Contributions to the Protection of Water Resources in Jordan

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Arabic word for water, Plural (miyah),
from: inamo, nr. 27, Vol. 7, 2001,

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Jordan

Content

- Introduction
- Project “Groundwater Resources Management”
- Groundwater management
  - The National Water Master Plan (NWMP)
  - The comprehensive groundwater model for the NWMP
- Measures for water protection
  - Vulnerability mapping
    - Examples: Irbid and Karak
  - Groundwater protection zones and by-law
    - Example: Pella spring
  - Surface water protection zones
    - Example: Wadi Mujib Dam
- Concluding remarks

Technical Cooperation with Jordan

Partners: NRA, MWI, WAJ

Projects in the Water Sector

- Arja – Uweina (1967-1969): Groundwater Resources Exploration
- Water Master Plan (with GTZ; 1973-77)
- El Lajjun Oilshale (1984-86): GW-Resources Exploration; GW-Model
- Azraq (1986): GW-Resources Exploration
- Siwaqa-Qatrana (1988/89): GW-Model
- Groundwater Resources Assessment for South Jordan (1986-1990)
- Groundwater Resources Assessment for North Jordan (1991-1999)
- Groundwater Resources Management (2002-2009): NWMP; GW-Protection Zones & Surface Water Protection Zones (Dams) with By-Laws

Change in Objectives

1967 – 1986: Mainly GW-Resources Exploration
Since mid 1980s: GW-Management Tools (Water Master Plan, GW-Modeling)
Since mid 1990s: GW-Protection Tools (GW-Vulnerability Mapping, GW-Protection Zones)
Since 2002: Legal Framework (GW-Protection Zones, Surface Water Protection Zones)

Groundwater Resources Management

Project goal :

Measures for groundwater protection are elaborated and implemented by the Ministry of Water and Irrigation

Activities (1st phase, 2002-2005):

Support to the National Water Master Plan

Establishment of groundwater protection zones:

> Elaboration of guidelines and a by-law

> Establishment of protection zones (at two sites) as examples

Application of concepts to prevent groundwater contamination

> Analysis and evaluation of groundwater vulnerability (maps, recommendations, advice)

> Evaluation of effects of anthropogenic contamination (transport models)

> Recommendations for preventive gw protection, dissemination of results

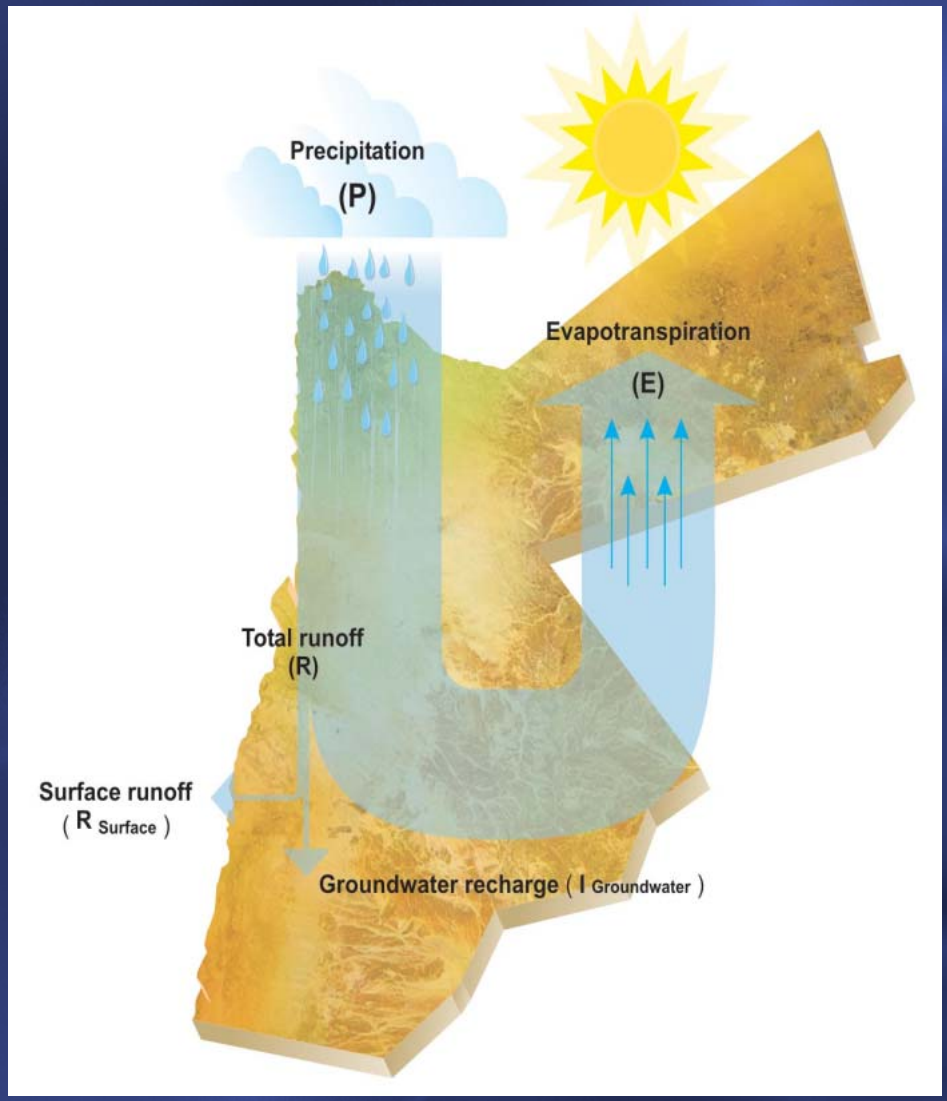
Groundwater Resources Management

2nd phase : July 2005 – June 2009 (4 years)

Main Tasks

- Establishment of Surface Water Protection Zones
  - Prepare draft By-Law / Guideline on Delineation of Surface Water Protection Zones
  - Delineate at least two Surface Water Protection Zones
- Groundwater Protection
  - Delineate at least five Groundwater Protection Zones
  - Support Planning Authorities in the Implementation of the Landuse Recommendations
- Integration of Water Resources Protection into Landuse Planning
  - Support Licensing Decisions (Inter-Ministerial Licensing Committee)
- Improvement of Water Quality Information
  - Compile up-to-date information about water quality (annual report)
- Application of concepts to prevent groundwater contamination

Support to the National Water Master Plan



National Water Master Plan of Jordan, Volume 5:

"**Groundwater Resources**"

Objective of the report:

to provide an up-to-date evaluation of the groundwater situation

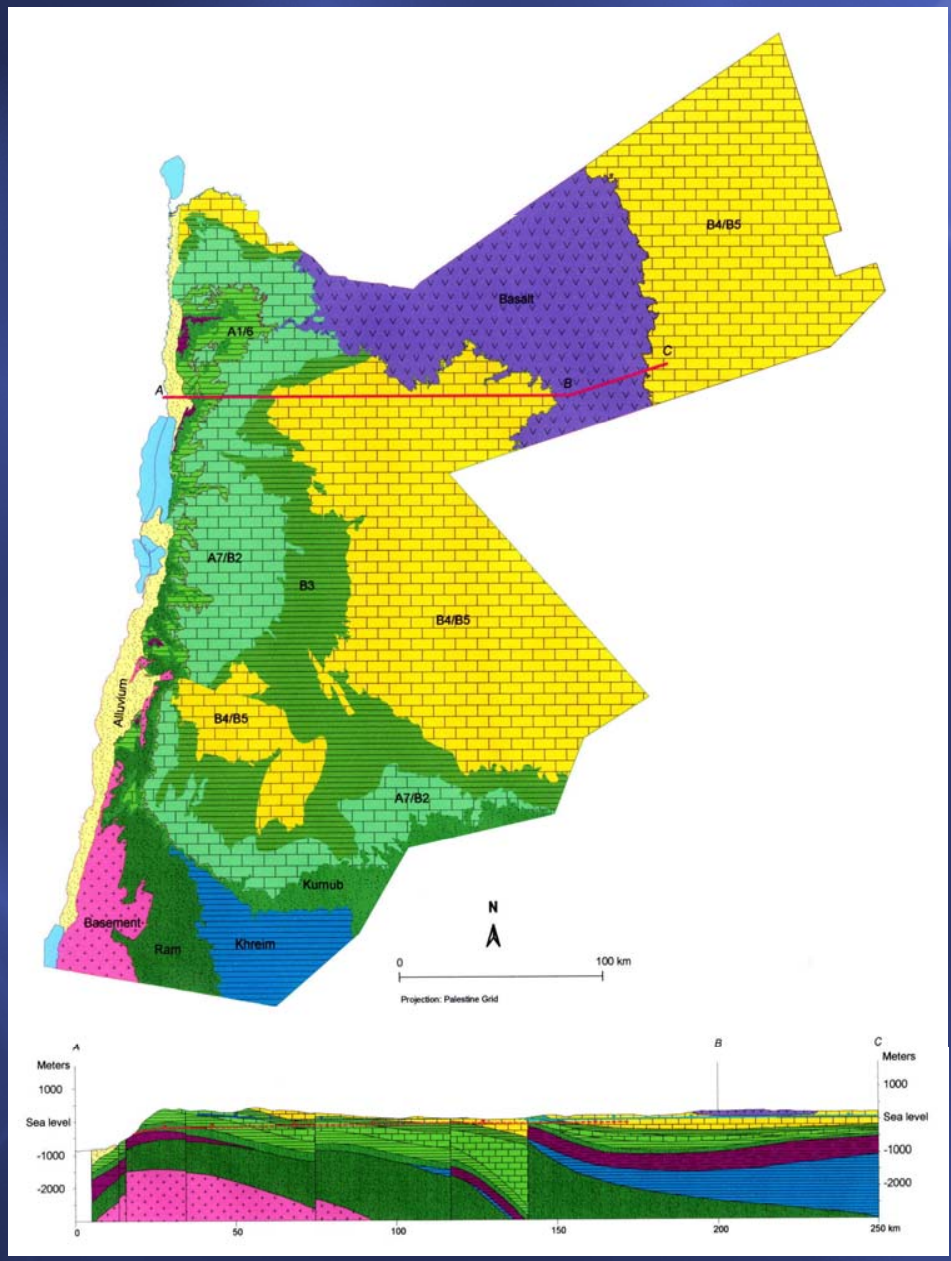
Preparation by:

Staff of the Groundwater Resources Management Project (MWI-BGR) in cooperation with the National Water Master Plan staff

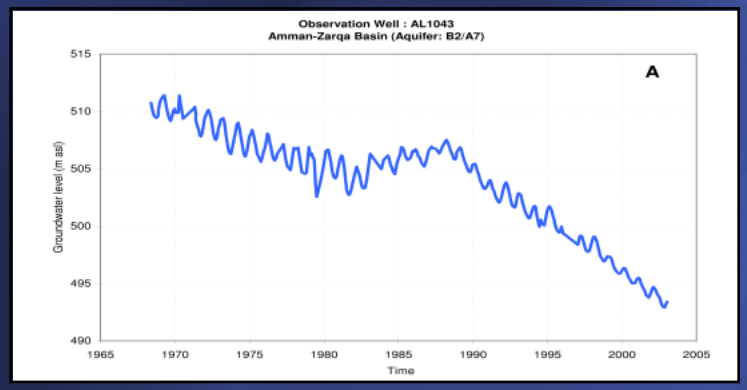
Simplified Hydrogeological Map of Jordan

Spatial distribution of aquifers and aquitards

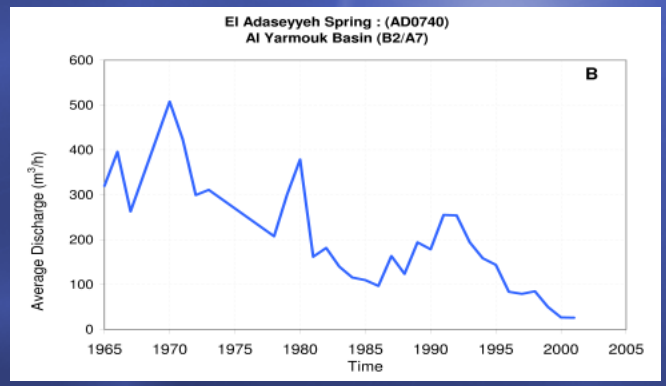
On a regional scale, the aquifers in Jordan can be grouped into three major aquifer systems.
This classification is based on their spatial distribution, lithology and the age of the geological units.



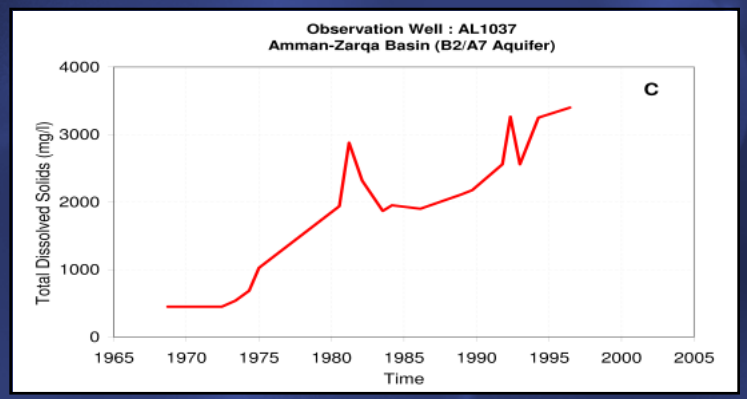
Observed Behaviour of Groundwater Levels and Quality



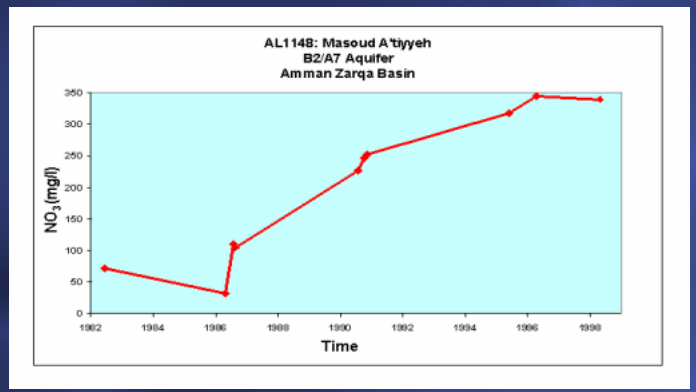
Decline in groundwater level



Decrease in spring discharge



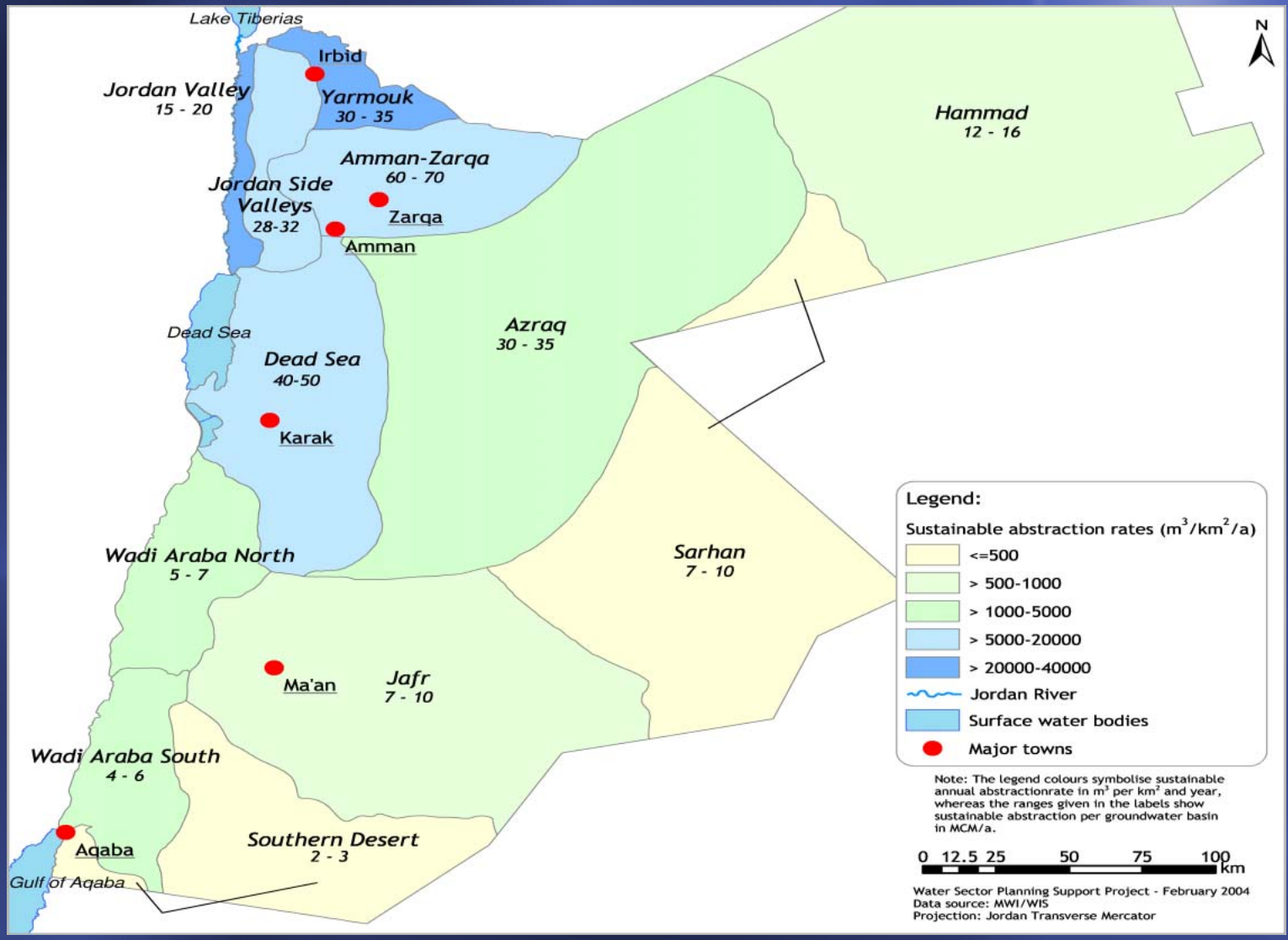
Increase in salinity

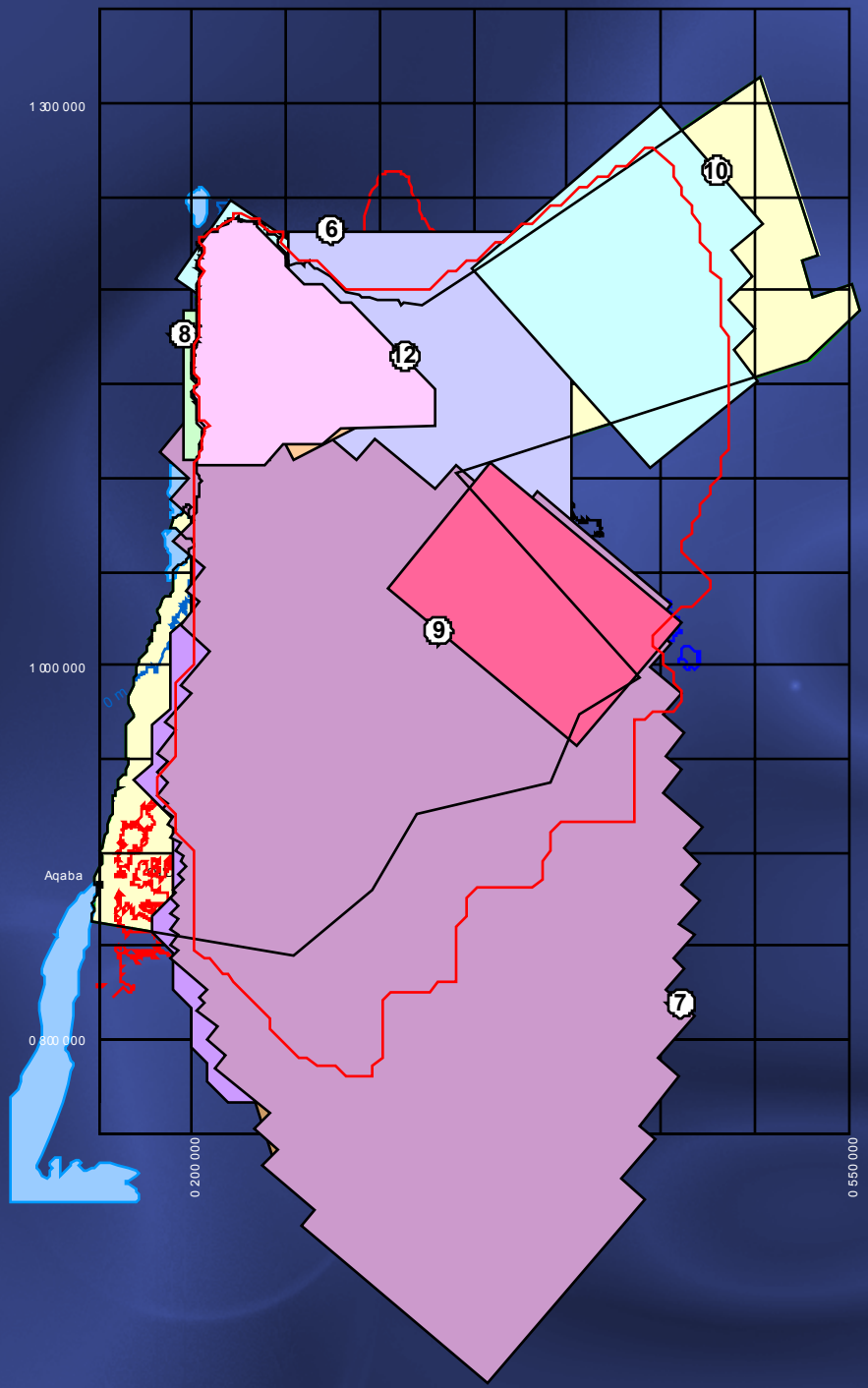


Increase in nitrate

Recommendations for Sustainable Groundwater Management

- Groundwater Abstraction Rates (within given limits) -

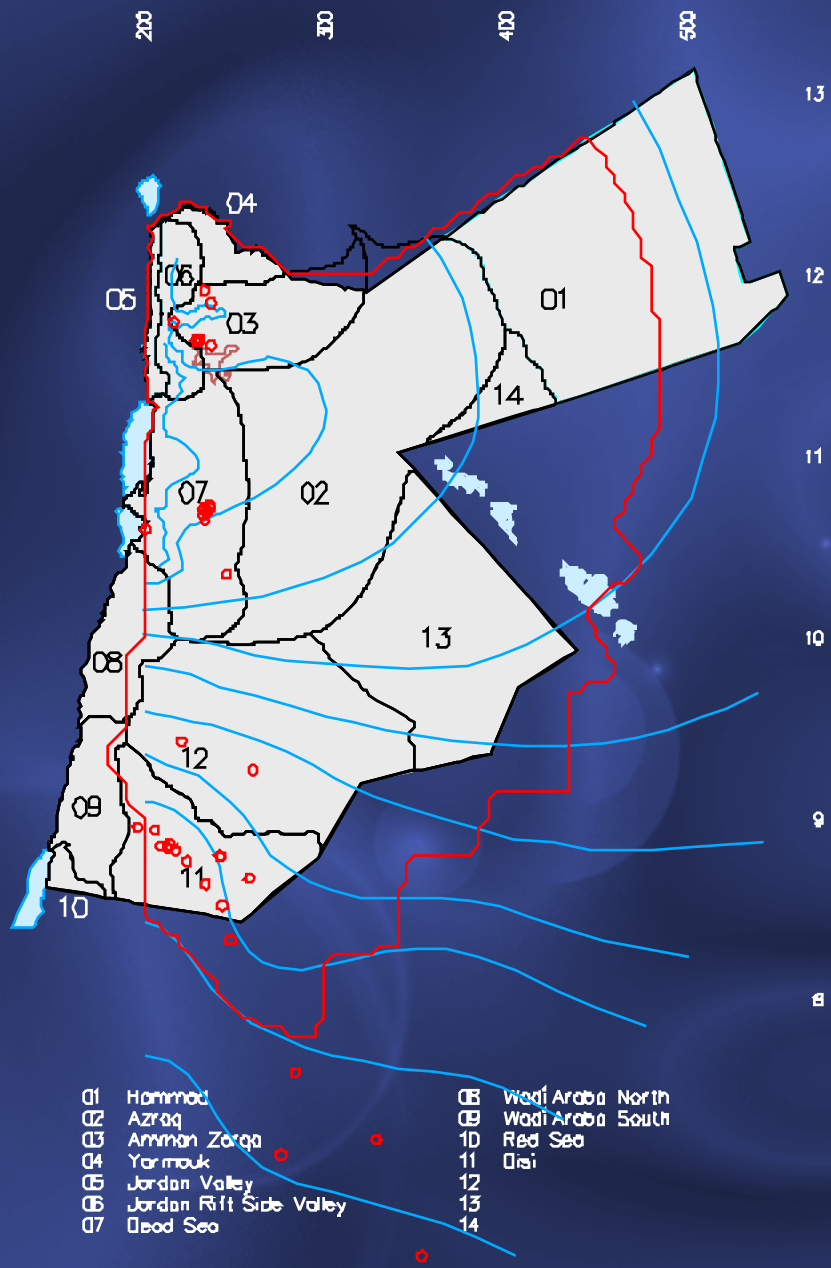




1	1986	El Lajjun
2	1989	Yarmouk
3	1989	Suwaqa-Qatrana
4	1991	South
5	1991	Tabuk (analytical)
6	1994	Azraq
7	1995	Qa Disi
8	1995	Jordan Valley
9	1995	Wadi Sirhan
10	1995	Wadi Hammad
11	1996	Muwaqqar
12	1997	North

Groundwater Models

Support to the National Water Master Plan



Development of a **three-dimensional groundwater model** of entire Jordan

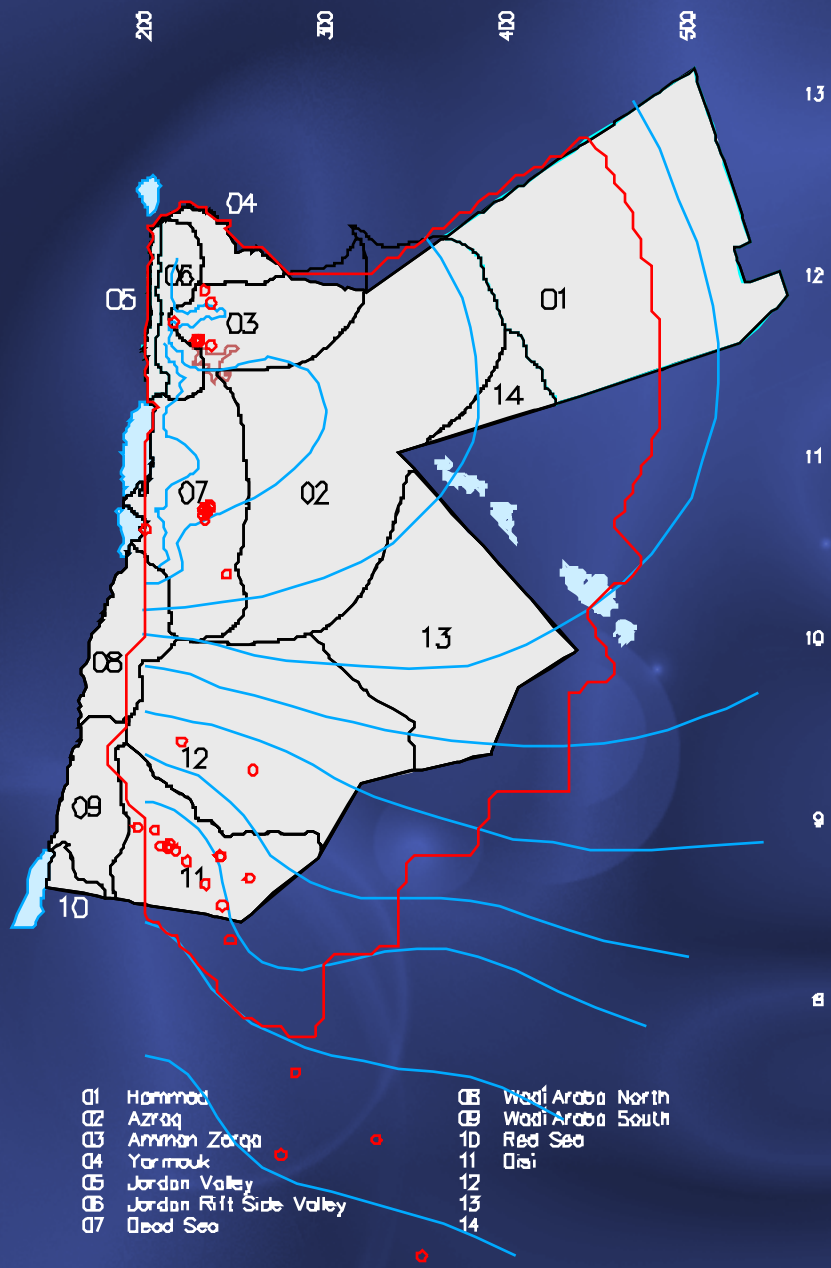
Objectives:

Determination of existing groundwater resources

Verification of recharge / discharge values

Tool for management of groundwater resources, (e.g. abstraction scenarios or climatic changes)

Support to the National Water Master Plan



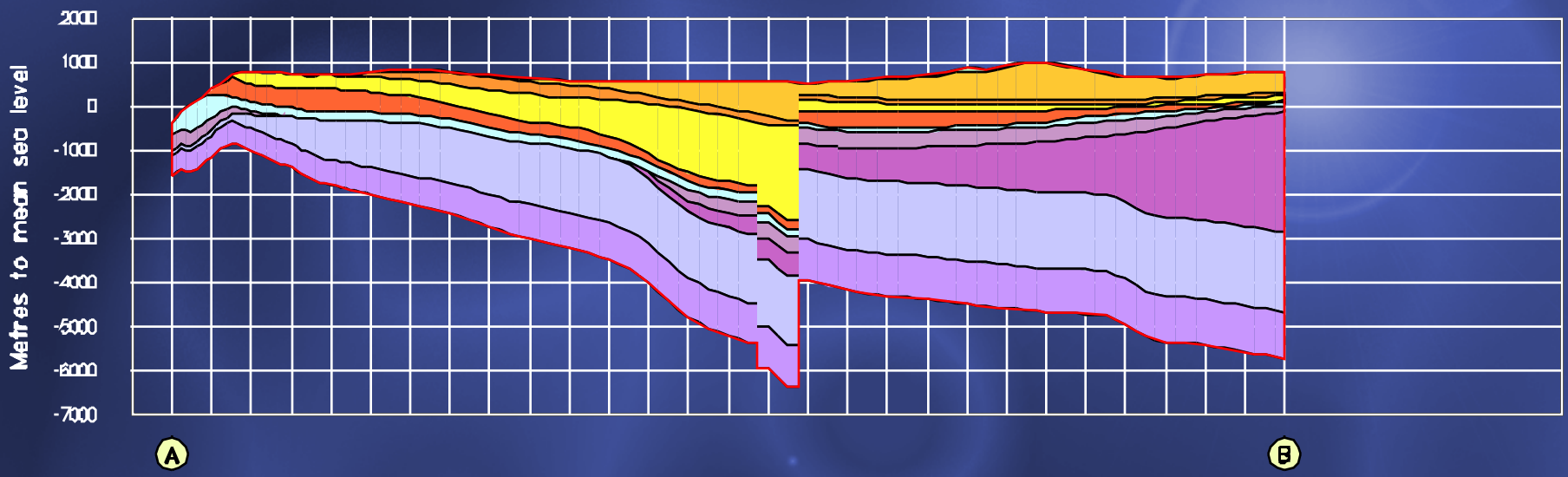
Model area:
100.000 km²

- 76.000 km² of the Jordanian territory -

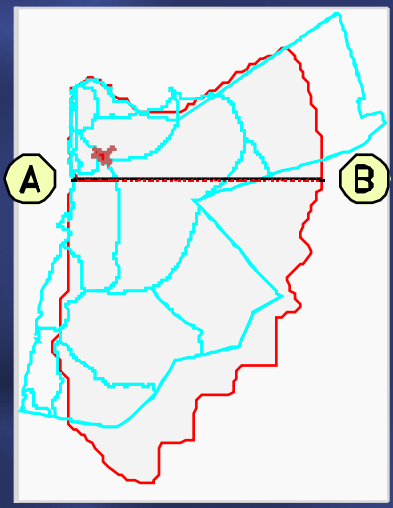
Simulation period:
30 years
starting 1976

Integrated Finite Differences
2.5 - dimensional

Groundwater basins and isolines of the piezometric surface of the sandstone complex



001 BA Azroq Basalt
002 B4/B5 Shallala Umm Rijam
003 B3 Muwaqqar
004 A7/B2 Wadi as Sir
005 A1/A6 Shuoyb Hummar Fuheis
006 KURNUB Subeihi Aarda
007 ZARQA Group Azab Ramtha Hudayb
008 KHREM Group Khreim
009 RAM Group Amud-Ajram
010 RAM Group Burj-Solib



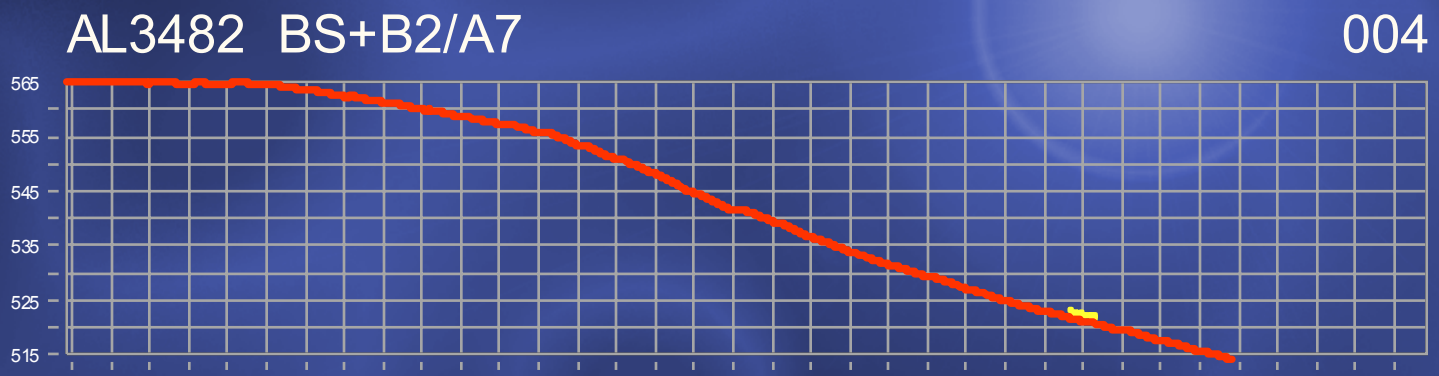
205000 1125000

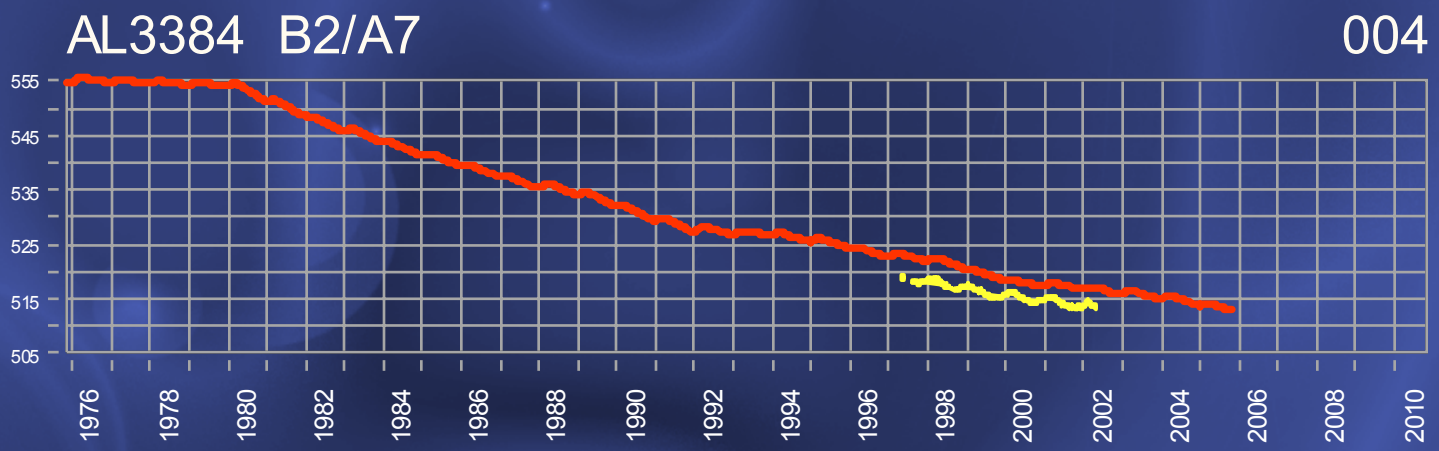
485000 1125000

Hydro-Geological Model

BGR

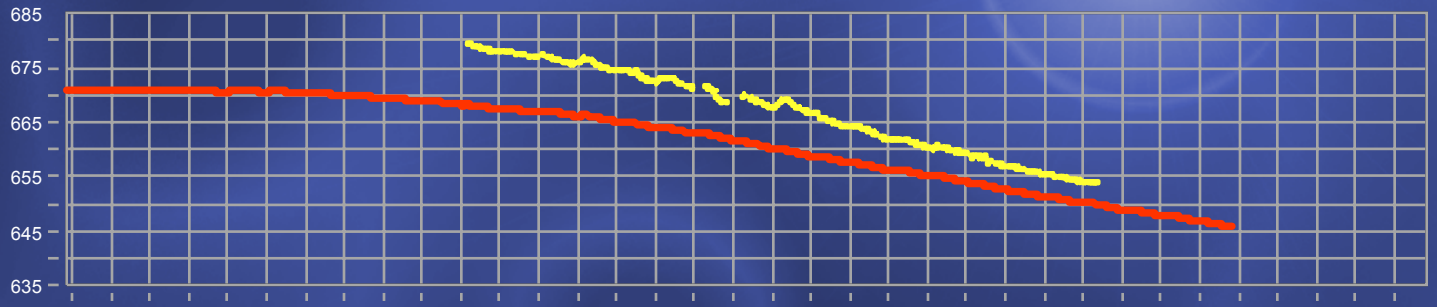
Hydrographs of the Calibrated Model



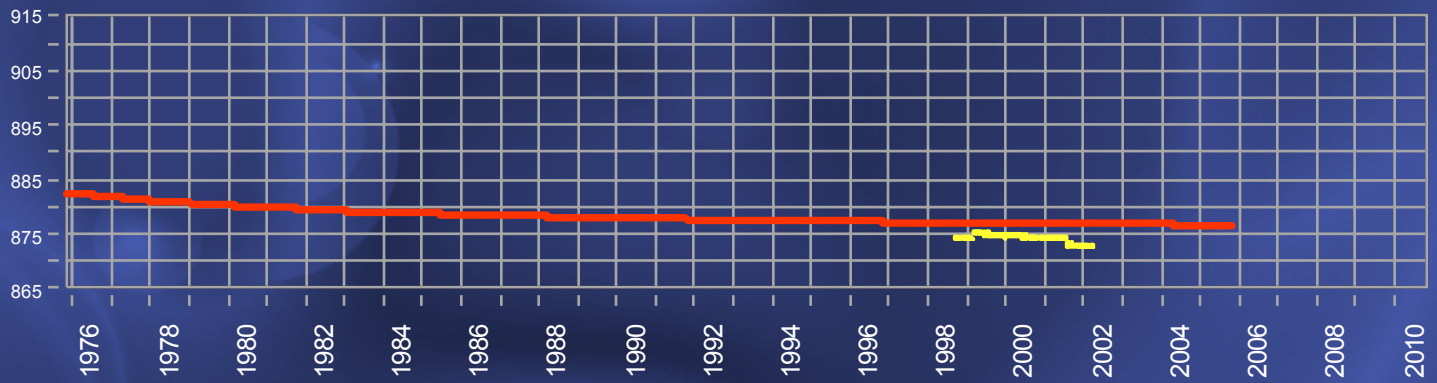


Hydrographs of the Calibrated Model

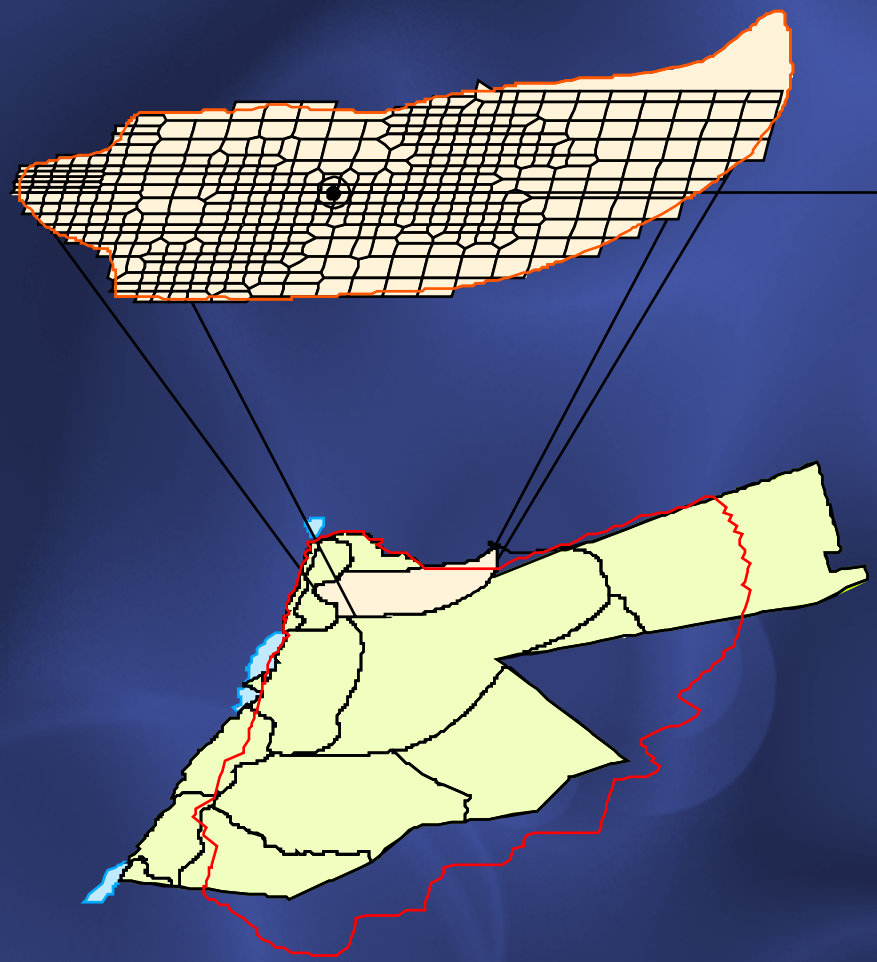
CD1106 B2/A7 004

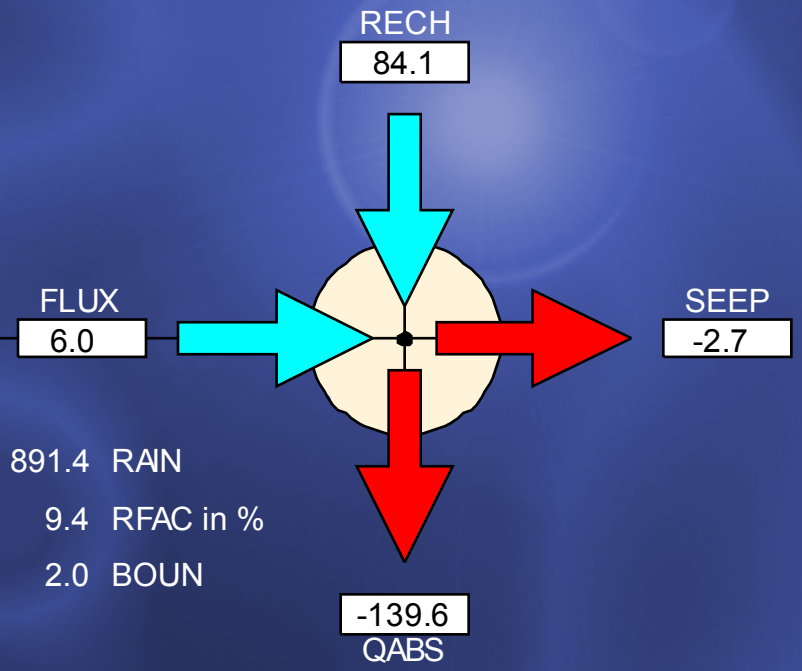


G3149 B4/B5 002



Groundwater Budget for Amman-Zarqa-Basin





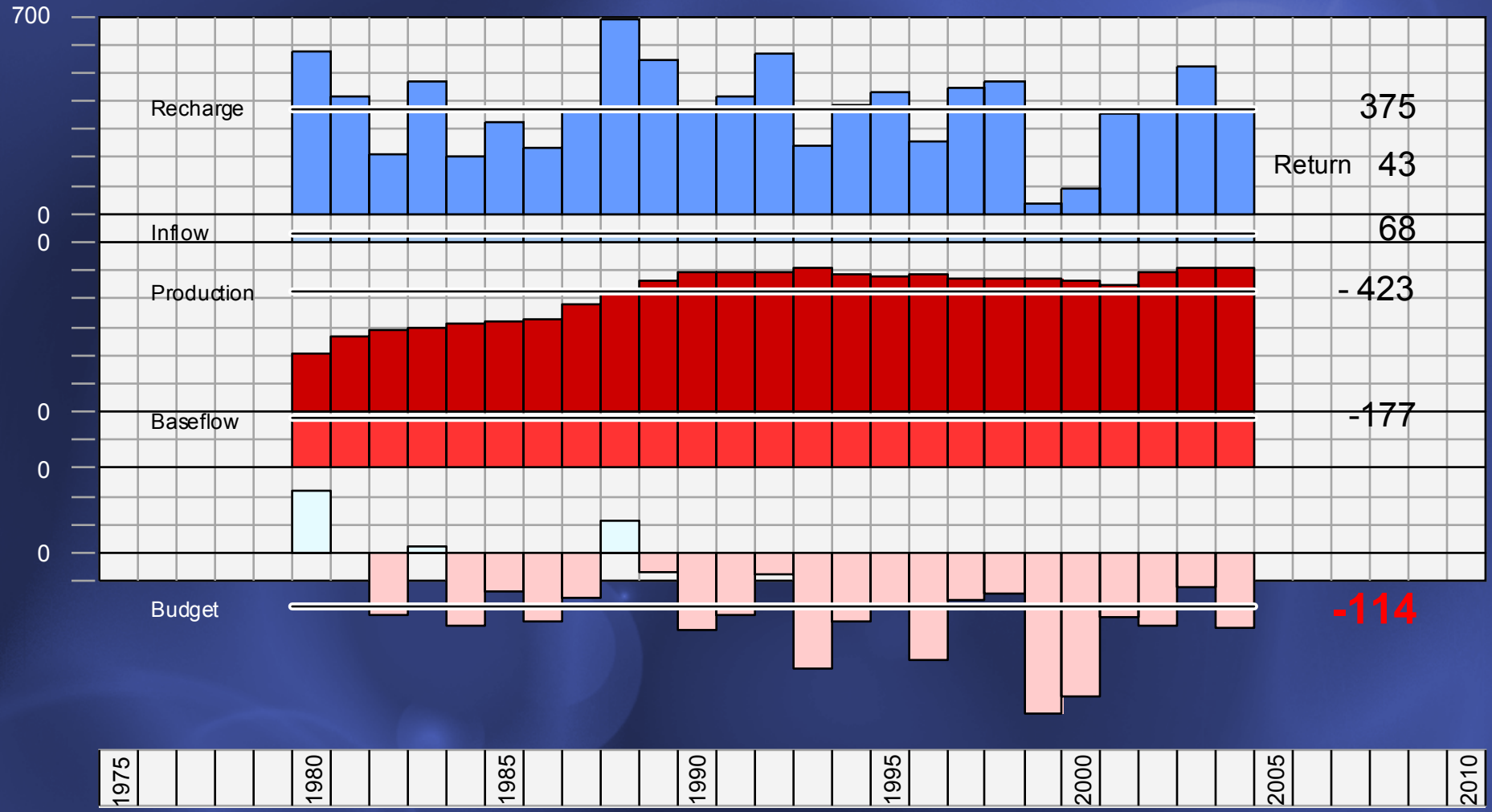
Amman Zarqa

G03

Number of cells : 424 4308.3 km²

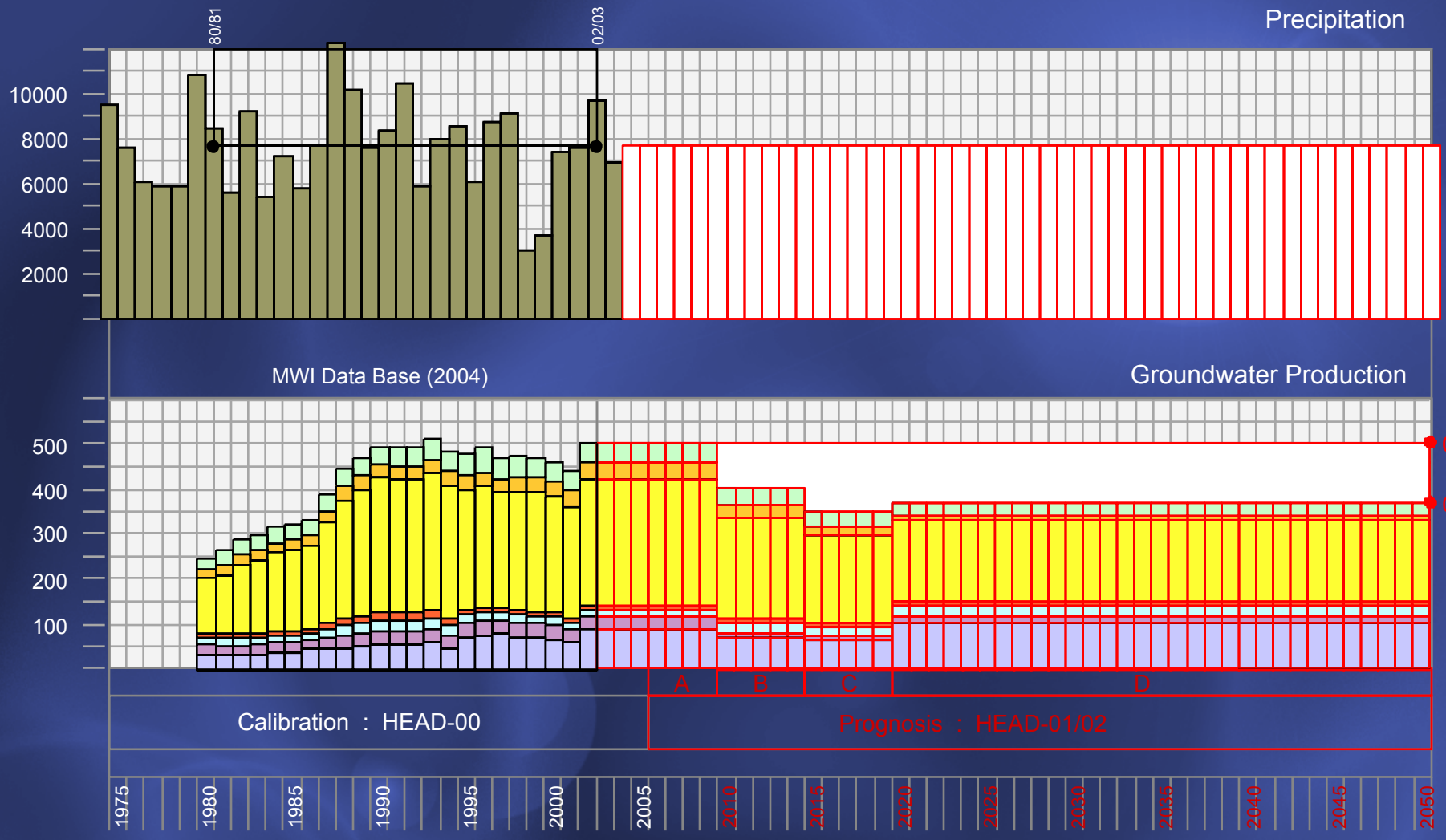
Total Budget : -52.2 2001

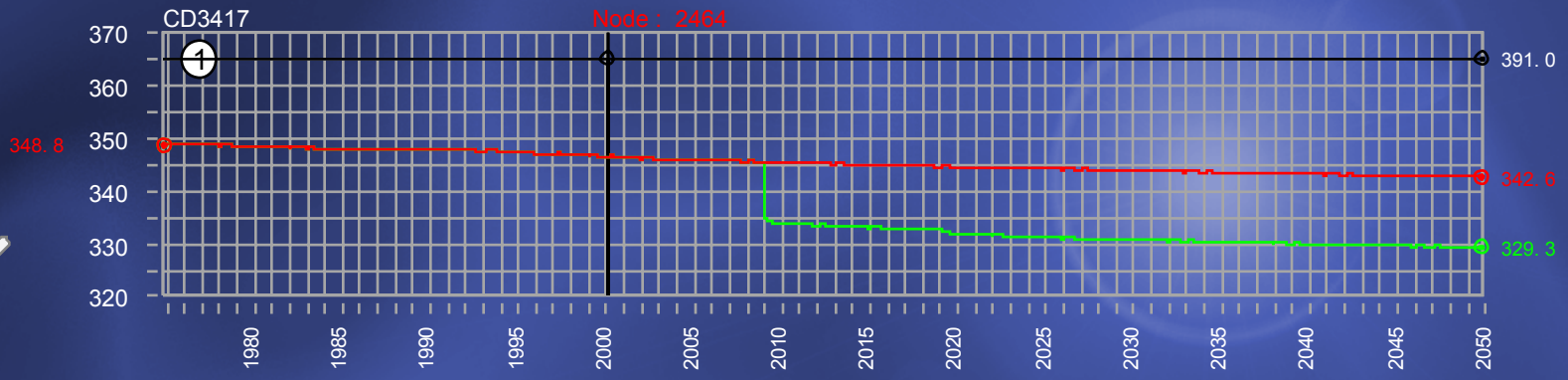
Volumes in million m³/year

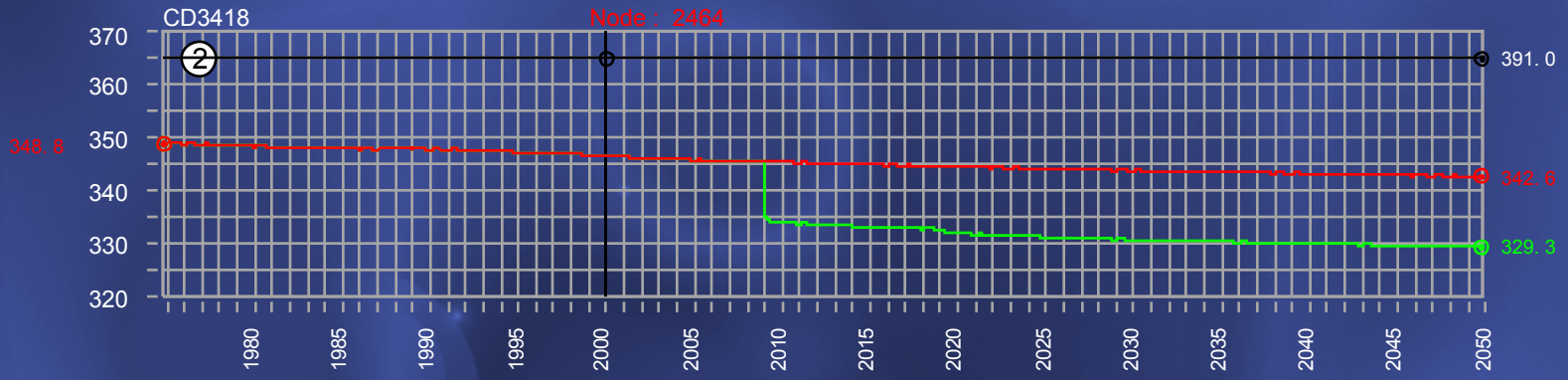


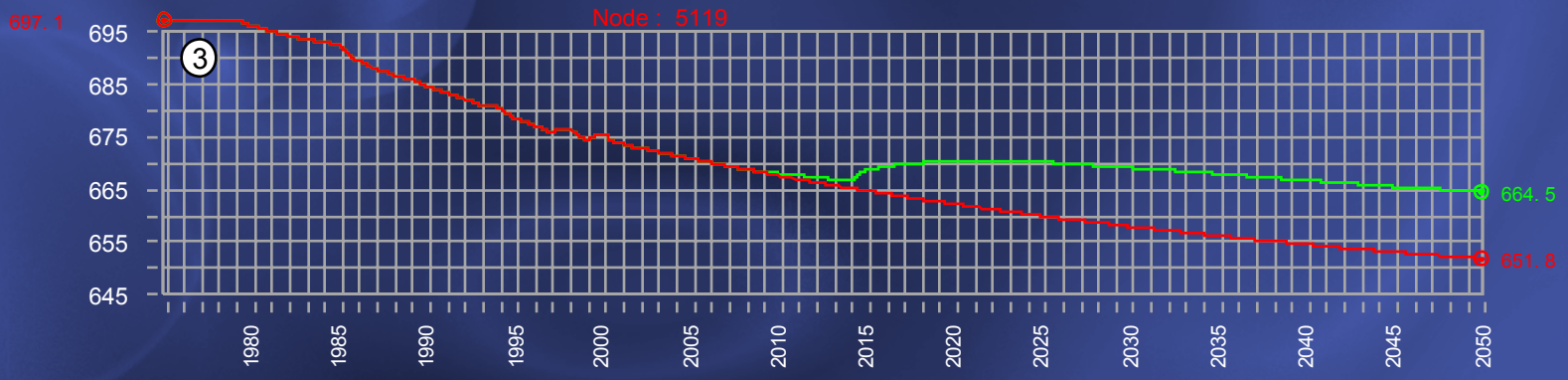
Total Groundwater Budget in MCM 1980 - 2004

Source : MWI - BGR - GSMO (2004)


Precipitation
80/81
02/03
10000
8000
6000
4000
2000
MWI Data Base (2004)
Groundwater Production
500
400
300
200
100
01
02
A
B
C
D
Calibration : HEAD-00
Prognosis : HEAD-01/02
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Productive Aquifers :
001 Basalt
002 B4 / B5
003
004 A7 / B2
005 A4
006 Kurnub
007 Zarqa Group
008
009 Upper Ram Group
010
Total Precipitation and Groundwater Production in MCM (million m3)







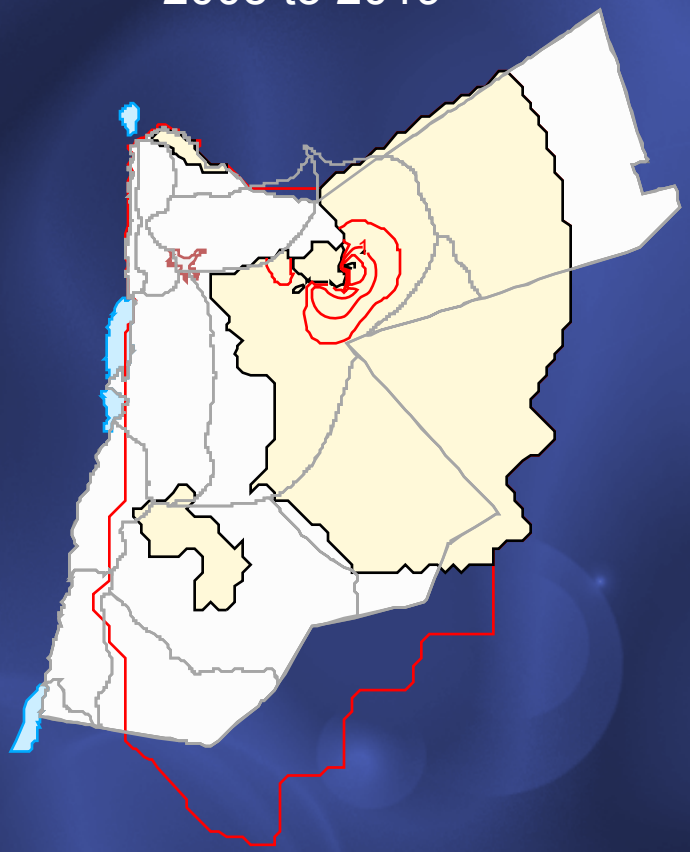
Groundwater Heads

Heads in [m]
ref. to mean sea level

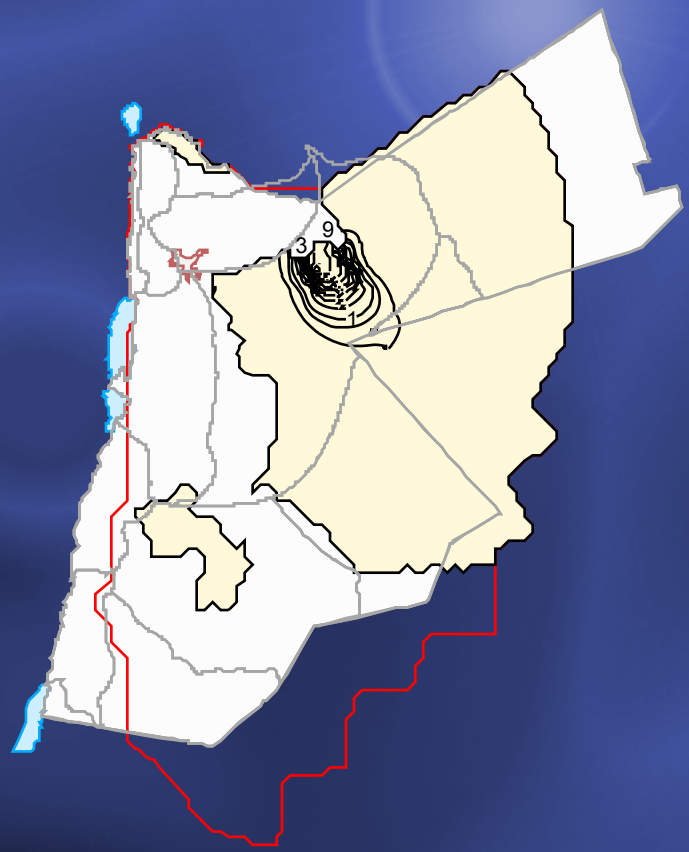
AQUI : 009

Drawdown for Scenario 2 in B4/B5

2005 to 2019



2019 to 2050

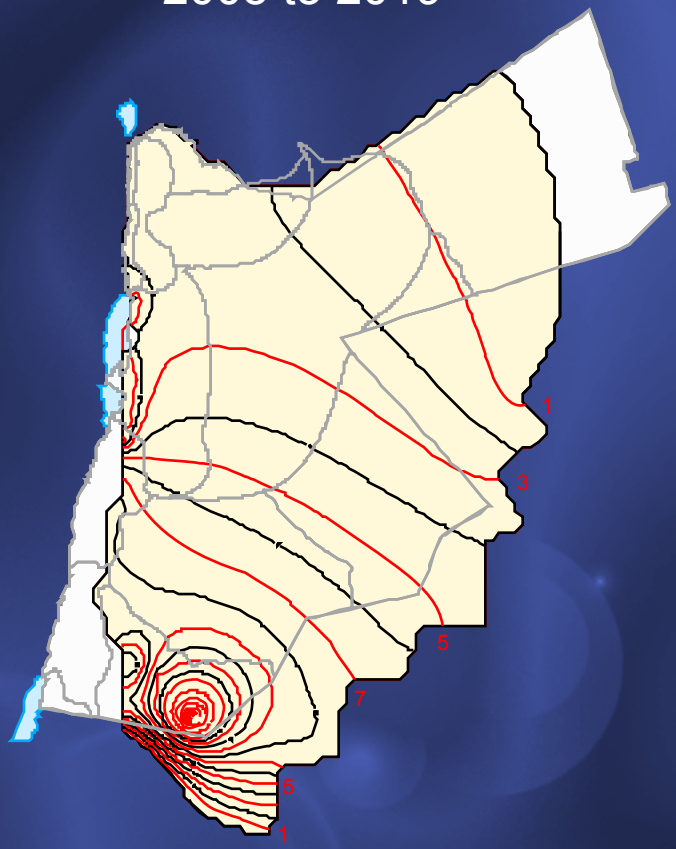


Drawdown, maximum : 2 m

Recovery, maximum : 10 m

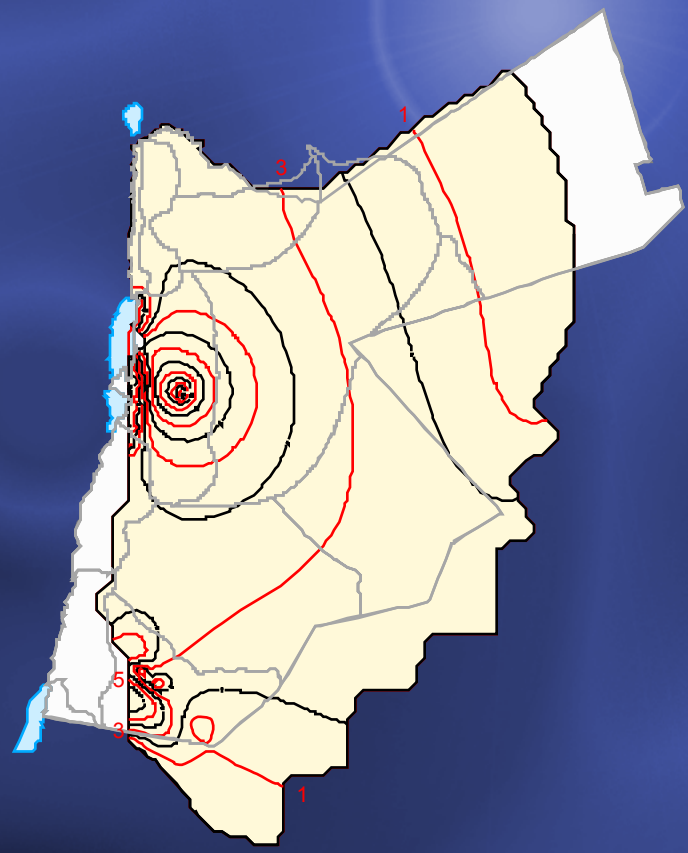
Drawdown for Scenario 2 in the Ram Group

2005 to 2019



Drawdown, maximum : 13 m

2019 to 2050



Drawdown, maximum : 24 m

Measures for Water Resources Protection (Jordan)

Groundwater

- **Groundwater Vulnerability Maps**
  introduced in 1996, 4 maps available:
  Irbid, South Amman, Qunayya spring, Karak-Lajjun
- **Groundwater Protection Zones**
  introduced in 1999; 3 protection zones established;
  5 in ongoing project phase
- **Groundwater Protection By-Law**
  initiated in 2002, to be issued soon

Surface Water (ongoing project phase)

- **Surface Water Protection Zones** (drinking water; ongoing phase):
  2 protection zones: Wadi Wala dam, Wadi Mujib dam)
- **Surface Water Protection By-Law** (ongoing phase)

Hazards to Groundwater (ongoing project phase)

- Improved Licensing Decisions
- Public Awareness
- Design Standards Waste Disposal Sites, Sewage Treatment Plants, etc.

Importance of Protection

Deterioration of water resources quality

- Increasing salinities and nitrate contents in heavily exploited / cultivated areas due to irrigation return flow (e.g. Badia, Dhuleil-Hallabat, Azraq)
- Insufficient collection and treatment of sewage water (capacity and efficiency)
  - ➢ high risk of bacteriological contamination
- Growing number of hazards to groundwater due to increasing industrial/commercial development
  - ➢ health risks (organic substances not sufficiently analyzed)

➢ Reduced availability of suitable water resources for drinking purposes

➢ Urgent need for water resources protection

Use of Groundwater Vulnerability Maps

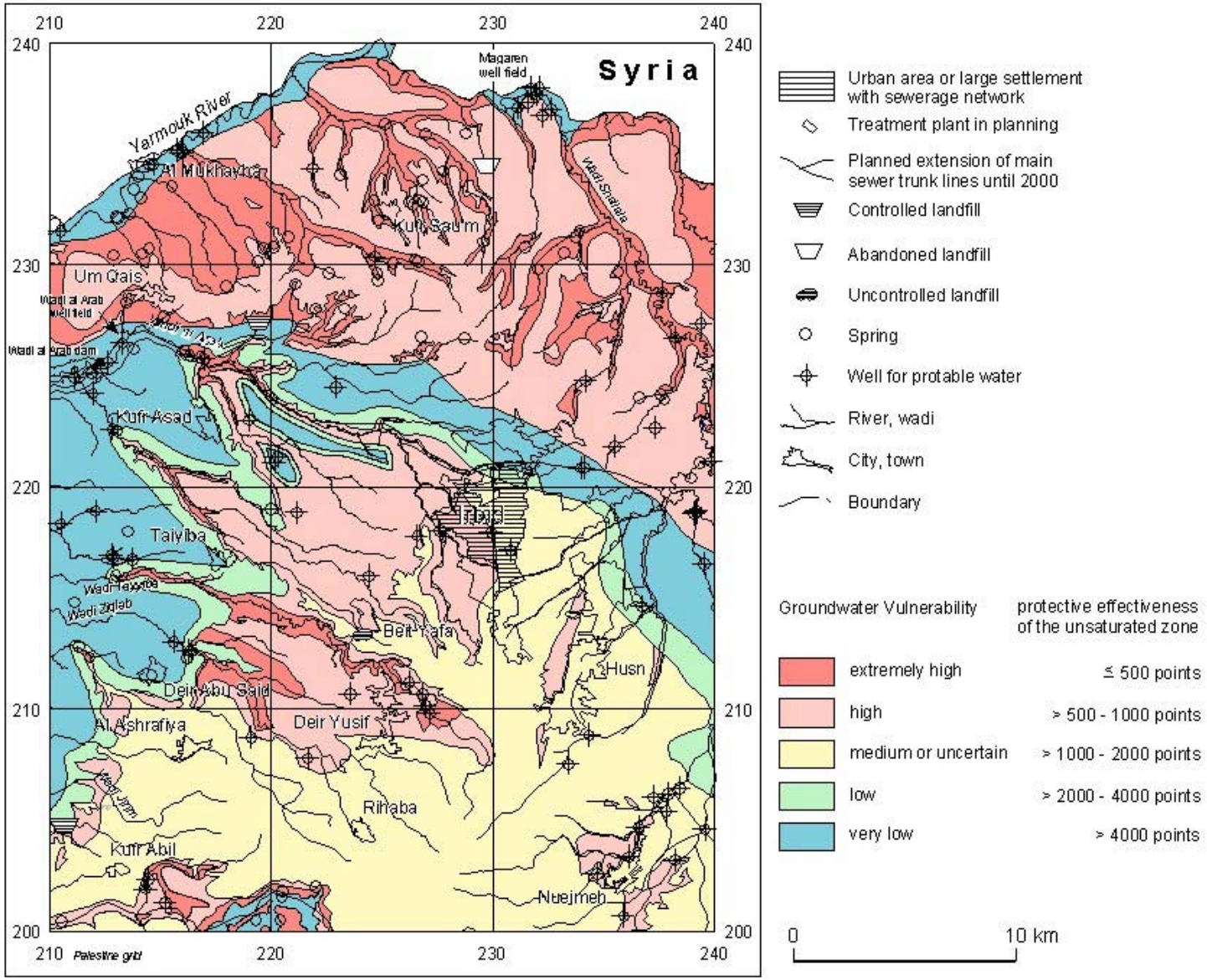
Land Use Planning (Planning Authorities):

- Selection of Areas for Activities Hazardous to Groundwater,
- Protection of very Productive Aquifers (conservation)

Water Resources Management (Water Authorities):

- Groundwater Protection Zone Delineation and Definition of Land Use Restrictions,
- Protection of Resources which may be Important in the Future,
- Design of Groundwater Monitoring Networks,
- Environmental Impact Assessments,
- Detection of Pollution Sources and Pathways.

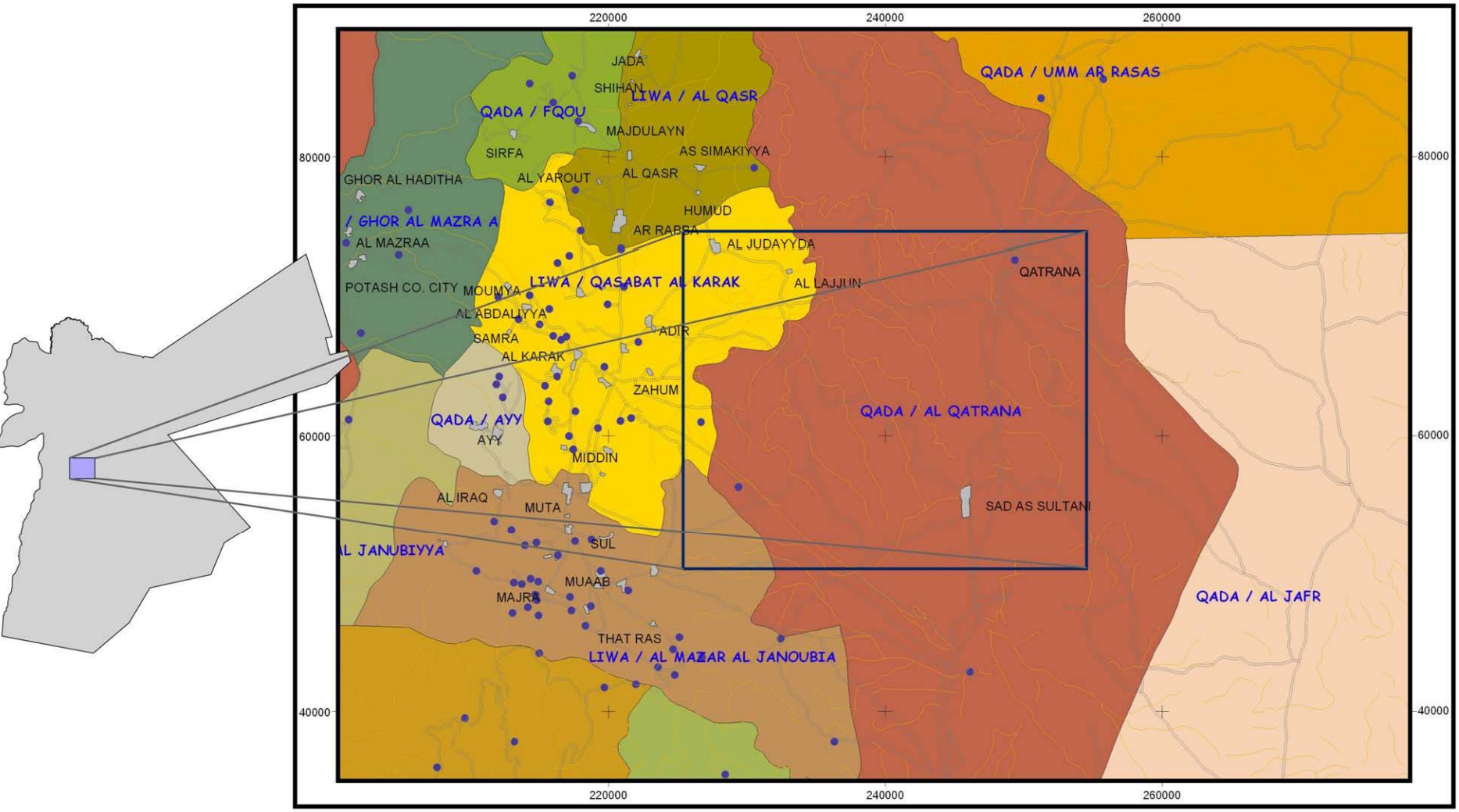
Groundwater Vulnerability Map of the Irbid Area

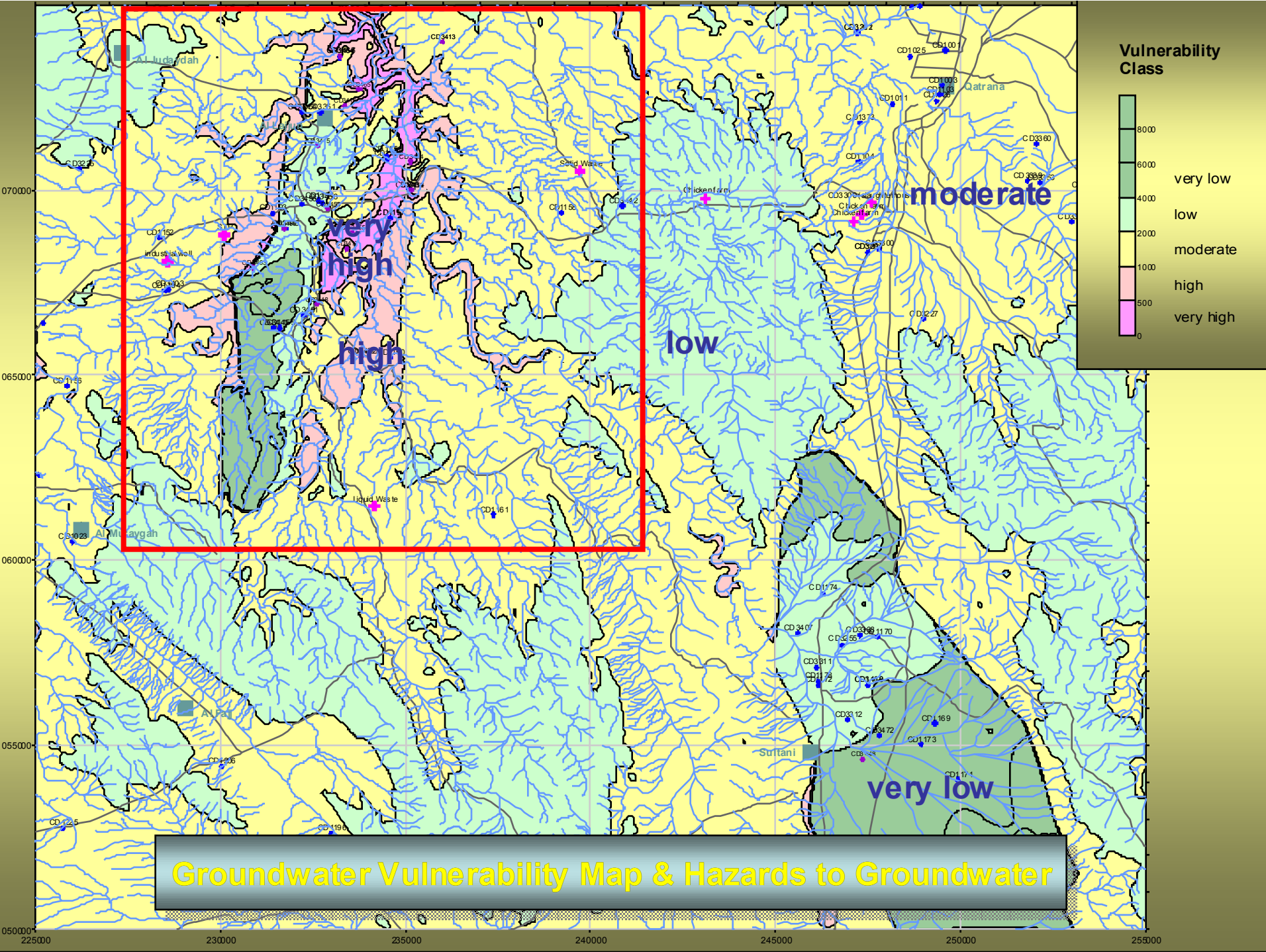


GW-Vulnerability Maps Prepared in Jordan

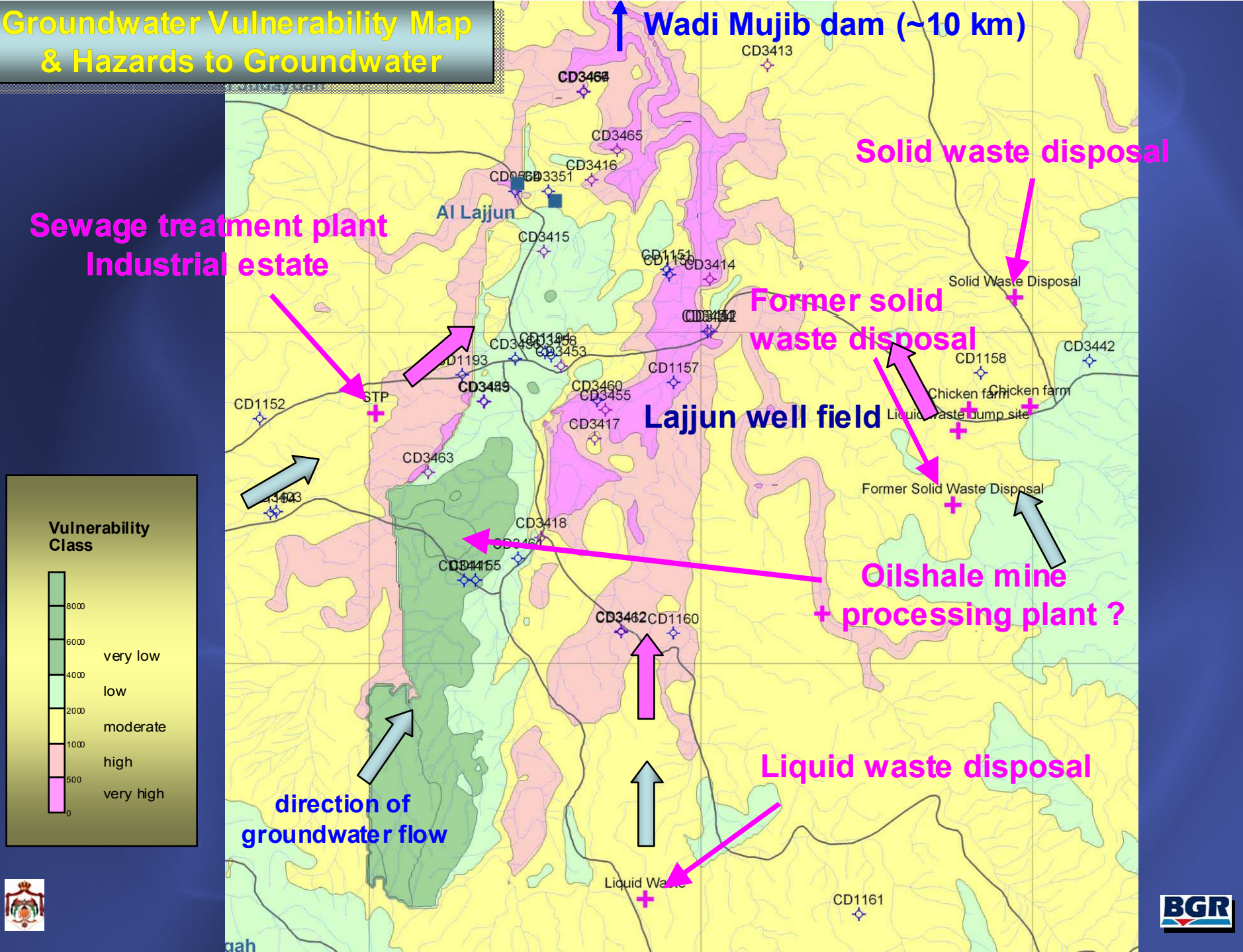
- Irbid area, northern Jordan
  (MARGANE et al., 1997, MARGANE et al., 1999)
- South-Amman, central Jordan
  (SUBAH et al., 1999)
- Qunayyah Spring Catchment (E of Jarash), northern Jordan
  (BROSIG, 2005)
- Karak – Lajjun Area, central Jordan
  (MARGANE et al., 2005)

Groundwater Vulnerability Map Karak-Lajjun Area

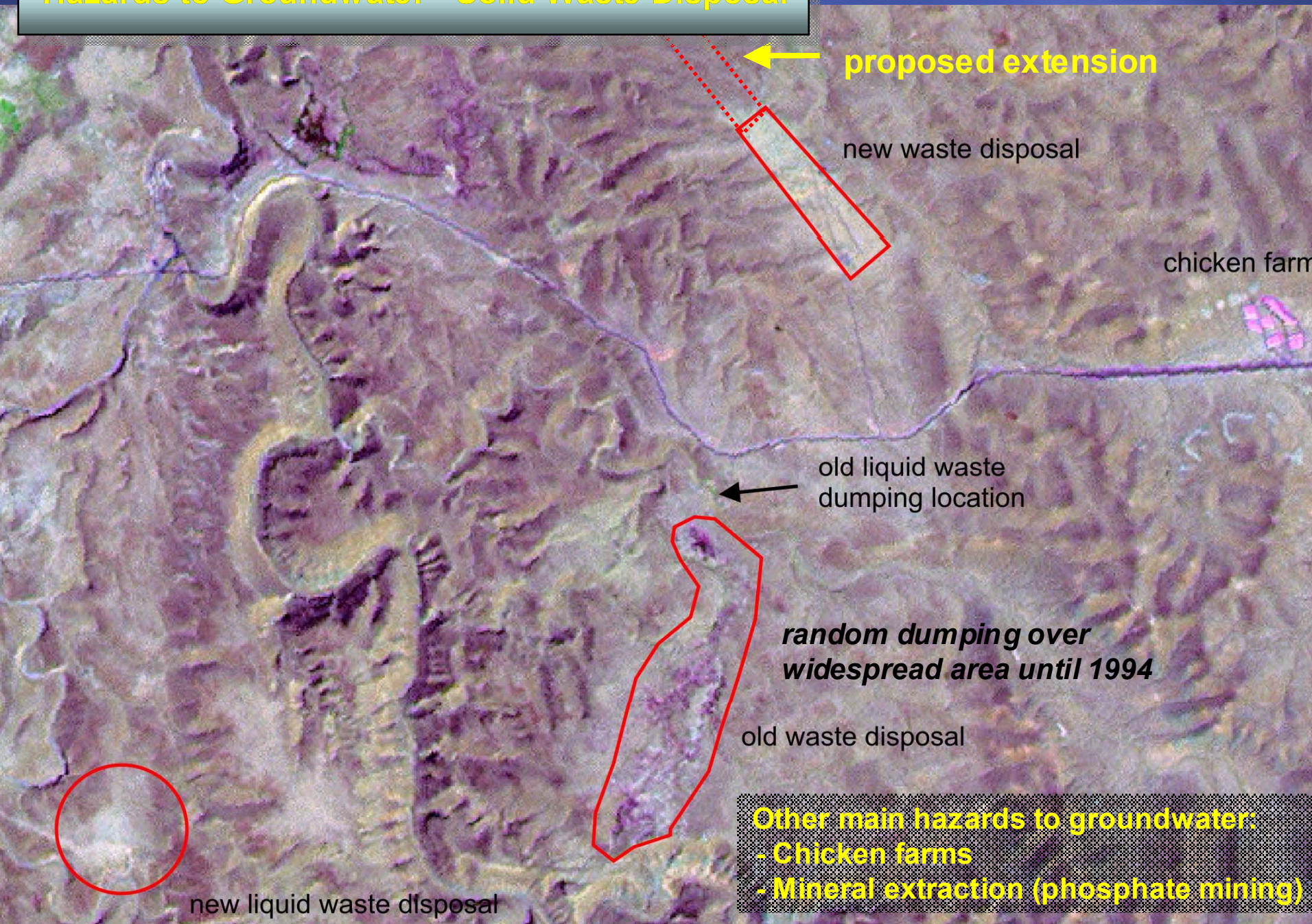



Vulnerability Class
8000
6000
4000
2000
1000
500
0
very low
low
moderate
high
very high
very high
high
low
moderate
very low
Groundwater Vulnerability Map & Hazards to Groundwater
Qatrana
Sultani
Al Judaydah
Al Muraygah
Al Fall
Solid Waste
Liquid Waste
Chicken farm
Industrial well
070000
065000
060000
055000
050000
225000
230000
235000
240000
245000
250000
255000

Groundwater Vulnerability Map & Hazards to Groundwater



Hazards to Groundwater - Solid Waste Disposal



Hazards to Groundwater - Solid Waste Disposal

- no base liner
- no top cover
- no leachate drainage system
- no compaction
- no gas collection
- no downstream GW-monitoring

Establishment of groundwater protection zones

Needs for the establishment of protection zones

Elaboration of guidelines:

- hydrogeological delineation
- regulations
- responsibilities

Legal regulations

water laws, resp. by-laws

Cooperation projects assist in the elaboration as well as the initiation of the process of preparing the legal regulations *(Proposal for a National Guideline for the Delineation of Groundwater Protection Zones in 2002, German-Jordanian approach)*

Establishment of protection zones as examples

e.g. Pella spring, Qunnayah spring, Wadi el Arab well field

GW-Protection Zones

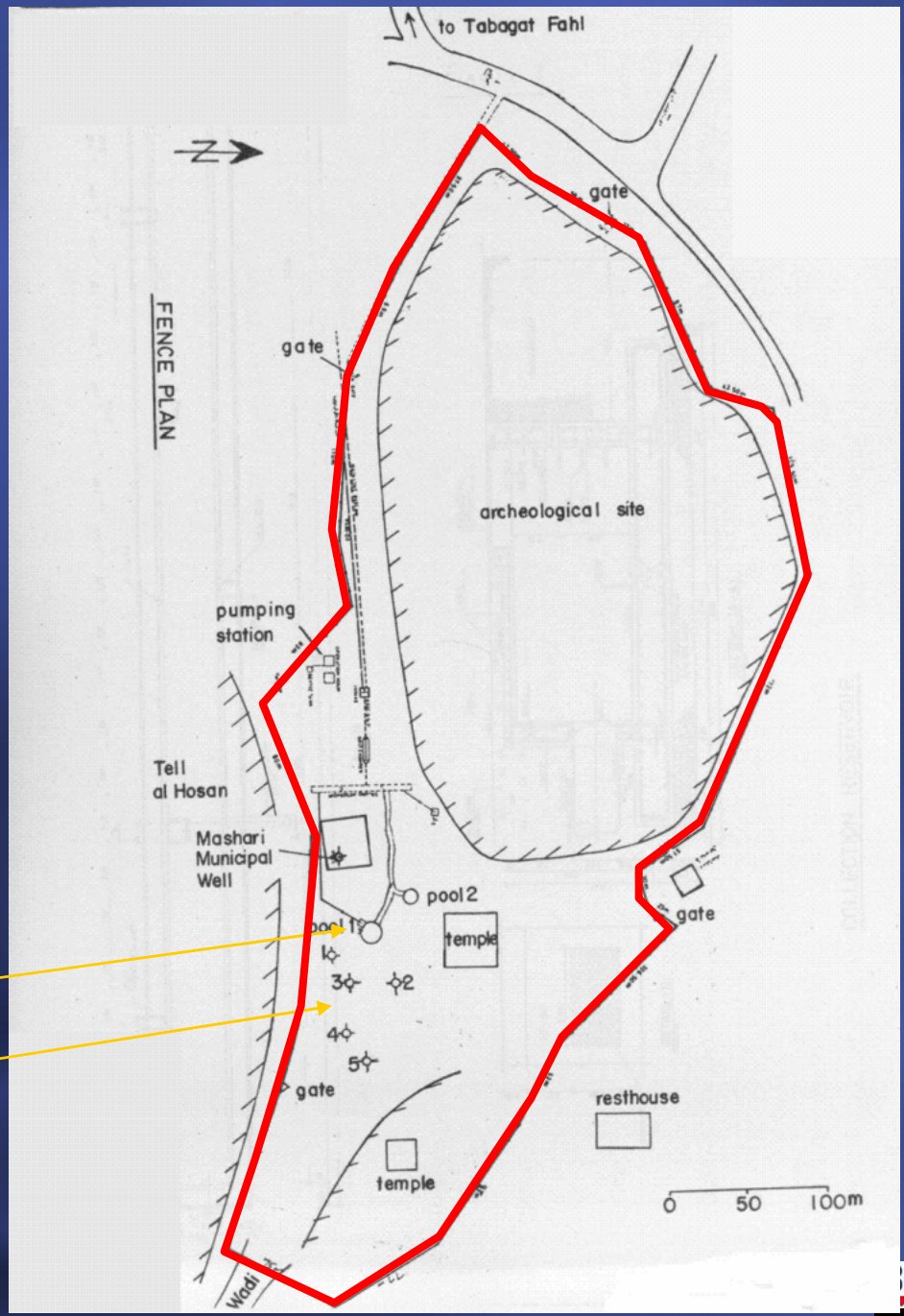
Example: Pella Spring (1999)

Zone I

Aim:
Immediate Protection of the springs and wells against direct pollution.

former pools

boreholes



Design and establishment of groundwater protection zones

Pella spring

GW-Protection Zones

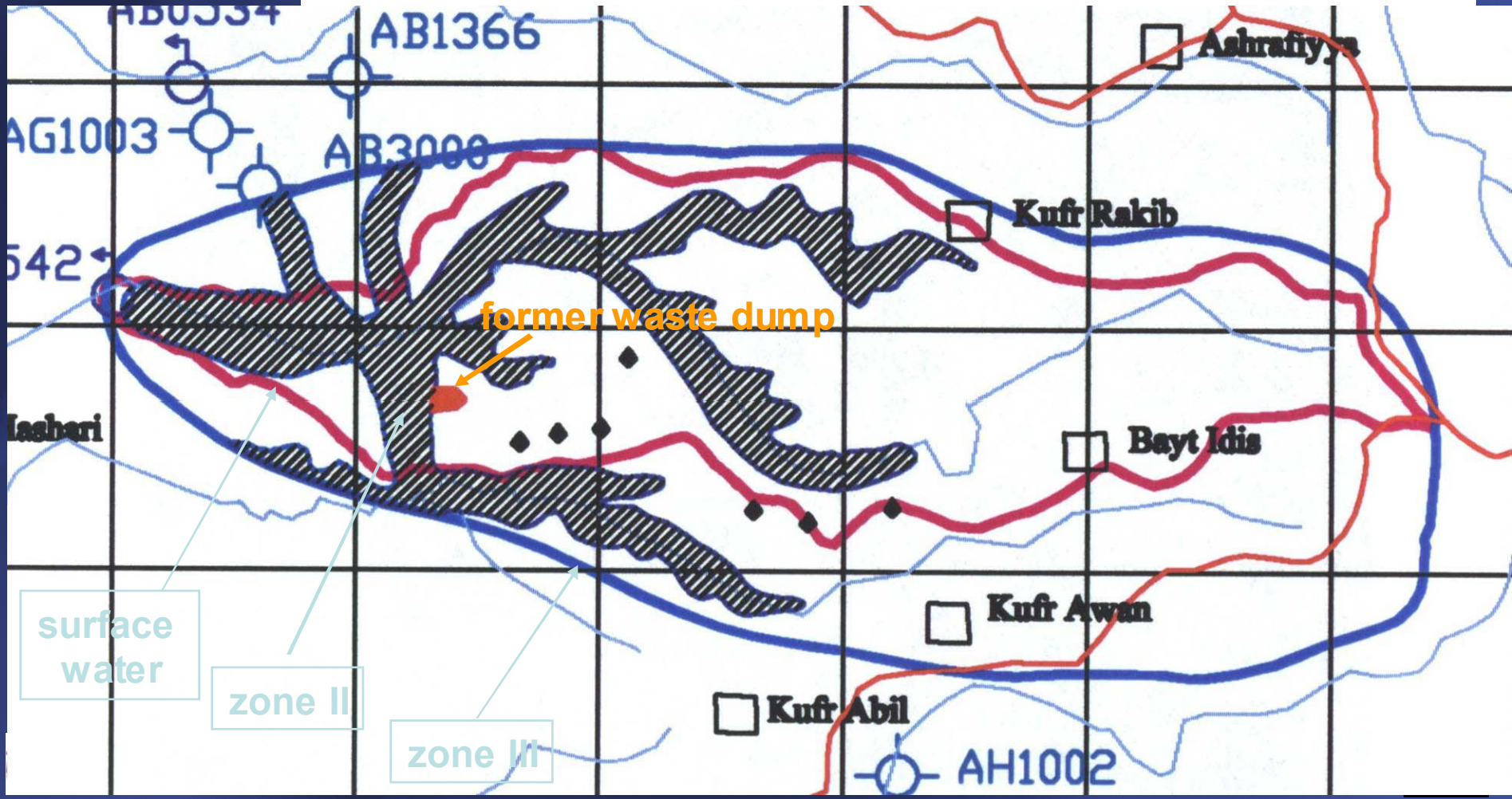
Example: Pella Spring

Aim:

Zone II – Protection against bacteriological pollution (50 days travel-time)

Zone III – Protection of the entire well contribution zone

Zones II and III



Initiation of Groundwater Protection By-Law

Important: Participation of all Stakeholders

Members of the **Higher Committee for Groundwater Protection** :

Ministry of Water and Irrigation
- Water Authority of Jordan
- Jordan Valley Authority
- Ministry of Environment
- Ministry of Municipalities
- Ministry of Agriculture
- Ministry of Health
- Ministry of Industry
- Universities
- Stakeholder Groups (Association of Agriculture)

By-Law proposed: November 2002
Status: pending for approval by Prime Minister

Surface Water Protection – Objectives

Protection Zones
(identical with aims of groundwater protection zones)

Zone I - Immediate Protection Zone
Protects the source and its immediate environment from any contamination and interference giving sufficient time for emergency response (to shut off water supply and replace it by emergency supply – 1 day).

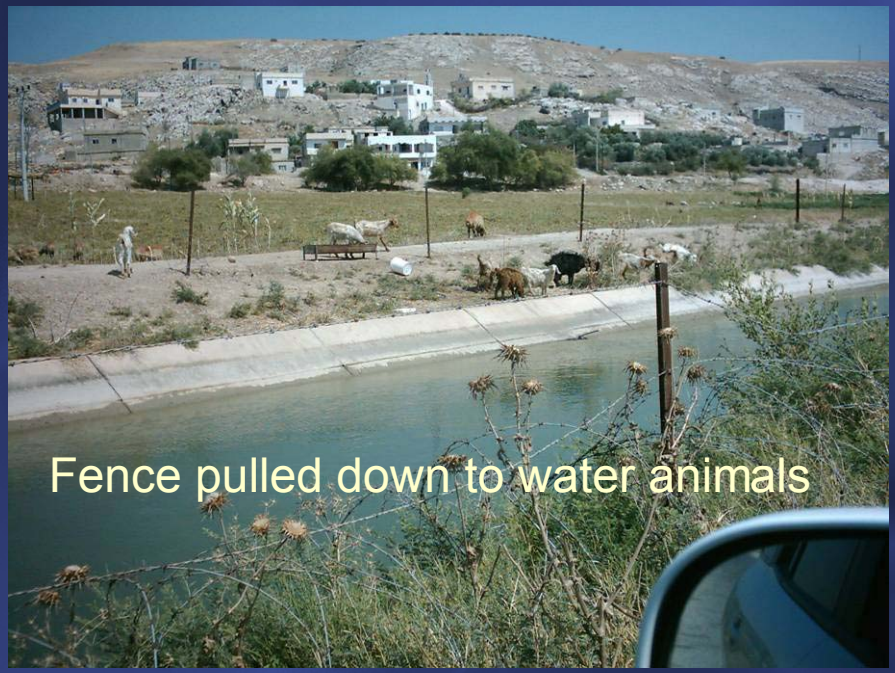
Zone II - Inner Protection Zone
Protection against pathogenic micro-biological constituents such as bacteria, viruses, parasites and worm eggs.
(50 days travel time = average lifetime of pathogens)

Zone III - Outer Protection Zone
Protection from contamination affecting water over long distances such as contamination by radioactive substances or chemicals which are non- or hardly degradable.

Surface Water Protection – Problems in Jordan

Numerous Hazards

Enforcement & Acceptance of Restrictions



KAC = King Abdullah Canal

Surface Water Protection – Problems in Jordan

Proximity to Hazards

e.g. infrastructure lines: roads not appropriately designed to avoid contamination (accidental spills, permanent contamination load)

Surface Water Protection – Problems in Jordan

Proximity to Hazards

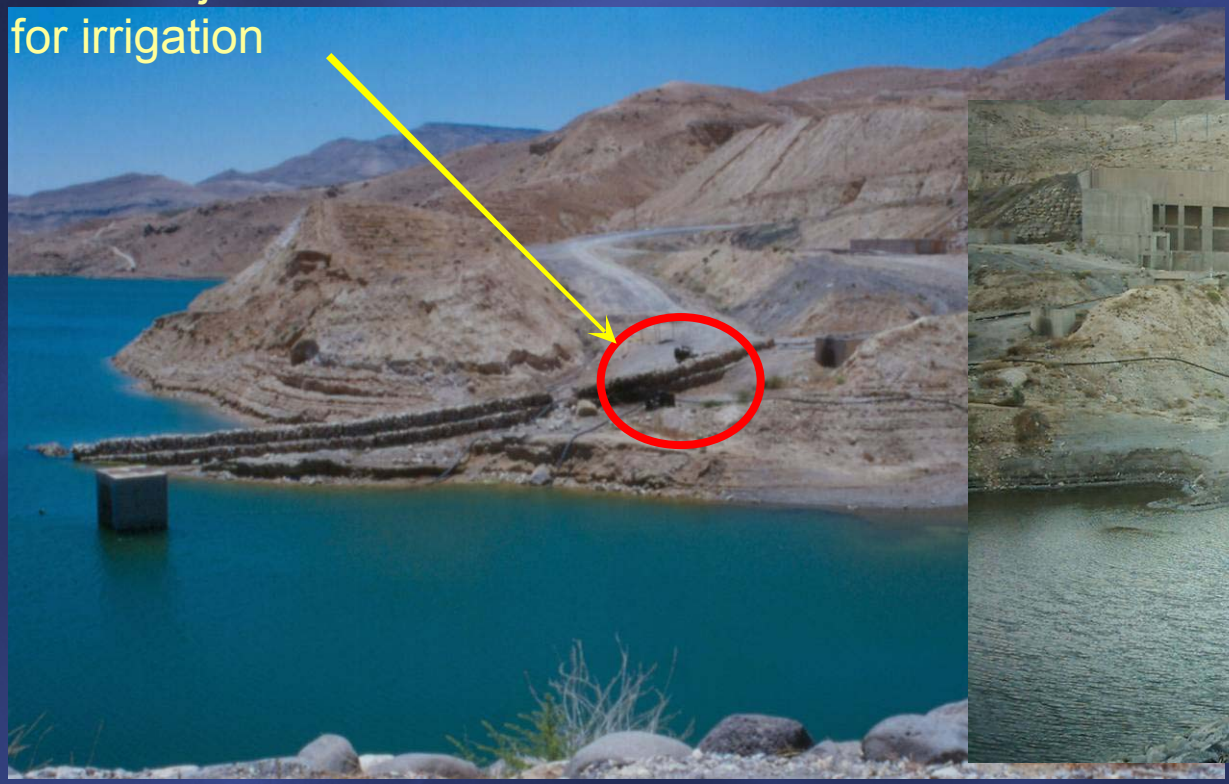
Road crossing dam crest at Wadi Mujib dam

Accident on dam crest may contaminate the dam for several years !

Surface Water Protection – Problems in Jordan

Proximity to Hazards

Generators set up at
Wadi Mujib dam
for irrigation



oil spill at dam

Surface Water Protection – Problems in Jordan

Proximity to Hazards

Surface Water Protection – Guideline

Types of Surface Water Resources

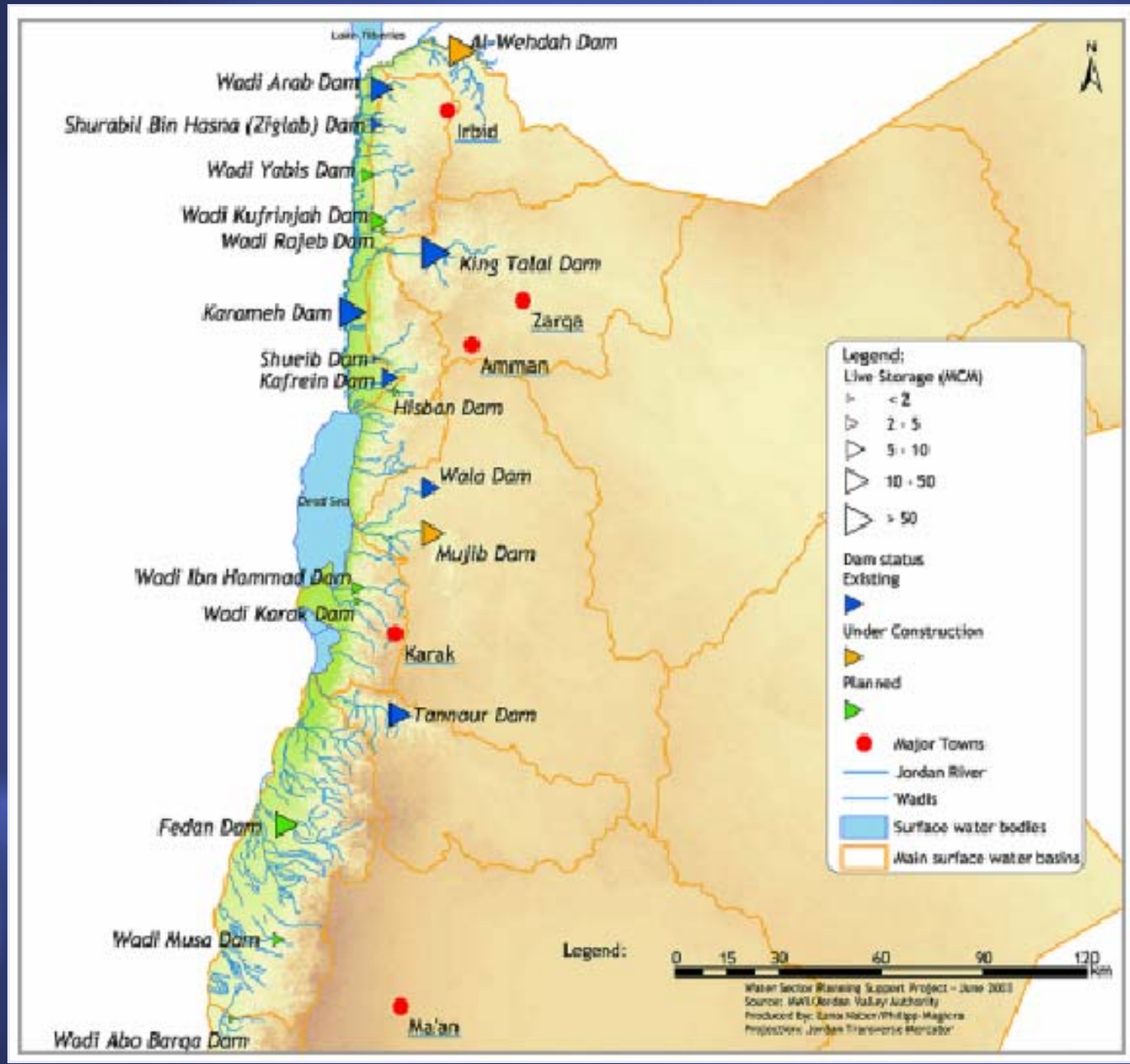
- Dams / reservoirs
  - used for irrigation
  - used for drinking water supply
- Canals
  - used for irrigation
  - used for drinking water supply
- Streams
  - used for irrigation
- (Reclaimed wastewater)

Considered in this guideline only:

➢ dams used for drinking water supply

Surface Water Protection

Dams in Jordan



Surface Water Protection – Dams in Jordan

Presently 10 large dams with over-year storage and a total live storage of 232 MCM/a:

- Wadi Mujib dam (35 MCM/a) - transferred to Deir Allah and Ghor Haditha (drinking Amman/irrigation Ghor Haditha; pipeline not completed)
- Wadi Wala dam (9.3 MCM/a) - used for artificial recharge / extraction at Wadi Wala well field (drinking Amman)

- Wadi Al Arab dam (16.9 MCM/a) - temporary storage of KAC flood waters (returned to KAC when needed: drinking Amman/irrigation Jordan Valley)

- King Talal dam (75 MCM/a) - used for irrigation in the central Jordan Valley
- Karameh dam (55 MCM/a) - used for irrigation in the central Jordan Valley
- Kafrein dam (8.5 MCM/a) - used for irrigation in the southern Jordan Valley
- Wadi Ziglab dam (3.9 MCM/a) - used for irrigation in northern Jordan Valley
- Wadi Shuayb dam (2.1 MCM/a) - used for irrigation in southern Jordan Valley
- Hasa/Tannour dam (16.8 MCM/a) - used for irrigation in southern Ghor
- Wadi Fidan dam (10.0 MCM/a; to be completed in 2005) - used for irrigation in southern Ghor

Surface Water Protection – Dams in Jordan

Planned/under construction (with expected year of completion and expected live storage):

- Al Wehdah dam (95 MCM/a for irrigation, domestic and industrial purposes in the North and Amman; expected to be completed in late 2005)
  - Special problem: inflow mainly from Syria, i.e. not under control of Jordanian Government so that little can be done to protect the resources; large-scale agricultural production
    - may result in elevated contaminant load from pesticides and fertilizers

-Karak dam (1.1 MCM/a from 2008 on)
-Wadi Ibn Hammad dam (3.0 MCM/a from 2008 on)
-Wadi Yabis dam (5.0 MCM/a from 2015 on)
-Wadi Kufrinja dam (9.0 MCM/a from 2015 on)

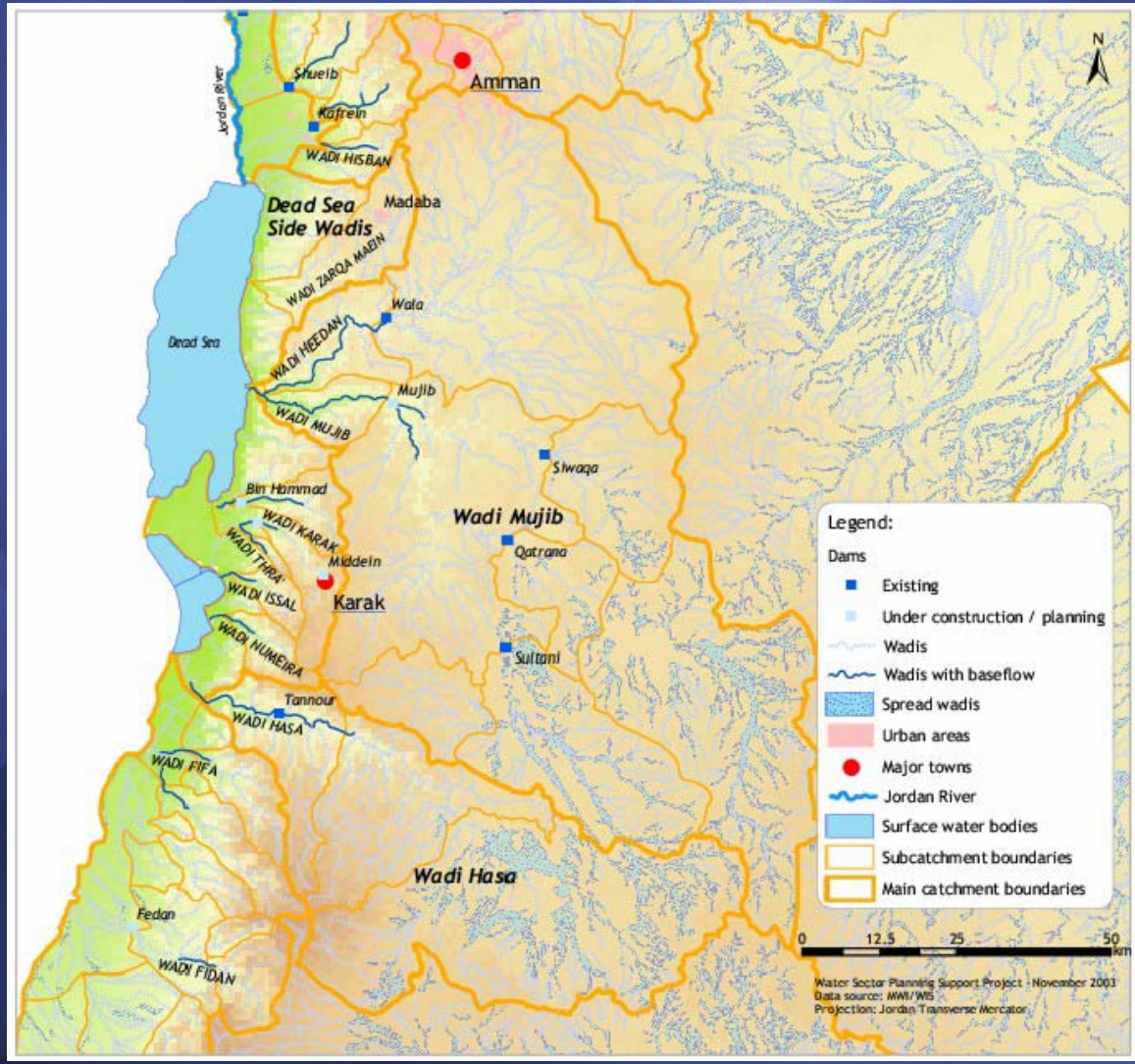
- : used for drinking water supply

Surface Water Protection – Dams in Jordan

Example
Mujib & Wala dams
(very large catchment areas)

Total Mujib catchment area:
6727 km²
Mujib upstream of dam:
approx. 4000 km²
Wala upstream of dam:
approx. 1500 km²

which zoning system ?
zone III required ?
which restrictions ?
how to monitor ?

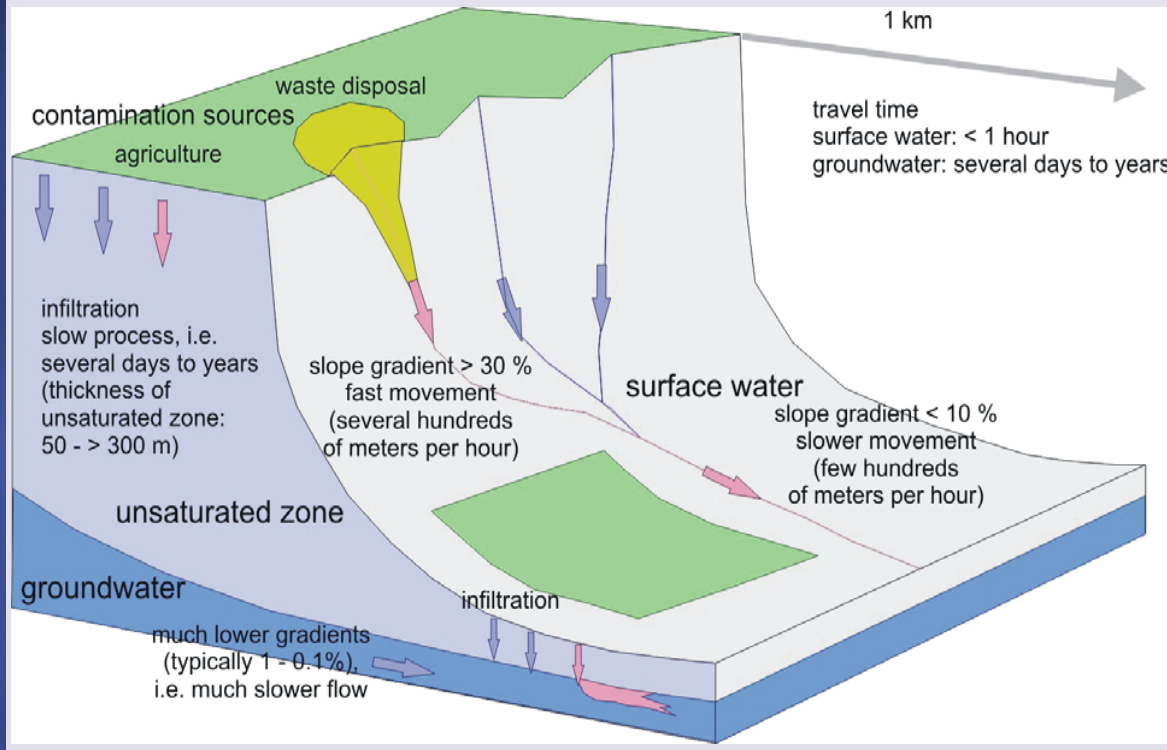


Zoning System

Under the typical conditions in Jordan the travel time in surface water is very short
➢ large protection areas

A compromise must be reached so that landuse restrictions are still acceptable

Time of Travel (TOT) in Surface Water and Groundwater



Groundwater has much longer travel times than surface water. Therefore surface water is much more vulnerable to contamination and the protection of surface waters is much more difficult than that of groundwater

Most critical factors in Jordan:

in the Surface Water Path:
- high slope gradients
- low vegetation cover

in the Groundwater Path:
- level of karstification, fracturing

result in relatively fast movement in surface water and groundwater

Surface Water Protection – Zoning System

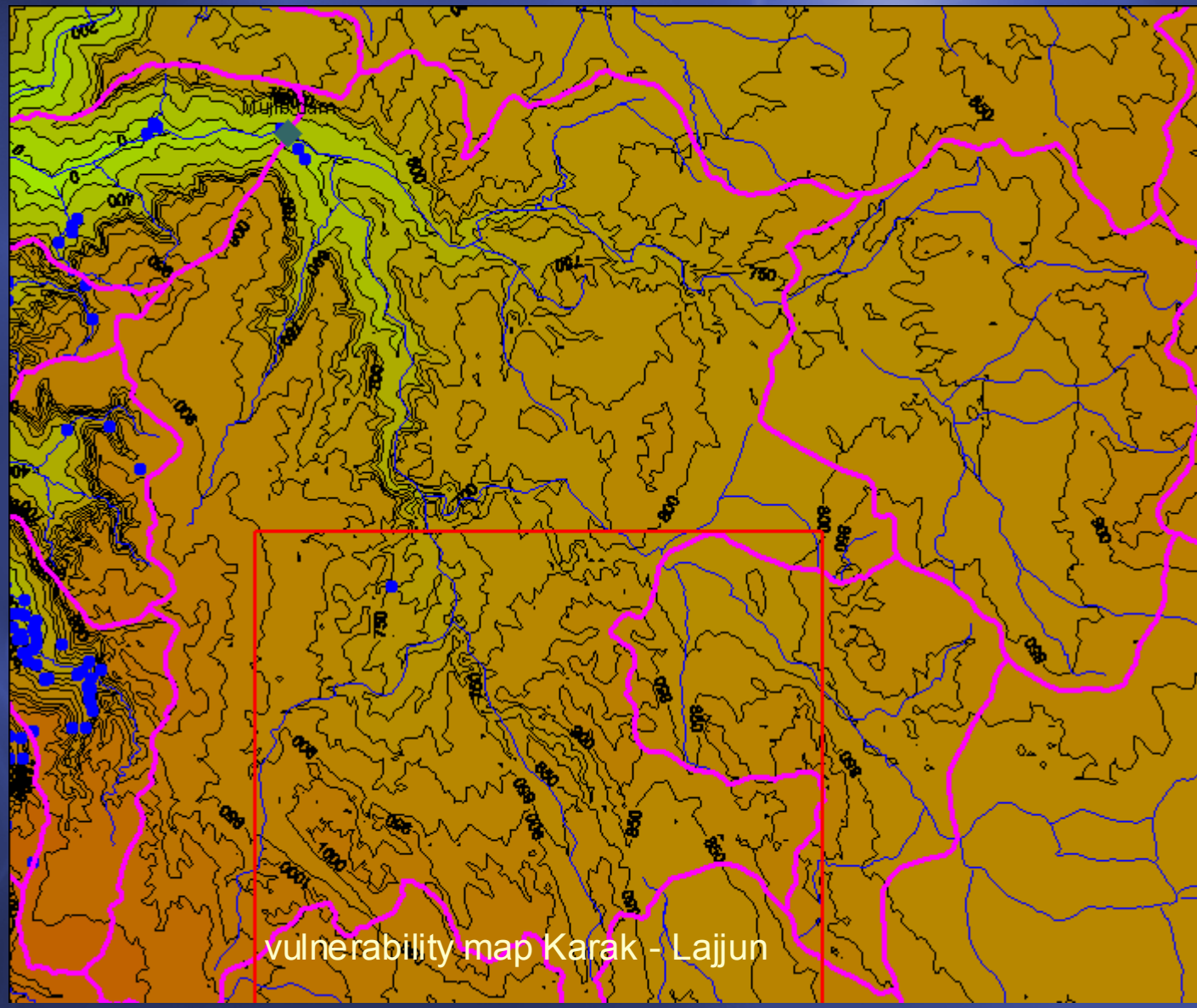
Zone I: buffer zone of 100 m around a reservoir, measured from the highest possible water level.

Zone II: buffer zone of 500 m around the dam, measured from the highest possible water level, if slope within this zone is below 2°. If the slope exceeds 2° at a distance of 500 m, zone II will reach to where the slope becomes less than 2°. In the upstream area, zone II will reach until a distance of a maximum of 5 km following the course of the main wadis discharging into zone I. Zone II will also encompass a buffer zone of 100 m to each side from the center of the main wadis discharging into zone I until a distance of 15 km, measured from the highest possible water level, following the course of the main wadis.

Wadi Mujib – Protection Zones & Hazards

Example
Mujib & Wala dams

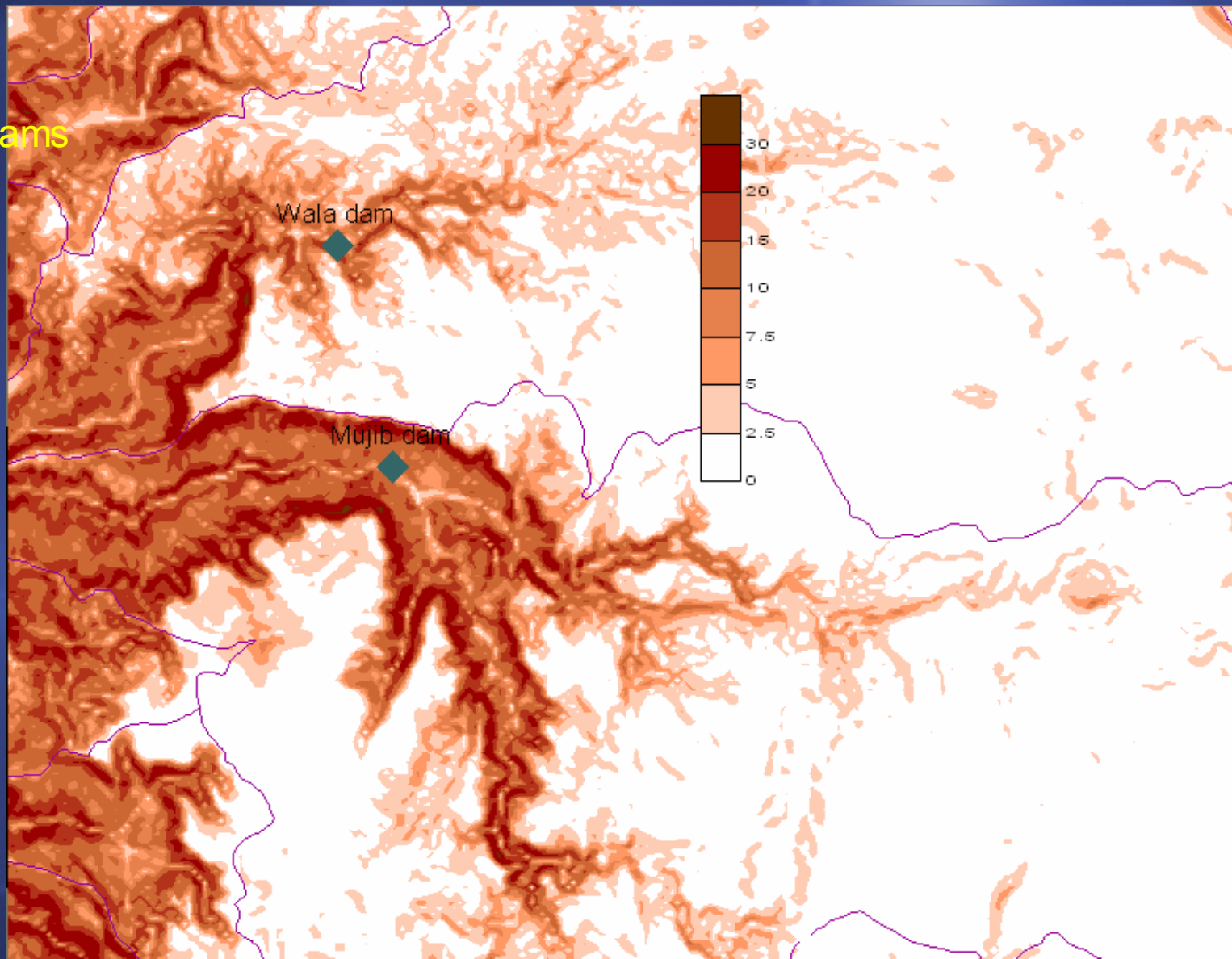
Digital Elevation Model & Catchment Area



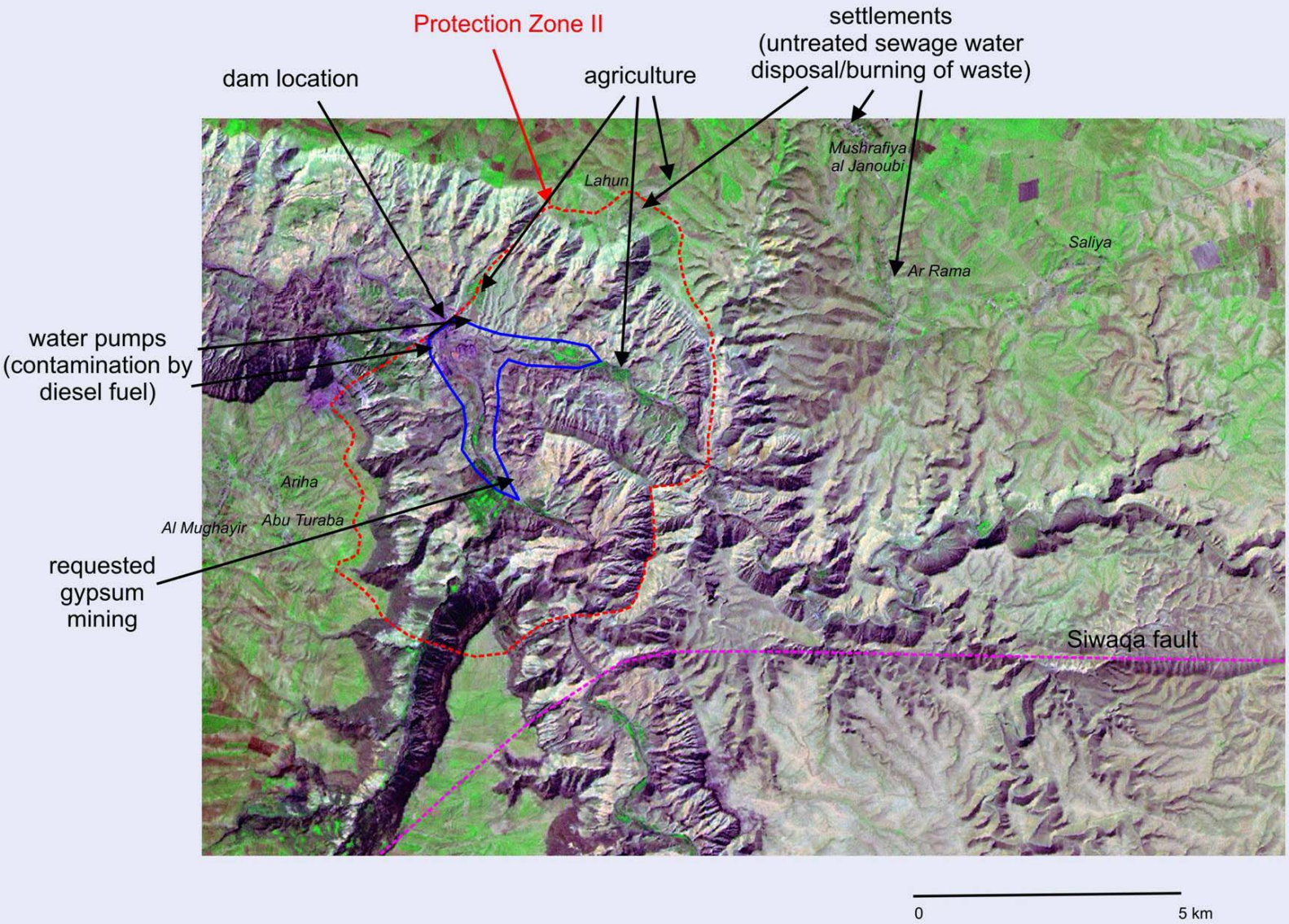
Wadi Mujib – Protection Zones & Hazards

Example
Mujib & Wala dams

Slopes [deg]



Wadi Mujib – Protection Zones & Hazards



Guideline for Surface Water Protection Zones

Procedure

- Compilation of International Guidelines
- Selection of a suitable Guideline for the Condition in Jordan & Discussion of Restrictions
- Preparation of a Draft By-Law
- Discussion – Amendment by Surface Water Protection Committee
- Signed by Prime Minister
- Preparation of a Surface Water Protection Ordinance
- Adoption by Minister of Water and Irrigation

➢ By-Law: establishes the legal framework

➢ Surface Water Protection Ordinance: regulates the details
e.g. how a protection zone document has to be prepared,
which administrative procedure has to be followed,
which restrictions have to be implemented,
which monitoring measures need to be implemented.

Guideline for Surface Water Protection Zones

The Ordinance on the Delineation of a Surface water Protection Zone for a dam consists of the following elements :

- A statement about the legal basis for the issuance of the ordinance,
- The study, defining the boundaries of the surface water protection zone,
- The administrative boundaries of the surface water protection zone, based on the study,
- A list of restrictions for activities and land uses in the different surface water protection zones,
- An inventory of all potential sources of contamination for the entire surface water protection zone, to be included in the study,
- An analysis of the susceptibility of the water supply source to those contamination sources, to be included in the study, including an evaluation of the degree of threat arising from each potential pollution hazard,
- A surveillance and monitoring scheme for compliance with defined restrictions,
- A contingency plan that describes how water supply is planned to be maintained in case of contamination and
- A remedial action plan that describes which measures are going to be implemented to avoid contamination in case of accidental contamination.

Concluding remarks

Concluding remarks

The main problems in groundwater resources management in Jordan are related to sustainability. Presently more groundwater is abstracted than recharged and protection of this limited resource must be improved.

Recommendations in the NWMP, Vol. V: GW Resources (amongst others):

On Groundwater Monitoring e.g.
Assessment / review of analytical requirements to develop an appropriate sampling plan
Assessment / review of monitoring well locations to ensure that an effective monitoring well network is in place. Implement if necessary refinement for the network depending on the importance of the aquifer and its vulnerability.

On Groundwater Development and Planning e.g.
The reduction of groundwater abstraction leads to a deficit in water supply.
To bridge this gap,

- limited use of fossil groundwater and brackish groundwater
- prospection and development of unused gw resources and artificial groundwater recharge for temporarily use
- development of sufficient alternative sustainable resources

Concluding remarks

On Groundwater Protection e.g.
The guidelines for the implementation of groundwater protection areas for all public water supplies are being prepared in Jordan. Implementation of these areas requires not only legal, but also technical and institutional support. Technical support includes carrying out relevant hydrogeological studies, inventory of possible sources of contamination for a groundwater protection area, and groundwater vulnerability assessment.

From NWMP, Vol. II, Planning Framework, Ch. 4.1.4 GW Protection:

With respect to groundwater protection it is recommended to adopt a legally binding regulation, or a guideline, for the delineation of groundwater protection zones.
The Ministry of Water and Irrigation should become responsible for defining groundwater protection zones and for the delineation of these zones in the interest of the general public within the scope of its responsibility for the national water resources (BGR, 2002).

Guidelines

Groundwater Guidelines prepared for ACSAD :

Vol. 4: GW-Vulnerability Mapping
Vol. 5: GW-Protection Zones
Vol. 6: Sustainable GW-Resources Management
Vol. 7: GW-Monitoring

download : www.acsad-bgr.org

Guideline on:
Groundwater monitoring for general reference purposes

download : www.igrac.nl

Arab Centre for the Study of Arid Zones and Dry Lands
ACSAD
Damascus

FEDERAL REPUBLIC OF GERMANY
Federal Institute for Geosciences and Natural Resources
BGR
Hannover

TECHNICAL COOPERATION

PROJECT NO.: 1996.2189.7

Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region

Volume 5

Guideline for the Delineation of Groundwater Protection Zones

Damascus

September 2003

Water - a fundamental necessity of life