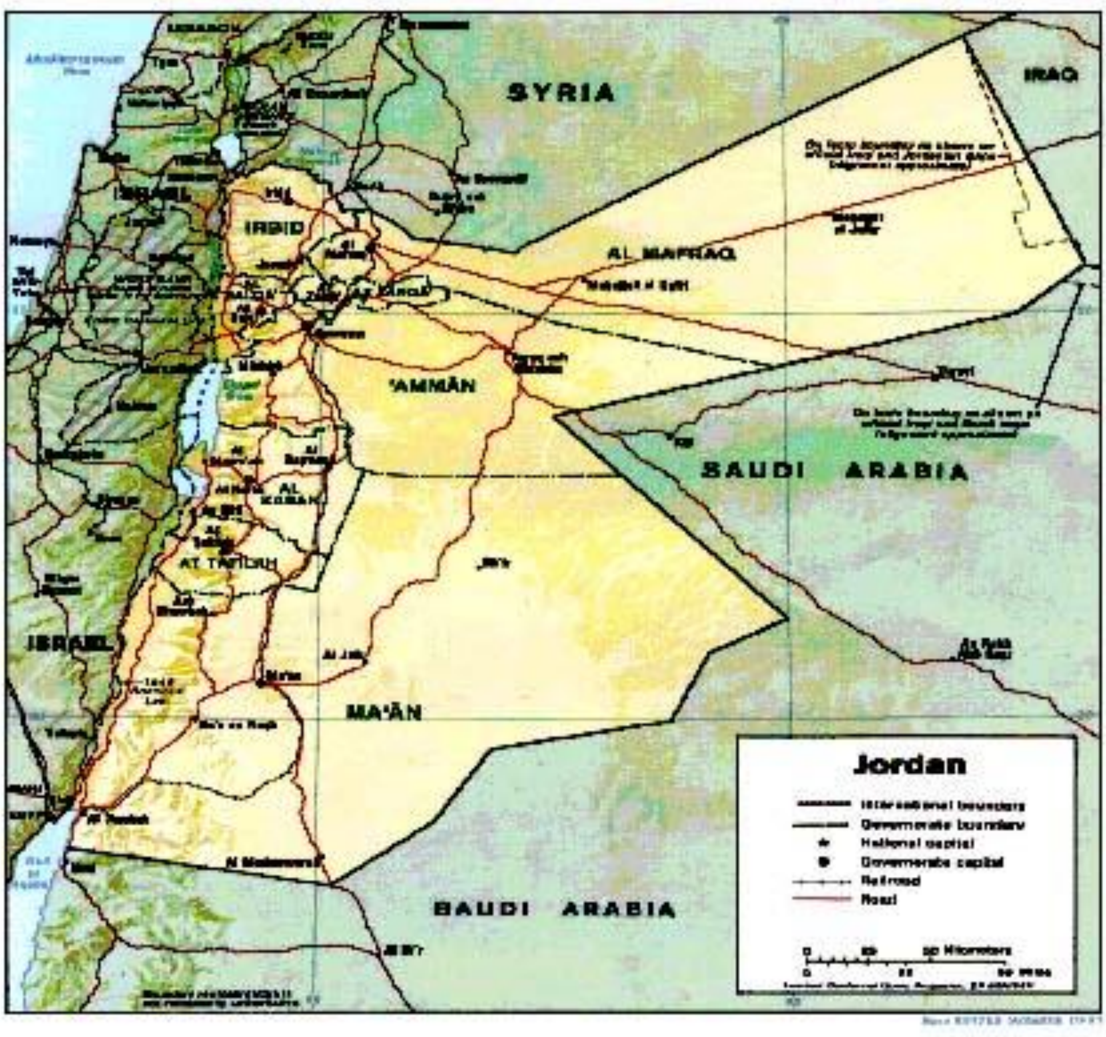


Figure 12: The Hashemite Kingdom of Jordan

4.2 Jordan Water Resources

Water resources in Jordan are dependent on the rainfall amount. Rainfall intensities vary from 600 mm in the north to less than 200 mm in the eastern and southern deserts, which form about 91% of the surface area. While the average total quantity of rainfall which falls on Jordan is approximately 7,200 MCM/year. Unfortunately, 85% of the rainfall, in approximation, evaporates back to the atmosphere while the rest flows in rivers and wadis. On the other hand, only 4% of the total rainfall volume recharge to groundwater (Ministry of Water and Irrigation, 2001).

There are three main water resources in Jordan: (1) surface water resources, which flows permanently in rivers, springs and flood flows, are about 693 MCM distributed unevenly in 15 basins, with high inter-seasonal and inter-annual variations and collective long term average base-flow for all basins of only about 359 MCM/year. (2) groundwater resource can be divided into renewable groundwater resources and nonrenewable groundwater resources. However, twelve groundwater basins have been identified in Jordan. Most basins are comprised of several groundwater aquifer systems. The long term safe yield of renewable groundwater resources has been estimated at 275 MCM/year (Ministry of Water and Irrigation, 2001).

Due to the scarcity of water from the two water resources, Jordan adopted the treated wastewater as a third source of water for irrigation practices. Treated wastewater generates at eighteen existing wastewater treatment plants covering the main cities. Unfortunately, industrial wastewaters from 61 factories are connected directly into sewage system that contributes 5,000 m^3/d.

4.3 The Study Area

The area of the study for this report consists from three major zones; the Northern zone, the Middle, and the Southern zone. The Northern zone extends from the upper north of the JV near Al-Addasiya and south to Baptism Site at the north of the Dead Sea. The Middle zone extends from Baptism Site to Wadi Araba (WA). And finally, the Southern zone that extends from WA to Aqaba port at the south of Jordan (**Figure 13**).

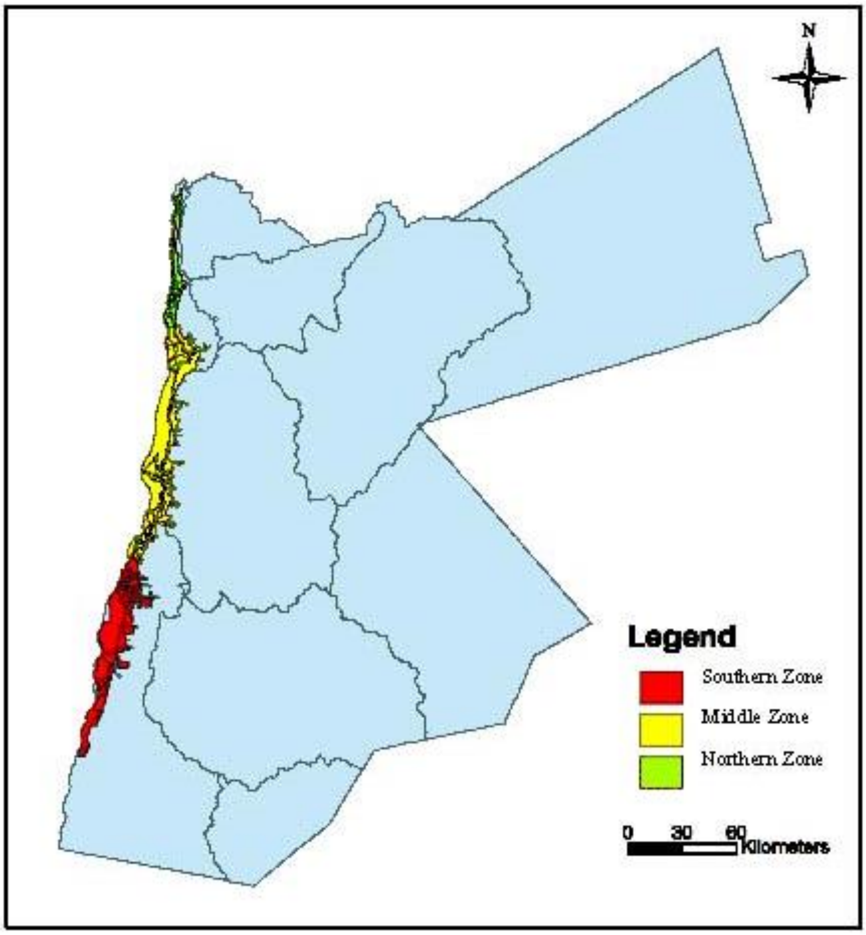


Figure 13: Study Area

4.4 Justification For Land Use Planning

As it is well known by now, there is a fresh water scarcity for irrigating agricultural crops in Jordan. Water quality has been altered considerably during the last decade, and therefore, due to improper agricultural plantation, crop and soil productivity is facing a new critical environment. One of the major solution to such a problem is to adopt new agricultural systems through providing a proper land use plan in order to enhance the crop, soil and water productivity within this new environment. However, total land use shifting will face social and economical barriers, and therefore, partial shifting is highly recommended. Such partial shifting might include plantation of less water intensive crops, establishing of aquacultures or fish farming, and introducing the agrotourism.

Redistribution of the main crops within this study area in the new land use plans is a critical demand to enhance the vertical economic return of the individual land unit as well as increase production quality according to the water status in Jordan. The main crops to be maintained are field crop (wheat), vegetables and field fruits (tomato, eggplants, pepper, etc., and fruit trees such as olive, citrus, banana, etc.) and livestock production (sheep, goats, cows, and camels) as popular crops. The suggested land use is based on studying the current popular crops planted within each zone and the crop suitability for soil and water characteristics of each zone or map unit.

One of the limiting factors facing the agriculture sector within semiarid and arid lands is the salt content of water used for irrigation and thus the soil-salt buildup due to improper agricultural management. Salt accumulation within the soil is function of the irrigated water quality, soil physical and chemical properties and the growing plant type and pattern. Soil affects salt accumulation by controlling the water flux density through the soil profile and the associated solute fluxes affected by mineral solubility and adsorption processes. At the same time, soils vary in their ability to adsorb and release ions by exchange and chemical transformations (Scott, 2000)

Salt effect on crop is primarily related to increase in soil osmotic potential. The osmotic potential, as part of total energy potential, is directly related to the total dissolved salt content in soil solution. Since plants absorb water as function of total potential gradient across the root membrane that is derived by evapotranspiration, the change in osmotic potential will diversely affect plant water absorption and thus the crop yield. As the potential of the soil solution increases, the absorption energy required to take up water by plant increases till reaching a point of a high osmotic potential where plant can not absorb water or generate forces to extract water from the soil profile. However, plants vary in their potential for water absorption. Some crops are able to tolerate salinity to a very high level by adjusting through either absorption of salts from the soil solution or synthesis of organic solutes. For example Halophyte tends to absorb salts and impound them in the vacuoles, while organic solutes serve the function of osmotic adjustment in the cytoplasm (FAO, 2002). Maas (1986) provided a list of tables reflecting the crop yield reduction according to salinity and the tolerance factor for a variety of plants.

The main sources of salt in soil are mineral weathering, irrigation water, crop type and soil cultivation practices as fertilization. Crops extract water from the rootzone resulting in an evapoconcentration of salts and other solutes in the soil solution that may precipitate if the solubility product of mineral exceeds through evapoconcentration. Since part of the study area is being irrigated by the effluent water from wastewater treated plants, it is highly recommended the use of different stress tolerant crop varieties to tolerate salt buildup in soil.

Although, planting of new crops native or water conserving that are best suited to local conditions require more social efforts in production and marketing arts, it is advisable to start planning such type of agricultural systems. Those new crops like green fodders, mangoes, avocados, dates, early seedless grapes, asparagus, more tolerant vegetables, fish farms, and forage plants are moderately tolerant to tolerant crops that tolerate salt stress in irrigated water and can be adopted to Jordan climatological environment.

4.5 Methodology Of Land Use Planning

Selection of the proper land use for each map unit and its subdivision was determined according to the following properties: (1) soil taxonomy, (2) water resources (quantity and quality), (3) soil salinity, (4) soil topography, (5) marketing, and (6) economy.

The planned agricultural land use planned at each study area depends directly and mainly on the available water resource for irrigation; primarily quality, and on the natural condition of the soil (salinity, texture, and slope). Subsequently, the agricultural land use plan of the each map unit was established on zoning process (i.e., the upper, middle, and the lower) according to the main water type currently used for agricultural practices.

The Ghor map unit for example located at the Northern zone of this study is divided into two parts; the upper and the middle. The upper Ghor map unit consists of non-saline soils of deep medium and fine textured Camborthids and Ustochrepts of moderately sloping where water resources are either rainfall or from Yarmouk river of high water quality (non-saline water) that lies above the command of King Abdullah Canal (KAC). Therefore, this zone has a high suitability for rainfed cereals. In the middle Ghor map unit, water resources vary dramatically from highly saline to saline, and therefore, the zoning includes three major parts; the non-saline KAC, saline-water of KTD zone, and the mixed water zone. Due to intensive non-managed agricultural usage of such land, salt has been accumulated considerable and therefore some areas may require a special leaching management or a proper irrigation management. The land suitability classification of such lands is of irrigable agriculture with proper management.

As a result, land suitability classification was established on the combination of both water resources type and the soil type for each soil unit map and its subsequent zoning. At the same time, the suggested plant tolerance type for each unit and its subdivision is tabulated according to Maas (1986) that was adopted by FAO 56 on the right hand of each land use table. The tolerance notations are HT for Highly Tolerant, T for Tolerant, MT for Moderately Tolerant, MS for Moderately Sensitive, and S for Sensitive.

Finally, the suggested agricultural land use were selected and tabulated on form of several choices starting from the best choice to the least suitable crop. For each group of crop tolerance as determined before according to Maas (1986) and adopted by FAO 56, the best plant or crop is determined according to (1) water demand (evapotranspiration), (2) crop ecology adopted from (Purdue University, 2004), and (3) socioeconomic aspects.

4.6 Land Use Plan

Within this section, each zone is subdivided into zones, where each zone is described in details. For each zone, the following study contains graphs showing relative map units exist within each zone, physiography of each map unit, soil taxonomy, water resources, the current land use, and the suggested land use including the limitations, advantages and opportunities.

4.6.1 The Northern Zone

The Northern zone lies within the JV that bounded on the west by Jordan River and at the east by the escarpment of the Northern Highlands. The valley resulted from major geological rifting along a vertical direction from Tiberius Lake in the north to Red Sea in the south, where the JV is laying in the northern part of the rift upstream the Dead Sea. The JV runs on from the African Rift, which is a collapsed ditch due to the spacing between the African and the Asiatic plates. Altitudes reach 300 to 450 meters below sea level; that is some 1,000 meters below the Jordan Highlands.

Twenty thousand years ago, the collapsed ditch was covered by a large lake, called Lake Lissan, which connected the Sea of Galilee to the Dead Sea. About 15,000 years ago, the lake disappeared slowly and the Jordan River began to dig its bed in the most recent lacustrine deposits. From this period, the JV was divided into three different soil map units, called Ghor, Katar and Zor (**Figure 14**). Due to the high variability of soil physical and chemical natures of those areas, the areas will be classified and planned separately.

Water resources at the JV are dependent on the rainfall amount. Precipitations range between 50 and 600 mm/year and rainfalls are mostly concentrated in the uplands running alongside the JV (Ministry of water and irrigation, 2001). Surface water resources (575 MCM/year) are mainly the Yarmouk River (40% of the global surface water) and the other eastern tributaries of the Jordan River called also side wadis. Jordan shares the exploitation of the Yarmouk River with Israel and Syria. Groundwater resources (275 MCM/year) in Jordan are divided in renewable and fossil water reserves. The available water resources are about 850 MCM/year with a total demand reaching now the 1,000 MCM/year.

The agricultural sector using around 64% of the total water resources in Jordan is also mostly located on the Jordanian Bank of the Jordan River basin. The irrigated area in the Jordan Valley is about 30,300 ha.

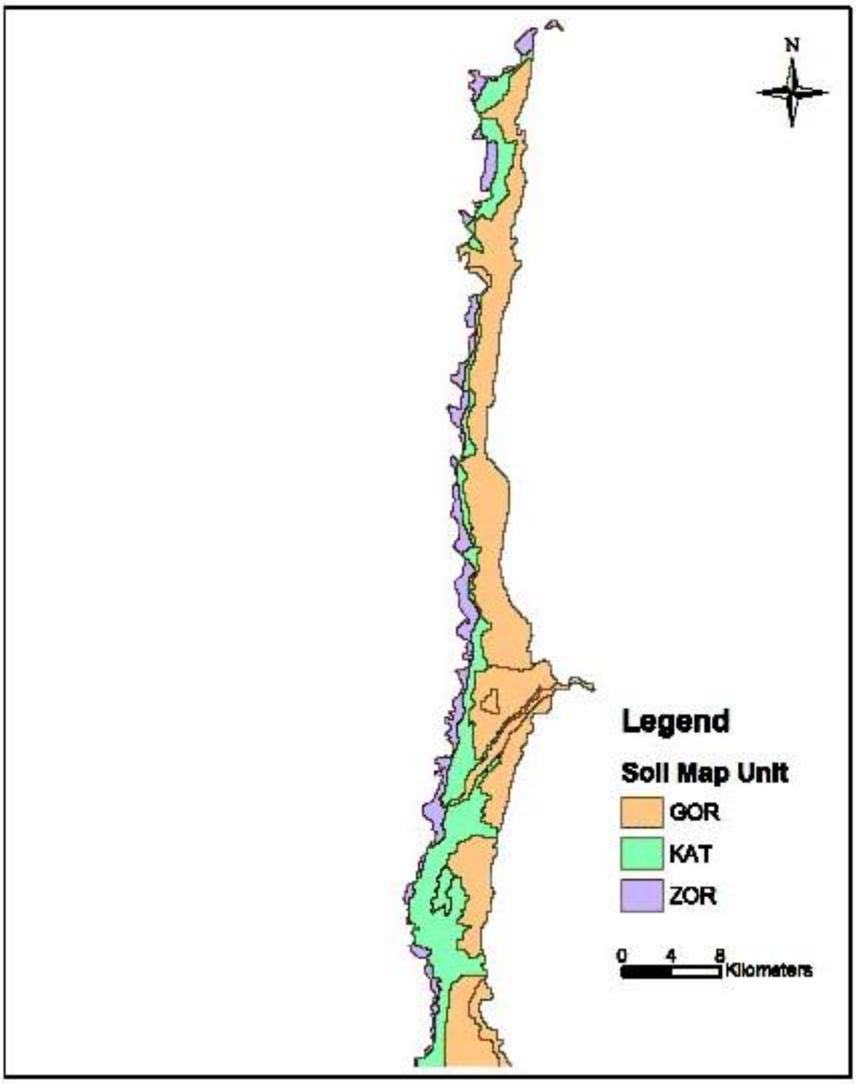


Figure 14: Soil Map Units at the Northern Zone

4.6.1.1 The Ghor

The current land use of Ghor map unit was following more or less the water quality distribution. According to current vegetative cover and water resources, the plantation at the Ghor can be classified into three major parts; the upper and the middle that lies within the Northern Area of the study area with this project, and the lower Ghor that lies within the Middle Area (**Figure 15**).

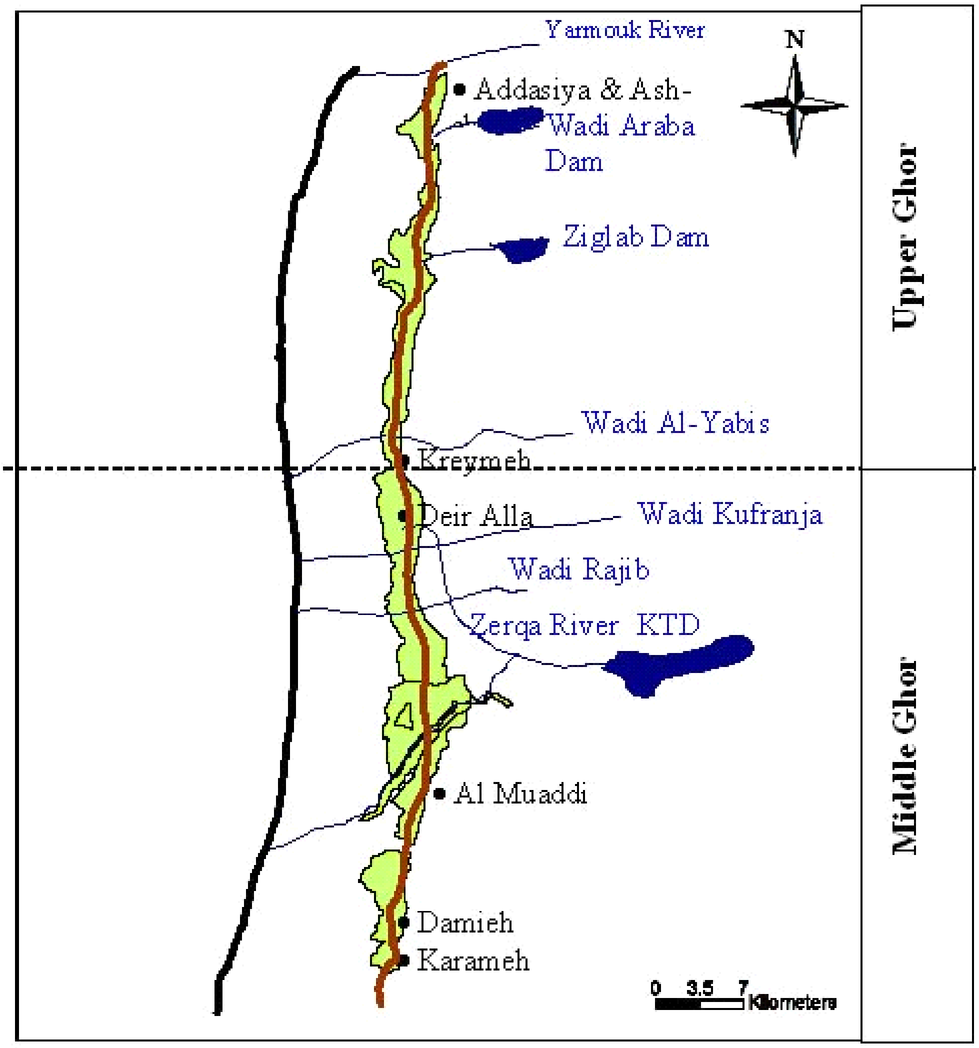


Figure 15: The Upper and the Middle Parts within Ghor Map Unit

(a) The Upper Ghor

Location

It represents the area that lies below the Yarmouk River through the village of North Shunah and Addasiya to the village of Kraymeh (**Figure 15**).

Physiography

The entire Ghor (also called Sahel) forms a continuous strip along the eastern edge of the JV Graben that occupies an area of 303 km^2 (Ministry of Agriculture, 1993). It is consisted from lacustrine deposits associated with alluvial fans and terraces of deep clay loam soils derived from erosion of the highlands. These deposits are deepest near their apices at the bottom of the escarpment, where they become stony, and gradually thins out towards the eroded edges between the Katar and the Zor. The soil is largely of calcareous origin with a cut through Zarqa and Shueib wadis with sandstone admixture lifted from Ajlun Group Limestones. Through a cross sectional view of the Ghor (**Figure 16**), the area varies according to slope from (1) steep, eroded, high angle alluvial fans, (2) moderately sloping stony to sand alluvial fans, (3) gently sloping fat loamy and silty alluvial fans. On the western side of the Ghor, the (4) Katar unit margins a slightly alluvium fans eroded by minor wadis, (5) some large wadis are slightly incised into fan alluvium and have bouldery floor, and (6) sometimes isolated hills on Lisan Formation protrude above the gently sloping fans and outcrops at the surface.

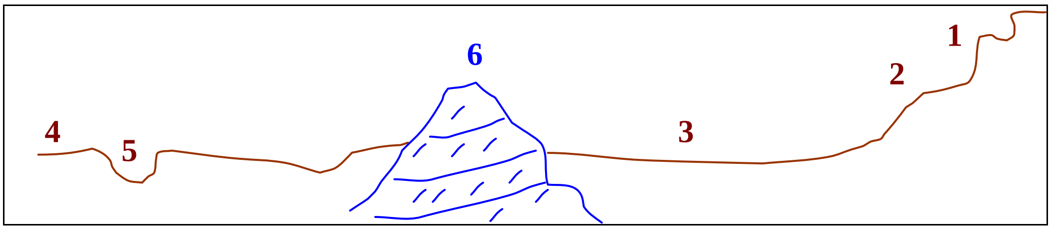


Figure 16: A Cross Section of the Ghor Map Unit

Soil Taxonomy (for all Ghor zones)

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Fine and loamy, mixed, hyperthemic, deep families of Ustochreptic and Ustollic Camborthids**: Yellowish brown (10YR 5\4-5\6) Ustochreptic and dark brown (10YR 3/3) Ustollic deep (>80 cm) silty clay loam, occasionally, silty clay; moderate and strong medium subangular blocky structure, with crumb structure in the upper horizons of the Ustollic subgroups; the higher organic matter of the Ustollic subgroup most likely due to land use and irrigation; organic matter contents highest in orchard crops which are not clean weeded; highly calcareous and weakly or non-saline; older gravely alluvium may occur within 60-80 cm on the upper margins of the units; occurs predominantly on facet (3) and occasionally on the lower margins of facet (2) with gradients < 2%.
2- **Loamy, mixed, hyperthermic, deep family of Ustochreptic Calciorthids:** Brown to dark brown (7.5YR 4\4) deep (>85 cm) clay loam and sandy clay loam: moderate medium and coarse subangular blocky structure: below 60-80 occurs 5YR 5\6 (yellowish red) gravelly loam, weathered older alluvium: very highly calcareous and weakly to non-saline: occurs on facet (5): gradients 2-7%.
3- **Loamy-skeletal, mixed, hyperthermic, deep (> 80 cm) family of Ustic Torriorthents and Torrifluvents**: Yellowish brown to dark (10YR 5\5 to 7YR 4\4) deep (>80 cm) very gravelly sandy loam and loam: weak medium subangular and angular block: very high calcareous and weakly saline: at times darker and redder older alluvium occurs below 100cm: occurs mainly on facet (1) and the upper part of facet (2): gradients 2-7%.
4- **Fine, mixed, hyperthermic, deep family of Typic Ustochrepts**: Dark brown and dark yellowish brown (7.5 YR – 10YR 4\4) deep (> 80cm) clay loam and light clay: weakly cracked surface: strong medium subangular block structure: highly calcareous and non-saline: occurs on facet (3) in the north of the unit: gradients <2%.

Water Resources

The main water source at the upper Ghor zone is the Yarmouk River that lies within the Yarmouk Rive sub-basin class according to water resources classification. The Yarmouk River contributes around 455 MCM to the Jordan River, however, recent analyses of discharge at Addasiya indicates a considerable decrease in the flow to around 380 MCM/year. According to Al-Jayyousi (1995), Jordan share from Yarmouk water is 100 MCM/year prior to the peace treaty, while other two riparian of Syria and Israel share 170 and 100 MCM/year, respectively. The water quality flowing within the river is considered of non-saline of very low electrical conductivity that is irrigable for even sensitive plants according to Baker-Harza (1955). The other small contributors for the upper Ghor zone are Wadi Arab Dam (with a storage capacity of 20 MCM), Wadi Jurum, Ziglab Dam, and Wadi Yabis which adds only water during winter.

Vegetation and Current Land Use

Twelve thousand years ago, the Ghor was covered by meadows including wild cereals. People who settled in these regions were the ancestors of the first farmers, as it happened in other places in the Middle-East. This zone stretches from the Hills to the Jordan River on a distance included between 15 and 25 km. Now almost the entire unit is under cultivation except that for the eroded high angle fans that has grass cover with some dwarf shrubs and herbaceous annuals and perennials in the north. In the drier south, the cover is sparser and more desertic.

Much of the land within the moderately sloping facet of the Ghor area lies above the command of the King Abdullah Canal (KAC), where wheat is grown in the north of this facet and sometimes with supplementary sprinkler irrigation. In the other parts of this facet, irrigated horticultural and tree crops are irrigated from groundwater. The main intensive agricultural area is found on loamy, silty, and clayey alluvial fan of the gentle sloping facet on which a range of horticultural crops and trees including bananas and oranges are grown through drip irrigation.

The current land use of Ghor map unit was following more or less the water quality distribution (**Figure 17**). At the first part of the upper Ghor (from Addasiya to Ziglab Dam near villages of Wadi Ryan), Citrus was and still the main crop. While at the second part of the upper Ghor (area located around the villages of Wadi Ryan and Kraymeh) is cultivated by vegetables in open field. The upper part of the Ghor was cultivated for long time since the beginning of the century with some vegetables on loamy soils and Banana on clayey soils till the construction of the King Abdullah canal in 1962. Such construction has altered and modified the land where the farmers have expand and adopted a new planting of citrus crops like mandarin, clementine and lemon and replaced bananas trees. From the seventeenth till the current day, farmers adopted very few new cultures but stayed really limited because farmers production market was more profitable than other trees.

On the other hand, mainly vegetables in open fields with some wheat and olive cover cultivate the second part of upper Ghor zone. This part also encountered the expansion of citrus but this expansion was reduced by the Jordan Valley Authority (JVA) regulation enforcement. Therefore, citrus cover is limited within this part.

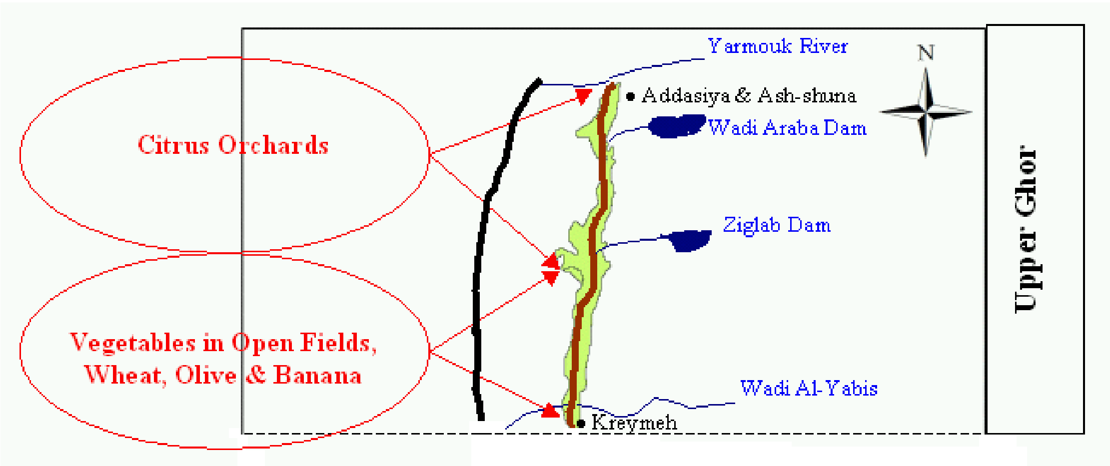


Figure 17: The Current Cropping Pattern at the Upper Ghor

According the government administrative division of statistics (**Table 19**), citrus is the most dominant crop in the Upper Ghor that accounts for 57% of the surface lands, while vegetables and cereals covers 17 and 14% of the total irrigated surface, respectively.

Table 19: Current Irrigated Vegetative Land Use in the Upper Ghor of the Jordan Valley

Kind of Crop	Irrigated Area (% of Total)	Irrigated Area (dunums)
Trees Crop	67.0	72,500
Olives	4.0	4,200
Citrus	57.5	62,200
Bananas	2.5	2,800
Others	3.0	3,300
Seasonal Crop	33.0	35,700
Barley and Wheat	14.0	15,100
Vegetables	17.5	19,000
Others	1.5	1,600
Total		108,200

Suggested Land Use Plan

Since the soils at the upper northern Ghor are non-saline (deep medium and fine textured Camborthids and Ustochrepts of either moderately sloping with stony soils or gently sloping) and the water resources are of high quality (either the natural rainfall that reaches sometimes 350mm or the high quality water of Yarmouk River), therefore, the land is highly capable for cereal production. It is suggested to use such lands for rainfed production. On the other hand, it is difficult to change the plant cover directly, therefore, as a matter of socioeconomic, it is better to leave the area for Citrus production as it is but with proper irrigation practice to achieve the best production with less water waste.

At the south side of the upper Ghor, the water availability reduces and therefore rainfed agricultural practices are smaller. The land suitability changes from rainfed to irrigable lands with moderately sensitive to moderately tolerant plants. Due to the high demands of citrus production, it is better to replace the citrus cover by Olive trees, Grapes, or Avocados as much as possible by keeping the citrus plants as a second choice.

Suggested Land Use Plan at the First Part of Upper Ghor

- **First choice is Citrus**
    - Limitations: Citrus is of high water demand that ranges from 900 to 1200 mm per growing period (an average of 1000mm) with a crop coefficient that varies from 0.65 to 0.75 at 70% canopy cover. Since Citrus very sensitive for frost, cold weather might cause a severe damage, and therefore, it should be planted within protected areas.
    - Opportunities and Advantages: It is difficult to change the plant cover directly, therefore, as a matter of socioeconomic, it is better to leave the area for Citrus production as it is but with proper irrigation practice through adapting drip irrigation with high efficiency. At the same time, this crop is considered a traditional food supply to the country within the Northern zone and therefore, it should stay to sustain traditional food and the living heritages within the Jordan Valley community.
- **Second choice: Grape**
    - Limitations: This crop has low limitations to be adapted at the Ghor area, however, if the water quality changed in future to more saline, then this crop may not tolerate the salinity since it is classified as moderately sensitive

crop, and thus the production quality and quantity might decrease (i.e. when the EC is above 2.5 mmhos/cm).

- Opportunities and Advantages: It is better to replace some of the existing crops with less water demanding crops to increase to water availability. Grape is of low water demand of 400-550 mm/growing period (with an average of 500mm) with low crop coefficient that varies between 0.3 to 0.8 at 70% canopy that can be grown on the Northern zone without any difficulties since its physiological demands (temperature, water, and soil) agrees with that at this zone for long, warm to hot dry summers and mild winters with mean daily temperature of at least 18°C.

- **Third choice is Olive**
    - Limitations: Olive with its botanical name Olea europaea has no limitations since it can tolerate up to EC of 8 mmhos/cm.
    - Opportunities and Advantages: Olives are supremely adapted to Mediterranean climates, and can be grown on a wide variety of soils. They are tolerant of high pH, salinity, excess boron, and drought, but are sensitive to flooding. It is of low water demand ranging from 400 to 700 mm/growing period (with an average of 600mm) and can adapt low rainfalls to about 200mm. It can tolerate cold hardiness approaching -15°C (5°F) in midwinter.
- **Fourth choice is Papaya.**
    - Limitations: This crop with the botanical name of Carica papaya has only a social limitation to be adapted at the Ghor since it never been introduced or cropped before. Farmers may refuse planting such new crop since it is not economically known. At the same time, if the water quality changed in future to more saline, then a different variety may be used as to tolerate the salinity, however, this crop is classified as moderately tolerant crop for salinity.
    - Opportunities and Advantages: Papaya is of moderate water demand ranging from 700 to 800 mm in summer months with average of 1000mm in dry conditions (an average of 88 mm), and with a good production with high economical return. It can be grown on a large range of soil ranging from warm temperate dry to moist through tropical very dry to wet forest life zones, papaya is reported to tolerate annual temperature of 16.2 to 26.6°C and pH of 4.3 to 8.0. Papaya is a tropical plant, killed by frost; does not tolerate shade, waterlogging, or strong winds, and may require irrigation in dry regions.
- **Fifth choice: Wheat**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.

Suggested Land Use Plan at the Second Part of Upper Ghor

- **First choice: Potato**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Potato with the botanical name of Solarium tuberosum is of low water demand ranging from 200 to 650mm/growing period depending on the growing season. It can be grown on four different seasons, during the beginning of autumn with an average water demand of 436mm, or at the middle of autumn with an average water demand of

282mm. It can also be grown during winter with an average water demand of 218 mm or at the spring with an average water demand of 359mm. Potato is considered a moderately sensitive crop concerning the salinity that can be grown on a wide range of soils ranging from boreal moist to wet through tropical very dry to wet forest life zone. Potato is reported to tolerate annual temperature of 3.6 to 27.8°C, and pH of 4.2 to 8.2. Potatoes are a cool weather crop, the optimal temperature for growth being 15–20°C for most cvs. Growth of tubers is best at soil temperature of 17–20°C, with usually no tubers formed above 32°C. They perform well on a wide variety of soils, sandy loams, silt loams, loams, and peats. Soil moisture tensions between 40 and 60 centibars seem to produce the best yields

- **Second choice: Broadbean-Corn**
    - Limitations: These crops have low limitations for adapting at the Ghor area, however, if the water quality changed in future to more saline, then these crops can not tolerate the salinity and thus the production quality and quantity might decrease.
    - Opportunities and Advantages: Broadbean is a winter crop of moderate water demand while Corn is a summer crop of low water demand (400-600 mm/growing period) and both are moderately sensitive for salt. Therefore, the annual water demand is about 800-1,000 mm with an average of 900mm. At the same time, such crop rotation type is important to stay within the Ghor area to sustain some of crop heritages along the community.
- **Third choice: Spinach-Squash**
    - Limitations: These crop have two no limitations to be adapted at the Ghor area. However, if the water quality changed in future to more saline, then these crops may not tolerate the salinity since they are classified as moderately sensitive crops.
    - Opportunities and Advantages: Spinach is a winter crop of low water demand while Squash is a summer crop with moderate water demand. The annual water demand for this cropping pattern is about 600-7,800 mm with an average of 700 mm.
- **Fourth choice is Olive**
    - Limitations: Olive with its botanical name Olea europaea has no limitations since it can tolerate up to EC of 8 mmhos/cm.
    - Opportunities and Advantages: Olives are supremely adapted to Mediterranean climates, and can be grown on a wide variety of soils. They are tolerant of high pH, salinity, excess boron, and drought, but are sensitive to flooding. It is of low water demand ranging from 400 to 700 mm/growing period (with an average of 600mm) and can adapt low rainfalls to about 200 mm. It can tolerate cold hardiness approaching -15°C (5°F) in midwinter.
- **Fifth choice: Avocado**
    - Limitations: This crop has two limitations to be adapted at the Ghor area. The first limitation is the social acceptance by farmers, and the second if the water quality changed in future to more saline, then this crop will not tolerate the salinity since it is classified as moderately sensitive crop.
    - Opportunities and Advantages: Avocado with the botanical name of Persea americana is of low water demand ranging from 500 to 750 mm (with an average of 650 mm) with low crop coefficient (0.6-0.85 at 70% canopy). It can tolerate salinity if using different varieties that has been tested in Israel such as Fuch-20 as a rootstock that can tolerate the salinity up to 380-400ppm. The avocado tree is remarkably versatile as to soil adaptability, doing well on such diverse types as red clay, sand, volcanic loam, lateritic soils, or limestone. The desirable pH level is generally considered to be

between 6 and 7, but, in southern Florida, avocados are grown on limestone soils ranging from 7.2 to 8.3.

(b) The Middle Ghor Zone

Location

It represents the area that lies between the villages of Kraymeh and Karameh near Baptism Site (**Figure 15**).

Physiography (same as Upper Ghor)

Soil Taxonomy (same as Upper Ghor)

Water Resources

At the middle Ghor zone, there are several side wadis that contribute the main flow of the river. The main tributary is the Zarqa River with an annual contribution of 62 MCM/year and the wastewater treatment plants contribute 35 MCM according to 1994 statistical analyses. Most of the Zarqa River water plus the treated wastewater are stored within the King Talal Reservoir (KTR) with a storage capacity of 86 MCM. Others contributes only add a small amounts to the Jordan River like Kufranja and Rajib that only add water in winter (Ministry of Water and Irrigation, 2001).

The water quality at this zone changes dramatically from fresh to saline due to mixing by treated wastewater from the KTD, therefore, in reality, there are three different agricultural patterns zoning within the middle Ghor that are related to water quality. The fresh water of the JV from the village of Kraymeh in the North to the village of Deir Alla in the South is contributed by additional water supply from Wadi Kufranja and Rajib and is intensively used for vegetable production under greenhouses.

Vegetation and Current Land Use

At the middle Ghor and around the KTD (the triangle of Zarqa) above Deir Alla village, the water is highly saline and the soil is building up salinity (where land reclamation is expensive and difficult), therefore, the cropping pattern at this area is of low productivity and dominated by tolerant plants of Barley and Wheat crops, in addition to small vegetable farms under greenhouses (**Figure 18**).

At the second part of the middle Ghor which lies south of Deir Alla village and along Al Muaddi to Karameh village and to Baptism Site, the saline water from the KTD is mixed with the fresh water of the Yarmouk River to form a new water quality of less salinity in the Canal, but still of high total dissolve salts and is being used to irrigate vegetables in open fields and large farms owned by important owners or institutions like the Ministry of Agriculture, the University of Jordan and some princes of the royal family on salty and sandy soils (of an excess of calcium and a lack of iron that are badly drained). These large farms are mainly planted with citrus or palm trees and constitutes around 70% of the surface in this area. At the South of Damieh village, there isn't anymore citrus farm because soils seem to be too salty. Those lands around the Karameh village are building up salinity, and therefore, they require a special drainage control or farming management to improve soil physical and chemical productivity.

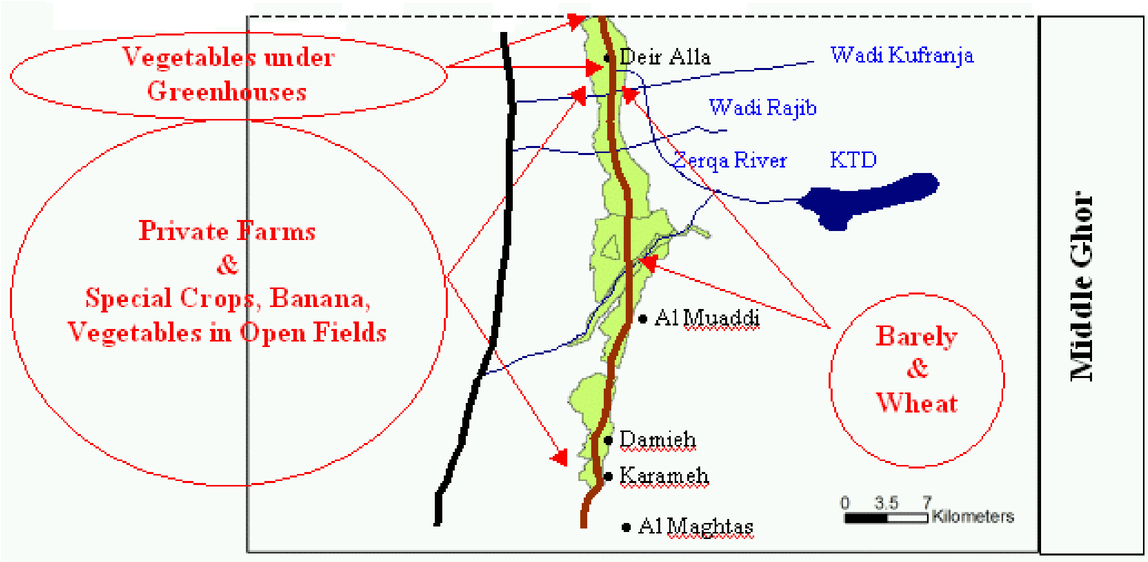


Figure 18: The Current Cropping Pattern at the Middle Ghor

According the government administrative division of statistics of 2002 (**Table 20**), 56% of the total land area is being cultivated by vegetable crops under greenhouses, while crop trees counts for 27% of the total land area. The area covered is centralized around the village of Deir Alla at the middle of the JV. On the other hand, Bananas, Wheat and olive trees are almost negligible at the middle Ghor, while some of moderately tolerant to tolerant trees of grapes and dates are cropped in some large farms.

Table 20: Current Irrigated Vegetative Land Use in the Middle Ghor of the Jordan Valley

Kind of crop	Irrigated Surface(% of total)	Irrigated Surface (dunums)
Trees crop	**27**	**19 200**
Olives	2	1 300
Citrus	16	10 900
Bananas	1	460
Grapes	4.5	3 100
Dates	3.5	1 700
Others		1 700
Seasonal crop	73	52 000
Barley and Wheat	12	8 300
Vegetables	56	39 900
Others	5	3 800
Total	**100**	**71 200**

Suggested Land Use Plan

In the middle Ghor, water resources vary dramatically from highly saline to saline, and therefore, the zoning includes thee major parts; the non-saline water from KAC, the KTD zone, and the mixed water zone. Due to intensive non-managed agricultural usage of such land, salt has been accumulated considerable and therefore some areas may require a special leaching management or a proper irrigation management. The land suitability classification of such lands is of irrigable agriculture with proper management. The upper middle Ghor can be planted by vegetables under greenhouses with Tomatoes, Spanish, etc. The KTD zone lands should be planted by only high tolerant plants like Barley and wheat. On the other hand, the mixed water can be grown by Palm trees. The Banana trees at the southern Ghor is suggested to be shifted to the mixed zone.

Suggested Land Use Plan at the KAC Zone of Middle Ghor

- **First choice is Squash (zucchini)**
    - Limitations: There are no limitations for using such a crop.
    - Opportunities and Advantages: The squash of the botanical name of C. pepo melopepo can be grown on wide range of soils, moderate sensitivity to soil salinity with water demand ranging from 400 to 600 mm/growing period depending on the growing season. It can be grown either.during spring with average water demand of 450mm, or during summer with 550 mm or during autumn wit an average water demand of 370 mm.
- **Second choice: Asparagus**
    - Limitations: The only limitation for this crop is the social acceptance by farmers and the community.
    - Opportunities and Advantages: This crop with the botanical name of Asparagus officinalis is of very low water demand that ranges from 310 to 600 mm (with an average of 450mm). It has a high tolerance to water and soil salinity. The asparagus plant has an extensive root system (often more than 10 feet per plant) and needs an open, well-drained soil for maximum development. Deep, loose soils such as mucks and light sandy loams are ideal. Asparagus will tolerate a slightly alkaline soil but not extremely acid.
- **Third choice is Tomato**
    - Limitations: Tomato is considered a moderately sensitive crop that might be affected by saline water.
    - Opportunities and Advantages: This crop with the botanical name of Lycopersicon lycopersicum is the most known and commercially used crop in Jordan, and therefore, it should be stay to keep the heritages of such crop between the community and the industrial section. This crop can be grown on wide range of soils types, but a deep, loamy, well-drained soil is ideal. Tomatoes grow best in a slightly acid soil with a pH of 6.2-6.8. Its water demand varies from 400 to 600 mm per growing period depending on the growing season type. It can be either planted on open field during autumn season with an average water demand of 417 mm, or in plastic houses during autumn with an average water demand of 280 mm, or during winter season with an average water demand of 240 mm.
- **Fourth choice: Cucumber**
    - Limitations: This crop has only one limitation if the water quality changed in future to more saline, then this crop will not tolerate the salinity since it is classified as moderately sensitive crop.
    - Opportunities and Advantages: This crop with the botanical name of Cucumis sativus is of low water demand ranging from 200 to 400mm depending on the growing cultivation type. It can be grown at the JV during autumn season with an average water demand of 380 mm or under plastic houses with an average water demand of 160 mm.
- **Fifth choice: Artichoke**
    - Limitations: The only limitation for this crop is the social acceptance by farmers and the community.
    - Opportunities and Advantages: this crop with the botanical name of Helianthus tuberosus is of very low water demand that ranges from 300 to 600 mm (with an average water demand of 450 mm) and is considered a highly tolerant to saline water. The Jerusalem artichoke is a suitable crop in any soil and climate where corn will grow. It survives in poor soil and in areas as cold as Alaska. It tolerates hot to sub-zero temperatures. The first frost kills the stems and leaves, but tubers withstand freezing for months. It grows best in a loose circumneutral loam, and in full sun, but can tolerate

some shade. Plants do not flower in northern Europe. Plants are sensitive to day-length, requiring longer periods from seedling to maturation of plant, and shorter periods for tuber formation. They do not grow where day-lengths vary little. It can be grown on wide zones ranging from cool temperate steppe to wet through tropical dry to moist forest life zones, Jerusalem artichoke is reported to annual temperature of 6.3 to 26.6°C, and pH of 4.5 to 8.2.

Suggested Land Use Plan at the KTD Zone of Middle Ghor

- **First choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438 mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60-70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7-8.
- **Second choice: Wheat**
  - Limitations: This crop has no limitations for adapting at the Ghor area.
  - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435 mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.
- **Third choice: Rye**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop with the botanical name of Secale cereale can tolerate annual precipitation ranging from 220 to 1,760 mm with an average of 790 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, rye considered a very high tolerance to saline water.
- **Fourth choice is Date Palm**
  - Limitations: The only limitation for this plant is the availability of seedlings for cultivation.
  - Opportunities and Advantages: This plant with the botanical name of Phoenix dactylifera can be grown on wide range of zones ranging from tropical desert to moist through warm temperate Tthorn (with mild frost) to dry forest life zones. Date palm is reported to tolerate high soil and water salinity, very tolerant of alkali soils with high water demand of around ranging from 310 to 4,030 mm (with an average of 1,200 mm). It can tolerate annual temperature of 12.7 to 27.5°C, and pH of 5.0 to 8.2
- **Fifth choice: Bermudagrass**
  - Limitations: There is no limitation for this crop.

- Opportunities and Advantages: Bermudagrass of the botanical name of Cynodon dactylon is reported to tolerate annual precipitation of 90 to 4290 mm (with an average of 1,000 mm), annual temperature of 5.9 to 27.8°C, and pH of 4.3 to 8.4. It is considered highly tolerant to saline water. It can be grown on wide zones ranging from cool temperate steppe to wet through tropical desert to wet forest life zones. It can form dense cover in almost pure stands, practically anywhere. Abundant as weed along roadsides, in lawns, on sandy wastes, along sand dunes, and readily takes possession of any uncultivated area. Plants withstand long periods of drought.

Suggested Land Use Plan at the Mixed Zone of Middle Ghor

- **First choice: Barley**
    - Limitations: There is no limitation for this crop to be used at this zone.
    - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7-8.
- **Second choice: Safflower**
    - Limitations: The only limitation is the social acceptance by farmers and the community.
    - Opportunities and Advantages: Safflower with the botanical name of Carthamus tinctorius can be grown in the temperate zone areas where wheat and barley do well ranging from cool temperate steppe to moist through tropical desert to tropical dry forest life zone. Safflower is reported to tolerate annual precipitation of 400 to 650mm per growing season (with an average of 550mm),annual temperature of 6.3 to 27.5°C, and pH of 5.4 to 8.2. It is considered a moderately tolerant to saline water. Safflower grows slowly during periods of cool short days in early part of season. Seedlings can withstand temperatures lower than many species; however, varieties differ greatly in their tolerance to frost; in general, frost damages budding and flowering thus reducing yields and quality. Safflower is a long-day plant, requiring a photoperiod of about 14 hours. It is about as salt tolerant as cotton, but less so than barley.
- **Third choice: Red Beet**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: Red Beet with the botanical name of Beta vulgaris is of very low water demand ranging from of 230 to 1150 mm with an average of 450 mm. It can be grown in zones ranging from boreal moist to rain through tropical very dry forest life zones. Beet is reported to tolerate annual precipitation Beet is moderately tolerant to saline water that is reported to tolerate annual temperature ranging from 5.0 to 26.6°C, and pH of 4.2 to 8. Beets and their relatives require a cool climate, and are able to withstand mild frost. Beets grow well in a variety of soils, growing best in a

deep, friable well-drained soil abundant with organic matter, but poorly on clay. Optimum pH is 6.0–6.8, but neutral and alkaline soils are tolerated in some areas. Some salinity may be tolerated after the seedling stage. Beets are notable for their tolerance to manganese toxicity.

- **Fourth choice: Grape**
  - Limitations: This crop has low limitations to be adapted at the Ghor area, however, if the water quality changed in future to more saline, then this crop may not tolerate the salinity since it is classified as moderately sensitive crop, and thus the production quality and quantity might decrease (i.e. when the EC is above 2.5 mmhos/cm).
  - Opportunities and Advantages: It is better to replace some of the existing crops with less water demanding crops to increase to water availability. Grape is of low water demand of 400-550 mm/growing period (with an average of 500mm) with low crop coefficient that varies between 0.3 to 0.8 at 70% canopy that can be grown on the Northern zone without any difficulties since its physiological demands (temperature, water, and soil) agrees with that at this zone for long, warm to hot dry summers and mild winters with mean daily temperature of at least 18°C.
- **Fifth choice is Date Palm**
  - Limitations: The only limitation for this plant is the availability of seedlings for cultivation.
  - Opportunities and Advantages: This plant with the botanical name of Phoenix dactylifera can be grown on wide range of zones ranging from tropical desert to moist through warm temperate thorn (with mild frost) to dry forest life zones. Date palm is reported to tolerate high soil and water salinity, very tolerant of alkali soils with high water demand of around ranging from 310 to 4,030 mm (with an average of 1,200 mm). It can tolerate annual temperature of 12.7 to 27.5°C, and pH of 5.0 to 8.2.

4.6.1.2 The Katar

(a) Location

The *Katar* is a thin strip made of outcropping calcareous marls running along the margins of the Jordan River channel in the northern side of the Garben and wides more in the southern part.

(b) Physiography

The eroded parts of recent alluvium and colluvium deposits along with the Pleistocene lake deposits forming a dissected lacustrine plain (Ministry of Agriculture, 1993). According to the cross sectional map (**Figure 19**) shows five different unique portions; (1) the flat to gently undulating with a thin cover of recent fan alluvium at the eastern portion of the plain, (2) the undulating and weakly dissected at the western part of the plan along the valley, (3) the deeply dissected badland slopes of the western margin, (4) the colluvial fans that fill the erosion valleys, and (5) the alluvial fans passing into the recent alluvium of the Jordan River.

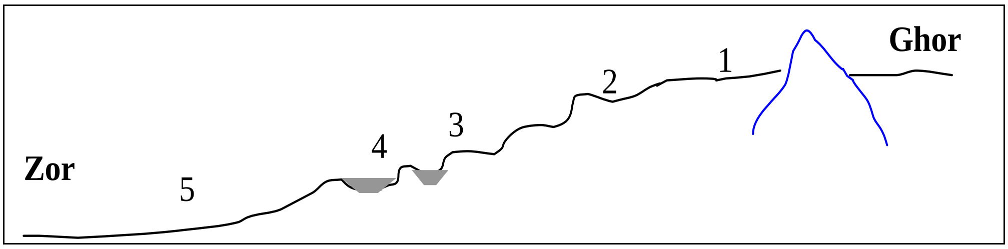


Figure 19: A Cross Section of the Katar Map Unit

(c) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Fine, mixed, hyperthermic, deep complex of families of Ustochreptic and Ustollic Camborthids:** Dark brown and dark yellowish brown (10YR 3\3-3\4) clay loam and silty clay loam: moderate fine subangular blocky becoming angular and platy with depth: high calcareous and moderately saline: occurs on facets (1), (2), (4), and (5) in the ustic-aridic moisture regime: gradients <2%.
2- **Fine, mixed, hyperthermic, deep family of Ustic Torriothents:** Light gray and light olive gray (10YR 7\2-6\2) deep (>80cm) clay, and silty clay loam: well defined varving of the original lacustrine material gives medium and fine platy structure: highly calcareous and moderately saline with gypsum below 150cm: occurs on facet (3) gradients 2-50%.
3- **Fine, mixed, hyperthermic, deep family of Cambic Gypsiorthids:** Brown (10YR 5\2-5\4) deep (>80cm) silty clay loam and silty clay: weak medium angular blocky structure: red silty clay loam and clay loam fan material in cracks: lustrous gypsum also occurs in cracks: highly calcareous and very saline: occurs on facets (1) and (2) in the arid section of the unit: gradients <2%.

(d) Vegetation and Current Land Use

This map unit has a restriction for land use since they are moderately to high saline, has a very low permeability were leaching of salt is very difficult, and the erosivity is very high along the margins due to high slope. Therefore, according to FAO classification for steep saline lands, it is highly restricted for forestry use only or for grazing. The salt accumulation within this map unit limits the plant growth to very salt tolerant plants like Halophytes only. In fact, these lands considered badlands of poor vegetation that are dominant mainly by *Ziziphus*.

As a conclusion of above, the recommended land use should restricted to protected areas from erosion by enhancement of natural wild grown plants within the area and should not be cultivated or used for agricultural practices.

(e) Suggested Land Use Plan

Since the Katar map unit is a thin strip made of outcropping calcareous marls of a moderately to high saline soils with very low permeability (badlands), leaching of salt is very difficult and extremely expensive, therefore, there is a highly restriction for its land use. The erosivity potential is also very high along the margins due to high slope. Such lands according to FAO classification is highly restricted for forestry use only or for grazing, and therefore, the planned land use for this unit should be on facets (1) and (2) with a very high salt tolerant plants like Halophytes only. The second choice is to restrict its land use as a protected areas of wild grown plants or forages plants.

Suggested Land Use Plan at the Katar Map Unit

- **First choice is Protected**
    - Limitations: no limitations.
    - Opportunities and Advantages: It is very difficult to mange this soil since it is highly saline that requires extremely extensive and expensive drainage system. And the erosivity potential is also very high, it better to keep those lands protected or to be used for other landuse purposes.
- **Second choice is Saltgrass**
    - Limitations: There is no limitation for using this crop.
    - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500mm (with an average of 400mm). It can tolerate draught too.
- **Third choice: Barley**
    - Limitations: There is no limitation for this crop to be used at this zone.
    - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Fourth choice: Rye**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop with the botanical name of Secale cereale can tolerate annual precipitation ranging from 220 to 1,760 mm with an average of 790 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, rye considered a very high tolerance to saline water.
- **Fifth choice: Wheat**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.

4.6.1.3 The Zor

(a) Location

The Zor map unit composed from a narrow flood plain of the Jordan River that occupies 65 km^2 that extends from the junction of the Yarmouk River to the north Dead Sea in the south of JV.

(b) Physiography

According to the cross sectional area of the Zor map unit (**Figure 20**), the Zor composed from (1) the meandering channel of the JR, (2) narrow levees, (3) flat alluvial cover plain, (4) cut-off meanders with sand bars of the JR channel, (5) older alluvial terraces, and (6) low lying saline plain around the Dead Sea (Ministry of Agriculture, 1993).

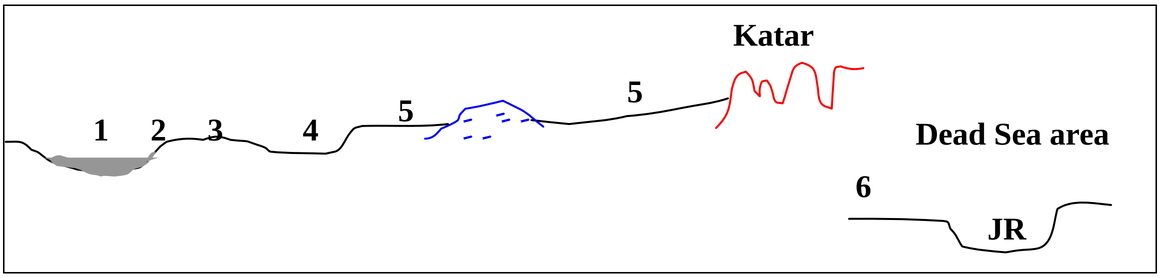


Figure 20: A Cross Section of the Zor Map Unit

(c) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Fine, mixed, hyperthermic, deep family of Ustollic Camborthids**: Dark brown (10YR 3\3-4\3) deep (>80cm) clay loam to clay: strong medium and fine subangular block structure with deep organic surface horizons: moderately calcareous and weakly to non-saline: water table between 100-200cm: occurs on floodplain facet (3) and leeves (2): gradients < 20%.

2- **Fine, mixed, hyperthermic, deep family of Ustochreptic Camborthids**: Brown to strong brown (7.5YR 4\4-5\6) deep (>80cm) silt clay loam: alluvial gravels occasionally occur below 100cm: moderate medium and fine subangular blocky structure: moderately calcareous and weakly saline: occurs on older alluvial terraces of facet (5): gradients <2%.

3- **Loamy, mixed, hyperthermic, deep family of Fluventic Ustochrepts**: Brown to dark brown (10YR 4\3) deep (>80cm) fine sandy clay loam and loam: original depositional layering evident: moderate medium and fine subangular and angular blocky structure: moderately calcareous and non-saline: occurs on facet (4) and (5) and occasionally (3) in the north of the unit: gradients < 2%.

4- **Fine, mixed, hyperthermic, deep family of Aquatic Ustifluvents**: Very dark grayish brown (10YR 3\2) clay overlying olive gray (5YR 5\2-4\2) clay: fine depositional varying visible: medium fine subangular block structure in topsoil, moderate coarse angular and subangular blocky structure in subsoil: moderately calcareous and non-saline: water table at 100cm but portable between 150-200cm: occurs on lowlyig parts of coverplain (3): gradients < 1%.

(d) Vegetation and Current Land Use

The Zor map unit is composed of calcareous alluvial soils (loamy sand near the river, clay loam towards the Katar) which originally was covered by meadows liable to flooding and by forests of tamarisks and poplar trees. The Zor unit can be classified into two main zones according to rainfall amounts. The northern zone receives a high rainfall where the soils of facet 3, 4 and 5 are suitable for cropping rainfed plants. The marginal zone at the center of Zor unit receives less rainfall, and therefore, has no suitability for cropping rainfed plants, however, soils of facet 4 and part of 3, where occasional flooding takes place, are suited for irrigated crops.

(e) Water Resources

(f) Suggested Land Use Plan

The Zor map unit soils are flood plains of deep fine textured soils. At the northern areas, which receive high rainfall, the soil are suitable for rainfed coping like Wheat and Barley and vegetables in open fields. On the other hand, the southern areas have very small capability for irrgable production, and therefore, it is suggested for fish farming mainly, while some can be used for forages with high tolerant crops like Barley and some Ornamentals.

4.6.2 Suggested Land Use Plan at the Zor map unit:

- **The first choice: Wheat**
  - Limitations: This crop has no limitations for adapting at the Ghor area.
  - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.
- **The second choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7-8.
- **Third choice: Saltgrass**
  - Limitations: There is no limitation for using this crop.
  - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500 mm (with an average of 400 mm). It can tolerate draught too.
- **Fourth choice: Wheatgrass**
  - Limitations: There is no limitation for this crop.

- Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600mm (with an average of 400mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.

- **Fifth choice: Bermudagrass**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: Bermudagrass of the botanical name of Cynodon dactylon is reported to tolerate annual precipitation of 90 to 4,290 mm (with an average of 1,000 mm), annual temperature of 5.9 to 27.8°C, and pH of 4.3 to 8.4. It is considered highly tolerant to saline water. It can be grown on wide zones ranging from cool temperate steppe to wet through tropical desert to wet forest life zones. It can form dense cover in almost pure stands, practically anywhere. Abundant as weed along roadsides, in lawns, on sandy wastes, along sand dunes, and readily takes possession of any uncultivated area. Plants withstand long periods of drought.

4.6.3 The Middle Zone

This part represents the lands that extend from Baptism Site near As Shuna (which is a part of the JV) on the north of the Dead Sea and the Dead Seat to the south till the beginning of Wadi Araba. The Dead Sea area composed from four main map units within the Dead Sea area and three map units within the southern part of JV (**Figure 21**), those map units are (1) lower Ghor, (2) lower Katar, (3) lower Zor, (4) Himara (Him) unit composed from dissected escarpment on Kurnub sandstone passing into Paleozoic sandstones, (5) Lisan (Lis) which is the undulating lacustrine plain, (6) Dhira (Dhi) consisting from Quaternary piedmont alluvial fans overlying Tertiary calcareous rocks, and (7) Safi (Saf) which is consist of medium and low angle piedmont fans.

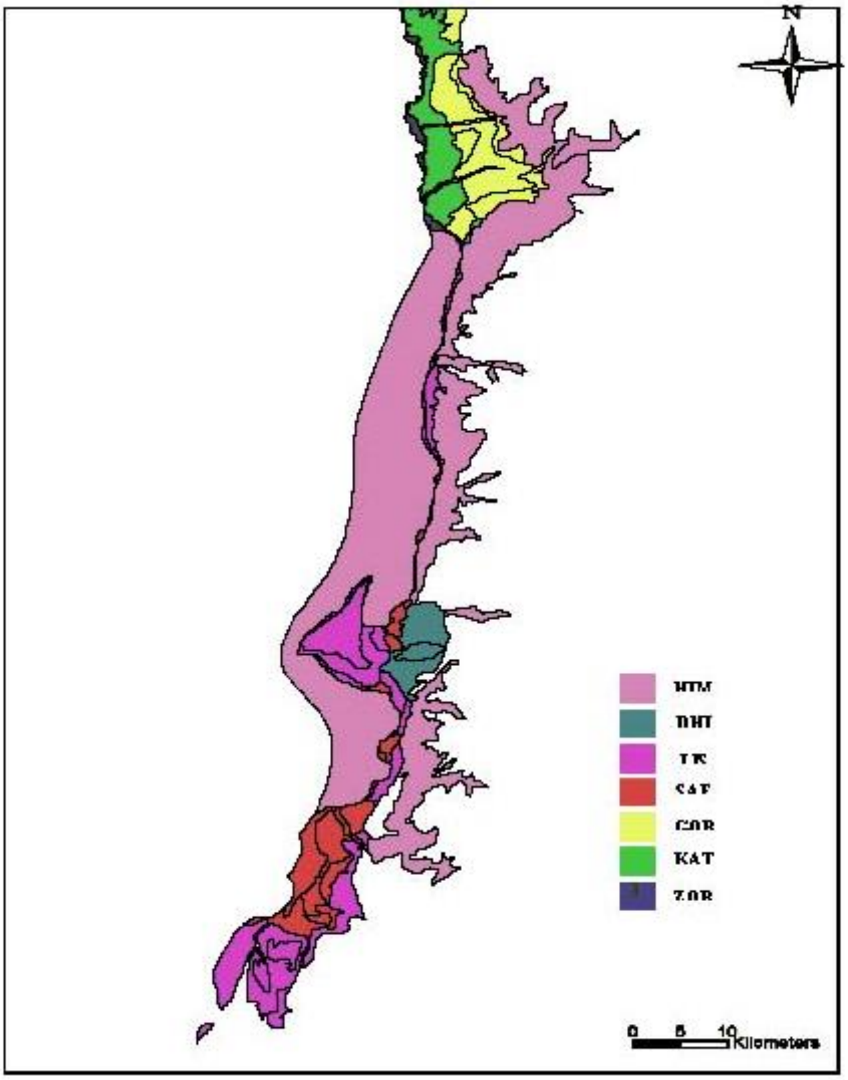


Figure 21: Soil Map Units at the Middle Zone

4.6.3.1 Ghor

(a) Physiography (have been discussed before)

(b) Soil Taxonomy (have been discussed before)

(c) Water Resources

At the Southern zone of the Ghor, there are three main water resources; Shueib dam, Kafrein Dam, and Wadi Hisban. The main river still encountering a high salinity during the base flow, however, during winter the small wadis water is mixed with the saline water at the main river and alter its salinity. This is the main reason of the intensive farming practices during the winter season at the southern Ghor.

(d) Vegetation and Land Use

The third zone within the Ghor area is the southern Ghor that lies between the village of Baptism Site to the Dead Sea This zone considered the largest part of the JV that extends between 9 and 12 km in the south against a maximum of 7.5 km in Karameh. The soils associated around the Jordan River are non-irrigable since they are highly saline and because of lack of irrigation or water divergence network. Farms within this zone depends more on groundwater resources for irrigation, unfortunately, the salinity of this water resource is deteriorating day by day to form a brackish wells.

There are two main sub-divisions of land cropping that depends mainly on water supply. The upper part (area stretches over along the 14.5 km of the King Abdullah Canal) that represent the uncontrolled portion of KAC where extra water which reaches the end of the canal section flows without any control in the concrete canal (**Figure 22**). Which give a chance for the farmers to pump their water needs from the canal directly. Additional seasonal water flows from Shueib dam to King Abdullah canal. The farmers have the right for this water as a share free of charge for use. Within this area and due to the abundance of various types of water, farmers are growing a little numbers of vegetables farms in open field or under greenhouses and a lot of bananas farms.

The second division represents a new water resource from Kafrein Dam and Wadi Hisban that never reach the KAC, which is not free of charge. The farmer use this type of water in addition to the private wells as a mix since their own private wells are saline to irrigate their bananas farms.

According the government administrative division of statistics (**Table 21**), the dominant cropping pattern used is Banana that covers approximately 33.5% of the total land area, while 37 % is being cultivated by vegetable and only 10 % by salt tolerant plants like Barley and Wheat.

Table 21: Current Irrigated Vegetative Land Use in the Middle Jordan Valley

Kind of crop	Irrigated Surface(% of total)	Irrigated Surface (dunums)
Trees crop	**48.0**	**14 900**
Olives	4.5	1 400
Citrus	6.0	1 800
Bananas	33.5	10 400
Others	4.0	1 300
Seasonal crop	**52.0**	**16 200**
Barley and Wheat	10.0	3 200
Vegetables	37.0	11 600
Others	5.0	1 400
Total	**100**	**31 100**

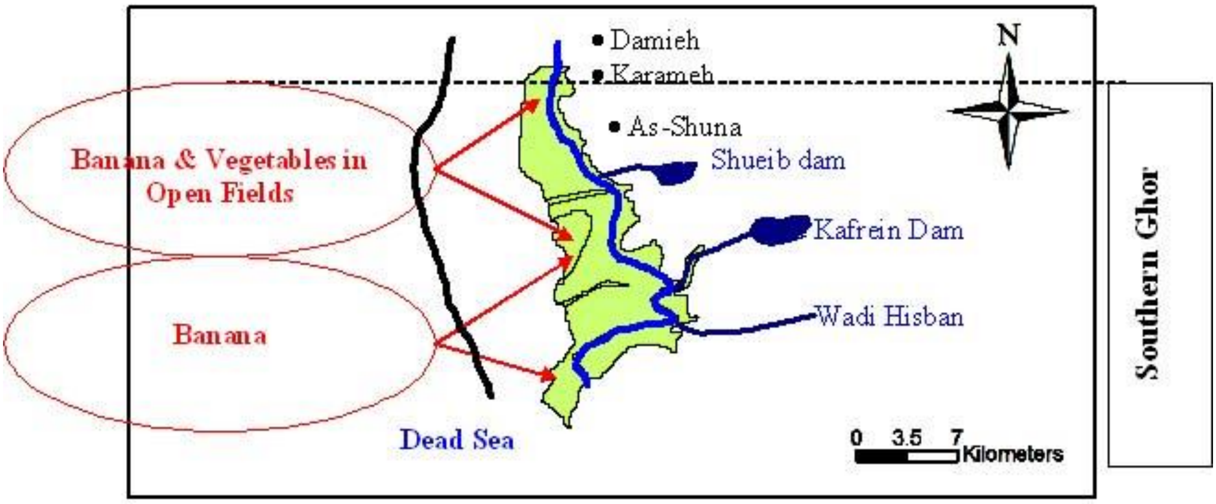


Figure 22: Current Cropping Pattern at the Ghor Map Unit within Middle Jordan Rift Valley

(e) Suggested Land Use Plan

The main water is highly saline and sometimes floods of fresh water from wadi are encountered where water is mixed with the saline water at the main river and alter its salinity. Therefore, the intensive farming practices during the winter season. The upper part that represent the uncontrolled portion of KAC along with additional seasonal water flows from Shueib dam to King Abdullah canal is suitable for tolerant to high tolerant plant production, and therefore, we suggest the replacement of Banana by Palm trees, Figs, and Papaya.

Suggested Land Use Plan at this part of Ghor Map Unit

- **First choice: Date Palm**
  - Limitations: The only limitation for this plant is the availability of seedlings for cultivation.
  - Opportunities and Advantages: This plant with the botanical name of Phoenix dactylifera can be grown on wide range of zones ranging from tropical desert to moist through warm temperate thorn (with mild frost) to dry forest life zones. Date palm is reported to tolerate high soil and water salinity, very tolerant of alkali soils with high water demand of around ranging from 310 to 4030mm (with an average of 1,200 mm). It can tolerate annual temperature of 12.7 to 27.5°C, and pH of 5.0 to 8.2.
- **Second choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438 mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60-70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7-8.
- **Third choice: Papaya**
  - Limitations: This crop with the botanical name of Carica papaya has only a social limitation to be adapted at the Ghor since it never been introduced or cropped before. Farmers may refuse planting such new crop since it is not economically known. At the same time, if the water quality changed in future to more saline, then a different variety may be used as to tolerate the salinity, however, this crop is classified as moderately tolerant crop for salinity.
  - Opportunities and Advantages: Papaya is of moderate water demand ranging from 700 to 800 mm in summer months with average of 1000mm in dry conditions (an average of 88 mm), and with a good production with high economical return. It can be grown on a large range of soil ranging from warm temperate dry to moist through tropical very dry to wet forest life zones, papaya is reported to tolerate annual temperature of 16.2 to 26.6°C and pH of 4.3 to 8.0. Papaya is a tropical plant, killed by frost; does not tolerate shade, waterlogging, or strong winds, and may require irrigation in dry regions.

- **Fourth choice: Wheat**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.
- **Fifth choice: Rye**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop with the botanical name of Secale cereale can tolerate annual precipitation ranging from 220 to 1,760 mm with an average of 790 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, rye considered a very high tolerance to saline water.

The second division of the Ghor representing the lands associated from the Kafrein Dam and Wadi Hisban water resources are of good quality, however, they are not free and therefore, farms within this zone depends more on groundwater resources for irrigation. Unfortunately, the salinity of this water resource is deteriorating, and therefore, we suggest the use of Palm trees and Papaya as a replacement for their Banana production.

Suggested Land Use Plan at this part of Ghor Map Unit

- **First choice: Date Palm**
    - Limitations: The only limitation for this plant is the availability of seedlings for cultivation.
    - Opportunities and Advantages: This plant with the botanical name of Phoenix dactylifera can be grown on wide range of zones ranging from tropical desert to moist through warm temperate Tthorn (with mild frost) to dry forest life zones. Date palm is reported to tolerate high soil and water salinity, very tolerant of alkali soils with high water demand of around ranging from 310 to 4,030 mm (with an average of 1,200 mm). It can tolerate annual temperature of 12.7 to 27.5°C, and pH of 5.0 to 8.2.
- **Second choice: Papaya**
    - Limitations: This crop with the botanical name of Carica papaya has only a social limitation to be adapted at the Ghor since it never been introduced or cropped before. Farmers may refuse planting such new crop since it is not economically known. At the same time, if the water quality changed in future to more saline, then a different variety may be used as to tolerate the salinity, however, this crop is classified as moderately tolerant crop for salinity.
    - Opportunities and Advantages: Papaya is of moderate water demand ranging from 700 to 800 mm in summer months with average of 1000mm in dry conditions (an average of 88mm), and with a good production with high economical return. It can be grown on a large range of soil ranging from warm temperate dry to moist through tropical very dry to wet forest life zones, papaya is reported to tolerate annual temperature of 16.2 to 26.6°C and pH of 4.3 to 8.0. Papaya is a tropical plant, killed by frost; does not tolerate shade, waterlogging, or strong winds, and may require irrigation in dry regions.
- **Third choice: Oat**
    - Limitations: This crop has no limitations for adapting at the Ghor area.

    - Opportunities and Advantages: Ranging from Boreal Moist to Rain through Tropical Very Dry to Dry
    - Opportunities and Advantages: This crop of the botanic name of Avena sativa can be grown in zones ranging from boreal moist to rain through tropical very dry to dry forest life zones. Common oat is reported to tolerate annual precipitation of 200 to 1000 mm (with an average of 438mm), annual temperature ranging from 5 to 26°C, and pH of 4.5 to 8.6. Oats are long-day plants. They thrive on a wide range of soils of ample, but not excessive, fertility. It is classified as moderately tolerant to saline water.
- **Fourth choice: Barley**
    - Limitations: There is no limitation for this crop to be used at this zone.
    - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Fifth choice: Sorghum**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Ranging from Boreal Moist to Rain through Tropical Very Dry to Dry. Sorghum of the botanic name Sorghum bicolor can be grown in zones ranging from cool temperate steppe to wet through tropical thorn to wet forest life zones. Sorghum is reported to tolerate annual precipitation of 350 to 400 mm (with an average of 350mm), annual temperature of 7.8 to 27.8°C, and pH of 4.3 to 8.7. Adapted to tropical and subtropical summer rainfall climate with rainfall from 25–125 cm annually; of little importance in more humid areas with higher rainfall. Adapted to wide range of soils varying from light loams to heavy clays; thrives best on light, easily worked soils of high fertility, with moderate to high available water, with erosion not a problem. Moderately well-drained soils are suitable for sorghums. Small amounts of alkali in sand reduces performance considerably. Tolerance to salinity is moderate.

4.6.3.2 Zor

The physiography, and soil taxonomy have been discussed before.

(a) Suggested Land Use Plan

In the same manor, the flood plains of deep fine textured soils of Zor are very saline at this part, and therefore, highly tolerant crops can only be grown. We suggest the use of Barley and saltgrass to tolerate the soil condition.

Suggested Land Use Plan at this part of Zor Map Unit

- **The first choice: Wheat**
  - Limitations: This crop has no limitations for adapting at the Ghor area.
  - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.
- **The second choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Third choice: Saltgrass**
  - Limitations: There is no limitation for using this crop.
  - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500mm (with an average of 400mm). It can tolerate draught too.
- **Fourth choice: Wheatgrass**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600mm (with an average of 400mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.
- **Fifth choice: Bermudagrass**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: Bermudagrass of the botanical name of Cynodon dactylon is reported to tolerate annual precipitation of 90 to 4290 mm (with an average of 1000mm), annual temperature of 5.9 to 27.8°C, and pH of 4.3 to 8.4. It is considered highly tolerant to saline water. It can be grown on wide zones ranging from cool temperate steppe to wet through tropical desert to wet forest life zones. It can form dense cover in almost pure stands, practically anywhere. Abundant as weed along roadsides, in lawns, on sandy wastes, along sand dunes, and readily takes possession of any uncultivated area. Plants withstand long periods of drought.

4.6.3.3 Katar

The Physiography, and soil taxonomy have been discussed befor).

(a) E- Suggested Land Use Plan

The dissected lacustrine plain of Pleistocene lake deposits is highly saline at this part, and therefore requires leaching. However, the leaching cost is very high and therefore, these lands has very low suitability to agricultural use. As a conclusion, we suggest their use for fish farming with salinity tolerant fishes.

Suggested Land Use Plan at the Katar map unit:

- **First choice is Protected**
  - Limitations: no limitations.
  - Opportunities and Advantages: It is very difficult to mange this soil since it is highly saline that requires extremely extensive and expensive drainage system. And the erosivity potential is also very high, it better to keep those lands protected or to be used for other land use purposes.
- **Second choice is Saltgrass**
  - Limitations: There is no limitation for using this crop.
  - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500 mm (with an average of 400 mm). It can tolerate draught too.
- **Third choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Fourth choice: Rye**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop with the botanical name of Secale cereale can tolerate annual precipitation ranging from 220 to 1760 mm with an average of 790 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, rye considered a very high tolerance to saline water.

- **Fifth choice: Wheat**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.

4.6.3.4 HIM

(a) Physiography

The HIM map unit represent the Himara unit that is a continuous long strip of land occupying the lowest portion of the Dead Sea escarpment that is around 441 km^2 and composed from Dissected escarpment on Kurnub sandstone passing into Paleozoic sandstones (Ministry of Agriculture, 1993). The HIM unit lies downslope of the Tell Alluba and Su'eidat limestone units at the upper of the escarpment.

The HIM unit contains eight different facets according to the cross sectional graph (**Figure 23**). Those are (1) the deeply dissected sandstone ridges and cliffs having a colluvial fans at their bottom slopes (2). The undulating sandstone plateau areas form facet (3) and are interrupted by sand stone outcrops as in facet (4). The undualted sandstone may dissected by wadis as in facet (5). The low level alluviul/colluvial fans form the facet (6) and slopes downwards to the Dead Sea. On other hand, Tufa deposits occur around spring forming facet (7), while steeper fans and dissected Lisan deposits forms facet (9). This unit varies in altitude between –200 m to 450 m with a relative relief of 150-250 m.

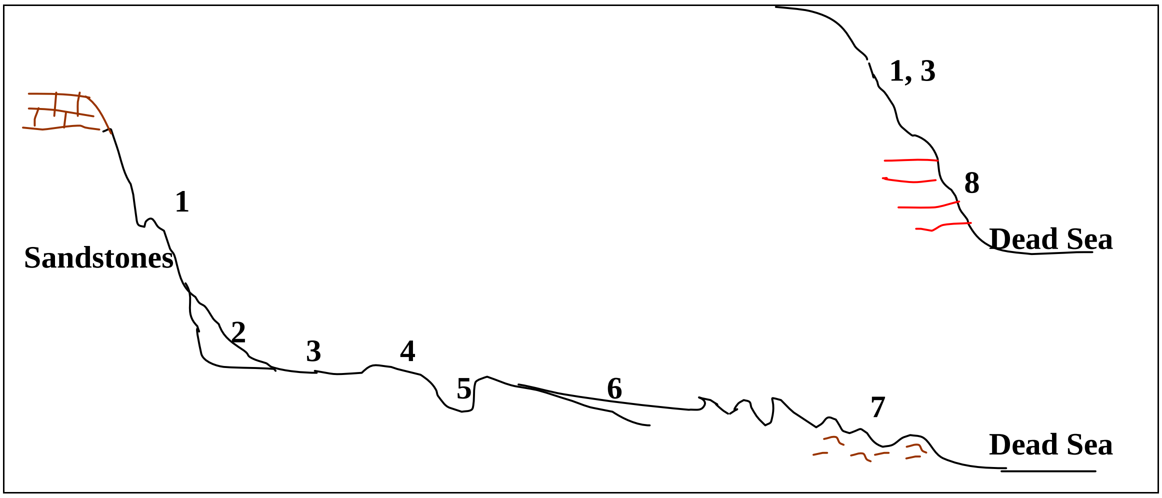


Figure 23: A Cross Section of the HIM Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Loamy-skeletal and sandy-skeletal, mixed, hyperthermic, shallow and moderately deep families of Typic and Lithic Torriothents:** Brown to strong (10YR 5\3-5\6) shallow and moderately deep (25-80cm) very stony clay loam to loamy sand: weak medium angular blocky structure: moderately calcareous and weakly saline: occurs on colluvium of facet (2), on ridges (1), on the sandstone plateau (3) and on parts of the lower fans (6): gradients 5-40%.

2- **Loamy, mixed, hyperthermic, moderately, deep family of Typic Camborthids and Typic Calciorthids:** Strong brown (7.5YR 5\6) deep (>80cm) loam and sandy clay loam: moderate medium angular and subangular blocky structure: highly calcareous and moderately saline: occurs on facet (6) and in a few facet (1) where is some admixture of limestone colluvium: gradients 4-44%.

(c) Vegetation and Land Use

The rainfall within this map unit is too low and therefore, most of this unit is uncultivated and supports grasses and shrubs as Retama, Daphne and Noea. The combination of steep gradients, stony soils and variable coarse textures render most of the unit unsuitable for irrigated agriculture especially parts of facets (2) and (6). Almost 90% s unit lies within aridic moisture regime and whole within hyperthermic temperature regime. There is some irrigation practices for fruit production and horticultural crops on the upper part of this unit. Some Barley is grown on sandstone colluvium within a narrow strip of the upper part of the unit under the ustic-aridic transional moisture regime.

(d) Suggested Land Use Plan

The soils of Himara represent dissected escarpment on Kurnub sandstone passing into Paleozoic sandstones are of steep gradients and very stony soils with variable coarse textures. Barley can be grown on sandstone colluvium within a narrow strip of the upper part of the unit under the ustic-aridic transional moisture regime. On the other hand, the uncultivated part can be used for grass and shrubs like Barley, Wheatgrass, Retama, Daphne and Noea.

Suggested Land Use Plan at the Himara map unit:

- **First choice: Barley**
    - Limitations: There is no limitation for this crop to be used at this zone.
    - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7-8.
- **Second choice: Wheatgrass**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600mm (with an average of 400mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.

- **Third choice: Retama**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.
- **Fourth choice: Daphne**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300 mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.
- **Fifth choice: Noea**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300 mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.

4.6.3.5 LIS

(a) Physiography

This undulating lacustrine plain form facet (10 as shown at the cross section of this unit (**Figure 24**). Some times the lacustrine plain is covered in places by gravel as in facet (2), and has deeply dissected and eroded margins as in facet (3). The eroded material from facet (3) forms a moderately to gentle slopping alluvial fans of facet (4). The latitude of this unit varies from –300m to –50m with the relative relief of 10-25 m (Ministry of Agriculture, 1993).

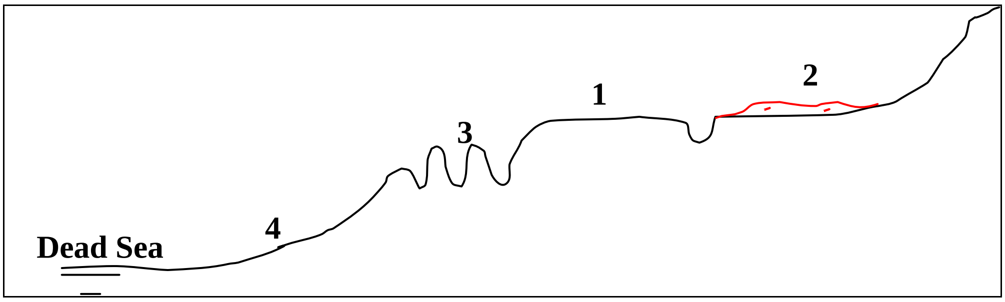


Figure 24: A Cross Section of the LIS Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Loamy, carbonatic, hyperthermic, deep family of Typic Torriorthent:** White (5YR 8\1-8\2) deep (>80cm) clay loam: finely varved marls: very high calcareous and very saline: occurs on facets (1) and (3): gradients 1-40%.

2- **Loamy, carbonatic, hyperthermic, deep families of Cambic and Petrogypsic Gypsiorthids:** Very pale brown to yellow (10YR 7\4-7\6) deep loam to silty clay loam: clear evidence of varving: secondary gypsic horizon between 25 and 50cm: the gypsic horizon is commonly cemented in a hard vitreous form, and it is not always clear whether the gypsum is primary or secondary: very high calcareous and very saline: occurs on facet (1).

3- **Loamy, mixed, hyperthermic, deep family of Haptic Hydraquetns:** Dark gray (N 4\0) deep silty clay loam: moderate organic matter: poorly ripened with high n value: very saline: occurs around the margins of the Dead Sea: gradients <1%.

(c) Vegetation and Land Use

Due to the high salinity of this unit, and the low permeability and high erosivity, this unit has little agricultural potential without costly reclamations. Unfortunately, some vegetables are grown on the more favorable sites but still the main unit is unclutivated. The current vegetation cover vary is sparse and include Retam and Tarfa on the plains of Ajram and Goda in the Wadis.

(d) Suggested Land Use Plan

It represents high saline undulating lacustrine plain of low permeability and high erosivity, therefore, this unit has little agricultural potential without costly reclamations. Unfortunately, some vegetables are grown on the more favorable sites but still the main unit is unclutivated. The suggested high tolerant plants at this unit are Saltgrass and Wheatgrass.

Suggested Land Use Plan at the Lisan Map Unit

- **First choice is Protected**
    - Limitations: no limitations.
    - Opportunities and Advantages: It is very difficult to mange this soil since it is highly saline that requires extremely extensive and expensive drainage system. And the erosivity potential is also very high, it better to keep those lands protected or to be used for other landuse purposes.
- **Second choice is Saltgrass**
    - Limitations: There is no limitation for using this crop.
    - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500 mm (with an average of 400 mm). It can tolerate draught too.
- **Third choice: Wheatgrass**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600 mm (with an average of 400mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.
- **Fourth choice: Wild Rye**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop can tolerate annual precipitation ranging from 200 to 550 mm with an average of 400 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, wildrye considered a very high tolerance to saline water.
- **Fifth choice: Barley**
    - Limitations: There is no limitation for this crop to be used at this zone.

- Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.

4.6.3.6 DHI

(a) Physiography

This unit is formed from Quaternary piedmont alluvial fans overlying Tertiary calcareous rocks (Ministry of Agriculture, 1993). The major facets as shown on the cross section (**Figure 25**), the undulating piedmont fan (1) that is eroded along its western margins as in facet (2), where it slopes down to eroded lisan marl, and dissected by wadis as in facet (3) flowing from the escarpment. Some times dissected slopes and ridges formed on Tertiary rocks as in facet (4) protrude through the fans. The altitude within this unit varies between –300 to 0 m with a relative relief of 20 m.

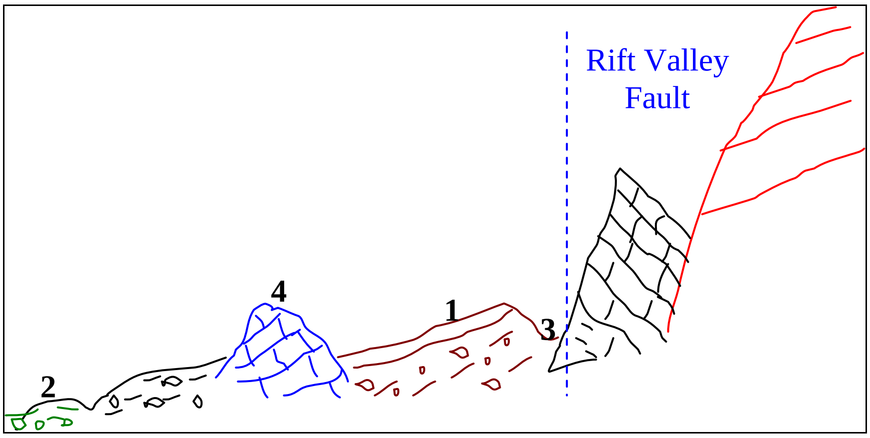


Figure 25: A Cross Section of the DHI Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Loamy-skeletal, mixed, hyperthermic, deep family of Typic Torriorthens:** Yellowish brown (10YR 5\6-5\8) and strong brown (7.5YR 5\6) vey gravelly loam and sandy loam on the lisan marl margins the color is light olive brown (2.5YR 5\6) with the same texture: weak fine subangular blocky structure: very high calcareous and very saline: occurs on eroded margins of facets (1) and (2), and along edge of major wadis (3): gradients 1-25%.

2- **Loamy and loamy-skeletal, mixed, hyperthermic, families of Typic Calciorthids:** Yellowish brown (10YR 5\8) deep (>80cm) stony and very stony silty clay loam: upper 40cm has lower stone content: weak and moderately medium subangular blocky structure: $CaCO_3$ pendants on stones and gravels: very highly calcareous and very saline: occurs on facet (1): gradients 6-12%.

(c) Vegetation and Land Use

Due to high salinity of this unit, the unit has no potential for rainfed agriculture and its irrigation potential is marginal. There are some vegetation cover that consists of sparse grasses and shrubs as Turfa. Small farming areas are irrigated for tomato and melons, however, the water supply appears inadequate to maintain a suitable salt balance.

(d) Suggested Land Use Plan

The Dhira soils represent very saline Quaternary piedmont alluvial fans overlying Tertiary calcareous rocks, and therefore, their capability for irrigation production is marginal. Due to high salinity of this unit, it is recommended to use such lands with grasses and shrubs like Wild Rye and Turfa.

Suggested Land Use Plan at the Dhira map unit:

- **First choice: Wild Rye**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate annual precipitation ranging from 200 to 550 mm with an average of 400 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, wildrye considered a very high tolerance to saline water.
- **Second choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Third choice is Saltgrass**
  - Limitations: There is no limitation for using this crop.
  - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500 mm (with an average of 400mm). It can tolerate draught too.

- **Fourth choice: Wheatgrass**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600mm (with an average of 400mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.
- **Fifth choice: Turfa**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300 mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.

4.6.4 SAF

(a) Physiography

This unit represents the Safi located immediately south of the Dead Sea and occupies 124 km^2 of Pleistocene and Holocene age derived from wadis draining towards the Dead Sea (Ministry of Agriculture, 1993). It consists from medium to high angle very stony fans of facet (1) that are associated with Wadi Mujib alluvium as shown in the cross sectional of this unit (Figure 15). Low angle fans of loamy and sandy texture forms facet (2) that are succeeded by saline flats of facet (3) towards the Dead Sea and along the fan margins in places (4). The altitude of this unit varies between –350m to –200m where the slope is less than 10m.

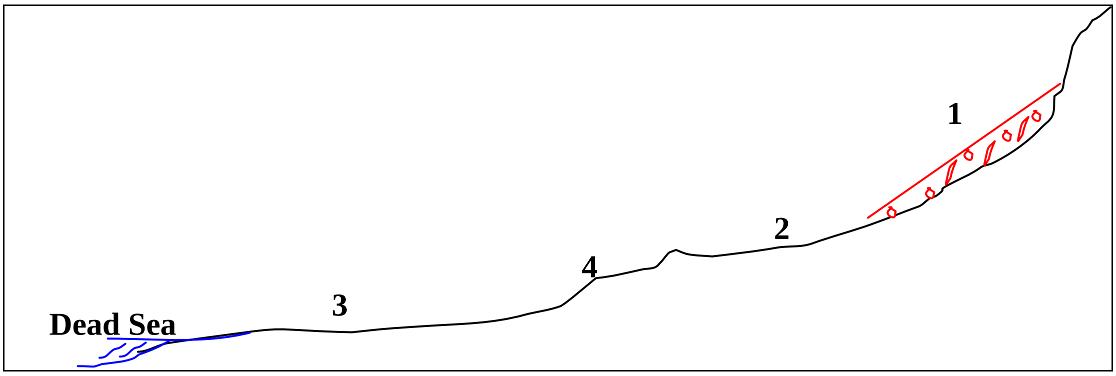


Figure 26: A Cross Section of the DHI Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Sandy-skeletal, mixed, hyperthermic, deep families of Typic Torriorthent:** Yellowish brown (10YR 5\6-5\8) deep (>80cm) very stony sandy loam to sandy clay loam with stone content to 80%. Some depositional horizonation visible: highly calcareous and moderately saline: occurs on facet (1): gradients 3-25%.

2- **Loam and sandy, mixed, hyperthermic, deep families of Typic Torrifluvents:** Brown to yellowish brown (10YR 4\4-5\6) deep (>80cm) loamy sand to silty clay loam: profiles in center of the facet have silty clay loam textures overlying sandy loam and loamy sand: depositional layering very evident: weak medium subangular blocky:

calcareous and moderately to weakly saline: salinity lowered under irrigation: water table >150cm: occurs on facet 2: gradients <5%.

3- **Loamy and sandy, mixed, hyperthermic, deep families of Aquollic Salorthids:** Dark brown and dark olive brown (10YR – 5YR 3\2-3\3) deep (>80cm) sandy loam and loamy sand: variable, often high organic matter content at surface and in buried horizons: very highly saline on facets (3) and (4): water table generally within 100cm: gradients <2%.

(c) Vegetation and Land Use

This unit is lies within aridic moisture regime where rainfall varies between 50-80cm. Due to the moderate to high salinity with general water tables within 100cm, this unit is only restrict to highly tolerant vegetation species that can tolerate the high salinity of soil and water. Therefore, this unit has no suitability for rainfed cropping. The relatively steeply sloping and very stony soils of the high angle fans have only marginal suitability for tree crops on the least stony members of the facet due to the highly permeability of such soil. In fact, the high angle of facet (1) supports only very sparse vegetation. At the same time, salt tolerant species as Nitraia, Aeluropus and Prosopis occurring on the saline flats of facet (3).

The high water table very saline soils could be drained and reclaimed for irrigation; however these lowlying soils have very little gradient and would be difficult to drain. The low angle fan alluvia of facet (2) have a moderately to high suitability for irrigated agriculture, and are intensively used for this purpose.

(d) Suggested Land Use Plan

The Safi lands represent a medium to high angle, very stony fans of Pleistocene and Holocene age derived from wadis draining towards the Dead Sea. The soils are associated with general water tables within 100 cm, and therefore, this unit is only restrict to highly tolerant vegetation species that can tolerate the high salinity of soil and water as Retam and Turfa for forage production. On the other hand, the relatively steeply sloping and very stony soils of the high angle fans have only marginal suitability for tree crops on the least stony members of the facet due to the highly permeability of such soils, therefore, it is suggested the use of Acacia for wood production and Retam, Turfa, Nitraia, Aeluropus and Prosopis tolerant species.

Suggested Land Use Plan at the Safi Map Unit

- **First choice: Retama**
- **Second choice: Turfa**
- **Third choice: Nitaria**
- **Fourth choice: Aeluropus**
- **Fifth choice: Prosopis**
    - Limitations: There is no limitation for these ornamental crops.
    - Opportunities and Advantages: These crops can tolerate precipitation as low as 300 mm only. All these crops considered as local type ornamental shrubs with a very high tolerance to soil and water salinity.

4.6.5 Southern Zone

This part extends from the Dead Sea to the Gulf of Aqaba that composed from three map units (**Figure 27**); (1) the Araba map unit that occupies 528 km^2 extending from Ghor Safi to the Gulf of Aqaba which has medium to low angle piedmont fans derived from basement Comples and Sandstones, (2) the Garandal map unit occupies 307 km^2 of the central part of WA and composed from a Quaternary aeolian sands forming an undulating cover plain with sand dunes, and (3) Ris which occupies 448 km^2 of the central WA and composed from undulated gravel hills developed on Tertiary conglomerates and Quaternary gravely alluvial fans.

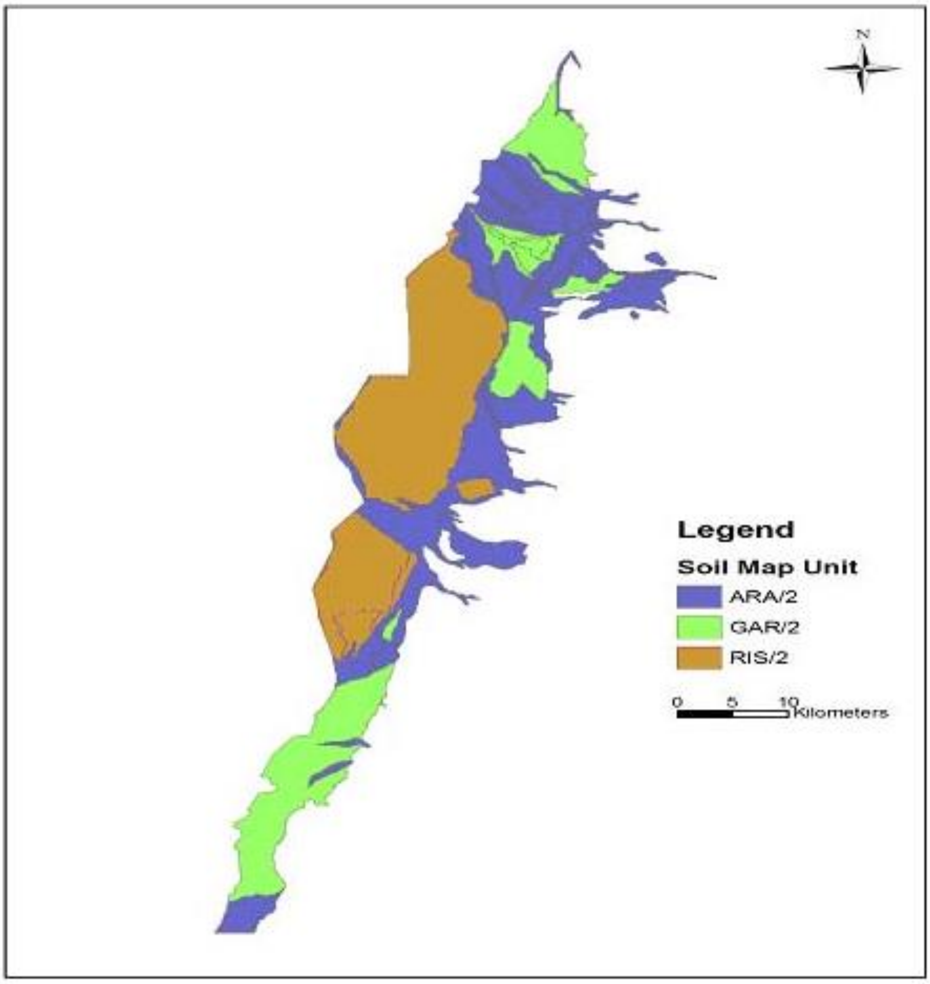


Figure 27: Soil Map Units of Wadi Araba

4.6.5.1 ARA

(a) Physiography

This map unit represent Araba Wadi throughout its length from Ghor Safi to the Gulf of Arabah that occupies 528 km^2. It consists from medium to low angle piedmont fans derived from Basement Complex and Paleozoic Sandstones. The cross sectional graph of the ARA unit **Figure 28** shows a medium to low angle fans of mixed texture alluvial material of facet (1) that is weakly incised by wadis. The remnants of older fan material forms facet (2) in some places. Other hand, Playas may occur on facet (3) and sometimes small sabkhas on facet (4) within this unit. There are some small spring sites within this map unit and often they occur at base of paleofans. The altitude within the ARA map unit varies from -100m to 1,300 m with a relative relief of 15 m.

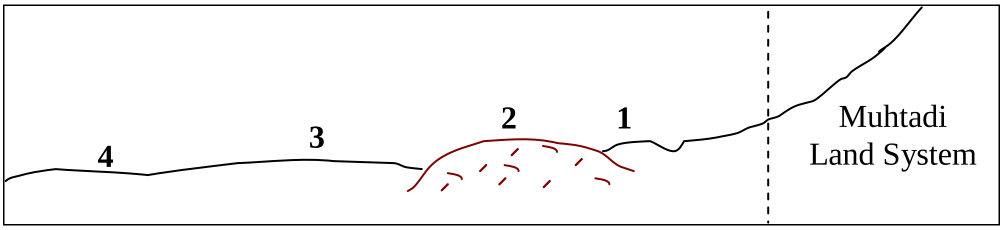


Figure 28: A Cross Section of the ARA Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Loamy, mixed, hyperthermic, deep family of Typic Calciorthids:** Strong brown (7.5YR 5\6) deep (>80cm) silty clay loam: dense gravel often occurs below 100cm, and surface has variable depth of aeolian sand: weak medium and fine subangular blocky: highly calcareous and normally strongly saline: Profile PM149 has been leached for irrigation, although no cropping at time of survey: occurs on facet (2) and on older, inactive areas of facet (1): gradients <2%.

2- **Loamy and sandy, mixed, hyperthermic, deep families of Typic Torriorthent:** Strong brown (7.5YR 5\6-5\8) deep (>80cm), sandy loam to loamy sand up to 30% gravel content: weak fine subangular blocky and single grain: very calcareous and moderately saline: occur on facets (1) and (2) in association with Typic Calciorthids: gradients <3%.

3- **Sandy, hyperthermic, deep family of Typic Torripsamments:** Brown (10YR 4\4) deep (>80cm), medium and fine sand: some reworking of surface by water in places: single grain: moderately calcareous and weakly saline: occurs in deeper aeolian sand cover on facet (1): gradients <2%.

(c) Vegetation and Land Use

Since the finer textured and less stony Typic Calciorthids have moderate suitability for irrigation, there are some small-irrigated agricultural units using drip irrigation from groundwater. Unfortunately, citrus and other tree crops, and horticultural products are grown, but only with limited success, and significant areas have been abandoned. Other very small-irrigated areas are associated with the springs where the water is used to irrigate the playa margins. The unit carries little natural vegetation except around spring and sabka margins, where dense vegetation of Chenopods occurs around the saline fringes of the sabkhas. In other areas with high water table species such as Nitraria, Tamarix, Aeluropus and Prosopis occur. The Arabah unit lies wholly within the aridic moisture regime with rainfall of <50 mm.

(d) Suggested Land Use Plan

Araba Wadi soils consist from medium to low angle piedmont fans derived from Basement Complex and Paleozoic Sandstones. The fine-textured and less stony Typic Calciorthids soils of ARA map unit are saline and therefore they require reclamation by leaching, and a high leaching faction to maintain salinity at low levels. The existing irrigation has not been very successful, due largely to the poor quality of the irrigation water, and therefore, the production should be concentrate on salt tolerant crops like Wheat, Barley, and Oatgrass.

Suggested Land Use Plan at the Araba Map Unit

- **First choice: Wheat**
    - Limitations: This crop has no limitations for adapting at the Ghor area.
    - Opportunities and Advantages: Wheat is of low water demand ranging from 400 to 650 mm/growing period (with an average of 435mm). It can tolerate high salinity since it is known as moderately tolerant to tolerant for some varieties.
- **Second choice: Barley**
    - Limitations: There is no limitation for this crop to be used at this zone.
    - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60-70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7-8.
- **Third choice is Saltgrass**
    - Limitations: There is no limitation for using this crop.
    - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500 mm (with an average of 400 mm). It can tolerate draught too.
- **Fourth choice: Wheatgrass**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600mm (with an average of 400mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.
- **Fifth choice: Wild Rye**
    - Limitations: There is no limitation for this crop.
    - Opportunities and Advantages: This crop can tolerate annual precipitation ranging from 200 to 550 mm with an average of 400 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, wildrye considered a very high tolerance to saline water.

4.6.5.2 RIS

(a) Physiography

Which represents the Rischi, the central section of WA that occupies 448 km (Ministry of Agriculture, 1993). The unit consists from undulated gravel hills developed on Tertiary conglomerates and Quaternary gravelly alluvial fans. According to the cross sectional map of this unit (**Figure 29**), facet (1) consist of steep sided hills on conglomerates with talus slopes, those sided hills might gently slope backslope on Quaternary alluvial fans forming facet (2). On the other hand, facet (2) is overlain by aeolian sands in places to form facet (3). There are some short colluvial slopes forming facet (4). The altitude within this map unit ranges from 0 to 300 m with a relative relief 50 m.

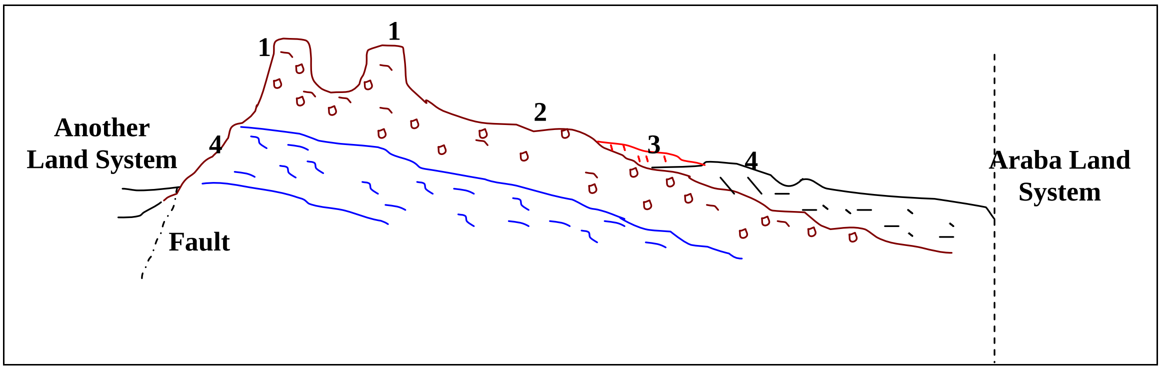


Figure 29: A Cross Section of the RIS Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Loamy, mixed, hyperthermic, deep family of Typic Calciorthids:** Strong brown (7.5 YR 5\6) deep (>80cm) stony sandy clay loam and silty clay loam: weak medium and fine subangular blocky structure: very highly calcareous and saline: most profiles very gravelly below 80cm: occur on facet (2): gradient <3%.
2- **Sandy- skeletal, mixed, hyperthermic, very shallow to moderately deep families of Typic and Lithic:** Strong brown very shallow to moderately deep (0-80cm) very stony loam and sandy clay loam: weak medium subangular blocky structure: very highly calcareous and moderately saline: occurs on all facets, but mainly on facets (1) and (4): gradient 2-40%.

(c) Vegetation and Land Use

The soils of this unit have no capability for rainfed production, and therefore, the unit is uncultivated, and the little natural vegetation is confined mainly to wadi channels.

(d) Suggested Land Use Plan

The soils of Rischi consist from undulated gravel hills developed on Tertiary conglomerates and Quaternary gravelly alluvial fans. The unit has no capability for rainfed production, and therefore, the suitability of the gently sloping alluvial fans for irrigation is limited by their stoniness and moderate to high salinity. It is recommended to use grass and shrubs as the main cover for this unit like with Turfa and Retam.

Suggested Land Use Plan at the Araba Map Unit

- **First choice is Saltgrass**
  - Limitations: There is no limitation for using this crop.
  - Opportunities and Advantages: This crop with the botanical name of Distichlis stricta is considered a highly tolerant for soil salinity. It can tolerate annual precipitation ranging from 200 to 500 mm (with an average of 400 mm). It can tolerate draught too.
- **Second choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Third choice: Rye**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop with the botanical name of Secale cereale can tolerate annual precipitation ranging from 220 to 1760 mm with an average of 790 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, rye considered a very high tolerance to saline water.
- **Fourth choice: Turfa**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300 mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.
- **Fifth choice: Wild Rye**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate annual precipitation ranging from 200 to 550 mm with an average of 400 mm. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. It also can tolerate annual temperature ranging from 4.3 to 21.3°C and pH of 4.5 to 8.2. At the same time, wildrye considered a very high tolerance to saline water.

4.6.5.3 GAR

(a) Physiography

This map unit represent the Gharandal area located at the in the central part of the WA occupying 307 km^2 of Quaternary aeolian sands forming and undulating coverplain with sand dunes (Ministry of Agriculture, 1993). According to the cross sectional map of this unit (**Figure 30**), the aeolian sand sheet coverplains forming facet (1) are weakly dissected by wadis forming facet (2). There are some linear sand dunes forming facet (3), which sometimes is enclosed by silt filled hollows between dunes as in facet (4). On the other hand, the sand sheet on the eastern margin merges with sandy and stony colluvium forming facet (5) from sand cover bedrock. The altitude in the GAR map unit ranges between -100m to 300m with a relative relief 20m.

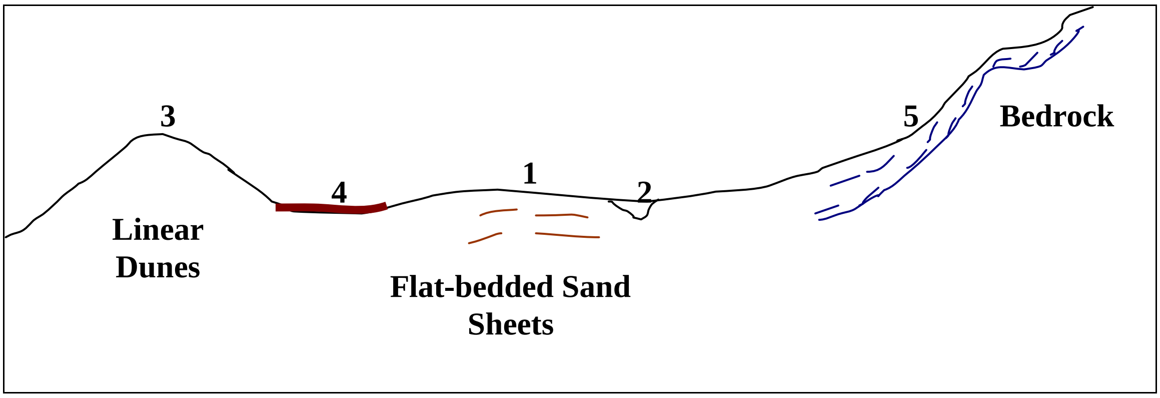


Figure 30: A Cross Section of the GAR Map Unit

(b) Soil Taxonomy

The following are the main soil taxonomies for the Ghor soils according to National Soil Map Project:

1- **Sandy, hyperthermic, deep family of Typic Torripsamments:** Reddish yellow (7.5 YR 6\8) deep sand: the older sands of the coverplain contain some $CaCO_3$ concentrations, but no Calcic horizon and have slightly brittle consistence, and very weak angular blocky structure: the recent dunes are deep loose sands: the sand is weakly to moderately calcareous and weakly saline: occurs on facets (1) and (3): gradient 1-10%.

2- **Loamy and sandy, mixed, hyperthermic, deep families of Typic Torrifluvents:** Brown (10 YR 4\4) deep (>80cm) very variably textured recently deposited alluvium in wadi channels and interdune hollows: textures mainly sandy, but silty clay loam top common in interdune hollows: moderately to highly calcareous and moderately saline: occurs on facets (2) and (4): gradient <2%.

(c) Vegetation and Land Use

The rainfall within this unit is less 50mm, and therefore, there is no cultivation. Vegetation cover is spares but include 'Retam', Haploxylon and 'Fars'. Acacia sp occurs in the wadi channels.

(d) Suggested Land Use Plan

The Gharandal area consists from Quaternary aeolian sands forming and undulating coverplain with sand dunes. These soils of GRA unit that are deep, undulating sandy soils with moderate to low salinity, high permeability and ease of leaching, have moderate suitability for drip irrigation and they have no potential for rainfed agriculture, therefore, it is suggested the use of Palm production.

Suggested Land Use Plan at this part of Gharandal Map Unit

- **First choice: Date Palm**
  - Limitations: The only limitation for this plant is the availability of seedlings for cultivation.
  - Opportunities and Advantages: This plant with the botanical name of Phoenix dactylifera can be grown on wide range of zones ranging from tropical desert to moist through warm temperate thorn (with mild frost) to dry forest life zones. Date palm is reported to tolerate high soil and water salinity, very tolerant of alkali soils with high water demand of around ranging from 310 to 4,030 mm (with an average of 1,200 mm). It can tolerate annual temperature of 12.7 to 27.5°C, and pH of 5.0 to 8.2.
- **Second choice: Barley**
  - Limitations: There is no limitation for this crop to be used at this zone.
  - Opportunities and Advantages: This crop with the botanical name of Hordeum vulgare is of very low water demand ranging from 200 to 500mm (with an average of 438mm) with a very high tolerance to saline water. It can be grown on varies zones ranging from boreal moist to rain through tropical very dry forest life zones. Barley is reported to tolerate annual temperature of 4.3 to 27.5°C, and pH of 4.5 to 8.3. It has a wider ecological range than any other cereal grain. Barley has a shorter growing season than wheat or oats and can be grown at higher latitudes. Some forms survive under extreme conditions and mature in 60–70 days. Barley is not particularly winter-hardy, so is grown as a spring crop. In areas with comparative mild winters as the Mediterranean, it is grown as a winter crop. Grown on soils that are too light or otherwise unsuitable for wheat cultivation; does well on light or sandy loam soil. Highest grades of barley are grown on fertile deep loam soils with pH of 7–8.
- **Third choice: Turfa**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.
- **Fourth choice: Retama**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop can tolerate precipitation as low as 300 mm only. It is considered as local type shrubs with a very high tolerance to soil and water salinity.
- **Fourth choice: Wheatgrass**
  - Limitations: There is no limitation for this crop.
  - Opportunities and Advantages: This crop with the botanical name of A. elongatum is of very low water demand ranging from 200 to 600mm (with an average of 400 mm) with a very high tolerance to saline water. It can be grown on different zones ranging from boreal moist through subtropical thorn to dry forest life zones. It can tolerate annual temperature of 5° to 19°C, and pH of 5.3 to 9.0.

4.7 Soil and Groundwater Pollution

Recently, groundwater contamination proved the faultiness of soil being a good filter media. Solute movement in soil is fucntion of contaminant properties and soil properties. Contaminant properties are the retention coefficient, transformation processes, and their solubility in water. The numerous soil physical properties are pore water velocity, tortuosity, organic matter content, and microbial population. Contaminants can flow through the soil to reach the groundwater in a varying rates. When the mobility of solutes increases, the potential risk that pollutants such as salts, nutrients and pesticides will be lost to both groundwater and through interception by subsurface drainage to surface water.

From the farm stand point, cultivation practices as application of chemical and organic fertilizers, pesticides, and soil and water amendments may influence the plant, soil water, and drainage water quality. There are large factors related to potential risk of groundwater contamination depending on application types, amounts, timing, irrigation type and efficiency, and soil flux properties. Since solute transport through the soil is mainly function of water fluxes, irrigation method and design determine to a great extent the solute fluxes through the soil. Crop may also affect solute movement by the addition of crop residues as an organic matter to the soil profile that in return increases soil metals and solutes adsorption capacity. Some plants are capable to accumulate large amounts of certain salts and toxic elements in their system.

The main agropollutants that affect the groundwater are pesticides and nutrients. Nutrients depending on soil, plant, and irrigation may leach or accumulate within the soil to a toxic limit. On the other hand, pesticides movement depends on its type that varies in their ability to sorb on the soil surface or to decay with time (half-life). Some pesticides may only found in surface water and some have the tendency to accumulate in groundwater. Herbicides are more common types of pesticides used for corn, soybeans and wheat monocultures agro-activities that is used only during mid-spring or early fall. In contrast, fruit and vegetable production demands numerous pesticides applications as fungicides and insecticides throughout the growing season. The highest soluble pesticide form is more likely to by the contaminating pollutants at the groundwater. However, areas of surface water most likely to be contaminated including intermittently ponded depressions and drainage ways.

Insecticides as chlorinated hydrocarbon are the most insoluble and persistent of all pesticides and may be expected to be strongly sorbed to the organic matter in soil. On the other hand, organophosphate and methylcarbomate classes of insecticides are less persistent in the soil environment, but however, inherently more toxic to humans. Herbicides as an organic weedkillers of complex families have a moderate range of persistence (Kearney and Roberts, 1998).

Soil contamination with the study area will vary according to the agricultural practices used at each unit and subunit. Within the Ghor map unit, the agrochemical applications vary intensive from the north to the middle zone. However, some areas might are susceptible for soil and groundwater contamination. The soil and water pollution potential depends on farmer land use and the cultivation practice adopted. The heavily cultivated vegetable units might have the most abundant insecticide pollution. Some of the water used for irrigation might recharge back to flow within the Canal and therefore might be another source for contamination for the next unit. Water flowing from the KTD might be a source of contamination depending on the time of year and the management practices used at the farm level. However, the contamination levels of KTD can be easily managed by several farm practices.

The Katar map unit is made of thin strip of outcropping calcareous marls running along the margins of the Jordan River channel. This unit is not cultivated and it is better to be used for other land use. While the Zor unit has some scattered wet lands that might be susceptible for contamination sice it is very close to both the Ghor unit and the Katar unit on one side and the Jordan Valley from the other side. Those small units might receive some effluents from the Ghor unit or could be easily contaminated from the surrounding cultivated units within the Zor map unit. The contamination again is a function of the farmer level of cultivation practices and the local water environment at the site.

4.8 Summary

According to soil and water quality investigated at each zone and map unit within the study area, the soil suitability was determined and tabulated in **Table 22**. The soil suitability varies from Suitable for rainfed agriculture to Non suitable for agricultural practices. According to the determined soil suitability, recommended plant tolerance to soil and water salinity was also determined and tabulated.

Table 23, **Table 24**, and **Table 25** summarize the suggested land use choices at the Northern, Middle, and the Southern zones, respectively. The tables provide the location of each map unit and the water resources used at each map unit for irrigation. The current land use for each map unit was also tabulated showing the cultivated areas in dunums for each crop as collected from the department of statistics. There are five different choices providing the average water requirement or demand for each crop under different cultivation practices. The water demand values were obtained from a GTZ report concerning the guidelines for brackish water irrigation in the Jordan Valley. At the same time **Table 26** and **Table 27** show the total cultivated area and the total area of each map unit under each zone, respectively.

Table 22: Land suitability for each map unit at each part of the JRV

		Zone	Area	Water Quality	Soil Quality	Soil Suitability	Recommended Plant Tolerant
Northern Zone	GOR	Upper Ghor	Upper	Non-Saline	Moderately to gentle slopping of deep medium and fine textured Camborthids and Ustochrepts.	Suitable for rainfed agriculture	MS
			Lower	Non-Saline		Suitable for irrigable agriculture	MS – MT
		Middle Ghor	Upper	Non-Saline		Suitable for irrigable agriculture	MS – MT
			KTD zone	Highly Saline		Suitable for irrigable agriculture under proper management	T – HT
			Mixed water	Saline		Suitable for irrigable agriculture under proper management	T – HT
	KAT	Katar			Dissected lacustrine plain of Pleistocene lake deposits of moderate to hagh salinity with low permeability and high erosivity.		T – HT
	ZOR	Upper Zor		Saline	Flood plains of deep fine textured soils	Suitable for irrigable agriculture under proper management	T – HT
		Middle Zor		Highly Saline		Suitable for irrigable agriculture under proper management	T – HT
Middle Zone	GOR	Lower Ghor	Upper	Saline	Moderately to gentle slopping of deep medium and fine textured Camborthids and Ustochrepts.	Suitable for irrigable agriculture under proper management	T – HT
			Lower	Saline		Suitable for irrigable agriculture under proper management	T – HT
	KAT	Katar			Dissected lacustrine plain of Pleistocene lake deposits of moderate to high salinity with low permeability and high erosivity.	Non suitable for agricultural practices	T – HT
	ZOR	Zor		Saline	Flood plains of deep fine textured soils	Marginal suitability for irrigable agriculture under proper management	T – HT
	HIM	Himra		---	Steep gradients, very stony soils of dissected escarpment on Kurnub sandstone passing into Paleozoic sandstones.	Marginal suitability for irrigable agriculture under proper management	HT
	LIS	Lisan		---	High saline undulating lacustrine plain of low permeability and high erosivity.	Very marginal suitability for irrigable agriculture under proper management	HT
	DHI	Dhira		---	Very saline Quaternary piedmont alluvial fans overlying Tertiary calcareous rocks	Very marginal suitability for irrigable agriculture under proper management	HT
	SAF	Safi		---	Medium to high angle, very stony fans of Pleistocene and Holocene age	Very marginal suitability for irrigable agriculture under proper management	HT
Southern Zone	RIS	Rischi		---	Highly saline, medium to low angle piedmont fans derived from Basement Complex and Paleozoic Sandstones	Very marginal suitability for irrigable agriculture under proper management	HT
	GAR	Garandal		---	Undulated gravel hills developed on Tertiary conglomerates and Quaternary gravelly alluvial fans.	Very marginal suitability for irrigable agriculture under proper management	MT-T

		Zone	Area	Water Quality	Soil Quality	Soil Suitability	Recommended Plant Tolerant
	ARA	Arabah		---	Quaternary aeolian sands forming and undulating coverplain with sand dunes of. moderate to low salinity and high permeability	Very marginal suitability for irrigable agriculture under proper management	T-HT

Table 23: Suggested cropping patterns choices at the Northern Zone

	Location	Water Resources	Current Land Use (Cultivated Area in du)*	Suggested Land Use Choices (average water requirement in mm)**				
				1	2	3	4	5
Upper Ghor	from Addasiya to Ziglab Dam near villages of Wadi Ryan	Yarmouk River Wadi Arab Dam Wadi Jurum Ziglab Dam	Citrus (62,200)	Citrus (1000)	Grape (500)	Olive (600)	Papaya 800	Wheat (438)
	from village of Wadi Ryan to Kraymeh village.	Wadi Yabis	Vegetables (19,000) Wheat (15,100) Olive(4,200) Banana (2,800)	Potato Aut1 (436) Aut2 (282) Winter (218) Spring (359)	Broadbean-Corn (900)	Spinach-Squash (700)	Olive (600)	Avocado (650)
Middle Ghor	from Kraymeh to Deir Alla village.	KAC	Vegetables (39,900)	Squash (450) spring (550) summer (370) autumn	Asparagus (450)	Tomato (417) open autumn, (280) plastic house, (240) winter	Cucumber (380) autumn, (160) plastic house,	Artichoke (450)
	from Kraymeh to Deir Alla village along Zarqa river.	KTD	Barley (8,300)	Barley (438)	Wheat (438)	Rye (790)	Palm (1200)	Bermudagrass (1000)
	From Deir Alla village to Baptism Site	Kufranja Rajib	Olives (1,300) Citrus (10 900) Banana (460) Grapes (3,100) Dates (1,700)	Barley (438)	Safflower (500)	Red Beet (450)	Grape (500)	Palm (1200)
Zor	Narrow flood plain of the Jordan River extends from the junction of the Yarmouk River to the north Dead Sea.		Scattered Cultivation lands	Wheat (438)	Barley (438)	Saltgrass (400)	Wheatgrass (400)	Bermudagrass (1000)
Katar	Thin strip of outcropping calcareous marls running along the margins of the Jordan River channel.		Uncultivated	Keep protected or different land use	Saltgrass (400)	Barley (438)	Rye (790)	Wheat (438)

* The cultivated areas are collected from the department of statistics (2002).
** Water requirement was determined according to Guidelines for Brackish Water Irrigation in the Jordan Valley (JTZ report).

Table 24: Suggested cropping patterns choices at the Middle Zone

	Location	Water Resources	Current Land Use (Cultivated Area in du)*	Suggested Land Use Choices (average water requirement in mm)**				
				1	2	3	4	5
Lower Ghor	Lands associated from Baptism Site aghtas to Kafrein Dam.	KAC Shueib dam	Banana (4,000) Vegetables(11,600)	Palm (1200)	Barley (438)	Papaya (1000)	Wheat (438)	Rye (790)
	lands associated from the Kafrein Dam and Wadi Hisban to Wadi Araba.	Kafrein Dam Wadi Hisban	Banana (6,400)	Palm (1200)	Papaya (1000)	Oat (438)	Barley (438)	Sorghum (350)
Zor			Uncultivated	Wheat (438)	Barley (438)	Saltgrass (400)	Wheatgrass (400)	Bermudagrass (1000)
Katar			Uncultivated	Keep protected or different land use.	Saltgrass (400)	Barley (438)	Rye (790)	Wheat (438)
Himara			Uncultivated	Barley (438)	Wheatgrass (400)	Retama (300)	Daphne (300)	Noea (300)
Dhira			Uncultivated	Wild Rye (400)	Barley (438)	Saltgrass (400)	Wheatgrass (400)	Turfa (300)
Lisan			Uncultivated	Keep protected or different land use.	Saltgrass (400)	Wheatgrass (400)	Wild Rye (400)	Barley (438)
Safi		Groundwater	Scattered Cultivation lands	Retam (300)	Turfa (300)	Nitraia (300)	Aeluropus (300)	Prosopis (300)

* The cultivated areas are collected from the department of statistics (2002).
** Water requirement was determined according to Guidelines for Brackish Water Irrigation in the Jordan Valley (JTZ report)

Table 25: Suggested cropping patterns choices at the Southern Zone

Location	Water Resources	Current Land Use (Cultivated Area in du)*	Suggested Land Use Choices (average water requirement in mm)**				
			1	2	3	4	5
	Groundwater	Scattered Cultivation lands	Wheat (438)	Barley (438)	Saltgrass (400)	Wheatgrass (400)	WildRey (400)
		Uncultivated	Saltgrass (400)	Barley (438)	Rye (790)	Turfa (300)	WildRey (400)
Araba		Uncultivated	Palm (1200)	Barley (438)	Turfa (300)	Retama (300)	Wheatgrass (400)
Rischi							
Gharandal							

* The cultivated areas are collected from the department of statistics (2002).
** Water requirement was determined according to Guidelines for Brackish Water Irrigation in the Jordan Valley (JTZ report).

Table 26: Total cultivated area for each map unit under the study zoning area

Study Zone	Map Unit	Total cultivated area (du)*
Northern Zone	Upper Ghor	108,200
	Middle Ghor	71,200
	Katar	Uncultivated
	Zor	**Small Irrigated Units**
Middle Zone	Ghor	31,100
	Katar	Uncultivated
	Zor	Small Irrigated Units
	Himara	Uncultivated
	Dhira	Uncultivated
	Lisan	Uncultivated
	Safi	Small Irrigated Units
Southern Zone	Rischi	Uncultivated
	Araba	Small Irrigated Units
	Garandal	Uncultivated

* The cultivated areas at Jordan Valley are collected from the department of statistics (2002).

Table 27: Total Area for Each Map Unit

Map Unit	Total Area*
Ghor	303,000
Katar	168,000
Zor	65,000
Himara	441,000
Dhira	51,000
Lisan	244,000
Safi	124,000
Rischi	448,000
Araba	528,000
Garandal	307,000

*The total areas are according to the National Soil Map and Land Use Survey, Ministry of Agriculture, August 1993.

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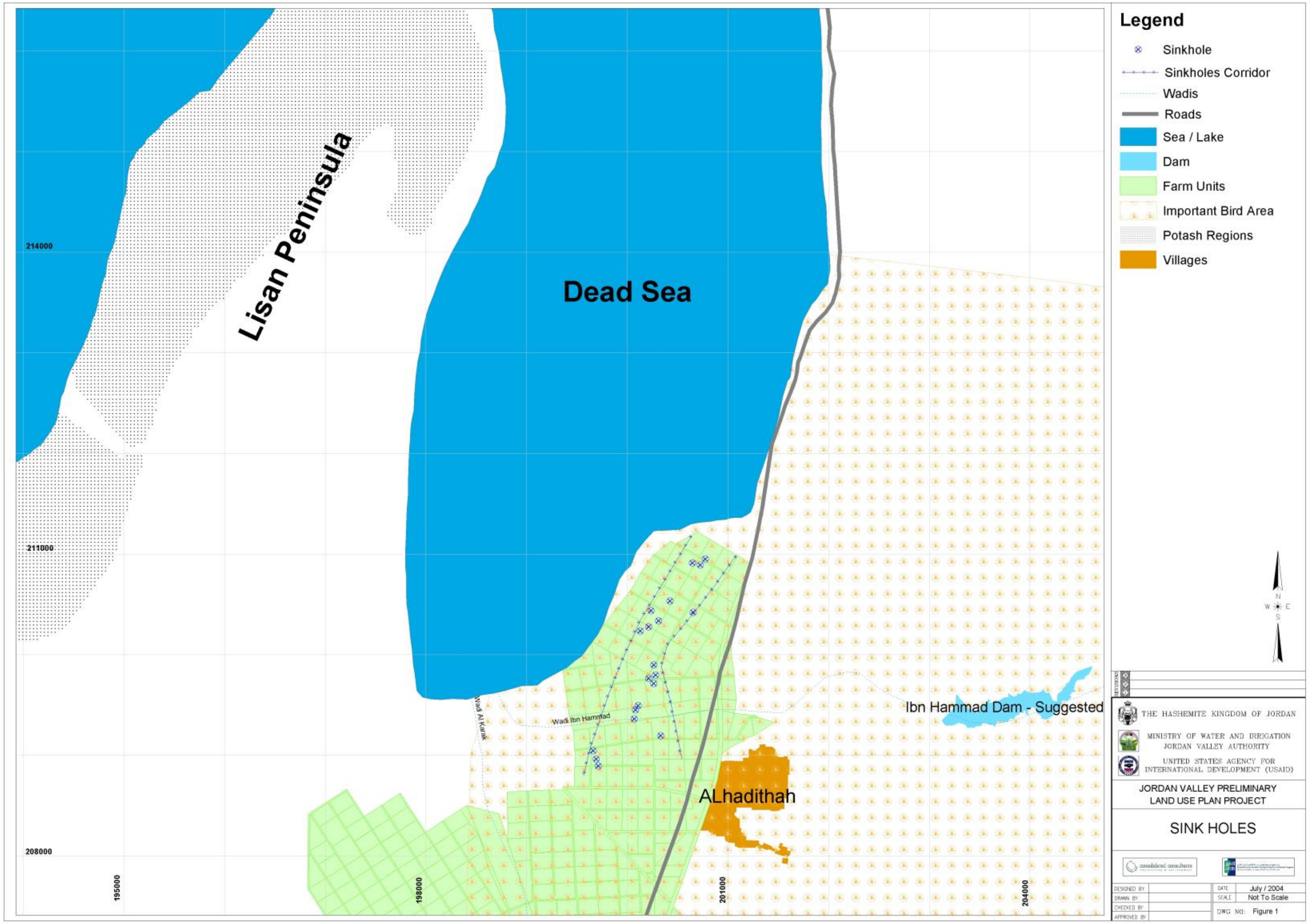
ANNEXES

ANNEX 1
GEOLOGIC MAP FOR JORDAN VALLEY



Legend
Sinkhole
Sinkholes Corridor
Wadis
Roads
Sea / Lake
Dam
Farm Units
Important Bird Area
Potash Regions
Villages
Lisan Peninsula
Dead Sea
Ibn Hammad Dam - Suggested
ALhadithah
Wadi Ibn Hammad
Wadi Al Karak
214000
211000
208000
195000
198000
201000
204000
N
W
E
S
THE HASHEMITE KINGDOM OF JORDAN
MINISTRY OF WATER AND IRRIGATION
JORDAN VALLEY AUTHORITY
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT (USAID)
JORDAN VALLEY PRELIMINARY LAND USE PLAN PROJECT
SINK HOLES
DESIGNED BY
DRAWN BY
CHECKED BY
APPROVED BY
DATE July / 2004
SCALE Not To Scale
DWG NO: Figure 1