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BMBF IWRM R&D Programme

SMART – IWRM

Integrated Water Resources Management in the Lower Jordan Rift Valley

Project Report Phase I

Leif Wolf, Heinz Hötzl (eds.)

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Disclaimer

Overall, the SMART project involved more than 70 researchers. This report is compiled chiefly from reporting requirements of each institution and in many cases only the responsible activity leaders are cited as authors since they submitted the input to this report. For a complete overview of involved researchers and their individual contributions in SMART I please consult the SMART List of publications as part D of this report.

Hinweis

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SMART – Sustainable Management of Available Water Resources with Innovative Technologies

IWRM – Integrated Water Resources Management in the Lower Jordan Rift Valley

SMART

BMBF IWRM R&D Programme

SMART – IWRM

Project Report Phase I

by Dr. Leif Wolf, Prof. Dr. Heinz Hötzl (Editors)

Part A Kurzfassung
Part B Executive Summary
Part C Scientific and technical results for each work package

Federal Ministry of Education and Research

Karlsruhe 2011

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- Universität Göttingen, Geowissenschaftliches Zentrum (GU)
- Universität Cottbus, Institut für Bodenschutz und Rekultivierung
- DVGW Technologiezentrum Wasser, Karlsruhe (TZW) (associated project)
- Fa. ATB Umwelttechnologien GmbH, Porta Westfalica (ATB)
- Fa. Hans Huber AG, Berching (HUB)

Israel

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- Tel Aviv University, Earth Science Departement, Tel Aviv (TAU)
- Hebrew University, Department of Geography, Jerusalem (HUJ)
- Ben Gurion University, J. Blaustein Institutes for Desert Research (BGU)
- Mekorot Co Ltd., Tel Aviv (MEK)
- Environmental & Water Resources Engineering, Haifa (EWRE)

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- Ministry of Water and Irrigation, Amman (MWI)
- Water Authority of Jordan, Amman (WAJ)
- Jordan Valley Authority, Amman (JVA)
- Jordan University, Amman (JUA)
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PART A

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PART A

KURZFASSUNG

Im Rahmen der Initiative des BMBF zum Integrierten Wasserressourcenmanagements (IWRM) wurde in den Jahren 2006 - 2010 das Forschungsprojekt SMART am unteren Jordan durchgeführt wobei ein spezielles Augenmerk auch auf der Förderung des wissenschaftlichen Austausches zwischen Jordanien, Israel und Palästina in einem hochgradig politisierten Kontext bei extremer Wasserknappheit lag. Das hier verfolgte Konzept des integrierten Wasserressourcenmanagements (IWRM) versucht konsequent multidisziplinäre Informationen immer früher in einen auf Nachhaltigkeit ausgerichteten Entscheidungsprozess einzubinden. Die Integration findet sowohl auf räumlicher Ebene (mit dem Flusseinzugsgebiet als bevorzugter Planungseinheit anstelle von Verwaltungsbezirken) als auch auf interdisziplinärer Ebene zwischen ingenieurs-, naturwissenschaftlichen und sozio-ökonomischen Betrachtungen statt. Im Jahr 2010 wurde eine Fortsetzung des Forschungsprojektes bis ins Jahr 2013 genehmigt. Der vorliegende Bericht stellt die Handlungsschwerpunkte und Zwischenergebnisse der ersten Phase dar und soll die Zusammenarbeit sowohl innerhalb des Projektes als auch mit der großen Anzahl betroffener oder eingebundener Stakeholder sowie potentiellen Forschungspartnern fördern.

Die wichtigsten Ergebnisse in stichpunktartiger Form sind:

- Etablierung des IWRM Begriffes bei Entscheidungsträgern und Forschungseinrichtungen in der Zielregion. Die Etablierung drückt sich insbesondere durch die aktive Mitarbeit der institutionellen Partner, sowie die vertieften Kontakte des Projektes mit der internationalen und deutschen Entwicklungszusammenarbeit aus. Das resultierende SMART II Projekt ist bereits mit den lokal präsenten Institutionen GIZ, BGR und KfW abgestimmt und nimmt auf den von ihnen identifizierten Forschungsbedarf Bezug.

- Wesentliche technologische Konzepte der SMART-IWRM Strategie wurden mit Verantwortlichen im jordanischen Ministerium (Ministry for Water and Irrigation) diskutiert und finden sich in der 2009 vom Ministry of Water and Irrigation veröffentlichten „Water Strategy 2008-2022" wieder. Danach unterstützt das Ministerium zukünftig den Einsatz von innovativen Technologien zur dezentralen Abwasserbehandlung und Wiederverwertung, Brackwasserentsalzung und künstlichen Grundwasseranreicherung. Entsprechende Aktivitäten sind im „Action Plan for Implementing the Strategy (2009-2022) for the Water Sector" festgelegt. In dieser nationalen Wasserstrategie wurden auch zentrale Elemente des SMART Capacity Buildings aufgegriffen: Das umfasst insbesondere den Themenkomplex „Bewusstseinsbildung für den IWRM-Prozess" und die Einführung entsprechender Curricula im Schulsystem.

- Aufbau einer transnationalen und interdisziplinären Projektdatenbank, die der Gesamtgruppe über passwortgeschützten Internetzugriff zur Verfügung steht. Die Datenbank enthält derzeit über 1,5 Millionen Einträge aus unterschiedlichen Ministerien und Forschungsprojekten (GIJP, GLOWA, EXACT, etc) und dokumentiert das erreichte Vertrauensverhältnis in diesem politischen Spannungsfeld. Das Datenbanksystem basiert auf einer Oracle-Lösung und besitzt eine web-basierte graphische Benutzeroberfläche. Über das speziell geschaffene Abfragemodul DAISY (Data Information System) sind gezielte Zugriffe sowohl auf alphanumerische als auch räumliche Datensätze möglich. Für alle Projektpartner wurde ein Handbuch sowie regelmäßig aktualisierte Nutzungsrichtlinien herausgegeben sowie Schulungen durchgeführt.

- Verbesserung und Aufbau detaillierter geologisch-hydrogeologischer Modelle in Teileinzugsgebieten (siehe z.B. Abbildung 1). Nach wie vor sind wesentliche Elemente der unterirdischen Fließsysteme aufgrund der oft hohen Überdeckung (> 200 m) nur unzureichend bekannt und speziell Quelleinzugsgebiete ungenügend abgegrenzt. Unter Verwendung geophysikalischer Messmethoden wurden daher zusätzliche Störungssysteme, versalzene Grundwasservorkommen, Heterogenitäten im Aquifersystem und verfüllte Rinnenstrukturen identifiziert (Jericho, West Bank; Al Jiftlik, West Bank; Tar el Mantha, Jordan; Wadi Shueib & Wadi Kafrein, Jordan; Shouna und Damia Area, Jordan). Somit wurden wesentliche Vorerkundungen für die künstliche Grundwasseranreicherung sowie für den Grundwasserressourcenschutz erreicht.

- Aufbau eines vereinheitlichten hydrogeologischen Konzeptmodells für den gesamten Jordangraben (Zusammenführung israelischer, palästinensischer und jordanischer Lokalbezeichnungen) in einem grenzübergreifenden 3D-Modell. Das neu erhaltene dreidimensionale Modell ist vollständig digital verfügbar und erlaubt das Einfügen beliebiger Schnittlagen.

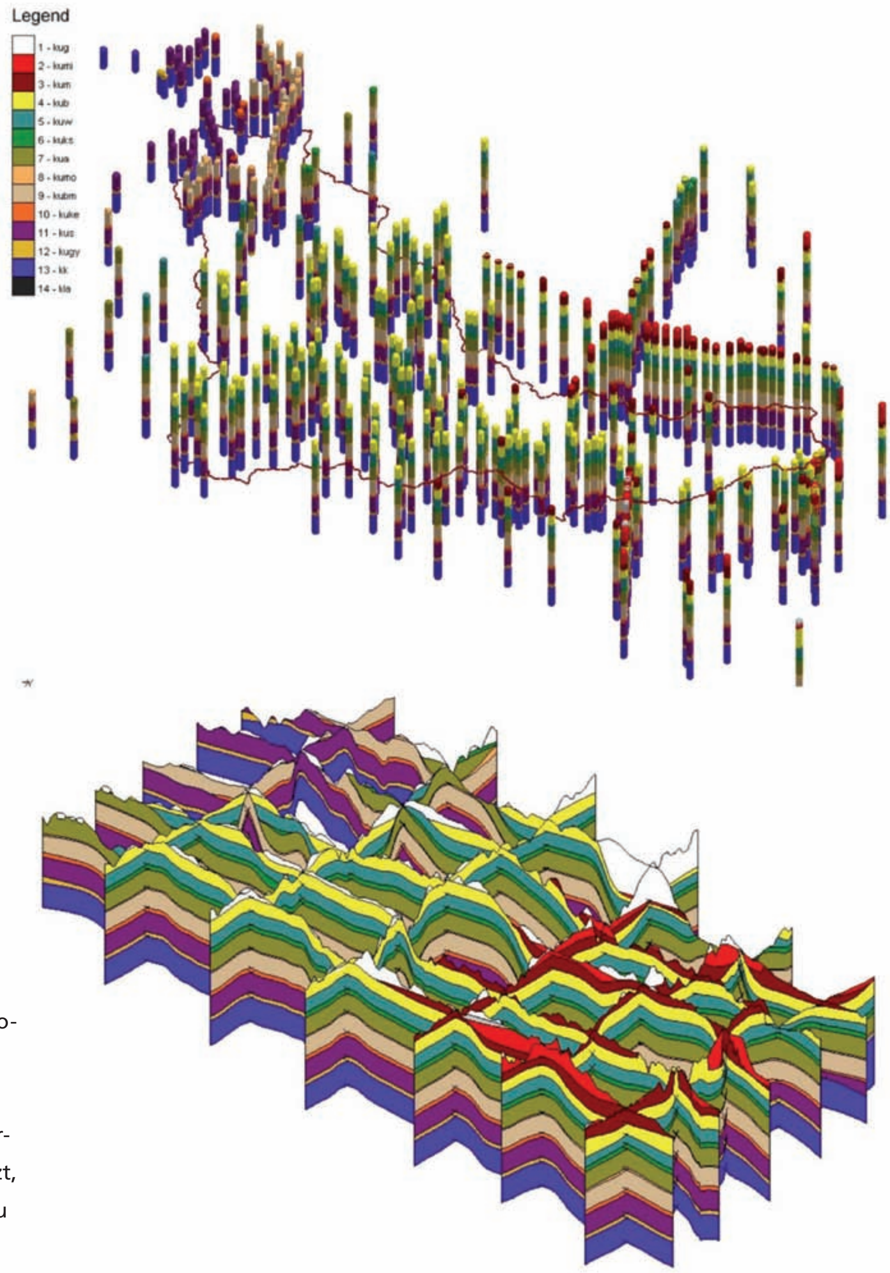

Abbildung 1
Ablauf zur Erstellung eines geologischen Schnitts am Beispiel eines Schwemmfächers im Bereich Wadi Kafrein/Shueib. Bohrkernaufnahmen werden benutzt, um die geologischen Schnitte zu konstruieren (GMS 6.0, ems-i) (Toll, 2009)

- Erstellung einer zusammenhängenden Vulnerabilitätskartierung der Westbank sowie einer Übersicht über bereits durchgeführte Grundwasservulnerabilitätsstudien im Untersuchungsgebiet. Siehe Abbildung 2 zur Veranschaulichung des Bewertungskonzeptes.

- Detailplanung, Bau und Inbetriebnahme einer Demonstrations- und Forschungseinheit für dezentrale Abwasseraufbereitung am Standort Fuheis, Jordanien (Abbildung 3). Am Standort Fuheis werden sowohl High-tech Lösungen wie SBR (Sequencing Batch Reactor) oder MBR (Membrane Bioreactor) als auch wartungsarme Retentionsbodenfilter und anaerobe Bioreaktoren eingesetzt. Parallel zu den Forschungsaktivitäten wurde damit eine repräsentative Demonstrationsplattform für die deutsche Wasserwirtschaft geschaffen, die aktuell von den Firmen Hans Huber AG, ATB und dem BDZ genutzt wird.

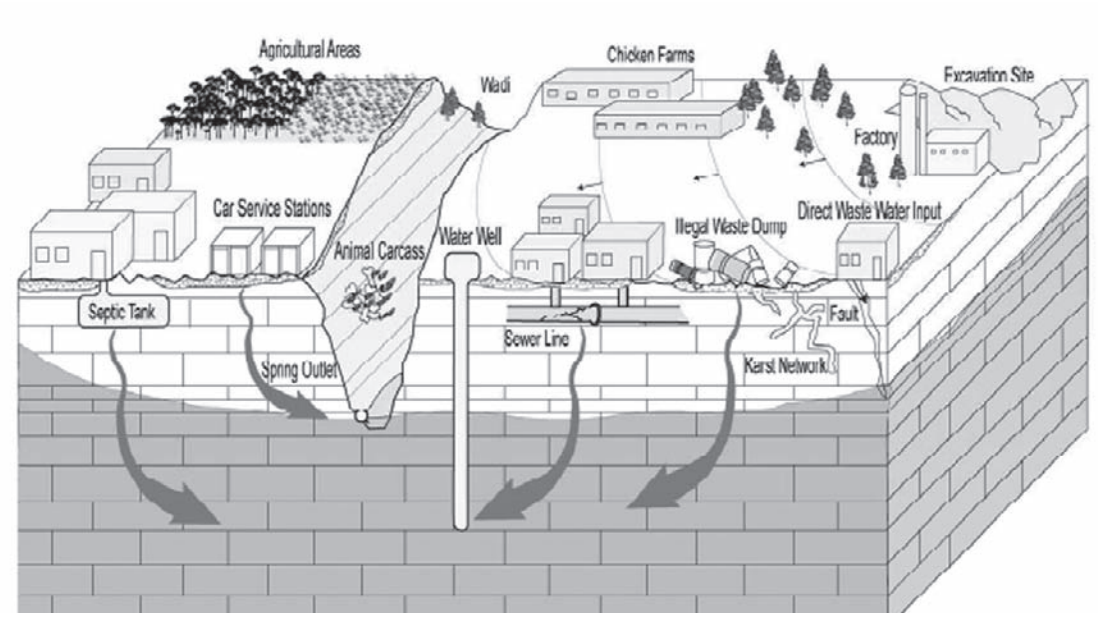

Abbildung 2
Schema der Gefährdungsbewertung von Grundwasservorkommen unter Berücksichtigung der Landnutzung (Hazards) und der Vulnerabilität der geologischen Abfolge (Werz 2009)

- Messtechnische und modellhafte Erfassung vertrauenswürdiger Wasserbilanzen in Teileinzugsgebieten (Abbildung 4): Im Rahmen des SMART I Projektes wurden mehrere Wadis mit Abflussmessstationen sowie meteorologischen Stationen ausgestattet und so eine in der Region dringend benötigte Verbesserung der Eingangsannahmen für die Ressourcenbewirtschaftung bewirkt (speziell Wadi Quilt, Wadi Auja, Wadi al Arab, Wadi Kafrein). Grundwasserneubildungsraten wurden sowohl indirekt über Ganglinienseparation als auch über Grundwasserspiegelschwankungsanalyse, über hydrochemische Analysen als auch über das Bodenwasserhaushaltsmodell JAMS bestimmt. Hiermit wurden auch neues Prozessverständnis und verbesserte Methodologien für semi-aride Gebiete erreicht.

- Das Implementierungspotential dezentraler Abwassersysteme in Jordanien wurde in Zusammenarbeit mit dem jordanischen Ministerium und lokalen Consultants detailliert untersucht und im Rahmen einer GIS-Analyse auch räumlich diskret an mehreren hundert Standorten dargestellt. Der resultierende Bericht wird aktuell von den Organen der deutschen Entwicklungszusammenarbeit aufgegriffen.

- Für die Gebiete im Wadi Quilt, Wadi al Arab, Wadi Kafrein und Wadi Shueib wurden kleinräumige numerische Grundwassermodelle erstellt, um die mittel- und langfristig zur Verfügung stehenden Wassermengen, umweltverträgliche Pumpszenarien sowie mögliche Verschmutzungspfade bestimmen zu können.

- Grenzübergreifendes Grundwassermodell: Unter Verwendung von Hochleistungsrechnersystemen wurde ein großräumiges numerisches Grundwassermodell mit 12 Lagen und mehr als einer Millionen Bilanzelementen erstellt. Das numerische Modell basiert auf einem vereinheitlichten hydrogeologischen Modell, welches durch die unterschiedlichen Partner der Anrainerstaaten im Rahmen des SMART Projektes erstellt wurde und welches das erste seiner Art in dieser Region überhaupt darstellt (Abbildung 4).

Abbildung 3
SMART-Forschungs- und Demonstrationsstandort für dezentrale Abwasserreinigungsanlagen sowie Wiedernutzung der geklärten Abwässer in Fuheis (Jordanien)

- Zur Erfassung der sozio-ökonomischen Rahmenbedingungen wurden in allen Teilgebieten und Anrainerstaaten Befragungsaktionen auf Haushalts- sowie landwirtschaftlicher Betriebsebene durchgeführt, insbesondere zur Akzeptanz dezentraler Abwasseraufbereitungssysteme sowie zur Verwendung abwasserbelasteter Mischwässer in der Landwirtschaft. Auf anderer Ebene wurden institutionelle Rahmenbedingungen direkt bei den involvierten Stakeholdern untersucht.

- Zur wissenschaftlichen Untersuchung der künstlichen Grundwasseranreicherung sowie generell der Speicherung von Regenwasser in Untergrundstrukturen wurden Versuchsstandorte im Wadi Kafrein und im Wadi Al Fara / Al Jiftlik Gebiet in Betrieb genommen (Abbildung 5). Speziell zu

Langzeit-Kolmationserscheinungen und der Belastung mit organischen Spurenstoffen durch Siedlungsabwässer wurden dabei für die Region neue Datensätze generiert. In den Grundwässern des Jordantals wurden in Zusammenarbeit mit dem Technologiezentrum Wasser Karlsruhe dabei weitverbreitet Rückstände von Pharmaka gefunden.

Vor der Definition übergreifender IWRM Szenarien wurde zunächst ein ausführlicher Bericht zum Stand der Wissenschaft und Technik in Bezug auf die weltweite Umsetzung des Integrierten Wasserressourcenmanagements erstellt (Deliverable D901). Detaillierte Szenarien wurden dann für die zwei Fokusgebiete der ersten Phase, Kaliya (West Bank) und Wadi Shueib, erstellt. Dabei erfolgte in beiden Fällen eine intensive Diskussion mit den lokalen Stakeholdern. Im Kaliya-Gebiet umfassen die Szenarien konkrete Maßnahmen zur Nutzung unterschiedlicher Ressourcen (Abteufen neuer Brunnen, Wasserimporte aus entfernten Quellen, Entsalzung von Brackwasser, Abwasserwiederverwendung sowie Investitionen in das Wasserverteilungsnetz). Im Fallbeispiel Wadi Shueib kommen die Ausweisung von Grundwasserschutzgebieten, die Aufbereitung belasteter Quellwässer, die Sanierung von Abwassersystemen sowie die dezentrale Abwasserbehandlung hinzu.

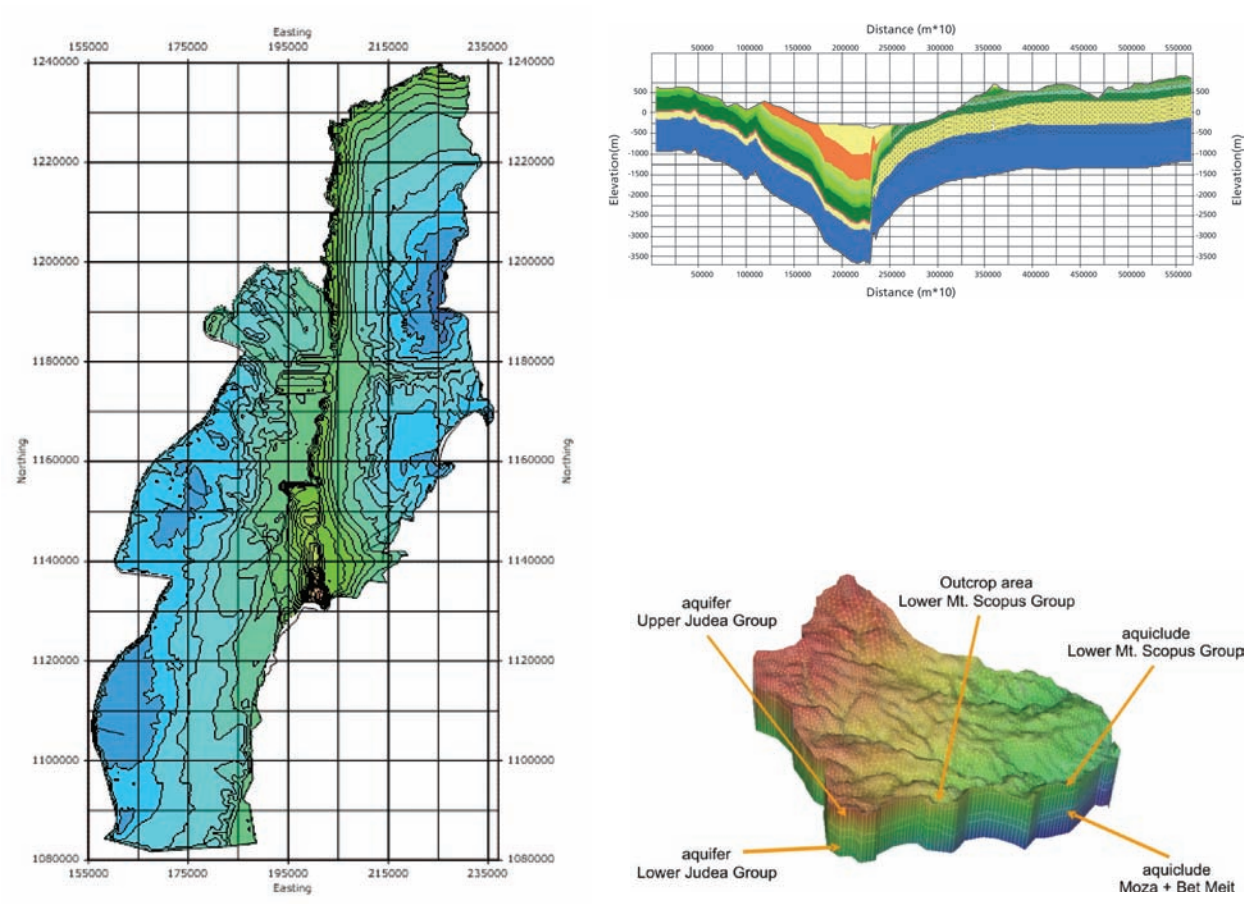

Abbildung 4

Grundwasserspiegel, dargestellt im regional-numerischen Grundwassermodell (a), ausgewähltes geologisches Profil, erstellt mit Hilfe des numerischen Modells (b), dreidimensionale Darstellung des Untergrunds von Wadi Quilt im numerischen Grundwasserfließmodell (c)

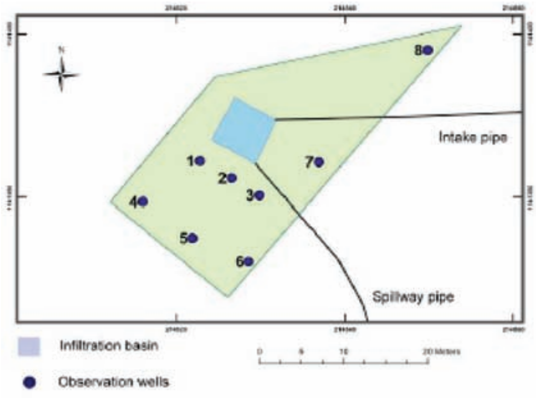

Abbildung 5

Versuchsfelder zur künstlichen Grundwasseranreicherung, **links:** Infiltrationspool Wadi Farah, Palästina
rechts: Versickerungsbecken Wadi Kafrein mit im Abstrom gelegenen Grundwasser-Kontrollmessstellen, Jordanien

Zur Erfassung des aktuellen Sachstandes wurde ein ausführlicher Bericht zur Verfügbarkeit unterschiedlicher Entscheidungshilfesysteme, die für das Integrierte Wasserressourcenmanagement zur Verfügung stehen, erstellt. Resultat des Vergleiches ist, dass die verfügbaren Werkzeuge entweder auf einer zu hohen Abstraktions- und Aggregierungsebene arbeiten, oder zu hohe Anforderungen an die Nutzergemeinde stellen. Aus diesen Gründen heraus wurde eine eigene, innovative Softwareentwicklung in Angriff genommen, die auf den Grundsätzen des kollaborativen Wissensmanagements und der Semantic Web Technology basiert (Abbildung 6). Das im Aufbau befindliche SMART-Wissensmanagementsystem nimmt dabei die Grundelemente des DPSIR (Driver, Pressure, State, Impact & Response) Konzeptes auf. Am Beispiel der Region Khaliya wurden gemeinsam mit den Stakeholdern multikriterielle Verfahren sowie die AHP (Analytical Hierarchy Process) Methode eingesetzt, um verschiedene Implementationsszenarien zu vergleichen.

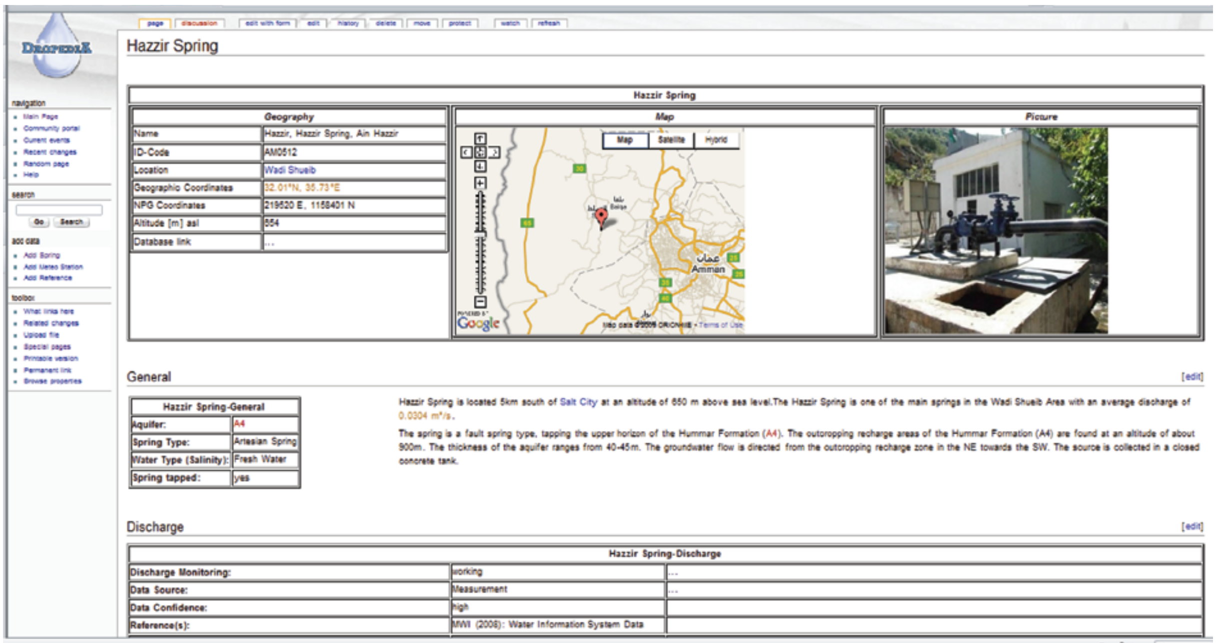

Abbildung 6

Beispiel für Semantic Web Informationsseite zu einer Trinkwasserquelle im Wadi Shueib

- Sowohl in Palästina als auch in Jordanien wurden Workshops zur Vermittlung der dezentralen Abwasseraufbereitung und des Grundwasserschutzes mit lokalen Repräsentanten durchgeführt. Von besonderem Erfolg war die Entwicklung von Unterrichtseinheiten zur Abwasserreinigung und deren Anwendung in palästinensischen und jordanischen Schulen („WaterFun“).

- Einen wichtigen Beitrag zum Capacity Building auf dem Expertenniveau bildet das PhD-Programm. Die 10 Kandidaten aus der Nahost-Region konnten bereits ihre Arbeiten abschließen oder stehen vor dem Abschluss ihrer Dissertationen und werden als Wissenschaftler an den Universitäten sowie als Angestellte in der höheren Verwaltung ihren Beitrag zur weiteren Entwicklung des IWRM in ihren Ländern leisten.

PART B

EXECUTIVE SUMMARY

Introduction

The overall aim of SMART is the development of a transferable approach for an integrated water resources management (IWRM) in semi-arid regions with water shortage. The main idea of SMART is to include all water resources of the Lower Jordan River, namely groundwater, wastewater, saline water, and flood water into an integrated management concept. This idea is implemented with a series of test sites along both sides W and E of the Jordan Valley in order to consider and include different hydrogeological settings and hydrological boundary conditions.

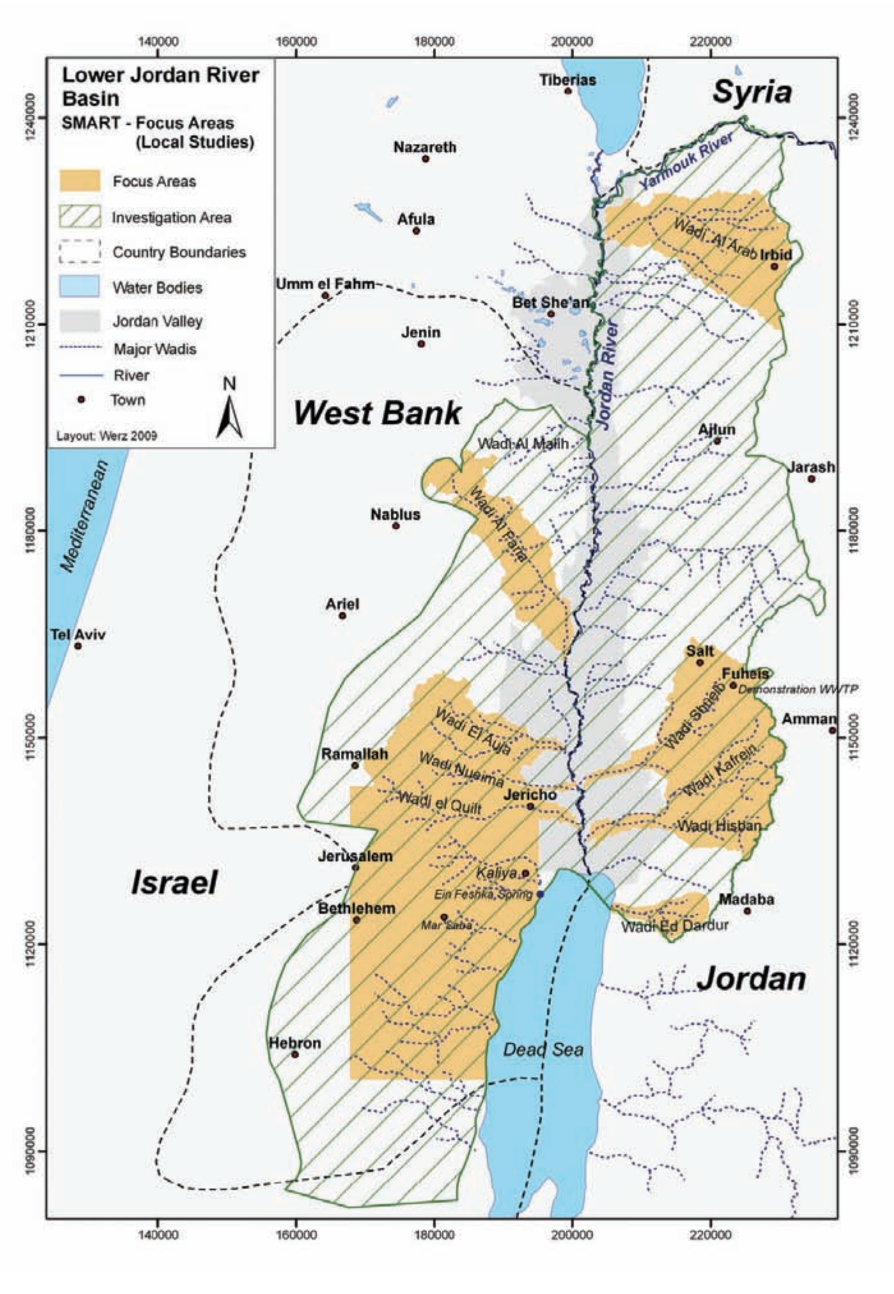

Figure I

SMART project: Location of the focus areas and the investigation area

The general approach to the complex IWRM problem was tested on different problems and questions with appropriate scientific detail in specific sub-catchment areas on a local scale. Later the technologies and results are transferred and foreseen for application on a regional scale in the investigation area of Lower Jordan Valley. The selection of the local study areas was based on existing monitoring infrastructure, a set of complementary hydrologic boundary conditions and water management challenges and last but not least the on the suggestions and preferences of the local partners and stakeholders in the region (Figure I).
The SMART project has been subdivided into eleven work packages in order to ensure structured communication and transparent distribution of responsibilities among the partners. Figure II shows a work flow diagram of the work packages.

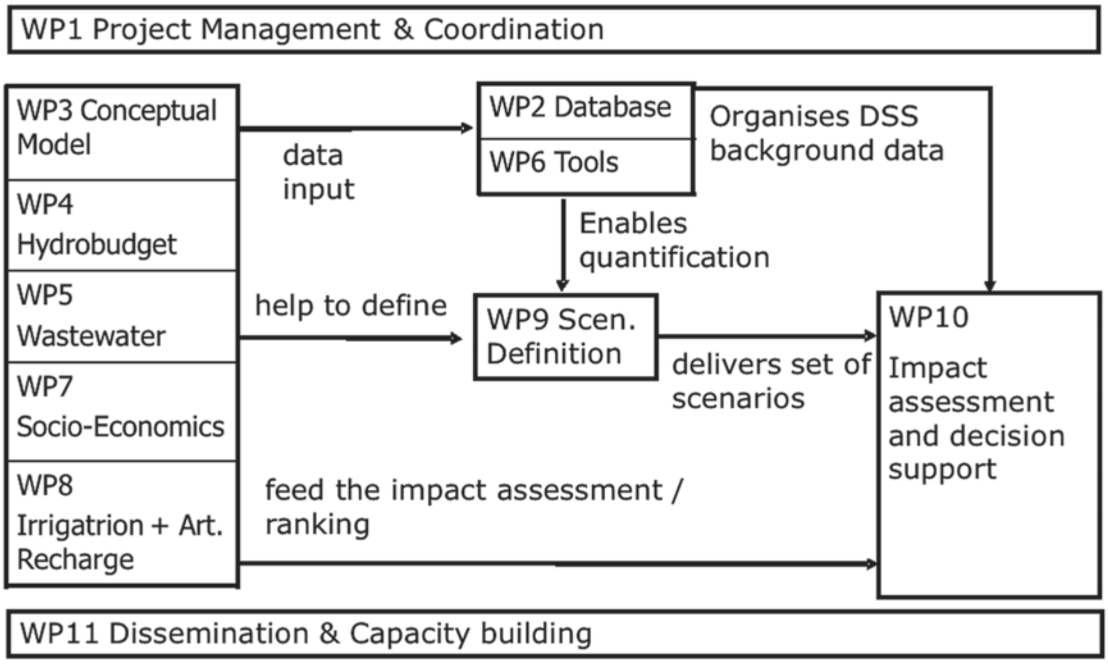

Figure II
Project work flow diagram

The executive summary lists the goals and key achievements which were obtained in each of the work packages.

WP1: Coordination

The project management so far was successful in maintaining a spirit of open scientific exchange among the partner institutions and thematically associated projects in the region. A significant amount of work was required to arrive at a good contractual basis with the international partners. Project progress was monitored using the set of deliverables and milestone specified in the proposal. The budgets of the PhD students were administered centrally in Karlsruhe.
Beyond the consortium itself, also institutions of the German development cooperation were approached. The current results were presented along a series of six scientific coordination meetings

and a kick-off meeting with up to 80 participants. The fifth scientific coordination meeting opened the SMART results also to a wide international audience in connection with the 7th conference of the European Water Resources Association, June 2009, in Cyprus.
The most up to date presentation of SMART results was delivered at the International IWRM Congress in Karlsruhe, November 2010, at which the SMART project delivered more than 20 oral presentations or posters.

WP2: Data and Information System (DAISY)

For the successful representation of the Lower Jordan River water resources in an IWRM concept a database management system (DBMS) was developed. In this management concept all natural and anthropogenic effects and variables were considered to efficiently supply all partners with input-data and information needed for the execution of the various project tasks and to achieve resulting decisions. Thus, the integral part of WP2 was to gather, review, compile, and organize all available data of the project area in a logical data structure and to classify its relevance for the project. The DBMS is based on an oracle system and web based graphical user interface (GUI). Via the data information system (DAISY) alphanumerical data and spatial data is provided and can be exchanged over transfer-drives. Into DAISY, a huge amount of data received from SMART project partners, former projects such as GIJP, GLOWA, EXACT, from literature and the internet and out of local and foreign databases have been screened, selected, evaluated and implemented. The multiple data sources include alphanumerical and/or spatial hydrochemical and water quality data, (hydro-) geological data, climatic data, satellite images as well as various reports. For all SMART project partners, a handbook and updated guidelines were prepared to ensure an effective usage and easy access. Within the framework of IWRM concepts, a constantly updated DBMS that identifies also gaps of knowledge and information is needed to achieve the strategic objectives of the project. As an invaluable tool, the DBMS allows people and institutions from different backgrounds and political environments to engage in informed discussions.

WP3: Geology, hydrogeology and geochemistry

In order to improve the knowledge on existing water resources and replenishment areas and investigate the status of water quality and sensitivity to pollution, WP3 focused on geological, hydrogeological, geophysical and geochemical investigations in the Lower Jordan Valley (LJV) and surroundings. For a conceptual hydrogeological model, natural groundwater recharge by precipitation and irrigation return flow was studied and geophysical investigations at the LJV (Jericho, West Bank, Shuna and Damia Area, Jordan) were carried out. The geophysical investigations identified fault systems, saline groundwater bodies, aquifer properties, buried wadis and ancient channels. Relevant thematic data layers were produced for a transboundary 3D conceptual geological model of the Lower Jordan River Basin (LJRB) including large parts of the West Bank and parts of Jordan from north of the Dead Sea to south of Lake Tiberias and east up to Amman.
The model represents a simplified, though reliable picture of the (hydro-) geological complexity of the area, to be used for the construction of the models for groundwater flow and transport accomplished in WP6. Quality issues relevant to the utilization of water were studied in Wadi Kafrein, Wadi al Arab, Bet She'an Valley (Jordan), Wadi Qilt (West Bank) and selected wells and springs in the Jordan Valley. Hydrochemical investigations were carried out to understand which components affect mineralization, composition and quality of the groundwater. Detailed groundwater analyses were done in the Jordan Valley area (Jordan) to evaluate the risk and long-term

effects of treated wastewater used for irrigation on the soils and the groundwater. As basis for groundwater protection schemes groundwater vulnerability was mapped in the eastern aquifer basin of the West Bank. With the results of the investigations done in WP3, areas for potential water resources development are identified and classified with regard to potential of exploitation, sustainability and local needs.

WP4: Hydrobudget

To identify the water resources and the current and expected deficits in the Lower Jordan River Basin in several focus areas, local water budgets were calculated. The results of WP4 are used for a better understanding of the runoff, discharge and recharge mechanisms of local catchments and allow a critical assessment of available regional water resources. They contribute to the regional water balance and therefore, to the regional flow model that is an essential tool for the prediction of the future development of the resources under conditions of expected changes in boundary conditions. The results also help to identify areas of different recharge potential and recharge mechanisms taking into account also artificial recharge, usage of treated wastewater, over-pumping and climate change. Local Water budget calculations were performed in the Wadi Kafrein, Wadi al Arab (Jordan) and Wadi Quilt (West Bank).
Different methodologies to quantify groundwater recharge were applied in the Eastern Basin of the West Bank (Jericho and Hebron - Dura area) using chloride mass balance and groundwater table fluctuation method. In the catchment areas of Wadi Qilt and Wadi al Arab recharge was quantified using direct and indirect measurements of discharge, the water-table-fluctuation-method and the application of the complex soil-moisture model JAMS. The goal of that combination of recharge techniques is to understand the recharge process on a catchment scale. The calculated groundwater recharge is used as a valuable input parameter of the numerical flow models in WP6. In five subwadis within the watershed of Wadi Kafrein, the rainfall-runoff relationships were investigated with the aim to estimate surface water resources available for usage in the future and to identify areas with high infiltration rates. Groundwater recharge within the catchments of Auja spring and Sultan spring is quantified using a combination of water budget estimations, spring hydrograph and chemograph analysis, well hydrograph analysis and soil water balance approaches. The output of WP4 contributes to an improved understanding of the hydrogeological processes needed for reliable water management plans and helps to plan groundwater storage that is an essential component in IWRM concepts.

WP5: Technologies – Managing wastewater for reuse

In arid areas, the application of water reuse concepts is a central element in IWRM strategies to satisfy growing water demand. In combination with environmental aspects, the situation calls for an increased application of decentralized wastewater treatment and reuse technologies. The overall purpose of WP5 was to develop and combine site adapted technologies for decentralized wastewater and sludge treatment in Jordan with a high hygienic standard. A demonstration site for decentralized wastewater treatment technologies in Fuheis was constructed using a combination of treatment technology options, both traditional and innovative. To achieve a high hygienic standard and to be able to reuse the treated wastewater for agricultural irrigation purposes, different technologies such as Sequencing Batch Reactors (SBRs), Soil Filter Eco-technologies, Anaerobic stabilization of sewage sludge and Eco-technological Sludge Mineralization. The construction of the SMART – Research and Demonstration Site was terminated in June 2009.

Special focus was laid upon the characterization of the treatment performance of different technologies and the quality of the irrigation water and sludge fractions produced for agricultural irrigation and fertilization purposes. For this reason a monitoring program was defined and the analytical methods for analyzing the selected parameters were established at the laboratories of the Balqa Applied University.

Together with the Ministry of Water and Irrigation the general potential of decentralized wastewater system solutions to be applied in the study area was determined. The annual wastewater production available for DWWT&R in the rural sector of the investigation area was calculated to be nearly 3.8 million m3 at the end of 2007. The future need of wastewater treatment and reuse facilities of the rural sector was estimated to be increasing by 0.11 million m3 per year, with an overall potential of new treatment capacity of nearly 15,500 population equivalents (pe) per year. The overall potential for implementing DWWT&R systems in the urban sector was estimated as nearly 25 million m3 of wastewater in 2007. The future need of wastewater treatment and reuse facilities required for the urban sector was estimated to be increasing at a rate of 0.12 million pe per year. Together with the decision makers and the stakeholders, a potential map with three regions has been defined: Region 1 with existing central wastewater infrastructure, Region 2 with already planned central infrastructure and Region 3 with the highest potential for implementing DWWT&R systems.

An important point for the acceptance of the use of treated wastewater are the water and wastewater tariffs that vary visibly in different sectors in Jordan such as households, retail, industry and agriculture. Comparing the water and wastewater costs in Jordan showed that in rural areas that are not connected to a sewer households may spend up to five times the money on annual water and wastewater expenses than urban residents that are connected to the sewer.

WP6: Tools for scenarios

Modern water resources management requires the availability of robust tools in various interrelated fields of activity. In order to achieve a sustainable state of water resources and to quantify the impact of climate change on water resources, a proper assessment of the groundwater resources as well as their quality is needed. Within WP6 several local models (Wadi Quilt, West Bank; Wadi Arab, Wadi Kafrein, Jordan) and a transboundary model were set up. Between the Dead Sea and Karameh (Jordan), a local model was constructed with the purpose to estimate the available groundwater resources in the unconsolidated aquifer and to suggest sustainable modes of aquifer exploitation from both, quantity and quality aspects, and to estimate their sensitivity to the impact of climate change.

To represent the complex (hydro-) geological situation, an integrated approach combining geological, geophysical, hydrogeological, historical, and chemical methods is applied. In all local catchment areas of the numerical models the influence of complex geological features on groundwater flow paths and storage were investigated. To provide global water budgets and to investigate large scale impacts of water utilization alternatives and their sensitivity to the global factors, a transboundary model in the scale of the project area was set up using High Performance Computing (HPC). The results of the local models help to refined large scale evaluations of water budgets in the various basins of the study area, whereas the output of the transboundary model assesses the regional water situation and its sensitivity to global effects. Thus, they help to design and test alternatives of water utilization and can form the basis for discussions and decisions of stakeholders and decision makers.

WP7: Socio-economic analyses and assessment

The implementation of water technologies it is not only dependent on scientific and technical factors, but also on social, political and economic variables. The socio-economic status of a community itself is a function of its water and wastewater situation. WP7 analyzes the socio-economic profiles and current water uses in selected pilot areas in the study area as input for the assessment of different IWRM scenarios in WP9 and WP10. Socio-economic profiles were prepared for Palestinian and Israeli communities in the western Lower Jordan Rift Valley (LJRV). For the profiles, literature reviews were done, questionnaires were completed and evaluated using Statistical Program for Social Sciences (SPSS) and Geographic Information Systems (GIS).
Interviews with some of the community's populations, key persons in the local authorities and in different sectors were conducted. In close cooperation with WP5, the institutional prerequisites and demand for the implementation of decentralized wastewater treatment and reuse (WWT&R) systems in Jordan are identified and analyzed. The aim was to assess the institutional framework conditions, the perceived demand and finally the acceptance of WWT&R among different stakeholders. In the analysis of demand, the perceptions of government representatives at the central government and governorate level, representatives of municipalities not yet connected to wastewater systems as well as households and potential end-users of treated wastewater in these communities were included. The results show that the physical setting supports a decentralized approach towards WWT&R in Jordan. In conclusion, it was perceived that decentralized WWT&R contributes to solve many of the problems Jordan currently faces, such as pollution of freshwater resources, social and health problems resulting from overflowing cesspits and low income among farmers. However, financing issues, risk of leakage, monitoring, odour and responsibility issues were major concerns.

WP8: Precision irrigation and artificial recharge

Wastewater treatment and reuse, water harvesting, artificial recharge and underground storage can be options to mitigate water scarcity in arid regions. To optimize the use of water for agriculture, it is also essential to apply irrigation technologies and implement irrigation management practices that focus on precision irrigation. WP8 studied these different innovative techniques as possible tools within IWRM concepts in (semi-)arid regions that offer additional water resources. Irrigation field experiments were conducted applying different effluent qualities obtained from waste stabilization pond systems, and subsequently treated by a hybrid ultra filtration membrane stage and reverse osmosis membrane system.
Experiments using membrane bioreactors to treat domestic wastewater were performed in Israel (Kiryat Sde Boker). The feasibility of artificial recharge in the Lower Jordan River Basin was assessed with site specific studies and construction of infiltration facilities (Wadi Kafrein, Wadi ad Dardur, Jordan; Al-Jiftlik area, Wadi Al Faria, Palestine) and with numerical groundwater models (Wadi Shueib, Jordan). To indicate places for detailed studies, a regional map displaying the potential for managed aquifer recharge using surface infiltration in NW Jordan was constructed. A water harvesting system using capillary break was designed and is currently constructed in Shehan mountainous area, Jordan. Within a study at Kafrein Dam (Jordan), the importance of dams or streams to collect base flow and flash-flood water for irrigation and to enhance artificial recharge to shallow aquifers in the Lower Jordan Valley was emphasized.

WP9: Definition of IWRM scenarios

Understanding the interactions between water, environment and society is the foundation of the IWRM for a specific area. In addition, IWRM must be extremely sensitive to national, political, cultural, and socio-economical conditions. WP9, which is strongly linked to WP10, included – besides a literature review on the state of the art of IWRM - the development of IWRM scenarios. Firstly, successful examples of IWRM worldwide were reviewed and then the local situations in the three countries were briefly explored. The SMART project was then reviewed according to the most relevant aspects for IWRM implementations based on the IWRM guiding principles. For the definition of IWRM scenarios, preference was given to realistic scenarios with detailed process quantifications on local scale during the first phase of the project.
The project started with prototype areas in Kaliya (West Bank) and Wadi Shueib (Jordan), but will continue especially with detailed analysis also in Jericho/Wadi Quilt (West Bank). For the definition of the scenarios, the constraints were defined and an inventory of all clients in the study area and their water needs were constructed. In a third step, numerous policy complex problems were identified and characterized as goals. These strategies included drilling new wells, importing water from distant sources, desalination of brackish water and improving the water supply system (pipelines, reservoirs).

WP10: Impact of IWRM scenarios

The main objectives of WP10 were to develop a decision support system (DSS) to demonstrate the links and interdependencies between hydrological, environmental-ecological, economical, social, and political sectors and to compare and rank different water resource management options. As basic step, a review of state of the art on DSS was accomplished. All the expected impacts resulting from the new mode of water resource utilization to be suggested for the Jordan River Valley (hydrological, environmental-ecological, economical, social and political) were identified and quantified. In a further step, existing water management software was employed and tested. To come closest to the project needs for a DSS, four types of DSS software were studied in detail (WSM, MULINO, MODSIM, WEAP) and tested on a pilot area in the LJV.
In parallel, the feasibility of developing a new DSS is explored. A concept for the application of the WEAP-Modflow software coupling was developed for the alluvial aquifer system downstream of the Wadi Shueib reservoir (Jordan). Multi Criteria Decision Making (MCDM) methodology and the Analytical Hierarchy Process (AHP) were used for defining and ranking the various alternatives of water management scenarios. For planning scenarios that need to be collectively evaluated from various viewpoints, corresponding to the knowledge of experts in different domains as well as to the interests of various stakeholders, a flexible knowledge-management framework for IWRM-related problem analysis and impact assessment in the Lower Jordan Valley was developed.
The SMART knowledge management tool is based on a “Semantic Wiki System” and embedded in the framework of a decision support process. This system results in a highly flexible and adjustable, yet easy to use SMART knowledge management tool which will contribute to make IWRM decision processes more informed, more transparent and more reusable.

WP11: Dissemination, training and technology transfer, SMART PhD-program

Know-how transfer is a fundamental issue in order to achieve an integrated water resource management concept for the Jordan River Valley (JRV). It is of prime importance to ensure widespread dissemination of the project results at various levels, i.e. scientific, engineering and administrative. WP11 focused on organizing project meetings and workshops, technology and know-how transfer, building a project web site and on training end-users. In this context a know-how transfer strategy through the development of a demonstration and training site for decentralized wastewater management and irrigation in Wadi Fuheis, Jordan, was developed. It is designed as an interpretive center with integrated showroom that allows presenting the technologies and gives a general overview on decentralized wastewater treatment and reuse options.
It will also be the platform to provide training and capacity building programs. Since capacity building plays a major role in the sustainable management of available water resources, within the project, a training program in the field of Decentralized Wastewater Systems Solutions (DWWSS) was designed, developed and tested as a pilot teaching unit for primary schools in Ramallah, Palestine and Amman, Jordan. The training enhances the reflection process about wastewater components and gives arguments to the participants to understand the possibilities of wastewater treatment and its reuse purposes in decentralized systems. To enhance intensive scientific and cultural exchange of the students from the participating countries, within the SMART project a PhD program was launched that is organising annual meetings of the PhD students. For promoting and sharing the results with the associated project partners and informing not only internal users, but also the public (e.g. stakeholders), a project website was established. The website provides current information about research and implementation activities, results of the work packages, information concerning the project, meetings and other news.

PART B

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PART C

SCIENTIFIC AND TECHNICAL RESULTS

Abreviations and Acronyms

AHP	analytical hierarchy process
BALQ	Al Balqa Applied University, Jordan
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources, Germany)
BGU	Ben Gurion University, Israel
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research, Germany)
BMBR	biofilm membrane bioreactor
CB	capacity building
CBA	cost benefit analysis
CBL	capillary break layer
CBS	capillary break system
CBSI	Central Bureau of Statistics, Israel
CEA	cost-effectiveness analyses
CL	capillary layer
CN	curve number method
DAISY	data information system
DBMS	database management system
DEM	digital elevation model
DGMS	dialog generation and management system
DI	on-surface drip irrigation
DO	dissolved oxygen
DOS	Jordanian Department of Statistics, Jordan
DPSIR	driving forces, pressures, states, impacts and responses – model
DSS	decision support system
DTS	demonstration and training site
DWWSS	decentralized wastewater systems solutions

EC	electrical conductivity
EM	Eigenvector method
EPS	extra cellular polymeric substances
ERM	earth resistivity meter
ESI	electrospray interface
EWRE	Environmental and Water Resources Engineering Inc, Israel
Fm	formation
GIJP	German – Israeli – Jordanian – Palestinian joint research project
GIS	geographic information system
GU	Göttingen University
GSC	grain size curve method
GTZ	Gesellschaft für Technische Zusammenarbeit (international cooperation enterprise for sustainable development with worldwide operations, Germany)
GUI	graphical user interface
gw	groundwater
HPC	high performance computing
HPLC- MS/MS	high performance liquid chromatography with tandem massspectrometric detection
hr	hour
HRD	human resource development
HRU	hydrological response units
IWRM	Integrated Water Resources Management
JAMS	Jena AdaptableModelling System
JD	Jordanian Dinar
JICA	Japan International Cooperation Agency
JRV	Jordan Rift Valley
JUA	Jordan University
JVA	Jordan Valley Authority
KfW	Kreditanstalt für Wiederaufbau
KIT	Karlsruhe Institute of Technology
LDAP	lightweight directory access protocol
LJRB	Lower Jordan River Basin

LJRV	Lower Jordan Rift Valley
LJV	Lower Jordan Valley
LLSM	logarithm least squares method
LOQ	limits of quantification
MBMS	model-base management system
MBR	membrane bioreactor
MCDM	multi criteria decision making
MCM	million cubic meters
MEK	MEKOROT, Israel
MLSS	mixed liquor suspended solids
MPI	message passing interface
MWI	Ministry of Water and Irrigation, Jordan
O&M	operation and maintenance
OMS	operations & management support
PAPA	Palestinian Agribusiness Participatory Approach
pe	person equivalent
PHG	Palestinian Hydrological Group, Palestine
PME	Palestinian Ministry of Education, Palestine
PWA	Palestinian Water Authority, Palestine
QUDS	Al Quds University, Palestine
RDBMS	relational database management system
RO	reverse osmosis
RSCH	Ramallah Schools
SAR	sodium absorption ratio
SCS	United States soil conservation service method
SDI	sub-surface drip irrigation
SER	secondary effluent from reservoir (reservoir effluent)
SEP	secondary effluent from ponds (waste stabilization ponds)
SPE	solid phase extraction
SPSS	statistical program for social sciences
SQL	structured query language
SRT	sludge retention time

sw	sea water
T	temperature
TAU	Tel Aviv University, Israel
UF	ultra filtration
UFZ	Helmholtz Zentrum für Umweltforschung (Centre for Environmental Research), Leipzig/Halle, Germany
UH	unit hydrograph
UKA	University of Karlsruhe, Germany
UT	University of Tübingen, Germany
VES	vertical electrical sounding
WAJ	Water Authority Jordan
WP	work package
WRS	water resources system
WTF	groundwater table fluctuation method
WW	wastewater
WWT	wastewater treatment
WWTP	wastewater treatment plant
WWT&R	wastewater treatment and reuse

1 COORDINATION

Involved Institutions: UKA
WP-Speaker: H. Hötzl
Compiled by: H. Hötzl, L. Wolf, W. Ali

1.1 Introduction

The central goal of the coordination work package (WP) is to ensure a sufficient workflow of the project. The following tasks were specified in the proposal:

- Communication and reporting to the BMBF authorities
- Overall progress and performance assessment
- Review and evaluate milestones
- Control quality of deliverables before publication
- Ensure communication and dataflow between partners
- Deal with possible problems
- Preparing the basis for technological implementation

1.2 Description of work and results

In addition to the fulfilment of the tasks, the following key achievements were made

- Onset of 17 PhD students working with SMART
- Information & communication with major stakeholders in the region
- Organisation of bi-annual coordination meeting
- Joint meeting SMART-GLOWA JR in Aqaba 2008
- Representation of SMART at GLOWA status seminars
- Representation of SMART at national and international conferences

Minutes were produced not only for the coordination meetings but wherever adequate also for smaller working group meetings. The minutes, along with pdf-versions of all presentations held at these meetings are available in the internal section of the SMART project homepage (www.iwrm-smart.org).

2 DATA AND INFORMATION SYSTEM (DAISY)

Involved Institutions: UFZ
WP-Speaker: S. Geyer
Compiled by: Christian Siebert (UFZ), Stefan Geyer (UFZ)

2.1 Background

Availability of updated information on all water related aspects of the catchment is a key factor of the IWRM process, thus, allowing rational decision making and also promoting information exchange between the large groups of actors in the Lower Jordan Valley (LJV). Consequently, the database management plays a central role in the SMART project by facilitation cooperation among the project partners and the governmental stakeholders. Thus, the database management system is directly linked to the decision support component of SMART.

A decision support system (DSS) is an interactive, computer-based system with, beside the dialog generation and management system (DGMS), two fundamental components:

- Database management system (DBMS): which is the central data bank for the DSS. It stores all types of data that are relevant for the DSS.

- Model-base management system (MBMS): transforms data from the DBMS into information that is useful in decision making.

A huge amount of DSSs with different architectures exist and new ones are generated day by day, however, the data and information management is the key issue for a DSS (Figure 2.1). The database allows people and institutions from different backgrounds and political environments to talk the same language. Querying capabilities as well as visualization tools are necessary ingredients. Data here include spatially distributed systems, time varying data and geo-referenced information (maps and point data).

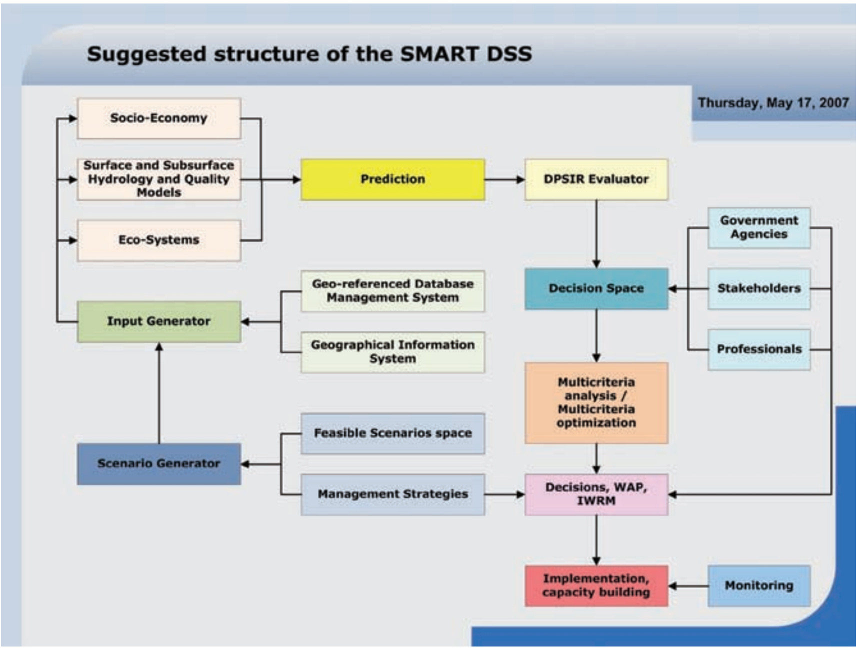


Figure 2.1
Suggested structure of the SMART decision support system (DSS) and the integral function of the database management system (DBMS); (Bensabat et al, 2007)

2.2 Objective and activities

As a result of the IWRM-character of SMART, the aim to develop an adapted DSS for the LJV, the interdisciplinarity and complexity of data and information which are needed from former and parallel projects and those which will be gathered during the project phase, a SMART database management system (DBMS) is necessary. That comprehensive database is developed to efficiently supply all partners with input-data for established systems and systems, which are under way (Modeling, Geographical information systems – GIS).

The DBMS is designed to be a data platform for collecting, storing of data and its sharing between partners, in order to ensure proper, efficient and fast supply of data and information needed for the execution of the various project tasks.

Therefore, project (basin) area and border were determined and subdivided into sub-areas of more homogeneous problems and characteristics also for allowing the focus on more specific local problems that could be then integrated into the project stream.

To fill in relevant historical and recent data, an integral part of the working package was to gather, compile, and organize all the available data on the Jordan Rift Valley (JRV) that is relevant and necessary to the project, including:

- **Agriculture**: current status of activities, crops, irrigation practices and applied technologies, irrigation schedules, efficiency (crops output per unit area of cultivated land per unit volume of irrigation). Link/interface to: WP4 –spatial characterization of land-cover by satellite images, results: information about development of agriculture (temporary and long term crop rotation/changes in respect to necessary amount of irrigation, changes in recharge, soil erosion)

- **Socio-Economy**: inventory of the cities and villages in the JRV, their current population and expected growth trends, water consumption (e.g. by sectors of activity) and expected water demand (prognoses, link/interface to WP 5-7), current output of wastewater and treatment levels and utilization, expected trends. Link/interface to: WP4 –spatial characterization of urban/rural development by aerial photographs, in respect to density, kind of communities

- **Geography**: up to date maps, aerial and /or satellite photography/images, in printed and electronic format. Link/interface to: WP4 –gathering and referencing maps as inputs for GIS projects (up to 1:50.000) satellite images from different periods, new data will be included to offer time-dependent remote sensing data from the study area or particular areas

- **Morphology**: up to date digital elevation models on GIS-readable base (e.g. grd, img) for study area/particulate areas (e.g. Israel Geological Survey base) or made out of georeferenced remote sensing data from stereographic sensor on ASTER-platform

- **Wells**: well characteristics (well location, depth, position of perforation, diameter, pump depth etc.); well time series of piezometric head and quality like chloride, nitrate and other elements that may exist in any of the institutional data warehouses. Have to be gathered for 3d-geological subsurface model and cross-sections

- **Springs**: characteristics (location, elevation, type, aquifer etc.), time series of discharge and quality (chlorides, nitrates and other elements)

- **Climate data**: rain-gauges characteristics (location, elevation, type of gauging device) and time series of rainfall data of various aggregations (storm aggregation for the analysis of runoff processes and monthly aggregation as input to the groundwater flow and transport models). Time series for precipitation and for other climatic data (e.g. temperature, air-moisture, solar radiation, wind-speed, etc.) in respect to specific and regional climatic conditions (e.g. Shakira, storm events…)

- **Aerial and satellite photography**: gathering/buying particular remote sensing data (high resolution for necessary small areas: aerial photographs), time series images for larger areas in respect to characterize development of urban/rural areas

- **Water distribution system**: layout and characteristics (diameter, discharges etc.)

- **Sewage network**: size, layout, treatment plants, type of treatment and capacity etc.

- **Water retaining and storing facilities for the collection of runoff**: size, capacity, location

All data stored in previous works and those delivered by project partners have been reviewed and classified according to database regulations and their relevance to the project. The purpose was to get a logical data structure (variables, units, parameters, etc.) and to avoid redundancy.

In cooperation with project partners, gaps of knowledge and information that needed to be bridged in the frame of the project were partly detected in order to meet the project objectives. Making all these information and data available, the data and information system assisted project partners to determine additional investigations (including field work) that were necessary to achieve the strategic objectives of the project.

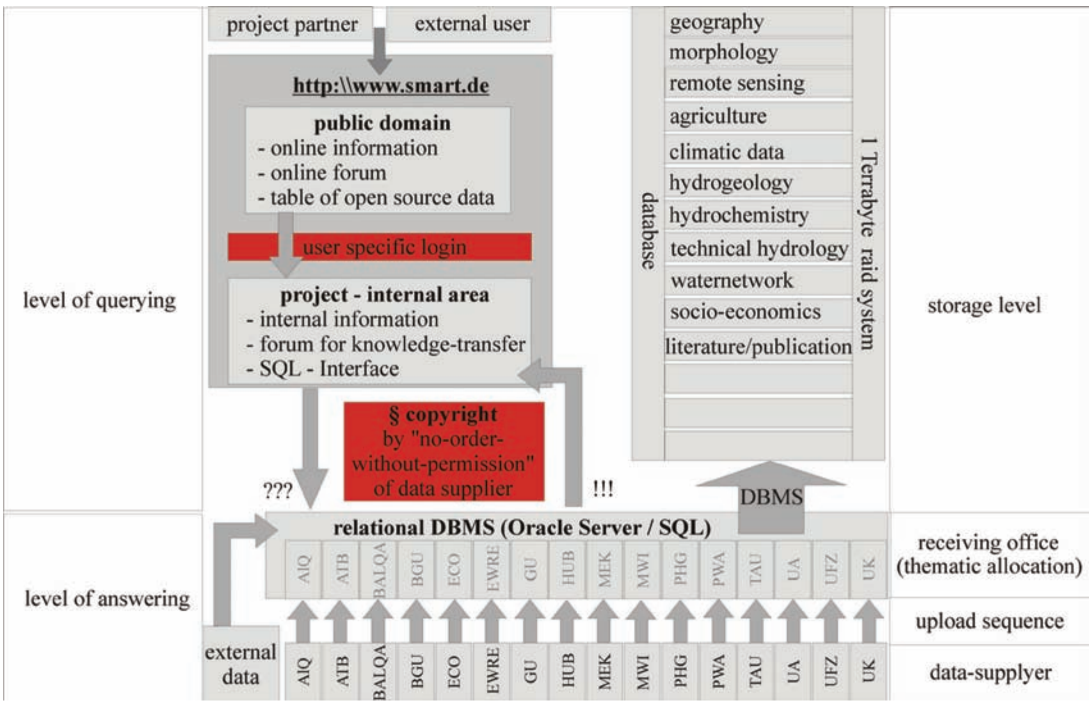


Figure 2.2

Conceptional flowchart of the relational database management system (RDBMS)

2.3 Design of DAISY

2.3.1 Conceptual model of DAISY

All implemented data are incorporated into the integrated relational DBMS (Figure 2.2), which is based on an Oracle-system at the Helmholtz-Centre for Environmental Research – UFZ. The DBMS makes them available via personal internet-portal and an interface to GIS platform. A web based graphical user interface (GUI) for data queries was established.

2.3.2. Realisation of DAISY (D201)

During the project, and as a result of discussions with and wishes of partners, an overall data and information system (DAISY) was developed (Figure 2.3). DAISY is mentioned to be the central inquiry location for all data requests and problems of the project. Additionally, it is a platform for focused and detailed public relation of SMART with a high developing potential.

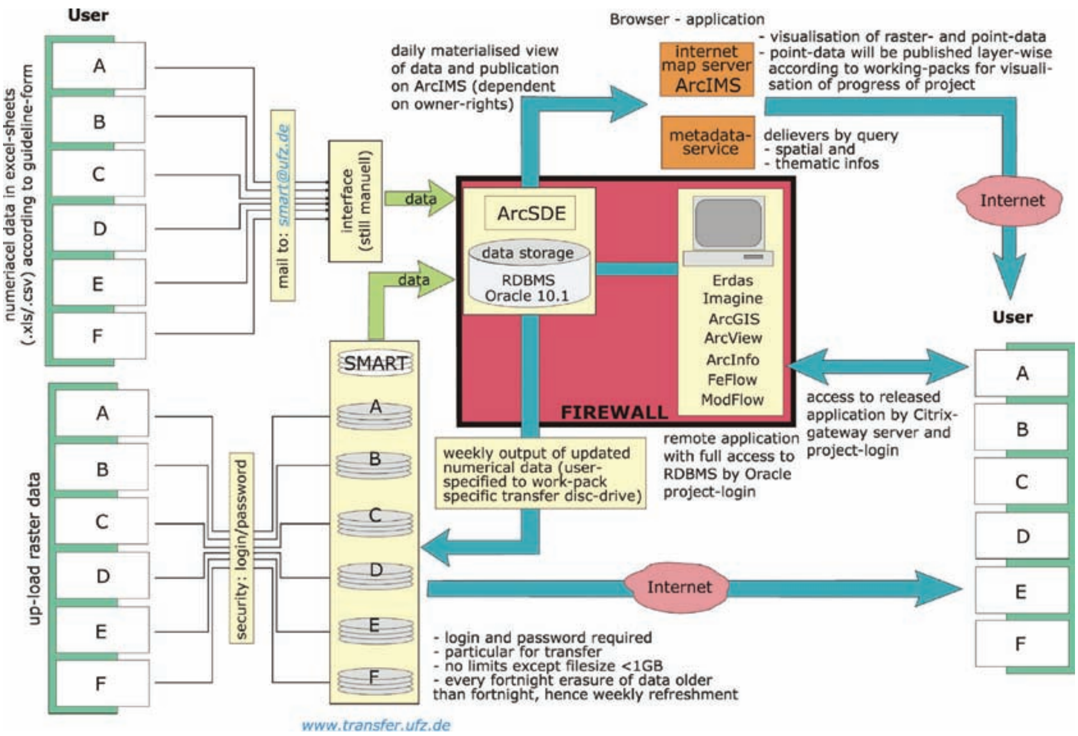


Figure 2.3
The design of the SMART Data and Information System DAISY at the UFZ

Because it is available for public, it is designed on several distinct security layers, which either keep public out and/or shields sensitive data against everyone. Hence, a key issue was to address data rights and establish a system for preserving rights and privileges to regulate the use and dissemination of data.

Partners do have personal access (login/password) to the web site for downloading and querying the DBMS. Hence, the download- and data-sharing interface is strictly password protected, administrator-controlled, copyright sensitive and working-group specific. Visibility and downloads of data is regulated by the permission of the data owner.

The data and information system DAISY, which is developed within the frame of the SMART project and working package 2 is designed to answer different issues:

- **DBMS – Oracle**: storage and providing alphanumerical data
- **ArcSDE**: storage and providing raster- and vector data
- **Transfer-drives**: being a secure platform for transfer, exchange and storage for all types of data between working groups, project members and institutions
- **DAISY-harvester**: GUI to request alphanumerical data of Oracle
- **ArcIMS/UMN**: interactive GUI to plot raster- and vector data and design maps

Furthermore, via a special Citrix-Gateway (see Chapter 2.3.6), every partner is able to use special software applications like Erdas Imagine, ArcGIS, Mathematica, Statistica, ModFlow, etc.

2.3.3. The graphical user interface of DAISY (D202)

After the first phase of developing DAISY, a easy to use and web based graphical user interface (Figure 2.4) was developed, to make access to DAISY for all users as easy as possible. Out of this mask, every user chooses his interests and his targets to surf on.

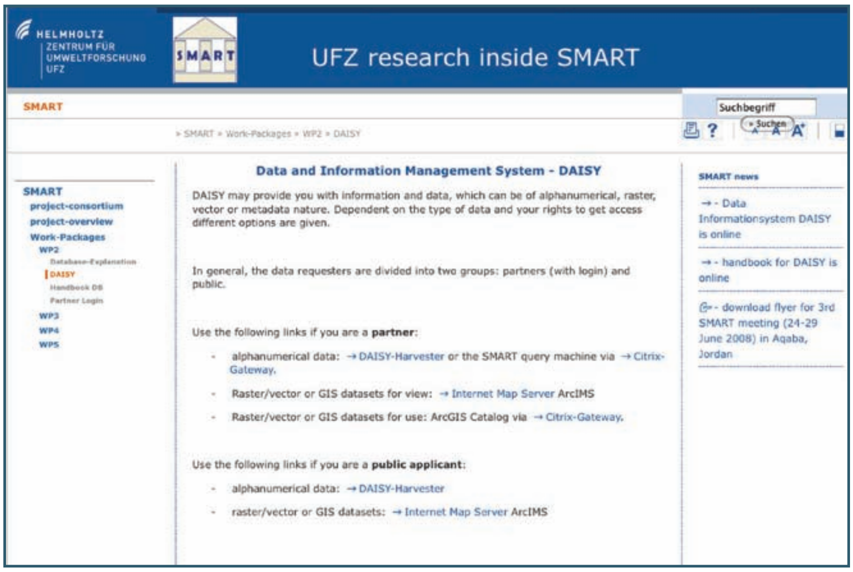


Figure 2.4
The entry to the Data and Information System DAISY

2.3.4 Security by password (D206)

Several datasets in DAISY are public domain and are visible for everybody, whereas sensitive datasets can be hidden by declaration of the data owner. However, on working-group base, data is visible for everybody due to the joint login.

To give all partner institutions a personal access – either to the transfer-drive or to the database – particular LDAP-logins were created and were sent by email to the project leaders of the institutions (Table 2.1). Because of distinct systems, logins for transfer-drive and database differ slightly.

Table 2.1: LDAP-information for all working groups

Institution	Login for https://citrixgw.ufz.de and query engine	Login http://www.transfer.ufz.de	Password
Al Balqa University	Smbalq	SMART_BALQ	*******
BDZ	Smbdz	SMART_BDZ	*******
Ben Gurion University	Smbgu	SMART_BGU	*******
ECO Consult	Smeco	SMART_ECO	*******
EWRE	Smewre	SMART_EWRE	*******
German-Jordanian-University	Smgju	SMART_GJU	*******
Göttingen University	Smug	SMART_GU	*******
The University of Jordan	Smjua	SMART_JU	*******
Mekorot Co.	Smmek	SMART_MEK	*******
Ministry of Water and Irrgiation	Smmwi	SMART_MWI	*******
Palestine Hydrological Group	Smphg	SMART_PHG	*******
Al Quds University	Smquds	SMART_QUDS	*******
Tel Aviv University	Smtah	SMART_TAH	*******
UFZ-HDG	Smhdg	SMART_UFZ_HDG	*******
UFZ-OEKO	Smoeko	SMART_UFZ_OEKO	*******
UFZ-UBZ	Smubz	SMART_UFZ_UBZ	*******
University of Karlsruhe	Smuka	SMART_UKA	*******
SMART consortium	Smart	Smart	17alpha

2.3.5 Security by firewall (D206)

The vulnerable and vital parts of DAISY are shielded against attacks by a firewall. Because most of the applications, services and query-machines are protected by that firewall, a gateway was created to slip through the wall by telling the guard the right LDAP-password (see Chapter 2.3.4).

To use the services of DAISY – except the transfer-drive and the DAISY-harvester – and, hence, get access to the alphanumerical or the spatial data, the Citrix-gateway is available by using a standard web browser (Firefox, Mozilla, Safari) and the link https://citrixgw.ufz.de (Figure 2.5). The following application is based on Java™, which must be enabled in security settings of the browser.

To pass the firewall and to use the Citrix-gateway, the particular LDAP-login information is necessary: login (Benutzername) and password (Kennwort). After a successful login, choose the SMART-server (Figure 2.6) and the firewall is passed.

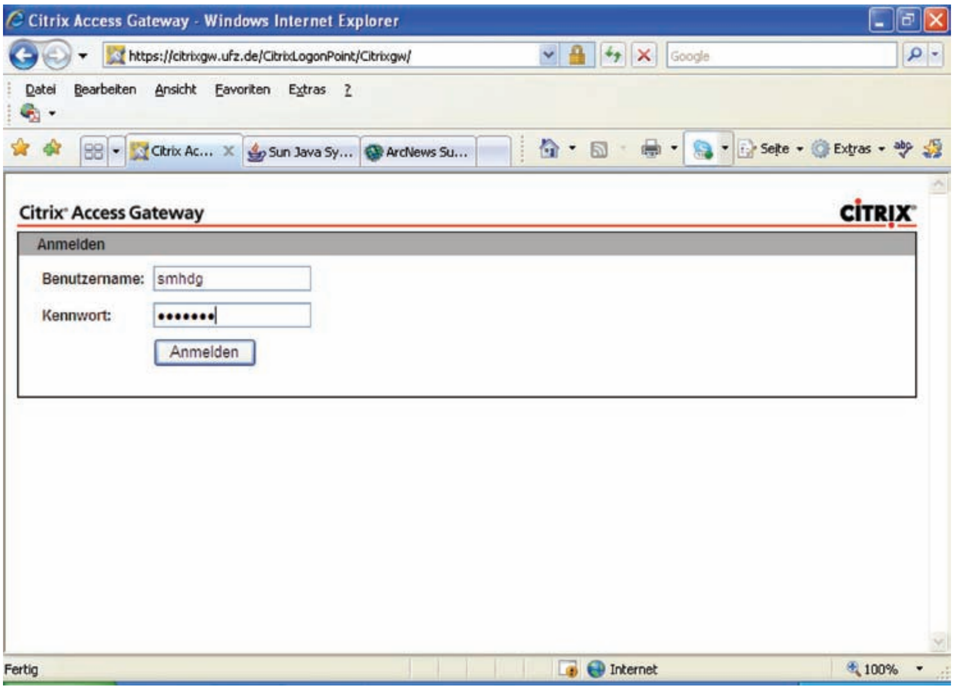


Figure 2.5
Login mask of Citrix-gateway to the SMART-database

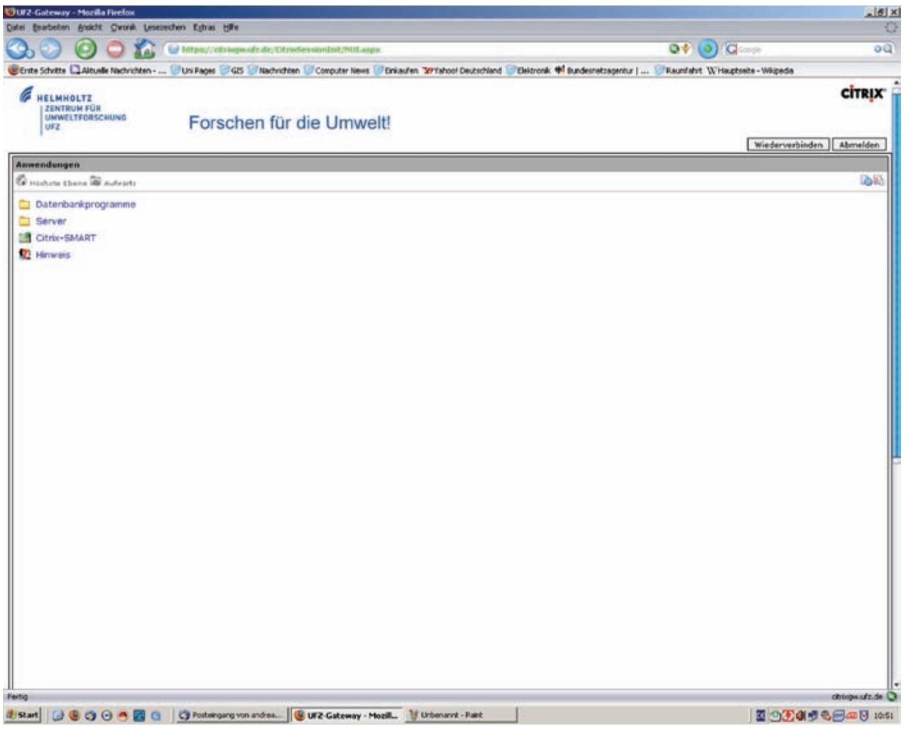


Figure 2.6
Within the gateway, the SMART-Server is available

2.3.6 Software suits

The Citrix-gateway is the entrance to the UFZ-system via a specific server which is particularly generated for SMART users (Citrix-Smart Server). The window that opens in the web browser is a mirror of the Smart Server (Figure 2.7) and offers a suite of software and the option to use ArcSDE, ArcIMS, the SMART-query-machine for well educated structured query language (SQL)-users to request alphanumerical data of the relational database management system (RDBMS) and much more.

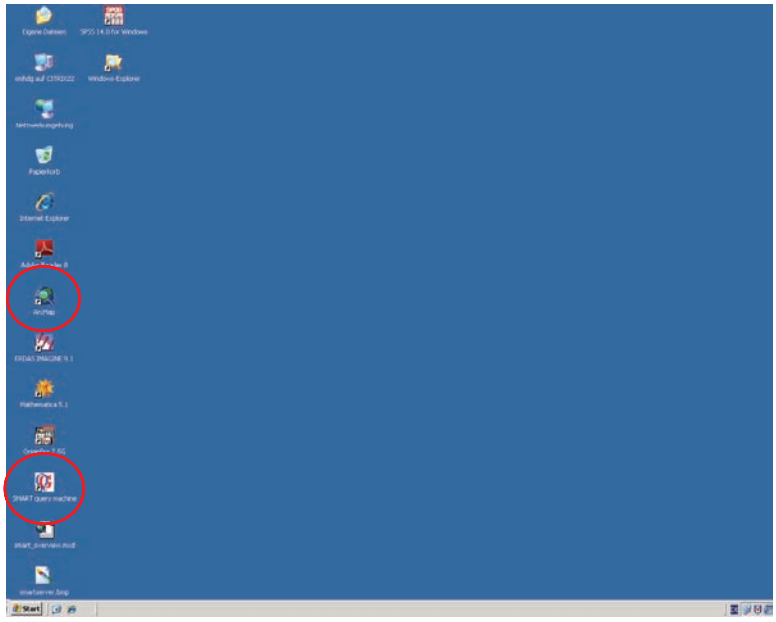


Figure 2.7
SMART-desktop with icons for applications such as query machine or ArcCatalog

2.4 DBMS – Oracle (via Citrix-gateway)

The most important issue of the DBMS is to supply the stored alphanumerical datasets. One optional application on the SMART-desktop is the query-machine, which gives the opportunity to send SQL-requests directly to the SMART-database. As it is directly linked to the database, the user has to logon by using the personal LDAP-login again.

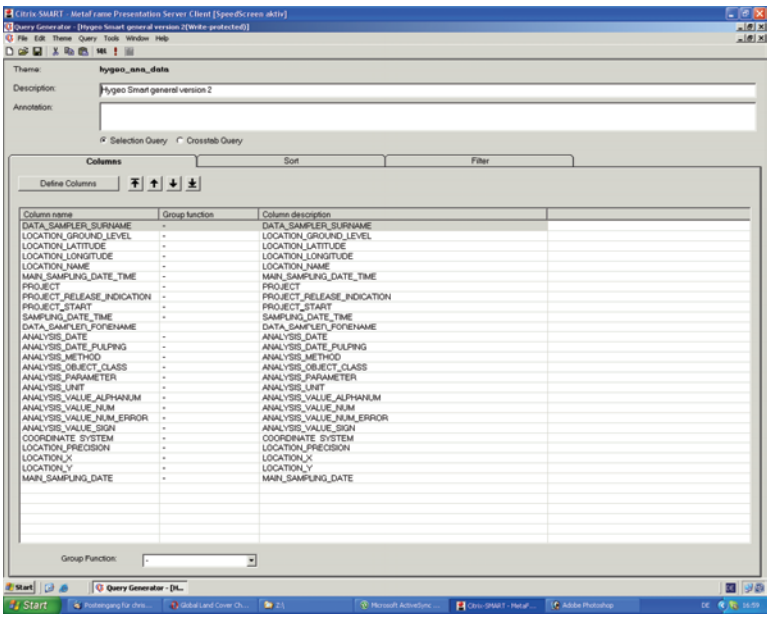


Figure 2.8
The surface of the query machine, particularly adapted to the necessities of SMART

The software answers on SQL-queries with the relevant database entries. Furthermore, it offers operations like filtering, sorting and logical linking as known from other SQL-applications and output options (Figure 2.8, Figure 2.9, Figure 2.10).

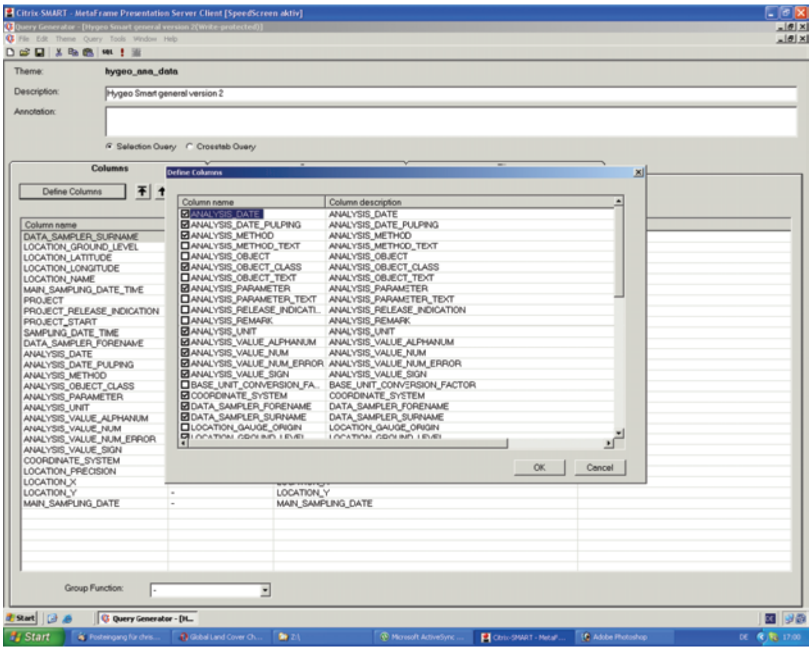


Figure 2.9
Example for the possibilities of requesting datasets

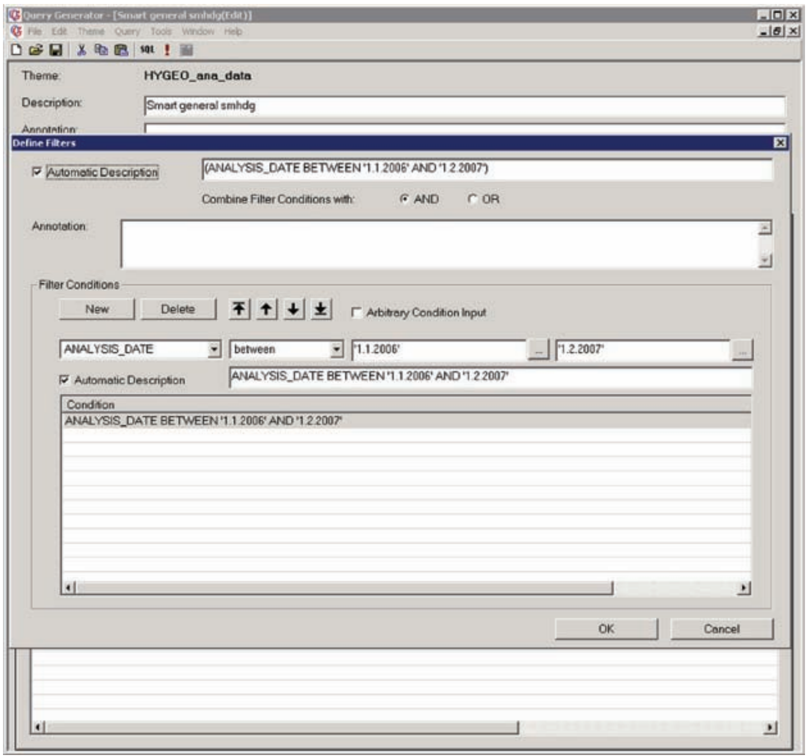


Figure 2.10
Answer filtration of the DB-request as an option in DBMS

All requests can be downloaded from the database, simply by saving and selecting the data format (.csv, .xls, .mdb, xml) that is suitable for your target application (Figure 2.11).

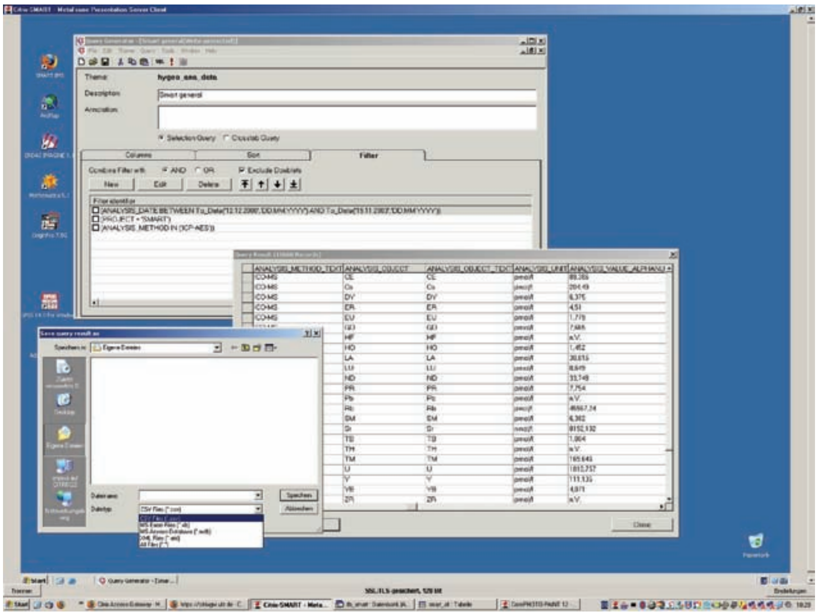


Figure 2.11
Interface to download DB-requests to the users' local machine

2.5 Arc-SDE (via Citrix-gateway)

The second group of data stored in the database, consists of raster- and vector- datasets. However, Oracle as a database for alphanumerical data is not able to handle spatially coded raster or vector data. For that purpose, an ArcSDE (one application in the ESRI-family) translates and administrates this data for Oracle. For access to this data, the ArcCatalog application has to be chosen. ArcCatalog is another application on the SMART-desktop and belongs to the ESRI suite of the Geographical Information System (GIS). ArcCatalog is a standard application designed similar to the Windows Explorer (Figure 2.12), and is able to surf the Oracle database and to provide the SMART-user with all available raster- and vector datasets.

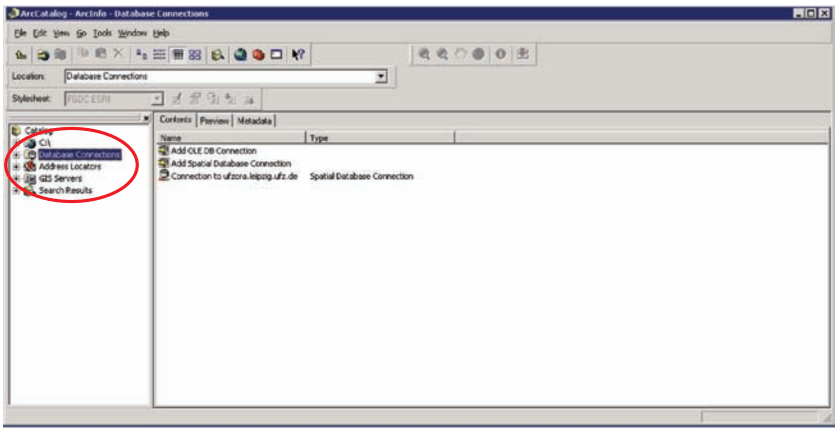


Figure 2.12
Design of the ArcCatalog interface and the connection to the database (in red circle)

For access to the ArcSDE and, hence, to the Oracle database, the user has to prepare a connection or data pipeline: by choosing "Database Connection" and the target "connection to ufzsde.leipzig.ufz.de" (Figure 2.13), the pipeline is prepared by using the following parameters:

- Server: ufzsde.leipzig.ufz.de
- Service: 5151
- User name: “arcims”
- Password: “imsuser”

and checking “save name/password”

After the connection is prepared once, all available spatial data which is already uploaded to the database, can be found in the folder “ufzora” (Figure 2.14).

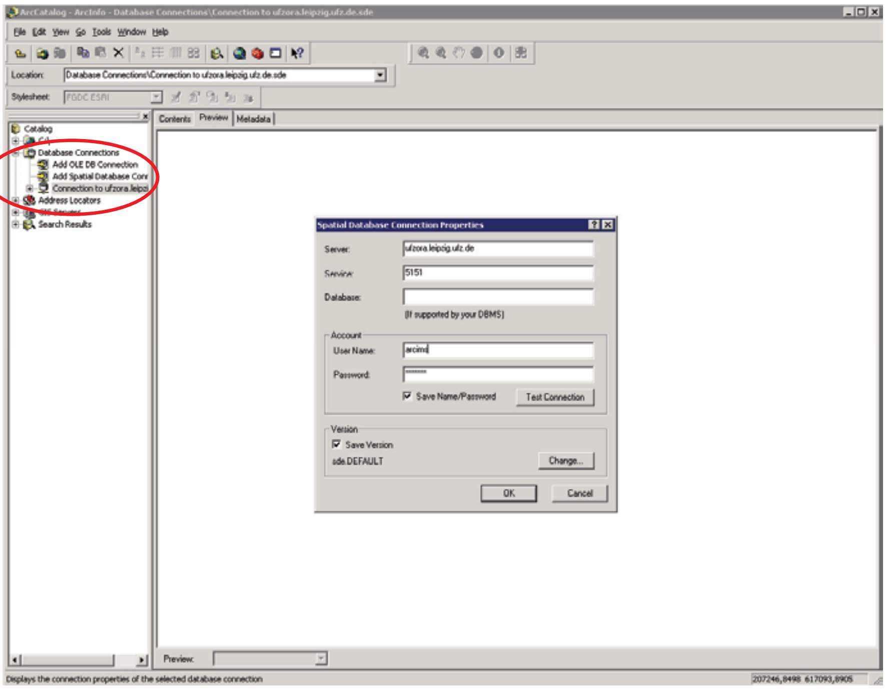


Figure 2.13
Interface to connect to ArcSDE as spatial database

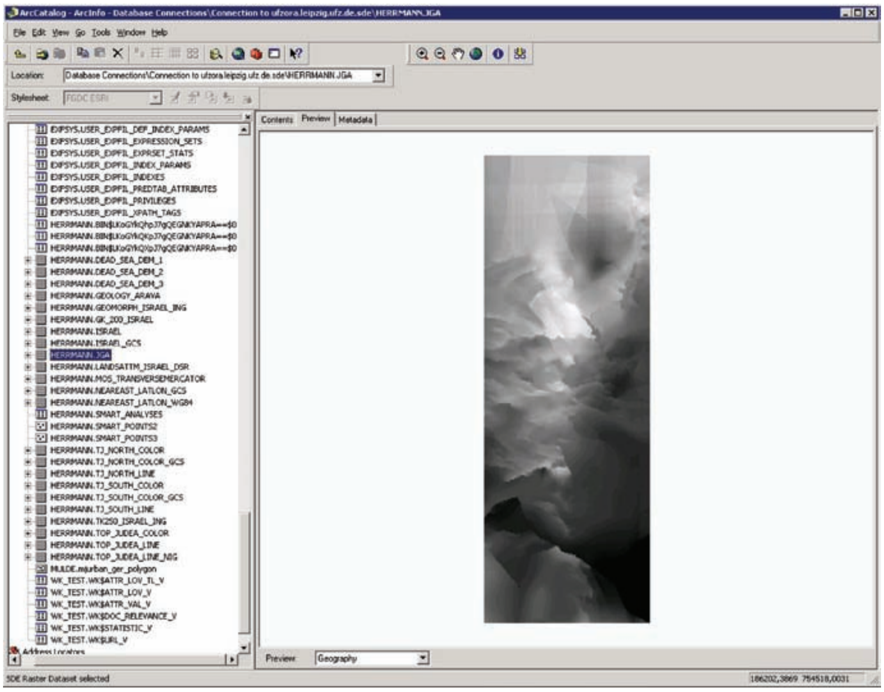


Figure 2.14
Interface of ArcCatalog, readily connected to the ArcSDE database

Because ArcCatalog is a browser or catalog that shows the spatial datasets contained in a folder, one is able to connect it to the users local machine and transfer datasets to a local hard disk or to external devices connected to the local machine. To prepare maps, queries or to use the extended functionalities of the GIS (e.g. spatial analyst) for the datasets of SMART, the ArcMap and ArcScene applications are available.

2.6 Transfer-drive (D208)

Usually, spatial datasets like maps, digital elevation models, etc. do have a huge size of several hundreds of Megabytes. RDBM-Systems like that of SMART are highly sensitive and have to be carefully administrated in order to provide users continuously with data. Such databases have no usual file system. Because of the security and content restrictions, a partner who wants to upload datasets to the RDBMS, cannot connect directly to the database. This is one of the reasons transfer-drives were implemented. Each working group has its own password-locked drive to prevent problems regarding data security. From there, the database administration takes the data, checks them with respect to logic and consistency (file formats, units, coordinate systems, etc.) and afterwards uploads the datasets to the RDBMS.

An additional advantage of the transfer drives is the quick exchange and storage of huge amounts of data (each set has to <1 GB) in a very safe way. The stored data is easily accessible from all over the world, because the drives are web-based. They are hosted by the UFZ and a backup is made for each drive twice a week. There are no restrictions, neither for the content, nor for the size of the drive. However, the size of a single file (or archive) must not be larger than 1 GB.

To access the drive, the following URL has to be entered into a standard Internet browser (e.g. Firefox, Mozilla, Safari): www.transfer.ufz.de.

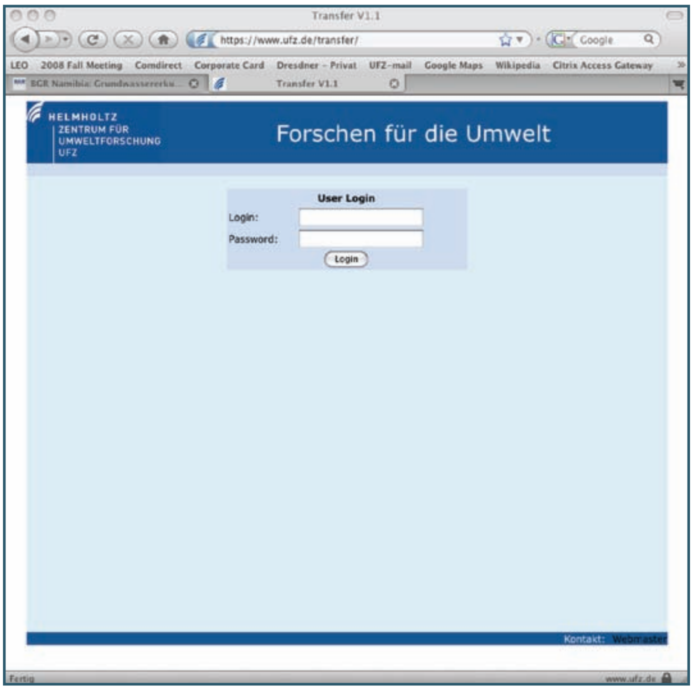


Figure 2.15

Login-mask of the SMART-transfer drive

Each working group has its own transfer-drive (Figure 2.15), according to the grouping of LDAP (see Table 2.1). For the access to the common SMART drive, the login "smart" and the password "17alpha" have to be used. However, for the access to a particular institutional drive, the appropriate login information is necessary, e.g. for Mekorot Co.: login: SMART_MEK, password: **** (see Table 2.1). When logged in, the surface for the joint SMART drive (Figure 2.16) appears.

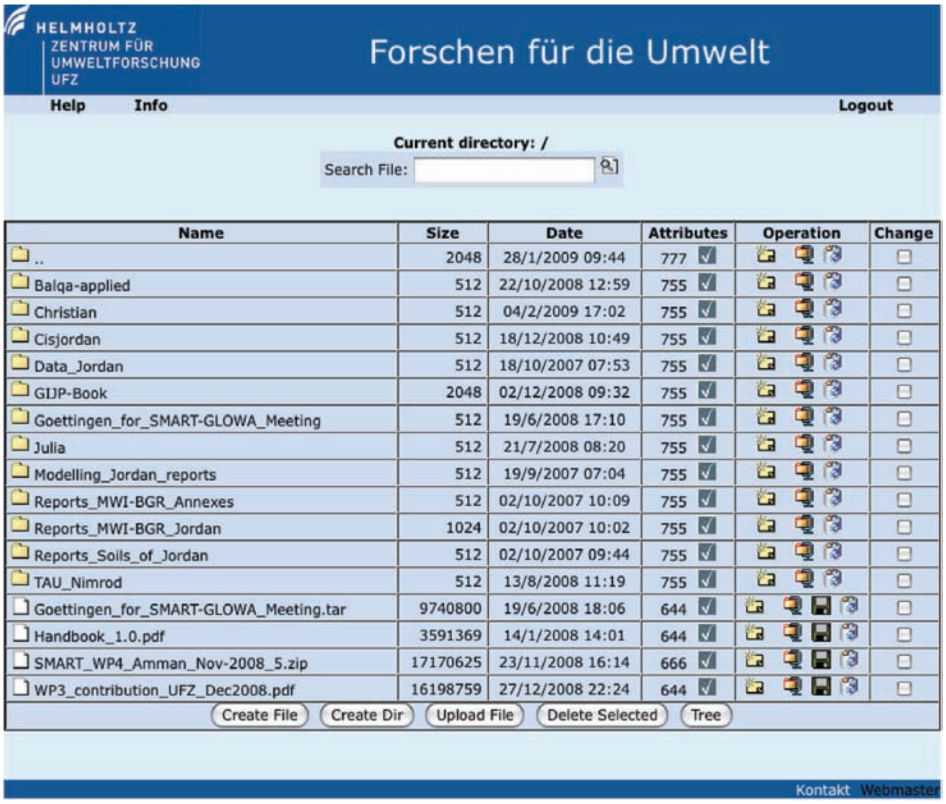


Figure 2.16 Exemplary content of the common SMART-drive

To switch between folders, to show the content, to up- and to download data, the following short instructions may be used:

- **Open a folder**
  click once with your mouse on the folder's name (it's a link, don't double click)

- **Create a directory**
  click on button "create dir"

- **Upload a file into a specific directory**
  choose the directory first by selecting it and then use the button "upload file" (Figure 2.17). Afterwards, use button "durchsuchen" (sorry it is a nonfixable bug, it's in German) and choose the file you like to upload. Then press "upload".

- **Download a file to a local disc**
  select the disc symbol behind the file and follow the instructions.

- **Delete a file**
  press on the recycle bin symbol

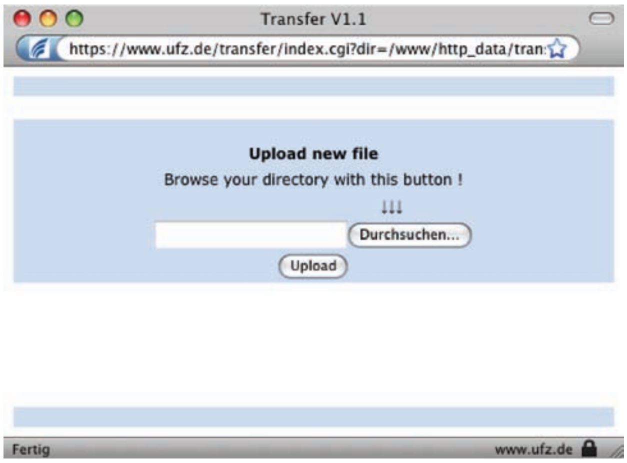


Figure 2.17
Interface to upload files

2.7 DAISY-harvester

The DAISY-data harvester is a comfortable and user-friendly web based graphical user interface (Figure 2.18) explore locations, types, time sequences and availability of datasets from external projects such as GIJP or from partners of the SMART-consortium.

Two types of visitors are allowed to use the harvester: the publicity and project members with LDAP-passwords (see Table 2.1). The public level allows the user to surf the data which is released by data-owners in the public domain. Such data is already published, received from authorities or gathered from literature and other databases. If SMART-members want to login, they have to use the login link and their LDAP-login, respectively.

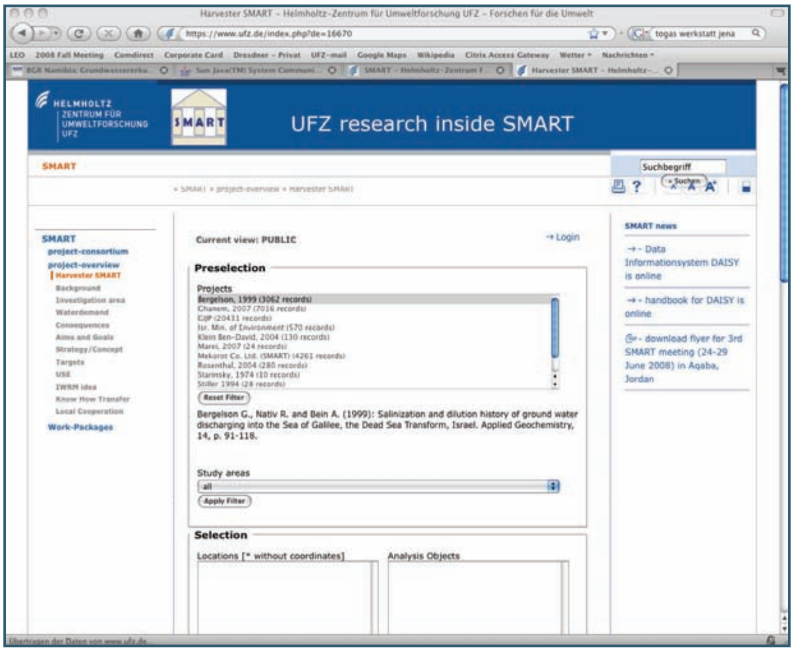


Figure 2.18
Portal to the DAISY-harvester: in the pre-selection, projects which provide data for the RDBMS are selectable

As a helpful tool for data search without knowing the data-owner (or projects), nor their scientific work, a short description of the data-owner (or project) is given below the list (Figure 2.18). After deciding upon the project, the location has to be refined (Figure 2.19).

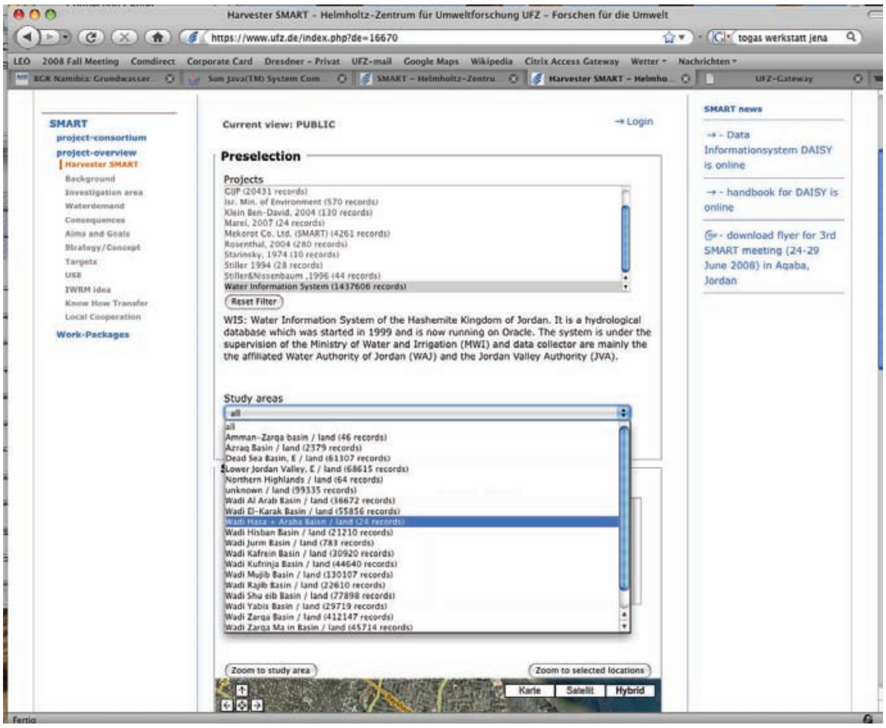
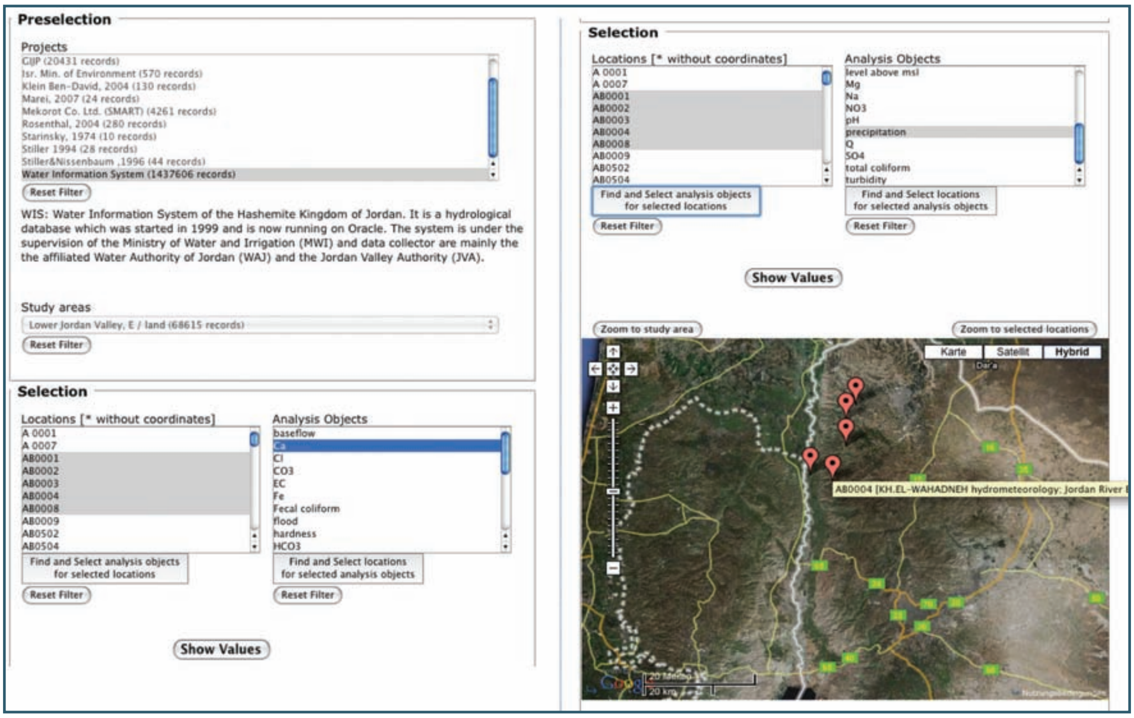


Figure 2.19
Refining the location of datasets



a) b)

Figure 2.20
a) Pre-selection and selection windows and the users' choices
b) Plot of selected locations inside the Google Earth application

After the pre-selection process is finished, the user is able to cross-filter and select the data of interest by location and analysis parameter (Figure 2.20-a).

In order to display the selected locations quickly or to support the decision process concerning the interest/importance of data points, a Google-Earth application is implemented. In the Google-application, selected locations are marked by red drops (Figure 2.20-b).

After selecting locations and parameter or analyses objects, the output of the data is possible as a table or as a diagram (Figure 2.21). In the diagram option, the user is able to select one of the requested locations (if a multi-location request was sent) or parameters (if a multiple-parameter request was sent). Additionally, the plotted frame of the time sequence can be chosen.

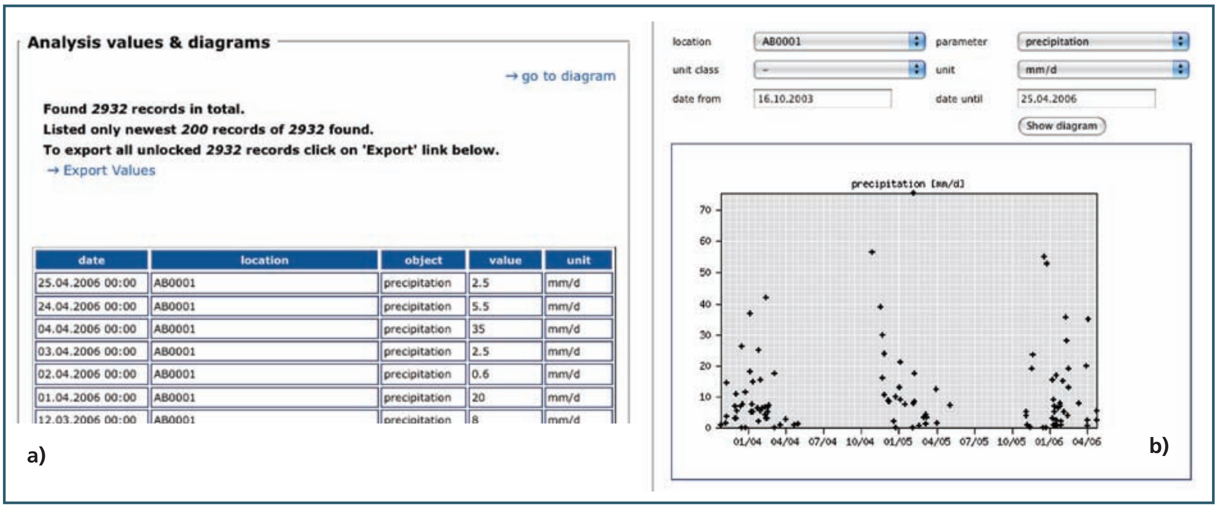


Figure 2.21
a) database answer on selected locations and parameters a) as table
b) as diagram with several plotting options

However, if the data is sensitive, not on public domain or not open to other groups but the affiliate group, the query-result will show you that there are datasets, who is the owner and how to get in contact with the data-owner (e-mail), in order to ask for the found data directly (Figure 2.22).

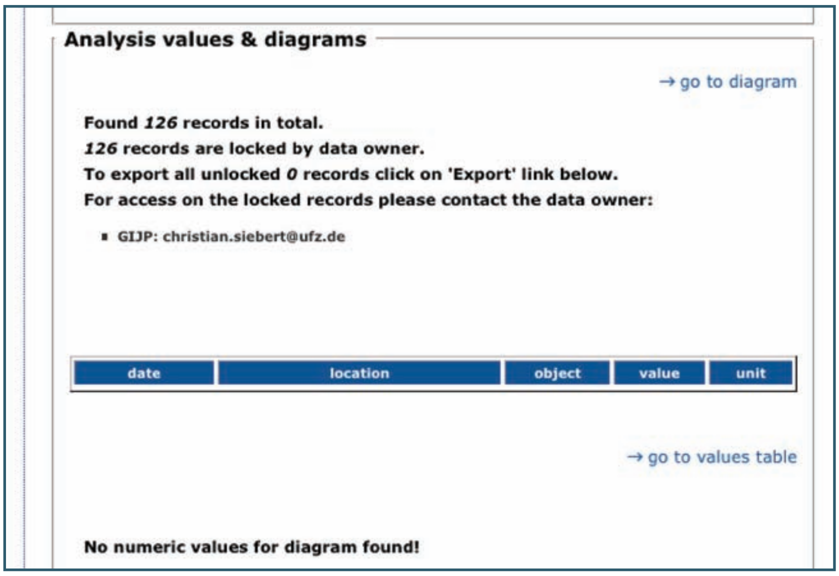


Figure 2.22
The database answer on requests for confidential datasets: information about the number of available datasets, out of those the number of locked datasets and the person in charge is given

2.8 Content of RDBMS and DAISY (D204)

A huge amount of data received from former projects, such as GIJP, GLOWA, EXACT, from literature and from the internet and out of local and foreign databases have been screened, selected, evaluated, compiled and finally implemented into the RDBMS and DAISY. Data from project partners such as the Ministry of Water and Irrigation, Mekorot, the Tel Aviv University, etc. or foreign partners such as the BGR have been compiled and implemented as well. These are:

Alphanumerical data (for SMART-area only), compiled, processed and maintained:

- Hydrochemical data from GIJP- and other precursor projects – (major-, minor-, trace elements, isotopes) of spring water, wells, rivers and other water bodies

- Reports of BGR and MWI: supply to transfer-drive as pdf, manual digitalization of relevant data, integration into the RDBMS

- Data about water quality of all wells in the Jordanian network (sporadically, major elements, NO3-, pH, electrical conductivity (EC), rarely E. coli)*

- Monthly data on water levels (if existent) for more than 500 wells in Jordan*, and for about 70 wells in Israel/Westbank for different time-frames[++]

- Monthly data on discharge (if existent) for more than 350 springs in Jordan since 1980*, and for 5 springs in Israel for different time-frames[++]

- Daily precipitation data (if existent) for ca. 70 stations in Jordan since 1980*, and daily and monthly sums for ca. 30 stations in Israel/Westbank[§]

- Climate data (if existent) for 8 evaporation stations in Jordan (temperature (T), humidity, radiation, evaporation, wind speed, sunshine hours) since 1980*, and for one climate station in Israel (T, humidity, radiation, wind speed, precipitation) [//]

- Daily discharge measurements for ca. 30 wadis in Jordan since 1980*

- Water levels: compilation and linkage of single datasets to machine-readable data formats

- Borehole data for ca. 90 drillings in Israel/Westbank (lining, depth, calibre, drilled formations, rock types)[#]

- Pump rates (if existent) for more than 300 springs in Jordan since 1996*

- Monthly pump rates for ca. 30 wells in Israel/Westbank since 2000[++]

- Pump test data (aquifer parameters) for more than 500 wells in Jordan*

- Borehole characteristics for more than 3000 wells in Jordan*

- Digital information about depth of the base/top of aquifers, geological formation and standardization of formations codes

Spatial raster- and vector-data (for SMART-area only), compiled, processed and maintained:

- Geological maps (1:50.000): scanned and geo-referenced for the entire Jordanian SMART-area, and for Israel/Westbank where hardcopy maps were available (18 sheets)
- Geological maps (1:200.000): scanned and geo-referenced for the entire Israeli/Palestinian territory, and parts of Jordan (4 sheets)
- Topographical maps (1:250.000): scanned and geo-referenced (2 sheets)
- Topographical maps (1:50.000): scanned and geo-referenced for the entire SMART-area
- Digital elevation model (DEM): processed by superposition of a) 25 m-DEM of John Hall (Israel) and 90 m-DEM of SRTM data (NASA)
- Map of catchment areas based on surface analyses of DEM
- Satellite images: all available ASTER-data (from NASA), compiled for the SMART-area (overflight: April 2001), supply of all 14 bands
- Satellite images: all available Landsat data of NASA compiled for SMART area (overflights: August 1999, May 2000, March 2002) supply of all 7 bands
- Vector data (shape files) for direct application in GIS and similar products:

  1.
  Projection and processing of existing data from literature and other data sources such as BGR, GTZ, GIS-world, GIS-community, FAO, UNESCO, etc.

  2.
  Production of data, including related attributes from geo-coded point-, polyline- and polygon-information: geological and tectonic elements, water bodies, streams, sampling locations, streets, infrastructure, structural, administrative boundaries, etc.

  3.
  Translation into a consistent datum-format and consistency analysis for data produced and supplied by project partners

- Geology (Jordan): digitalization of formation outcrops in the SMART-area based on scanned geological maps (separate shape file for each formation); scale: 1:50,000
- Land-use and soil maps: compiled, geo-referenced and optically processed
- Soil (Jordan): digitalization of soil-types for the entire SMART-area; scale: 1:200.000 or 1:50.000 (for more detailed investigation areas)
- Land-use (Jordan): digitalization of land-use maps for the entire SMART-area; scale: 1:200.000 or 1:50.000 (for more detailed investigation areas)

Data sources:

*	Water Information System MWI	//	Internet
++	Mekorot	#	TAU
§	Ghanem		

2.9 Training and tutorial (D203, M23)

2.9.1 Training (D203)

Presentation of work and targets with respect to the build-up and realisation of the RDBMS at the UFZ during the:

- Coordination meeting and workshop at the University of Göttingen, January 2007
- Coordination and informal meeting in Karlsruhe, August 2007
- 1st scientific meeting in Amman, March 2007

Presentation of database, the build-up structure of the RDBMS and explanation of access to the data and information center during the:

- 1st scientific meeting in Amman, March 2007
- 2nd scientific meeting in Amman, October 2007
- 3rd scientific meeting in Aqaba, June 2008

Online-demonstration of database access via citrix-gateway und ArcIMS during the

- 1st und 2nd scientific coordination meetings in Amman, March and October 2007

Preparation and dissemination of a handbook and a guideline (step-by-step guide for the RDBMS-system in English, including screen-shots for better understanding)

Supply of a handbook on the web based DAISY and, additionally, on the transfer-drive for all partners of SMART.

2.9.2 Workshop for maintenance (M23)

- Karlsruhe, October 2006
- Göttingen, December 2006 and January 2007
- Amman, April 2007

3 GEOLOGY, HYDROGEOLOGY AND GEOCHEMISTRY

Involved Institutions: TAU, UJ, UFZ, UBI, UKA, MEK, Al Balqa, QUDS
WP-Speaker: A. Flexer (TAU)

3.1 Introduction

Reliable data of the (hydro-) geological, hydrochemical and geophysical conditions and of water quality and quantity in the project area are of indispensable value for reliable model results. The objective of WP3 was to design a conceptual hydrogeological model, to collect, revise and preprocess existing data, and to accomplish additional field investigations in order to improve the knowledge on the (hydro-) geological situation in general, on existing water resources and replenishment areas. Furthermore, the status of water quality and sensitivity to pollution were investigated and areas with preliminary potential for development were delineated to obtain a picture as complete as needed for the models and the project's goals.

3.2 Conceptual hydrogeological model (D301)

3.2.1 Entire Lower Jordan Valley

Compiled by: Akiva Flexer, Annat Yellin-Dror, Nimrod Inbar (TAU)

3.2.1.1 Introduction and methods

As first step a conceptual model of the Lower Jordan Rift Valley (LJRV) geology and hydrogeology was constructed. It included the definition of the model borders, of the major geological layers to be taken into account for the purpose of water resources evaluations and the major faults (those capable of having an impact on the groundwater flow and transport processes). To this end a digital elevation model (DEM) with a resolution of 1x1 km was constructed for the elevation of the Top Turonian layer. Then a similar DEM was constructed for the thicknesses of the relevant layers above and below the Top Turonian. Additionally the major faults were mapped, together with their dip. All this information was organized within the frame of a GIS. Once the study area borders were determined the data layers needed for the digital conceptual 3D geological model were constructed as follows:

The water bearing layers on both sides of the LJRV were decided upon 3D geological maps and models and the stratigrafic correlation of the aquiferial layers for the project area (Table 3.1).

Topography: a digital elevation model (topography map) of the whole study area was constructed based on data from John Hall (Figure 3.1).

Top Turonian: Digital structural maps of the Top Judea Group in the western side of the LJRV and Top Ajlun Group in the eastern side of the Valley were prepared (Figure 3.1).

Faults: Additional data layer for the conceptual model was the fault distribution in the study area. In view of the fact that the study area is fractured by huge amount of local small faults with various thrown, only the major faults were taken into consideration and implemented in the conceptual model (Figure 3.1).

Isopach maps: Isopach maps were prepared for all the water bearing layers above and below the Top Turonian structural map in order to calculate their thicknesses for the conceptual model (Figure 3.1).

Digital elevation model: A digital elevation model (DEM) with a spatial resolution of 1x1 km was constructed for the elevation of the Top Turonian layer. Then a similar DEM was constructed for the thicknesses of the relevant layers above and below the Top Turonian. Additionally the major faults were mapped, together with their dip (Figure 3.1).

The LJRV aquifers are notoriously known to include substantial volumes of saline brackish water. These saline bodies need to be mapped in order to prevent salinization of the aquifer, subsequent pumping scenarios could be used for low-cost desalination.

Delineation of replenishment areas: Digital geological and outcrop maps were constructed on a scale of 1:50,000 (Figure 3.2) and areas of natural replenishment as well as area of replenishment from irrigation were delineated on the basis of existing data and additional data collected in the frame of this project (aerial photography, satellite imaging, field surveys etc.). The aim is to have a more precise description of the replenishment areas in the LJRV, which shall in turn allow a more detailed evaluation of the water budgets, to be calculated in WP4.

Geophysical investigation: To this end novel geophysical investigation and inference technologies was applied on the data from existing seismic lines in order to map the deep-seated stratigraphy with in the basin-Fill (Figure 3.3). All seismic lines available in the study area were collected and interpreted and time to depth converted, some were re-processed as well. The geological information established from seismic interpretation was implemented in the 3D geological model (Figure 3.3).

Finally a conceptual geological model of the LJRV was established. It represents a simplified, though reliable, representation of the hydro-geologic complexity of the area, to be used for the construction of model for the simulation of groundwater flow and transport.

Table 3.1

The stratigrafic correlation of the aquiferial layers for the project area on both sides of the JRV

Western JRV (Israel and Palestine)	Eastern JRV (Jordan)
Avedat Gr.	Eocene
Mount Scopus	B3 Aquiclude, Muwaqqar Fm.
No equivalent in Israel and Palestine	B1,B2 Aquifer, Ghudram, Amman Fms.
Turonian, Nezer Fm.	Turonian A7, Wadi Sir Limestone
Upper Cenomanian, Weradin, Kfar Shaul Fms.	A5-A6 Shueib Fm
Aminadav Fm	A4 Humar Fm.

Middle Cenomanian, Moza, Bet Meir Fms.	A3, Fuheis Fm.
Lower Cenomanian, Kesalon, Soreq Fms.	A1-A2, Naur Fm.
Aptian, Kefira Fm.	No equivalent in Jordan
Lower Cretaceous, Kurnub Gr.	Kurnub Gr.
No equivalent in Israel and Palestine	Azab

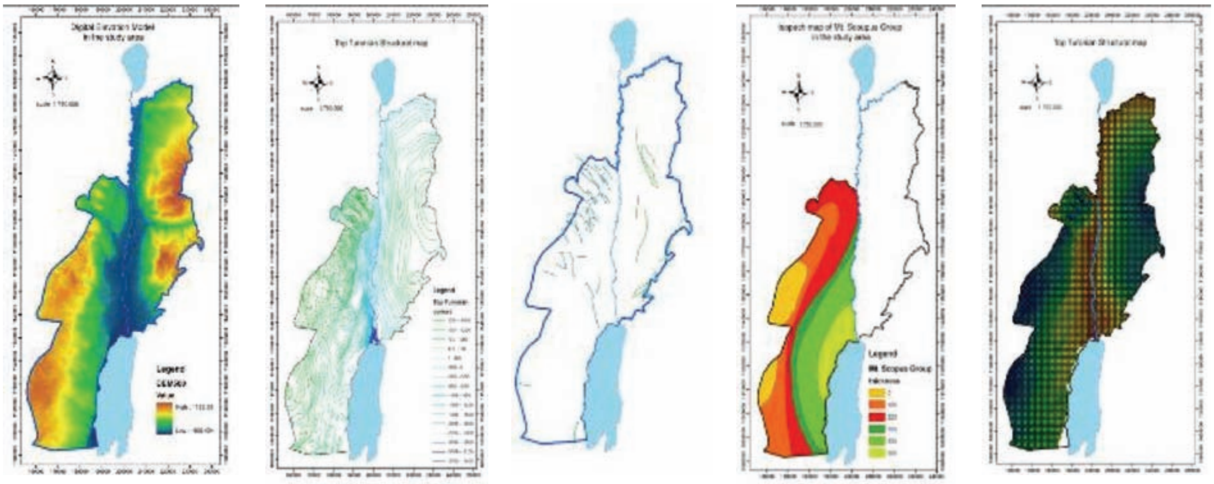


Figure 3.1
Digital maps and data constructed for the conceptual geological model of the study area (From left to right: Topography, Top Turonian structural map, fault pattern, isopach map, digital elevation model)

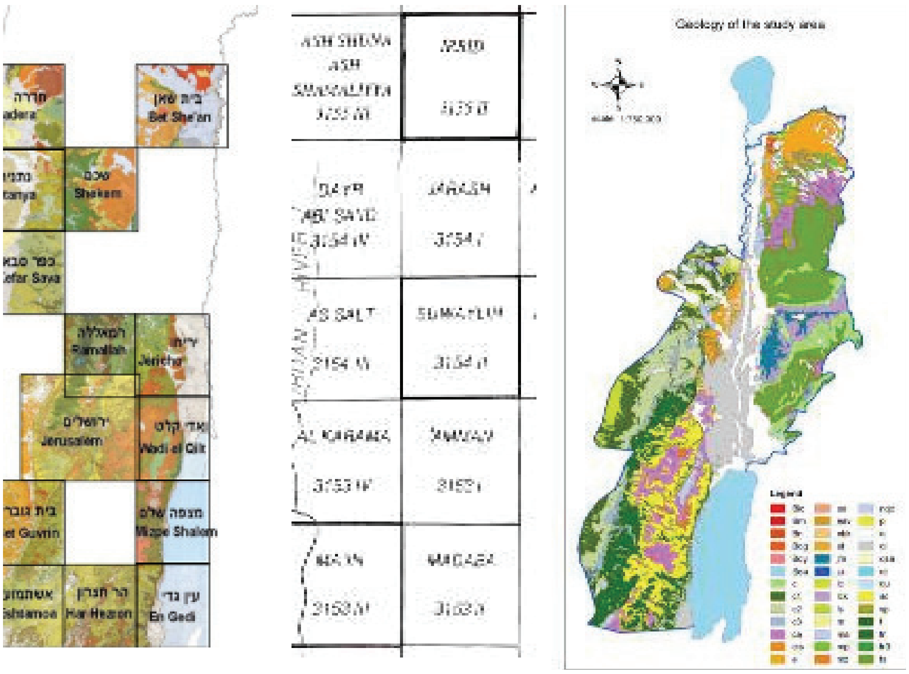


Figure 3.2
Geological maps available in the study area at a scale of 1:50.000 and the digital geological and outcrop map of the study area (also available on a scale of 1:50.000)

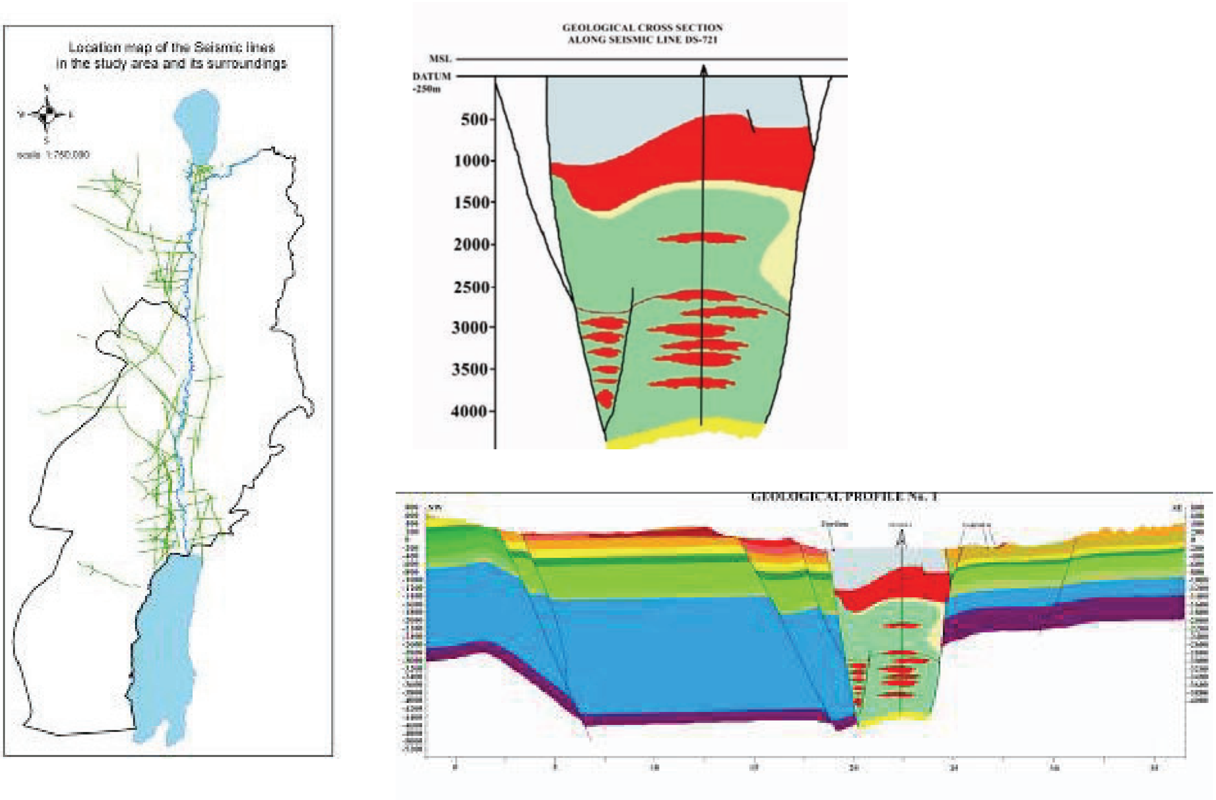


Figure 3.3
Geophysical investigation and inference technologies applied on the data from existing seismic lines in order to map the deep-seated stratigraphy with in the basin-Fill. The composite cross-section presented in the figure was constructed based on the combined seismic line interpretation within the basin-fill and geological information of the basin margins

3.2.1.2 Results

The complex geological structure of the LJRV is constructed of successive basins and swells, lows and highs that have therefore an important implication on groundwater exploitation, their quantity and quality. The 3D conceptual geological model was constructed with all available data of the area which were investigated, processed and interpreted by various methods described above in order to outcome with the most precise model.

A digital elevation model of the LJRV, including the ground-surface down to the deepest water bearing layer was prepared and will be made available to all the partners involved in modeling activities.

By now computerized geological cross-sections can be produced randomly across the study area in all directions (Figure 3.4).

Regular geological cross-sections and outcrop maps were constructed using traditional geological methods („hand made“) from previous studies, borehole data, geological maps and seismic data and then compared to the geological cross-sections and exposed layers created from the resulting model (Figure 3.5). The output show good agreement with the existing cross-sections and outcrop map.

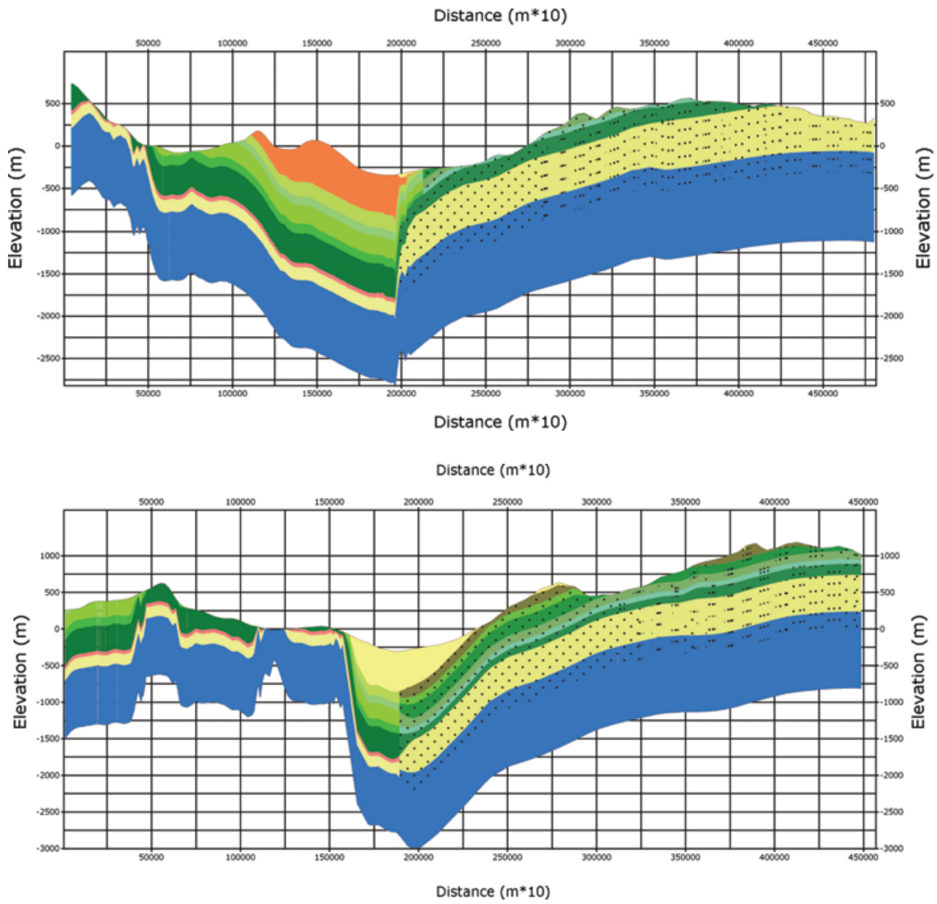


Figure 3.4

Computerized geological cross-sections produced randomly across the study area

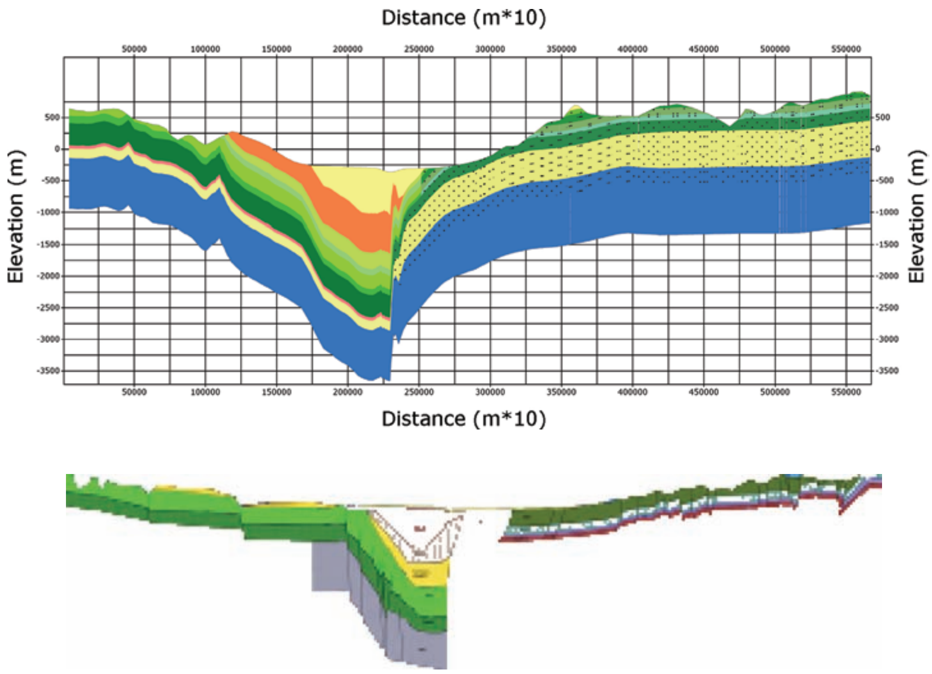


Figure 3.5

Regular geological cross-sections and outcrop maps constructed in a traditional geological method („hand made") and compared to the Geological cross-sections and exposed layers created from the resulting model. The output presented show good agreement with the geological cross-sections and elevation

3.2.1.3 Expected impacts and future research

The 3D conceptual geological model is one of the most significant contribution to IWRE studies in general and the LJRV in particular. The model will further be used to the evaluation of the groundwater resources in the LJRV.
The detailed 3D geological mapping of the area is the basic working tool for the computational models for the simulation of flow and transport of WP6. Further work includes the continuation of the exploration of more sites and locations for the implementation of areas with preliminary potential for development and drillings. Areas of natural replenishment as well as areas of replenishment from irrigation will be delineated on the basis of the outcrop maps. The aim is to have a more precise description of the replenishment areas in the LJRV which shall in turn allow a more detailed evaluation of the water budgets to be calculated in WP4. Estimations of regional water budgets taking into consideration regional variations (Eastern Aquifer, Jordan Valley, Jordanian Rift margins) will be provided. The infiltration mechanism across thick unsaturated zones have to be assessed, areas suitable for development of water resources of all types and for artificial storage (seasonal and long-term) have to be identified. In a further research, the SMART 1 results for new subsurface water resources (new drillings for fresh and saline waters) as well as regional planning of the connections to the distribution network in the study area are implemented. Areas for potential water resource development will be identified and classified by order of preference (with regard to the potential of exploitation (fresh and brackish, sustainability, impact on adjacent sources, preliminary cost-benefit analysis, local needs, etc.). Protection zones to prevent effluents contamination for the existing and future supplying water wells will be delineated.

3.2.2 Recharge studies

Compiled by: Elias Salameh (JUA)

3.2.2.1 Introduction and methods

To obtain additional data on groundwater recharge that can be later included in the modeling process, recharge into the groundwater was studied from two points of view, namely natural recharge by precipitation water and recharge by the infiltration of treated wastewater and spring water in the form of irrigation returns flows.

Natural Groundwater Recharge

In Jordan, natural groundwater recharge amounts have been estimated as fixed proportions of the amount of precipitation. But this approach does not seem to be accurate, especially because such an approach results in a total recharge of 277 MCM/yr for the whole country, whereas extraction (2 - 3 decades ago) of about 500 MCM/yr from both springs and wells did not result in noticeable drops in groundwater levels.
The new approach takes the measurements of precipitation and flood flows and tries to allocate to evaporation all water that satisfies the evaporation force of the climate for the specific area during the season in which soil moisture for evaporation is available (Table 3.2).

3.2.2.2 Results

The results of this approach show that the natural recharge water into the aquifers of the target area of SMART project are almost double the amounts calculated by other approaches.
The recharge water calculated with this new approach satisfies in a better way the water balance of the study area, herewith explaining the lower drops in the groundwater levels than has been expected using other methods.
Another outcome of the new approach is the effect of the climatic changes (decreasing precipitation) on surface and groundwater resources. The evaluation shows that declines in precipitation amounts of 10% will cause in the target area of the SMART project 39% decrease in flood runoff, 16% in groundwater recharge in rain rich areas (>500 mm/year) and 59% in areas receiving around 300 mm/year.

Table 3.2
Decreases in groundwater recharge rates as a result of 10% decrease in precipitation rates

Station	Salt	Madaba	Jordan University	Irbid	Deir Alla	Baqura	Rayyan
Present recharge (total) in mm/yr	286.5	104.2	213.2	181.5	0.3	90.9	60.4
Decrease in groundwater recharge							
in mm/yr	46.7	34	38.2	38.7	0.0	24.7	17.1
in % of total recharge	16	33	18?	21	0.0	27	28?

3.2.3 Expected impacts and future research

The results mentioned above are alarming and should be considered in any water resources development plan for the Lower Jordan area.
However, the natural recharge calculations obtained in the present study must be verified by monitoring groundwater levels and spring discharges in a variety of catchment areas within the SMART target area.

3.3 Water quality assessment (D302)

3.3.1 Hydrochemical investigations in the Lower Jordan Valley

Wadi al Arab, Bet She'an Valley, Wadi Qilt
Compiled by: Christian Siebert (UFZ), Stefan Geyer (UFZ)

3.3.1.1 Introduction and methods

The graben sediments of the Jordan Valley consist of marine and lacustrine clastica, as well as evaporates. However, both, Wadi Qilt/Nueima and Wadi al Arab cut into the margins (Figure 3.6) and are characterized by a 2-aquifer-system.
In Wadi Qilt, the upper aquifer (Bina) as well as the lower aquifer consist of limestone and dolomite and are intensively used for groundwater abstraction. The aquifers of Wadi al Arab consist mainly of limestone, whereas the lower one (A7/B2-Aquifer) is also composed of chert. In both regions, springs occur only in the upper aquifer. The water of the lower aquifer is made available by (deep) abstraction wells.

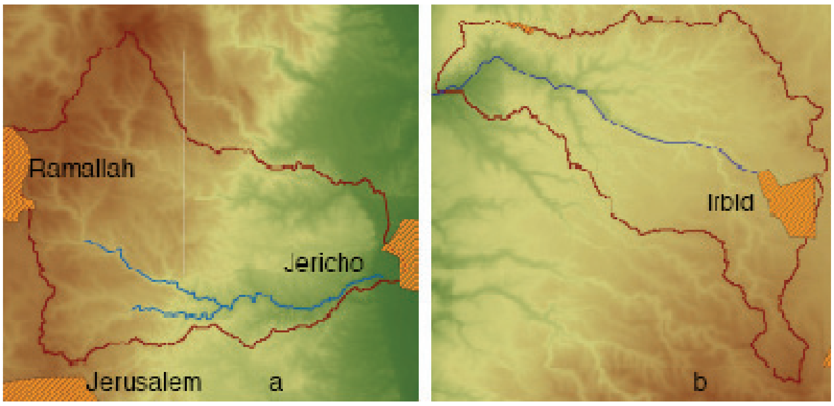


Figure 3.6
The surface catchments of Wadi Qilt/ Nueima in Israel/Palestine (a) and Wadi Al Arab in Jordan (b), colours from green to brown indicate increasing elevations

All groundwaters are characterized by the dissolution of marine sediments and evaporates but are also subject to anthropogenic contamination, especially by sewage leakage into the aquifer. To understand which of these components are responsible for the mineralization and composition of the water, spider diagrams were used. In this type of diagram, concentrations of various elements in the water are plotted on a logarithmic scale and normalized to sea water (index „sw"). Salinization, caused by marine evaporates can be detected very well. The concentration of sea water is lined out at value 0, all values above show enrichment and all below depletion with respect to sea water. The following characteristics can be lined out as general for the regional geology.

3.3.1.2 Results

In comparison to Nasw and Clsw, in all sampled waters Basw, Ysw and the heavy alkalines are enriched. The latter ones and K are delivered to the water by Na-ion exchange from clay minerals, by dissolution of marine evaporates and by residual brines. As a result of abundance and solubility of U-minerals in the Al-Hisa phosphates, the water in Wadi al Arab shows a high variability in U content. All other waters show similar low U-contents, because of the lack of U-minerals in the limestones.

Wadi Qilt

In the catchment of Wadi Qilt, beside Rimonim 1 and Kokav Hashachar, the wells of Mizpe Jericho, Jericho and Arab project cluster, respectively, have been studied (Figure 3.7). The general characteristics are mentioned above. While Mizpe Jericho wells are drilled into the Upper aquifer (Bina Fm.), the further east situated wells of Jericho cluster reach also the Lower aquifer (Kefira and Soreq Fms.). As for the Arab project wells, they are situated at the front of the sediment fan of Jericho and are drilled into the sediments of the fan and the graben filling.

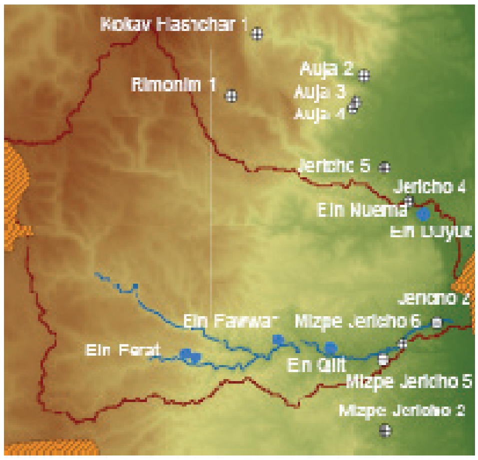


Figure 3.7
Wadi Quilt/Nueima and partly Wadi Auja with the location of wells and springs as sampling locations

A gradient of salinization is observable from Mizpe Jericho to Jericho and finally to the Arab project wells (Figure 3.8). All wells of the Judea Group aquifer are slightly but clearly enriched in heavy alkalines (Rb, Cs) with respect to Ksw and Nasw. However, ions like Na, Cl, Br resulting from dissolution of salt or involvement of residual brine, show distinct enrichment in Jericho wells with respect to Mizpe Jericho wells. That fact points to the stronger contribution of the Lower Aquifer which is next to the boundary fault and influenced by salinized waters from the Graben. The Mizpe Jericho wells are subject to dissolution of rock salt

($Na_{SW}/Cl_{SW}=1$), while the influence of CaCl-brines from the Lower Aquifer in Jericho wells ($Na_{SW}/Cl_{SW}<1$) is distinct. Both Arab wells show similar patterns to Jericho cluster, however, they are subject to much more intense salinization which is observable by a flat pattern from Y_{SW} to K_{SW}, and an enrichment of almost all ions by one magnitude except Y, Cs, Ba, HCO_3 and U (Figure 3.8).

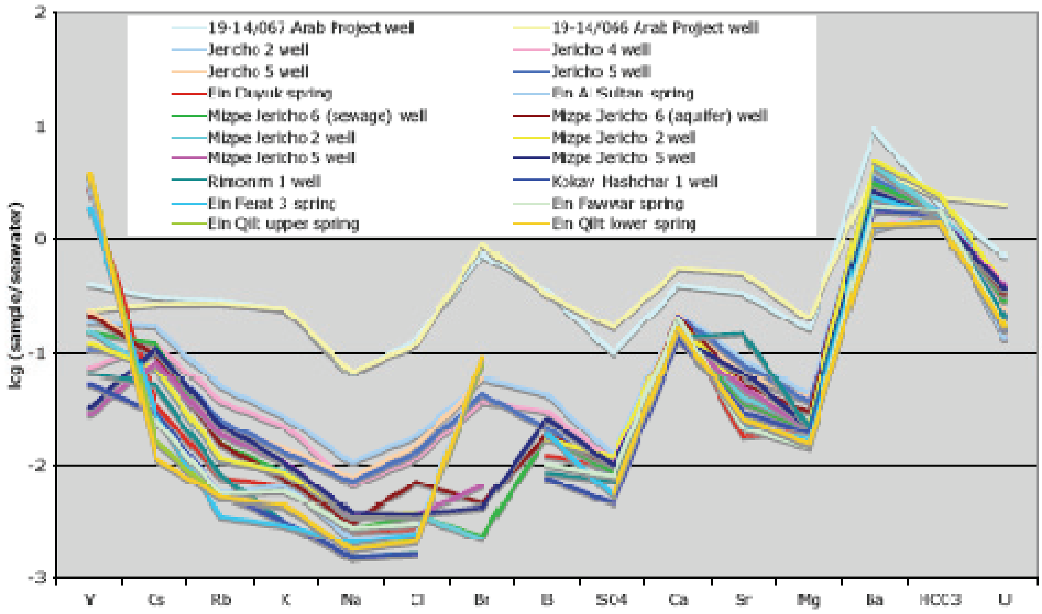


Figure 3.8

Spider pattern of sea water normalized ionic concentrations in waters of Wadi Qilt/Nueima and the Arab project in Jericho

All groundwater from the Judea aquifer is marked by a Ca_{SW}/Sr_{SW} >>1, which is typically for Cretaceous limestones (Siebert, 2006). The similarity in the spider pattern between those wells which are situated in the mountain range and those of the Arab project shows that the latter ones get their main contribution of water from the Judea Group, too.

As for the springs in the Wadi system, they all show the typical pattern of the Upper Aquifer, shown by the comparable pattern of well Huqoq, situated in the Galilee Mountains (Figure 3.9). In direct comparison with Mizpe wells, the only but strong difference is observable in the very high Ysw content of the springs, which is half a magnitude higher than in sea water. Another exception is the enrichment in Brsw in both Ein Qilt springs. None of the sampled springs in Wadi Qilt or in the fan of Jericho (Ein Duyuk, Ein Sultan) show an distinct enrichment of salt ions. Their patterns are similar to those of the Upper Aquifer system (Mizpe Jericho cluster).

The rare earth elements (REE) and Y (henceforth combined to REY) show relatively similar patterns for all water in the Qilt system. However, those of the springs Ein Ferat, Ein Fawwar and Ein Qilt and those of Mizpe Jericho cluster show flat patterns from La to Lu or even slightly soup bowl like pattern, while those of the waters in Jericho and in the Arab project wells show decreasing patterns from La to Lu (Figure 3.10). Regarding the springs, the slightly depletion in middle REEs in respect to the light and heavy REE and the strong negative Ce-anomalies show a precipitation of FeOOH in these aquifers (Bau, 1999).

As for Ein Qilt, the main difference to the other springs in the Wadi course is the missing negative Ce-anomaly. The hydraulic system of Ein Qilt is assumed to be an overflow spring. Hence, with respect to the karstified systems of Ein Fawwar and Ein Ferat, the relatively low oxygen content in such a system prevents a generation of strong negative Ce-anomaly, although the water is from the same aquifer. In the Arab project wells, in wells Mizpe Jericho 5 and 6 and in Jericho 2, positive Ce-anomalies show less oxygen concentrations in these waters.

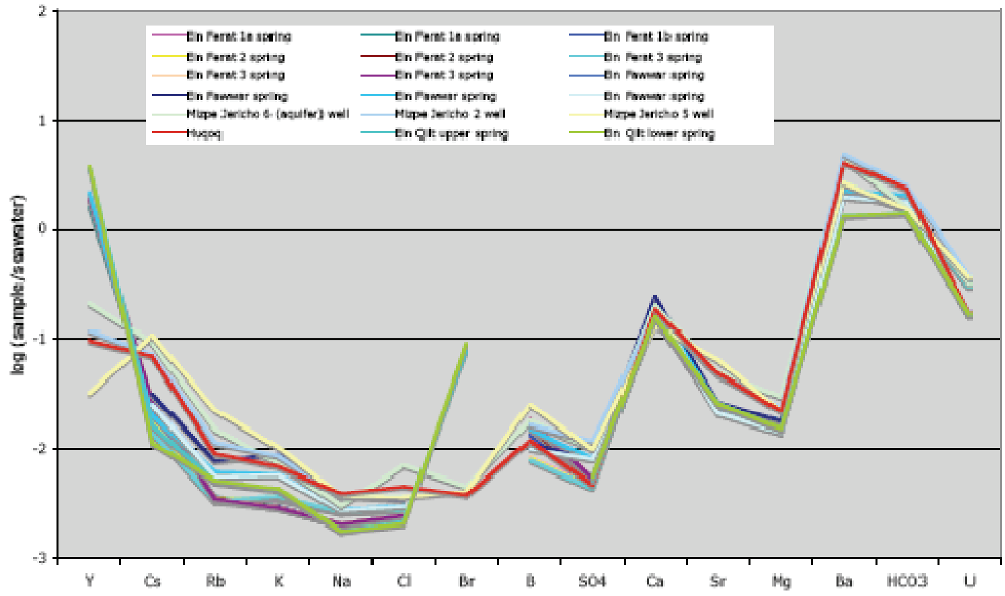


Figure 3.9

Spider patterns of springs in the Wadi Qilt and for comparison those of wells Huqoq, Mizpe Jericho 6, 2 and 5

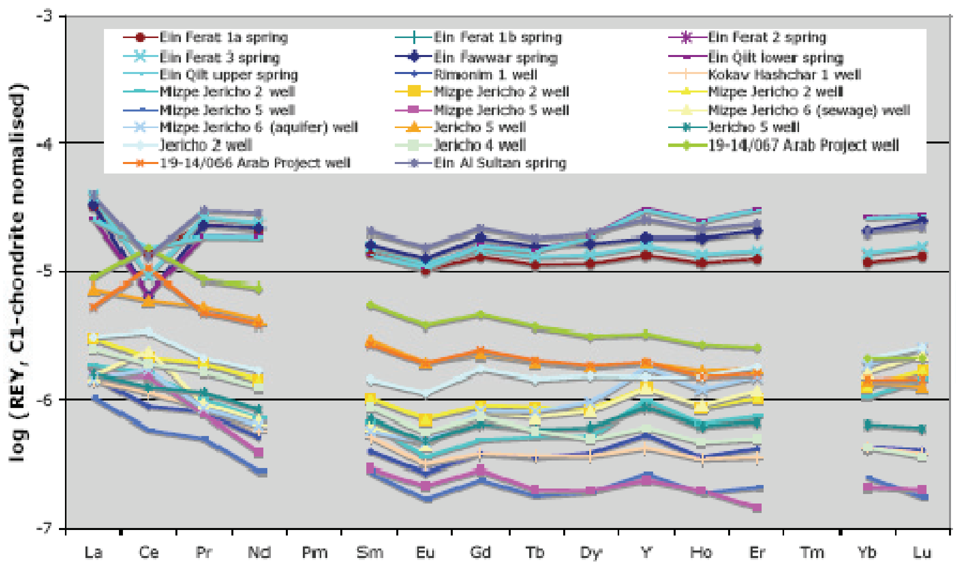


Figure 3.10

REY-pattern of groundwater in the Qilt/Nueima system

Wadi al Arab

Beside wells Kufr Yuba 1 and North Shuna, in the catchment of Wadi al Arab, the well fields of Al Arab and Kufr Asad occur (Figure 3.11). All wells in the latter ones are drilled in the A7/B2 aquifer and show a relatively similar REY pattern. Both, water of Ein Baruqa and Ein Khanzir, emerge in the Eocenic B4 Aquifer and show soup-bowl like patterns (Figure 3.12) that point to either FeOOH precipitation or to a distinct loss of phosphates (Irber, 1996; Bau, 1999; Hannigan & Sholkovitz, 2001).

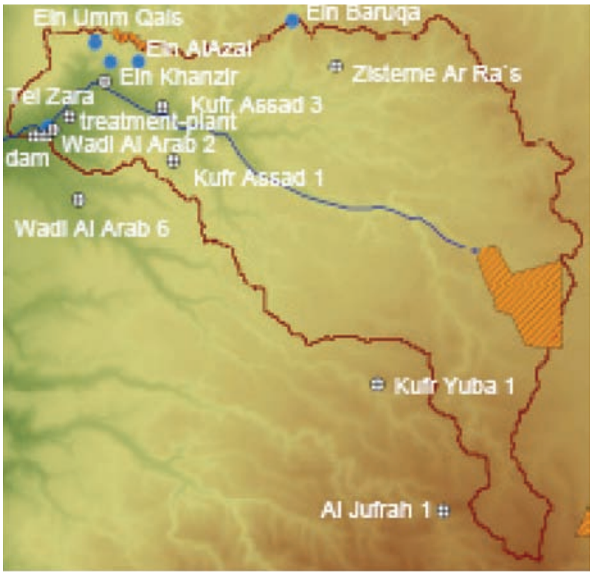


Figure 3.11
Wadi Al Arab and the sampling locations therein

The water in Al Arab well field show flat pattern with similar C1-normalised La- and Lu-contents. When Ce anomalies occur, they are always slightly positive, a circumstance what points to low to no oxygen contents in the waters. Only Ein Khanzir shows a negative Ce anomaly, representing oxygen rich fast groundwater system in the drainage area of the spring. In almost all waters, light negative Eu-anomalies occur, which are typically for groundwater systems percolating through marine sedimentary rocks (Figure 3.12).

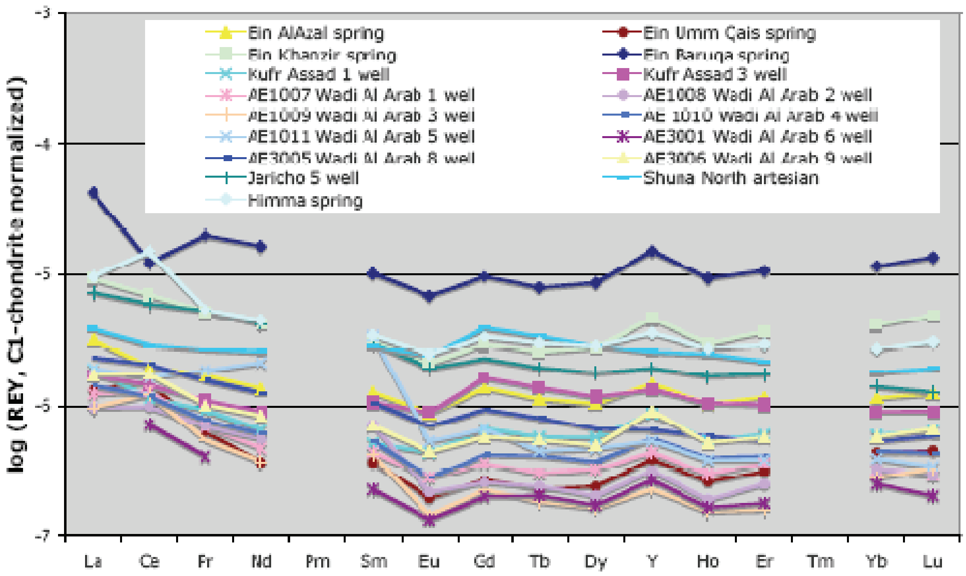


Figure 3.12
REY-pattern of groundwater in the Wadi Al Arab. For Comparison with patterns from Wadi Qilt/Nueima system, REY-pattern of well Jericho 5 is plotted

The spider pattern in Wadi al Arab wells and springs are highly different. Waters from Al Arab well field show the typical patterns, shown in Figure 3.13, with strong positive Cssw-anomalies and very low Clsw/Brsw ratios which points either to an influence of residual brine or to a strong Br-source in the aquifer. Low Cl/2xSO4 ratios point to a close connection to the bituminous rocks of Senon and Eocene. The compositions of these waters are similar to those of Hammat Gader springs in the Yarmouk gorge. Only the hot well Shuna North which is drilled in the boundary fault zone shows a slightly different pattern with decreasing sea water normalized values from Cs to Br and very low Usw-contents which shows the strong reducing conditions in that water (Figure 3.13).

Water of Ein Himma, situated in the southern Yarmouk gorge, opposite of Hammat Gader show similar pattern to the Wadi Al Arab well 6 and Hammat Gader springs.

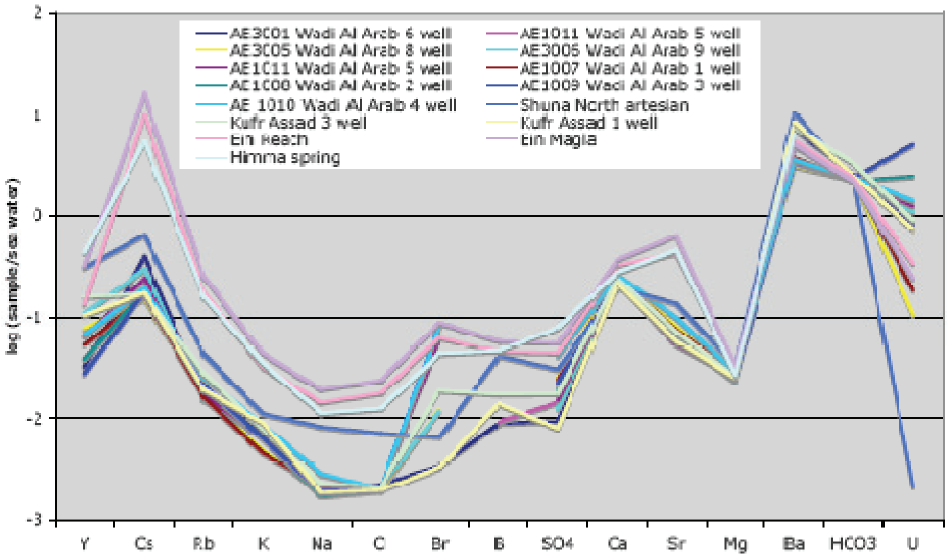


Figure 3.13

Spider pattern of well water in Wadi Al Arab Samples of Ein Reach and Ein Magla, both springs in Hammat Gader (Yarmouk gorge) are plotted for comparison

The springs in Wadi al Arab don't show the strong positive Cs_{sw}-anomaly of the A7/B4 waters (Figure 3.14). Their origin is the Eocene B4 (Umm Rijam) limestone aquifer. In contrast to waters from the A7/B2 Aquifer, water from Ein Khanzir shows Cl_{sw}/Br_{sw} >1 and low Ca_{sw}/Sr_{sw}-ratios. Despite, the aquifer of origin is relatively young (Eocene), the Ca_{sw}/Sr_{sw} ratio in all waters except Ein Khanzir are higher than 1. Ein AlAzal spring shows a similar pattern to Kufr Yuba well which is situated south of the drainage area of Wadi al Arab (Figure 3.11) with strong decreasing sea water normalized values from Y to Cl.

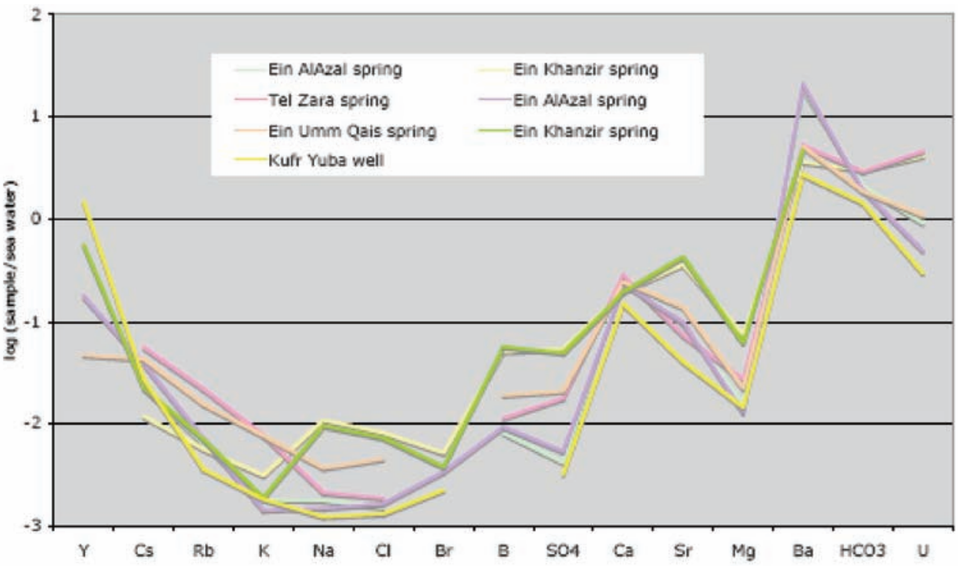


Figure 3.14

Spider pattern of spring water in Wadi Al Arab. For comparison, sample from Kufr Yuba well is plotted inside

Bet She'an Valley

Water from Bet She'an valley was sampled in autumn 2008 and still is in analyzing process. The first results are shown in Figure 3.15. They show mainly increasing patterns from sea water normalized K to HCO3. Answers for heavy alkalines (Cs and Rb) and for REY are still not possible.

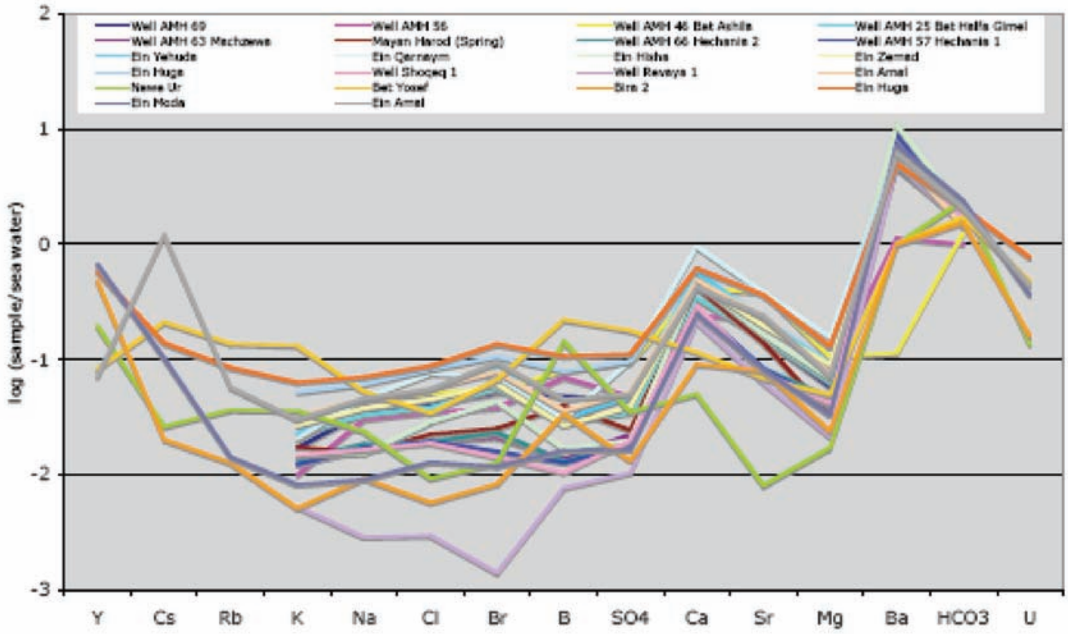


Figure 3.15

Spider diagram of water from wells and springs in the Bet She´an valley, along a NE-SW cross section through the graben

3.3.2 Further hydrochemical investigations

Compiled by: : S. Geyer, C. Siebert (UFZ)

3.3.2.1 Methods

Additional quality issues relevant to the utilization of water in the LJRV were investigated, including impact of problematical dissolved compounds introduced by the natural geological background as well as organic and inorganic compounds by anthropogenic activities. These factors affecting the groundwater quality were identified and their impact of the current and expected chemical composition of the water to be produced will be quantified.

Water quality assessment was conducted in specific and chosen areas in the study area (Figure 3.16). Water was sampled by the UFZ Group during the research years 2007 and 2008. All data points illustrated in Figure 3.16 were doubled sampled for isotopes, main chemistry and trace-chemistry. Most of the sampled data and analyses are available in the data base and the final report for D302 deliverable on water quality assessment.

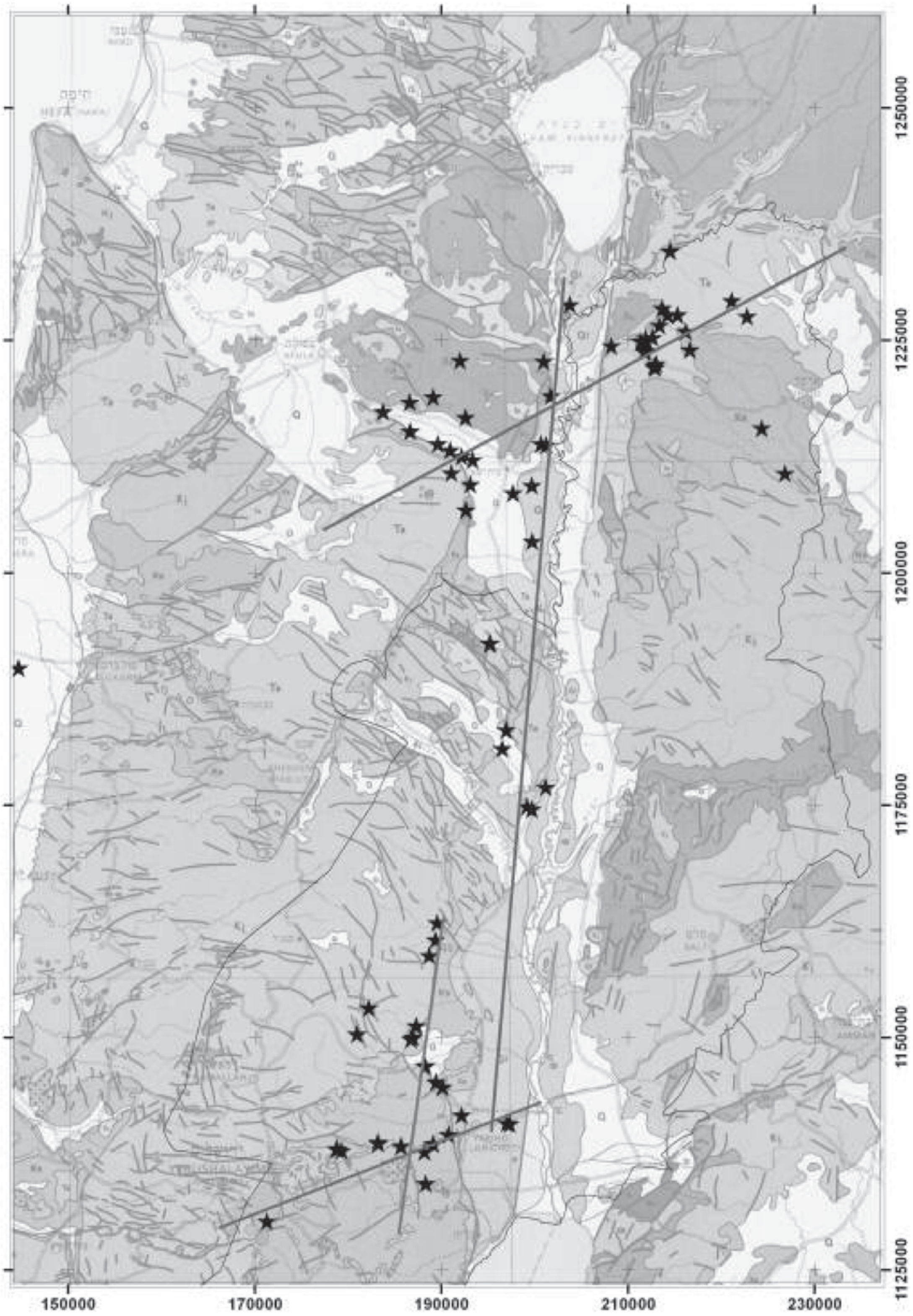


Figure 3.16

Water sampling locations of the UFZ Group during the research years 2007 and 2008

3.3.3 Hydrochemical investigations in the Lower Jordan Valley – Wadi Kafrein

Compiled by: E. Salameh (JUA)

3.3.3.1 Introduction and Methods

Along the project area in Wadi Kafrain all accessible springs and wells were sampled on a monthly basis and analyzed on their normal chemical composition, BOD, COD, PO4, pH, EC, T in order to set the frame-work for groundwater vulnerability in that area.

For that same purpose, a few tens of soil samples from different sites in the area have been collected and analyzed on their moisture content, grain size distribution, permeability, etc. This will assist in studying the impacts of different land uses on the groundwater quality.

3.3.3.2 Results

The groundwater quality in the area is still good and can be used for municipal proposes after minor treatment such as infiltration and chlorination.

In areas neighbouring urban centres, the nitrate concentration exceeds the WHO and Jordanian Standard for drinking water (JS 286). This requires intervention to alleviate infiltration from cesspools into the groundwater bodies.

The deep aquifers of Kurnub and Zarqa group contain brackish to salty water especially in areas bordering the Jordan Valley. The sources of salinity of these aquifers have not yet been clarified but they can be attributed either to evaporite residues in the aquifers or to incomplete flushing of the aquifers containing residues of Dead Sea (Lisan Lake) water when the level of that lake was 240 m higher than the present Dead Sea level.

3.3.3.3 Expected impacts and future research

The analysis of the groundwater resources of the area will allow recognizing the natural aquifer water quality and will assist in understanding and quantifying the human impacts on these resources.

Thus, this will assist in working out programs to protect the aquifers such as building of sewage systems, less use of fertilizers, optimization of irrigation water amounts etc.

After having established the knowledge about the present groundwater quality, changes in this quality as affected by climatic changes and land use development have to be monitored and clarified in order to prevent groundwater deterioration.

3.3.4 Hydrochemical Investigation of springs and selected wells from the West Bank dewatering towards the Lower Jordan Valley

Compiled by: M. Ghanem (UBI)

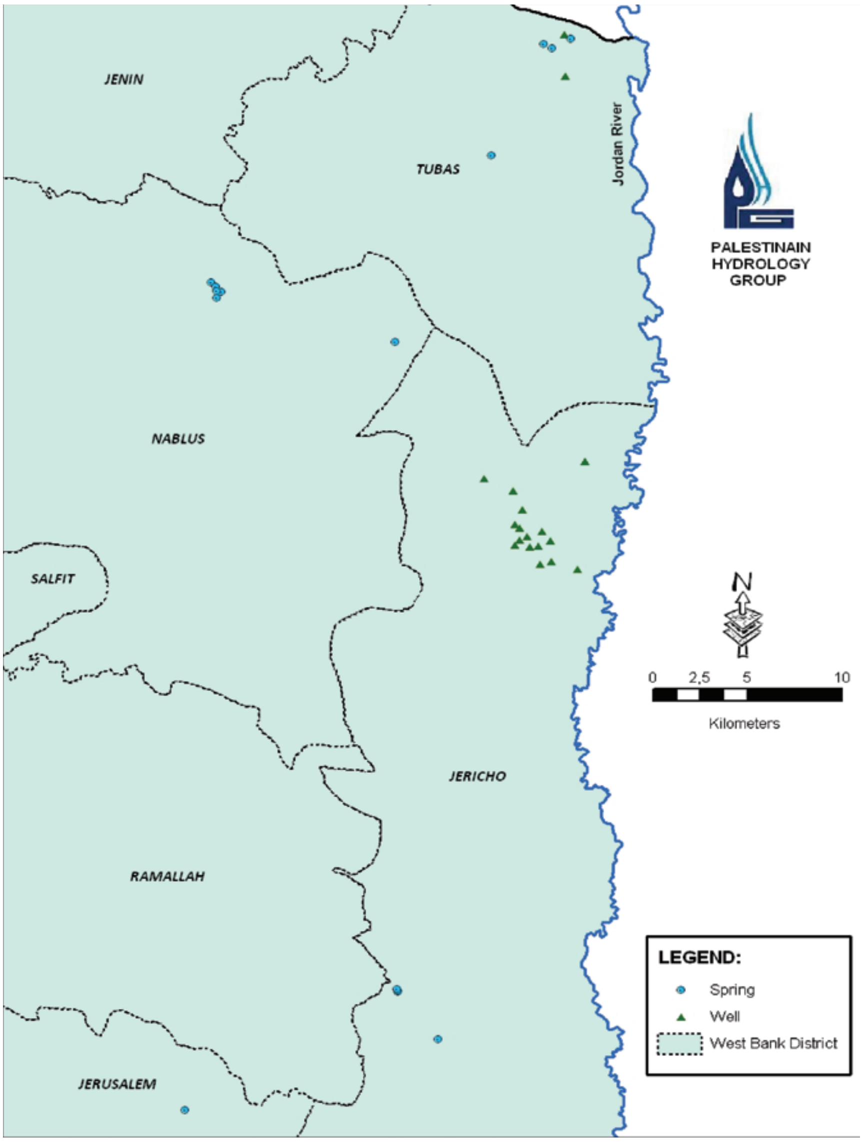


Figure 3.17
Sampled sites of springs and groundwater wells

3.3.4.1 Introduction

20 springs and 19 groundwater wells located in the Upper Jordan Rift Valley (Figure 3.17) were sampled in 2008. The water samples were analyzed for major ions and heavy metals (Table 3.3), and the obtained data was used for further hydrochemical characterization, such as the determination of water types, saturation indices and water quality evaluation.

Table 3.3

Results of the chemical analysis showing minimum, maximum and average concentrations

	Springs			Wells		
Element (mg/L	Min.	Max.	Average	Min.	Max.	Average
Na	14.0	608	79.1	61	444	253
K	1.0	42.0	4.6	3	47	25
Mg	5.0	94.0	21.4	34	158	107
Ca	39.0	291	76.0	58	186	125
Cl	26.8	830	88.7	171	860	647
SO4	4.0	98.2	14.7	2	96	17
NO3	1.2	9.8	4.5	5	28	11
HCO3	56.0	179	98.1	61	117	81
Li	0	0.7	0.2	0.04	0.81	0.34
Fe	0	1.3	0.1	0	0.33	0.04
Mn	0	3.0	0.3	0	0.01	0
Element (µg/L)	Min.	Max.	Average	Min.	Max.	Average
Ni	0	18.0	5.7	0	6.0	3.1
Al	0.03	1290	132.1	0.04	196	76.1
Cr	0	4.0	0.7	0	5.0	1.1
Ba	0.03	43.0	1.1	0.05	0.19	0.11
Cd	0	0.0	0.0	0	0	0
Cu	0	6.0	0.4	0	0	0
Pb	0	140	18.7	0	132	32.5
Zn	23.0	254	84.3	0.14	168	89.4
Co	0	6.0	2.6	0	5.0	2.6
Bi	0	1170	139.3	0.35	623	344

3.3.4.2 Results

Three different water types were found in spring water samples: Na-Cl, Na-HCO_3 and Ca-HCO_3 types. Thus, most of the spring samples belong to the earth alkaline water group and show prevailing bicarbonate and sulfate or chloride concentrations. Few samples show increased portions of alkalis, and only one sample can be classified as alkaline water (Figure 3.18-a). The sampled groundwater wells were of Na-Cl type. The well samples can be classified as earth alkaline water group with increased portions of alkali and prevailing sulfate and chloride concentrations (Figure 3.18-b).

The water of the spring samples shows the following ionic strengths for major ions:

$Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$ and $Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-}$

While well samples have the following ionic strength for the major ions:

$Na^{+} > Ca^{2+} > Mg^{2+} > K^{+}$ and $Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-}$

The saturation indices (SI) were calculated for calcite, aragonite, dolomite and gypsum according to the equation

$$SI = \log (IAP/K_{sp}),$$

whereas IAP signifies the ionic activity product of the ions, and Ksp signifies the solubility product of the mineral. All water samples were found to be undersaturated with respect to the minerals mentioned above, and therefore, waters are potentially able to dissolve any of these minerals.

Regarding the WHO guidelines and Palestinian standards for water quality, 88% of the spring samples exceed the proposed values for Pb. Two spring samples (Malih and Mayta spring) also show exceeding concentrations for Na, Fe and Al, and additionally, samples from Mahil spring exceed the guideline values for K and Cl. Furthermore, the elevated Ca concentrations reflect the limestone origin of the water samples.

For the well samples, the guideline values are exceeded for at least one major ion per sample (Table 3.4). Moreover, 93% of the well samples exceed the proposed Cl concentration. This reflects the water-rock interaction of the area.

Table 3.4

Guideline values for water quality and percentages of exceeding samples for some major ions; PS: Palestinian Standard, WHO: World Health Organization.

Guideline	samples exceeding guideline values for				
	Na	K	Ca	Mg	Cl
	53%	93%	87%	53%	93%
WHO (mg/L)	200	12	75	125	250
PS (mg/L)	200	10	100	100	250

For the spring samples, an increasing concentration trend is shown from west to east for the parameters of Na^{+}, K^{+}, SO_4^{2-}, Co, Bi, while a decreasing trend is shown for Ca^{2+}, HCO_3^{-}, Li, Ni, Pb, NO_3^{-} and Al. For the north – south profile, an increasing concentration trend is apparent for Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Pb and Bi, while a decreasing trend is shown for the parameters NO3-, Cl^{-}, Ba and Al.
The increasing concentration trends of Na^{+}, SO_4^{2-}, as well as of Fe, Co, Bi and Li (Figure 3.19) towards the south are caused by natural and manmade polluted sources. These put marks on both, surface water and groundwater. The industrial wastewater discharge in Faria area increased the concentrations of Co and Bi (from west to east; Figure 3.20) and poses a threat to groundwater quality.

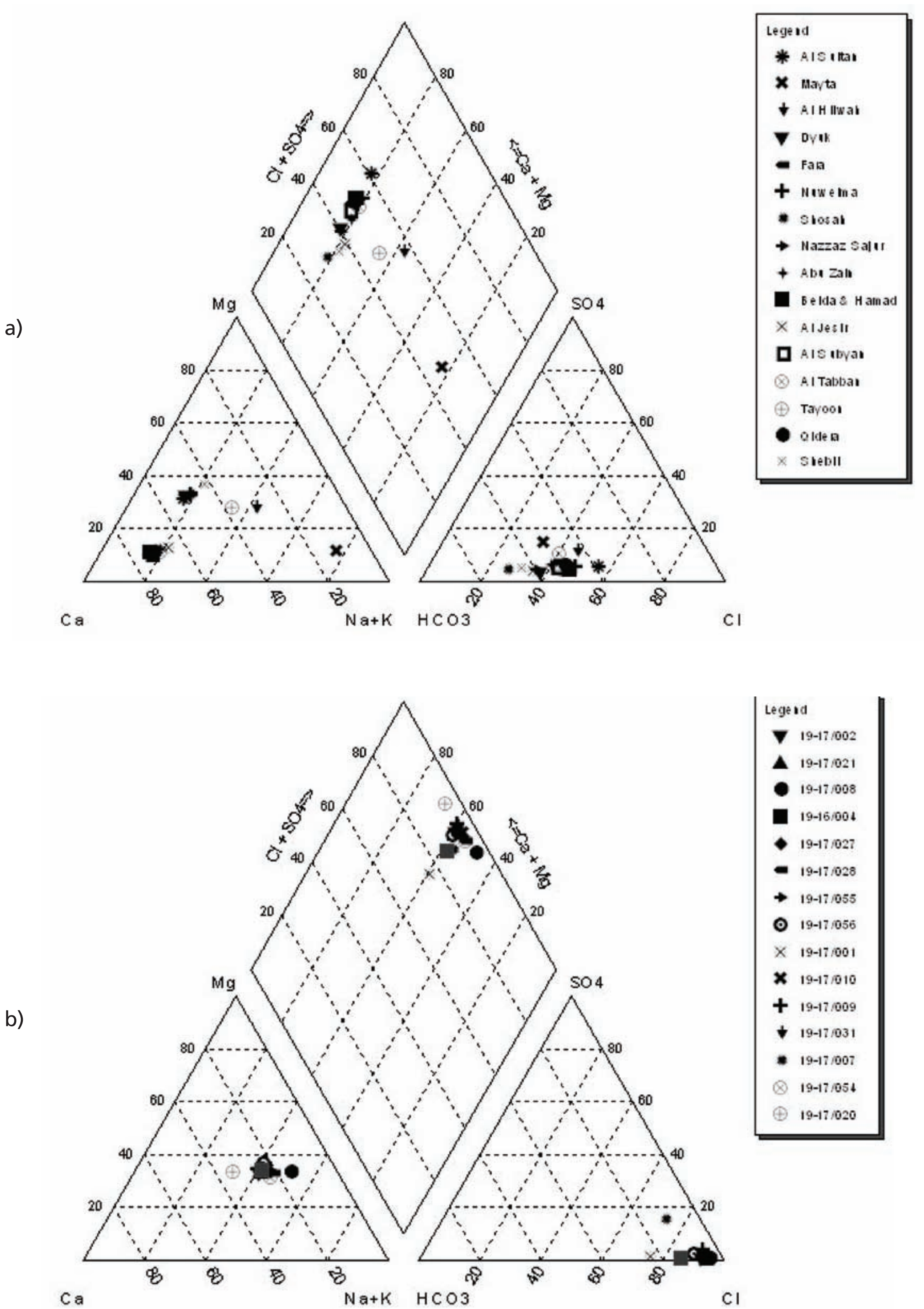


Figure 3.18

Piper diagram for a) the springs and b) the wells

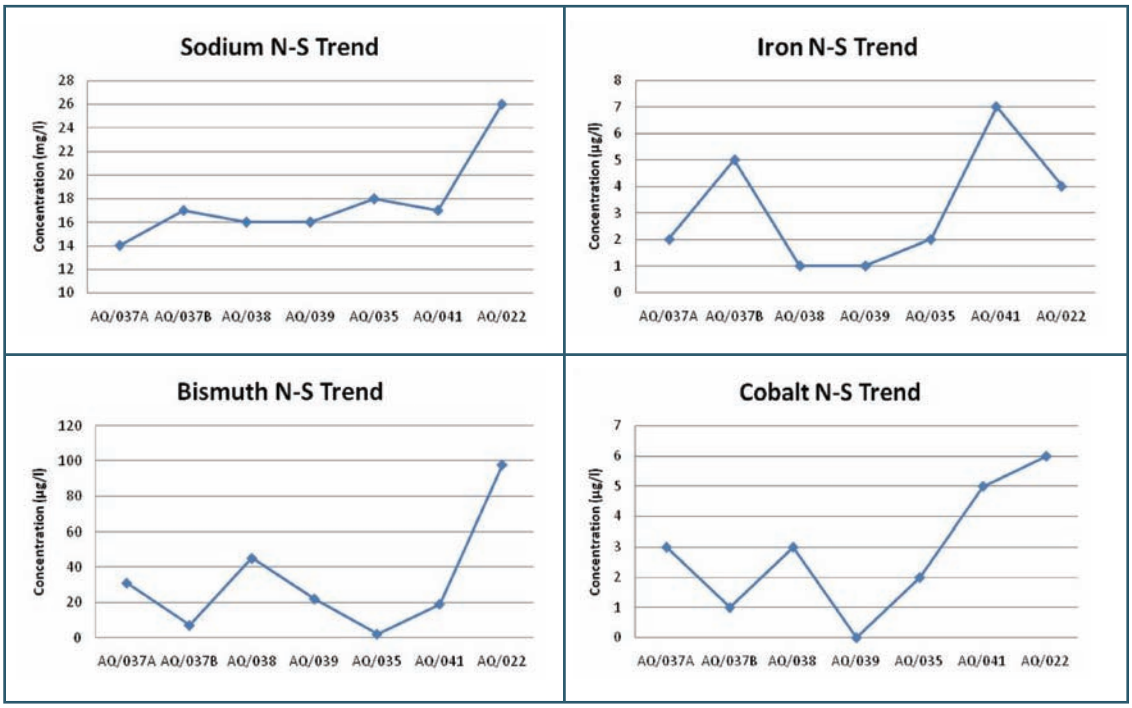


Figure 3.19

N-S trend of Na and the heavy metals Bi, Co, Fe (spring samples)

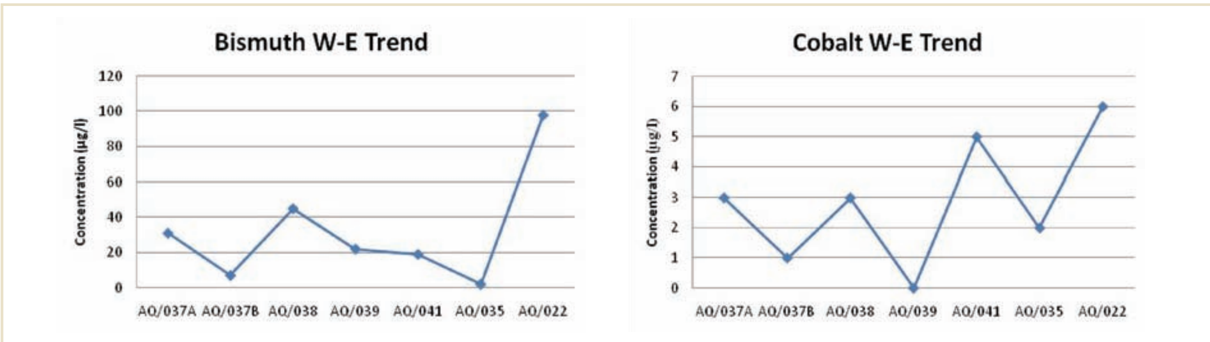


Figure 3.20

W-E trend of the heavy metals Bi and Co (spring samples)

3.4 Risk assessment of water resources in the Lower Jordan Valley (D303)

Compiled by: H. Werz (UKA)

3.4.1 Introduction and methods

In order to assess the water resources' risk in the Lower Jordan Valley all existing studies in that region that investigated the risk of groundwater or, accordingly, the vulnerability of groundwater and groundwater hazards were collected and listed, displayed in a regional map and tabulated regarding their special characteristics (Table 3.5, Figure 3.21).

Further on, a regional vulnerability map of major parts of the West Bank in scale 1:200,000 applying the PI-Method was constructed using multi-layer GIS analysis, slope analysis and interpolation operations (Figure 3.21).

Detailed groundwater sampling and analysing were done in the Jordan Valley area (Jordan) to study the risk and accordingly the long-term effects of treated and blended wastewater used for irrigation in agriculture on the soils and the groundwater. For the study in the Jordan Valley water samples were taken from wastewater, surface water and groundwater sites. Characteristic anthropogenic substances including mobile trace organics such as pharmaceuticals, endocrine disruptors and trialkyl phosphates were analysed.

3.4.2 Results

The vulnerability of groundwater to contamination in the Eastern Aquifer Basin of the West Bank is assessed as predominantly moderate (52.1%) and low (41.6%). This is explained by the facts that great depths to groundwater tables occur and groundwater recharge amounts are low. A high vulnerability is assigned to 5.8%, a very low vulnerability to 0.5% of the study area. Areas of high groundwater vulnerability are delineated in the central hills. Steep slopes and surface lead to a concentration of flow and to a high degree of bypassing. This decreases the effectiveness of the natural protection and increases vulnerability. Despite their comparatively small area percentages, the highly vulnerable areas are of very high significance: those areas are representing potential point sources of contaminants, especially because they are mostly delineated on the urbanized areas of the central hills (Ramallah, Jerusalem, Hebron and Bethlehem). Anthropogenic point sources of pollution are present in those urbanized areas and endanger the groundwater quality because the natural protection is low.

For the study in the Jordan Valley, water samples were taken from wastewater, surface water and groundwater sites. Characteristic anthropogenic substances including mobile trace organics such as pharmaceuticals, endocrine disruptors and trialkyl phosphates could be detected in more than 90% of the sampled groundwater sites in the northern, middle and southern part of the valley (Figure 3.22). This indicates a widespread influence of (treated) wastewater on the Shallow Groundwater Aquifer. Some of the substances were also found in groundwater samples with concentrations exceeding the normal background and (maximum) permissible levels.

3.4.3 Expected impacts

The results of the vulnerability map contribute as basis for further research activities regarding aspects of groundwater risk assessment and delineation of groundwater protection zones. They can be included for further land use planning in the region.

The results of the second study gives useful indications about a possible threat to groundwater caused by leaching and shows the effects of treated wastewater or reclaimed water on the soils and the water in the Jordan Valley.

Location	Area	Purpose	Author	Date	Methode	Published
Dead Sea Groundwater Basin	~ 4438 km^2	Vulnerability	Al-Hanbali & Kondoh	2008	DRASTIC	Hydrogeology Journal (16): 499-510
Ramtha Zone	~ 140 km^2	Vulnerability	Sharadqah et al.	2003	DRASTIC	Conference proceedings: Aquifer Vulnerability & Risk, Mayo, Mexico, 28.-30-May 2003, pp 357-366
Irbid Area	~ 1500 km^2	Vulnerability Hazards	Margane et al.	1997	German Approach. Hölting 1995 No special method, only listing of existing hazard without classification	Angew. Geol., (45) 4: 175-187
Irbid Governate	~ 1600 km^2	Vulnerability Hydrochemistry (contaminants)	Nawafleh	2007	DRASTIC and EPIK	PhD thesis unpubl.
Azraq Basin (NW)	~ 870 km^2	Vulnerabilty Risk	Al-Adamat et al.	2003	DRASTIC, DRASTIC + land use	Appl. Geography (23): 303-324
South of Amman	~ 1400 km^2	Vulnerability Hazards	Hijazi et al.	1999	German Approach, GLA-method Hölting 1995 Guidebook Vrba and Zaporozec, 1994)	Unpublished BGR & MWI report, Amman
Russeifa landfill	~ 1,2 km^2	Vulnerability	El-Naqa	2004	DRASTIC (Aller et al, 1987)	Environ Geology (47): 51-62
Jordan Valley (between Rama & Karama)	~ 150 km^2	Vulnerability	Kuisi et al.	2006	SINTACS (Civita, 1997)	Environ Geology (50): 651-667
Qunayyah Spring catchment	~ 112 km^2	Vulnerability	Brosig	2005	Transit Time Method	Diploma thesis unpubl.
Qunayyah Spring catchment	~ 112 km^2	Vulnerability	Brosig et al.	2007	Transit Time Method	Environ Geol DOI 10.1007/s00254-007-0898-0
Shueib catchment	~ 200 km^2	Vulnerability & Hazard and Risk	Werz & Hötzl	2007	PI-Method (Goldscheider 2001) COST Action 620 guidelines (Zwahlen et al. 2003)	Hydrogeological Journal, Vol. 15. Issue 6: 1031-1049
Karak-Lajjun Area	~ 7 km^2	Vulnerability & Hazard	Margane et al.	2005	German Approach, GLA-method Hölting 1995 No special approach (location)	Unpublished BGR & MWI report, Amman
Aqaba	~ 270 km^2	Vulnerability & potential pollutants	Al Farajat	2001	DRASTIC (Aller et al, 1987) (location, emitted pollutions, impact)	PhD thesis unpubl.

Location	Area	Purpose	Author	Date	Methode	Published
Eastern Aquifer Basin, West Bank	~ 3250 km^2	Vulnerability	Bastian	2008	PI-Method (Goldscheider 2001)	unpupl.
Western Mountain Aquifer	~ 2000 km^2	Vulnerability	Bachmat & Wollman	2000	„mean real travel time of a pollutant"	Water Science & Technology, Vol. 42 (1-2): 417-421
City of Nablus Palestine	~ 6 km^2	Vulnerability to WW disposal	Aliewi et al.	1999	Numerical simulations of chloride concentration (MODFLOW)	Groundwater in the Urban Environment: Selected City Profiles, Chilton (ed.), Balkema Rotterdam: 301-309
Sharon Region, Israel	~ 700 km^2	Vulnerability + impact of extensive land use Land use Index	Secunda et al.	1998	DRASTIC	Journal of Environmental Management 54: 39-57

Table 3.5

Existing vulnerability and hazard studies in Jordan, the West Bank, Israel and Palestinian Authorities

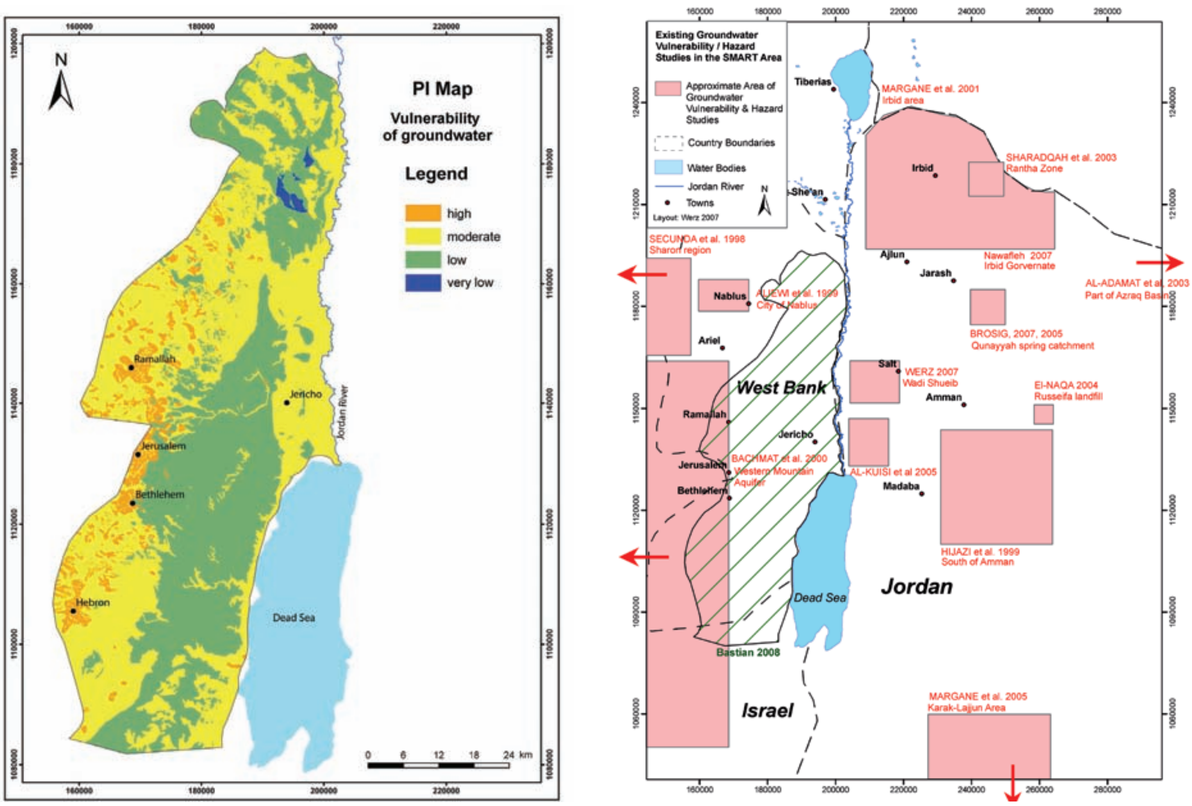


Figure 3.21

Left: Groundwater vulnerability map of the Eastern Aquifer Basin in the West Bank (Bastian, 2008).

Right: Vulnerability and hazard studies in Jordan, West Bank, Israel and Palestinian Authorities.

Green-striped area was mapped during the SMART project.

The water scarcity in Jordan led to the need to exploit unconventional water resources like treated wastewater. Both studies contribute to groundwater protection strategies by delineating areas that are vulnerable to contamination and by showing the effects that reclaimed water can cause on the groundwater and the soils.

3.4.4 Future research

Further research in the first study area should aim to map groundwater hazards to produce groundwater risk intensity maps. At contamination hot spots or special vulnerable areas located in the neighbourhood of springs or wells used for drinking water, high resolution maps should be produced. The vulnerability map of this study can be used for delineating those regions. The results should influence the delineation of protection zones in that region. To receive (semi-) quantitative results the vulnerability map can be combined or verified with tracer test, isotope studies or transport modelling simulations. Existing strong contamination in wells or springs in the West Bank should be compared with the results of the vulnerability or potential hazard map at those locations.

For the evaluation of the long-term effects of irrigation with reclaimed water on groundwater and soils it is necessary to observe possible (concentration) changes over a longer time span, if possible considering small-scale spatial geologic and geographic variability and the irrigation water quality. It is recommended, especially for the soils, to assess the source of heavy metals by investigation of the particulate matter in the irrigation water. As a geogenic source cannot be completely excluded for heavy metals, the accumulation of persistent and plainly anthropogenic substances such as the pharmaceuticals, endocrine disruptors and trialkyl phosphates which were investigated in the water analyses could be of further interest for future soil investigations.

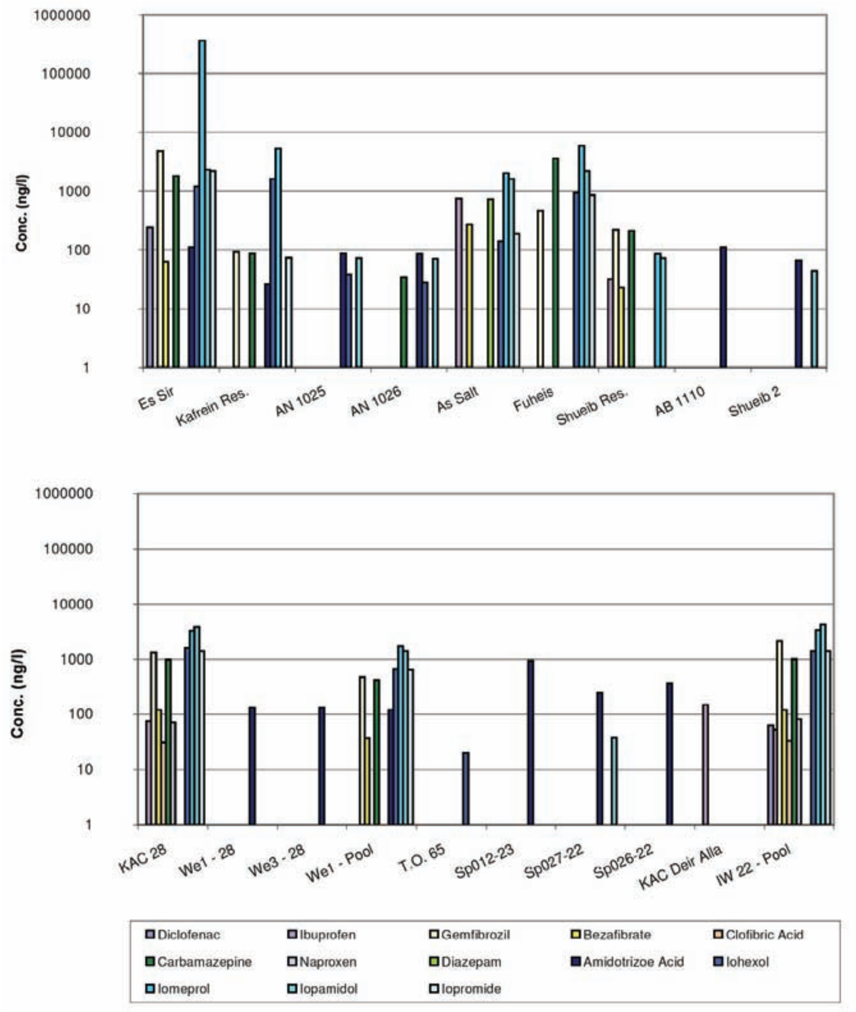


Figure 3.22

Detected pharmaceuticals at specific locations in the Jordan Valley (Pöschko, 2008)

3.5 Report on areas with preliminary potential for water development (D304)

Compiled by: Y. Guttman (MEK)

3.5.1 Introduction and scope of the work

The initiation of the Jordan Rift Valley created a base level for the surrounding surface and groundwater. In the Rift Valley there are several basins that were interpreted as pull-apart basins (Anker, 2007). In some basins, beside the common sediment sequence (gravel, sand, clay etc.), there are large evaporates layers that may contain also salt layers. In places where these salt layers may have hydraulic connection to the aquifers, they can affect the quality of the groundwater by raising their salinity.

The management of the water resources in the study area has to take into account the overall picture including the occurrence of salt bodies in the vicinity to the pumping wells. Pumping of saline water from the regional aquifers is one way to protect the wells from salinization (among others; such as reducing the pumping rate, higher the water level etc.).

The goal of this deliverable is to locate areas for drilling wells that will pump saline water that in one hand will help in protecting the fresh water body and in the other hand will be an additional water source for the agricultural activities in this area. For example, saline water can be used for Palm plantations directly or after mixing with treated effluents.

3.5.2 Hydrogeology background

The Jordan Valley is the base level for the surrounding surface and groundwater. In the western side of the Jordan Valley, the regional aquifer is the Judea Group aquifer. The total thickness of the Judea Group is about 800 - 850 m. The aquifer is composed of limestone and dolomite interbedded by marls and clays. The natural replenishment is mainly from direct precipitation on their outcrops.

In order to capture the fresh water before it flow into the deep layers within the Jordan Valley, net of wells were located along the foothills. During the commencement of production from the wells the salinity was low. Concomitantly to the decline of water levels the salinity started to rise. The increase in salinity was accompanied by seasonal salinity fluctuations.

The salinity values in the natural replenishment zones range from 30 to 50 mg/L Cl^- and remained constant throughout the years. In wells located along the foothill, a wide range of salinity values are observed ranging from 30 to 600 mg/L Cl^-. In the wells located along the foothills two types of salinity behavior were observed (Figure 3.23). In certain wells such as Fazael 2, the salinity is constant over time. In other wells such as Fazael 6, salinity fluctuates seasonally by tens to hundreds mg/L Cl^-.

During high demand periods in which the monthly pump rate is very high, there is an increase in the salinity, and vice versa. Such a behavior indicates that very close to the radius of influence of the well there is saline water and that the wells are pumping mixtures of fresh and saline water. The chemical composition supports this assumption. The chemical composition of these wells plot on the middle part of the mixing line between the fresh water end-member and the saline water end-member (more detail in the book „The water of the Jordan Valley by H. Hötzl, P. Möller, E. Rosenthal, 2009).

The Judea Group aquifer in the valley itself is deeply-seated and overlain by thick sequence of Basin-fill young formations. Therefore the area of the basin-fill was considered over the years as unsuitable for groundwater exploitation. A set of seismic lines were re-interpreted in order to study the geological structure in the deep formations within the Jordan Valley (Anker, 2007) as well as the continuation of the Judea Group aquifer from the foothill into the center of the valley.

It was found that the Judea Group aquifer is encountered at a relatively shallow depth, which varies from a few hundred meters in the west (east of the foothill) to more than 1000 m close to the

Jordan River in the east. Several east stepping fault blocks were encountered in the area. Additional result of the seismic study was the discovery of a lenticular shaped sedimentary body located within a structural depression in the east near Auja. This sedimentary body highly resembles the appearances of salt bodies in seismic lines (Anker, 2007).

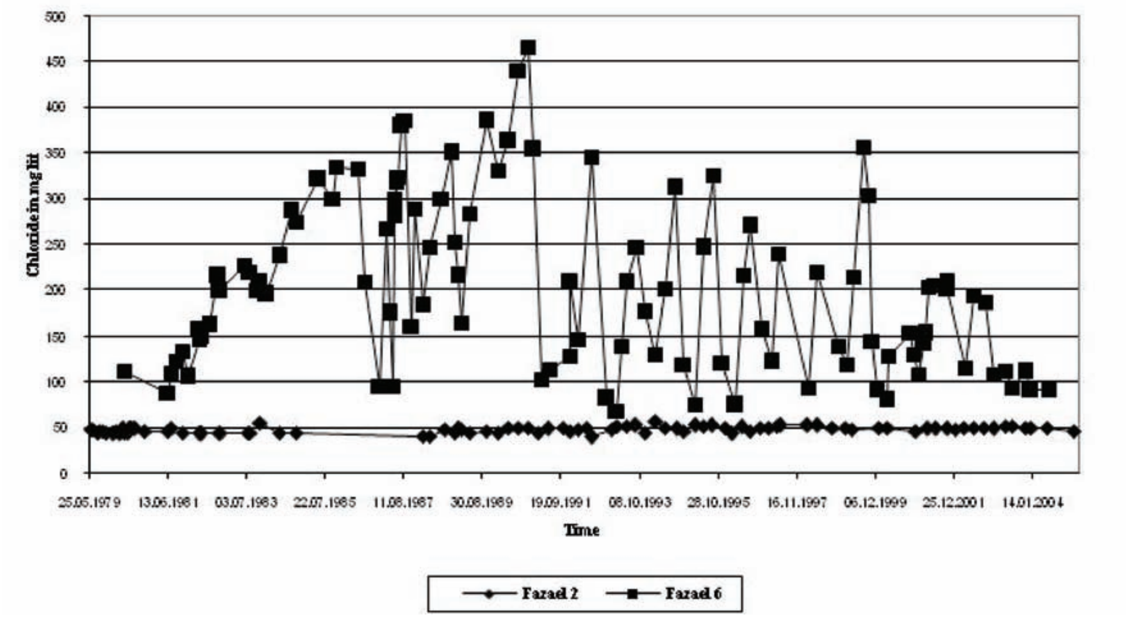


Figure 3.23

Two types of salinity behaviors in the Fazael well field

3.5.3 Summary and results

The study included review of previous geological and hydrological studies (many of them under the GIJP and SMART projects), study of the existing water systems in order to locate the propose sites (wells) close to the supply systems and to reduce the connecting investments and field survey with the local authorities for locating the proposed wells. Preliminary, three proposed sites had been chosen. Two of them are shown in Figure 3.24.

The result of the newly seismic interpretation reveals several conspicuous structural features, which are of considerable hydrological importance for this area. It was found that the Judea Group water bearing aquifer layers within the Valley are probably encountered at a relatively shallow depth (Figure 3.25). There is a continuity of the aquifer layers from the foothill (where are the existing wells) to the east. The hydraulic connection between the fresh water body and the saline water body as was mentioned before means that for protecting the fresh water body from salinization, it is recommended to pump in parallel to the pumping of the fresh water also saline water from the saline water body. This action will reduce the pressure of the saline water body and reduce the flow from the eastern part of the aquifer towards the well fields. The saline water will be used for agricultural purposes in the region.

The depth of the wells will be between 300 - 550 m (depend on the outcrop). The target is the Upper Judea Group and the expected discharge is around 200 cum/hr with salinity between 2000 - 2500 mg/L Cl^-.

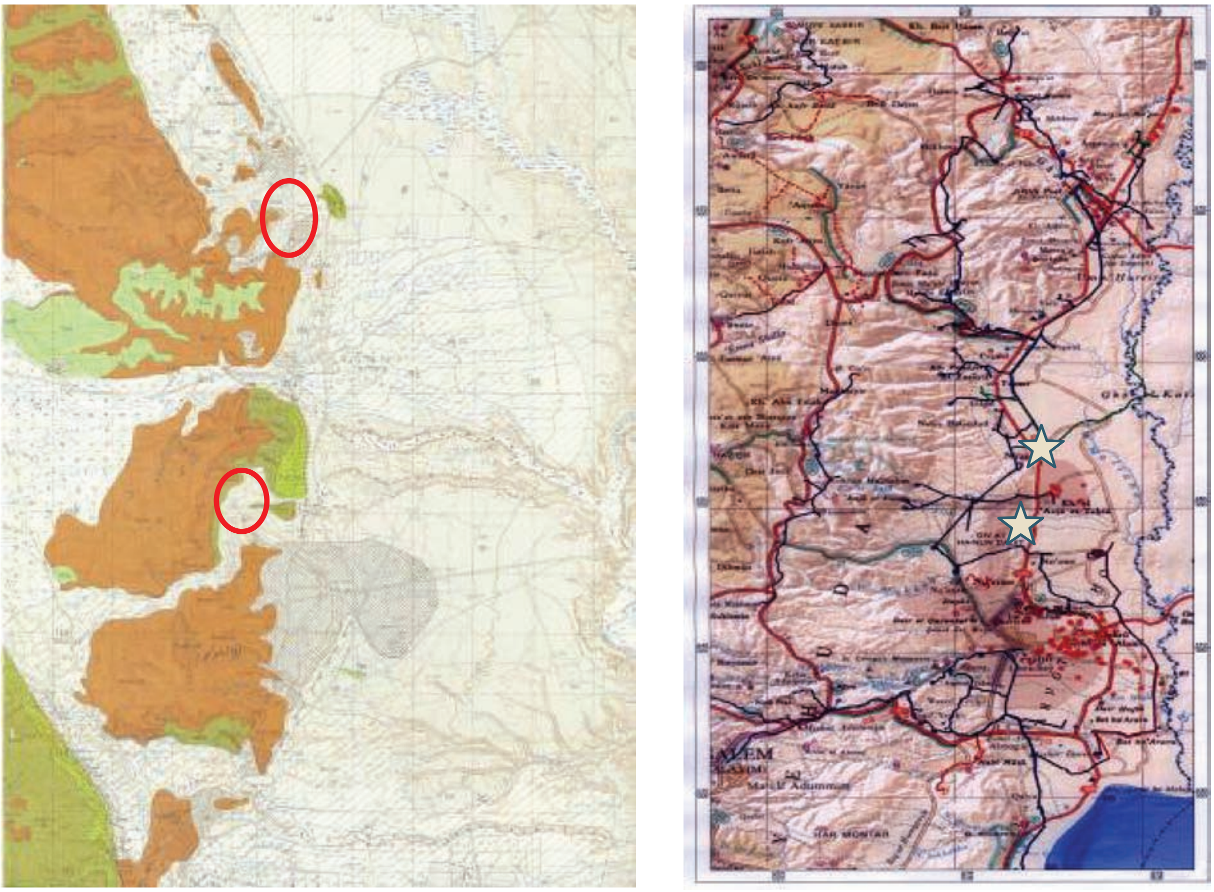


Figure 3.24
Location of the two proposed wells on a geological map and on a water supply network

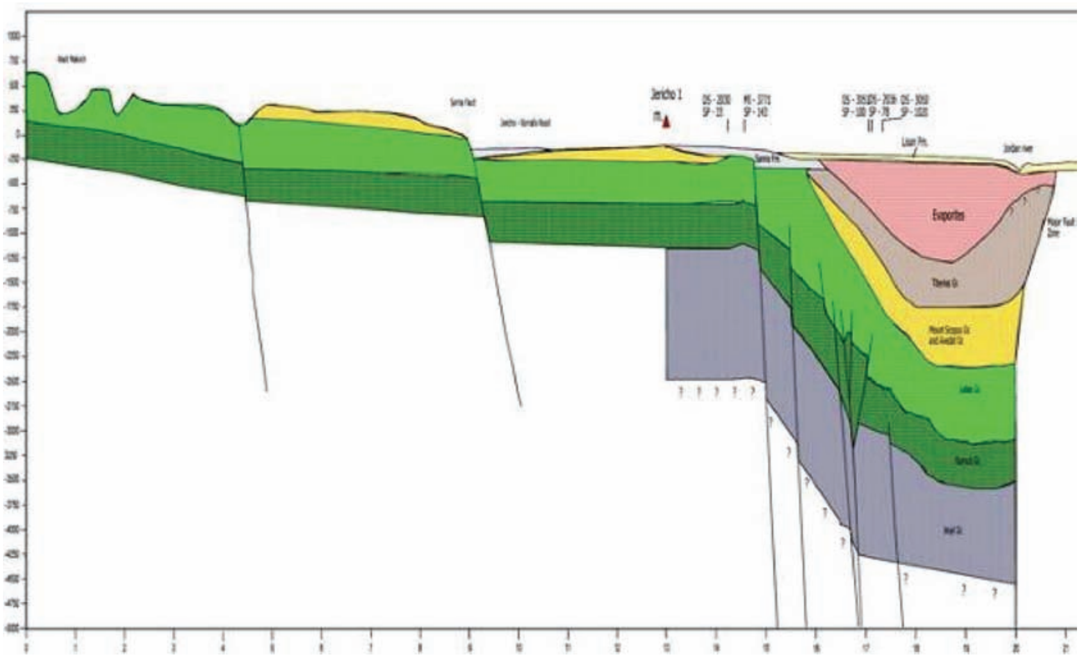


Figure 3.25
Geological W-E cross section from Jerusalem to the Jordan River (Anker, 2007)

3.5.4 Expected impacts

The water supply for the livelihood in the study area is base on local sources. The most important resource is the fresh water that is used primary for domestic purposes. Saline water is an additional source that can be used directly for agricultural purpose or as a source for local inland desalinization plants.

The saline water is coexisting with the fresh water. Overpumping in the fresh water body may cause a sharp drop of the water level and migration of saline water into the fresh water body. The result is a potential rising in the water salinity and deterioration in the water quality of the fresh water body. Pumping from the saline water body will reduce its pressure and may prevent the migration of the saline water towards the fresh water body.

From the IWRM concept, the co-operational of the two water body (fresh and saline) is the only way to protect the fresh water body from salinization and to prevent its quality for long periods.

Drilling of the new proposed wells in the saline water body (Figure 3.24) is integrated in the sustainable development concept of the study area. Mekorot- Israel National Water Co. is willing to drill these wells in order to increase the available water to the local customers.

3.5.5 Future research

Future research need to improve the preliminary potential site and to suggest additional site if possible. Another task is to get the response to this task from the local users and the water supplier.

Design of how and where to connect these wells to the water system and calculate the cost efficiency of this action (price per cum) is part of the future needs in this field.

3.6 Geophysical investigations at the Lower Jordan Valley (D305)

3.6.1 Eastern Lower Jordan Valley, Jordan

Compiled by: A. Al-Zoubi (BALQ)

3.6.1.1 Introduction and methods

The study area for geophysical investigation covers the northeastern corner of the Dead Sea, Shuna and Damia area. The geophysical exploration included:

- Reinterpretation of the previous seismic lines in Shuna area/ East Jericho (investigation of the subsurface structure)
- Continuous Vertical Electrical Sounding-(CVES; investigation of underground resistivity distribution)
- Electromagnetic Radiation (EMR; investigation of the active faults)
- Proton Magnetic Resonance (PMR; investigation of the groundwater)
- Ground Penetrating Radar (GPR; investigation of the shallow subsurface strata) and
- Time Domain Electromagnetic (TEM; investigation of the water quality).

The main objectives of the geophysical exploration are the following

- Delineate shallow active faults and fractures
- Estimate the depth of the shallow aquifers
- Estimate aquifers properties (water content, permeability)
- Monitor the variation of water contents with time
- Delineate buried wadis and ancient channels
- Delineate the boundary between fresh and saline water

From the geological point of view, the main geological features of the area, the distribution of the Jurassic – Cretaceous rocks in the foot hills, have folding in the in the north-east –southwest direction where the thick sediments of the Tertiary and Quaternary deposits crop out along the rift valley. The Dead Sea –Jordan Valley fault affected all the structural geology along the study area.

3.6.1.2 Results

Seismic Interpretation
The southern part of the study area has a good seismic line coverage as shown in Figure 3.26. Several faults cut the study area mainly in the north-western and north-eastern directions (Figure 3.26 right). The seismic interpretation identified four unconformities along the seismic reflection profiles. These reflection boundaries include the top of the pan-African basement (R4), the base of the Mesozoic (R3), the base of the Cretaceous (R2), and the base of the post-Eocene (R1) section. The seismic data shows that the basin has a full pull-apart structure (Figure 3.27).

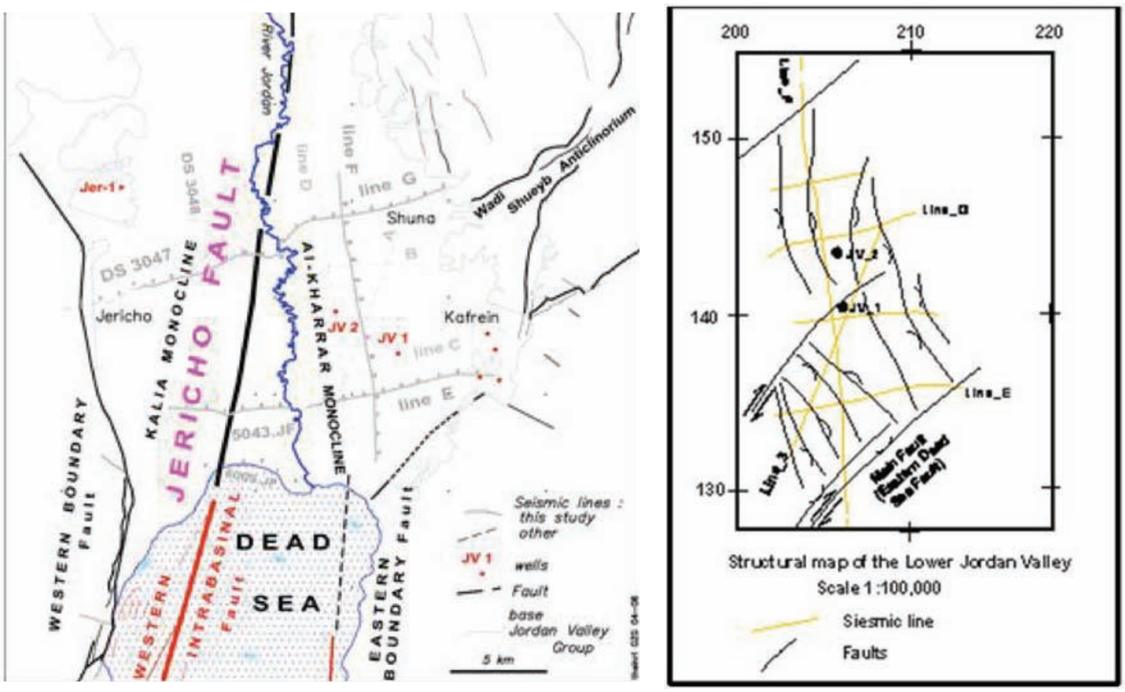


Figure 3.26

Left: Schematic structural map of the Shuna area (Al-Zoubi et al. 2007)

Right: Structural map of the Shuna area showing location of the faults mainly determined by seismic lines

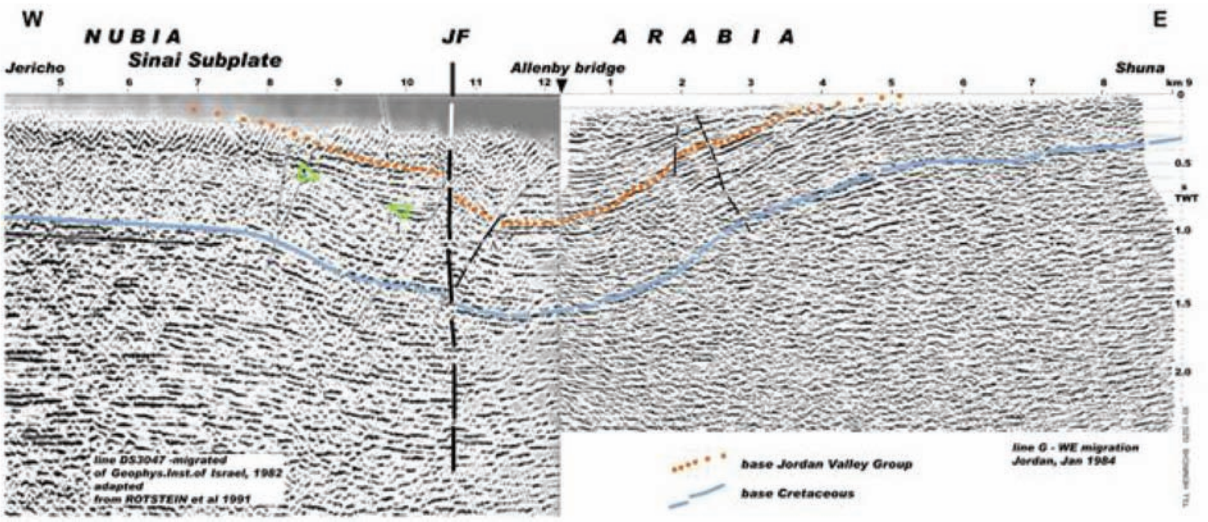


Figure 3.27

Seismic lines show the basin structure (Al-Zoubi et al. 2007)

Vertical Electrical Sounding (CVES)

Fortytwo VES measurements in the Shuna/ Jericho area were carried out in order to investigate the subsurface structure and to evaluate the geohydrological conditions of the area. The VES data were interpreted to obtain the initial 1D-model. The initial model was used to obtain maps of resistivity distribution with depth (50, 75 and 100 m). Four geoelectrical zones were delineated (Figure 3.28, left). These zones do not necessarily reflect the subsurface lithology of the study area due to the complicated situation of the area. In addition to the subsurface geology, the variation of resistivity reflects the existence of the fresh water bearing rocks, fracture zones and bearing of saline water. The VES results allowed us to judge the groundwater quality. The fresh water bearing formations appeared to be at the eastern end of the study area, whereas the saline one appeared to be at the western side along the Jordan River. The brackish water was found to be in the central part of the study area with interfingering of channels and lenses of fresh or saline water. The boundary between the water quality zones seems to be related to the subsurface structure (faults). These faults increase the permeability of the rocks (Figure 3.28, right).

Proton Magnetic Resonance (PMR)

PMR measurements are used to estimate indirectly the water content of saturated and unsaturated zones of the subsurface. It is also used to estimate aquifer properties (porosity, permeability, transmissivity). Sixteen PMR stations were conducted. The permeability cross section in the north south direction along the JV shows that there are three different permeability zones as following: (i) a low one with permeability values less than 10^{-5} m/s that represents low permeability materials (clay and silt), (ii) a moderate one with values ranging between 10^{-5} to 10^{-4} m/s that represents moderate permeability materials (fine sand) and (iii) a high one with permeability values higher than 10^{-4} m/s that represents high permeability materials (coarse sand). The main result from the PMR is presented in form of a cross section including permeability values, and a cross section including the water content (in %) distribution with depth.

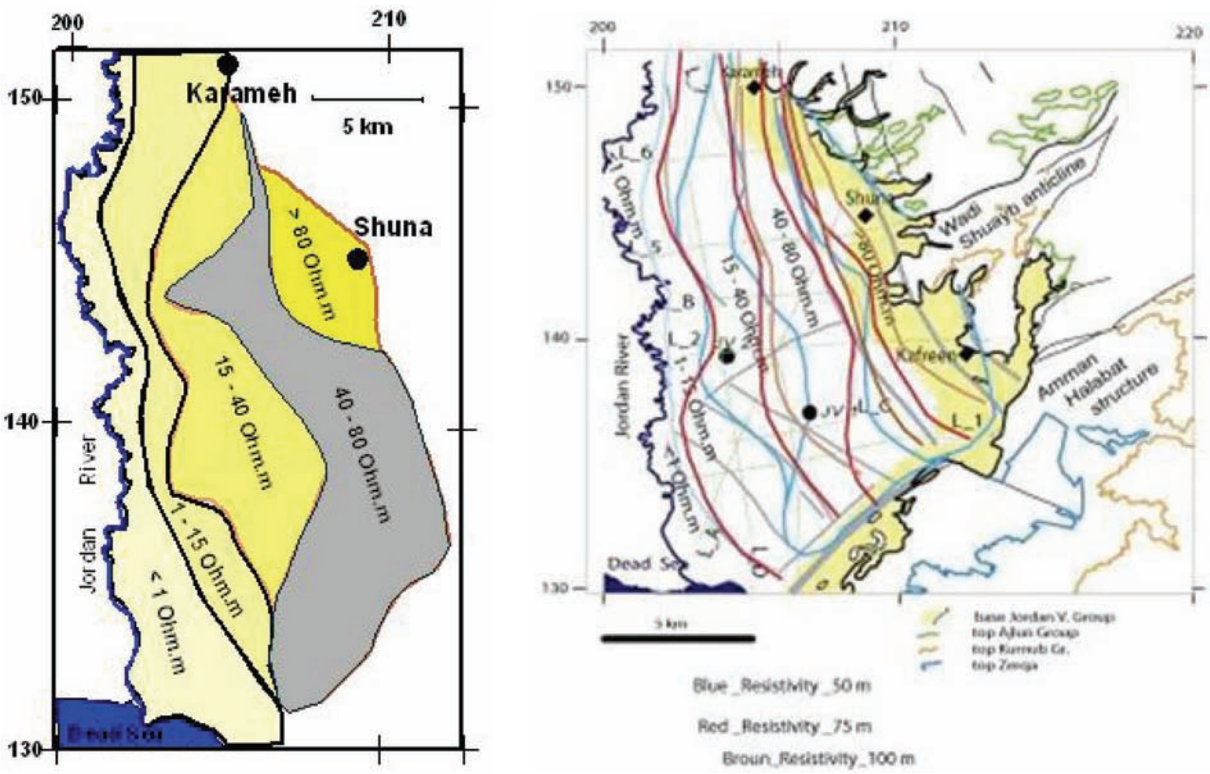


Figure 3.28

Left: Resistivity distribution zones

Right: Map showing the resistivity distribution with faults location (the faults gray color)

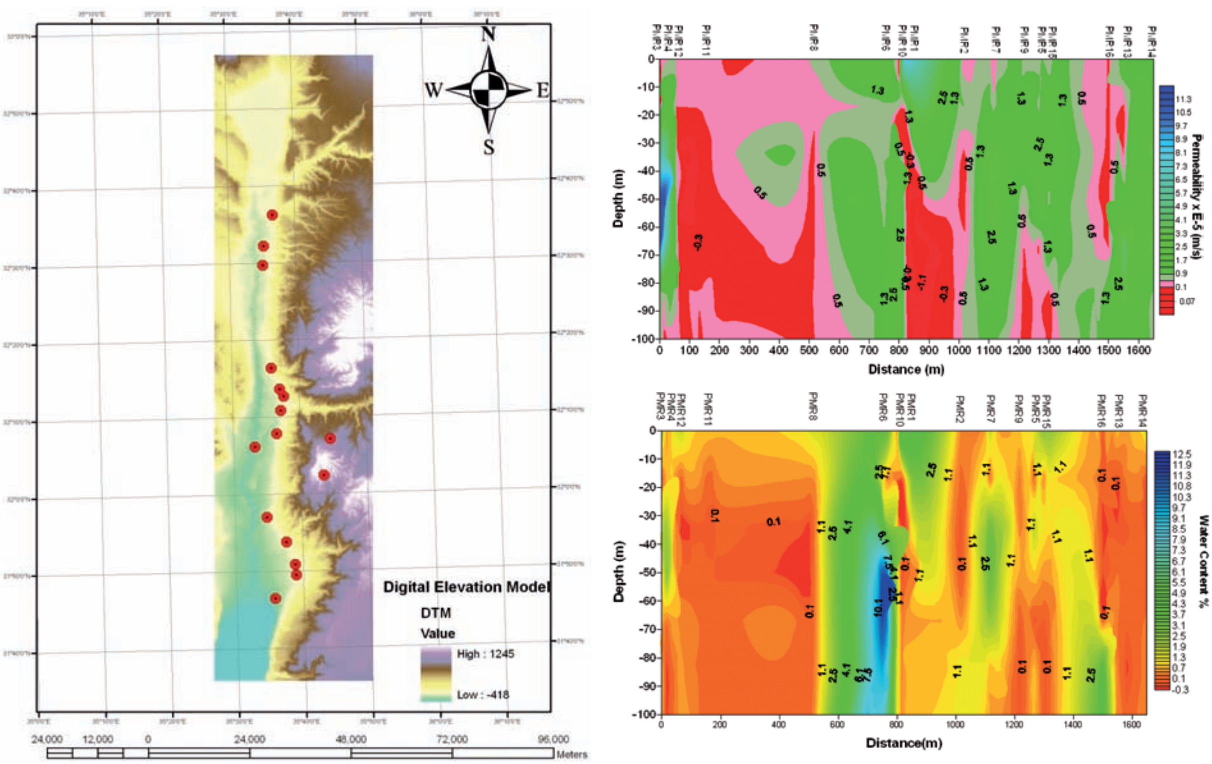


Figure 3.29

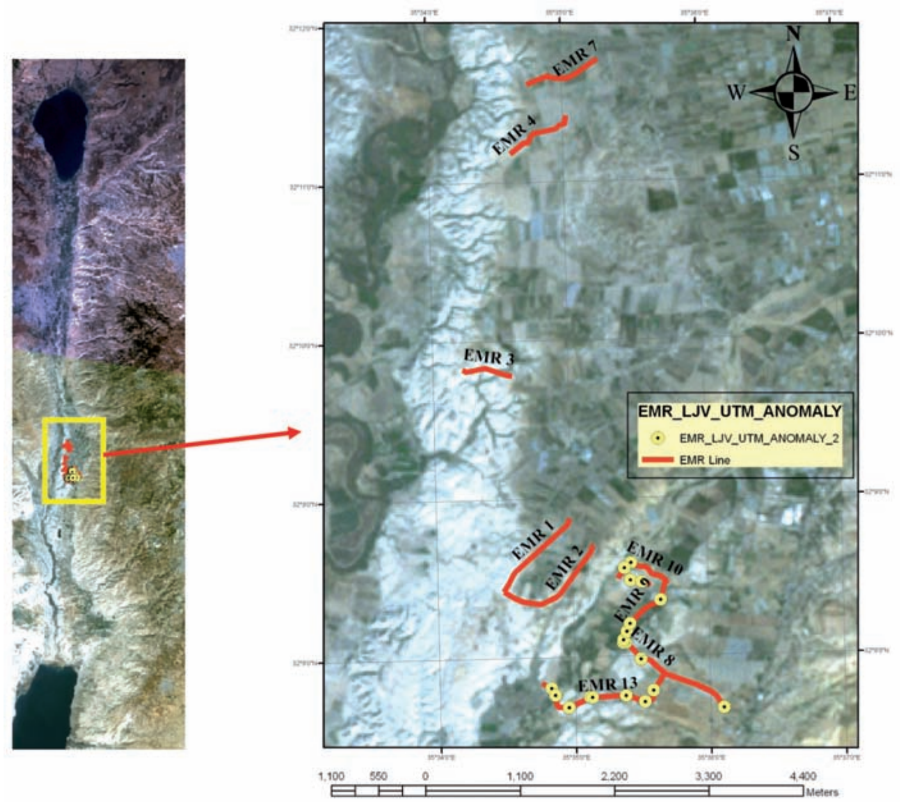
Left: Location map, **Upper right:** Permeability changes with depth along the JV.

Lower right: Water content distribution with depth along the JV (blue color: areas of relatively higher water content, red colour: areas of relatively lower water content).

Electromagnetic Radiation (EMR)

Fourteen EMR lines with different length and directions were conducted at the study area. The EMR results show that there are several shallow cracks distributed in the area (Figure 3.30). These shallow cracks and fault increase the infiltration of the irrigation water from the surface.

a)



b)

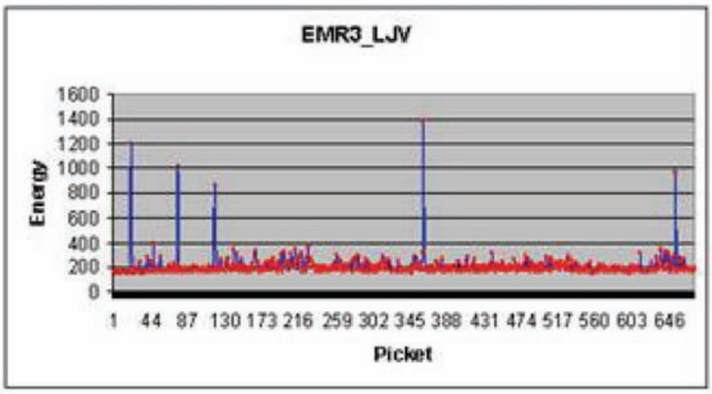


Figure 3.30

a): EMR profile location map and the EMR anomaly, **b):** EMR anomaly along the EMR3

Ground Penetrating Radar (GPR)

Fourteen GPR profile were conducted in the study area. The GPR sections show water saturated zones represented by high reflection of the electromagnetic waves with different depths. The water table and saturated layers could be detected as shown in Figure 3.31. Several shallow faults and old channels were detected (Figure 3.31).

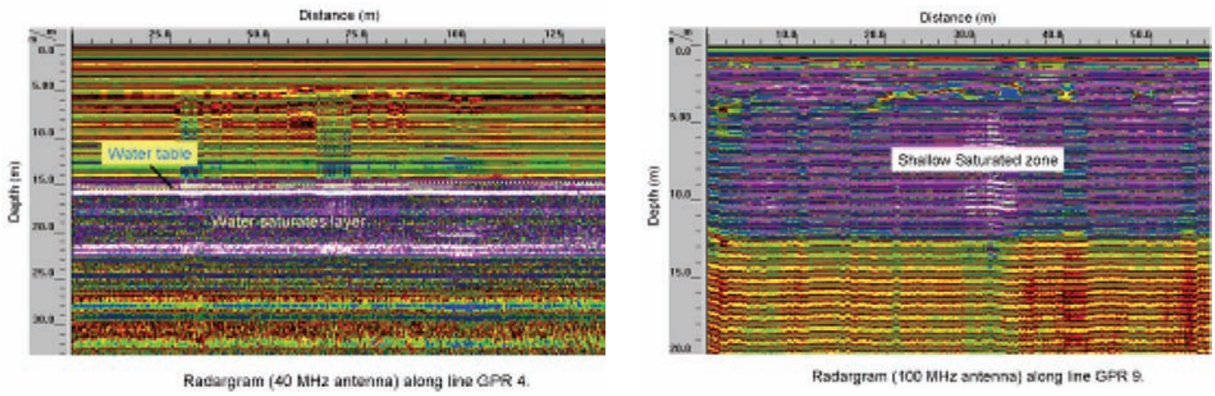


Figure 3.31
Left: Radargram-cross section showing the water table
Right: Radargram (100 MHz antenna) -cross section along the profile.

Time Domain Electromagnetic (TEM)
Ten TEM soundings were distributed in the study area, and three TEM sections were constructed. Four late log-log plots showing the apparent resistivity as a function of time of the stations SU01, SUO2, SU03, and SU04 (Figure 3.34) along the section 1 and their corresponding one dimensional inversions along section 1 are presented in Figure 3.34. The tomoghraphic geoelectric section along section 1 is shown in Figure 3.34. The resistivity range along section 1 varies between 1 to 53 Ohm-m. There is a clear low resistivity zone beneath station SU01 and SU02 which may represent a clay layer. The high resistive zones which act as a barrier between the low resistive layers can be identified along the section. The very low resistive layer (less than 2 Ohm-m) is located at -370 m a.m.s.l. and may represent the depth of saline water. An inferred normal fault can be located between SU01 and SU02 (Figure 3.35).

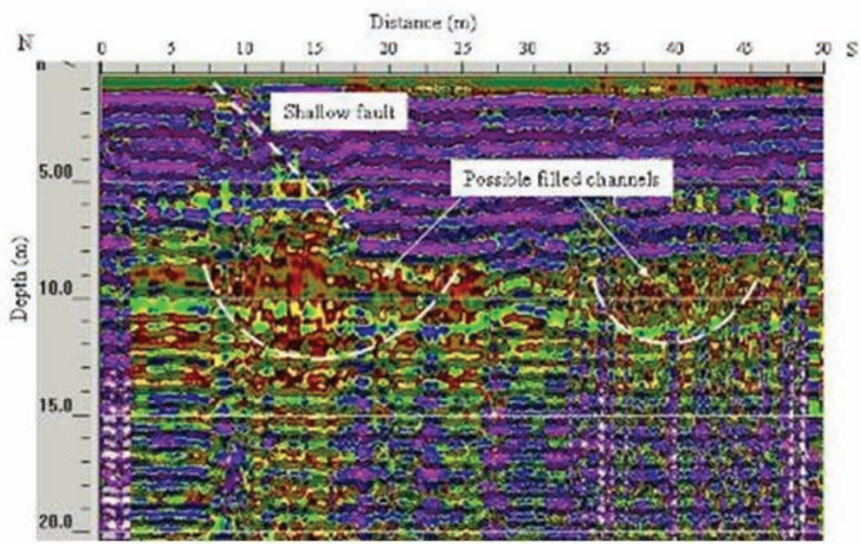


Figure 3.32
GPR profile showing faults and old channels

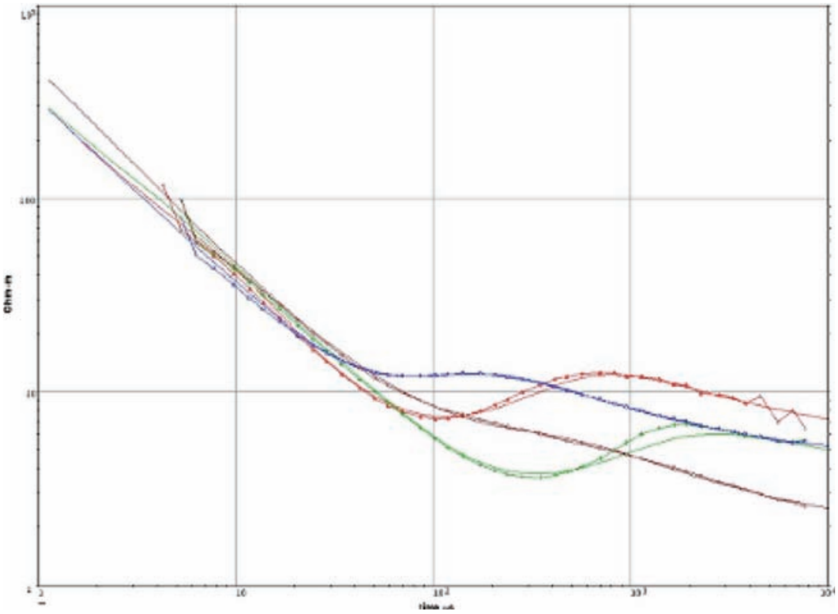


Figure 3.33

Log-log plot of apparent resistivity as a function of time for stations from SU01 to SU04

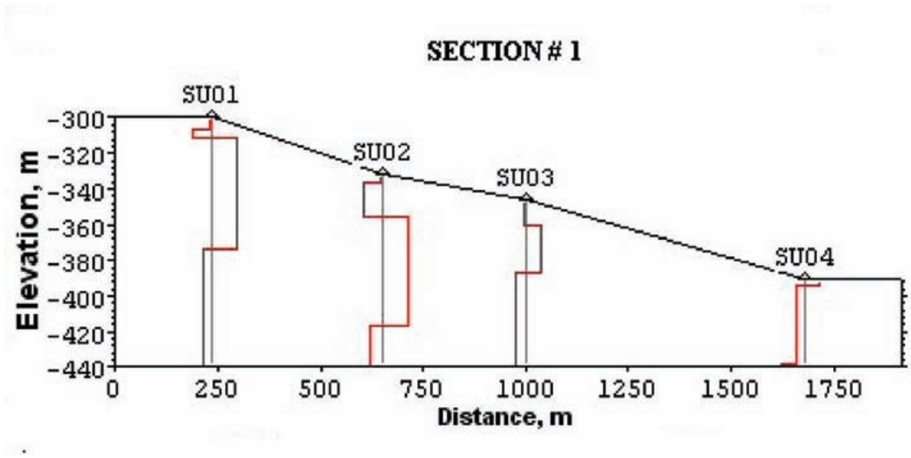


Figure 3.34

The corresponding one dimensional inversions along section 1

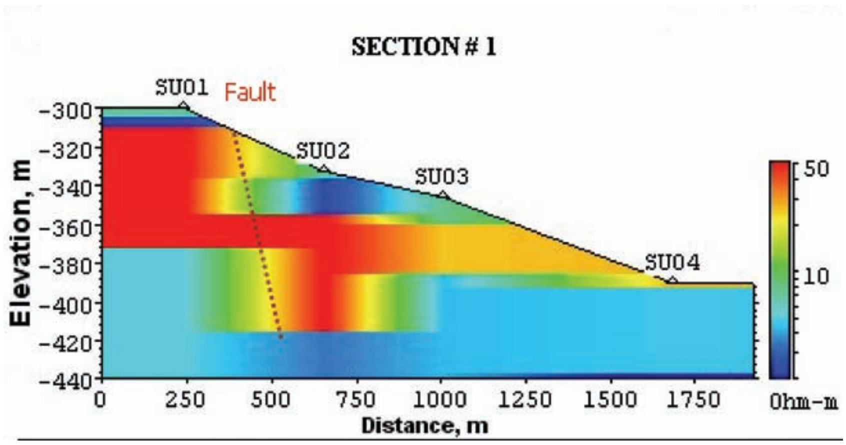


Figure 3.35

Tomoghraphic geoelectric section along section 1

3.6.1.3 Conclusion

The geophysical investigation in the Lower Jordan Valley (mainly in the southern part of the Jordan Valley/Shuna and Damia area) shows that the study area is characterized by:

- Wide ranges of variation in geophysical parameters such as resistivity. The variation of the resistivity values depends on the existence of saline water, fracture zones in addition to the geological strata. The high resistivity values are related to the dry shallow layers. Where the low resistivity is related to very low reflection, the fracture zones include saline water.

- The geophysical measurements revealed the existence of a narrow zone which is up to 3 km wide and contains saline groundwater in some places. This zone extends 20 - 25 km along the Jordan River starting from the Dead Sea shore line in the south.

- The recent sediments and wadi deposits close to the foothills at the eastern side of the Jordan Valley consist of brackish to fresh groundwater. In some places these deposits appear to be in form of lenses.

3.6.2 Western Lower Jordan Valley – Wadi Quilt, Palestine

Compiled by: A. Marei (QUDS)

3.6.2.1 Introduction and methods

The surface geological survey was conducted during the seventies of the last century by Begin (1974). The current geological investigation was focused on the subsurface geology of Jericho area, so a geophysical investigation was carried out by using the Vertical Electrical Sounding (VES) method to identify the lateral and vertical extensions of lithological layers. Figure 3.37 presents an east-west cross section. Through this method, we were able to identify a new structural feature (S-N fault system), saline bodies along this fault system which cause the salination of groundwater and an impressive old drainage system of Wadi Quilt.

3.6.2.2 Results

By using the VES, the major fault system was identified with south-north direction and is located to the west of Jericho city. At a depth of 150 m, carbonate rocks of the Upper Beit Kahel (UBK) formation (Cenomanian age) could be identified. A contact between the UBK carbonate rocks and the sediments of the Dead Sea Group was clearly detectable. In most of the previous geological studies, it is mentioned that the chalky formation of Abu Dis builds a barrier between the upper aquifer and the local Plio-Plistocene aquifer. However, the results of this study show that there is a geological corridor in the eastern part of the study area through the chalky unit of Abu Dis formation, which allows a contact of the carbonate aquifer and the shallow aquifer systems (Figure 3.37).

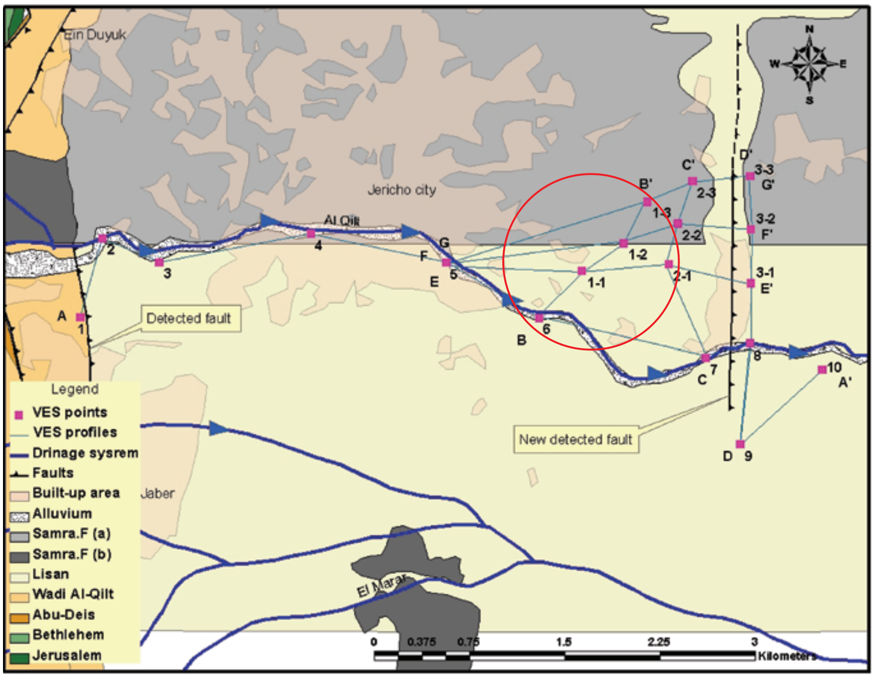


Figure 3.36

VES-sites along Wadi Quilt in Jericho city, with the new fault system, and the gravel mass of the old drainage drainage channel in the eastern part

Beyond that, a new south-north fault could be located in the eastern part of Jericho city. This fault was mapped for the first time during this study. Furthermore, a huge gravel mass deposit with 30 m thickness close to the surface was mapped for the first time as well. This gravel mass is considered an indicator for the old wadi fan deposit. Lastly, saline groundwater bodies which were mentioned in earlier studies could be located at depths of 120 and 160 m. They are concentrated along the new fault system in the eastern part of Jericho city. The findings of this study were subsequently used to assess a potential recharge site in the Jericho area (Chapt. 8.6).

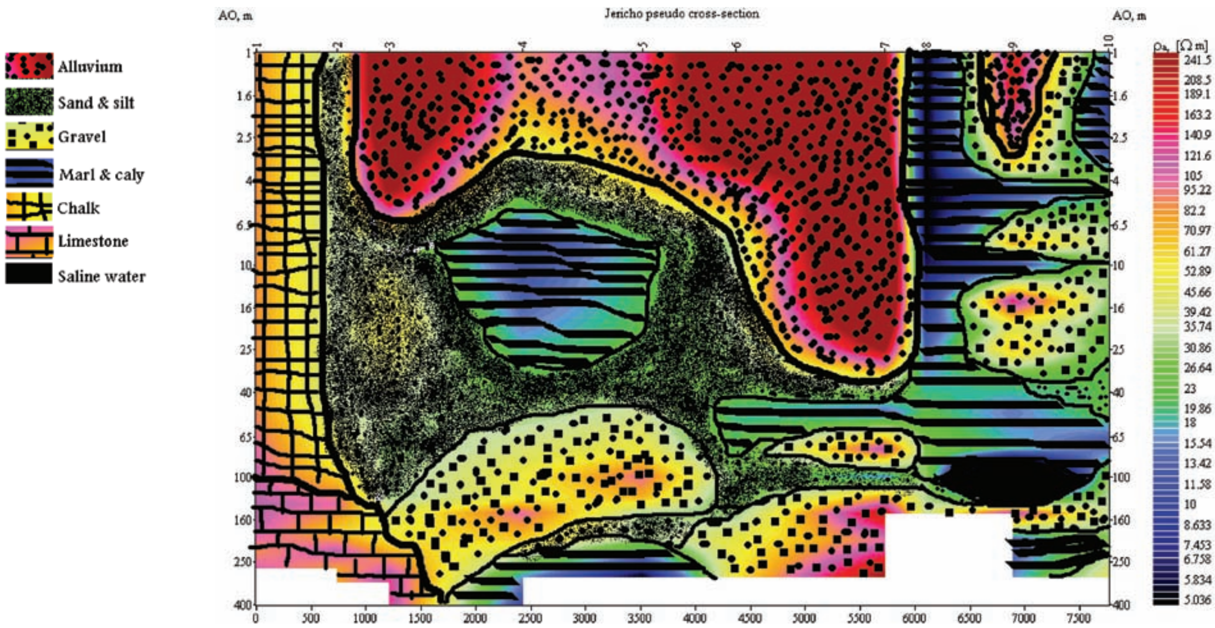


Figure 3.37

Extracted lithological profile along the A-A’ west-east cross sections (with logarithmic exaggeration of Y-axis)

4 HYDROBUDGET

Involved Institutions: UG, UKA, QUDS, UFZ
WP-Speaker: M. Sauter (UG)

4.1 Description of work and results

4.1.1 Water budget calculations for Wadi Kafrein, Jordan

Compiled by: A. Sawarieh (UKA)

The rainfall data in the Wadi Kafrein catchment are the records of the rainfall stations in and in the vicinity of the catchment. The rainfall stations which are within the actual catchment are Wadi Es-Sir, Na'ur and Adasiya Janoubia. The rainfall data records of these stations are available for a period of 27 hydrological years (from 1979/1980 to 2005/2006; MWI data bank) and were used in the rainfall and runoff analysis. The rainfall records were analyzed as daily, storm by storm, monthly and annually. The effective rain fall was calculated based on intensity duration frequency curve (IDF) analysis of Wadi Es Sir rainfall station.

Isohyetal presentation is the generally accepted method of averaging precipitation over an area. The isohyetal maps are generated to show the spatial distribution of rainfall over selected areas and are usually drawn by computing the annual average precipitation of the available gauging stations in this area. Based on the average precipitation data of 27 hydrological years (1979-2006), an isohyetal map was constructed (Figure 4.1).

Rainfall volumes of the study area were computed by determining the area between successive annual rainfall isohyets. The area is then multiplied by the average annual rainfall of each area to provide the volume of precipitation in MCM/yr for that particular area. The latter steps are repeated for every part of the catchment area between the isohyets drawn. The summation of these volumes is the actual average annual precipitation amount in the study area, which amounts to 55.985 MCM/yr.

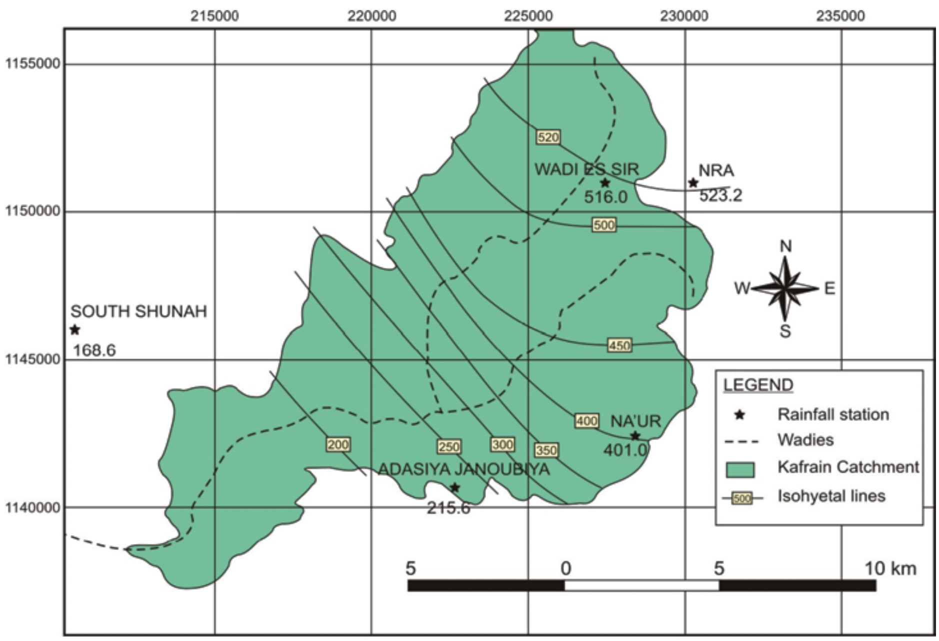


Figure 4.1
Isohyetal map of the annual average rainfall for the period (1979 - 2006) in the Kafrein catchment

In the Wadi Kafrein catchment, many springs discharge from different aquifers with average discharge ranging from 0.447 to 417.2 m3/hr. The discharge of the springs shows a direct relationship to the rainfall events.

The characteristics of the storm and runoff including the runoff characteristics of the hydrograph such as lag time, time of concentration, time to peak, recession time and the base time of the hydrograph were studied in order to derive the Synthetic Unit Hydrograph (UH) for Wadi Kafrein, and to derive the flood hydrograph for different return periods. The estimation of the flow was calculated using the United States Soil Conservation Service method (SCS) and the Curve Number method (CN) for the available rainfall data.

The runoff depths and volumes were computed for the water years 1979/1980 up to 2005/2006 using the Soil Conservation Service (SCS) Curve Number Method. The rates of evapotranspiration were calculated using the empirical evaporation formula of Wundt (1953).

Groundwater recharge was calculated with the formula:

$$INF = P - R - P.Et – Ia$$

Where INF = the infiltration, P = the precipitation, R = the runoff, P.Et = the actual evapotranspiration and Ia = the initial abstraction.

It was found that the maximum computed runoff was ca. 33.6 MCM in the water year 1991/1992 and the minimum runoff was estimated at 0.037 MCM in the water year 1993/1994. The average annual runoff for the period of records is 6.3 MCM/yr. Thus, the estimated runoff coefficient is equivalent to 9.15% of rainfall during the 26 years period of analysis. The amount of recharge is equal to 5.6 MCM/yr. This is equal to 9.05% for the same period of analyses. The results were used in the calculation of water budget elements to estimate the infiltration rate per storm, as well as they were used in the estimation of runoff frequency analysis.

It must be noted, that this is a first order estimate only. The formula used for the actual evapotranspiration (WUNDT 1953) is an empirical formula which was derived under different climatic and geologic conditions.

4.1.2 Recharge estimation with the chloride mass-balance method in the catchment area of the Eastern Basin

Compiled by: A. Marei (QUDS)

Twentyfive rainfall samples were collected during the hydrological years 2006/2007 and 2007/2008 at QUDS weather station which is located within the catchment area of the eastern basin at an elevation of 685 m amsl. The chloride contents of the rainfall samples were measured and evaluated. The average weighted chloride contents of the rainfall samples ranged between 7 and 12 mg/L. This value is close to those found by Herut et al. 2000 where the concentration ranged between 6 and 14 mg/L in the mountain area. Available average long-term rainfall data (30 years) for the Ramallah weather stations with an average rainfall of 648 mm were used for this study. The weighted average chloride content of the rainfall samples and the long-term average rainfall of the Ramallah station were considered as input components for the recharge calculation.

Spring water samples were collected to represent the groundwater body in the Eastern Basin. These springs are located in Jericho and Hebron – Dura area. Samples with NO_3^- above 15 mg/L were excluded from the calculation. The chloride content of the spring water was considered as an output component for the recharge calculation. Recharge rates for each sampling site over the catchment area were calculated by using the equation:

$$R = P \times \frac{Cl_p}{Cl_{gw}}$$

Where R: recharge (mm/yr), P: rainfall (mm/yr), ClP: weighted average chloride concentration of rainfall (mg/L) and Clgw: average chloride concentration of groundwater (mg/L). By applying this method (chloride mass balance), the calculated annual recharge ranges between 130 at the upper eastern slopes and 292 mm/yr at the top of the mountain. Consequently, the recharge rate over the eastern basin ranges between 26% and 45% of the annual rainfall.

Jericho area

Due to the natural salinity of soil and rock layers, the chloride mass balance method is not applicable in this area. Therefore, we chose the groundwater table fluctuation method (Healey and Cook 2002) to estimate the recharge volume of the shallow aquifer system. Eleven groundwater wells were chosen along the drainage system of Wadi Qilt. Mapping of the potential recharge strata was carried out along the wadi course, because the recharge to the Plio-Pleistocene Shallow Aquifer System depends only on the infiltration of surface water during runoff events in the rainy season. The maximum number of flooding days in which water flows along the wadi course and the contact time between the gravel lenses and the flooding water determines the amount of recharge to the unconsolidated aquifer system is 10 days/yr.

The results show that groundwater recharge is not limited to the western side of the aquifer, but also takes place at the eastern side of the aquifer depending on the subsurface distribution of the gravel layers of the old wadi drainage system. The duration time for the groundwater response to the recharge ranges between one month and more than one year. The heterogeneity of this aquifer system, due to the inter-fingering of gravel, sand, silt and clay lenses, makes the prediction of infiltration rates difficult. Our calculation shows, that the total annual recharge volume of the Jericho aquifer system does not exceed in any case 0.27 MCM, while the current abstraction rate is about 1.0 MCM/yr.

These results explain the continuing salinity increase during the last 60 years. The increase in the water demand and the limited recharge aggravates the management of this particular aquifer. Without artificial recharge techniques which make use of storm water runoff, deterioration of groundwater in terms of quantity and quality will continue and will have an enormous impact on the social and economical status of the Jericho Oases.

4.1.3 Developing a water budget for Wadi el Arab, Jordan and Wadi Qilt / Wadi Nueima, West Bank

Compiled by: T. Rödiger, C. Siebert, S. Geyer (UFZ)

One part of WP4 is the quantification of groundwater (gw) recharge in the catchment areas of Wadi Qilt and Wadi al Arab. This quantification consists of the combination of the following methods:

- direct and indirect measurement of discharge (1)
- water-table-fluctuation-method (2)
- application of the complex soil-moisture model JAMS to the regionalisation of groundwater recharge (3)

The goal of that combination is to understand the recharge process on a catchment scale. The independent results of the first two methods are used for examining plausibility of the soil moisture model JAMS. The calculated groundwater recharge is the most valuable input parameter of the numerical flow model mentioned in WP6.

Methods

(1) For measuring the discharge, an indirect and a direct method was used. The first method is based on measuring the amount of surface runoff. The data is analysed by using the procedure of e.g. Wundt (1953) or Natermann (1958) to divide the rate of surface runoff into direct runoff and base flow which represents the groundwater recharge of the river catchment. However, for the second method described by Natermann (1958), the measurement of discharge of springs fed by their particular catchment represents the base flow.

(2) The groundwater table fluctuation method (WTF-method) is based on analysing changes of the groundwater table over time. Therefore, high-resolution data of the groundwater table has to be obtained. The storage coefficient of the aquifer system is an additional information which is required.

(3) The soil moisture model JAMS will be used in both of the above mentioned catchment areas. One of the advantages of JAMS is the similarity of the calculation grid and the groundwater flow model grid. JAMS is a soil moisture balance model which uses local climate data and input parameters such as slope, aspect, land cover, soil, and altitude. The parameter soil can be further divided by specific physical conditions such as field capacity, thickness, hydraulic conductivity and possibility of capillary rise of water. Some of the parameters have to be determined in the laboratory. For land cover, additional floral characteristics like stomata resistance, root depth, growth height and leaf area index define the value.

The mentioned input data for JAMS is spatially organized in hydrological response units (HRU) which leads to a spatially discriminated output. The HRU mesh builds a raster of defined scale, and therefore, it is necessary to up- or downscale the input data, e.g. satellite scenes, aerial photographs and field data.

Out of this data, JAMS calculates the evaporation, runoff and recharge. In Figure 4.2, the internal program code is visualised.

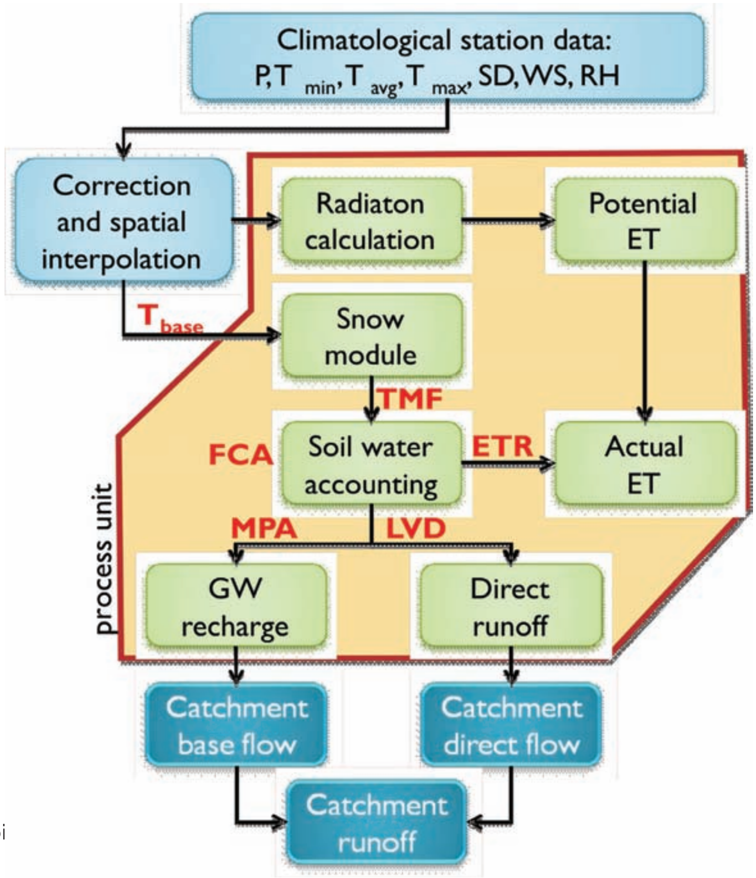


Figure 4.2

The internal program code of the soi moisture model JAMS (Krause 2005)

Instruments of discharge measurement were installed in the catchment areas of Wadi Qilt and Wadi al Arab. Water level and stream velocity loggers are used on the spring systems of En Perrat and En Duyouk in Israel.

In Jordan, these instruments were used directly in the river bed of Wadi al Arab. At all 3 stations the instruments were destroyed either by natural flood or human impact. Hence, it was not possible to obtain long-term records. The interpretation of the remaining discharge records will follow. As a result, in Wadi al Arab, twice a week the discharge of two springs has been directly determined by hand. Out of that, we were able to calculate the groundwater recharge to ca. 40 mm/yr for both systems in the Wadi al Arab.

In both catchments, the WTF-method was rarely useful, because a direct record of the groundwater table using groundwater level loggers was not possible. The only data available is historical data with an insufficient resolution. In the catchment area of Wadi al Arab the historical groundwater level data of well Kufr Assad was used for the WTF-method (Healey and Cook 2002). The casing of well Kufr Asad is developed in the main aquifer A7 / B2, which represents the geological layers from Wadi Sir Formation until Amman al Hisa Formation. The WTF-method is based on the storage coefficient for the aquifer A7 / B2. Analysis of available local pumping tests adduced a general storage coefficient of 1.5 %. With this general parameter a groundwater recharge of about 45 mm/yr was calculated. Figure 4.3 shows basic parameters such as gw-level and results of the WTF-method in the area of well Kufr Asad in the time period 1983 until 1998.

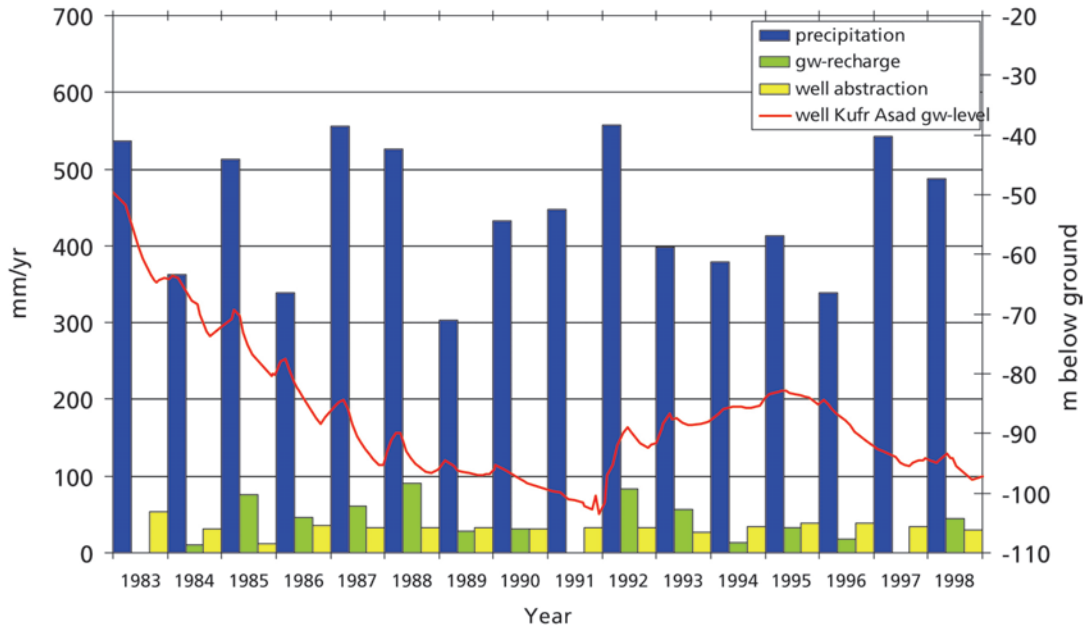


Figure 4.3
Main parameter and results for the WTF-method in the area of well Kufr Asad in Jordan

The next step to evaluate a high precise water balance for Wadi Al Arab, was to develop a soil moisture model (JAMS) for the Wadi. As necessary climate data, values from different climate stations for the period 01-1980 till 12-2008 were used. The directly measured surface runoff (Water Information System, MWI 2000-2005) of the wadi and the discharge of spring Ein Asal were used for the calibration of the model. Calibration parameters are e.g. stomata resistance and leaf area index for the vegetation, field capacity for soil and the percolation rate of the lithology in the area of replenishment. Figure 4.4 show the calibration of the simulated and directly measured (observed) surface runoff.

Based on satellite data and aerial photographs, in Wadi al Arab 13 different classes of land cover were determined (Figure 4.5 a). Figure 4.5 b show the groundwater recharge calculated by JAMS for the groundwater catchment area of Wadi al Arab.

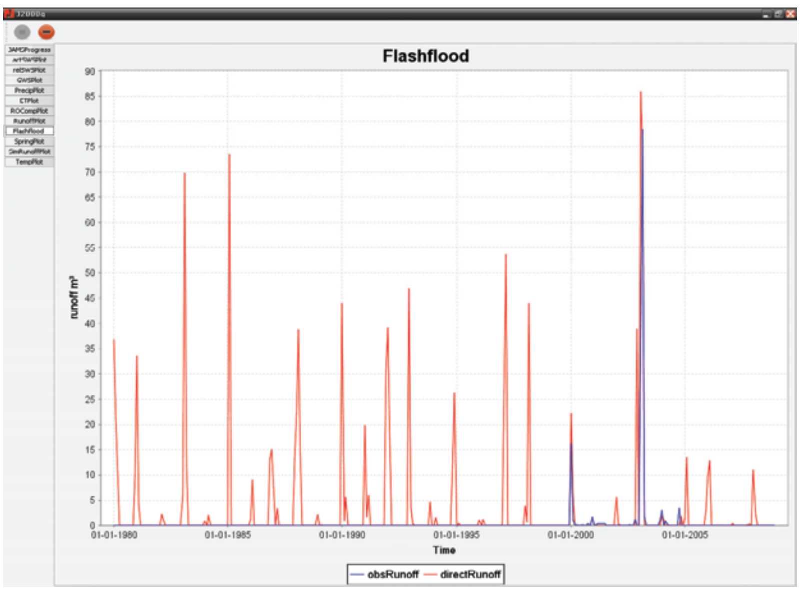


Figure 4.4
The simulated and observed surface runoff in JAMS for the period 1980 till 2008

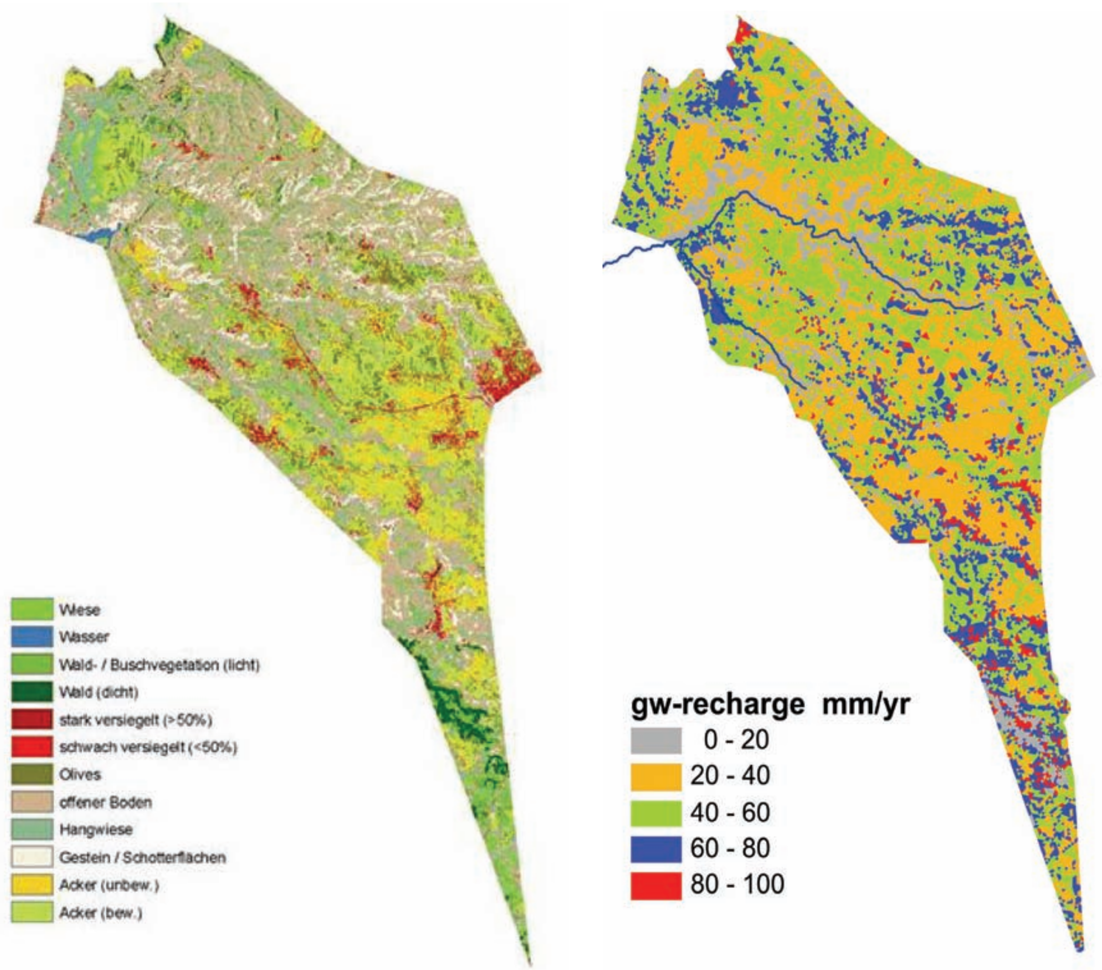


Figure 4.5

Shows a) classification of land covers and b) the distribution of the simulated groundwater infiltration in Wadi al Arab

For additional validation of the model outputs, the data will be compared to the groundwater recharge calculated by the WTF method and the direct and indirect discharge methods (Figure 4.6).

As an example and out of the three used methods, the outcomes of JAMS will be documented below. For the period 1980 - 2008 following rounded annual parameters of the Wadi al Arab water budget were calculated on a monthly base:

precipitation = evapotranspiration + gw-recharge + direct runoff

443 mm/yr = 378 mm/yr + 47 mm/yr + 18 mm/yr

As a result, Figure 4.6 shows, the average groundwater recharge for all used methods is nearly equivalent and can be generalised to be about 47 mm/year.

Because of the successful calibration and validation of the Wadi al Arab model, parameter characteristics such as vegetation and percolation rate can be transferred to the Wadi Qilt area. The soil moisture model of Wadi Qilt will be finished within the next few months.

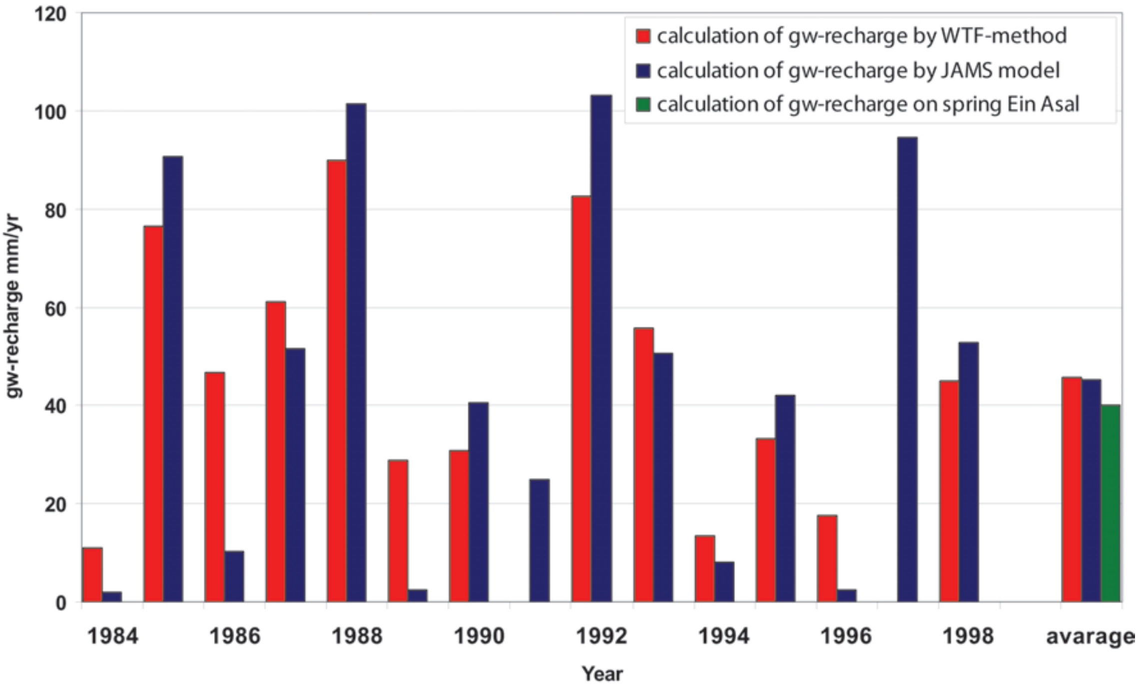


Figure 4.6

Shows the comparison of the different used methods to calculate groundwater-recharge in Wadi al Arab

Figure 4.7

Installation of the equipment for measuring the runoff

4.1.4 Rainfall-runoff relationships in the area of Wadi Kafrein, Jordan

Compiled by: M. Toll, M. Sauter (GU)

In most of the rainfall runoff studies in Jordan, the input data, especially the streamflow data, is neither complete nor consistent and lacks gauged data. In most of the arid wadis, high magnitude flood events cause directly a change in the morphologic cross-section, and it might even destroy any concrete gauging station which lowers the probability of obtaining any long-term records for a defined cross-section considerably. Wadi Kafrein has very limited and short records of streamflow measurements.

Surface runoff generated in arid and semi arid zones as a direct response to high rainfall intensity is of flashy type which means that they last only for a few minutes or up to a maximum of several hours. As mentioned above, these high magnitude floods are known to destroy gauging stations and change the morphology of the wadi. Direct velocity measurements during flood events have to be continuous since the runoff amounts change rapidly, either increasing or decreasing depending on the rain storm event. Additionally, the measurement of the velocity by using a current meter is difficult and dangerous due to the sediment load.

Therefore, small subwadis were studied on a microscale. This gives more reliable and accurate results because the measuring environment can be controlled better and involves less personal risk. Five subwadis within the watershed of Wadi Kafrein have been chosen to measure the rainfall and the runoff (Figure 4.7). Furthermore, these subwadis have different characteristics, such as geology, slope, rainfall intensity and land use. This provides the opportunity to investigate the effect of these factors on the generation of surface runoff.

Several rain gauges were installed, each in the catchment area of one selected subwadi, and the depth of the generated runoff in every subwadi was measured by automatic pressure transducers. The runoff depths were later calibrated by either a current meter or the salt dilution method, depending on the wadi and the storm characteristics. Furthermore, climatologic parameters were measured. To cope with extreme flash floods of the whole catchment, a surface water dam at the outlet of Wadi Kafrein has been used to estimate runoff quantities by the change of storage in the reservoir.

4.1.5 The use of high resolution multi parameter spring discharge data sets to estimate travel times through thick vadose zones

Compiled by: S. Schmidt, M. Toll, M. Sauter (GU)

Auja spring and Sultan spring (synonym: Elisha spring) in the Jericho region are two of the largest springs in the West Bank. They exhibit different discharge characteristics. Whereas Sultan spring possesses a rather constant discharge, Auja spring displays high fluctuations linked to precipitation events. Therefore, different dominating recharge mechanisms are assumed for the two springs: mainly rapid and concentrated recharge for Auja spring and predominantly slow and diffuse recharge for Sultan spring.

Groundwater recharge within the catchments of Auja spring and Sultan spring will be quantified using a combination of water budget estimations, spring hydrograph and chemograph analysis, well hydrograph analysis and soil water balance approaches. The research effort is focused on the temporal and spatial identification of groundwater recharge in karst aquifers with thick unsaturated zones.

The approach requires the measurement of time series of spring discharges as well as water level in boreholes with high temporal resolution. It is based on time derivatives of hydrographs and recession coefficients of reservoirs (Geyer et al. 2008).

To improve the conceptual and hydrogeological model as a basis for the quoted methods, we especially investigate the karst system of Auja spring. Additionally, applied methods include 3D-geological model construction and artificial tracer testing. To obtain the mean residence time of groundwater, environmental tracer modelling is performed.

As stated, a crucial point for our investigation is to measure high-resolution spring hydrographs and chemographs in order to separate the different recharge components. However, up to date discharge of most springs in the West Bank is measured at a monthly or even coarser interval, no permanent gauging stations exist. Furthermore, Auja spring site was in a very bad condition in 2007. Installation of equipment would not have been possible. Therefore, the Auja site underwent an intensive rehabilitation effort during 2007 and 2008. Figure 4.8 shows the Auja spring site before and after construction efforts. A multi-parameter probe, which measures water level, temperature, pH, turbidity, and conductivity at a very high resolution was installed.

Figure 4.8

Left: Status of the old spring house at Auja spring. No weir existed at that time

Right: Rebuilt spring house (background), where the multi-parameter probe is installed and the measuring weir (front)

In the Sultan spring, already in 2007 a multi-parameter probe, the same equipment as at the Auja spring site, could be installed. Figure 4.9 shows the response of the Sultan spring karst system to a recharge event (January to February 2008). To improve the resolution of the discharge measurement, a new gauging station at the canal was installed in late 2008.

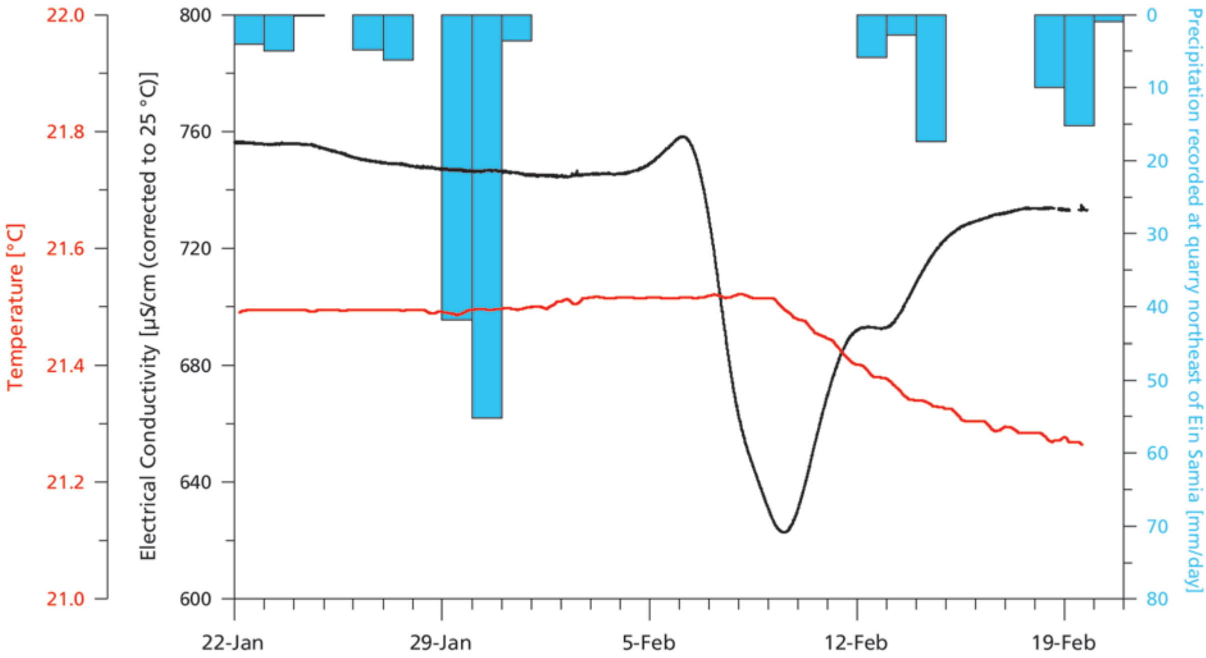


Figure 4.9

Recharge event, recorded by the multi-parameter probe at Sultan spring in early 2008. The data indicates that only about one week after the event the precipitation water reaches the spring. This is a rather common behavior of a karst spring, but, due to the rather steady discharge was not expected to this extend at Sultan spring.

Additional installations in the catchment of Auja spring include: one meteorological station plus 6 supplemental automatic rain gauges, two automatic recording soil moisture stations (four sensors each, recording depth profiles), one water level sensor in a monitoring well (another 6 wells will be equipped in March 2009). Furthermore, soil moisture determination will be extended to the whole catchment area using satellite radar image analysis.

To close the water budget and to quantify surface runoff as well, we intend to rehabilitate and equip a runoff gauging station in the catchment. However, due to the necessary authorisation procedure (nature reserves area) this can be realised for the hydrological year 2009/10 at the earliest.

4.1.6 Chemical analytical procedure to use mobile organics as flow and transport indicators

Compiled by: T. Licha, M. Sauter (GU)

Main goal of this activity is to improve the ability to use organic compounds as indicators for processes at larger scale. In order to use chemical compounds as flow and transport indicators, a real multi method for their chemical analytical determination is established for obtaining unbiased data sets at economic level. Concerning pharmaceuticals, combination and optimization of analytical procedures, sampling procedure and further sample treatment was completed. The optimization process included both, on-site sample pre-concentration using solid phase extraction (SPE) as well as qualification/quantification using high performance liquid chromatography with tandem mass spectrometric detection (HPLC-MS/MS). The developed method features the following:

- Broad range of selected compounds from distinctively different sources and with a broad range of transport properties (log Kow range, acid base properties)

- Limits of quantification (LOQ) in the low ng/L range

- Low standard deviation (< 5%)

- Acceptable recovery rates in various matrices (groundwater, river water, secondary treated effluent and synthetic seawater)

The on-site pre-concentration technique was optimised with the focus of a) low limits of detection, b) ability for high temporal resolution, c) providing unbiased data sets. Especially the latter is innovative as sampling location and laboratory are far apart and the postage of water samples would require an enormous logistical effort. The suggested procedure has been successfully tested on samples from a different location.

The method will be used in the next rainy season for the analysis of samples in the Auja area as well as in the Kafrain area.

Material and methods

Sample preparation & solid phase extraction (SPE)

All samples were kept at 4°C for 24 h allowing particles to settle and the supernatant water was used for further processes. In brief, duplicates of 500 mL aliquots of groundwater sample were spiked with internal standard and phosphate buffer (pH 6,8) and were loaded onto Waters OASIS HLB cartridges at 15 mL/min. In case of secondary treated effluent samples, 100 mL of sample were diluted with blank-free tap water to a final volume of 500 mL and spiked and extracted like the groundwater samples. The cartridges were conditioned with MeOH prior to extraction. After extraction, the cartridges were rinsed with demineralized water and dried under vacuum for 10 min followed by freezing until the elution of compounds. Compounds were eluted using MeOH, ethyl acetate and n-Hexane. Solvents were evaporated using a gentle stream of nitrogen and the analytes were redissolved in 5% MeOH with 5 mM NH_4Ac.

HPLC-MS/MS

Samples were analyzed using a HPLC-MS/MS-system 1200L with electrospray interface (ESI) from Varian Inc. Due to the fast polarisation switch, it was possible to perform positive and negative ionization modes together in the same analysis. Briefly, a binary pump system (Prostar 210, Varian Inc.) and an autosampler (Prostar 410, Varian Inc.) were used for all analyses. The analytes were separated using 200 x 2 mm Varian Polaris C18 Ether column with 3 µm particle size. A binary gradient consisting of 10% MeOH (v/v) and 0,015% formic acid (v/v) in water (eluent A) and 100% MeOH (eluent B) at a flow rate of 200 µL/min were used. The gradient was as follows: 0% B was held for 0:50 min, increased to 5% by 0:10 min, increased linearly to 95% by 39 min and held for 3 min. A 12 min equilibration step at 0% B was used at the end of each run resulting in a total run time of 55 min per sample. An injection volume of 100 µL was used for all analyses. A representative chromatogram is shown in Figure 4.10. Table 4.1 shows general information about the individual compounds.

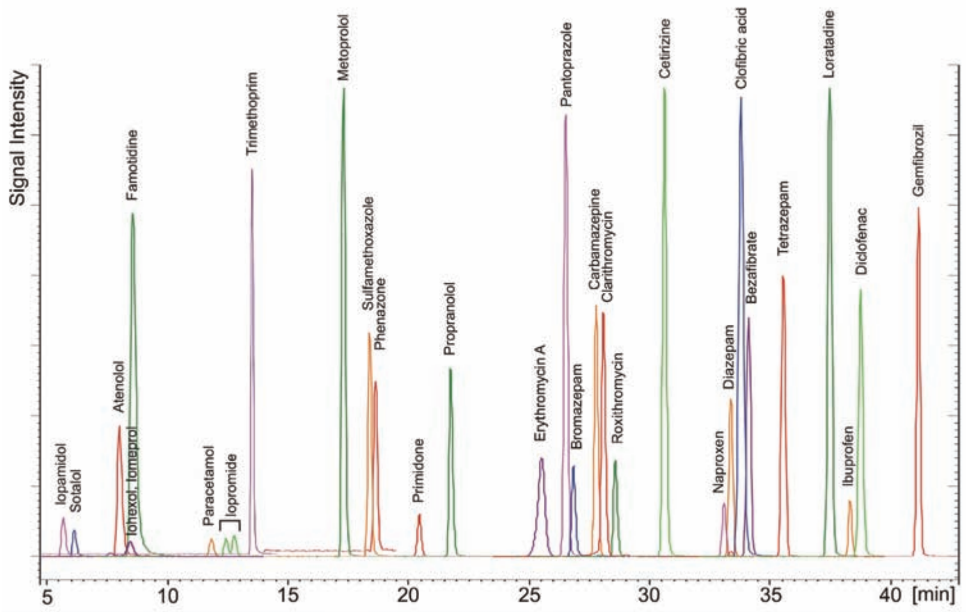


Figure 4.10
HPLC-MS/MS chromatogram of a standard solution (internal standards excluded)

4.2 Expected impacts

The results achieved until now allow a better understanding of the runoff, discharge and recharge mechanisms of local catchments and they eventually allow a critical assessment of available water resources. They contribute to the regional water balance and, therefore, to the regional flow model. The latter is an essential tool for the prediction of the future development of the resources under conditions of expected changes in boundary conditions, i.e. conjunctive use schemes, artificial recharge, usage of treated waste water, over-pumping and climate change. The results also help to identify areas of different recharge potential and recharge mechanisms. However, further detailed research is needed to identify the recharge processes from the continued collection of the event-based hydrological data. Only with a large number of analyzed events and, therefore, with a solid statistical basis will the respective drawn conclusions have the expected validity.

The better understanding of the rainfall-runoff relationship helped on the one hand for the estimation of surface water resources available for usage in the future and on the other hand for the identification of areas with high infiltration rates. The developed lab techniques for the identification of xenobiotica can be used in the future to assess a possible impact of xenobiotica from wastewater infiltration on consumers in the Lower Jordan River Basin (health risk assessments), i.e. the vulnerability of water resources.

Table 4.1
General information about the individual compounds; n.d.: not determined

Application	Compound	Log KOW	pKa
Contrast Media	Iohexol	-3,09	n.d.
	Iomeprol	-2,79	n.d.
	Iopamidol	-2,63	10,7
	Iopromide	-2,05	n.d.
Antihypertensive agents	Atenolol	~ 0	9,6
	Sotalol	~ 0	8,3 & 9,8
	Metoprolol	1,1	9,7
	Propranolol	3,2	9,5
Ulcer treatment	Famotidine	0,2	6,8
	Pantoprazole	2,0	3,8
Antibiotics	Sulfamethoxazole	0,9	5,6
	Erythromycin A	1,6	8,8
	Clarithromycin	2,1	9,0
	Roxithromycin	2,7	9,0
	Trimethoprim	0,8	7,1
Anticonvulsants, Sedatives	Primidone	0,9	12,3
	Bromazepam	1,6	2,9 & 11
	Carbamazepine	2,5	14,0
	Diazepam	2,7	3,3
	Tetrazepam	3,2	4,3
Lipid regulators	Clofibric acid	2,9	3,0
	Bezafibrate	4,3	3,6
	Gemfibrozil	4,8	4,7
Anti-inflammatory drugs	Phenazone	0,4	1,4
	Naproxen	3,2	4,2
	Ibuprofen	3,7	5,2
	Diclofenac	4,5	4,2
Antihistamines	Cetirizine	1,5 (pH 3,5-7,5)	2,2 & 2,9 & 8,0
	Loratadine	3,6	5,0
Analgesic	Paracetamol	0,5	9,9

4.3 Future research

The dominant research need is to critically assess recharge depths, their variability in space and time and in the characteristics of the different recharge mechanisms. In particular, the travel times through the thick vadose zones, and therefore the water storage potential of this compartment need to be quantified. These processes will have to be studied in different aquifers of the study area. An improved understanding of the hydrogeological processes will result in reliable water management plans. Alternative abstraction scenarios will have to be discussed (conjunctive use). The employment of the groundwater storage will also be an essential component in the IWRM concepts, i.e. the storage of available water during peak times in winter and their abstraction during dry periods in summer. Water engineers can make use of natural storage potential of the aquifers to overcome water shortage or water quality deterioration during dry summer seasons or even during years of drought. A major research field will be the testing and introduction of different artificial recharge techniques. This concept has the potential not only to alleviate water shortage problems during dry summers, but also to overcome periods of drought. Water quality monitoring, especially for hazardous components (e.g. Xenobiotica), have to be undertaken in order to ensure that no health risks for consumers result from the usage of treated wastewater components for artificial recharge.

5 TECHNOLOGIES – MANAGING WASTEWATER FOR REUSE

Involved Institution: UFZ, MWI, BALQ
WP-Speaker: R. Müller (UFZ)

5.1 Introduction

Water shortage is one of the dominant factors for the economic development in many countries. Worldwide agriculture and water consumptions are responsible for the dramatic water situation in some areas. One of the main part of this project focuses on the research, demonstration and implementation of Decentralized Wastewater Systems Solutions (DWWSS) that integrate wastewater treatment and its reuse. Especially in Jordan, treated wastewater is considered as a valuable water resource for irrigation. The water demand exceeds natural supply by about 150%, which has led to a deficit in drinking water. Hence, the Government of Jordan has imposed that all new wastewater treatment projects must include feasibility and design aspects for treated wastewater reuse. Decentralized treatment involves using a combination of treatment technology options, both traditional and innovative. In arid areas, the opportunity for water reuse offers added value benefits and makes decentralized wastewater treatment and reuse technologies useful tools for a sustainable system solution.

Decentralized wastewater treatment system solutions may contribute to more reliability and flexibility in Jordan's rural wastewater management. Innovative technologies may be combined with local "treatment and reuse trains", to meet hygienic standards, treatment goals, overcome site conditions and to address environmental and socio-economic requirements. The overall purpose of this working package was to develop and combine site adapted technologies for decentralized wastewater and sludge treatment. Reuse of treated water and sludge for irrigation purposes and technology transfer were the prime objectives of this working scheme. After the start-up phase of the different technologies, a specific optimization and monitoring program for each module and for the combinations were carried out. The implementations of the technologies were performed in close interaction with WP7, WP8, and WP11.

5.2 Site description and site provision (D501)

Compiled by: A. Subah (MWI)

5.2.1 Introduction

An optimal site selection has significant importance for the success of any project. In order to construct a demonstration and research plant for decentralized wastewater treatment technologies in Jordan, this study aimed at the selection and description of a demonstration site that offered the highest potential for constructing a demonstration plant for decentralized wastewater treatment and reuse.

5.2.2 Methods

The requirements for the selection of the demonstration site were as follows:

- The site should have to be selected near to an already existing wastewater treatment plant (WWTP), which will provide raw sewage to the demonstration plant and to make use of the infrastructure (roads, power supply, drinking water, fences etc.).
- The site should have to be located near to Amman and even better to As-Salt, where the project partner Al-Balqa Applied University is located.
- The area should have to be large enough to construct the plant, provision of irrigation fields and to have the opportunity to extend it in the future.
- The foundation soil should have to be suited for an economic construction of the demonstration plant.

The Jordanian Ministry of Water and Irrigation (MWI) proposed three potential sites that were suitable and also available to construct the SMART- Demonstration and Research Plant for Decentralized Wastewater Treatment. They were: Fuheis, Wadi As-Sir and As-Salt. The locations of the three sites along with the capital city Amman have been demonstrated in the following map (Figure 5.1).

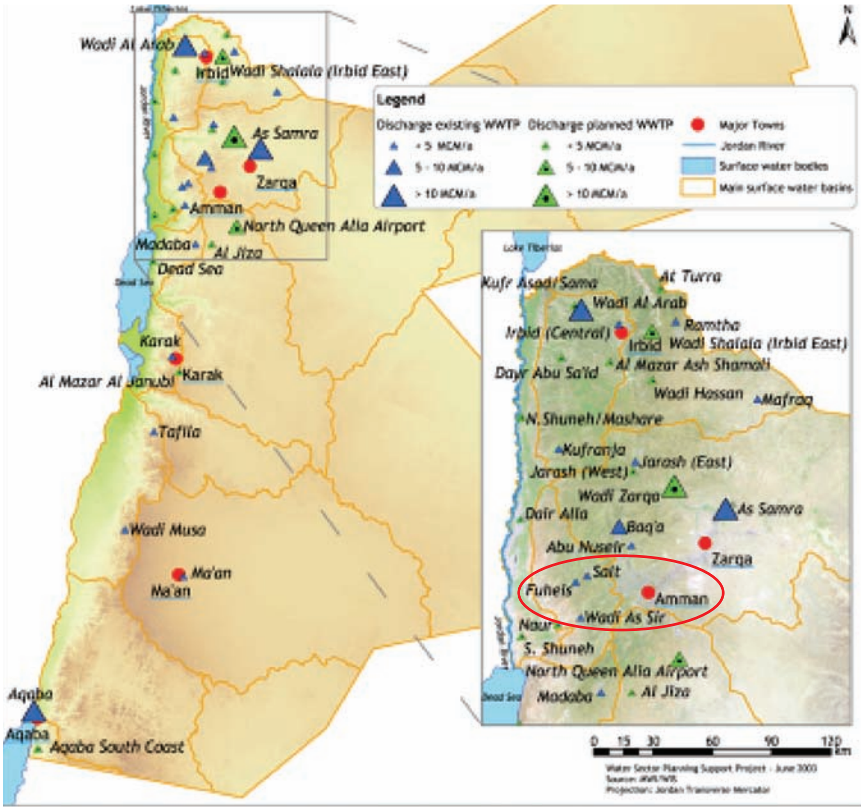


Figure 5.1
Location of the probable sites for constructing the demonstration plant

After a visit to the three potential sites, the Jordanian Ministry of Water and Irrigation (MWI) and the Water Authority of Jordan (WAJ) along with the UFZ and Al-Balqa Applied University decided to select the 'Fuheis wastewater treatment plant (WWTP) of WAJ' as the best suited site.

The selected site is located approx. 17 km away from Amman City centre and fairly close to the Al-Balqa Applied University. The plot (see Figure 5.2) is rather fairly sloping and well established with a good foundation soil.

The total area available for the construction is about 2400 m2. The site selection was accomplished by the end of the year 2006. Figure 5.3 shows the topographical view of the selected Fuheis site prior to the construction of the SMART-Demonstration and Research Plant.

Figure 5.2
Satellite image of the construction site in Fuheis, Jordan

Figure 5.3
Topographical view of the selected site at Fuheis prior to the construction phase of the demonstration plant and irrigation fields

5.3 Provision of the demonstration plant (D502)

Compiled by: R. Müller, M. Van Afferden (UFZ)

5.3.1 Introduction

The planning and construction of the research and demonstration site for decentralized wastewater treatment technologies in Fuheis was carried out within this working scheme. For the selection of the core technologies that have a great potential for a sustainable implementation in DWWT&R solutions in Jordan, the following general considerations have been made prior to the technology selection.

No ideal wastewater treatment technology exists which is applicable to all conditions and it is even more difficult to compare different technologies. Often the ranges of treatment efficiency within one technology vary between different brands and different producers in a wider range. For instance, an eco-technology is not always related to the lower maintenance costs. The technology has the potential of its own but it depends on the provider and local conditions too. This means that before taking the decision for one or the other technology, each region and each situation must need to be analyzed individually, with the constant concern of incorporating the local needs in the selection of appropriate technologies.

Despite these fundamental facts, we tried to pre-select core-technologies with the potential to be integrated in DWWT&R solutions in Jordan by applying a Multi-Criteria Analysis (MCA). Considering the low income conditions in Jordan, the need for achievable technologies on one hand and the high income population in some suburban zones that can afford even high-tech solutions, the following spectrum of core-technologies was pre-selected:

- two eco-technologies: Wastewater treatment pond system (anaerobic, facultative and polishing pond) (Pond-Sys) and a subsurface vertical flow constructed wetland (V-Wetland),
- two activated sludge technologies (extends aeration (Ext-Aer) and sequencing batch reactor (SBR),
- two bio-film technologies: Rotating disc reactor (Rot-Disc) and trickling filter (Trick-Filt), one membrane bioreactor (MBR)

These technologies were evaluated considering the criteria given in Table 5.1 which have an emphasis on rural and suburban regions in Jordan.

Following the multi-criteria analyses methodology, each of the criteria (given in Table 5.1) was weighted assigning an importance factor from low=1 to high=10. These factors were applied to three evaluation targets that are related to the quality of the treated wastewater and existing Jordanian Standards:

Table 5.1
Criteria defined for the pre-selection of "Decentralized Wastewater Treatment Processes" that have the potential to be integrated in DWWT&R solutions in Jordan

No.	Criterion	Relevance for Jordan
C1	BOD5 Removal	Jordan already defined quality standard for reclaimed water
C2	Pathogen removal (E. coli)	
C3	Nitrogen removal	
C4	Water loss/Salinity increase	Water scarcity requires a higher percentage of water reuse
C5	Robustness	Stability of plant operation, maturity of technology, low, failure incidence
C6	Operable	Not needed special professional skills required for O&M
C7	Investment costs without land	Low income conditions of the area should be reflected
C8	Land requirement	High land costs should be reflected
C9	Affordability (Low Operation Costs)	Low income conditions of the area should be reflected
C10	Sludge production	Low sludge production can reduce O&M costs

The aim of the technologies chosen for the demonstration plant at Fuheis site was to focus on an economically and ecologically efficient way for the treatment of domestic wastewater and sludge, which would provide a high quality resource for reuse in agricultural purposes. After analysing the Multi-Criteria Methodology for technology selections, the following different techniques with special focus on a combination of these technologies were applied in order to achieve a high quality in the treated wastewater and sludge effluent at Fuheis site.

The technologies are:

- Sequencing Batch Reactors (SBRs)
- Soil filter eco-technologies for wastewater treatment
- Separation of solid materials from the raw wastewater and anaerobic stabilization of sewage sludge
- Sludge drying beds for eco-technological sludge mineralization

5.3.2 Technology descriptions

Brief discussions on the technologies that are installed and in operation at the Fuheis demonstration and research site are given in the following sections.

5.3.2.1 Sequencing batch reactors (SBR)

Within the frame of appropriate technology selections, three Sequencing Batch Reactors (SBRs) were installed in parallel with other technologies at the Fuheis demonstration site. Sequencing Batch Reactor (SBR) is a discontinuously operated fill- and draw activated sludge process. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions. The adaptation of the SBR plants to the site specific conditions concerning the raw wastewater quality and to optimize their treatment performances under Jordanian climatic conditions were the prime objectives of this research work.

ATB Environmental Technologies Ltd. supplied three plants as commercially available Add-On kit; a conventional SBR plant, an SBR with UV light and a so-called Continuous Batch Reactor (CBR). These Add-On kits were fitted as a single component in each tank as shown in Figure 5.4.

All the SBR treatment units were operated and maintained by the local operators and frequently supervised by the Al-Balqa Applied University with the collaboration of ATB Environmental Technologies Ltd.

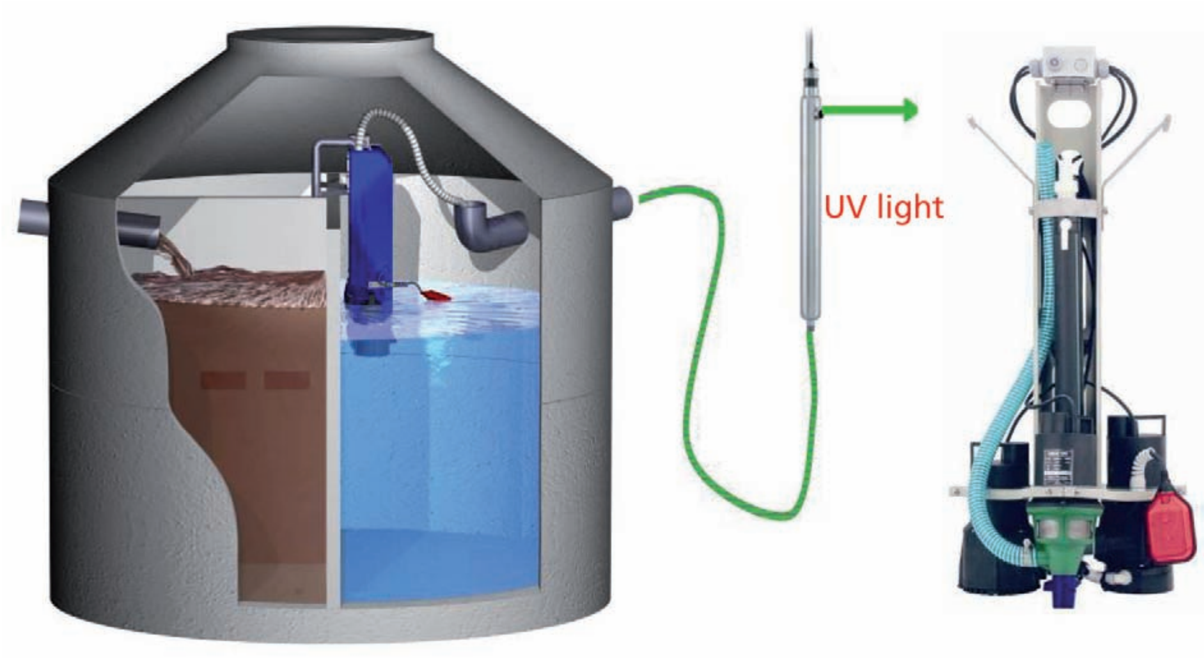


Figure 5.4
Schematic of SBR with UV-light and SBR Add-On kit

Unlike conventional activated sludge process, various phases occur in a sequence within the same reactor. All the reactors were operated in the mode with feed, anaerobic, aerobic, settling and decanting phases and therefore all biological, oxidation, sedimentation, nitrification and de-nitrification processes were occurred in a single tank. The design flow rate of each SBR reactors at Fuheis site was 1,200 L/day (approx. 16 pe).
With the co-operation of ATB technicians, the SBR plants were installed within the pre-constructed tanks at the Fuheis site. One of the installed and under operation plant is shown in Figure 5.5 for better understanding of the whole treatment units.

Figure 5.5
SBR unit under operation at the Fuheis test site, Jordan

5.3.2.2 Soil filter eco-technologies

Eco-technology refers to treatment systems designed on holistic ecological principles with the aims of harnessing natural processes and minimizing inputs of additional electricity or chemicals. Examples include constructed wetlands, ponds and sand filters. Eco-technologies require only minimal and simple maintenance, provide robust performance and have low operating costs. They can be designed to satisfy a wide range of effluent quality requirements. Hence, they are ideal for decentralized and remote applications. For better comparison on treatment efficiencies, two different types of vertical filter systems were installed at the Fuheis test site. They were:

1) Multi-stage Single-Pass vertical filter system and
2) Recirculating vertical filter system.

1) Multi-stage single-pass vertical filter system

The multi-stage single-pass vertical system was designed to produce high quality effluent in a passive way (no electricity or pumps required on a sloping site). It was designed to treat 3,400 L/day (approx. 46 pe). The system consisted of a septic tank (primary treatment), 1st stage vertical filter (secondary treatment and nitrification), organic de-nitrification reactor (removal of nitrate), and a 2nd stage vertical filter (pathogen reduction and further polishing).
The schematic flow diagram of a multi-stage single-pass system is shown in Figure 5.6.

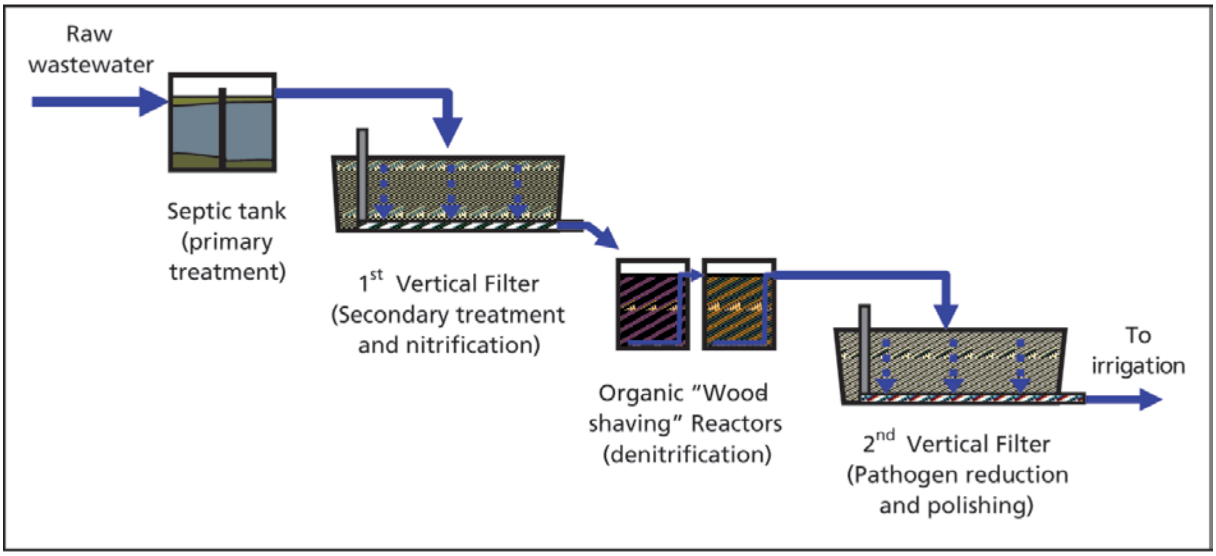


Figure 5.6

Schematic profile of Multi-Staged Single-Pass Eco-technology system

The vertical filters were tested with and without wetland plants to see the effect on the treatment performance and water balance.
Figure 5.7 shows the cross sectional view of one of the single-pass vertical filters with plants on it.

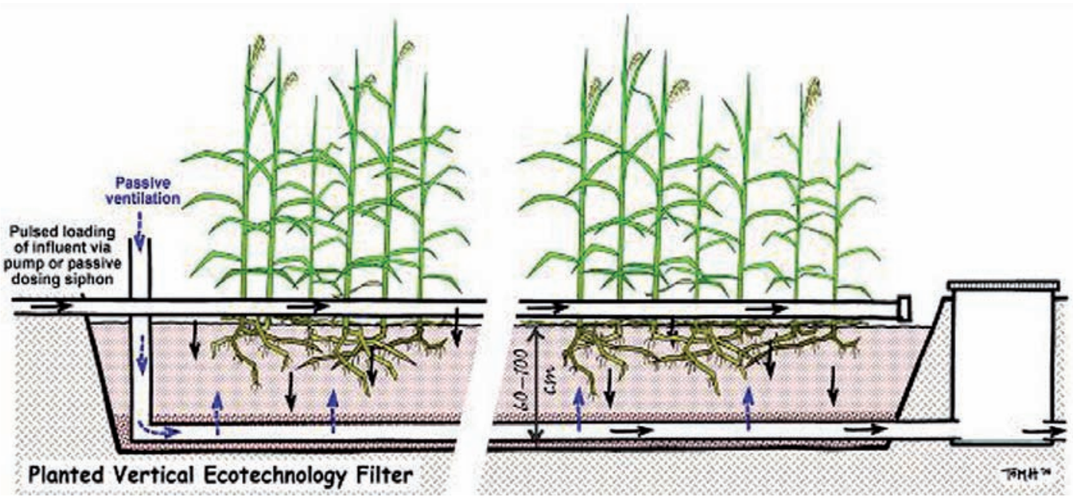


Figure 5.7

Cross sectional view of one of the single-pass vertical filters

2) Recirculating vertical filter system

Recirculating vertical filter systems are a state-of-the art eco-technology designed to produce a high quality effluent within a relatively small foot-print. It consisted of a septic tank for primary treatment, followed by a recirculation tank. Effluent was pumped from the recirculation tank onto the vertical filter before then flowing through a flow splitting device from where a portion of the effluent was returned to the recirculation tank while the rest leaves the system and was used for irrigation. The system was designed to treat 2,000 L/day (approx. 27 pe).

The vertical filter consisted of a 0.8 m deep bed of 4-8 mm tuff gravel. Wastewater was pumped onto the upper surface of the vertical filter in small pulses and percolated downwards towards a series of drainage pipes which were connected to ventilation risers to enhance oxygen transfer to the bottom of the filter. The schematic profile of a Recirculating vertical filter system is shown in Figure 5.8.

Between loading events, the filter media remains unsaturated and therefore promotes aerobic processes such as organic matter decomposition and nitrification (conversion of ammonium to nitrate). Attached growth micro-organisms compete against and attack pathogenic organisms. Physical filtering, entrapment and sorption are also important treatment processes.

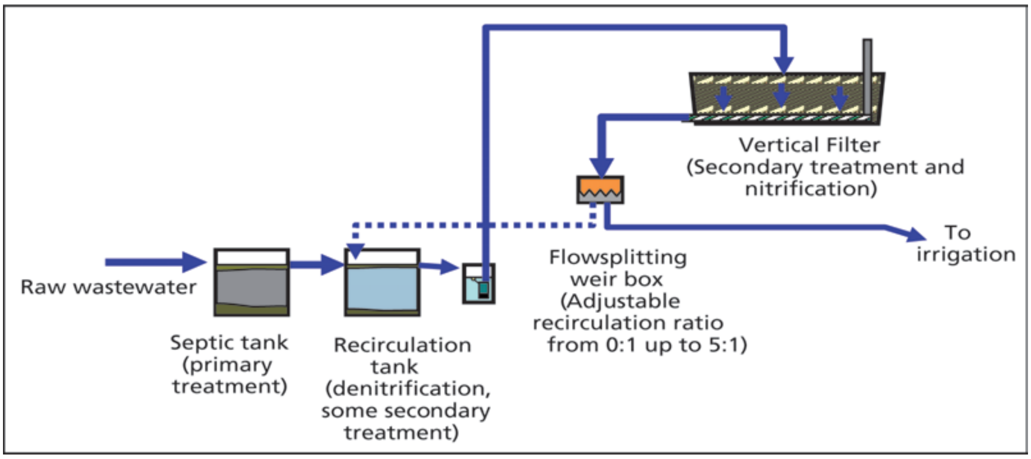


Figure 5.8

Schematic profile of the Recirculating Vertical Filter Eco-technology system

A portion (50 – 85%) of the water leaving the vertical filter was returned to the front end of the recirculation tank where it was mixed with the septic tank effluent which was anaerobic and rich in organic matter. This provided the conditions required for the denitrification process (conversion of nitrate into nitrogen gas). Recirculation also improved performance stability by buffering flow peaks and diluting shock loads of contaminants.

Figure 5.9
The recirculating vertical filter and flow splitter

Figure 5.9 shows the installed recirculating vertical filter and flow splitter weir box devices at the Fuheis demonstration site in Jordan.

Key design parameters (loading rate, recirculation ratio) were targeted to be optimised for the Jordanian conditions. The water balance and the effect of plants on treatment and water loss were also investigated. The design, construction and technical supervision of both the soil filter eco-technologies were provided and monitored by The UFZ.

5.3.2.3 Anaerobic bioreactor for sewage sludge treatment

Anaerobic treatment aims to the stabilization of municipal sewage sludge and to produce high quality fermentation residues. The production of biogas contributes to the competitiveness of the technology. In addition to that, the anaerobic treatment leads to a significant reduction of pathogenic organisms. Sewage sludge was either part of the raw wastewater or the product of the nearby WWT plant.

The company HUBER SE supplied a containerized plant which consists of a mechanical solid/liquid separator (pipe-strainer), followed by a hydrolysis reactor and an anaerobic bioreactor. The aim was to adapt the screen in an efficient way (screen size varies from 0.2 - 1.0 mm), that separates a great portion of solid material from raw wastewater. The performance of the pipe-strainer was measured by the solid removal efficiency.

The digestion was carried out in a two-stage anaerobic reactor. The performance of the reactor was monitored and optimized by measuring TSS, VSS, VOA, pH, Temp., nutrients, faecal indicators, pathogens (both influent and effluent) and the biogas production. Depending on changes of the hydraulic load and the load of suspended solids, the maximum degree of sludge degradation was targeted to be detected. The process flow diagram of the anaerobic bioreactor plant is shown in Figure 5.10.

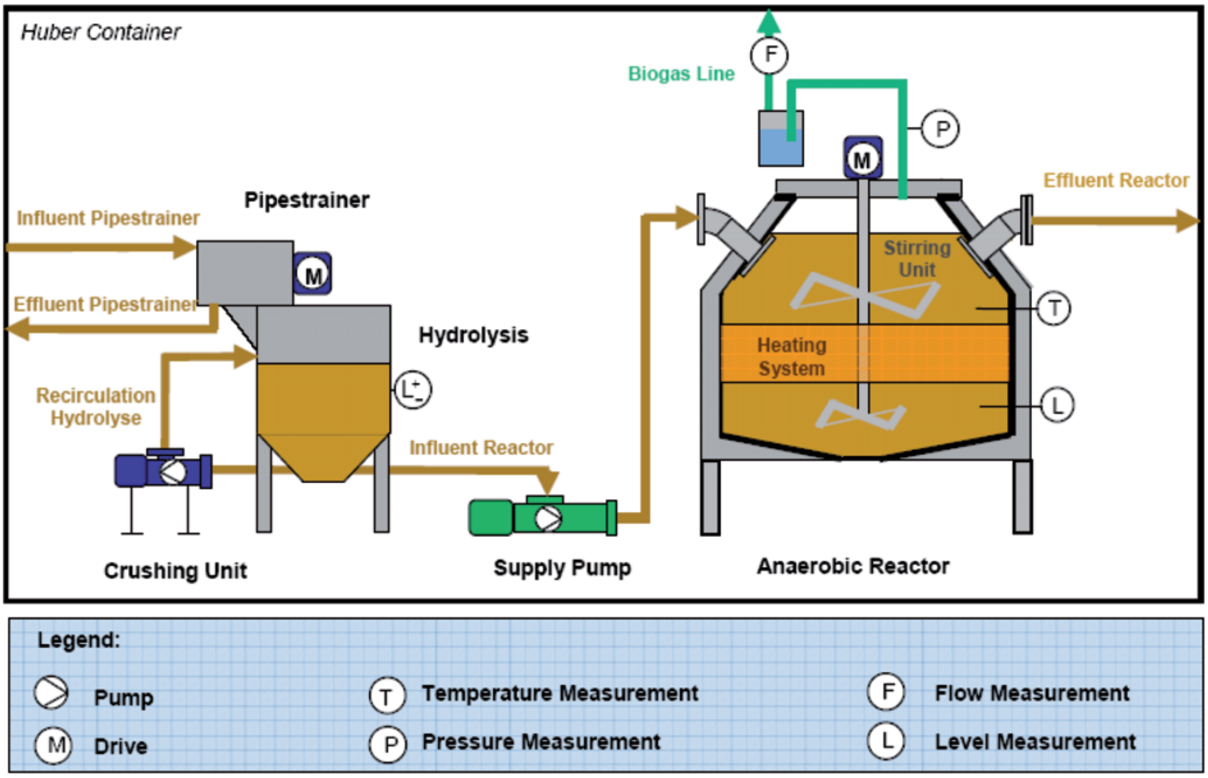


Figure 5.10

Process flow diagram of anaerobic sludge treatment technology

Figure 5.11 shows the inside view of the anaerobic bioreactor plant that was provided by HUBER SE for the Fuheis demonstration site in Jordan.

Figure 5.11

Anaerobic bioreactor plant at Fuheis site (inside view)

Digested sludge was aimed to be dried in sludge drying beds for further pathogen removal, sludge dewatering and mineralization. Dried sludge will be demonstrated for reuse as organic fertilizer at the site.

5.3.2.4 Sludge drying beds for sludge mineralization

Sewage sludge requires transport, disposal or further processing, which is becoming an increasing problem in Jordan. Eco-technological sludge treatment performs with the volume reduction and mineralization of municipal sewage sludge without an additional energy input. This research work aimed to adapt the technology under Jordanian climatic conditions and to produce high quality dried biosolids, which can be re-used as organic fertilizer.

Within this investigation, 3 planted (common reed; Phragmites australis) sludge drying beds were constructed. The decomposition mechanism results from the complex interaction between the plant roots, micro-organisms, sludge and filter materials.

The reasons for using plants in plant beds were: i) the root structures maintain porosity (i.e. drainage pathway), ii) transferring of O2 into the sludge residue iii) increase the microbiological activity within the root-near environment of the rhizosphere iv) dewatering the sludge at high osmotic pressures v) lead to a continuous conditioning and restructuring of the settled sludge vi) production of plant biomass.

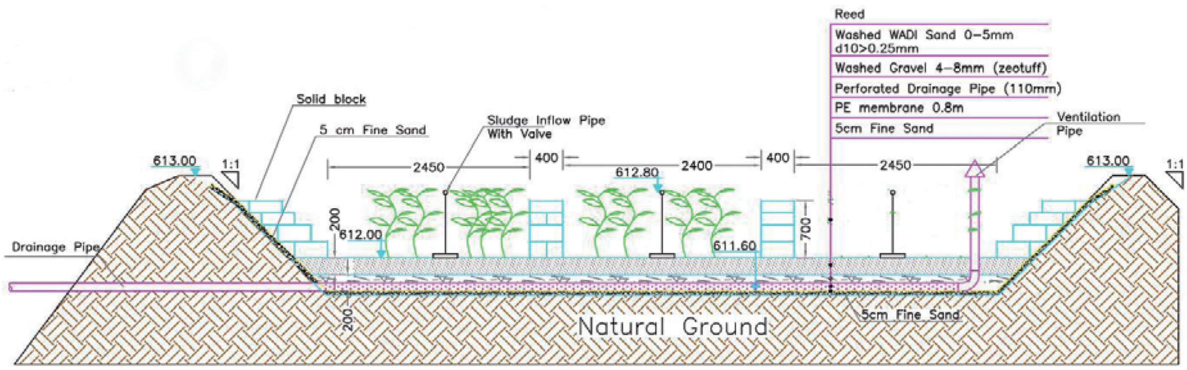


Figure 5.12
Sludge drying bed eco-technology (cross-sectional view)

Investigation on the improvement of sludge dewatering by evapo-transpirations under local climatic conditions were made. By changing of sludge hydraulic loading and suspended solid loading, the sludge dewatering efficiency and plant response were also investigated. The cross-sectional view of sludge drying bed eco-technologies is shown in Figure 5.12.

The potential influences of plant (root) growth on sludge mineralization and hygienic quality improvement will be monitored in each bed, by measuring organic matter content, dry matter content, metals, total nitrogen, available phosphorous etc. within the biosolids in future. Demonstrating the beneficial reuse of dried biosolids (final product) as organic fertilizer in agriculture and for soil improvements will also be carried out. An overview of the sludge drying beds is shown in Figure 5.13.

Figure 5.13
Sludge drying beds under sludge operations at Fuheis site

After the establishments of the reed plants and the acclimatization phase in each segments of sludge drying beds, the sludge loading was started and the dewatering process were closely monitored. The follow-up activities will include the optimization of sludge loading rates, leachate drainage facilities, response of plants, water and solid mass balances etc. in future. The potential of such technologies under a high temperature and high evapo-transpiration rates will be investigated and optimized.

5.3.3 Methodology

The raw sewage of the WWTP at Fuheis has a rather different quality as compared to the wastewater composition in Germany and it is short-listed in the following table 5.2:

Table 5.2
The quality of the raw sewage from the WWTP at Fuheis (2006)

COD	1090 mg/L
BOD	607 mg/L
TSS	570 mg/L

The dimensioning of the decentralized WWTPs at Fuheis was based on these above mentioned data. These design criteria were comprised for the planning of the infrastructure (roads, sewer lines, power supply, central control devices etc.) development. The treatment modules were de-

signed by the German project partners UFZ, ATB and HUBER. The UFZ and the Al-Balqa Applied University (BALQ) were responsible for the coordination of the infrastructure development.
The UFZ was particularly responsible for the soil filter eco-technologies for wastewater treatment and sludge drying beds for eco-technological sludge mineralization. The process flow diagram of the demonstration plant in Jordan is shown in Figure 5.14.

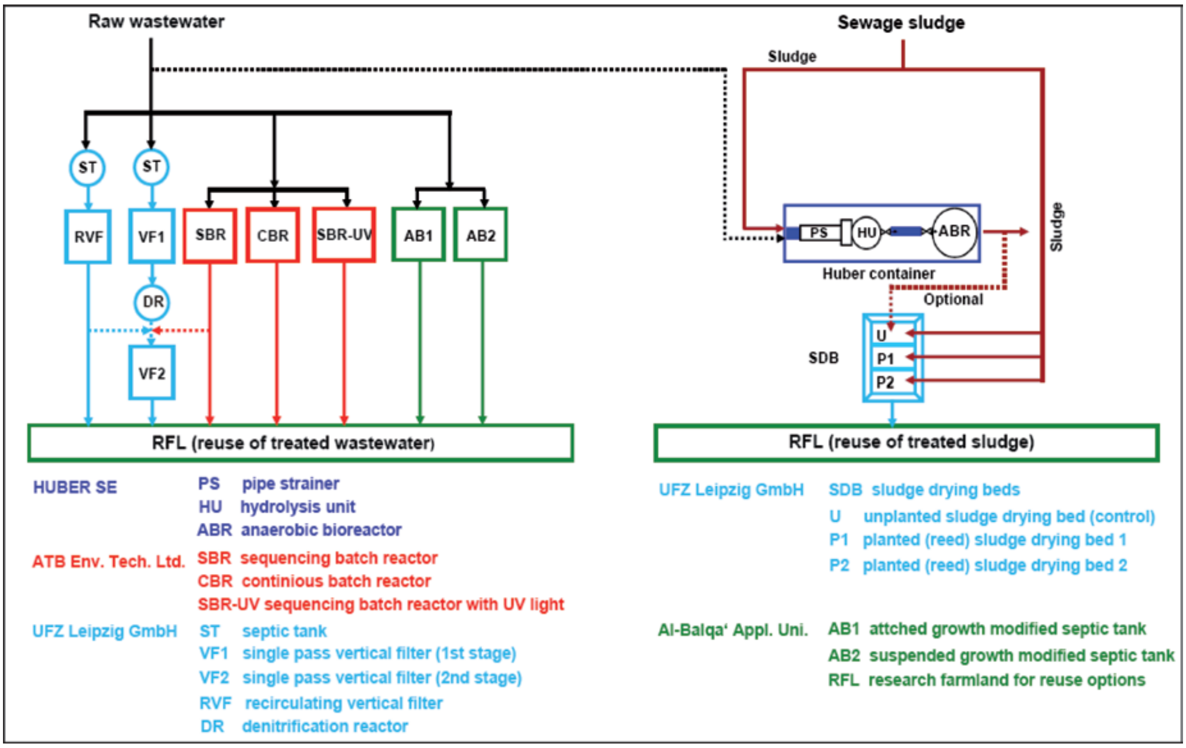


Figure 5.14
Process flow diagram of the demonstration plant at Fuheis site

Based on the preliminary design of the plant, the detailed planning and supervision were sub-contracted to WTL Wassertechnik Leipzig GmbH and to BDZ – Training and Demonstration Centre for Decentralized Sewage Treatment, for the design of "Training and Exhibition Trail – the Show Room" (van Afferden and Müller 2007).

The preliminary planning was finished in May 2007. Meanwhile, the companies HUBER and ATB had accomplished the design and dimensioning of their plants in close coordination with the UFZ. The preliminary technical planning and the design of the exhibition trail were presented to the Jordanian Ministry of Water and Irrigation (MWI). After the planning was approved by the MWI, the engineering offices continued with the planning works. The executive planning was finished in July 2007.

A national call for tenders was published in Germany and then cancelled without any affordable offers. Afterwards, some of the most promising companies both in Jordan and Germany were as-ked to make an offer for the construction of the plant. The planning was revised thoroughly for better adaptation to the market situation in Jordan and to find every potential for cost savings.

Finally, in March 2008, the Jordanian company Nabil Ayoub Wakileh & Co. (NAW) was selected to enter into the contract. After receiving the signed permission to take over the site from the Ministry of Water and Irrigation (MWI), the construction works started on 1st of June, 2008. Site overview of the demonstration plant with all the proposed construction works are shown in Figure 5.15.

Figure 5.15
Overview of the demonstration plant and irrigation fields after the construction works at Fuheis

It is worth mentioning that the SMART-Research facility is and will be open for further co-operations in the frame of decentralized wastewater treatment. Therefore, activities of another BMBF project ("DEAD-SEA") have already been included within the framework of the demonstration plant at Fuheis.

The proposed technologies were installed and started operating immediately after the construction phase in 2009. The inclusion of the demonstration area "the Show Room" with an exhibition walkway and two pavilions at each end makes the site even more attractive and convenient to the spectators for getting all the information they need about the technologies (e.g. fact sheets, posters). Figure 5.16 shows the overview of the technologies along with the training and exhibition trail at the Fuheis test site.

Figure 5.16
Overview of the technologies along with the training and exhibition trail "The Show Room" within the demonstration plant at Fuheis

It is worth mentioning that the SMART-Research facility is and will be open for further co-operations in the frame of decentralized wastewater treatment. Therefore, activities of another BMBF project ("DEAD-SEA") have already been included within the framework of the demonstration plant at Fuheis.

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5.3.4 Site Hand-Over and the opening ceremony

After the construction of the site, the demonstration plant was handed-over to the local Al-Balqa Applied University. With the co-operation of Al-Balqa University, the Jordanian Ministry of Water and Irrigation invited all the project partners for a meeting and subsequently the opening ceremony.

The ceremony was scheduled on 18th of March 2010. All the Jordanian, Palestinian, Israeli and German project partners were attending the ceremony.

The inauguration ceremony was started with the hand-over of the symbolic key from the German Ambassador in Jordan to the president of the Al-Balqa Applied University, which also reflected the German-Jordan friendship from the political point of view (see Figure 5.17).

Figure 5.17
The inauguration and site hand-over ceremony at the Al-Balqa University

Since then, the demonstration site is open for the public and will be operated and maintained by the Al-Balqa Applied University. Figure 5.18 shows the demonstration of the Fuheis site to the visitors, organised by the project-partners on the day of the inauguration ceremony.

Figure 5.18
Site demonstration and official visit by the local project-partners

5.3.5 Future research

Several training sessions for the scientists and operators will be provided by the partner companies at the demonstration site. Moreover, with the collaboration of the local Al-Balqa University, an on-site monitoring program will be established and development of further research programs will be carried out on a regular basis.

5.4 Provision of optimized irrigation water (D503)

Compiled by: B. Abbassi (BALQ), M. Van Afferden (UFZ)

5.4.1 Introduction

The adaptations of relevant design components for different wastewater and sludge treatment technologies towards the local climatic conditions were carried out at this demonstration site. A special focus was laid upon the higher quality of the effluent, which plays an important role to reuse the treated wastewater and sludge for agricultural irrigation and fertilization purposes. Main objectives of reuse were:

- Utilization of the treated wastewater as resource for nutrients and irrigation water
- Utilization of treated sludge as organic fertilizer in agriculture

For small and decentralized wastewater treatment systems, agricultural irrigation can be an attractive alternative for reclaimed water reuse. Irrigation water quality considerations (category/class of treated water), long-term effects on agriculture and annual crop production (yield) will be investigated and optimized within the frame of this research work.

Treated wastewater quality was defined by the Jordanian Ministry of Water and Irrigation (MWI) in the standards for the quality of irrigation water and treated sludge (as fertilizer). Table 5.3 shows the allowable limits (standard values) for the reuse of treated wastewater in Jordan.
According to the Jordanian standard (JS893/2006), it is not allowed to:

- Discharge any raw sewage into the environment.
- Irrigate crops, which are eaten raw, with treated effluent regardless of water quality.
- Irrigate crops that are eaten cooked unless the faecal coliforms are less than 1000/100 ml and the nematode eggs count is less than 1/liter
- Irrigate crops and trees (including fruit trees) which are exposed to animal feed
- Use sprinklers for irrigation except for golf courses

Table 5.3
Allowable limits for the reuse of treated wastewater in Jordan (MWI 2006)

Parameter	Unit	Cooked Vegetables, Parks, Playgrounds and Sides of Roads within city limits	Fruit Trees, Sides of Roads outside city limits, and landscape	Field Crops, Industrial Crops and Forest Trees	Water discharge to wadies, streams and water bodies	Artificial recharge of groundwater aquifers
		A	B	C		
Biological Oxygen Demand	mg/l	30	200	300	60	15
Chemical Oxygen Demand	mg/l	100	500	500	150	50
Dissolved Oxygen	mg/l	>2	-	-	>1	>2
Total suspended solids	mg/l	50	150	150	60	50
pH	unit	6-9	6-9	6-9	6-9	6-9
Turbidity	NTU	10	-	-	-	<2
Nitrate	mg/l	30	45	45	45	30
Total Nitrogen	mg/l	45	70	70	70	45
Eschericia Coli	MPN or CFU*/100 ml	100	1000	-	1000	<2.2
Intestinal Helminthes Eggs	Egg/l	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1

*Most probable number or colony forming unit

Reclaimed wastewater reuse in agricultural irrigation can be demonstrated or applied to a broad variety of crops including industrial crops (wood trees, olive), grasses, forest trees (pine, oak), field crops (forages, grains, fibres), fruits, vegetables etc.

Therefore, the objectives of the research activities were to develop and combine site-adapted technologies in the field of Decentralized Wastewater System Solutions that integrate wastewater and sludge treatment and reuse, with special emphasis on demonstration, technology transfer and capacity building. Special focuses were laid upon the operational safety as well as the requirements on higher effluent quality for irrigation water.

5.4.2 Methodology

A specified research program was carried out to adapt the technologies to the site-specific conditions and to evaluate different technologies in terms of cost, hygienic treatment and salinity, in order to meet Jordanian standards of treated wastewater reuse into the fields of application. Specific conditions were the climate (distribution of rainfall and temperature) and the quality of the raw wastewater.

The scientific and technical supervision were carried out by the UFZ, the Al-Balqa Applied University (BALQ), along with the collaboration of ATB Environmental Technologies GmbH and HUBER SE, especially for the optimization and dissemination phase.

Since September 2009, a continuous monitoring (wastewater sampling and analysis) program and operation & maintenance (O & M) tasks were carrying out by the Al-Balqa Applied University and the laboratories of the Water Authority of Jordan (WAJ) for evaluating the irrigation water and sludge quality. Specifications of irrigation water quality have been shown in Figure 5.19.

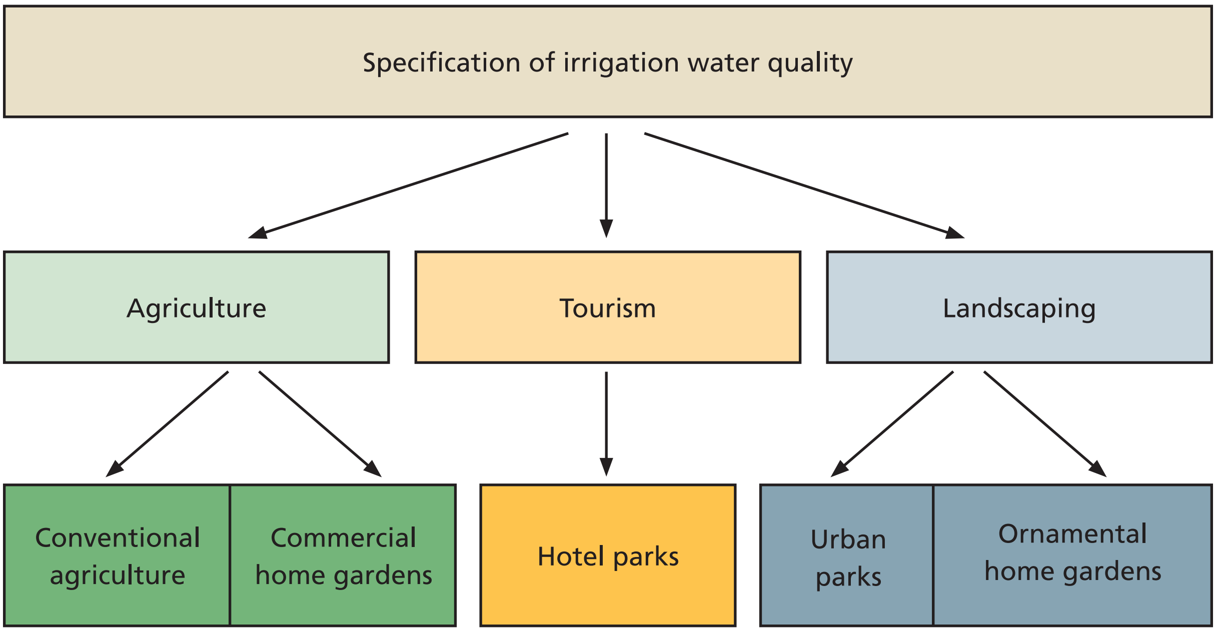

Figure 5.19
Specification of irrigation water quality

The monitoring program aims to demonstrate the feasibility of technologies by characterizing different physical, chemical and microbiological parameters of treated wastewater and sludge, which comply with the Jordanian standards and guidelines for reuse in agriculture. After the start-up phase of all the technologies, a continuous monitoring program was carried out by the laboratories of Al-Balqa Applied University and the Water Authority of Jordan (WAJ) on weekly routine basis.

The monitoring program was divided into three sections: start up, optimization (evaluation I), and stable operation (evaluation II). Within each of these sections the sampling points, the sampling frequency and the parameters were adapted to the requirements of the operation phase. The agricultural irrigation fields (research farmlands) were irrigated 2-3 times per week. Along with the wastewater and sludge quality parameters, the monitoring program also included the changes in soil nutrient content (N, P & K), salinity, water and salt balance, yield characteristics etc.

In general, wastewater physico-chemical and microbiological parameters like pH, redox, EC, Turbidity, COD, BOD_5, TSS, NH_{4}-N, NO_{2}-N, NO_{3}-N, TN, PO_{4}-P, TP, *E. coli*, and Intestinal Helminthes Eggs were monitored on a regular basis targeting the quality of Jordanian standard for agricultural reuse. Other parameters like metals (Zn, Fe, Mg, Cu, Cr, Cd, Ni, Pb, As), Cations (Mg^{2+}, Ca^{2+}, Na^{+}, K^{+}), Fat, Oil & Grease, SO_4^{2-}, TDS, TVSS etc. were also monitored simultaneously within the framework of this program.

Sludge physico-chemical and microbiological parameters like dry matter content, Total N, available P, BOD_5, heavy metals, *E. coli*, Intestinal Helminthes Eggs etc. will be monitored within the raw sewage sludge and digested/mineralized sludge. Intensive sampling activities are shown on a prescheduled sampling day at the Fuheis site in Figure 5.20.

Figure 5.20
Wastewater sample collections from different treatment units at Fuheis site

Adaptations to various irrigation water quality (A, B or C) depending on different crops, types, permeability of soil, local climatic conditions, long-term effects on agriculture, annual crop production (yield), salt accumulations (EC) to a harmful level, water and salt balance etc. will be investigated and optimized within the frame of this research work in different agricultural test site at Fuhies.

Intensive sampling and analysis of wastewater samples from different treatment systems started in August 2009. Sampling frequency and locations, parameters, and types of analysis were designed according to the monitoring purposes and thus the overall treatment performance of each technology can be optimized during each monitoring phase.

5.4.3 Results

Analytical methods for analyzing the selected parameters are not yet completely established. Due to some logistical and technical difficulties, not all the parameters defined in the monitoring program could be reliably measured until the end of the reporting period. Therefore, this report is not covering all the detailed analytical results of different parameters as mentioned in the monitoring program for wastewater and sludge quality measurement. Only some of the important parameters from the influent and effluent of different technologies have been briefly discussed here. A complete data set of all the analytical results collected from well established analytical methods will be obtained at the end of the proposed monitoring program at Fuheis site and it is planned to publish the results in different scientific journals in future.

5.4.3.1 Sequencing Batch Reactors

Preliminary analytical results from the sequencing batch reactors showed that all three treatment units SBR-UV, CBR and conventional SBR performed well with a high removal efficiencies (>90%) of COD and BOD5. A mean COD value of 627 ± 108 mg/L in the raw wastewater influent decreased to a mean value of 48 ± 12 mg/L in the effluent of SBR-UV treatment unit, which attributed to a mean COD-concentration reduction of 92%. According to the Jordanian standard, the allowable

COD limit value for category 'A' irrigation water is 100 mg/L. Therefore, this technology is showing high quality in terms of effluent COD concentration, which is well below the allowable limit value for a high quality irrigation water.

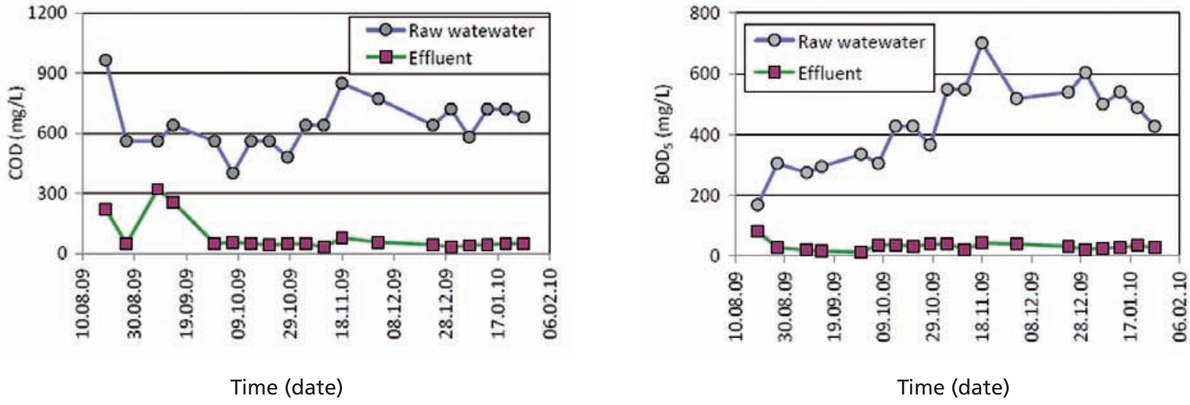

Figure 5.21
Inflow and outflow concentrations of COD and BOD5 in SBR-UV unit

Similarly, a mean BOD5 concentration of 436 ± 123 mg/L in the raw influent was decreased down to a mean value of 30 ± 10 mg/L, which showed a concentration reduction of nearly 93%. Allowable BOD5 limit value for category 'A' irrigation water is 30 mg/L in Jordan. These results are shown in Figure 5.21.

Allowable limit value of TSS for category 'A' irrigation water is 50 mg/L, which is the most suitable for the drip irrigation systems in Jordan. In SBR-UV treatment system at Fuheis site, a mean TSS concentration of 248 ± 135 mg/L in the raw influent was decreased to a mean TSS value of 34 ± 24 mg/L, with a mean TSS-concentration reduction of 86% (See Figure 5.22). This result from SBR-UV unit also suggested a high quality of treated wastewater effluent as for agricultural irrigation reuse purposes.

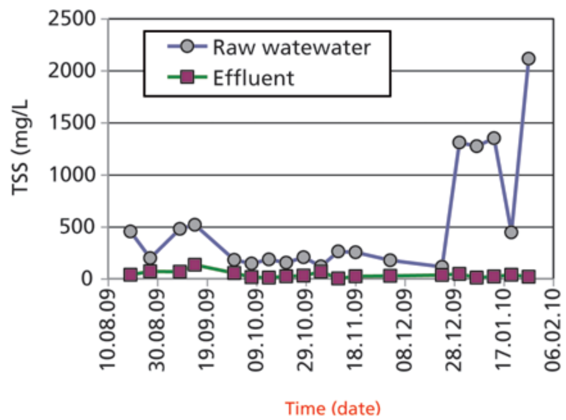

Figure 5.22
Inflow and outflow concentrations of TSS in SBR-UV unit

From the analytical results of NO_3-N and PO_4-P inflow and outflow concentrations, no remarkable changes can be seen and probably it is too early to come to a final conclusion. The monitoring program will continue further and by knowing the complete analytical results of NH_4-N, Total N and

Total P, the performance of the SBR units will be evaluated and will be compared with the other treatment systems that are simultaneously running at the site. The inflow and outflow concentrations of NO_3-N and PO_4-P until the end of January 2010 are shown in Figure 5.23.

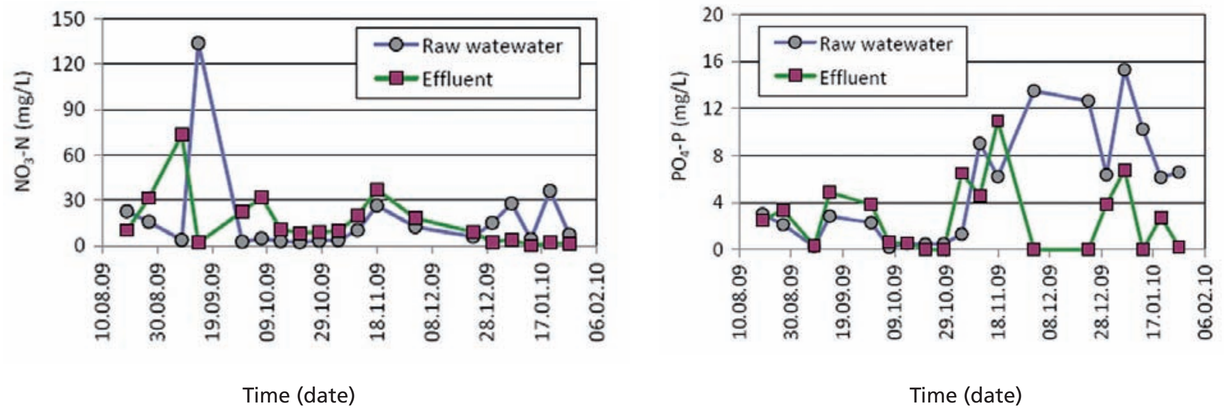

Figure 5.23
Inflow and outflow concentrations of NO3-N and PO4-P in SBR-UV unit

Apart from some small technical problems with the conventional SBR unit at the Fuheis site at the beginning, the other SBR units (SBR-UV and CBR) were apparently adapted to the Jordanian wastewater quality and under the local climatic conditions. More analysis and technical optimization will be continued before drawing any concluding remarks on the treatment efficiency of this particular technology.

5.4.3.2 Soil filter eco-technologies

1) Multi-stage single-pass vertical filter system

Wastewater samples were collected and analyzed from different sampling locations of multi-staged single-pass vertical soil filter system. Raw wastewater was pumped into the septic tank and the analytical results of the effluent showed that a mean value of 41% and 45% of COD and BOD5 was removed from the raw influent after the primary treatment in the septic tank, respectively.

This septic tank effluent goes into the 1st stage vertical filter system as influent for secondary treatment and nitrification. The outflow results from the 1st stage showed significant concentration reduction (>90%) of COD and BOD5 (Figure 5.24). After the 2nd stage of the treatment system, the mean concentration of both COD and BOD5 were decreased down to 41 ± 12 and 26 ± 12 mg/L, respectively. These values are well-below the allowable limit value of category 'A' treated wastewater in Jordan, which are 100 mg/L and 30 mg/L for COD and BOD_5, respectively.

Two denitrification tanks were used for the removal of nitrogen from the 1st stage effluent before flowing into the 2nd stage vertical filter system, which was operated for pathogen reduction and further polishing. Analytical results of NO_3-N showed that a mean value of 38 ± 13 mg/L from the effluent of VF1 was decreased down to 28 ± 6 mg/L after the denitrification midpoint and further decreased to 24 ± 12 mg/L immediately after the 2nd stage VF2 (see Figure 5.25).

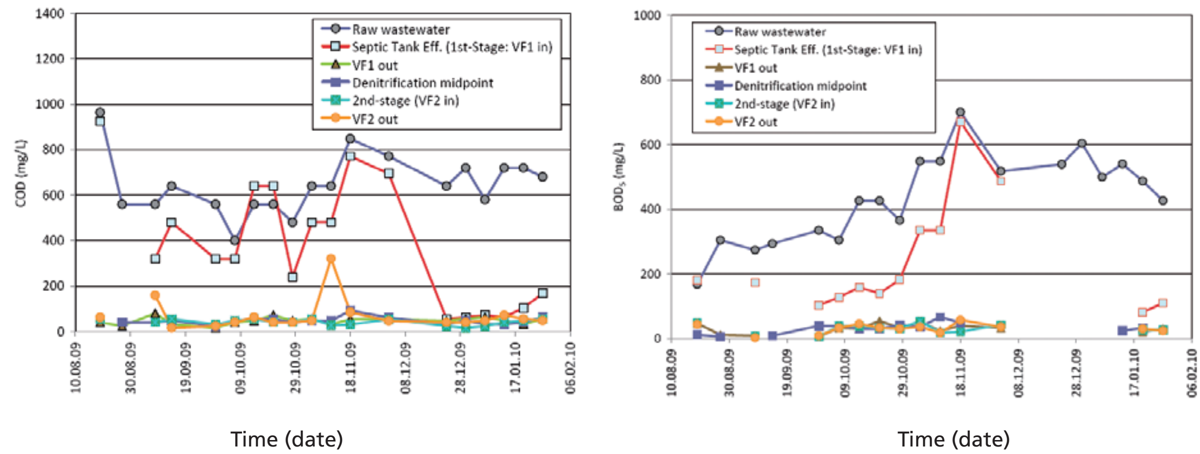

Figure 5.24

Inflow and outflow concentrations of COD and BOD5 in multi-staged single-pass vertical soil filter eco-technology

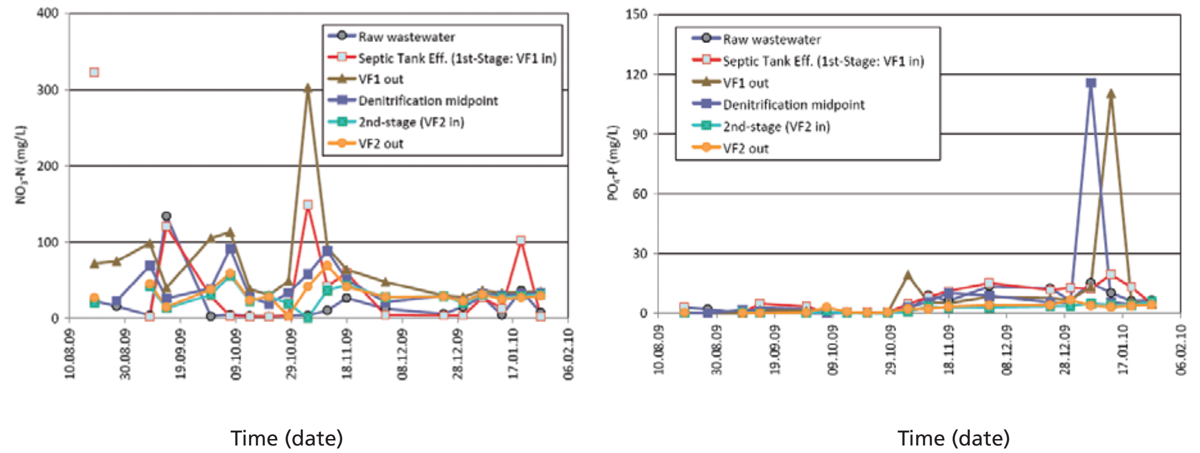

Figure 5.25

Inflow and outflow concentrations of NO_3.N and PO_4.P in multi-staged single-pass vertical soil filter eco-technology

A slightly high accumulation of NO_3.N was observed in the effluent of the VF2, but in principle, significant decrease of NO_3.N concentration was observed in this multi-staged treatment system. Remarkable PO_4.P concentration declination in this system is also shown in Figure 5.25.

Completed analytical results of other physico-chemical and microbiological parameters, specially the plant nutrients (N & P) and E.coli would be included in future for making any further conclusion on the treatment efficiency of such systems under Jordanian climatic conditions and potential of the effluent for agricultural reuse purposes.

2) Recirculating Vertical Filter System

After the septic tank primary treatment, the analytical results showed that a mean value of 42% and 47% of COD and BOD_5 was removed from the raw influent, respectively. This septic tank effluent goes into the recirculation tank for secondary treatment and denitrification. Effluent from the recirculation tank goes into the vertical filter VF3 as influent. A mean COD and BOD_5 value of 35 ± 11 mg/L and 23 ± 15 mg/L in the effluent of VF3 resulted in a mean concentration-reduction of 94% and 95%, respectively (see Figure 5.26).

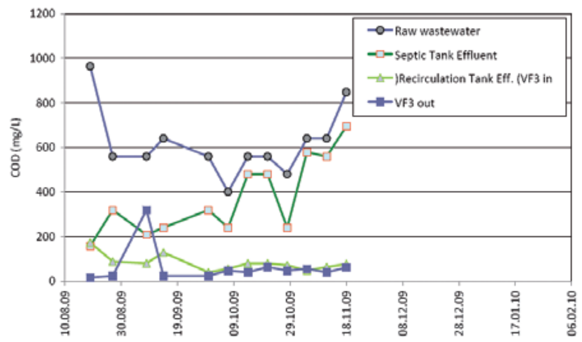

Figure 5.26

Inflow and outflow concentrations of COD and BOD5 in recirculating vertical soil filter eco-technology

The mean COD and BOD5 concentration in the raw wastewater was 627 ± 108 mg/L and 436 ± 123 mg/L, respectively. Since a portion (50 – 85%) of the water leaving the vertical filter is returned to the front end of the recirculation tank where it mixes with the septic tank effluent, therefore a fluctuation of COD and BOD5 removal was observed at the initial phase of operation in the recirculation tank effluent. Nevertheless, the analytical results clearly show that the effluent quality is well below the Jordanian standard for irrigation water in terms of COD and BOD_5 concentration.

Significant fluctuations were observed in the outflow dynamics of both $NO_{3\text{-}}N$ and $PO_{4\text{-}}P$ concentration from the vertical filter VF3 at the end. After the septic tank pre-treatment, high concentration of $NO_{3\text{-}}N$ and $PO_{4\text{-}}P$ was observed in the outlet of recirculation tank and also in the VF3 effluent. The reason might be that more nitrification occurred after the recirculation and hence a high concentration was shown in the outlet. No clear correlation can be observed from the inlet and outlet concentration of both $NO_{3\text{-}}N$ and $PO_{4\text{-}}P$ in this system (see Figure 5.27).

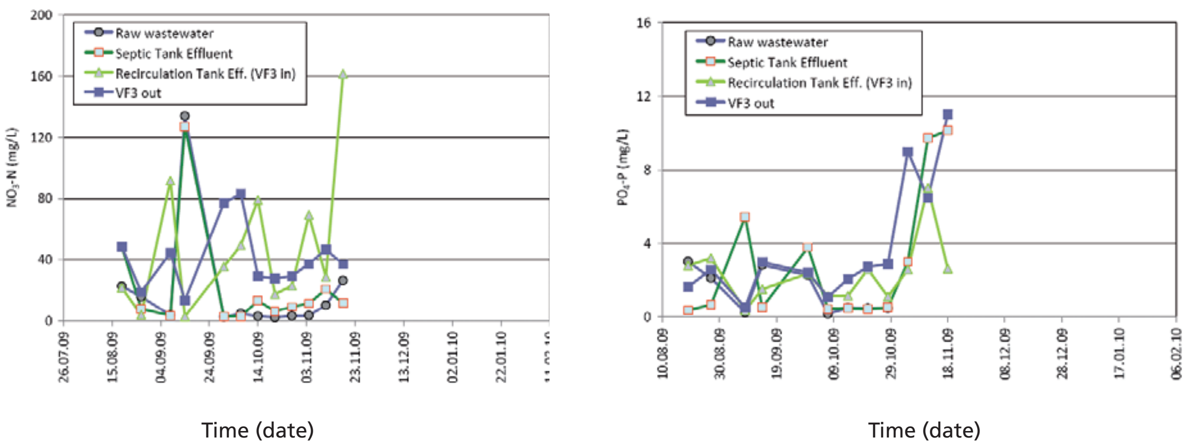

Figure 5.27

Inflow and outflow concentrations of $NO_{3\text{-}}N$ and $PO_{4\text{-}}P$ in recirculating vertical soil filter eco-technology

Completed results of $NH_{4-}N$, Total N, and Total P would be necessary to comment on the water quality results and treatment efficiencies. This will be carried out in the next phase of the project after the corresponding methods are established and a quality control system is installed.Other parameters like *E.coli* counts and Intestinal Helminthes Eggs would also be compared with the Jordanian standard in future.

Therefore, the final assessment on the treatment performances and adaptations of different technologies will be accomplished within the framework of 2nd phase of the project.

5.4.3.3 Anaerobic bioreactor for sludge treatment

After the initial start-up phase of the HUBER Anaerobic Bioreactor container plant in April 2009, it was found that some of the technical re-adjustments were necessary in order to feed the raw sludge into the container plant. After fixing the problem, the system re-started in June 2009 and shortly afterwards due to some electro-mechanical problems within the Hydrolysis level measuring sensor and the control panel, the whole system was shut-down for another couple of months. A new sensor was replaced within this period of time and the whole treatment unit is running again. Therefore, the sludge quality results from the anaerobic sludge stabilization plant are not yet available at the Fuheis demonstration site.

5.4.3.4 Sludge Drying Bed for Sludge Mineralization

Plantation in each bed was carried out in May 2009 and after facing some stressful climatic conditions, the plants were established. The sludge storage and distribution system was re-designed and re-installed replacing the initial project proposal due to some technical reasons. The secondary treated sludge from the nearby WWT plant with a designed hydraulic loading rate (HLR) was distributed to the sludge drying beds for dewatering and mineralization. Sludge distribution will be carried out on a regular basis. Accumulation of total solids in each bed, evapo-transpiration data, water and solid mass-balance results will be collected and will be accomplished in the next phase of this project.

5.4.4 Future research

More advanced training on different technologies and development of further research program will be carried out on regular basis in future. In order to allow a safe reuse, wastewater has to be treated to adequate levels or standards. Safe use refers primarily to the removal of pathogens. This parameter might risk sustainable agricultural production and groundwater quality. Therefore, several other innovative and advanced technologies can be installed in future within the existing framework for better removal of pathogenic microorganisms from the treated wastewater. For example, the Membrane Bioreactor (MBR) can be used as a combination of biological treatment based on the activated sludge process and separation with Ultra Filtration (UF) membranes. Moreover, new eco-technology design, construction and adaptation will be carried out in the next phase of the project in order to achieve high biological secondary and tertiary treatment efficiencies. Therefore, future research will focus on the fundamental aspects of advanced treatment systems that need to be installed for a high quality treated wastewater for agricultural reuse purposes.

5.5 Proposal and description of other sites (D504)

Compiled by: M. Van Afferden, R. Müller (UFZ)

The results of this working package have already been published in a more detailed report (Van Afferden et al. 2008) which is available on the SMART web page.

5.5.1 Introduction

The key objective of this study was to select sites that offer the highest potential for the future implementation of system solutions for decentralized wastewater treatment and reuse. Therefore, this technical report presents the methodology, findings and recommendations for selecting potential sites for further research on the implementation of Decentralized Wastewater Systems Solutions (DWWSS) in Jordan, especially in the investigation area of the "Lower Jordan Rift Valley".

In particular, the sites should offer:

- reasonable amounts of wastewater to be treated
- a strong potential for replication in the region and nation
- provisions for water reuse
- strong prospects to improve the current situation

5.5.2 Methodology

Site identification was accomplished by applying a stepwise "filtration process" for the three main sectors: rural, suburban and tourism. Based on this filtration, the project team, in close co-operation with the MWI, WAJ and concerned stakeholders, identified potential sites that offer a high potential for the implementation of DWWSS at local level and also for replication in the region and nation. The collected data was included in the GIS-Database and the selected sites were analysed and described in more detail. For the purpose of this report, the definition of "rural" and "urban sector" was taken from the Jordanian Department of Statistics (DOS). In this manner each locality with 5,000 or more inhabitants is considered "urban", the remaining localities are considered "rural" (DOS 2004a).

In the first step, the general potential of the three sectors to implement DWWSS was assessed. Based on the available statistical information, suitable regions were then pre-selected. Figure 5.28 provides the general methodology used for the pre-selection of sector specific regions for the implementation of DWWSS.

In step 2, region specific information was considered and the most promising sites were selected in close collaboration with local stakeholders, key professionals and representatives of MWI and WAJ (Figure 5.29).

In step 3, the selected sites were analysed and described in more detail for further investigations in other working packages of SMART, to finally assess decentralized wastewater treatment and reuse systems that principally may improve the current situation.

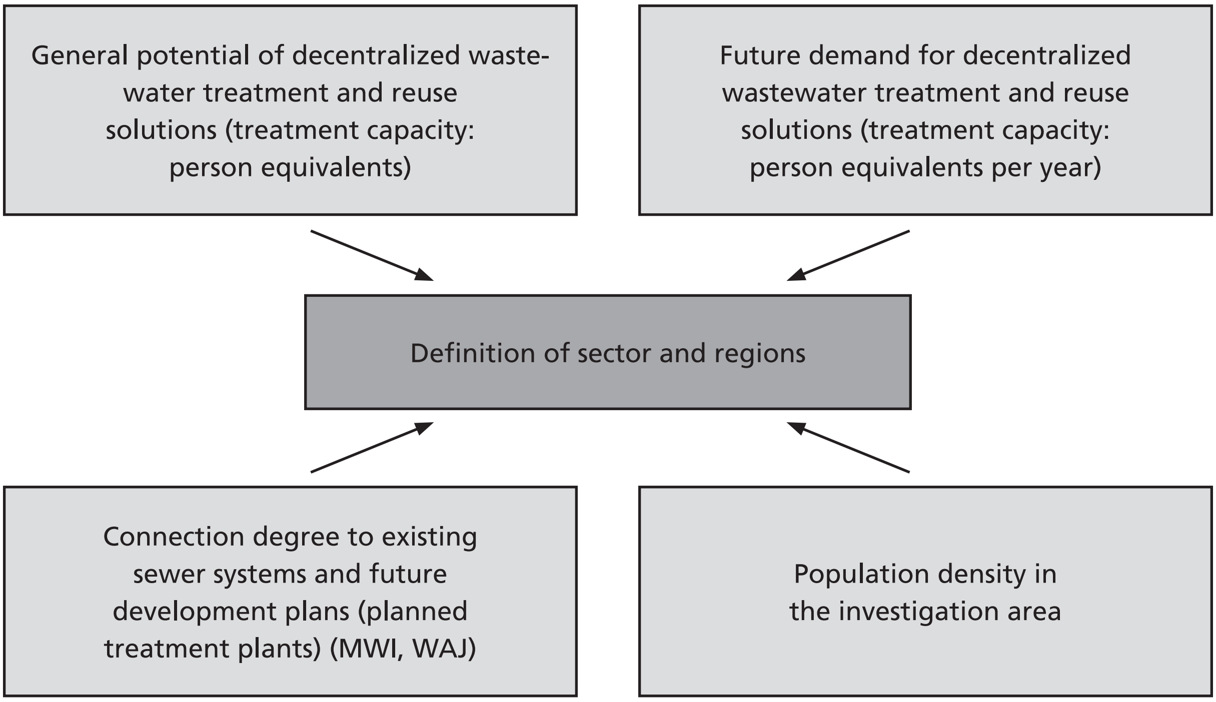

Figure 5.28
Step 1 – Data and information used for the pre-selection of sector specific regions for the implementation of DWWSS (decentralized wastewater systems solutions)

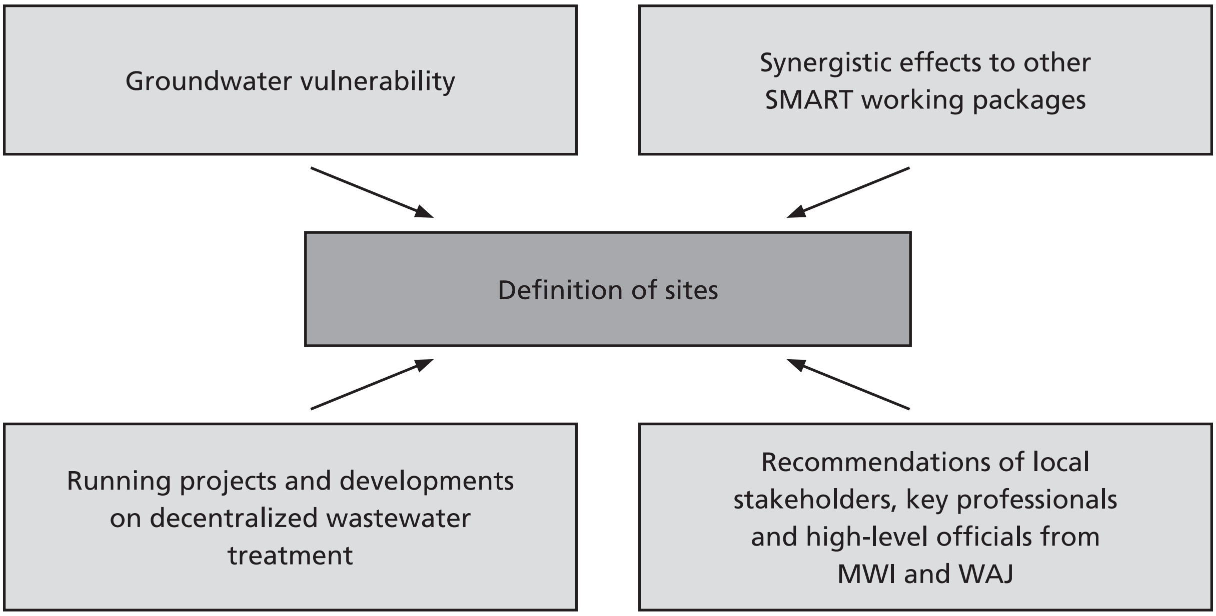

Figure 5.29
Step 2 – Criteria for identifying potential sites for the implementation of DWWSS

5.5.3 Results: Step 1 – Definition of sector and regions

The main outcome of Step 1 was an analysis of the overall potential for implementing decentralized wastewater management systems in the investigation area for the three sectors: rural, suburban and tourism. Furthermore, the regions with the greatest potential for implementing decentralized wastewater treatment and reuse technologies were identified and presented in geo-referenced maps. The key starting point for the selection of potential sites and the assessment of the overall potential for implementing decentralized wastewater treatment and reuse systems in the lower Jordan Rift Valley was the total domestic wastewater generation in Jordan.

5.5.3.1 Rural sector

Small and rural communities often cannot afford expensive wastewater treatment facilities and their population may be too dispersed to make centralized treatment a realistic option. In these circumstances, decentralized wastewater treatment is often the best solution for wastewater management. Most of the small communities in Jordan lack public sewerage services and the rural population mainly depend on improperly designed and inadequately managed on-site wastewater disposal systems. Actually, no clear organizational framework exists to manage appropriate sanitation methods for these small communities. These problems cannot be solved unless the existing treatment systems are upgraded and/or sewer systems are installed.

The available statistical data on "Population and Housing" are structured into 12 governorates and 51 districts, according to the administrative division of Jordan. Since the investigation area was defined by hydro-geological criteria and not by administrative districts, the governorates and districts which are located in the investigation area have been identified. The investigation area as shown in Figure 5.30 above stretches had more than 8 governorates. Out of those governorates, Irbid, Ajlun, Jarash and Balqa were considered to lie completely in the investigation area. For Mafraq, Zarqa, Amman and Madaba, demographic data from those districts were excluded which didn't lie in the investigation area.

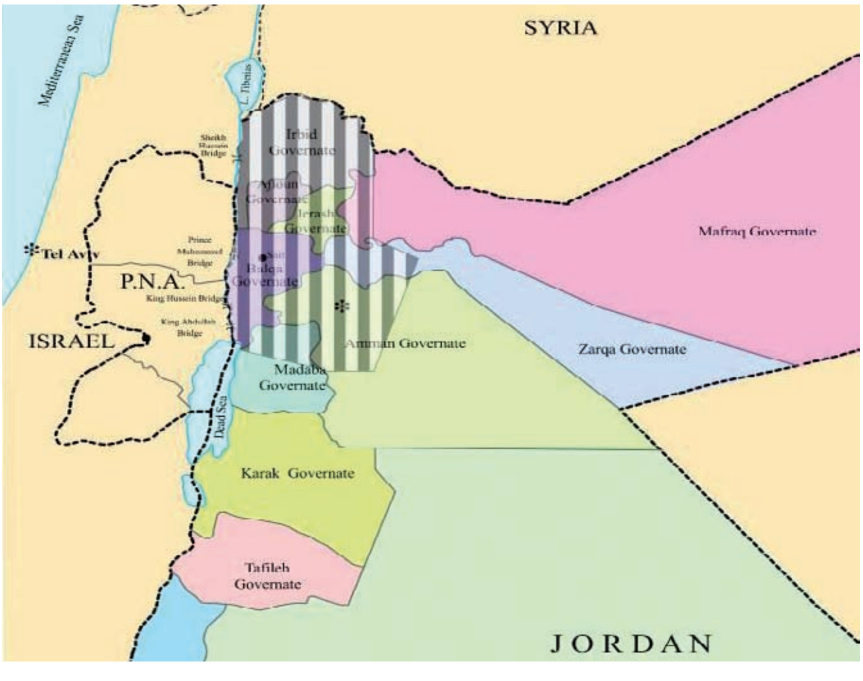

Figure 5.30
Governorates within the investigation area (striped area)

Estimation of the current and future wastewater generation and treatment capacity

The current total wastewater generation and the total treatment capacity of the rural sector were estimated and are shown in Table 5.4. By using an annual population growth rate of 2.5% (The Hashemite Kingdom of Jordan, 2007), the annual increase in wastewater generation and the annual need for treatment capacity were also calculated.

Table 5.4

Estimation of the current wastewater generation, total treatment capacity, the annual increase in wastewater generation and the treatment capacity in the rural sector of the investigation area.

Specific wastewater production	L $person^{-1}$ day^{-1}	**19.8**
BOD5-Person equivalent	g $person^{-1}$ day^{-1}	**25**
Rural population 2007	No.	**551,104**
Connection degree public sewer	%	**5.0**
Population growth rate	%	**2.5**
Total annual wastewater generation	m^3 $year^{-1}$	**3,783,687**
Total annual BOD5 production	t $year^{-1}$	**4,777**
Total treatment capacity to be installed	pe	**523,549**
Annual increase in wastewater generation	m^3 $year^{-1}$	**111,553**
Annual increase in BOD5 production	t $year^{-1}$	**141**
Annual need of new treatment capacity	pe	**15,436**

The objective of the definition of rural regions suitable for future implementation of DWWSS was to condense the results of the sector analysis and to provide decision support for the MWI. The data were included in the GIS-Database, and three regions were defined (Figure 5.31):

- Existing central WWT
- Planned central WWT
- Potential for decentralized WWT

These regions are indicated in light yellow in Figure 5.31 and cover the Lower Jordan River Valley from the Dead Sea in the south to the border with Syria in the north; the region north and east of Irbid and the center of the investigation area with exception of some existing and planned developments in the governorates Ajloun and Jarash.

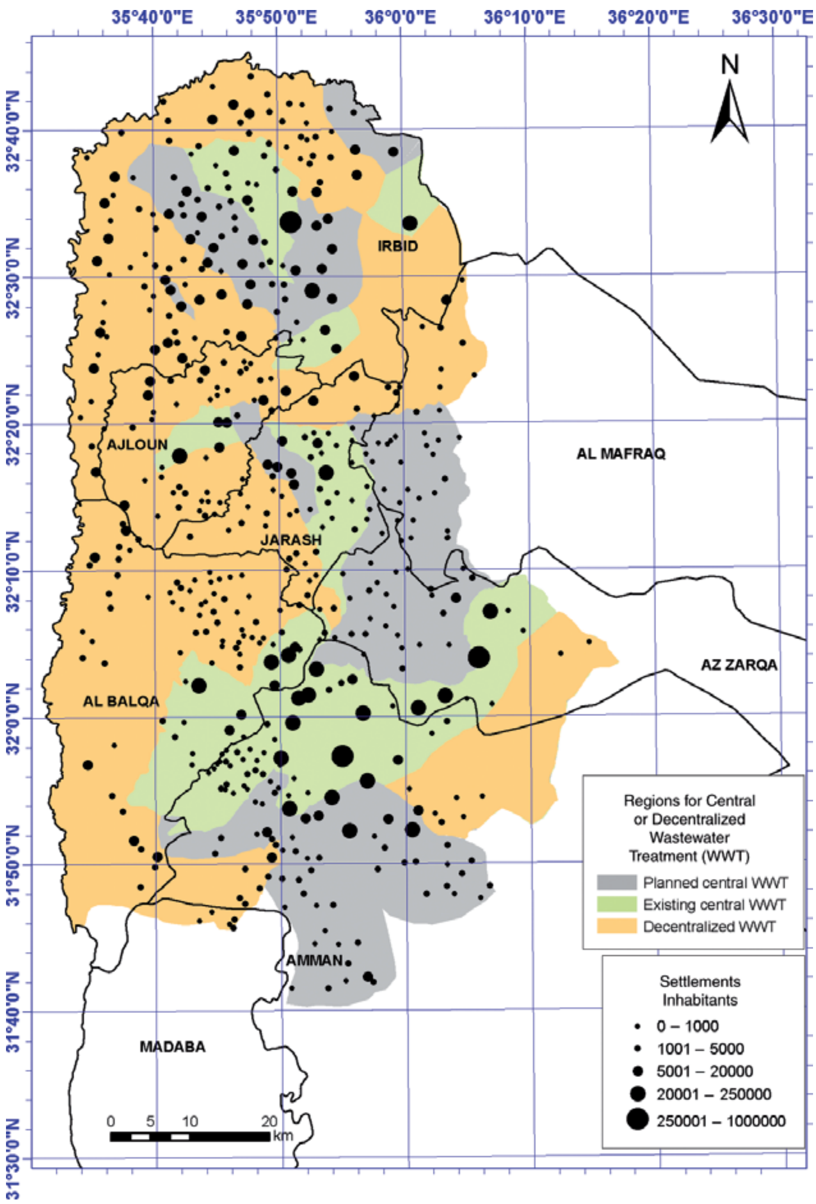

Figure 5.31

Proposed rural regions for future investigations on the implementation of DWWS in the rural sector

5.5.3.2 Urban sector

The urban population in the investigation area was calculated to 4.1 Million in 2007. The 105 urban communities identified, were accounted for 88% of the population in the investigation area and 72% of the extrapolated total Jordanian population in 2007.

Connection degree to existing WWTP

As shown in Table 5.5, the connection degree of the population to the sewer systems in the investigation area was estimated to 69%. For the rural sector, a connection degree of 5% was assumed. For the urban sector, a connection degree of 75% to the existing central treatment plants in the investigation area was calculated by taking both numbers into account.

Table 5.5

Connection degree to existing wastewater treatment plants (WWTPs)

Sector	Connection degree to existing WWTPs (%)
Investigation area	69
Urban sector investigation area	75
Rural sector investigation area	5

Estimation of the current and future wastewater generation and treatment capacity

The annual increase in required wastewater treatment and reuse facilities within the urban sector was estimated to be 2.8 MCM, corresponding to an overall potential of new treatment capacity of 0.11 pe per year (Table 5.6).

Table 5.6

Estimation of the current wastewater generation, total treatment capacity, the annual increase in wastewater generation and the treatment capacity in the urban sector of the investigation area

Specific wastewater production	**L $person^{-1}$ day^{-1}**	65.8
BOD5-Person equivalent	**g $person^{-1}$ day^{-1}**	73
Urban population 2007	**No.**	4,147,611
Connection degree public sewer	**%**	75
Population growth rate	**%**	2.5
Total annual wastewater generation	**m^3 $year^{-1}$**	24,903,293
Total annual BOD5 production	**t $year^{-1}$**	27,628
Total treatment capacity to be installed	**pe**	1,036,903
Annual increase in wastewater generation	**m^3 $year^{-1}$**	2,790,011
Annual increase in BOD5 production	**t $year^{-1}$**	3,095
Annual need of new treatment capacity	**pe**	116,168

5.5.3.3 Tourism sector

It is expected that tourism will emerge as a key driver of Jordan's economy in the future. The Jordan Ministry of Tourism developed the National Tourism Strategy for the period 2004 - 2010 with a private-sector-led perspective on placing tourism as a major income-generating and revenue based sector (UN-DESA 2007). This strategy facilitates the new development of international-style tourist resorts, such as the eastern shoreline of the Dead Sea, also eco-tourism services and nature-based enterprises, such as those in the Dana Nature Reserve in southern Jordan, the Azraq Oasis in the eastern Desert, and the Mujib Reserve next to the Dead Sea.

For the tourism sector, the calculation results in a total annual wastewater generation of approximately 3.2 MCM, which is equivalent to a total treatment capacity of approximately 26,000 pe and comprises with 1.8% to the total annual wastewater production in Jordan (176 MCM). The future annual increase in wastewater production was estimated to approximately 0.11 MCM per year. This is equivalent to new annual treatment capacities of only 900 pe.

5.5.4 Results: Step 2 – Selection of potential sites

On the basis of the results of Step 1, a more specific analysis of the pre-selected areas was carried out with the objective to collect the most promising individual sites for a future implementation of decentralized wastewater treatment and reuse technologies.

5.5.4.1 Rural sector

Groundwater vulnerability
Since the predominant area was characterized by a high to extremely high groundwater vulnerability, the current situation might represent a risk of groundwater pollution by uncontrolled dumping of septage waste or leakage from septic tanks. The implementation of DWWSS might therefore be a feasible solution to reduce the risk of groundwater contamination. The vulnerability analysis of Werz and Hötzl (2007) indicates that about one third of the area shows a high vulnerability of the groundwater. From a groundwater protection and groundwater management point of view, the implementation of DWWSS in the rural area of Wadi Shueib might contribute to the protection of the vulnerable and already contaminated groundwater resources.

Running projects
In 2004, the Water Authority of Jordan proposed a list of 10 candidate regions, for hosting two pilot wastewater treatment and reuse facilities. Four of the proposed candidate regions lie within the investigation area: North Shouneh, Kufr Asad, Humra, Karameh.

Synergistic effects to other SMART working packages
The main SMART activities in Jordan are concentrated in Wadi Al Arab, Wadi Kafrain (including Wadi As Sir and Wadi Naur) and Wadi Shueib. Most of the wastewater and groundwater related working packages are carried out in the Wadi Shueib. From the point of synergistic support within the SMART project team, Wadi Shueib would be a major candidate for the selection of sites for a potential implementation of DWWSS.

Several options have been discussed for selecting villages for further investigation. Finally Ira and Yarqa have been selected as potential sites, mainly due to the facts of existing groundwater contamination, topography and the related SMART activities that are in progress in Wadi Shueib. A third village “Ramah” was selected to represent the villages in the Lower Jordan Valley.

5.5.4.2 Urban sector

The governmental representatives underlined that the suburban sector has a great potential for the implementation of decentralized technologies. From the 26 development projects, four new settlements with housing units for impoverished families have been selected for future investigation. The four settlements are given in Table 5.7.

Table 5.7
Communities for further investigation of decentralized wastewater system solutions (DWSS) in the SMART-project

Name of Project	Village	No. Of inhabitants
Princess Eiman	Salem	8,040
Al Mostanedeh	Abu Alanda	3,350
Abu Alanda	Abu Alanda	6,700
N´qaira	Amman	10,050

5.5.5 Results: Step 3 – Description of potential sites

Brief descriptions of potential sites in both rural and urban sector have been given in the following section:

5.5.5.1 Rural sector
The three villages Ira, Yarqa and Al Rama are situated in the Balqa governorate west and southwest of Amman. In this working scheme, a detailed description of the villages is given, encompassing location, structure, housing, social structure, climate and cropping pattern, wastewater situations etc. Here, for instance, a brief description of the selected ‘Ira’ village is discussed.

Location
Ira is a village that is situated in an undulating region of the Wadi Shueib catchment area. Several side wadis join to the main wadi bed creating multifaceted natural valleys in the vicinity. The compact centre of Ira lies on a hill (Figure 5.32a), which is surrounded by olive trees and little building clusters.

Ira is located 12 km southwest of Al Salt Municipality. Its elevation is 520 to 610 m above sea level. The whole area is approximately 4.4 km2 which is around 5% of the area of Al Salt Municipality. 41% of the area is developed (Figure 5.32b).

Wastewater situation
In Ira, nearly all houses have septic tanks in their backyards. The closest central WWTP with enhanced biological treatment is the As Salt WWTP, which is in a linear distance of 6 km.

Figure 5.32
Village Ira: a) View to the village center & b) topographical map

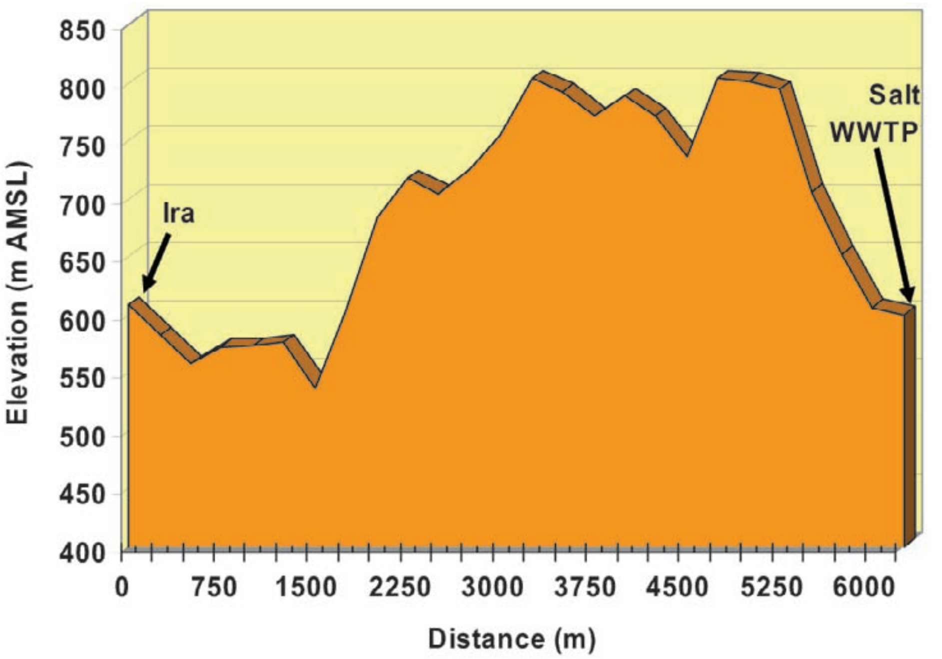

Figure 5.33
Ira: Distance and elevation profile to the As Salt central wastewater treatment plant

Connecting Ira to this treatment plant, which still has a free treatment capacity of 75,000 pe, is hindered by the topography with an elevation difference of 200 m that would require several pumping stations (see Figure 5.33).

5.5.5.2 Urban sector

A brief description of the selected sub-urban region is given. The four sites are located in the southeast of Amman in distances between 8 and 16 km from the centre of the city. A sewage treatment plant called WWTP-A and a trunk sewer system for the region south of Amman were designed in 1999. The selected sites (Princess Eiman, Al Mostanadeh, Abu Alanda and N´qaira) are located within the area of WWTP-A. Nonetheless, the sites are not yet connected to the sewage network of WWTP- A, which allows the development of an alternative wastewater treatment and reuse concept and its comparison with the planned central wastewater project.

5.6 Water and wastewater tariffication in Jordan (D505)

Compiled by: S. Sorge, M. Van Afferden (UFZ)

5.6.1 Introduction and methods

Jordan is known as one of the most water scarce countries in the world (MWI 2007) and faces water scarcity due to an enormous population growth and over-abstraction of water. The water and wastewater sector in Jordan is heavily subsidised by the Government of Jordan, in order to ensure that people in urban and rural areas have a minimum of service. Cross-subsidies between the non-residential and residential sector help paying the water costs as well (MWI 2007). The MWI is the official body for the Jordan water sector. It is responsible for investment decisions, procurement of financial resources and tariff setting for water supply, wastewater collection and re-use of treated wastewater (MWI 2007, USAID 2005b).

Water and wastewater tariffs vary visibly in different sectors such as households, retail, industry and agriculture. Tariffs in Jordan are set to guarantee the minimum needed water consumption at a subsidised fixed price per m³. Customers with a higher consumption subsidise customers with a lower one, assuming that the customer with a higher consumption is wealthier (Taha and Bataineh 2002; Wardam 2007). In its strategy MWI states that the pricing of water shall be differently for different water qualities and end uses. Pricing of water, sewerage and treated wastewater should at least provide for the recovery of operation and maintenance costs (MWI 2007).

Different regions in Jordan need to be distinguished when comparing water and wastewater prices, e.g. Amman, the capital of Jordan, and Zarqa, an industrial town face much higher tariffs than other governorates of the Kingdom. Therefore, the methodology for comparing the water and wastewater tariffication systems in Jordan was realised by the:

- Tariffication in the residential sectors
- Tariffication in the non-residential sectors
- Cost recovery of the water and wastewater sector
- Cost recovery in the framing sector
- Price strategies implemented by WAJ

5.6.2 Results

5.6.2.1 Water tariff (residential sectors)

In Jordan, all governorates employ four tariff blocks for pricing water. The blocks are divided into the following categories 0 - 20 m³, 21 - 40 m³, 41 - 130 m³, 131 - more m³ for Amman; 0 - 20 m³, 21 - 40 m³, 41 - 185 m³ for Zarqa and more than 186 m³ for other governorates. These categories describe the water consumption per household quarterly and, thus, mirroring the billing cycle of water services. The first 20 m³ block of all governorates is not dependent on the quantity of water consumption (Taha and Bataineh 2002). Thus, whatever amount of water a household consumes, a flat rate is being charged. The other remaining blocks are calculated taking the quantity of water consumption into account.

Block pricing

In Amman, water consumption within the first pricing block is approximately 1.5 times more expensive than in other parts of the country (Figure 5.34a). Additionally, in Amman the highest tariff block already starts at an amount of 131 m^3. In Zarqa and other governorates, customers only pay the highest tariff after having consumed 186 m^3 (Figure 5.34b).

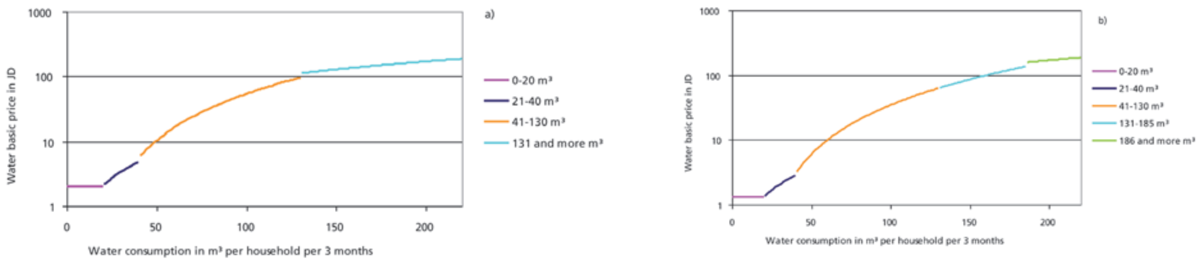

Figure 5.34

Tariff structure of water in a) Amman, b) Zarqa and other governorates (data from Daoud 2004; AWC 2008).

Figure 5.34 demonstrates that the graphs of the different pricing blocks in Amman and other governorates are not including the additional fees. In all governorates, the slope of the graph starts flat and ascends steeply in the second and third pricing block, meaning that the more water is being consumed by the customer the more money has to be paid. In the last pricing blocks, the slope of the curve gets flatter again which has a great benefit for customers with high water consumption. Figure 5.35 demonstrates the comparison of water prices between Amman and other governorates.

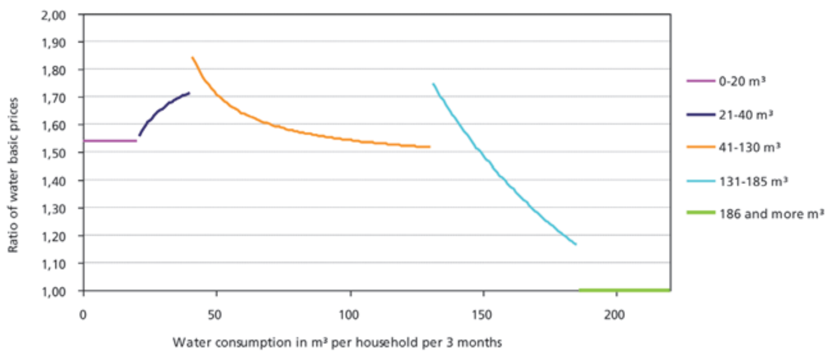

Figure 5.35

Comparison of water prices between Amman and other governorates (data from Daoud 2004; AWC 2008).

Additional permanent charges

Besides the pricing blocks, additional permanent charges are applied to the water tariffication scheme in Jordan. Fees for water meters and an extra surcharge are added to the quarterly water bill of the customers. In addition to the components that are charged with the water bill, there are other fees that need to be paid on certain occasions, including water meter moving, water subscription, complain of water consumption, restoring disconnected water supply, etc.

5.6.2.2 Wastewater tariff (residential sector)

In comparison with the water sector, the wastewater tariff is also organised in increasing volumetric block pricing. Similarly to water, there are three different price categories for wastewater in Jordan: one for Amman, one for Zarqa, and one for the rest of the country.

Block pricing

While the highest wastewater tariff block already starts at a quarterly wastewater production of 131 m³ per household in Amman, the highest pricing block only starts at a wastewater quantity of 186 m³ in Zarqa and other governorates. In all cases the first pricing block is a flat rate. Figure 5.36 a & b illustrate the ratios of the wastewater prices between Amman and Zarqa and also Amman and other governorates. Remarkable is that, customers in Amman with a wastewater generation just above 130 m³ and thus being categorised within the fourth pricing block, pay 1.7 times as much as those in Zarqa and even almost the double of customers in other governorates in Jordan.

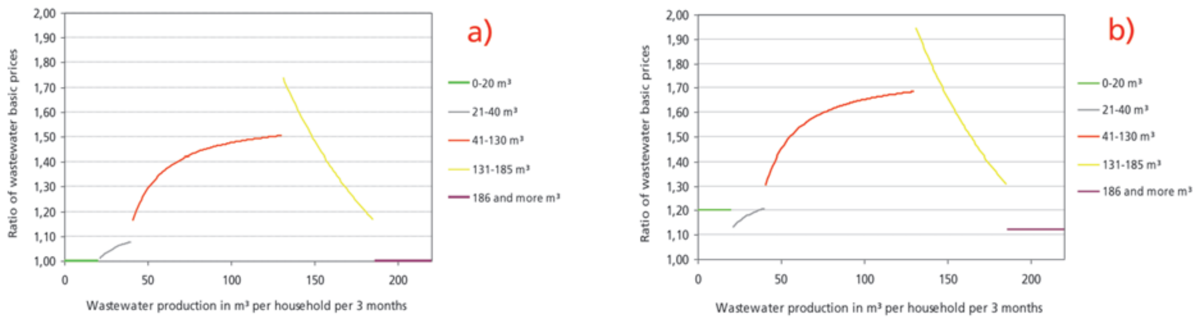

Figure 5.36

Comparison of wastewater prices between a) Amman & Zarqa and b) Amman & other governorates (data from Daoud 2004; AWC 2008).

Cesspits, septic tanks

In rural areas, households are rarely connected to sewerage systems. Mostly there are cesspits or septic tanks installed. They continuously need to be emptied and, thus, create maintenance costs. A cesspit is estimated to cost around JD 600 (ECODIT/IRG 2004 in USAID 2005b). Construction costs may vary extremely, depending on storage capacity, ground and soil conditions.

Other fees

Similar to the water tariffication, there are also other fees in the wastewater sector that need to be disbursed on certain occasions. Those includes: an annual sewage tax, connection to the sewage system application fee, etc.

5.6.2.3 Tanker tariff (residential sector)

Countrywide, there are mostly rural regions where either water supply or wastewater disposal can only be assured by using tankers. These tankers may be run by individuals or companies. A few septage tankers are also operated by the municipality (USAID 2005).

Water tanker
A rationing program has been running since 1988 in Jordan. Many households only receive water once or twice per week for 12 to 24 hours during summer time. The water is stored in citizens' private roof tanks (Abdalla et al. 2004, Abu-Madi 2004). The price for the additional water delivery amounts JD 1.5 per m³ (Wardam 2007). Abdalla et al. (2004) and Taha and Bataineh (2002) give the price for water delivery by private tankers at a regulated amount of JD 2.0 per m³ in Amman and JD 1.75 per m³ outside of Amman. Studies show that 2.3% of the income of the families in Amman is spent on water during winter time and 4.6% in summer. These costs include the delivery by water tanks and indirect costs such as tanks on the roofs and pumping costs. In rural areas, costs amount 1.5% in winter and 2.3% in summer time (Taha and Bataineh 2002).

Septage tanker
Rural based households, which use septic tanks or cesspits, need to clear them on a regular basis in order to prevent overflow. Usually, septage tankers that are run by companies or individuals pump these cesspits out. WAJ is responsible for the registration and regulation of all private tankers upon payment of a JD 100 deposit. Tanker drivers pay a monthly fee of JD 20 to receive the permit to dump their sludge at a wastewater treatment plant operated by WAJ (USAID 2005b). This price is the same throughout the country. Families pay between JD 10 to 30 for the tanker driver for pumping their cesspits and septic tanks. In another USAID (2005) study, the costs for emptying cesspits are given in a range of JD 20 to 45 per trip. In Shobak, it is reported that households pay between JD 5 and 25 for this service, depending on the travel distance of septage tankers (USAID 2005). In case the cesspit of a household overflows, WAJ charges JD 55 (USAID 2005b).

5.6.2.4 Water and wastewater billing

A summarized picture of the annual water and wastewater expenses for a household in an urban area is given in Table 5.8. Assuming a household with average water consumption and size, the annual water and wastewater tariff can be calculated accordingly. Water and wastewater expenses are then compared with the annual income of the household.
The entire SMART project area encompasses eight domains. The current working scheme (D505) of SMART was focussed on the Balqa governorate and three of its villages (D504, "Proposal of other sites"). In this area, the average household size is 6 persons with an average annual income of JD 2,663.40 per family (DOS 2003). Taking into account the rural character of the studied villages, the annual income of JD 2,377.70 can be adopted. In Balqa, the total annual water bill of a family with 6 persons per household is approximately JD 69. Around 2.6% of the annual income is spent on water and wastewater (Table 5.8).

Calculating the same scenario for an average household in a rural area without sewerage connection in Balqa governorate, a completely different picture is drawn. Assuming a cesspit needs to be reconstructed and maintained regularly, the water and wastewater expenses of such a family can amount JD 250 annually which is more than 10% of the annual average income (Table 5.9).

Table 5.8

Annual water and wastewater expenses for a household in an urban area in the Balqa governorate

Balqa urban (sewerage)	Value	Unit	Income in JD per year	Expenses in JD per year	Literature
Labour		JD	2,663.40		DOS (2003)
Water consumption					
		86.00	Lpcd		
		46.44	m³/3 months		24.54
Wastewater					
Flat tax sewerage	9.00	JD/year		9.00	depends on location
Production	46.44	m³/3 months		15.06	
Sewer connection (25 years usage) real estate value (Zone B)	25% of 200 m²	JD/25 years		20.00	
Total			2,663.40	68.60	
					2.58%

The goal of the World Bank is to spend less than 5% of the annual family income on water and wastewater services (World Bank 1997). It becomes clear that rural areas have annual expenses that exceed this recommendation by far.

Table 5.9

Annual water and wastewater expenses for a household in a rural area of the Balqa governorate

Balqa rural (cesspit)	Value	Unit	Income in JD per year	Expenses in JD per year	Literature
Labour		JD	2,377.70		DOS (2003)
Water consumption					
		86.00	Lpcd		
		46.44	m³/3 months		24.54
Wastewater					
Flat tax sewerage	9.00	JD/year		9.00	depends on location
Cesspit pumping	13.00	JD/month		156.00	USAID (2005b)
Cesspit costs (assumption: 10 years usage)	600.00	JD/10 years		60.00	USAID (2005b)
Total			2,377.70	249.54	
					10.49%

5.6.2.5 Water tariff (non-residential sectors)

At present, there are two blocks, one up to 5 m³ and the other one above this. In all governorates, industry and retail pay the same rates for water, namely, JD 1 per m³. Non-residential customers also have to pay additional fees such as meter fees and an additional surcharge. While the meter fee is the same for all clients, the additional surcharge amounts JD 0.5 for the first pricing block and JD 1 for the second block except of Amman where industry and retail customers have to pay JD 1.5 (AWC 2008).

5.6.2.6 Wastewater tariff (non-residential sectors)

The wastewater tariff is JD 0.5 per m³ throughout the country, except for the two big cities Amman and Zarqa. In those cities, charges are 12% higher than in the rest of Jordan where JD 0.56 per m³ wastewater has to be paid (Daoud 2004; AWC 2008).

5.6.2.7 Cost recovery of the water and wastewater sector

In the water strategy of MWI (2007), cost recovery of the water and wastewater sector is explicitly aimed at. Operation and maintenance (O&M) costs need to be fully recovered. Furthermore, it shall also recover the capital costs. MWI (2007) states, that more private capital will be introduced to the water projects. Until full cost recovery is reached, MWI (2007) claims that projects are financed by concessionary loans, private borrowing and/or in form of public-private-partnership arrangements.

5.6.2.8 Operation and maintainance (O&M) and full cost recovery

The O&M costs of the water sector in Amman are 20% higher (JD 0.56 per m³ billed) than in other governorates (JD 0.45 per m³ billed). Based on the actual supplied volume of water, the numbers decrease to JD 0.29 per m³ for Amman and to JD 0.23 per m³ for other governorates (Abdallah et al. 2004). Taking into account that more water is supplied than actually billed, it becomes clear that water utilities in Jordan have big trouble recovering their costs.

In case of water, full cost recovery is only achieved countrywide with a water consumption of 131 m³ quarterly. In case of wastewater, costs are fully recovered with a consumption of 131 m³ for Amman, unlike other governorates where only slightly more than half of the costs reach full recovery. The first pricing blocks in both water and wastewater sector do not even recover O&M costs. Figure 5.37 shows the O&M and full cost recovery for water consumptions of 20 m³ and 131 m³ quarterly in Amman, Zarqa and other governorates.

The following conclusion can be derived from these figures. Although Zarqa has only a third of Amman's water consumption (34.4 compared to 94.1 MCM in 2002) and much less inhabitants (838.7 compared to 2,027.7 thousand), in both tariff blocks O&M and full cost recovery rates are similar or even higher. This is contrary to the wastewater sector (Figure 5.38) where it is clearly shown that both tariff blocks reach a higher O&M and full cost recovery in Amman than in the rest of the country.

Summarising, in Jordan full cost recovery for water is at around 70% and for wastewater approximately 102%. Considering both sectors, full cost recovery reaches 78% (EcoConsult 2008).

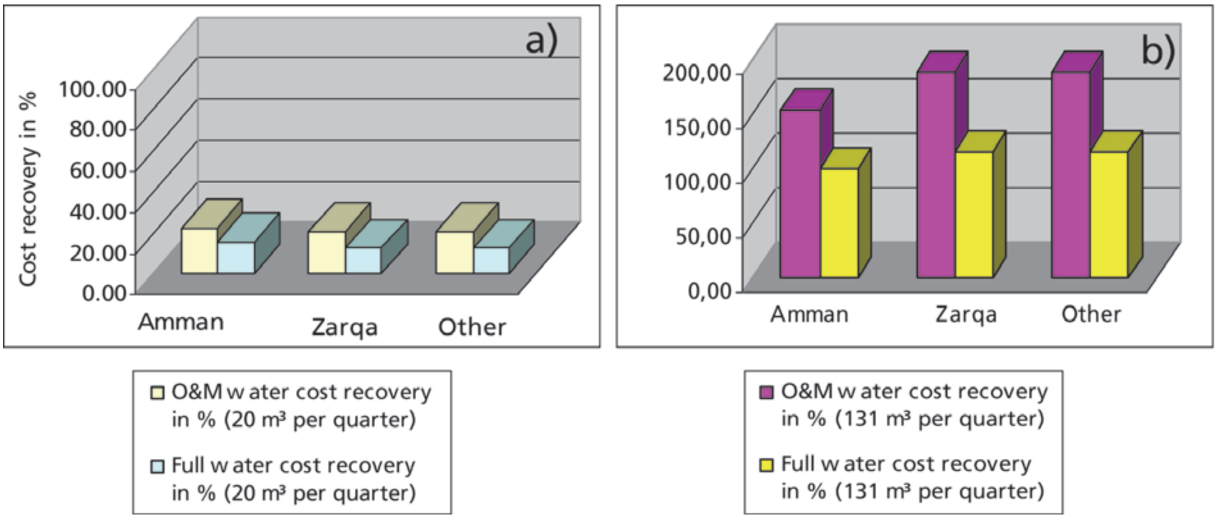

Figure 5.37

O&M and full water cost recovery for the consumption of a) 20 m³ per quarter, b) 131 m³ per quarter

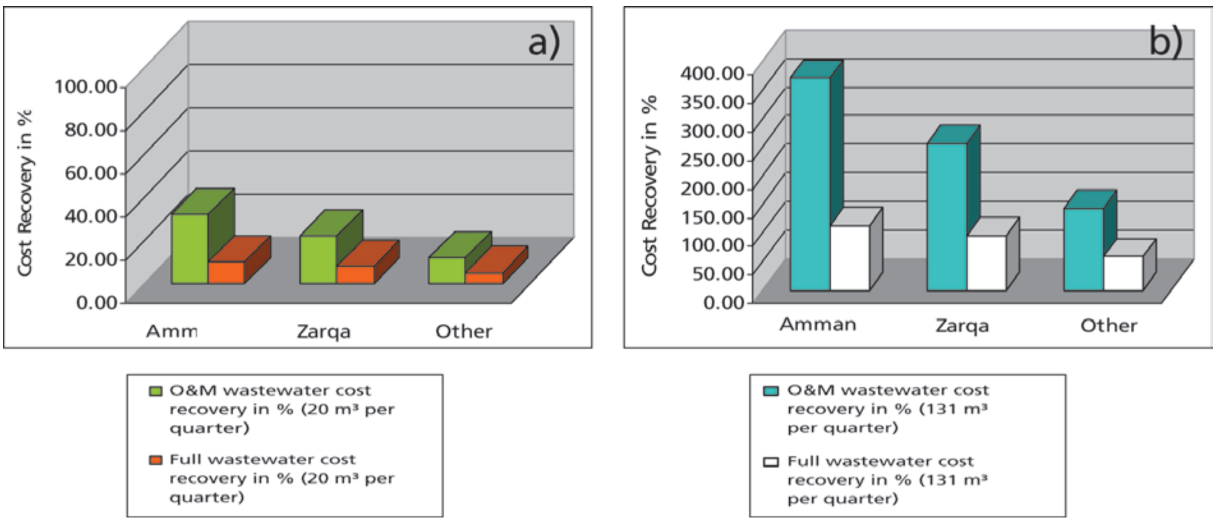

Figure 5.38

Operation and maintainance (O&M) and full wastewater cost recovery for the consumption of a) 20 m³ per quarter, b) 131 m³ per quarter

Table 5.10

Distribution of total revenues and retail revenues (MWI et al. 2004) [* prognosis]

Item\Year	1998	2002	2006*	2010*
% of water billed by residential sector	77%	85%	86%	87%
% of water billed by non-residential sector	23%	15%	14%	13%
% of water revenue to total revenue	62%	58%	63%	64%
% of wastewater revenue to total revenue	30%	34%	31%	31%

Revenues

MWI et al. (2004) summarise the distribution of MWI's revenues in Table 5.10.

In the last ten years the percentage of water which was billed by the residential sector constantly increased. In parallel, the water billed by the non-residential sector decreased, diminishing the subsidising character of the residential sector. MWI et al. (2004) also show that the percentage of the water revenue is still twice as much as that of the wastewater revenue.

5.6.2.9 Cost recovery in farming sector

The cost recovery in the farming sector is discussed by MWI (2007) explaining that irrigation water is an economic commodity with a social value. Since it provides food and employment, agriculture enjoys governmental support in form of subsidy and tax exemptions (MWI 2007). In spite of these preconditions, MWI (2007) also strives for the recovery of operation and maintenance costs with irrigation water prices. It even states that parts of the capital costs are supposed to be recovered aiming for full cost recovery.

5.6.3 Future research

The second project phase sets out to pre-select a first set of site specific (for sites selected in D504) financing and operation models for adapted treatment and reuse technologies. Against this background, the expected degree of cost recovery will be estimated, with a view to three main categories of costs, namely financial costs, operating costs, and as far as possible environmental & resource costs. On the basis of this analysis, detailed indicators for the later assessment of cost recovery for the feasible scenarios and target groups will be defined. On the basis of the status quo analysis, the third phase of the task focuses on the future implementation of appropriate operating and financing models for the proposed sites and decentralized system solution. Finally, a selection of potential operating and financing models will be made and a new cost-recovery tariffication system will be suggested for each selected site.

6 TOOLS FOR SCENARIOS

Involved Institutions: EWRE, UG, UT, UFZ
WP-Speaker: J. Bensabat (EWRE)

6.1 Introduction

A number of activities took place in this work-package, including:
- Local model of the eastern side of the study area, from the Dead Sea to Karameh (UG);
- Local model of Wadi Kafrein (UG and the O. Kolditz group (UFZ));
- Local model of Wadi Qilt/Wadi Nueima (UFZ);
- Local model of Wadi al Arab (UFZ);
- The development of the computational trans-boundary model (EWRE);
- Testing multi-processor technologies for speeding up the computational times (EWRE).

In the following sections, we shall present the work carried out so far, the achieved results and the work that remains to be performed.

6.2 Description of work and results

6.2.1 Local transient 3-D GW-flow model in the lower Jordan Valley, Jordan: the unconsolidated aquifer on the eastern side of the Jordan River between the Dead Sea and Karameh

Compiled by: M. Toll, M. Sauter (UG)

The purpose of the local model developed by UG is to estimate the available groundwater resources in the unconsolidated aquifer, between the Dead Sea and Karameh and to suggest sustainable modes of aquifer exploitation, from both quantity and quality aspects and to estimate their sensitivity to the impact of climate change. To this end, a three dimensional computational model of this area was constructed. A detailed description of the activities that were undertaken is provided below.

An integrated approach, combining geological, geophysical, hydrogeological, historical, and chemical methods was adopted, in order to satisfactorily represent the complex hydrogeology (Figure 6.1). The aquifer geometry and composition is described with the help of geological, hydrochemical, and geophysical methods. As far as the water budget is concerned, the recharge to the considered aquifer is estimated with geological methods and available data sets, while the abstraction from the aquifer is estimated with the help of remote sensing techniques. A historical approach is used to detect the general conditions under which the groundwater system has been in the past. Afterwards, this information is implemented into a flow model.

On the basis of the findings we developed a numerical 3D-transient-model integrating all important features of the hydrogeological system (Figure 6.2). To this end, we used the FEFLOW finite element code (FEFLOW 5.2, WASY Ltd.). Input parameters were mostly pre-processed by the ArcGIS 9.2 software package (ESRI Ltd.).

Calibration runs were carried out for the time period 1955 - 2008, in order to identify the values of the relevant hydraulic parameters of the model. During this time period we identified a number of stress periods, including periods of intense rainfall, of drought, and of anthropogenic impacts, like building of storage dams and military conflicts.

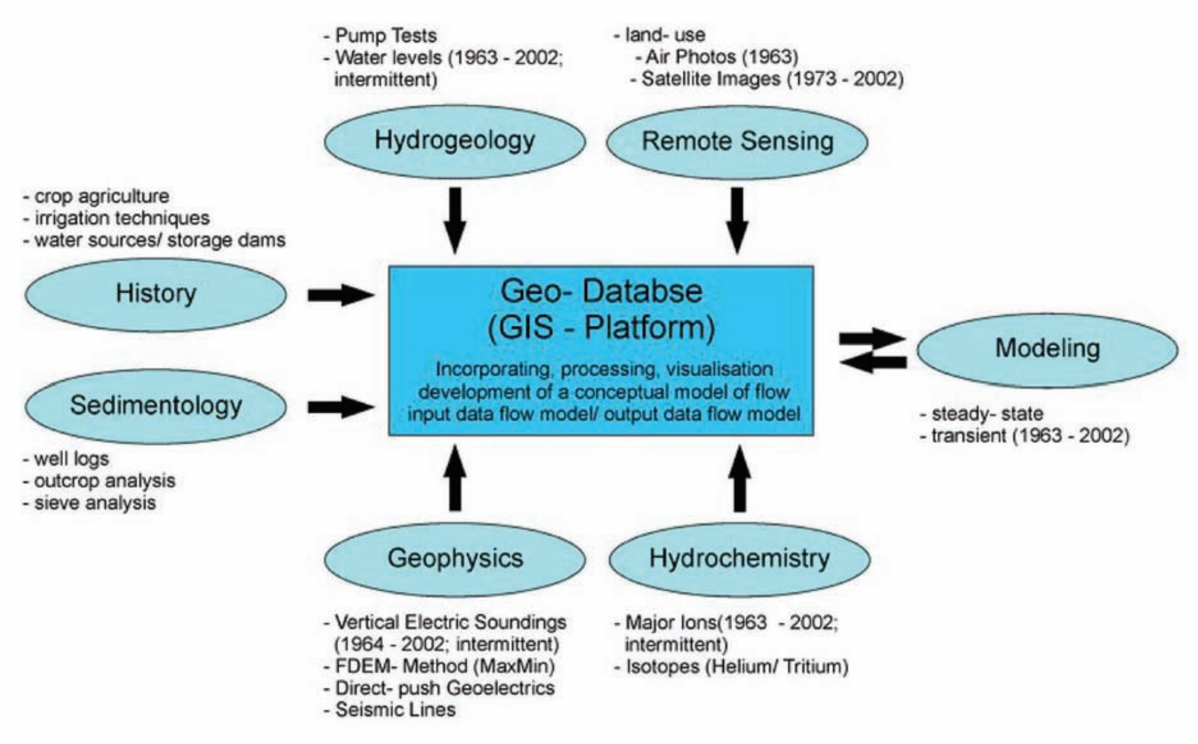

Figure 6.1

Incorporation of the information of previous chapter into a geodatabase. With the help of the information gathered in the geodatabase a flow model is set up. The results of the flow modeling are stored afterwards in the same geodatabase.

6.2.2 Groundwater resources in western Jordan: a hydrogeological investigation of the influence of complex geological features on groundwater flow paths and storage in the Wadi Kafrein area, Jordan

Compiled by: M. Toll (UG), M. Sauter (UG), O. Kolditz (UFZ)

The Jordan Valley is a part of the Jordan-Dead Sea-Wadi Araba-Rift Valley, which extends from the Red Sea to Lake Tiberias and beyond with a major 107 km sinistral strike-slip fault between the Arabian plate to the east and the northeastern part of the African plate to the west. Due to extensional forces a topographic depression was formed. As a result of an arid environment it was filled with evaporites, lacustrine sediments, and clastic fluvial components. A subtropical climate with hot, dry summers and mild humid winters with low amounts of rainfall provide excellent farming conditions. Therefore, the Jordan Valley is considered as the food basket of Jordan and is used intensively for agriculture. As a result, hundreds of shallow wells were drilled and large amounts of groundwater were abstracted since groundwater is the major source for irrigation. Consequently, groundwater quality decreased rapidly since the sixties and signs of over-pumping and an increase in soil salinity were evident. In order to achieve a sustainable state of water resources and to quantify the impact of climate change on water resources, a proper assessment of the groundwater resources as well as their quality is a prerequisite.

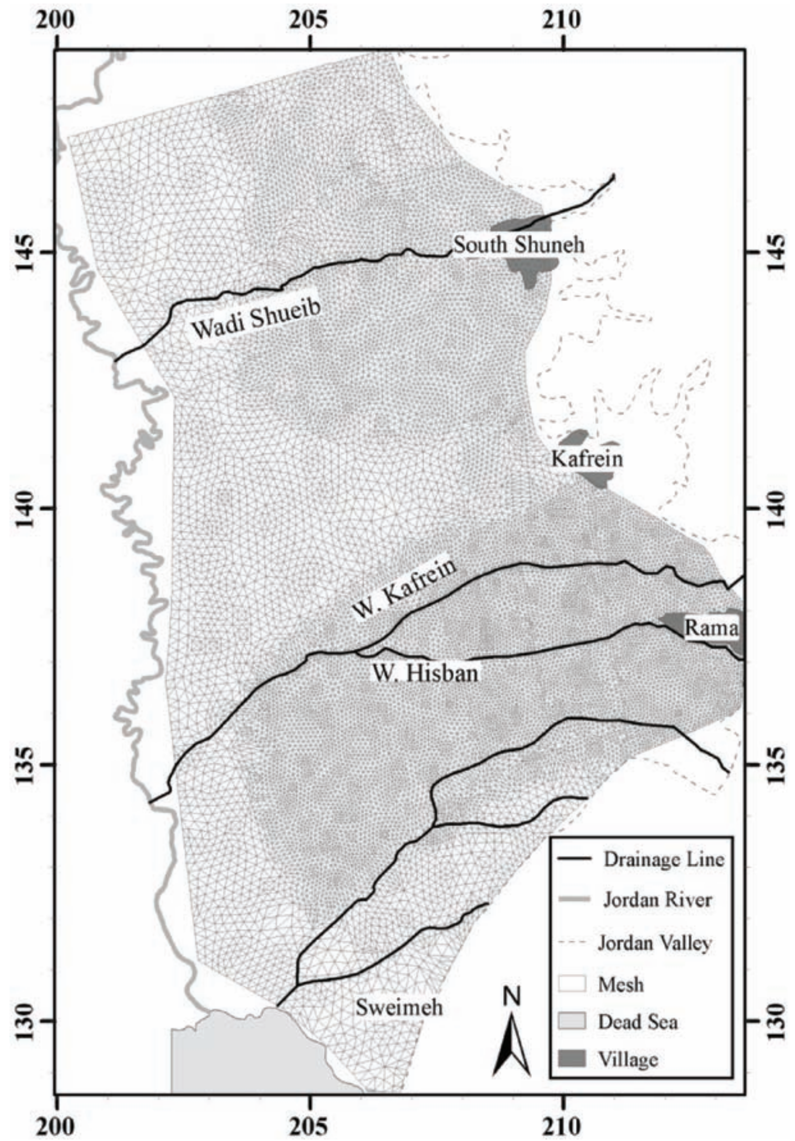

Figure 6.2
Finite element mesh of the study area

Due to its proximity to the active plate boundary the geology of the study area is rather complex. All available geological and geophysical data set along with several field surveys were used to generate a 3D-geometric-geological-model, which incorporates all important geological features, such as faults, fold and thickness variations of the different geological strata. On the basis of these findings a numerical 3D-transient-model integrating all important geological features of the hydrogeological system was developed. The numerical model was implemented by using the object- and process-oriented GeoSys/Rockflow model (Figure 6.3 and Figure 6.4) developed at the Department of Environmental Informatics at the Helmholtz Centre for Environmental Research, Germany. In order to be able to provide reliable predictions about the impacts of climate change scenarios on the groundwater system, the flow model will be tested against stress periods depicted during the historical review of the test area. These stress periods will include periods of intense rainfall, of drought, and of anthropogenic impacts, like e.g. the building of storage dams at wadi outlets. Recommendations for future sustainable groundwater abstractions are given.

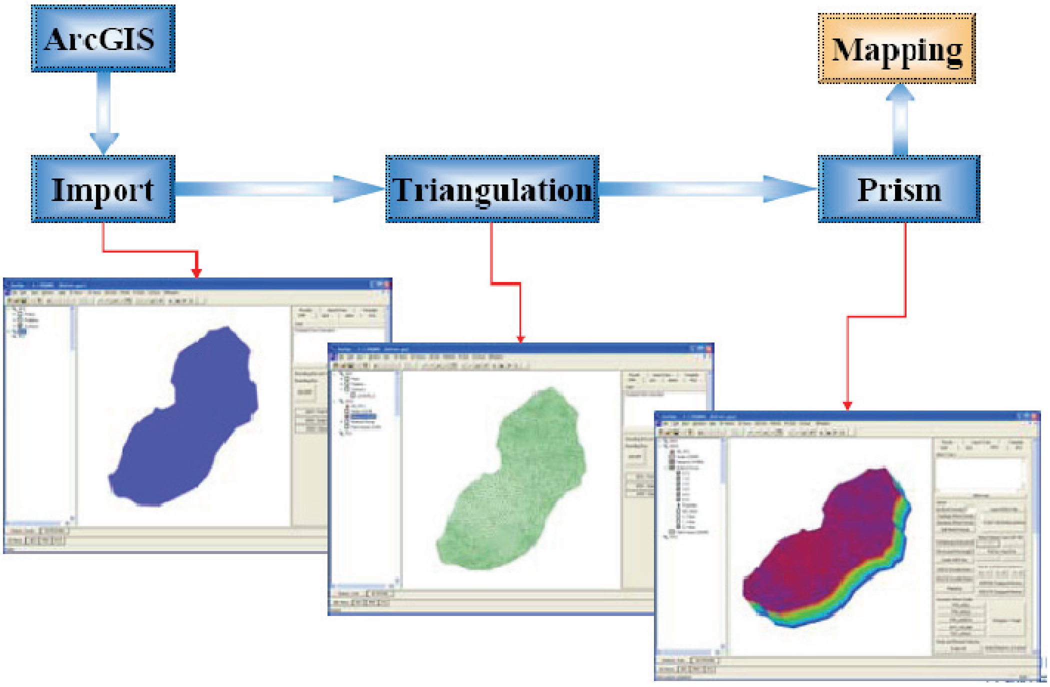

Figure 6.3
Importing procedure of the the ArcGIS raster data (geometry of the different geological layers) into GeoSys program

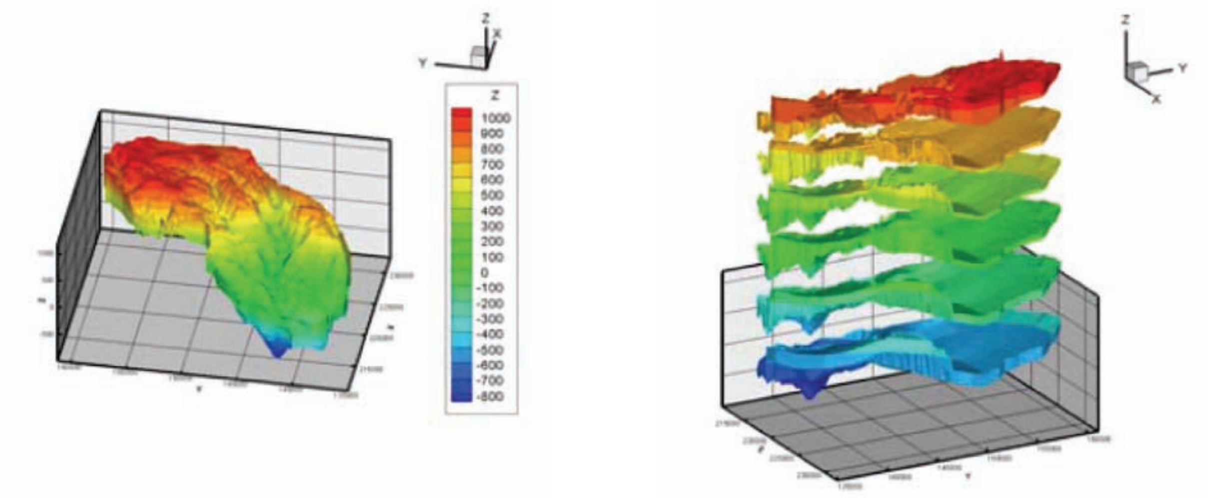

Figure 6.4
Imported 3D-geometry of the different geological layers in the Wadi Kafrein area

6.2.3 Model of Wadi Al Arab and Wadi Qilt / Wadi Nueima

Compiled by: T. Rödiger, C. Siebert, S. Geyer (UFZ)

In this basin, the important aquifers are those of the Lower and Upper Judea Group (Cenomanian-Turonian). The layers of the Bet Meir and Moza formation build up an altogether 120 to 150 m thick aquiclude, which separates the Lower from the Upper Judea Group aquifer. Further towards the Graben, the Upper Judea Group aquifer is covered by Senonian cherts.

In Wadi al Arab, the Turonian to Paleocenic rocks of Amman al-Hisa and Wadi Sir Formation represent a continuous aquifer. At the top of that A7-B2 aquifer, the Muwaqqr formation builds the aquiclude of B3. At the top and mainly in the north-western part of the catchment area remain, the Eocene aquifer of Umm Rijam formation crops out.

According to the hydrogeological separation, 3D-underground-models have been calculated by GMS 6.0 (ems-i) which take the major aquifers, aquicludes and faults into consideration (Figure 6.5). Therefore, geological maps and borehole records were evaluated in order to construct geological cross sections (Figure 6.6).

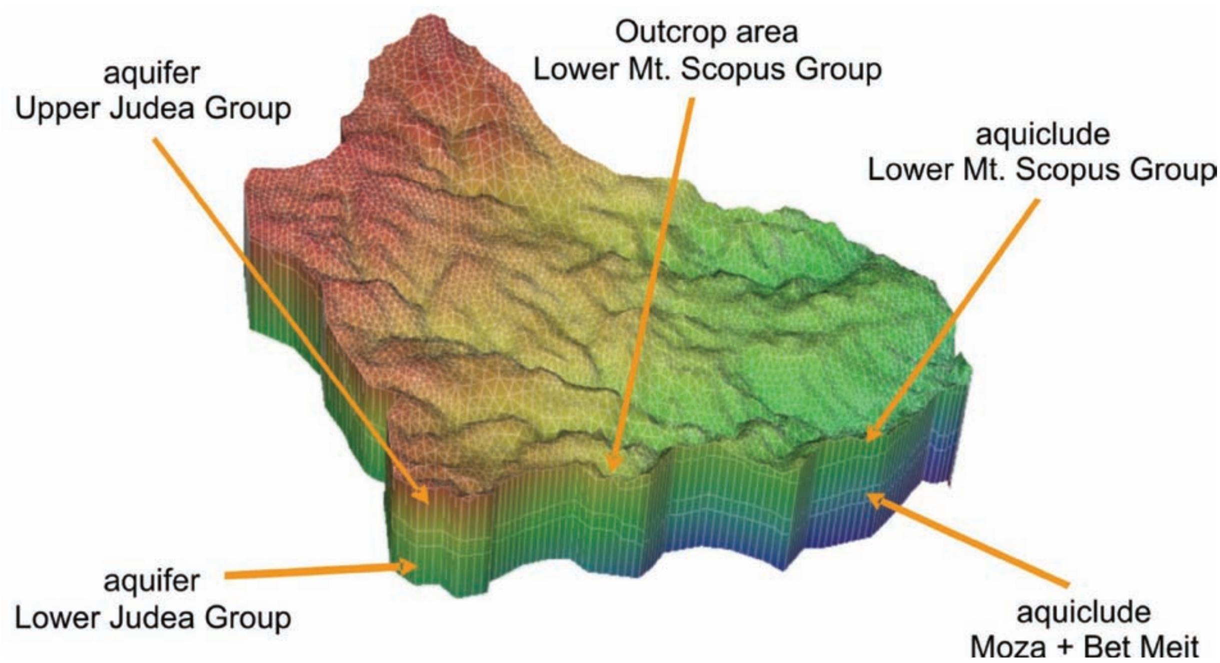

Figure 6.5
The 3-D underground model of Wadi Qilt

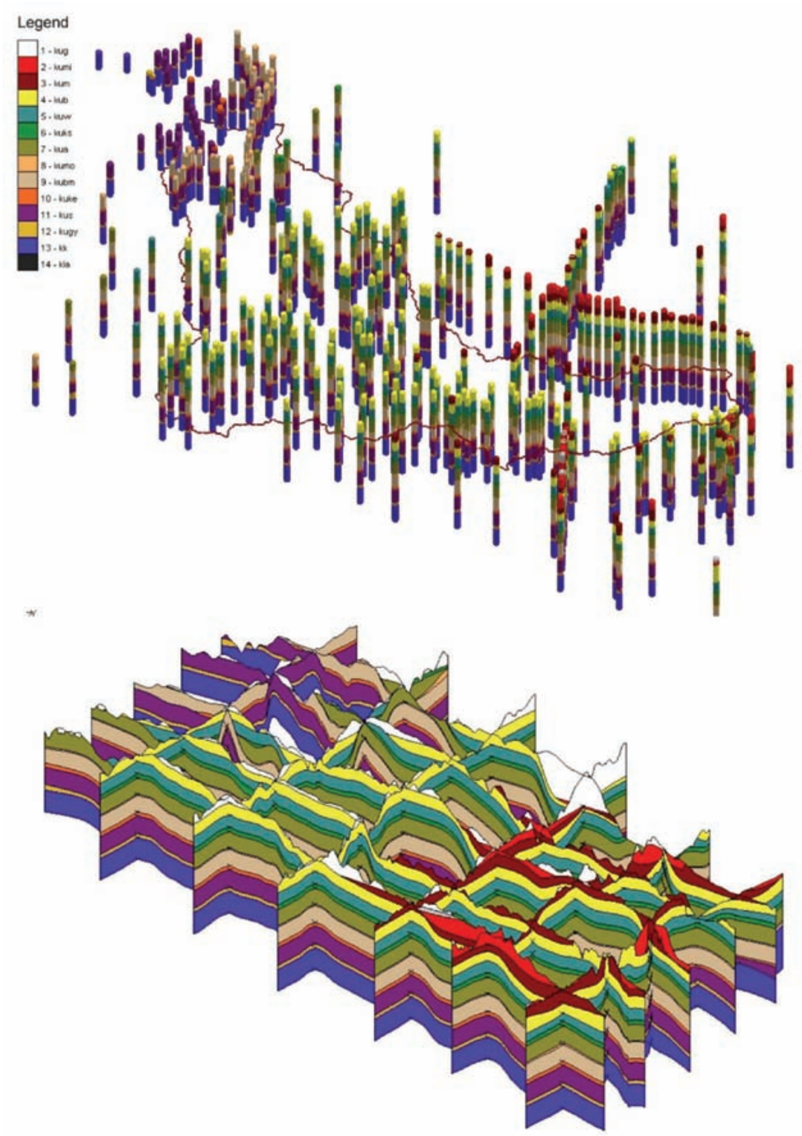

Figure 6.6

The procedure of construction of geological cross sections is shown. Borehole records were used in order to construct geo-logical cross sections (GMS 6.0, ems-i).

The elevation of each boundary was taken by digitizing the constructed cross sections to earn a digital underground surface elevation model of each formation. The nodes of the surface network were coded by x, y, and z-coordinates. Hence, the layers were imported into the numerical flow model and are the base of the 3D-flow-model (FEFLOW 5.2, WASY Ltd.). To determine the underground catchment, maps of equi-potential groundwater table were performed and compared with the underground-DEM. The underground catchments of both study sites are about 600 km² in space.

The first step was to prepare a steady state flow model. For that purpose, the subsurface catchment water divide has been defined as 1st kind boundary conditions (no flow boundary). The uppermost surface of the model is represented by the DEM. The model of Wadi al Arab is a 3-layer model, while Wadi Qilt model consists of 4 layers (Figure 6.7 and Figure 6.8).

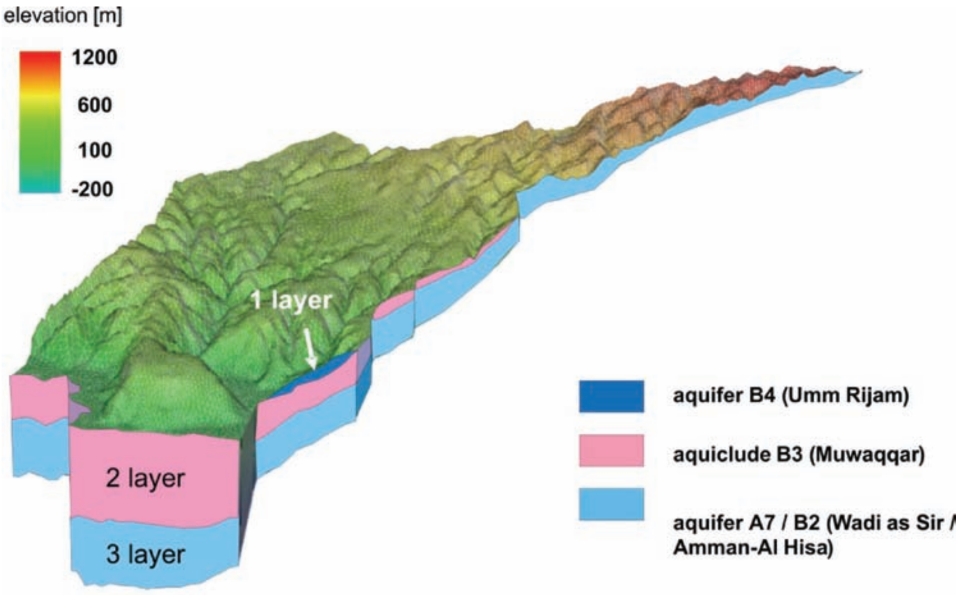

Figure 6.7
The model body of Wadi al Arab

The Graben flanks are defined to be boundaries of fixed heads (2nd kind boundary conditions). At the model surface, the ephemeral streams were not defined as 3rd kind boundary (river/transfer boundary), because they seldom to never show contact to the groundwater table which is mostly far below. Further, the definition of the wadi as 3rd kind boundary would imply errors in the model, because the FeFlow-model gets an additional recharge source during the dry season. Larger spring systems are represented by a 4th kind boundary condition (well). Their average discharge was taken from literature in order to get a sink term (Figure 6.9).

As a first assumption, groundwater recharge calculated by the empirical equation of Guttman and Zukerman (1995) has been taken for the study region. The used average amounts of precipitation take the gradient from the mountain range to the Dead Sea and Jordan Valley into consideration. Based on these conditions a range of gw-recharge from 20 until 120 mm/yr was calculated for the steady state model.

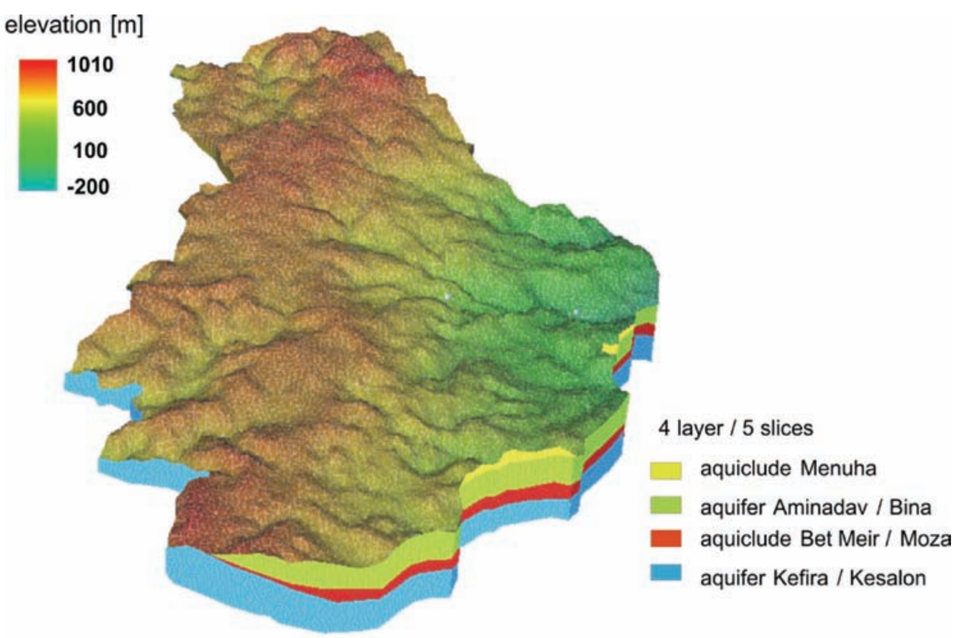

Figure 6.8
The model body of Wadi al Qilt

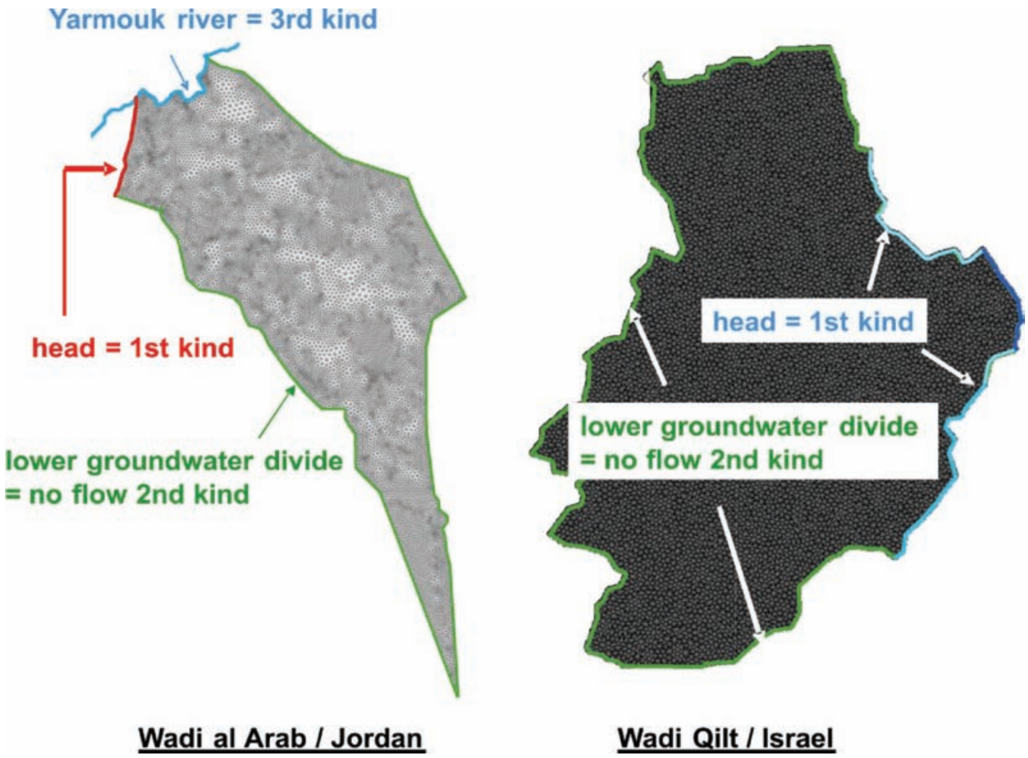

Figure 6.9
The boundary conditions of the groundwater flow models

After preparation of the numerical flow models, an automatic calibration of transmissivities was realized by using PEST modul.

The model calibration was done by comparing observed and simulated groundwater heads. The estimated hydraulic conditions of layers of high permeability (karstified limestone) are between 10 - 3 and 10 - 4 m/s. However, those of silt and clay are mainly between 10 - 7 to 10 - 9 m/s. The median of hydraulic conductivity values lies between 10 - 5 and 10 - 6 m/s, a range which represents the regional conductivities of limestone very well (Freeze and Cherry 1979), which is proven by pump tests.

The results of the steady state model, e.g. Wadi al Arab, are shown in Figure 6.10.

To prepare the transient model, representative values for validation such as groundwater table records with a monthly to half-yearly resolution were outlined and evaluated. Hence, to calibrate the model, hydraulic conductivities and the storage coefficients were used.

Regarding groundwater recharge, output files of JAMS (WP4) are converted to input files for the transient FeFlow model. However, first model runs show a temporarily shift between groundwater recharge, and the comparable reaction of the groundwater table is observable.

The recharge function of JAMS represents the soil zone. In difference, usually the recharge of an aquifer does happen directly at the groundwater surface.

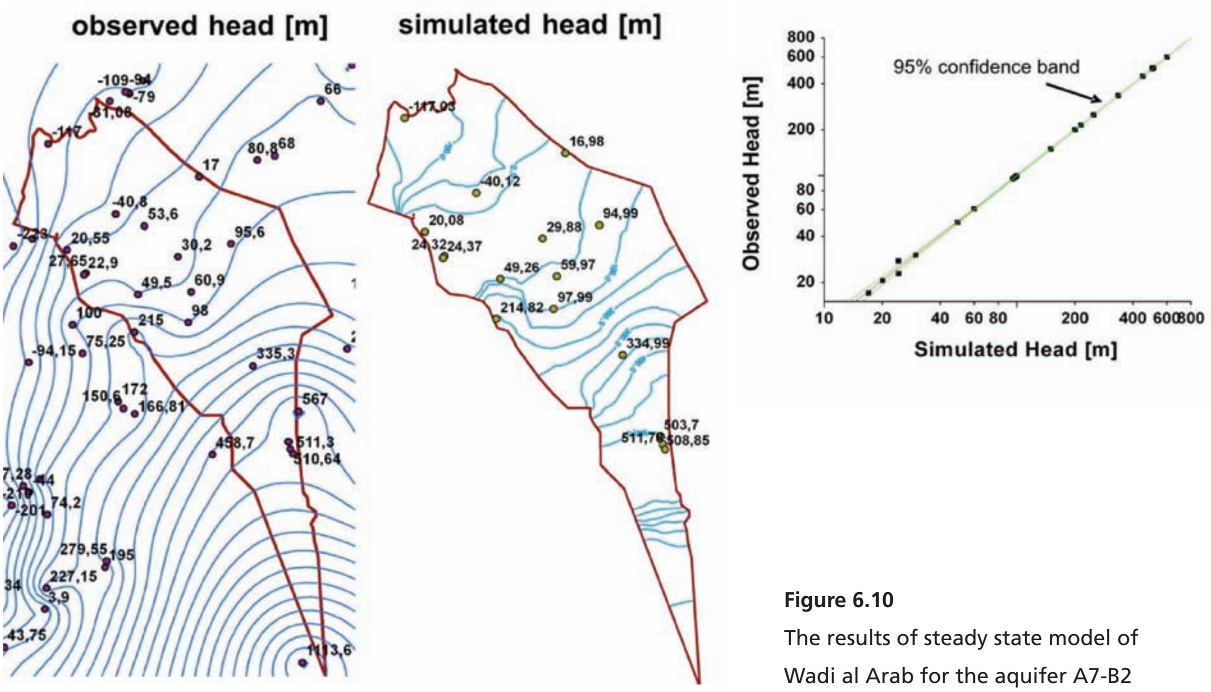

Figure 6.10
The results of steady state model of Wadi al Arab for the aquifer A7-B2

6.2.4 The transboundary model

Compiled by: J. Bensabat (EWRE)

The transboundary model is destined to cover the whole project area. The rationale for constructing such a large model is to have a tool capable of providing insight into global water budgets at the scale of the project area, and to investigate large scale impacts of water utilization alternatives and their sensitivity to the global factors (extreme fluctuations in replenishment trends resulting from climate change etc.). The first step in the development of the transboundary model was the conceptual model that was developed in WP3. The model boundaries are illustrated in Figure 6.11. These are mostly defined by hydraulic water divides (no natural boundaries).

Once the model boundaries are set, the relevant geological layers that need to be included in the model were set (see report WP3), both, in the western and in the eastern parts of the study area. Faults capable of having an impact on the groundwater flow were included. A two dimensional mesh encompassing the study area was created using an algorithm by Shimada (1993) for the generation of 2D-points (the bubble pack algorithm). Faults were considered as constraints and points along them were generated separately. The resulting points were triangulated using a Constrained Delaunay Triangulation (Anglada 1997). The resulting mesh comprises 42,660 2D-points and 84,876 2D-triangular elements (see Figure 6.11).

The model geology was mapped by means of a dense grid (1 km x 1 km) and by mapping the dip along the faults. The selected methodology was: a Digital Elevation Model (DEM) of the Top Judea formation (in Jordan: the Top Ajlun) was created. Then, the thicknesses of the layers (above and underneath the top Judea) were prepared. Finally, we obtained from John Hall of the Geological Service of Israel, a DEM of the ground surface elevation. The elevation of the layers was then derived by adding or subtracting layer thickness with regard to the elevation of the Top Judea. The elevation of any layer was then truncated, if it was found to be higher than the ground surface elevation. The input DEMs (ground surface elevation, Top Judea elevation and the thicknesses of the relevant geological layers) were projected onto the model mesh, by means of an interpolation procedure, based on a method suggested by L.B. Montefusco and G. Casciola (1989).

The resulting 3D-model comprises 13 levels (or 12 layers), a superposition of non-parallel 2D-meshes, such as the one illustrated in Figure 6.11. The resulting 3D-element is a six-node triangular prism. The 3D-mesh comprises 554,580 3D-nodes and 1,018,512 3D-elements.

Cross-sections across the model were created and compared satisfactorily to existing ones (see Figure 6.12 and Figure 6.13). The outcrop layer was created by mapping the geological map (vector version obtained from the Geological Survey of Israel) onto the outcrop layer of the mesh. The resulting outcrop map, as inserted in the model, is illustrated in Figure 6.14.

6.2.5 High performance computations

Compiled by: J. Bensabat (EWRE)

Two workstations, capable of High Performance Computing (HPC) operations are being tested at EWRE:

- one workstation with two Xeon Quadcore processors (total of 8 processors);
- one workstation with one Xeon Quadcore processor and an AMD 9250 Fire steam processor (having ~300 dedicated processors).

The first workstation achieves parallel use of the various processors by means of the Message Passing Interface (MPI) software and algorithms that take full profit of the parallelism (such as Argonne PetSc and Sandia Laboratories Trilinos package). The AMD firestream processor is supplied with a compiler and an optimized version of key libraries, thus, allowing high performance calculations for most of the mathematical operations involved in the simulation of groundwater flow and transport calculations. The MPI based HPC has been tested, and in the coming months the testing of the AMD 9250 card should be started.

6.3 Expected impacts

The objective of the local models is to provide refined, yet local, evaluations of the water budgets in the various basins of the study area. The role of the transboundary model is to provide a regional insight of the water situation, its sensitivity to global effects such as the climate change and to help design and test large alternatives of water utilization that could clearly be understood and discussed on a rational basis by the various partners and stakeholders associated with SMART.

6.4 Future research

Some of the local models will be further improved in order to incorporate, transport phenomena and, thus, to evaluate local exploitation scenarios. The transfer function which represents the time gap between JAMS and FeFlow model will be solved begin of 2009 . The soil moisture model of JAMS shall be incorporated into the transient model of Wadi al Qilt. The transboundary model will be completed and first runs will be performed.

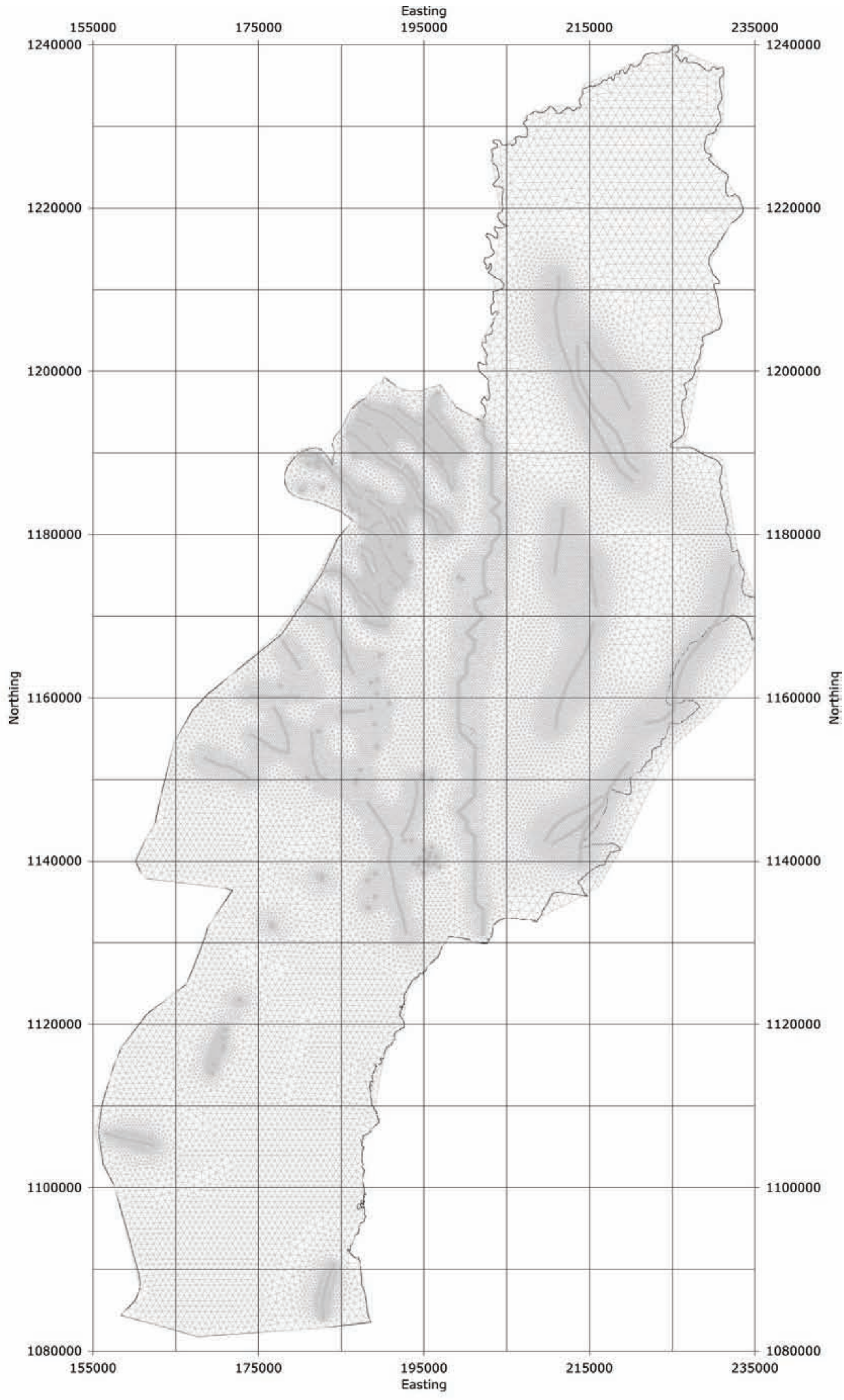

Figure 6.11

Plan view of computational mesh

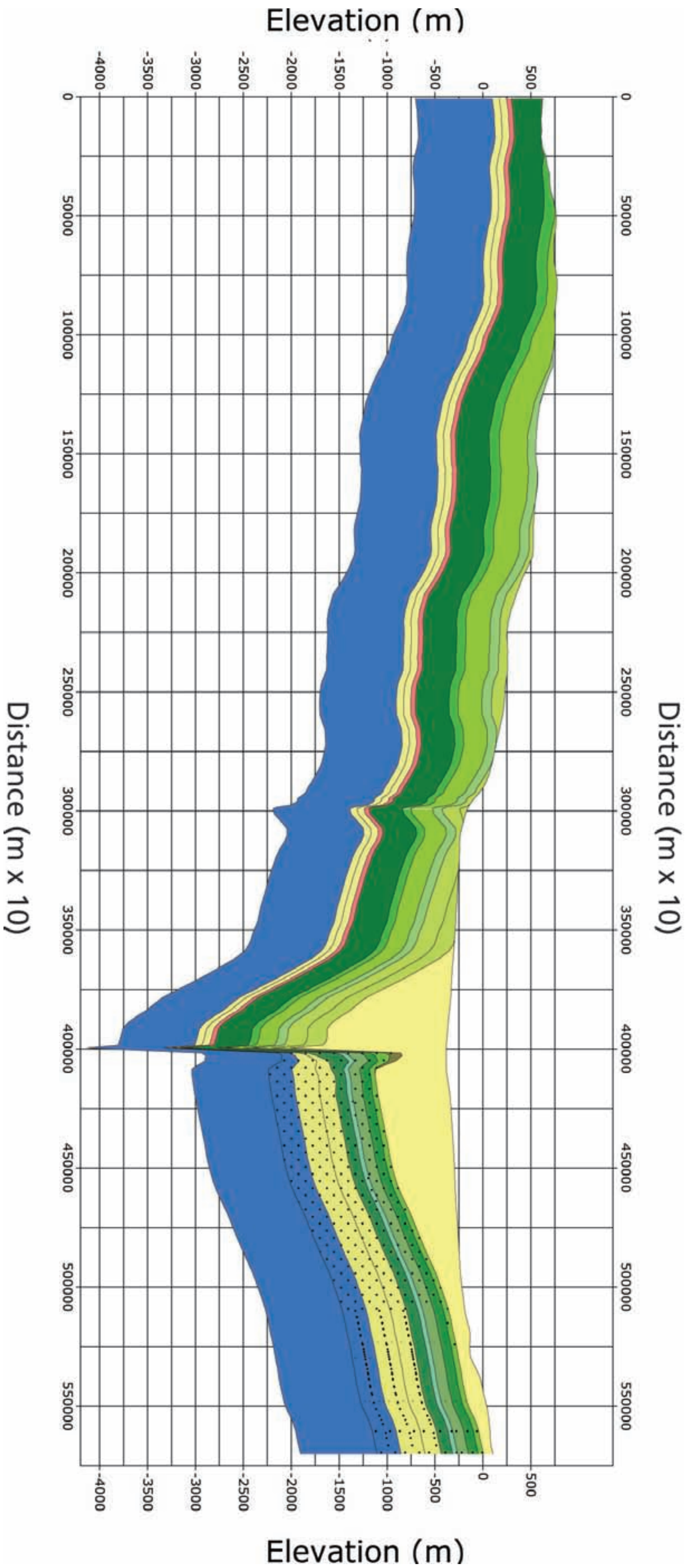

Figure 6.12

Model cross-section from west to east (middle part of the project)

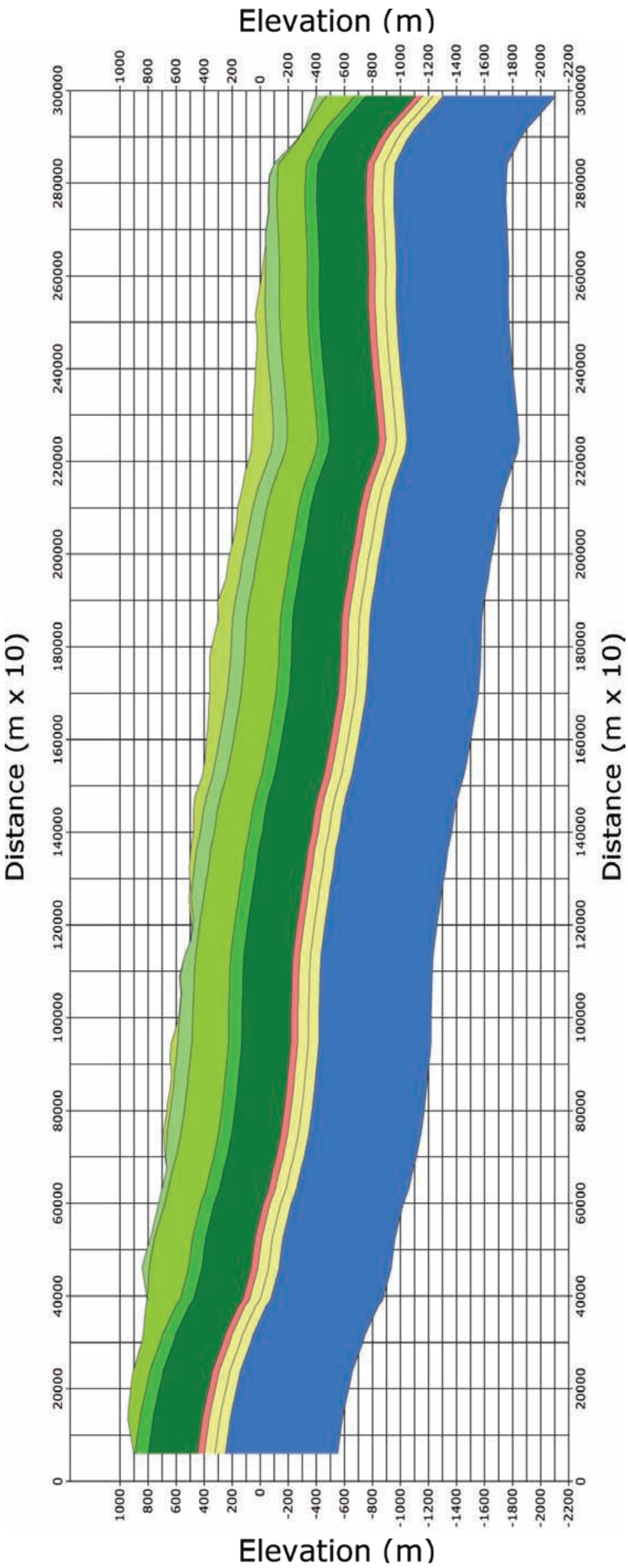

Figure 6.13

Model cross-section from west to east (southern part of the model)

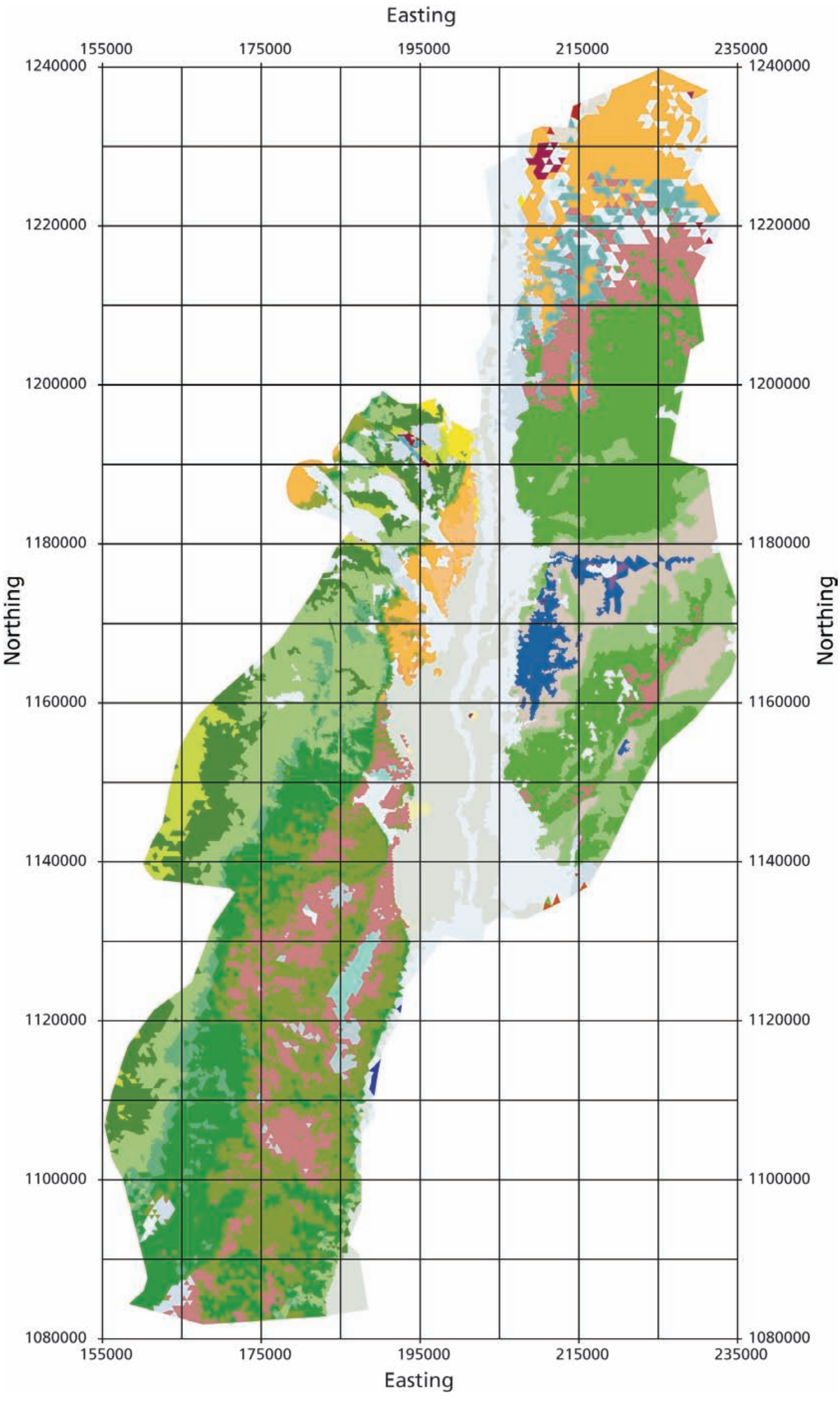

Figure 6.14
Model of the geologic outcrops

7 SOCIO-ECONOMIC ANALYSES AND ASSESSMENT

Involved Institutions: PHG, UFZ, EWRE, EcoConsult
WP-Speaker: A. Tamimi (PHG)
Compiled by: A. Tamimi (PGH), I. Dombrowsky (UFZ),
T. Milgrom (EWRE), R. Daoud (EcoConsult)

7.1 Introduction

As previous explorations in the study area have shown, several technical solutions to address water scarcity are available, but are either not used at all or not being applied appropriately. This experience demonstrates that the implementation of water technologies it is not only dependent on scientific and technical factors, but also on social, political and economic variables, and it calls for an approach that takes the socio-economic and political context of implementation into account.

The main objectives of this work package were twofold:

- Analyze the socio-economic profiles and current water uses in selected pilot areas in the study area as input for the assessment of different integrated water resources management (IWRM) scenarios in WP9 and WP10.

- Analyze the institutional prerequisites and demand for the implementation of decentralized wastewater treatment and reuse (WWT&R) systems. This work was done in close cooperation with WP5.

7.2 Description of work and results

7.2.1 Socio-economic profiles and current water uses in the study area

Background
An important prerequisite for the successful implementation of water technologies is a thorough understanding of the socio-economic characteristics of its users. At the same time, the socio-economic status of a community is also a function of its water and wastewater situation. Analyzing the socio-economic profile and current water uses also provides the reference point for the development of alternativ e water management scenarios.

Methodology
Socio-economic profiles were prepared for Palestinian and Israeli communities in the western Lower Jordan Rift Valley (LJRV). Basic data on selected Jordanian villages in the eastern LJRV were collected in the context of WP5 (see Chapter 5).

7.2.1.1 Palestinian side

A baseline survey was carried out targeting 15 Palestinian communities in the Lower Jordan Rift Valley as shown in Figure 7.1. The objectives of the survey were to develop a socio-economic profile of the communities and to assess the water uses of these communities. In each of the localities respondents were randomly selected to generate both, quantitative and qualitative data on selected parameters and indicators. A total of 207 questionnaires were filled. The collected data was analyzed using Microsoft Excel, the Statistical Program for Social Sciences (SPSS) and the Geographic Information System program (GIS). For quality control more than 50% of the data entered was cross checked. The number of samples taken does not statistically represent the area, but results do give a general idea about the targeted communities.

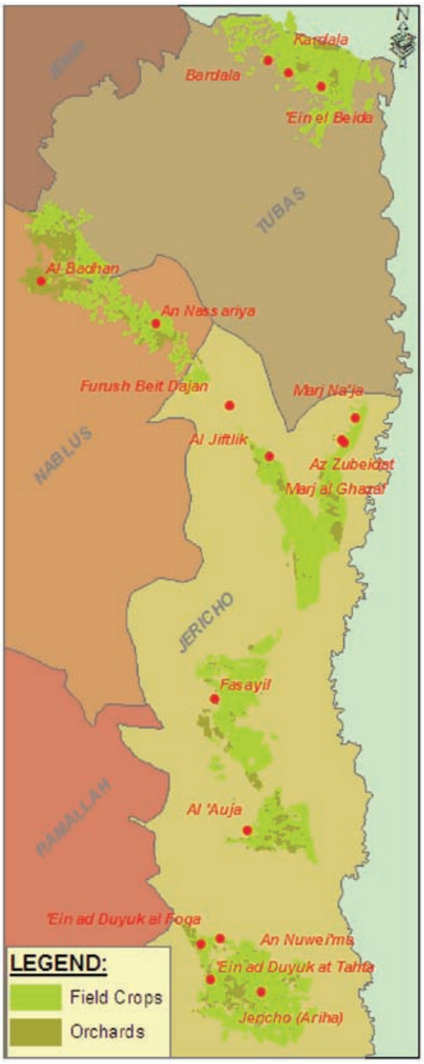

Figure 7.1
Palestinian communities surveyed

Figure 7.2
Israeli communities surveyed

7.2.1.2 Israeli side

In addition, a socio-economic profile of the Israeli populations living in the Lower Jordan Rift Valley was carried out (Figure 7.2). This included demographic and socio-economic data, data on the water supply produced within the LJRV and data on current water consumption and expected water demand. The findings were based on a literature review, statistical information from the Central Bureau of Statistics in Israel (CBS) and interviews with some of the community's populations, key persons in the local authorities and in different sectors.

7.2.2 Main results

7.2.2.1 Palestinian side

The survey shows that the Palestinian communities in the Jordan Valley mainly rely on agriculture as source of income. About 80% of the total income is generated in agriculture. On average, a family consists of nine members. About 40% of the household members are under the age of 15. Many of the respondents have very little schooling and only a marginal portion has attended vocational school. The average number of family members permanently involved in agriculture is 3.6, while the average number of family members temporarily involved in agriculture is 1.7. However, the majority of heads of family are involved in more than one job. The most commonly cultivated crops are wheat, squash, eggplant, tomato, corn, banana, cucumber, cauliflower and dates in descending order. The majority of the respondents earn between 1,000 to 3,000 NIS per month.

In terms of water supply for domestic purposes residents mainly rely on water networks and the Israeli water company Mekorot (Figure 7.3). They usually do not use rainwater harvesting for their water supply due to the scarcity of rainfall in the area. Most households rely on more than one source.

The mean monthly household expenditure on water supply for domestic purposes in the targeted areas was estimated to be 95 NIS. The monthly income from selling water is limited in most of the targeted areas but seems to form a major income source in Marj Na'ja (1,400 NIS). The majority of respondents were at least fairly satisfied with the domestic water supply in terms of both, quantity and quality.

In terms of water supply for agricultural purposes, most of the respondents use more than one source but mainly rely on springs and groundwater wells. Almost half of the respondents rely on springs for agricultural water supply (Figure 7.4). Drip irrigation is the most commonly used irrigation method. Rain-fed irrigation is limited due to the limited rainfall quantities in the area. The average annual expenditure on agricultural water supply is 11,881 NIS. This amount constitutes 20% of the total expenditure on agricultural activities. Notwithstanding this, some users take water supply from springs or groundwater wells without paying. Others take their supply from Mekorot and do not pay their bills which are ultimately deducted by Israel from the Palestinian tax revenues. More than half of the respondents are dissatisfied with the water supply for agriculture in terms of quantity. Replies of the respondents varied when asked about their satisfaction with the management of water quality. This is mainly due to the lack of knowledge about water quality and the fact that they judge it only by the salinity.

The majority of the land available for potential agricultural expansion will be used for cultivating grains if both, labor and water are provided. The average willingness-to-pay for water supply for agricultural expansion was 5,238 NIS per year.

Table 7.1

Main water sources for domestic purposes in the Palestinian communities

Water Source	%
Network	50,27
Purchasing Water from Company (MEKOROT)	32,42
Public Groundwater Well	7,62
Springs	6,17
Tankers	2,1
Privat Groundwater Well	0,82
Familiy Groundwater Well	0,6

Table 7.2

Main water sources for agricultural purposes in the Palestinian communities

Water Source	%
Springs	44,92
Purchasing Water from Company (MEKOROT)	24,04
Public Groundwater Well	17,59
Springs	12,10
Tankers	1,34

7.2.2.2 Israeli side

Within the study area, there are 33 Israeli/Jewish localities with a population of 12,292 residents. The study area generally follows a rural settlement pattern. The statuses of rural localities in the study area are classified as 16 Cooperative Moshav, 6 Kibbutz, and 10 communal localities. The difference between these types of localities derives from the equality and the level of cooperation in ownership of property and of means of production. These localities are unionized into three separate regional councils which provide various municipal services for the villages within their jurisdictional boundaries: Jordan Valley, Megilot-Dead Sea and Mate-Biniamin. There is also one urban Local Council in the study area: Ma'ale Efraim.

Population growth in the study area is higher than the national average, mostly due to high fertility rates and slightly from migration (3.3% Jordan Valley, 7.9% Megilot-Dead Sea, 7.4% Mate-Biniamin, 2.7% Ma'ale Efraim). Additionally, the age structure in the study area shows a slightly different population pyramid than the national one. Nationwide, approximately 28% of the total population are under the age of 15, compared to about 21% in Jordan Valley, 24% in Ma'ale Efraim, 30% in Megilot-Dead Sea, and 43% in Mate Biniamin. According to the Israeli CBS the socio-economic level based on education, standard of living, labor force, health, etc. of the population living in the respective regional councils is medium to low. Agriculture is still the main source of income. Most commonly cultivated crops are palm, herbs (e.g. basil and asphodel), grapes and vegetables (e.g. peppers and cherry tomatoes), flowers and olives. However, many of these localities have branched out into industry and tourism, and some of their members begun to work as salaried employees in the adjacent urban centers. The industrial branches support the cultivation activities and market-oriented productions for export and for the local markets.

The main fresh water supplier for the consumers in the study area is Mekorot. The water is supplied from a local distribution network, mainly from drilling water from the Mountain Aquifer. The drilling wells are connected to a reservoir (water plant) and are transferred from it to the consumer by pipe lines. Figure 7.3 summarizes the total water supply (fresh and saline water) provided by Mekorot for the study area between the years 2000 to 2007.

With the exception of Ma'ale Efraim Local Council the main water consumer in the study area is agriculture. Water consumption is highest in Jordan Valley Regional Council due to the existing cultivation area and lowest in Ma'ale Efraim Local Council.

Two water associations exist in the study area, which supply water for agricultural use. Each association operates a water reservoir, Tirza at the northern part of the LJRV and Og at the south. Tirza reservoir collects flood-water flowing downstream from Triza stream, and Og reservoir collects wastewater from eastern Jerusalem neighborhoods and from Ma'ale Adumim locality. Water supply is occasionally mixed by different types such as salt water, flood water and treated wastewater.

Domestic effluents of 21 localities are treated in oxygenation ponds. Four localities use septic tanks. In addition, four domestic wastewater treatment plants (WWTPs) collect effluents from localities and discharge or reuse treated sewage back into the environment. The main agricultural use of treated wastewater (WW) is for irrigating palm trees.

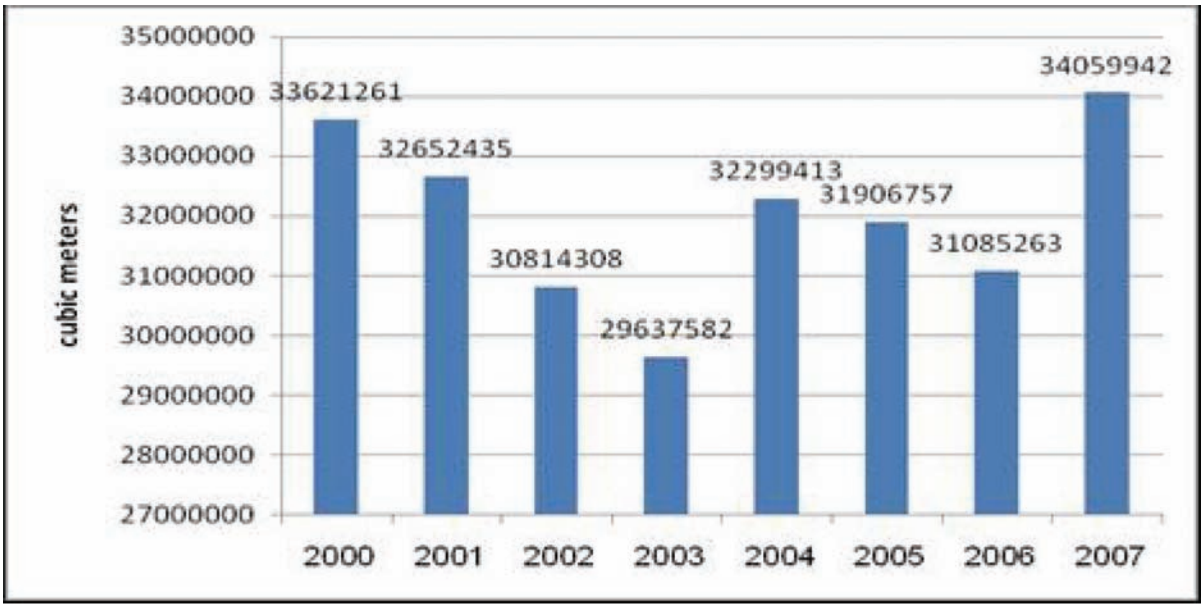

Figure 7.3

Water supply provided by Mekorot to Israeli communities (cubic meters)

7.2.3 Institutional prerequisites and demand for the implementation of decentralized WWT & R systems

7.2.3.1 The problem

Since the mid 1990s a paradigm shift has been advocated to move from centralized to a decentralized wastewater treatment (Venhuizen 1997). Instead of a "linear" model where freshwater is used to flush wastewater and the treated wastewater is disposed into rivers, it is suggested to close cycles of fluid and solid waste flows at a local level. This decentralized approach is expected to serve certain, in particular remote, areas at less costs and to provide additional benefits in the form of additional locally available sources of water and biomass. It is also argued that these solutions are more flexible under conditions of demographic and global change and reduce the risks of large infrastructures investments (Hamilton, B. A., R. D. Pinkham, et al. 2004).

Obviously, this concept is principally of great relevance for (semi)-arid countries, such as in the Middle East (Bakir 2001). However, in the past, it has proved very difficult to implement appropriate technologies for wastewater re-use due to institutional barriers and public opposition (Steenvoorden 2004; Dolnicar and Saunders 2006; Hurlimann and McKay 2006).

As the institutional conditions for decentralized WWT&R vary from country to country, in Phase I of the SMART project, it was decided to carry out a study of Jordan, as the main SMART activities related to decentralized WWT&R focus on Jordan. In Jordan, so far, mainly a centralized approach towards WWT&R has been applied. To date, there are 21 public WWTPs in the country, connecting 63% of population, see WP 5). About 78% of all treated wastewater is being treated in one plant (As Samra), and the large majority of the treated WW is being reused for irrigation in the Jordan Valley. The results of WP5 show that in total there is a rural population of about 660,000 in the Jordanian part of the Jordan Basin that are either not connected to central plants or that are not expected to be connected in future. These 660,000 people produce about 20 MCM/yr of wastewater that could be treated and reused in a decentralized manner.

Against this background, a study was carried out investigating the possibilities and impediments of implementing decentralized solutions in Jordan. The aim was to assess both, the institutional framework conditions and the perceived demand for and views towards WWT&R among different stakeholders.

7.2.3.2 Methodology

The analysis of the formal institutional framework conditions was based on a comprehensive analysis of legal and policy documents.

In the analysis of demand, the perceptions of government representatives at the central government and governorate level, representatives of municipalities not yet connected to wastewater systems as well as households and potential end-users of treated wastewater in these communities were included (Table 7.3). At the village level, data collection focused on three villages that had previously been selected within the SMART project as potential test sites for decentralized WWT&R, the villages Ira, Yarqa and Al-Ramah. Qualitative interviews were used to obtain information from experts at the government and governorate level as well as of municipal councils, as they are particularly suited to describe individual perceptions. In order to investigate end-users' views and perceptions regarding decentralized WWT&R focus groups were used. The advantage of focus groups is that they allow introducing a certain topic to a group and that participants are collectively able to raise more issues than an individual alone and, hence, interaction and feedback within the group provides insights into the issues that are relevant to people (Morgan 1998; Brouwer, R., N. Powe, et al. 1999).

All interviews and focus groups were tape-recorded and transcribed. Arabic transcripts were translated into English.

Table 7.3
Interviews and focus groups carried out in Jordan

Stakeholder group	Institution	Number of interviews	Language	Date
Central Government	MWI & WAJ	3 face-to-face interviews	English	January 2008
Governorate	Irbid & Balqa	4 face-to-face interviews	English	January 2008
Municipal councils	Ira, Yarqa & Al-Ramah	3 face-to-face interviews	Arabic	April 2008
End-users (residents)	Ira, Yarqa & Al-Ramah	3 focus groups	Arabic	April 2008

7.2.3.3 Main results

Institutional framework conditions: actors, roles and decision-making powers
Jordan, a constitutional monarchy, is characterized by a three-tiered government consisting of a central government, 12 governorates and 99 municipalities. Overall, the main decision-making power lies with the central government, and important public services such as health care, education as well as water supply and sanitation are being provided by the respective line ministries through their regional branches within the governorates. Furthermore, since the mid 1990s, the government promotes the participation of the private sector in the provision of these services. In parallel, there have also been attempts to strengthen the local governance level with a reform in 2001 and the issuing of a new municipalities law in 2007.

The main actors and responsibilities in the water sector are laid out in Figure 7.4. The Ministry of Water and Irrigation (MWI) sets policies which are implemented by the Water Authority of Jordan (WAJ). All decisions with respect to public wastewater projects are taken at the central WAJ level (WAJ Law Art. 6), and implemented through the regional branches of WAJ in the governorates. Furthermore, since 2001, WAJ may transfer the operation and ownership of wastewater projects to other entities, such as the private sector, municipalities or non-governmental organizations. Any decision on such management transfers needs to be approved by the Cabinet/Council of Ministers (WAJ Law Art. 28). In addition to WAJ, the Jordan Valley Authority (JVA) is responsible for all aspects related to socio-economic development in the Lower Jordan Valley (below the 300 meters contour line).

The MWI laid down a strategy for the water sector in 1997 and a set of water-related policies including a wastewater policy in 1998. This policy (as well as the strategy) emphasizes the importance of wastewater treatment and reuse. It explicitly states that central treatment plants shall be built to serve semi-urban and rural communities (§ 6). However, it also mentions that the choice of technology is a question of operation and maintenance (O&M) costs (§ 18) and that innovative approaches shall be explored for small communities (§ 19). It also expresses the intention to increase the participation of the private sector (§ 57). The wastewater policy thus reflects the centralized approach towards WWT&R in Jordan, but also provides room for testing decentralized approaches.

As the main responsibility for the provision of public wastewater services is with WAJ, at present, municipalities in Jordan have no formal responsibility in that matter. Still, WAJ may transfer management responsibilities to municipalities, and the municipalities law of 2007 provides sufficient flexibility as Art. 3 states that the municipality manages all local services, facilities and projects assigned to it by itself. Overall the capacity of Jordanian municipalities is said to be low and a World Bank study in 1995 found that Jordanian municipalities only have access to 5.5% of public budget compared to 20 - 30% in other developing countries (USAID 2005). According to the municipalities law of 2007 sources of income include (Art. 44 - 53): 6% of fees levied on petroleum, 40% of fees levied on vehicle acquisitions, and 3% of auctioned movable assets within the municipality.

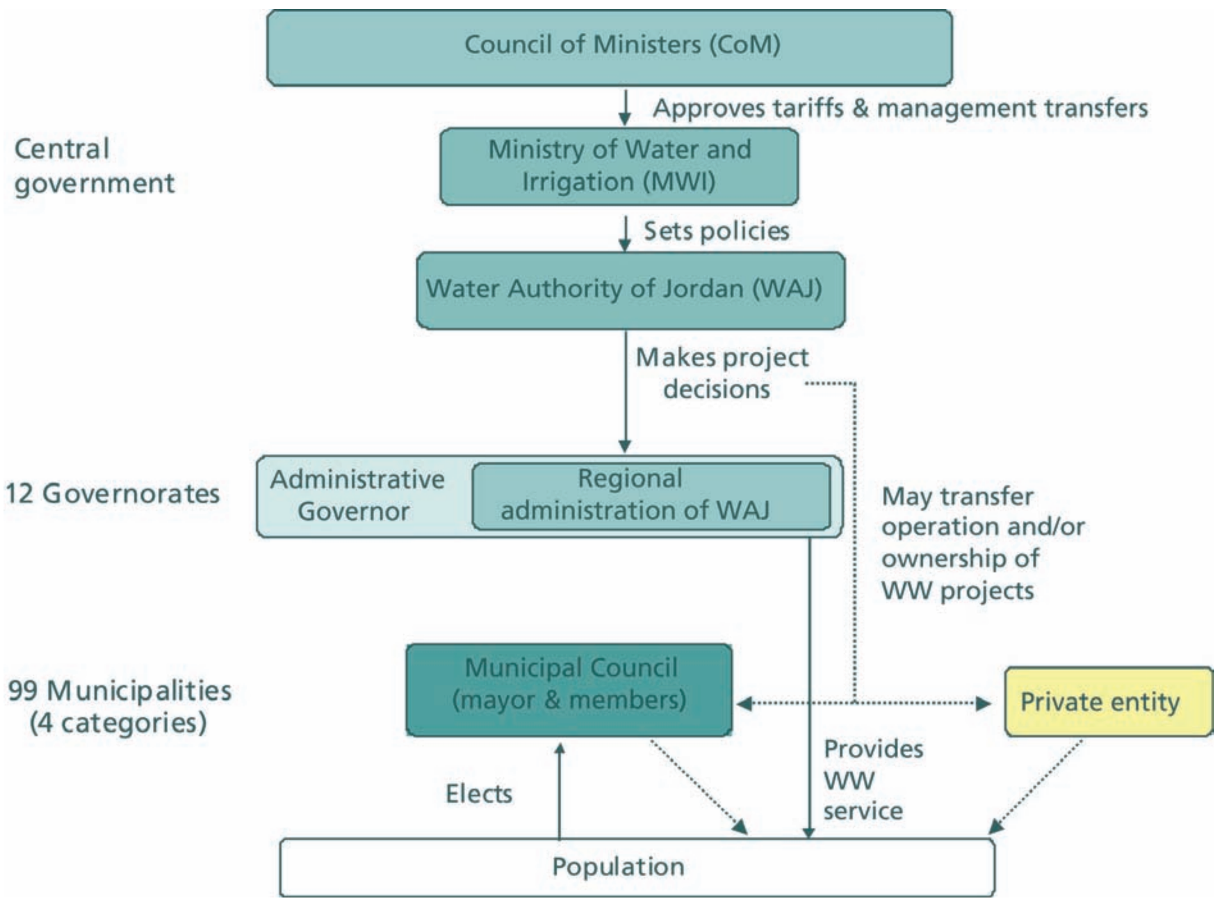

Figure 7.4

Responsibilities for provision of public wastewater services in Jordan. Source: own compilation

Powers to finance wastewater services

The main sources of income for WAJ for investments in the water sector are: (1) water tariffs and wastewater charges; (2) property taxes of 3% of net rent transferred from the Ministry of Finance to the MWI and (3) donor grants and loans.

In setting wastewater charges, the WAJ Board makes recommendations to Cabinet/Council of Ministers. The principles for doing so are laid out in the Wastewater Policy (1998) as follows: (1) cover at least O&M costs of treatment, (2) differentiated charges possible, and (3) the price of treated wastewater should at least cover O&M costs of delivery. Despite this policy, at present, wastewater charges do not fully cover O&M costs (USAID 2005; Sorge, Daoud et al. 2008). The objectives of the Wastewater Policy are also not attained with respect to the pricing of treated wastewater for reuse as the price of treated wastewater is currently fixed at 0.01 JD/m³ for irrigation and at 0.05 JD/m³ in industry. Any higher prices would compete with subsidized water for irrigation the price for which varies between 0 and 0.07 JD/m³ (Sorge, Daoud et al. 2008). However, those not connected to central wastewater treatment partly pay high tanker costs (ibid., see WP5).

Preliminary conclusions

Overall, it can be argued that the physical setting supports a centralized approach towards WWT&R in Jordan which is currently being pursued by the Jordanian government. This notwithstanding, due to the specific topography and settlement patterns, some potential for decentralized WWT&R exists in the country which is not being exploited to date. From an institutional point of view, decentralized management and cost-recovering financing are principally possible, but both has to be planned through the WAJ as central government authority, and any decisions on the transfer of management and ownership as well as on wastewater charges ultimately relies on a decision by the Cabinet/Council of Ministers. At the same time, the readiness and the capacity of private sector or municipalities to engage in operations is so far not entirely clear. Furthermore, current pricing policies probably limit the room of maneuver to recover full costs, however, there are first indications that the Jordanian government might be willing to experiment with wastewater charges in selected pilot areas (see WP5). Hence, decentralized WWT&R is feasible in Jordan, but at present, it needs to be realized through the central government/cabinet level. This might prove to be cumbersome, but would have to be tested. In practical terms this implies a two-prone approach: (1) (with) WAJ to demonstrate technical and economic feasibility for remote rural and/or new urban areas; and (2) explore opportunities for institutional change in order to allow a larger-scale bottom-up implementation.

Demand for decentralized WWT&R

The perceived demand for treated wastewater also perceived advantages of and concerns vis-à-vis decentralized WWT&R and was analyzed for central government and governorate administrators, municipal councils and end-users, respectively (Table 7.4). In addition, at the end-user level a pretest on willingness-to-pay (WTP) was carried out.

Table 7.4

Comparing perceptions on decentralized wastewater treatment and reuse (WWT&R) in Jordan

	Administrators	Municipal councils	End-users
Perceived demand for WWT	· Irrigation · Fertilizer · Industry · Landscaping	· Irrigation Fertilizer	· Irrigation · Fertilizer · Construction · Outdoor cleaning · Watering animals
Perceived advantages of decen- tralized WWT&R	· GW protection · Save fertilizer · Increase income of / reduce subsidies to farmers	· GW protection · Prevent social & health problems associated with cesspits	· GW protection · Reduce social & health problems · More convenient · Reduce odour
Perceived concerns related to decentralized WWT&R	· Affordability · Monitoring · More staff	· Affordability · Responsibility · Odour, flies	· Affordability · Responsibility · Location of plants

All stakeholder groups perceived that there is great demand for treated wastewater in Jordan and mentioned a range of potential uses. Irrigation water and fertilizer in agriculture were considered to be the main uses for treated wastewater, and, contrarily to expectations, no concerns were raised with regard to the quality of treated wastewater. Apart from uses in agriculture, stakeholders at the government and governorate level identified large-scale uses that address water scarcity problems in the entire country (e.g. forestry and landscaping), whereas municipal councils and residents (end-users) suggested uses from the perspective of village and individual household needs (outdoor cleaning and drinking water for animals) (Table 7.4).

Views towards decentralized WWT&R in rural areas were positive in all stakeholder groups, and there was agreement that decentralized wastewater treatment would protect freshwater sources. Again, stakeholders at the government and governorate level looked at the big picture, e.g. cost advantages of decentralized solutions in remote areas, whereas stakeholders from municipalities voiced local benefits, such as preventing odour and social problems between neighbours (see Table 7.4). There was a strong interest among municipal councils and end-users to change the unsatisfactory situation related to overflowing cesspits.

All stakeholder groups also aired a number of concerns. In all stakeholder groups affordability was perceived as a key problem. In addition at the municipal and end-user level there were some concerns about potential nuisances from wastewater treatment plants (e.g. odour and flies). Both municipal councils and end-users were also concerned that they might have to take responsibility for operating and monitoring the plant. At the government level monitoring decentralized WWT&R as well as potential leakage and environmental pollution were perceived as risks. However, overall the potential advantages seemed to outweigh the concerns in all groups.

During the interviews and focus groups, municipal councils and end-users were presented with two options for decentralized wastewater treatment in their villages: (1) one treatment plant for the entire village, and (2) several smaller treatment plants shared by two or more houses. They were then asked which of these options they would prefer. In the mountainous villages Ira and Yarqa both municipal councils and end-users favoured the 'one plant' alternative. Reasons included insufficient space between houses for several treatment plants and the desire to locate the treatment plant outside the village to avoid problems with odour and flies. Due to the geographical distribution of Al-Ramah in form of three clusters (Al Shaghoor, Al Mayar and Al Nahdah), after a lengthy discussion it was proposed, in line with the municipal council, that each cluster within the village should have one treatment plant.

Participants were prompted at the end of the discussions to state whether they would be willing to pay for (1) using treated wastewater, e.g. for irrigation, and (2) for the connection to the sewerage system. Overall, initial WTP was low. In Ira, none of the participants would pay anything, not even the price they currently pay for treated wastewater for irrigation (10 fils/m³), because they felt that the service should be paid for by the Government. In Yarqa, some participants stated that they would be willing to pay up to 0.5 JD/m³ in order to enhance irrigation of olive trees. In Al Ramah, the majority of participants were positive towards paying for treated wastewater: Some participants stated that they would pay 10 fils/m³ and one participant was willing to pay 100 JD/month in order to irrigate his crops. WTP for sewerage connection was strongly anchored to the amount of money people currently pay for tanker disposal. Overall, the sense of personal responsibility to contribute towards the financing wastewater services appears to be low, despite the fact that the participants were aware of the range of benefits associated with WWT&R. A sophisticated willingness-to-pay/Contingent Valuation study with end-users could help to educate end-users and better assess ability and willingness-to-pay.

In conclusion it was perceived that decentralized WWT&R would solve many of the problems Jordan currently faces, such as pollution of freshwater resources, social and health problems resulting from overflowing cesspits and low income among farmers. However, financing issues, risk of leakage, monitoring, odour and responsibility issues were major concerns.

7.3 Expected impacts

7.3.1 Socio-economic profiles and current water uses in the study area

The socio-economic profiles and current water uses in selected pilot areas, and as such the description of the status quo, are an important input for the development of IWRM scenarios in WP9 and WP10.

7.3.2 Institutional prerequisites and demand for the implementation of decentralized WWT&R systems

The analyses of the institutional framework conditions and of demand are important prerequisites for a successful implementation of decentralized WWT&R systems. The analysis of the institutional framework condition is an important input for the design of sustainable operating models for decentralized WWT&R (in WP5). The analysis of demand was a first step towards a participatory planning process that (1) engages relevant stakeholders in the decision-making process, (2) takes concerns into account and (3) tailors respective solutions in a way that suits end-users' needs. The analysis also provides important information for the selection of a potential site for a pilot implementation of decentralized WWT&R systems. The study furthermore provides first indications on willingness-to-pay which is an important input towards the development of sustainable financing models for decentralized WWT&R systems (in WP5).

7.4 Future research

Future socio-economic research will focus on advanced economic analyses of alternative technologies for the mobilization of additional water resources. Furthermore, the aim is to promote participatory a planning processes within the project. Detailed cost and financial analyses will be carried out within the technology work package.

· **Quantification of benefits of decentralized WWT&R and CBA:** The benefits of decentralized WWT&R will be quantified and a cost benefit analysis (CBA) will be carried out. The quantification of the benefits of wastewater treatment is warranted as it is important to assess the costs on non-action (e.g. costs of the pollution of aquifers or of social conflicts). While the costs of alternative treatment technologies have already been assessed in WP5, in Phase II main focus would be on quantifying (i) the environmental, health and social benefits of (decentralized) wastewater treatment, and (ii) the benefits of additional units of treated wastewater to potential re-users. On the basis of the respective cost and benefit estimates a CBA will be prepared. In order to quantify the benefits of wastewater treatment, building upon research in Phase I, a contingent valuation study will be carried out. The results of the contingent valuation study will also feed into the participatory development of sustainable financing models.

· **Cost-effectiveness analyses (CEA) of alternative technologies:** The aim is to carry out comprehensive comparative cost analyses of alternative technologies for the mobilization of additional water from local resources (decentralized WWT&R, managed aquifer recharge, brackish water desalination) in respective pilot areas for the provision of additional water as input to the development of IWRM scenarios. An important prerequisite for such CEAs is that the respective technologies will be cost in the technology WP.

· **Methodologies for participatory planning processes.** Participatory planning is an important prerequisite for the successful implementation of water management measures. At present, the input by affected population into the planning processes is still limited in the study area. A first step towards a participatory planning process was taken through the focus groups in Phase I. These efforts shall be expanded in Phase II. One specific opportunity to include affected households and end-users in the planning process will be provided in the context of the contingent valuation study. Based on the institutional analysis in Phase I a proposal and methodology for a participatory planning process will be developed and discussed with the respective stakeholders. If agreement will be reached workshops involving decision-makers and affected population will be moderated. The implementation of the participatory planning process will be observed and scientifically evaluated.

8 PRECISION IRRIGATION AND ARTIFICIAL RECHARGE

Involved Institutions: UJ, BGU, UKA, QUDS, GJU
WP-Speaker: E. Salameh (JUA)

8.1 Precision irrigation technologies and technologies suitable for the region (D801)

Compiled by: G. Oron (BGU)

8.1.1 Introduction and methods

Wastewater (mainly domestic wastewater) treatment and reuse is one of the foremost directions of solving water shortage in arid regions. Simultaneously, it solves wastewater disposal issues related to improved environmental control. The nutrients contained in the effluent have an economic value since artificial fertilization can be minimized. One of the main issues of effluent reuse is the dissolved solids content that might risk sustainable agriculture production and ground-water quality. The dissolved solids can primarily be removed by reverse osmosis treatment processes. It can be accomplished by combining in series an ultra filtration (UF) membrane stage with a reverse osmosis (RO) membrane stage, as examined in the field with a pilot system in the agriculture areas near the City of Arad, Israel (Figure 8.1). Further improved efficient water use can be achieved by drip irrigation, both on-surface and sub-surface drip irrigation (DI and SDI, respectively) systems. SDI has a series of advantages. One of the main drawbacks during effluent application through DI is the risk of environment pollution.

Irrigation field experiments were conducted applying six effluent qualities obtained from a series of waste stabilization pond systems, and subsequently treated by a hybrid UF and RO membrane system. The long term experiment was conducted in the commercial fields near the City of Arad. The six treatments were examined in four blocks (replications) each replica in an area of around 170 m2. Effluent qualities differ primarily in the salinity as expressed by the electrical conductivity (EC). Effluent qualities were adjusted to contain similar content of nutrients as given by N, P and K.

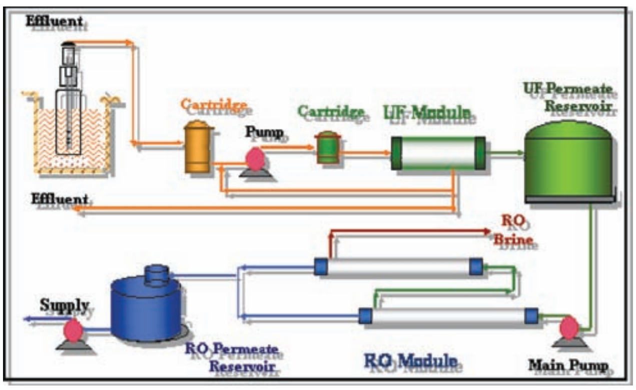

Figure 8.1
Schematic description of the hybrid membrane system in Arad, Israel

The different effluent qualities were applied for irrigation of water-melons. Netafim RAM emitting pipe ISO 9261A- was used for irrigation. The drip laterals were 96 cm apart with a length of 16 m. The emitters with a flow rate of 1.2 L/hr were spaced 25 cm apart on the laterals. Subject to class evaporation pan data and the crop coefficient, the field was irrigated 2 to 3 times per week. Monitoring included observation of changes in soil nutrient content, salinity and yield characteristics.

8.1.2 Results: The effect of effluent quality on the salinty of soils and on watermelon yields

Mean total amount of effluent applied during the growing period was around 2,637 m3/ha. The results of the continuous monitoring indicate the effects of effluent qualities on soil properties (Figure 8.2). Soil properties are subject to continuous (several seasons) application and cumulative phenomena of applying same quality effluent in same plots. The purpose is to examine the accumulated effects of applying various effluent qualities on the soil properties and sustainable production. It can be clearly observed that the RO effluent application is associated with the lowest soil salinity and sodium adsorption rate (SAR) in the soil. The highest SAR and salinity can be observed for the reservoir effluent (SER) and the secondary effluent from the waste stabilisation ponds (SEP). All other SAR and salinity levels in the soil were between the upper values of the SER and SEP effluent and the lowest one as indicated by the RO effluent.

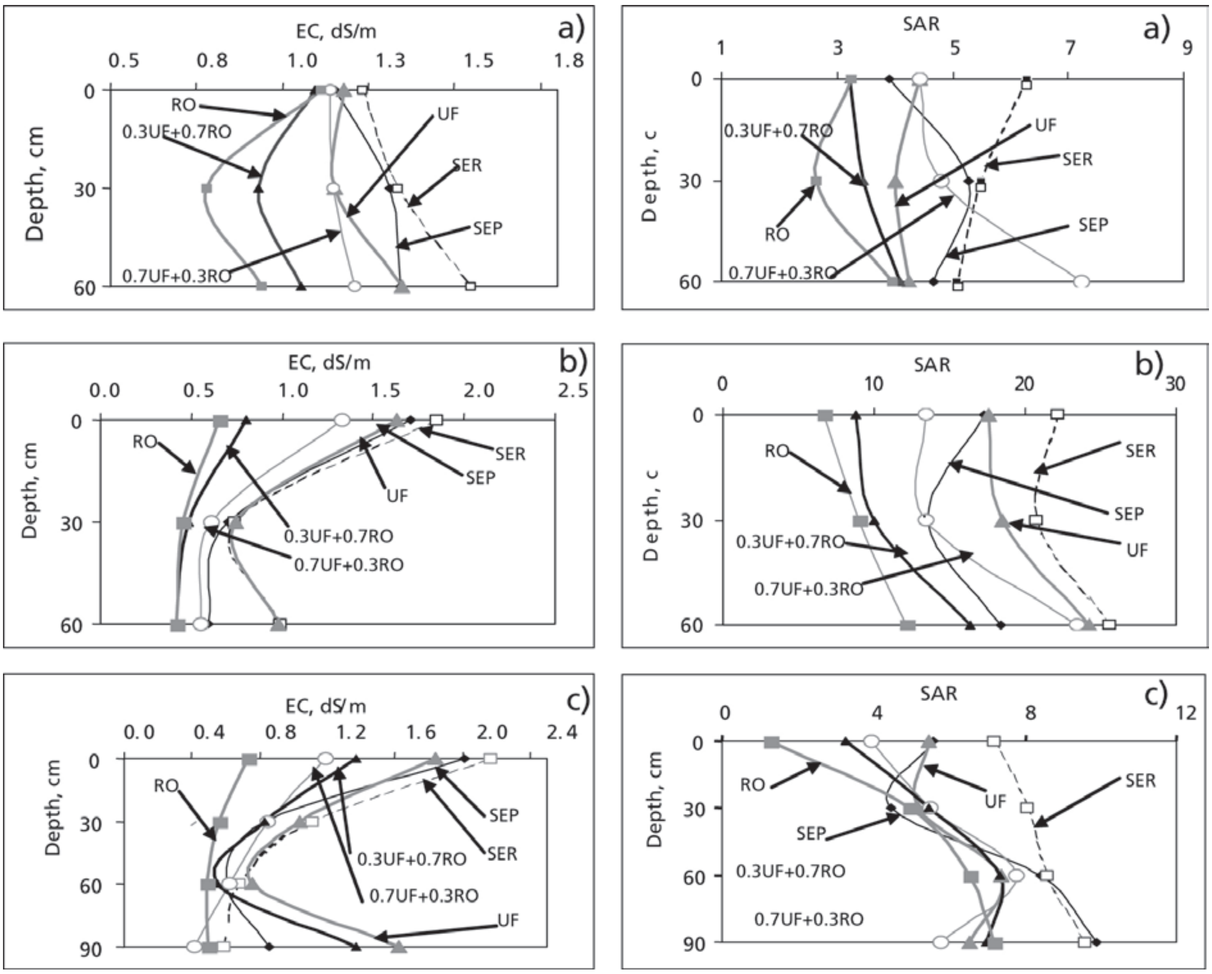

Figure 8.2

Variations in soil salinity-electrical conductivity (EC) and sodium absorption ratio (SAR); profiles subject to different qualities of applied water. Arad, watermelon, 2005 [a)-Initial (07 April); b)-Middle of irrigation season (08 June); c) Final (03 August)].

A similar tendency can be identified for the watermelon yields. Best yield was obtained for the plot receiving the RO effluent (Figure 8.3). The lowest yield was obtained for the effluent from the reservoir (the highest salinity). The effect of salinity on the yield is well emphasized by the difference between the treatments which received different ratios of UF and RO effluent (70% and 30% RO effluent and the inverse).

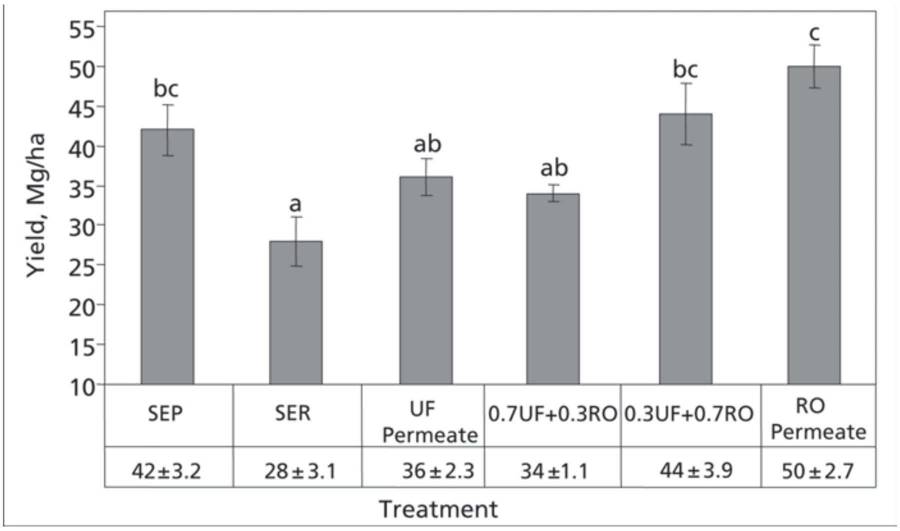

Figure 8.3
Variations in watermelon yield as a function of the applied effluent quality; (SEP: Secondary Effluent from Ponds; SER: Secondary Effluent from Reservoir; UF-Effluent after UF membrane treatment; RO-Effluent after RO membrane treatment).

8.2 Precision irrigation of tomato in the Lower Jordan Valley, Palestine (D801)

Compiled by: A. Marei (QUDS)

8.2.1 Introduction

The main objective of this study is to identify and investigate the actually needed irrigation water in terms of quantity for growing tomato and gain high crop production. This objective was satisfied through optimizing the irrigation volume of needed water for growing tomato at different stages, saving water without reducing the production and increasing water productivity. Agriculture consumes more than 80% of the region's available water which will be reduced to half by the year 2050. Hence, this leads to more concerns about the optimal use of water resources.

A comparative study was conducted for the growth of tomato under green house conditions (2.5 dunums (du)), whereas one factor (water consumption) was variable.

8.2.2 Methods

A cherry tomato, variety 1335 (cluster), was planted in the green house in 28 lines with double rows, 15 lines of them under study control. Experimental design was divided into three blocks (B1, B2, B3), each block included five lines with five treatments (T1, T2, T3, T4, T5), where the latest was connected with another 13 lines irrigated by farmer (T5) with an experience of 25 years and who was controlled by irrigation engineers of the Palestinian Agribusiness Participatory Approach (PAPA) project. The treatments were randomly selected without replacement. Each treatment value referred to an irrigation percentage of ETc (crop water requirement).

8.2.3 Results

The study showed that the actual required water was less than the applied volume. This volume ranged between 12.4 - 33.6% of the applied water used by the trained farmer (treatment T5), and reached 51.5 - 62.5% of the water applied by normal farmers. This result can cause a decrease in the vegetable production cost, sustain agricultural activities and protect the Shallow Aquifer from agricultural return flow.

The study also indicated that the average irrigation water productivity in the district was 15 kg/m3. Using the study data for better irrigation management in the area, the agricultural land could be increased from 14.2 to 33.7% (%referring to T5 farming). However, while referring to the average of what farmers used in Jericho district, the agricultural land could be enlarged from 76 to 166.7%. The best results for field efficiency according to economic values were achieved by the treatment conditions in farm 2 (T2; field efficiency: 75%), followed by T1, T4, T5, and T3. The provided conditions in T2 can save more than 100,000 m3 of water per season in 500 du of tomato green houses in Jericho district related to T5.

8.3 Feasibility of wastewater reuse for irrgation – the membrane bioreactor (MBR) technology (D802)

Compiled by: G. Oron (BGU)

8.3.1 Introduction and methods

Domestic wastewater has to be treated to adequate levels in order to allow safe use. Safe use refers primarily to the removal of pathogens and ultimately also to the removal of the dissolved solids. Membrane Bio-Reactors (MBR) are used for diverse options of wastewater qualities. The MBR consists of a combination of biological treatment based on the activated sludge process and separation with ultra filtration membranes. However, fouling phenomena is an inevitable consequence of membrane filtration of wastewater. Mixed Liquor Suspended Solids (MLSS) concentration, particle size distribution and Extra cellular Polymeric Substances (EPS) are key significant biological parameters directly related to fouling rates. Improving biomass properties is an alternative to minimize membrane fouling and enhance MBRs' efficiency combined under different operating conditions. A possible and promising approach to minimize membrane fouling and increase treatment efficiency is by implementing the Biofilm Membrane BioReactor (BMBR) as an advanced approach. A hollow fiber membrane module of ZW-10 (Zenon Inc, Canada) and the AqWise carriers (AqWise Inc, Israel) were combined to reduce the biofouling on the membranes surface. The carriers function as biofilm support media under ambient desert conditions (Kiryat Sde Boker, Israel). The moving-bed BMBR was equipped with a draft tube (diameter of 295 mm) and AqWise carriers occupying 20% of the reactor volume as the biofilm support. The driving force generated by the airlift enhanced the carriers' circulation. The fixed-bed BMBR consisted of a draft tube (diameter of 235 mm) with two meshes installed at upper- and bottom-channel and 60% of the reactor volume of AqWise carriers in the external tube. Artificial meshes were used for stopping the carriers entering the internal tube. Therefore, only mixed liquor was in the internal tube. Three configurations of the MBR were examined, namely a conventional airlift MBR, moving-bed BMBR and fixed-bed BMBR. The BMBR was operated under a cycle of 5 min filtration/15 second backwash, 30 days of Sludge Retention Time (SRT), and 3.4 m3/hr of aeration rate.

8.3.2 Results of operting various configurations of MBR

The results (Table 8.1) were obtained for 17 operating days of the airlift MBR, 25 operating days of the moving-bed BMBR and 3.5 operating days of the fixed-bed BMBR. Poor nitrification process was probably due to inhibition/toxicity induced in the chicken manure or chicken food, or due to high MLSS concentrations (from 5,660 up to 10,730 mg/L) resulting in an insufficient dissolved oxygen (DO, average value: 0.5 mg O2/L) in the moving-bed BMBR, and probably due to a too short running time for the nitrifiers growing in the fixed-bed BMBR, respectively. Moreover, it was found that there was a thick and sticky sediment layer containing sludge and carriers accumulating on the bottom of the external tube under anaerobic conditions in the fixed-bed BMBR system. Consequently, a decrease of the liquid recirculation and MLSS concentration in the internal tube (only 159 mg/L in average) could be maintained. That might explain the sharp increase of the fouling rate during the 3.5 operating days. An increase of phosphorus removal efficiency in the fixed-bed BMBR was observed, probably due to sedimentation in the sticky layer. The results for Zeta potential (-20.43 mV) and particle size distribution exhibited a colloidal system of the mixed liquor with an incipient instability behavior, which proved high fouling potential in MBR systems.

Table 8.1

Mean removal efficiencies for main quality parameters in the airlift MBR (membrane bioreactor), moving-bed and fixed-bed BMBR (biofilm membrane bioreactor)

	airlift MBR	moving-bed BMBR	fixed-bed BMBR
COD	81.3% (570-106 mg/L)	89.1% (579-63.3 mg/L)	83.6% (528-86 mg/L)
BOD^5	96.9% (207-6.4 mg/L)	98.6% (225-3.1 mg/L)	93.6% (259-17 mg/L)
NH_4-N	46.7% (43.1-23 mg/L)	39.5% (28.5-17.2 mg/L)	41.6% (41.9-24.5 mg/L)
TN	26.8% (43.8- 32.1 mg/L)	30.5% (29.8-20.7 mg/L)	37.0% (43.2-27.2 mg/L)
PO_4-P	24.6% (12.1-9.1 mg/L)	14.2% (11.8-9.3 mg/L)	52.3% (12.3-5.9 mg/L)

8.3.3 Expected impacts

The BMBR experiments provided evidence that wastewater can be treated to acceptable levels and that the effluent can be reused for irrigation. Most important, the MBR treatment device has a small footprint, requiring minimal land for installation and operation. Also, under given conditions, additional MBR devices can be added (LEGO format), thus, are flexible enough according to conditions in the area. An additional outcome that the MBR can be implements for domestic wastewater reclamation in small and isolated communities. The use of small treatment devices has primer advantages for effluent reuse for diverse purposes in rural areas.

8.3.4 Future research

Future research will focus on implementation of modified treatment methods allowing obtaining effluent with minimal content of pathogens and dissolved solids. Extra efforts will focus on reducing the adverse effects of fouling processes that reduce the membrane flux and on operation regimes enabling to reduce the energy demand.

8.4 Feasibility of artificial recharge in Jordan (D803)

Compiled by: L. Wolf, A. Sawarieh, M. Zemann (UKA)

8.4.1 Introduction and methods

In order to assess the feasibility of artificial recharge in the Lower Jordan River Basin, site specific studies were carried out in Wadi Kafrein and Wadi ad Dardur. In addition, a regional map displaying the potential for managed aquifer recharge was constructed using multi –layer GIS analysis, slope analysis and buffer operations. A numerical groundwater model was set up at the Wadi Shueib reservoir in order to estimate the influence of the artificial recharge from the dam floor on the wellfields below.

Further on, detailed studies and construction of infiltration facilities were carried out in the Wadi Faria, Palestine. The studies were done within a close cooperation of Dr. M.Ghanem (on behalf of PHG) and Dr. Amer Marei (Al-Quds University) and are reported there.

In Wadi Kafrein, an infiltration basin was constructed (see Figure 8.4) and operated for more than one year to investigate (i) possible clogging problems from the infiltration of wadi baseflow with wastewater components (ii) water quality of the wadi baseflow in high temporal resolution and (iii) removal of pollutant load during the sub-surface passage.

In Wadi ad Dardur pre-studies were performed for the detailed planning of a dam to capture flash-floods in a small rural catchment and to infiltrate it into the carbonate aquifer. The studies included geological mapping in scale 1:10,000, site selection, delineation of the surface catchment area, estimation of runoff volumes, negotiations with local farmers, specification of construction details and development of a cost assessment.

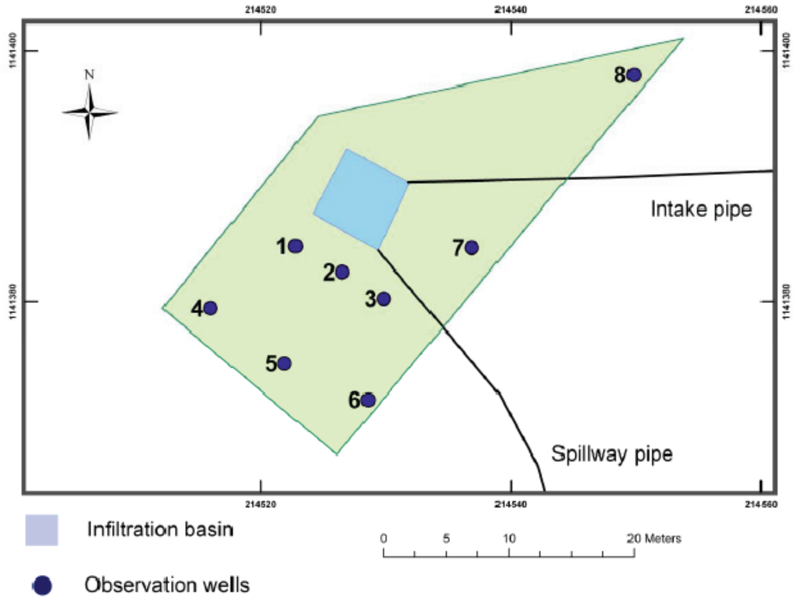

Figure 8.4
Detailed plan of the artificial recharge test site Wadi Kafrein (Zemann 2008)

8.4.2 Results

At the coarse alluvial gravel sediments of the artificial recharge test site in Wadi Kafrein, very high infiltration rates up to 2,000 L per m² per day were observed. Clogging was visually observed but had only minor impact on the infiltration rate. To allow ready transfer of results to other test sites with different hydraulic boundary conditions, the results were used to calculate k_f-values for the basin bottom between 1.18 * 10^{-6} m/s to 2.4 * 10^{-6} m/s.

The online monitoring of EC in the wadi baseflow and the WWTP As Sir, which is discharging into the wadi showed a consistent daily pattern with values between 1,150 µS/cm and 1,450 µS/cm The comparison with the WWTP effluent variations showed that quality variations of the treatment process are not responsible for the observed pattern but that the variations in discharge of the WWTP are in tune with the quality variations of the baseflow (Figure 8.5).

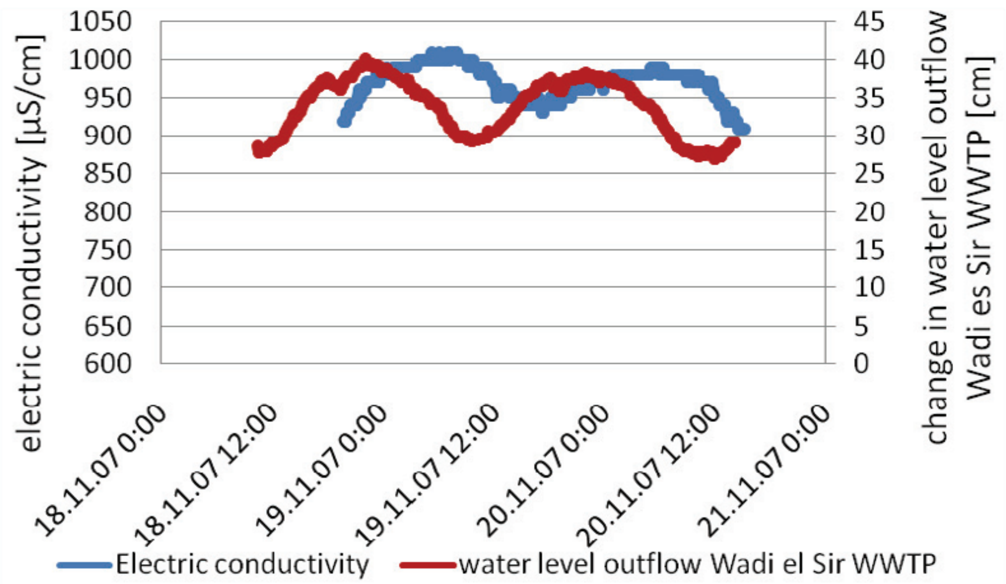

Figure 8.5
Variations in water quality of the wadi baseflow corresponding with discharge variations in WWTP outflow (Zemann 2008)

Water quality sampling of the wadi baseflow showed that the waters are within the Jordanian standards for artificial recharge. Nearly all parameters meet the national standards for artificial recharge. Only some pharmaceutical concentrations, especially x-ray contrast media, are remarkably high in comparison to former water analysis in the area.
In Wadi ad Dardur, a site was selected as shown in Figure 8.6. The surface catchment area at the site was assessed as 4.14 km² with an average yearly rainfall of 150 mm/yr. The first technical draft of the dam design foresees a reservoir capacity of ca. 13,000 m³.

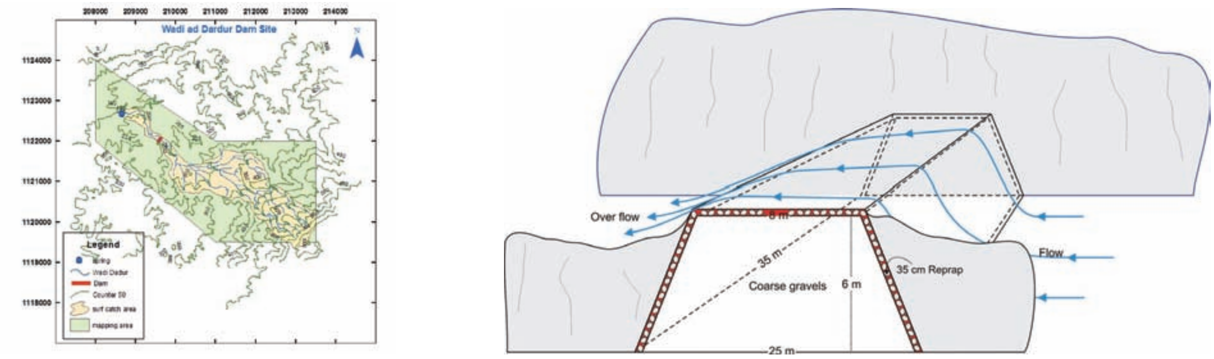

Figure 8.6
Mapping exercise & location of the proposed dam site; dimensions of the proposed dam structure

8.4.3 Expected impacts

The infiltration tests at the Kafrein test site demonstrate the excellent prospects for the construction of artificial recharge schemes in alluvial wadi sedimens. A flash-flood dam in Wadi ad Dardur may become a valuable example to exploit a currently underused resource in the JRV: small rural wadis. Both studies directly contribute to mitigate water scarcity by offering additional groundwater resources and by reducing evaporation.

8.4.4 Future research

Future research need is given by the selection of the most appropriate techniques for the various areas which are suitable for managed aquifer recharge and by the need to assess the environmental soundness of the operation. Managed Aquifer Recharge is not implemented in sufficient scale in the LJV. Implementation barriers must be identified, successful prototypes need to be operated and cost-efficiency must be proven.

8.5 Assessment of artificial recharge for the shallow groundwater aquifer in Al Jiftlik & Wadi Al Faria, West Bank (D803)

Compiled by: A. Marei (QUDS), M. Ghanem (UKA)

8.5.1 Introduction

An artificial recharge test site was selected in the Al-Jiftlik area at the edge of the Faria basin in the Upper Jordan Rift Valley. An artificial, cylindrical pond of 15 m diameter and 3 m depth was used, possessing a volume of 400 m^3. The parameters of hydrogeological settings, hydrochemical characteristics of allocated water bodies, geophysical investigations and the aquifer system potential of the area were used for the selection of the test site (Figure 8.13). It is located within the shallow Pleistocene aquifer of 30 - 50 m saturated thickness. Three groundwater wells in varying distances (50 - 1000 km) were used for the system monitoring. The filling water for the test system originates from the wadi flood waters transported via a 1.5 km open water canal.

8.5.2 Methods

The Schlumberger method was applied to conduct geoelectrical investigations by using a Earth Resistivity Meter (ERM) in order to draw geophysical profiles of the Al-Jiftlik area. The aim of this investigation was to determine the thickness and distribution of different strata and to determine possible artificial groundwater recharge in sites along the wadi area. In order to obtain the hydraulic conductivity, sieve analyses were carried out. Physical and chemical properties were determined for eight target wells existing in the study area.

The major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-}, NO_3^-, HCO_3^-) as well as heavy metals (Fe, Zn, Li, Cr, Co, Ni, Cu, Cu, Mn, Al, Cd, Ba, Pb, Bi) were analysed, and from these the water type was found to be Na–Cl. The analyzed parameters were also used to produce linear correlation analyses. The results of the saturation index show that all the groundwater samples were found to be undersaturated with respect to all minerals.

8.5.3 Results

The soil texture is dominated by clay to clayey loam (Figure 8.9). It has a low infiltration potential and a high runoff potential. The hydraulic conductivity is very small and ranges between $2 - 9 \times 10^{-5}$ m/s.

The surface flood method is not suitable to be used in artificial recharge, as the clayey soil texture has a low infiltration potential. Here, the suitable method used for artificial recharge is the injection of flood water into a 3 m deep pond that is located lower than the Lisan Formation.

The thickness of the unsaturated gravel aquifer in the lower part of Al-Jiftlik is about 20 m. This layer could be used to store flood water. From the ERM-measurements (Figure 8.7, Figure 8.8) it can be seen that five sub-layers are located within the unconfined aquifer systems. These sub-layers are related to the Pleistocene-Neogene age and the limestone in the depth to the Cenomanian age.

The lower eastern zone of the study area is facing huge salinization problems of aquifer water (Figure 8.10, Figure 8.11, Figure 8.12) while nitrate pollution is less notable there. EC-values are higher than 4,000 µS/cm. It is well known that only tolerant crops are able to tolerate salinity levels higher than 2,200 µS/cm. Farmers mix brackish well water with wadi water of lower salinity to obtain irrigation water with tolerable salinity content. Groundwater salinity increases towards the east where the Lisan Formation is dominant, and it emerges through long duration time, reactions between fresh water, marl, clay and minerals of the Lisan Formation, especially in the lower part of the study area, and the over pumping by the farmers.

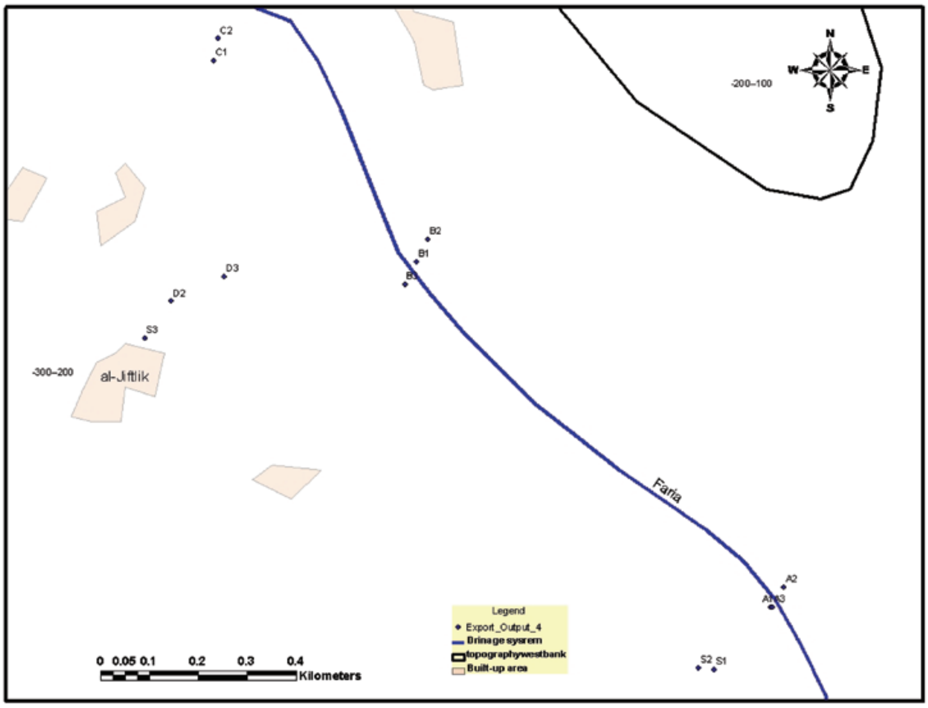

Figure 8.7

3 VES profile locations in Al–Jiftlik study area

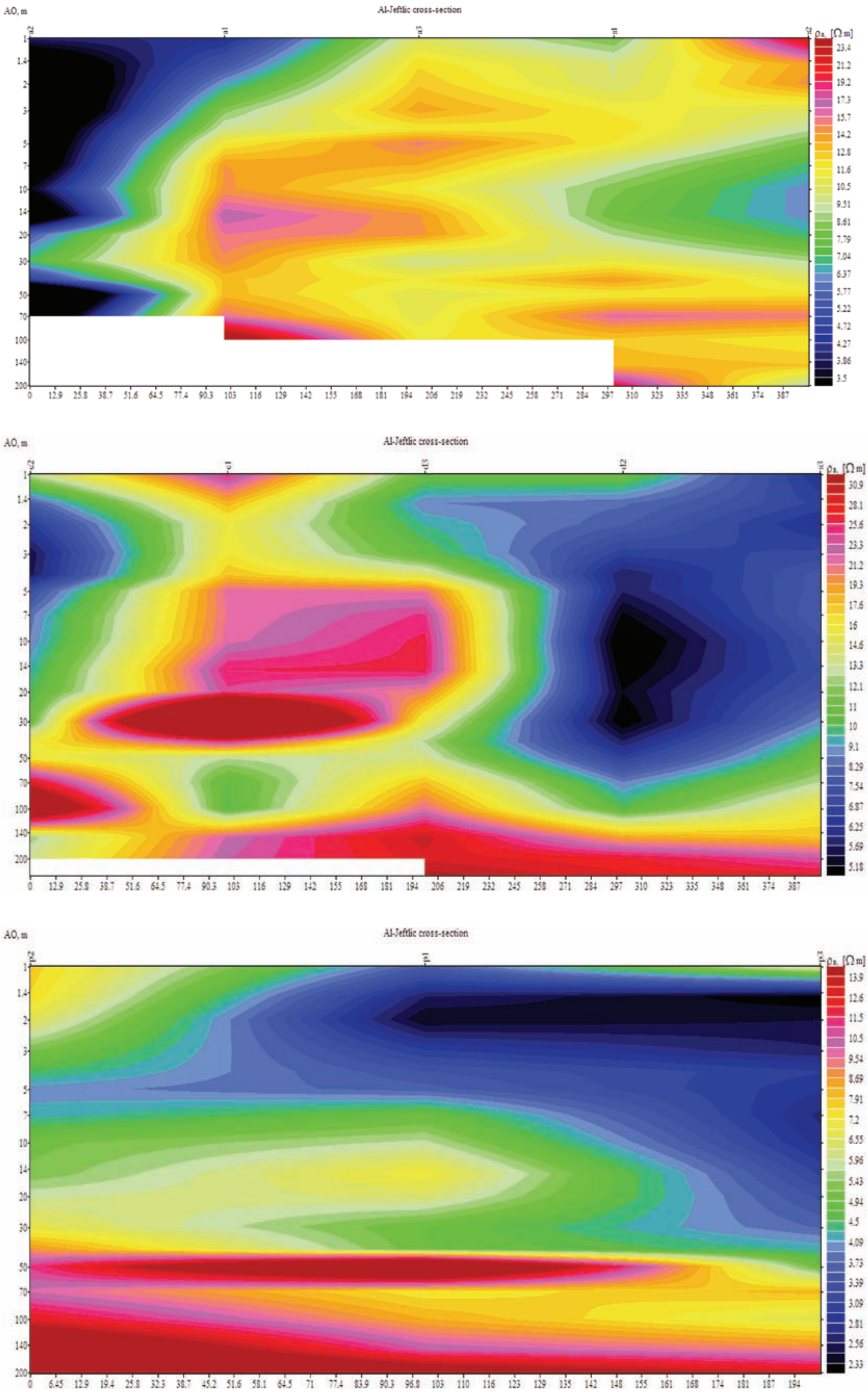

Figure 8.8

VES east profiles in the Al–Jiftlik area. VES: vertical electric sounding

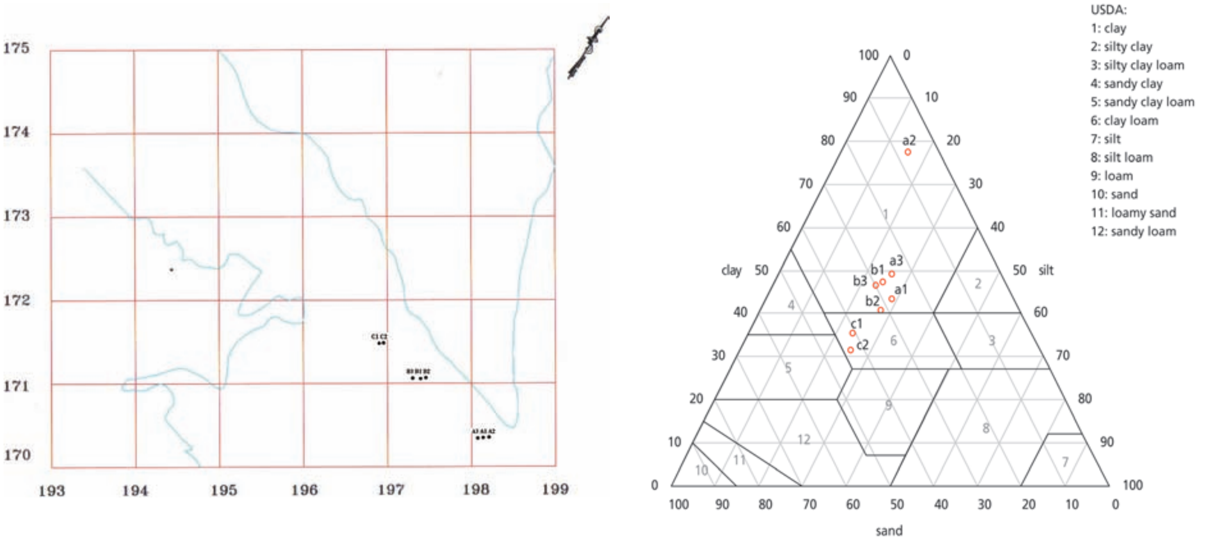

Figure 8.9

Left: Location of the soil samples Right: Texture triangle for Al-Jiftlik soil samples

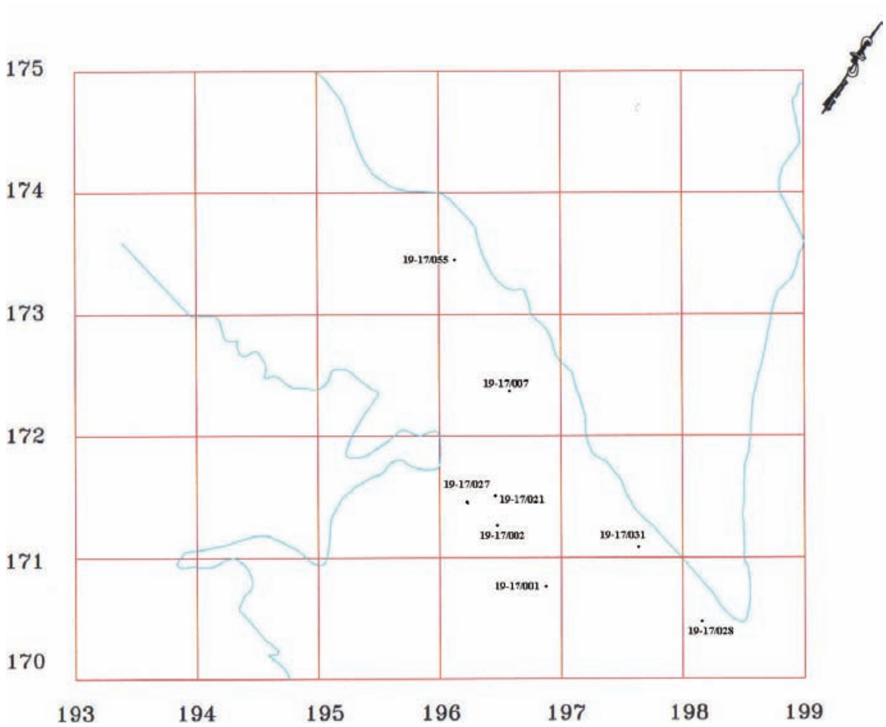

Figure 8.10

Location of groundwater wells

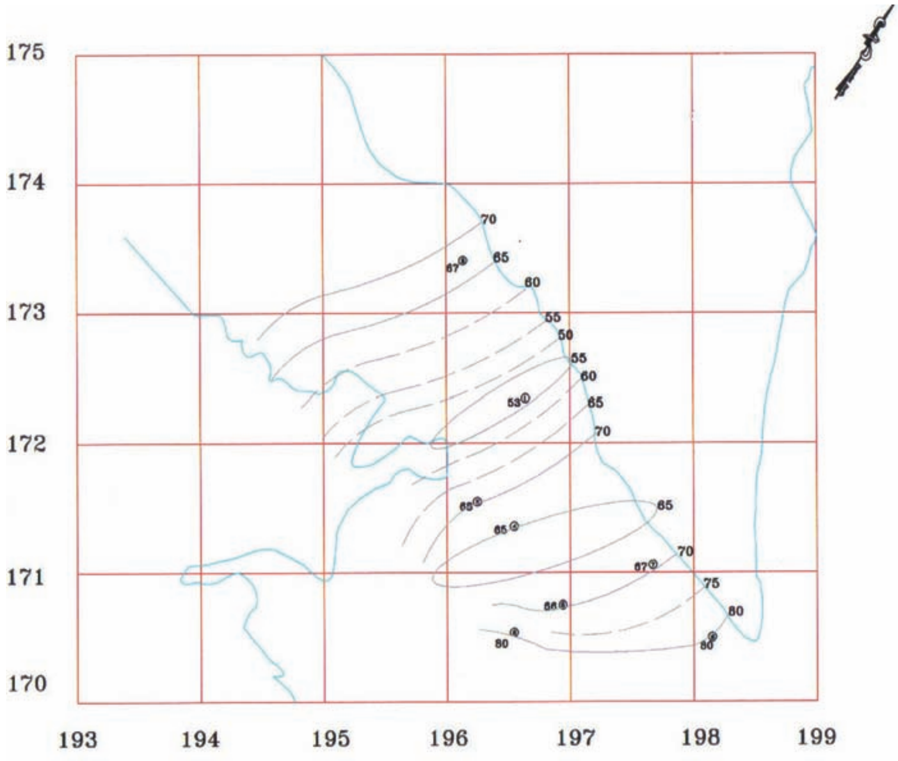

Figure 8.11
SO_4^{-2} concentration in mg/L

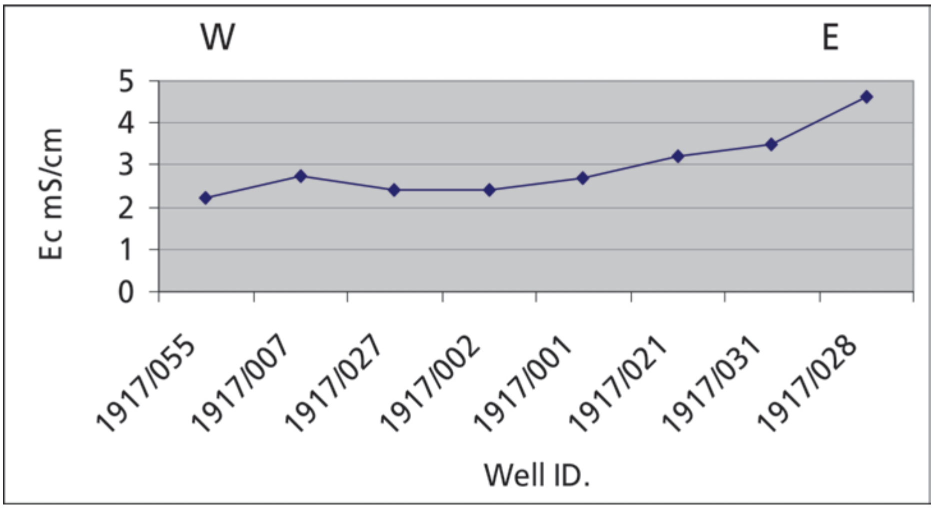

Figure 8.12
EC of the wells in the studied area

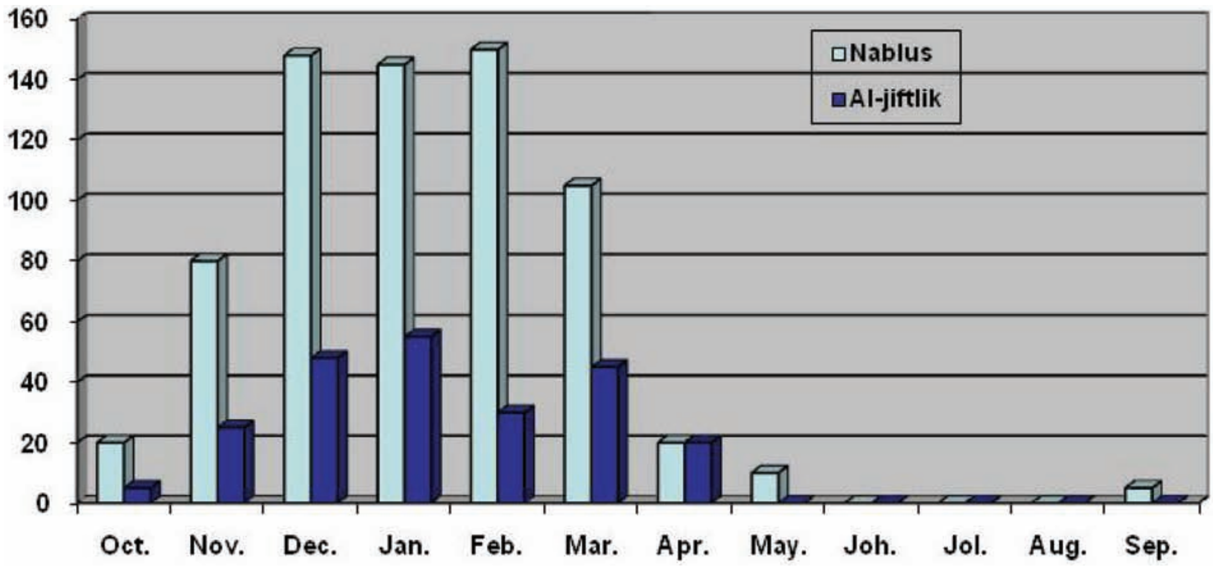

Figure 8.13
Average rainfall distribution in mm

8.5.4 Expected impacts and future research

The qualitative risk assessment of the spring system in E-W direction of the Malih and the Qilt area is the main output of these results. With regard to different pollution sources that are recorded in the area, natural and manmade pollution of domestic, agricultural and industrial activities are considered the major threats to the qualitative potential of the water resources in the Jordan Rift Valley. The investigation will be of benefit for future locations of artificial recharge sites in the region.

The water quality assessment study in the Jordan Rift Valley is a link to the manmade pollution sources in the area. The risk assessment study of springs of the E-W profile will accompany future qualitative models in the area and will build the base for future planning of artificial recharge sites as well as for evaluations of qualitative assessment with regard to the WHO-standards. Furthermore, the artificial recharge experiment in the Faria catchment is necessary in order to get an actual idea about the groundwater potential of the area.Within the scope of further investigations, the recharge rate of the Pleistocene aquifer should be determined and compared to the calculated transmissivity value that was extracted from the conducted pumping test campaign of pre-test investigations.

8.6 Assessment of a potential artificial recharge site in Jericho (D803)

Compiled by: A. Marei, M. Subeih (QUDS)

8.6.1 Introduction

The hydrogeology of the shallow aquifer system in Jericho area is highly depending on the recharge mechanisms through Wadi Al Quilt storm water. This aquifer is intensively used in the last five decades. The uncontrolled abstraction and the low recharge rate are major factors still causing groundwater degradation. Water chloride contents rose from 600 mg/L in 1970 to more than 2,600 mg/L in 2007, and only 20 groundwater wells out off 90 boreholes are still abstracting water with different quality. The depths of these wells range between 80 – 200 m. In the sixties of the last century, the total abstraction was about 3.5 MCM/yr, and this quantity was diminished to less than 1.0 MCM/yr in the late 1990's due to the lowering of the groundwater table to more than 30 m below surface in most of the boreholes. Wadi al Quilt crosses Jericho Shallow Aquifer from west to east with a total length of 7 km. The width ranges between 10 to 70 m, the average depth is 7 m.

8.6.2 Methods

Four investigation methods were used in order to accomplish the hydro-geophysical study. The recharge rate was determined by the groundwater table fluctuation method (WTF). Underground lithological investigation focused on potential gravel layers by using the vertical electrical sounding method (VES). The permeability of Wadi al Quilt sediments was determined by grain size curve method (GSC), and texture classification. Hydrochemical analysis was involved to investigate the spatial distribution of the groundwater chemical constituents.

14 wells were selected to estimate the recharge rate. Recharge rate values were classified into three domains. High recharge rates (0.09 m/d) which occur in the middle section of the wadi with a total length of 2,650 m. Intermediate recharge rates with an average rate of 0.06 m/d occur in the western section of the wadi with a total length of 3,000 m (Figure 8.14).

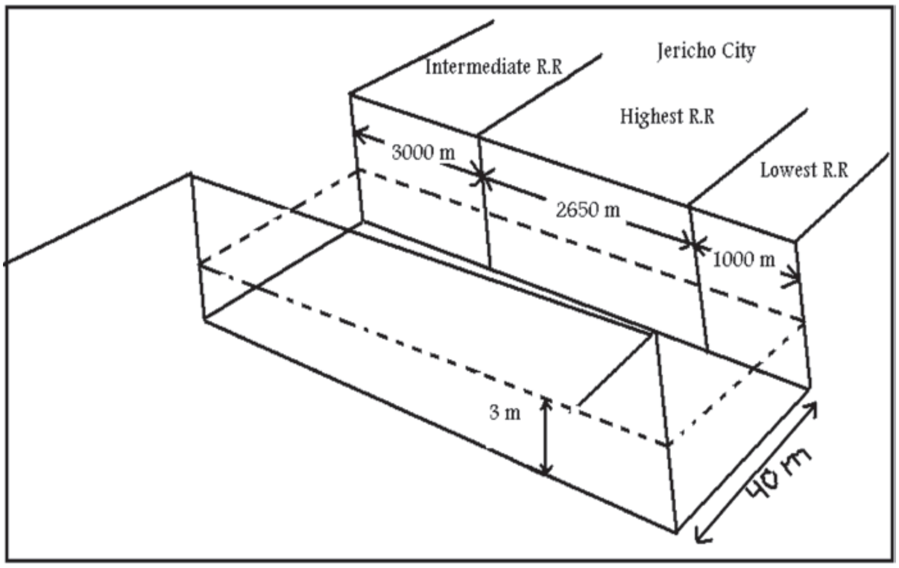

Figure 8.14
Block diagram of the Wadi al Quilt pathway in Jericho with general dimensions and recharge rate zones

19 VES points were accomplished along the wadi stream and Jericho area. The sounding depth was ranging between 80 - 250 m. Electrical resistivity of the gravel ranged between 100 - 200 Ωm. Sandy-silty resistivity ranged between 30 - 70 Ωm. Marly-clay resistivity ranged between 10 - 30 Ωm. The saline groundwater body resistivity was less than 1.0 Ωm. A saline groundwater body was identified at 100 m depth in the area of Ketf Alwad to the east of Jericho city (Figure 8.15).

10 representative soil samples were collected at 40 cm depth along the wadi floor. The highest permeability value was calculated to be 5.89 * 10-4 m/s with sandy loam texture. The lowest permeability was 4.53 * 10-5 m/s with silty texture. The estimated area of the rechargeable gravel layer was 1.1 * 106 m2, with an average thickness of 65 m.

The actual calculated recharge volume of the shallow aquifer which took place during the flooding time was 160,500 m3/yr, this value is calculated based only on 8 flooding days/yr. It is possible to rise the recharge volume up to 240,000 m3/yr, this could be achieved by building a small earth dams across the wadi. By increasing the retention time of the wadi flow for additional four days, the recharge volume will rise up 33%. This action could delay the total destruction of the shallow aquifer.

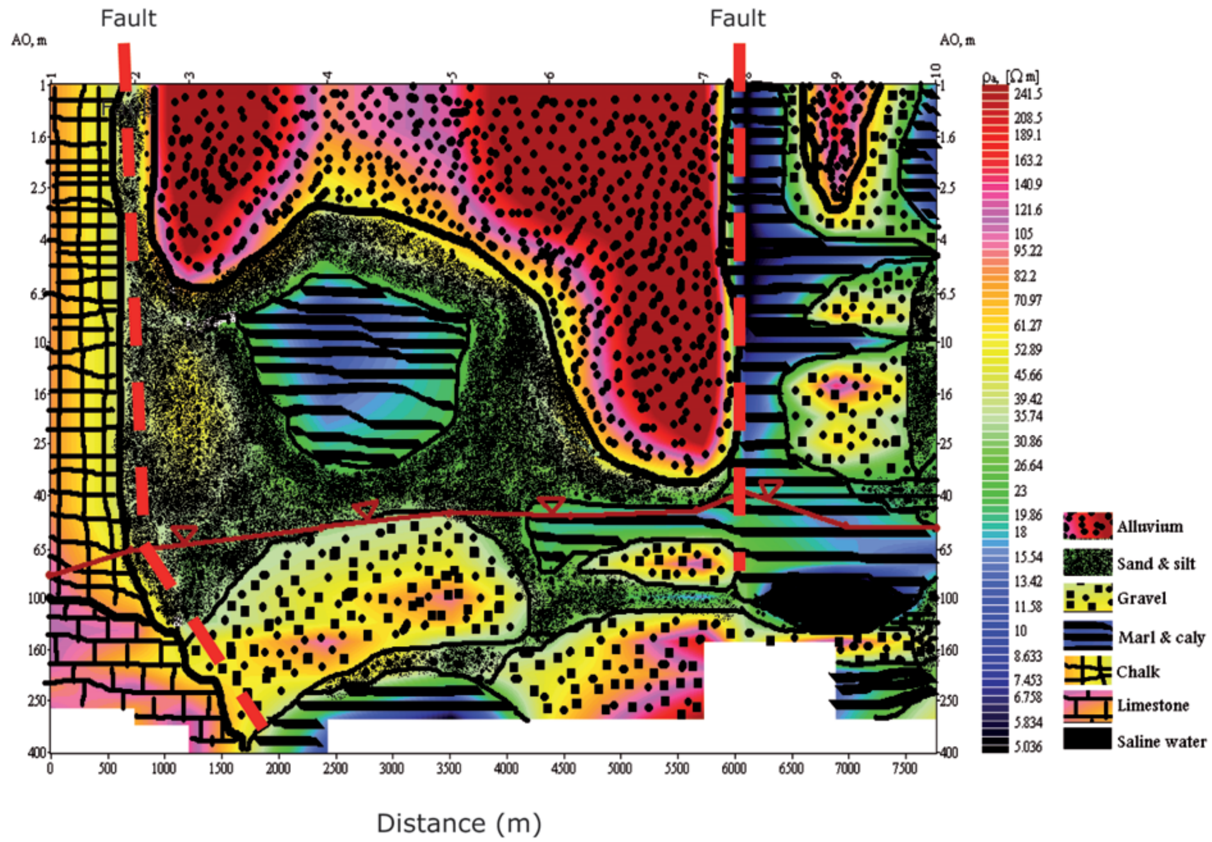

Figure 8.15

West – east lithological profile along Wadi al Quilt pathway

8.7 Unsaturated zone transformations // Feasibility of saline water irrigation (D804)

Compiled by: E. Salameh (JUA)

8.7.1 Introduction and methods

Suction cups (Figure 8.16) are used in this project to study the chemical and physical changes that take place during the down percolation of water through soils.
Suction cups were installed at depths of 20, 40 and 60 cm in areas irrigated with:
- Treated wastewater (Wadi Es Sir and Fuheis treatment plants)
- Spring water in Wadi Es Sir Valley where that spring water is used for irrigation

8.7.2 Results

Samples from the test sites have been collected and were subsequently analysed for their chemical composition (normal chemical analysis), BOD, COD, pH, T and EC. The obtained results of the chemical analyses have not yet been interpreted before a longer observation period because the soil-water system needs to stabilize first.

8.7.3 Expected impacts

In the future, less fresh water will be available for irrigation. Irrigation needs will be generally covered by reusing treated waste water. The effects of such shift on soils and groundwater have to be considered in the planning schemes in order to avoid both, accumulations of salts in the soil and groundwater quality degradation.

Figure 8.16
Installation of suction cups at
a) Wadi Es Sir and Fuheis treatment plants,
b) Wadi Es Sir Valley

8.7.4 Future research

Suction cups are installed to a depth of 60 cm, which is generally the depth of the soil horizon. But the infiltrating water continues in its downward movement to the groundwater body, and undergoes further changes in its composition. It is necessary to study these further changes and their effects on the quality of the groundwater.

8.8. Water harvesting using capillary break systems (D805)

Compiled by: A. Hamaideh (GJU)

8.8.1 Introduction and methods

The project aims at testing the Capillary Break System (CBS) as an innovative intermediate technology for subsurface water storage with 44 times reduction in evaporation rate in comparison with other water harvesting techniques. This system is know-how technology for dry climates, where evaporation rates from water bodies reach 80 - 85%. It is planned to be constructed across minor tributaries of wadis in semiarid or arid regions. The conceptual idea is that such a system can be implemented by the local people using locally available sediments. The collected and stored water in the wadi's subsurface using this technology can be used for agricultural or environmental purposes. The objectives of this research pilot project are:

- to understand and analyse the capillary break system from soil hydrological point of view,
- to determine the effect of layer thicknesses on the evaporation rate, and
- to improve design methods and concepts of CBS as a water harvesting technique, taking into account temperature and wind gusts effects on the performance of CBS.

The CBS (Figure 8.17) consists of three layers:

- a capillary break layer (CBL) of coarser-textured (e.g. gravel) at the soil surface with over-capillary pores,
- a capillary layer (CL), finer-textured (e.g. sand or medium gravel) underneath the top CBL with capillary pores, and
- another CBL, coarse-textured over-capillary layer at the bottom.

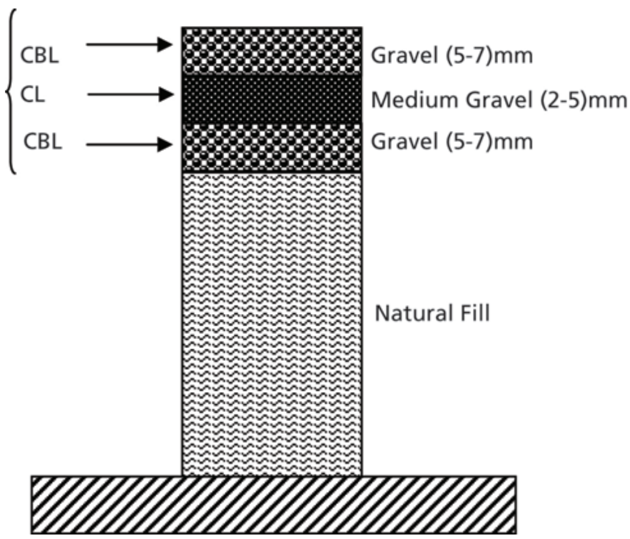

Figure 8.17
CBS, capillary layer (CL), two capillary block layers (CBL), storage body, and impervious bedrock

Each layer serves a distinct purpose. The upper gravel layer stimulates surface water infiltration; vertically downward water movement is not restricted by the two underlying CL and CBL towards subsurface storage. The fact that vertically upward movement of soil moisture driven by evaporation can occur in liquid and gaseous form, employs the bottom gravel layer to restrict the upward movement of liquid moisture. The breaking of the capillary rise processes is due to the oversized capillary pores. Vapour transport through the air-filled pores is reduced by the central capillary layer, where the air-filled porosity is smaller and the tortuosity is larger.
The conception of the CBS is an alternative in developing rainwater harvesting systems in Jordan. It is intended to integrate traditional methods of rainwater harvesting used by local Bedouin tribes and watershed management projects activities. These specific methods which have been used for centuries, like roman wells, stone walls, terraces, and hafir techniques, offer a potential solution to the problem of water shortage in Jordan, particularly related to herdsmen and their needs.

8.8.2 Site description

The project is located in the Shehan mountainous area – Karak Governorate, Jordan, at an elevation of about 930 m a.m.s.l. The pool will be excavated in a wadi with a length of 1.8 km sloped toward the location of the pool. The maximal elevation upstream is 1066 m a.m.s.l.

8.8.3 Hydrological data

- The area of the watershed is 1.5 km2
- The average annual rainfall depth over the catchment area is 342 mm.
- The rough estimate of the amount of runoff using curve-number method showed that a storm with gross precipitation of 30 mm will produce about 15,000 m^3 of runoff water. Such storms occur not less than five times per year in the catchment area.

8.8.4 Construction

The construction of the water reservoir is designed to minimize the seepage of the collected water in order to facilitate accurate measurement of evaporation. Plastic sheets will be used to cover the soil in order to prevent any seepage that may occur.

The pool will have a trapezoidal shape as shown in Figure 8.18. All calculations will include estimations of the volumes of excavation, concrete, rock fill, gravel, sand, clay, quantities of plastic sheet, and stone wall construction. Near the structure, a zero scenario will also be stimulated. A trapezoidal basin with concrete lining beside the CBS is designed to be building, in order to be able comparing the results.

A monitoring station is also planned to be installed in the site (weather station, tensiometers, etc.). Described construction work was carried out in 2008 and finished in May 2009, so that monitoring could start in the we period 2009/2010.

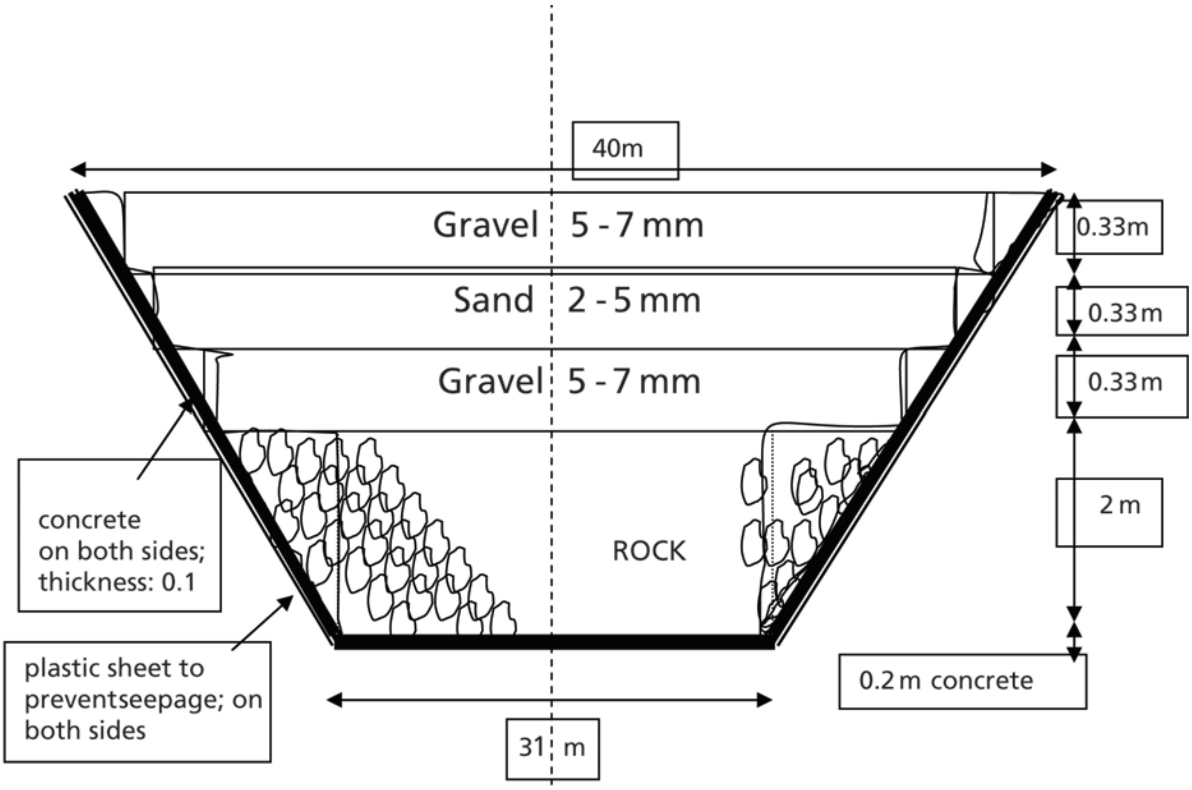

Figure 8.18
Pool with trapezoidal shape

8.9 Utilisation of flash-floods // Seasonal and long term storage of water of multiple qualities (D806)

Compiled by: A. Sawarieh (UKA)

8.9.1 Introduction and methods

The Kafrein Dam was constructed in 1968 on Wadi Kafrein in the Jordan Valley and in 1996 was raised by 7 m to increase its capacity to 8.5 MCM. The dam intended to store winter flows for downstream irrigation as well as to recharge the groundwater. Wadi Kafrein has two major tributaries: Wadi Es Sir and Wadi Na'ur. These wadis have permanent base flow supported by many springs and seepages scattered in the catchment area, the floods during winter and by treated waste water which is discharged from Wadi Es Sir Treatment Plant. The whole catchment area is drained by a small perennial river (Wadi Kafrein) which is dammed at the emergence to the Jordan Valley by the Kafrein Dam. The long term average discharge of Wadi Kafrein is 6.4 MCM/yr: 1.6 MCM/yr as surface runoff and 4.8 MCM/yr as groundwater base flow.

This study is aimed to assess the effects of the dam water (different qualities) on water quality and quantity of the downstream aquifer.

Kafrein observation well-1 was used to monitor the groundwater level fluctuation downstream on a monthly basis to assess the dam water effect on the groundwater quantity.

Several water sampling points (wells) were selected to study the effect of Kafrein Dam water on groundwater quality in the aquifer downstream (Figure 8.19), these wells were sampled on quarterly bases and analyzed for cations, anions, NO_3, NO_2, NH_4, Total Nitrogen, PO_4, BOD, COD and isotopes in the Water Authority Jordan.

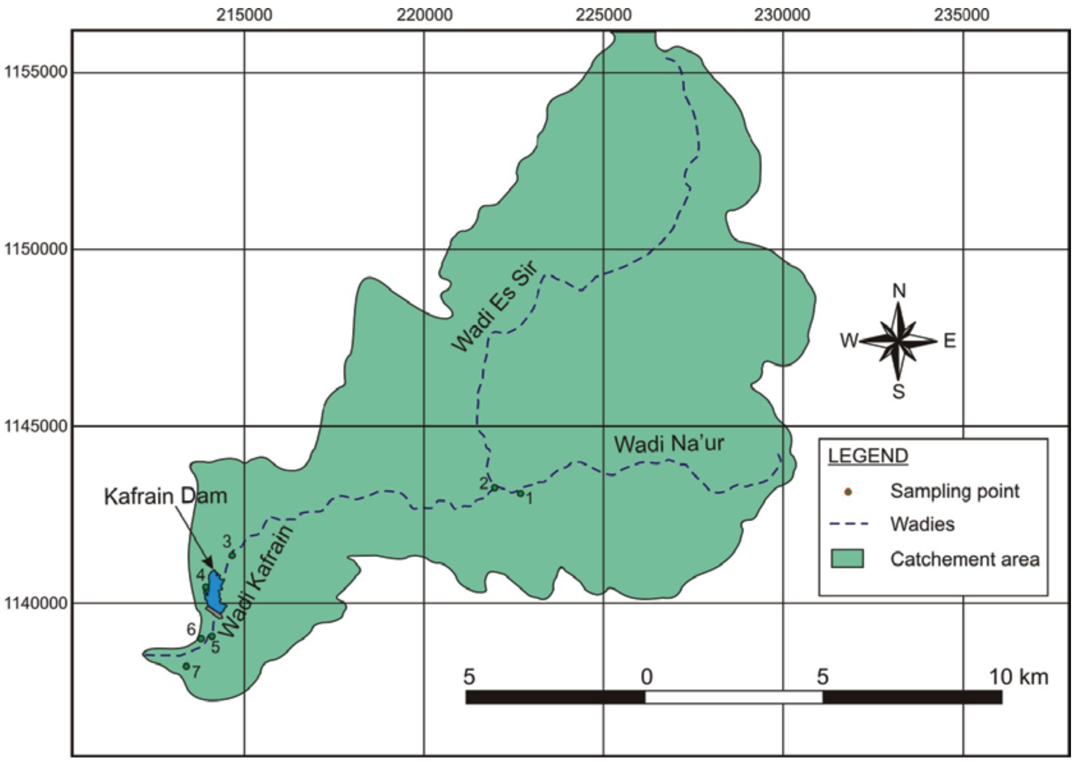

Figure 8.19

Wadi Kafrein catchment and the sampling point locations

8.9.2 Results

The online monitoring of water level in the Kafrein observation well and in the Kafrein Dam showed a direct recharge of groundwater by surface water in the area, and this can be seen from the seasonal variations in groundwater levels which showed marked rises as a result of reservoir inflow caused by rainfall in the wet season. There is clear evidence of recharge from the Kafrein dam and other tributary areas as the effects of high precipitation nearby 2002 and 2003 are clearly visible (Figure 8.20).

Water quality sampling of all stream flow resources (sampling points 1, 2 and 3) as well as the Kafrein dam (point 4) in Figure 8.19 showed that the waters are within the Jordanian standards for artificial recharge. The EC-values of the mixture of Wadi Es Sir and Wadi Na'ur waters is about 950 µS/cm increased to about 1400 µS/cm after mixing with Wadi Es Sir Water Treatment Plant water in summer and to about 1000 µS/cm in winter. The EC-value of the stored water in Kafrein Dam is about 1200 µS/cm and decreased after water infiltrated to the shallow (gravel) aquifer downstream to 1080 µS/cm (sampling point 6) and to 1020 µS/cm in (sampling point 5). The EC-value at sampling point 7 is about 4500 µS/cm because it discharges water from the lower (sandstone) aquifer. Almost all analysed parameters meet the national standards for artificial recharge and show decrease in their concentrations after water infiltrated to the downstream aquifer.

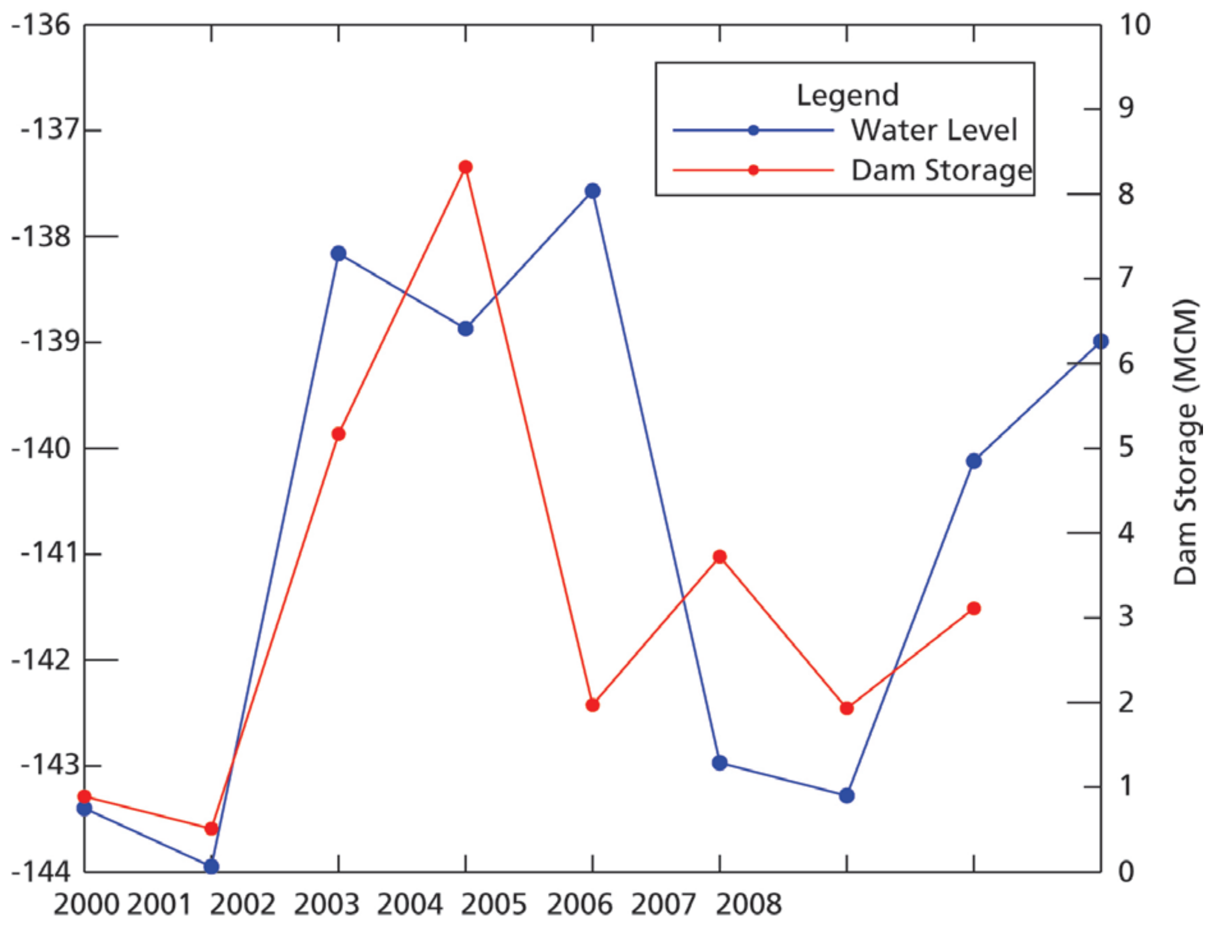

Figure 8.20
Long term water level correlation (2000 - 2008) between Kafrein Dam storage and Kafrein observation well downstream

8.9.3 Expected impacts

The results show the importance of constructing dams on other streams to collect base flow and flash-flood water for irrigation and to enhance artificial recharge to shallow aquifers in the Lower Jordan Valley. This will directly contribute to mitigate water scarcity in the region.

8.9.4 Future research

It is clear that the above described results only provide an indication that recharge is taking place, but that needs much more investigation to establish the qualitative and quantitative effects of the recharge from the dam due to the complexity downstream of the utilization process of the dam water since part of the infiltrating water from the dam is pumped back to it.

9 DEFINITION OF IWRM SCENARIOS

Involved Institutions: MEK, EWRE, UG, UKA
WP-Speaker: Y. Guttman (MEK)
Compiled by: Y. Guttman (MEK), J. Bensabat (EWRE), B. Rusteberg (UG), D. Riepl (UKA), L. Wolf (UKA)

9.1 Introduction

WP9 and WP10 are strongly interlinked. Upon the first screening exercises, the completion of the literature review on available decision support systems (D1001) and the completion of the state of the art of IWRM (D901), it was decided to focus on local scenarios with meaningful data first. An intensive stakeholder dialogue was started in both prototype areas, Khalya (west of the Jordan River) and Wadi Shueib (east of the Jordan River).

9.2 Description of work and results

9.2.1 State of the art on IWRM

In order to provide a substantial basis for the common understanding of IWRM within the project, a state of the art report on IWRM was produced in the first year. The report firstly reviews successful examples of IWRM worldwide and then explores briefly the local situation in the three countries.

Following this exercise, the project was reviewed according to the most relevant aspects for IWRM implementation, selected in the present report and based on the IWRM guiding principles. Selected aspects are: water resources planning, policies and programs, information, legislation, water budget assessment, water recycling and reuse, water saving, conflict resolution, water pollution control, capacity building, institutional development, socio-economics, impact assessment and mitigation, as well as management and monitoring. The review showed that most of the IWRM relevant aspects are at least partially considered in the SMART project. Figure 9.1 summarizes the overall results. In the following, the main results and conclusion, together with some recommendations, are listed.

The review of the SMART project according to the relevant aspects for IWRM implementation led to the following statements:

- Most of the aspects relevant to IWRM implementation are at least partially considered in the SMART project.

- The important water budget assessment is well considered in the project (WP4). Quality of water budget estimations will depend on the quality of the available data base and available models. Future water deficits in the region to be estimated depend on the development and water management scenarios to be designed.

· Water resources planning and management is partially treated in WP9 and WP10. Important input is expected from most of the work packages. SMART gives emphasis on groundwater management, wastewater reuse and irrigation management. Potential water input into the project region (see also Red Sea-Dead Sea canal), desalination as well as conjunctive use of surface and groundwater resources are important planning and management options to be treated in more detail. There is a need for integrated concepts for water resources planning and management in the project region, considering all potential measures, available water resources and water users. Special attention should be given to the aspect of transboundary water management and development of a joint Master or Regional Water Management Plan.

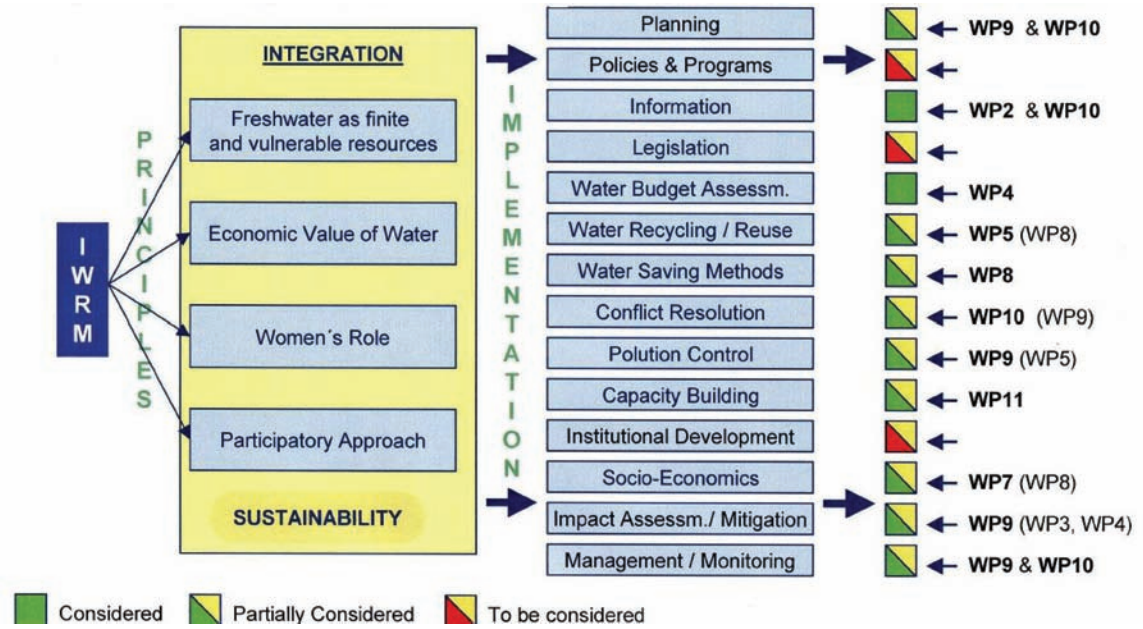

Figure 9.1
SMART versus IWRM Standards

· Water recyling/ treatment is considered in WP5. Works are focusing on the evaluation of innovative Waste Water Treatment (WWT) technologies under local conditions. Further attention should be given to the comparison of these technologies with common alternatives to contribute to transparency in decision making. Wastewater reuse for irrigation and infiltration to the aquifer is treated in WP8. For the implementation of IWRM, integrated concepts for wastewater reuse in the project region are required, considering all sources and options for treatment and reuse.

· Information is well considered within SMART. The comprehensive data base to be designed within WP2 will contribute to the successful development of all other project tasks. The Decision Support System (WP10) contributes to the analysis of different development and water management scenarios, as well as to the communication and interaction with the Decision Making Group in order to support water resources planning and management decisions.

· The implementation of water policies and programs, as well as the legal base and institutional development are not explicitly considered in the project. Information on relevant legislation should be collected within WP2. Recommendations regarding to water policy/program implementation and institutional development should be treated within WP10.

· The assessment of water saving should be improved within the project. Attention is given to the introduction efficient methods for localized irrigation. There is a need for an overall assessment of the potential for water saving in the project region.

· Water pollution control is partially considered by means of wastewater treatment (WP5) and in the context of the environmental impact assessment of water resources planning and management options to be studied for different development scenarios (WP9). To attend IWRM requirements, integrated concepts for water pollution control and environmental protection should be established.

· Socio-economic studies are focusing on the wastewater treatment and related impacts as well as benefit-cost studies for irrigation with non-conventional water resources. Nevertheless, special attention should be given to the socio-economic impact of development and water resources planning and management scenarios, the determination of cost-benefit factors for the implementation of new hydro-infrastructure and development of adequate socio-economic models for decision support.

9.2.2 Definition of IWRM Scenarios

The implementation of Integrated Water Resources Management (IWRM) should link between land and water uses in a basin scale. As stated before, preference was given to realistic scenarios with detailed process quantifications on local scale during the first phase of the project. The framework of the entire Lower Jordan Basin was discussed with stakeholders from the three countries in detail and provided the background for the local scenarios. The project started with prototype areas in Kaliya and Shueib, but will continue especially with detailed analyses also in Jericho/Wadi Quilt.

9.2.2.1 Kaliya

The Kaliya region that is an isolated area was selected as a pilot study area for demonstrating the IWRM concept (see Figure 9.2).

In the first step, **the constraints** of the selected study area – the Kaliya region – were defined. This region is located in the northern Dead Sea area which is an extreme arid zone (average precipitation is less than 100 mm/yr). The constraints bound with the different water resources (fresh water, brackish water, springs and sewage) that are accessible in this region. Fresh water is supplied from Mizpeh Jericho and Jericho 2 wells. The fresh groundwater resources originate from the rainfall recharging the aquifer along the anticline axes in Hebron, Bet-Lehem, Jerusalem and Ramallah areas. The springs are the local groundwater resources. Their salinity varies between 600 - 6,000 mg/L Cl. The water is used for local agriculture up to salinity of 1,500 mg/L Cl. The brackish water from the Feshkha springs is supplied to Kaliya area and the brackish water from Kane and Samar springs is supplied to Mizpe Shalem area. The total discharge of the springs is approximately 90 - 95 MCM/yr. Only a very small amount (about 1 MCM/yr) of brackish water is used today for the local agriculture. Most of the spring's water is flowing to the Dead Sea and is lost there.

The sewage generated at east Jerusalem neighborhoods and Ma'ale Adumim locality is stored at Og reservoir (volume: 1.3 MCM). Part of the treated wastewater is utilized for the local agriculture (only palm trees are irrigated) and the rest (until 2008) was transferred northward to Fazael area. Today the sewage from the Og reservoir is used in the Kaliya area. As it is seen in Figure 9.2, the water supply system in this area is separated from the main area (Fazael-Uja).

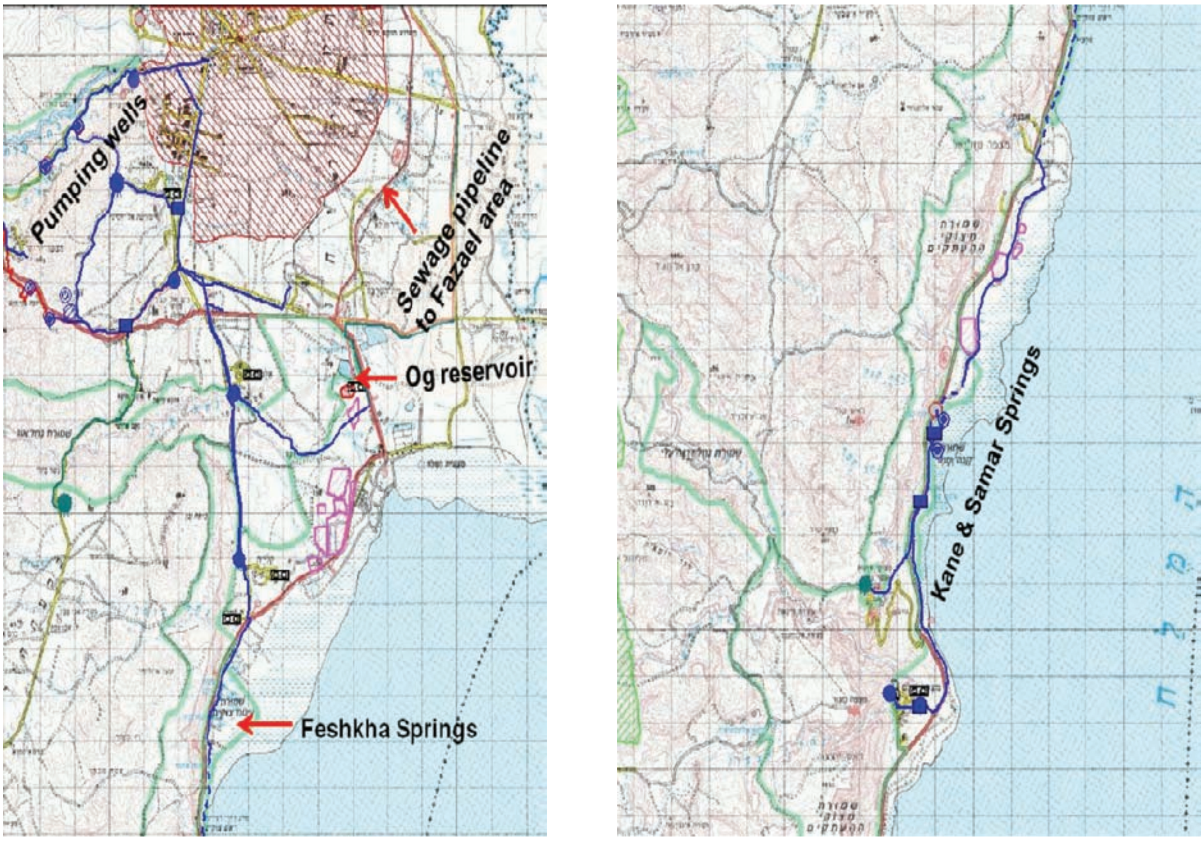

Figure 9.2
Location map of the study area and the water supply network (left side-Kaliya area, right side-Mizpe Shalem area)

The Israeli water **policies** for this area are:

- to convert water for agricultural uses
- to increase domestic water consumption as a result of urban/rural development
- and to develop the water supply for the tourism sector due to its high income

The future development depends on reliability in water supply (quantities and qualities) along the year. Thus, the current fresh water supply availability is the **limiting factor** for future development (agriculture, domestic use, tourism), especially during the high demand seasons (see Table 9.1).

The second step was to construct an inventory of all clients in the study area (see Figure 9.3) and their water needs. These include:

The domestic sector with a total population of 1,150 residents living in 6 localities with a yearly demand of approximately 230.000 m^3/yr. The population growth is extremely high (7.9%, valid for 2006), and therefore, water demand is expected to increase.

Table 9.1

Fresh Water Production & Demand – Mizpe Jericho and Jericho2 wells (2004)

	Cubic meters per year	Peak day (m3)
Existing water production	5,800,000	18,040
Demand	5,491,000	24,242
Total balance	309,000	-6,202

Six types of agricultural cultivations exist in this study area: 2,000 Dunum (1 Dunum = 1,000 m^2) of palm trees; 1,000 Dunum of cherry tomato; 500 Dunum of pepper; 300 Dunum of grapes; 100 Dunum of basil; and 30 Dunum of asphodel – with a total demand of 5,850,000 m^3/yr.

Four areas of tourist accommodations include 167 guest rooms which consume 81,600 m^3/yr. During 2007, a total of 360,000 visitors were numerated visiting Eynot Zukim (Feshcha) and Kumeran natural parks and consumed approximately few thousands m^3/yr (there is no separated measurement of water that is supplied to these parks). It is impossible to evaluate the visitors attending the other 7 Natural Reserves in the region. The findings show that most of the water demand is for tourism and agricultural uses.

The natural environment (the spring's natural reserves): to maintain the life of the flora and the animals in these natural reserves, a minimum amount of water should continue to flow from these springs to the Dead Sea. The actual number is unknown. In some meetings the numbers of approximately 10 MCM/yr per spring area was suggested (Guttman, personal comments). The maximum water volume that can be drawn from the Mountain aquifer in Mizpe Jericho well field is between 8 - 10 MCM/yr (Guttman et al. 2004).

The third step was to identify numerous policy complex problems and to characterize them as goals (multiple criteria). The defined scenarios are summarized in Table 9.2.

Table 9.2

Scenario definition for the study area

Increasing the fresh water demand	Increasing the agriculture sector	Domestic water use	Tourism
Drilling new wells	Broadening existing plots	Development and populating this area is first of all a political issue	Develop new and attractive sites and beaches along the Dead Sea shore
Importing water from existing sources	Developing new areas for plantation		Develop the potential climate-therapy, thermal and spa sites
Desalination of brackish water	Bring additional water and increasing the reuse of brackish water and sewage		Build hotels and other tourism facilities
Improving the water supply system (pipelines, reservoirs)			

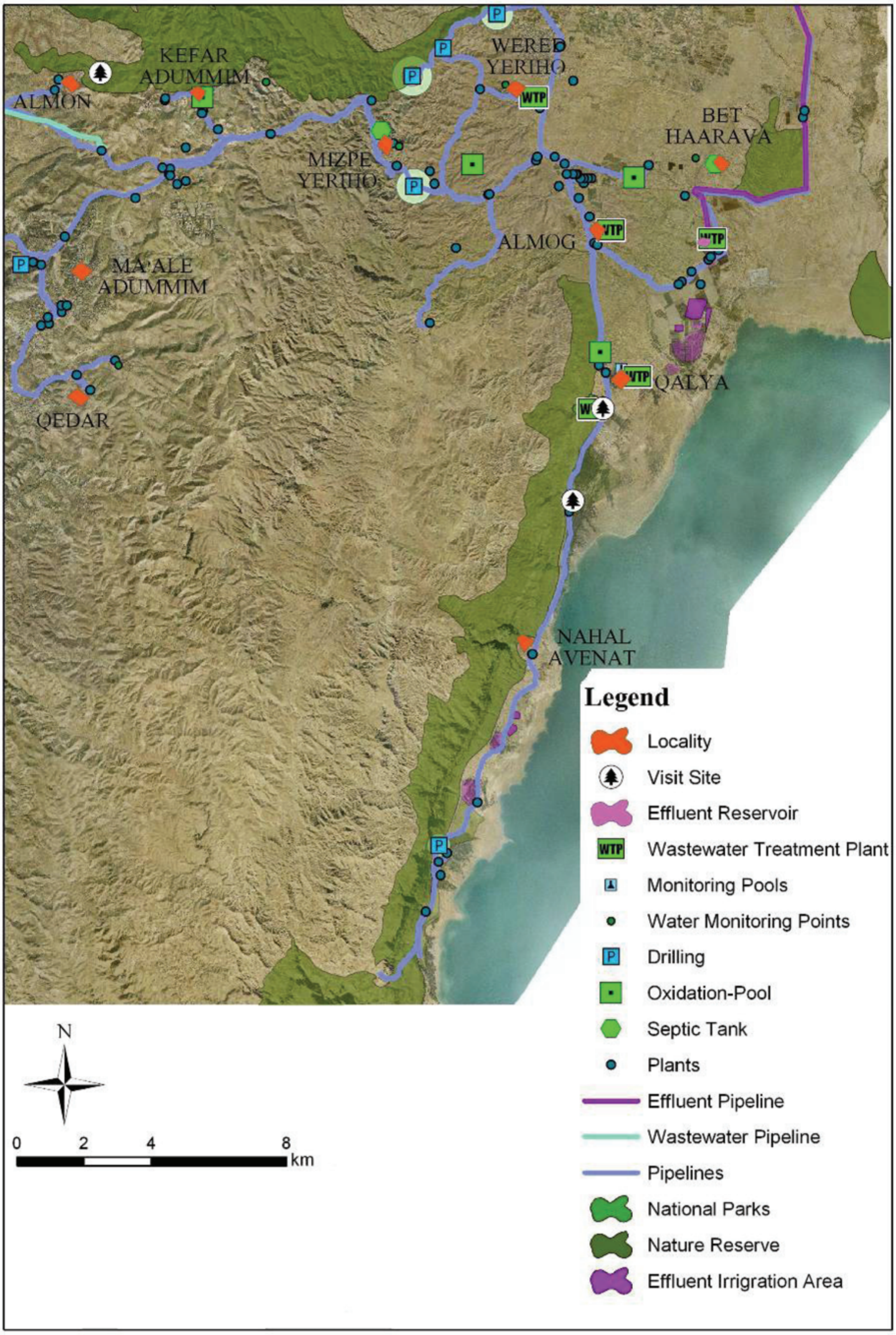

Figure 9.3

Location map of the study area and the water clients

In this current research, the criteria of which the policy makers will need to analyze and facilitate their decision making are: Protecting the aquifer from deterioration, minimizing the gap between demand and supply, especially on peak days, and maximizing the client's economic profit.

9.2.2.2 Wadi Shueib

Wadi Shueib, an eastern side wadi of the Jordan Valley (Figure 9.4), is characterized by a steep relief with elevations ranging from -200 m bsl in the southwest up to 1,240 m asl in the northeast. The surface catchment amounts to 197.5 km². The area belongs to the Balqa Governorate and comprises 5 larger municipalities (Salt, Fuheis, Mahis, Yarka, Ira) and several small hamlets. The population density, as well as most agricultural activity is concentrated in the higher altitudes in the northern part of the Wadi. The dense drainage network of the escarpment discharges the periodic flush floods of the rainy season to the Jordan Valley floor. The baseflow in the main channel is perennial and comprises the discharge from several springs, the outflow of the two sewage treatment plants in Salt and Fuheis, as well as untreated sewage from smaller municipalities (Ira and Yarka). In 1968, a dam was constructed in Wadi Shueib at the outlet in order to catch up the flows, but it falls dry during the summer months.

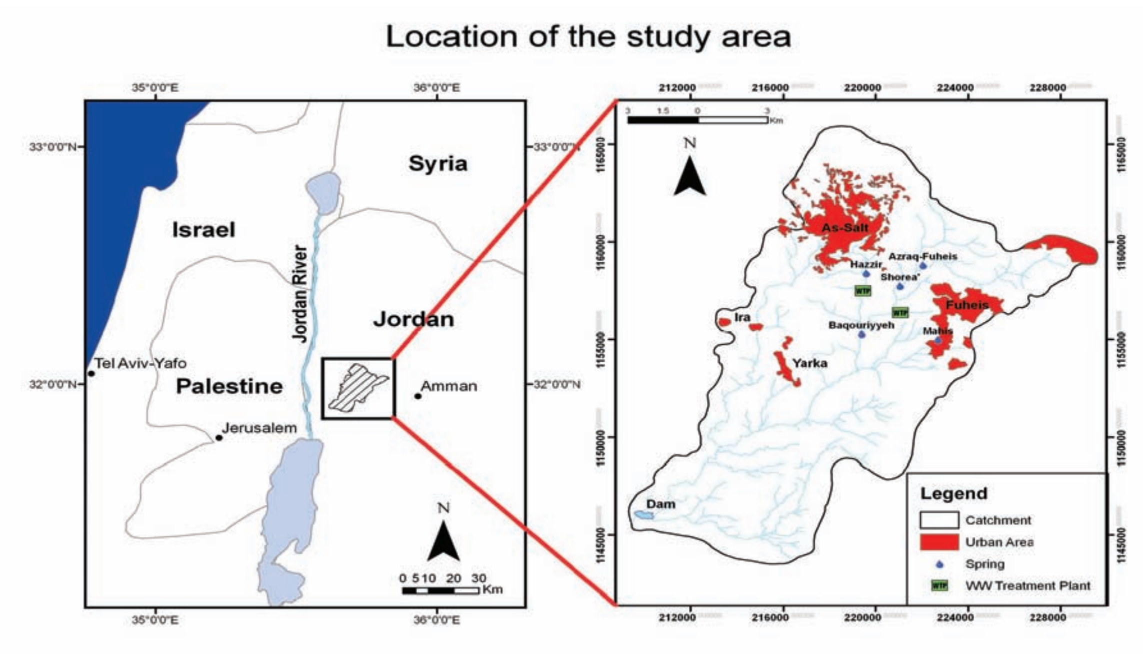

Figure 9.4
Location of the Wadi Shueib in Jordan

The urgent issues for the water management in the Wadi Shueib are related to the municipal water supply, being the main user. Due to microbiological and nitrate contamination, the available freshwater resources from the spring discharge are not used to their potential extent.

The high rate of physical losses in the water infrastructure increases the supply need to cover the municipal demand by over 40%. To cover the municipal demand, water is imported at a rate of 2.2 MCM/yr from the water supply of Amman. With regard to the high population growth in Jordan and the increasing living standards, this situation is likely to aggravate in the near future.

The sewer coverage is only about 65%. Consequently, contamination of groundwater is widespread and in many cases contributes to the high coliform levels in spring waters mentioned above.

Key components of the water flows in Wadi Shueib were conjoined in a holistic water cycle diagram (Figure 9.5).

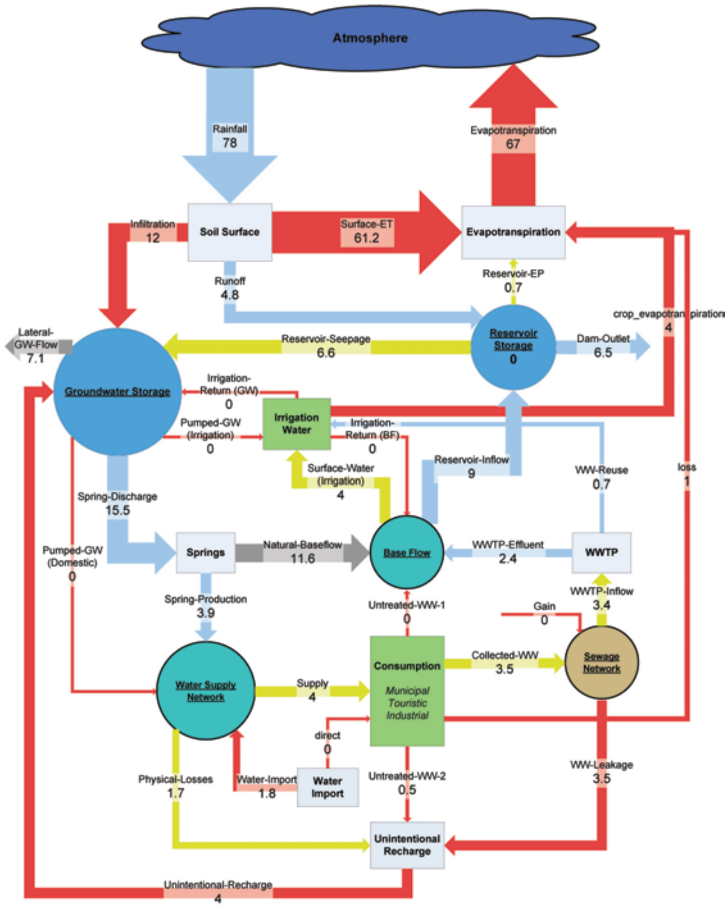

Figure 9.5
Holistic water cycle diagram for Wadi Shueib. Numbers on arrows indicate annual water flows in m². Colours of arrows indicate reliability of the source or information

9.3 Expected impacts

Understanding the interactions between water, environment and society is the foundation of the IWRM for a specific area. In addition, IWRM must be extremely sensitive to national, political, cultural, and socio-economical conditions. To this end, this study deals with the scenarios definition for Kaliya Region, as part of an IWRM framework.

9.4 Future research

The next step will be to analyze efficiently the multi criteria problems and determine which objective out-weight another, by recognizing the necessity for trade-offs between the alternatives to best serve the common interest of the study area. The methodology chosen for breaking the multiple problems down and aggregating the solutions into a conclusion is Analytic Hierarchy Process (AHP). According to this method, prioritization process is held through comparison of alternatives and is measured by rating.

10 IMPACT OF IWRM SCENARIOS

Involved Institutions: MWI, UKA, EWRE, MEK
WP-Speakers: A. Subah, K. Hadidi (MWI)
Compiled by: Leif Wolf (UKA), Jacob Bensabat (EWRE), Yossi Guttman (MEK), David Riepl (UKA)

10.1 Introduction

SMART is based on the concept of an Integrated Water Resources Management (IWRM), which, by definition, needs to take into account environment, eco-systems, socio-economy, water supply and demand management, the need to preserve the water resources for future generations, etc. In the case of the Lower Jordan Valley (LJV) it also needs to take into account subjectively conflicting interests, as the project area is shared by three different political entities, with often acute problems of communication.

Beside different socio-economical and technical aspects, the planned IWRM has to deal with the physical characteristics of the area, such as climate, geology, hydrology (surface and subsurface), land-cover, etc. All these variables are often connected. To achieve the management of the LJV-water resources and the resulting decisions, all these natural and anthropogenic effects and variables have to be calculated and evaluated.

The accompanied decision making in natural resources management is always based on the assumption that the decision maker had the required cognitive and integrating capabilities. However, the degree of complexity of the system LJV and the need to evaluate the interconnection and –action makes a computational decision support system necessary.

The key objectives of this work package can be summarized as follows:

- Identify and quantify all the expected impacts resulting from the new mode of water resources utilization to be suggested for the JRV (hydrological, environmental-ecological, economical, social, and political)

- Develop a decision support system to demonstrate the links and interdependencies between the different sectors (hydrological, environmental-ecological, economical, social and political)

- Compare and rank different water resource management options using a transparent methodology

Upon the first screening exercises, the completion of the literature review on available decision support systems (D1001) and the completion of the state of the art of IWRM (D901), it was decided to focus on local scenarios with meaningful data. An intensive stakeholder dialogue was started in both prototype areas, Khalya (west of the Jordan River) and Wadi Shueib (east of the Jordan River).

10.2 Description of work and results

10.2.1 Review of state of the art on decision support systems

Decision support systems (DSS) are powerful tools integrating scientific methods for supporting complex decisions with techniques developed in information science, and are gaining an increased popularity in many domains. They are especially valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker and in which precision and optimality are of importance. Decision support systems aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, aiding the process of structuring, and optimizing decisions. Normative DSSs offer a theoretically correct and appealing way of handling uncertainty and preferences in decision problems. They are based on carefully studied empirical principles underlying the discipline of decision analysis and they have been successfully applied in many practical systems. We believe that they offer several attractive features that are likely to prevail in the long run as far as the technical developments are concerned. Because DSSs do not replace humans but rather augment their limited capacity to deal with complex problems, their user interfaces are critical. Key elements of the IWRM decision making process are shown in Figure 10.1.

Most, if not all, of the reviewed DSS package conceptualize the Water Resources System (WRS) under scrutiny as a possibly capacitated, directed flow network. The term "capacitated" refers to upper and lower bounds on all flows in the network, and "directed" refers to a priori specification of flow direction. The various components of the WRS are represented as a network of nodes, both storage (i.e. reservoirs, groundwater basins and storage right accounts) and non-storage (i.e. river confluences, diversion points, demand locations, stream-flow gauging stations, return flow locations, etc.), and links or arcs (i.e. canals, pipelines, natural river reaches and decreed water rights) connecting the nodes. Since all inflows, demands, system gains and losses must accumulate at nodes, increasing the density of nodes in the network thereby increases the accuracy of the calculation. Some DSS regard the nodes as single cell reservoirs; others address the nodes with detailed groundwater and/ or surface water simulation tools. All the other analyses, such as optimization, multi-criteria analysis or DPSIR formulation, come on top of this basic system.

In reality, few of the reviewed software packages meet the wider definition of a DSS. Most of them have notable GUI, GIS, database and simulation capabilities. Most of the optimization procedures deal with the problem of water allocation, and only two of them cast the decision making process into the DPSIR paradigm.

With increasing scope and "integration" of the respective DSS, the challenge is presented by the inclusion of domain knowledge from an ever larger group of experts with different backgrounds. Knowledge management and the ability to communicate in a common terminology become critical factors. All of the systems still lack proper visualisation of the problems in linked surface water-groundwater systems.

All these conclusions would naturally lead to the development of a new DSS specifically adapted to the LJV and its challenges. However, this will be a complicated time consuming and resource demanding task. We then suggest to progress in two parallel tracks: study in detail four DSS which seem to be closest to our needs (WSM, MULINO, MODSIM and WEAP). These will be tested on a pilot area in the LJV and their performance would be assessed. In parallel we would explore the feasibility of developing a new DSS based on the recommendations stated below.

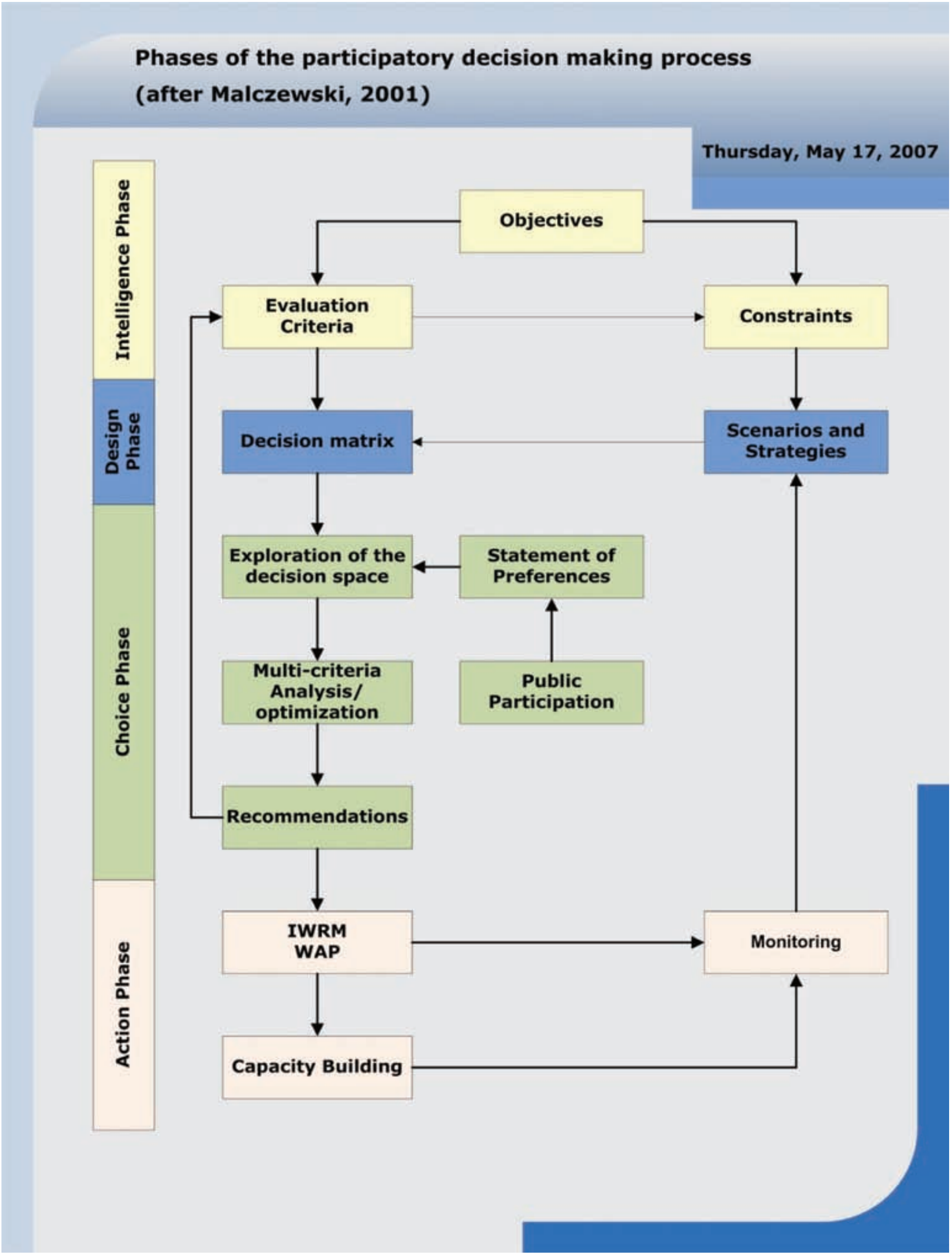

Figure 10.1

Phases of participatory decision making process (after Malczewski, 2001)

10.2.2 Stakeholder consultation exercises

The viewpoints on IWRM of key stakeholders in the three entities were intensively discussed during the SMART coordination meetings. Representatives from the Jordanian Ministry for Water and Irrigation (MWI), from the national Israeli water supplier Mekorot as well as from the Palestinian Water Authority (PWA) and Palestinian Hydrological Group (PHG) gave presentations on the actual status of their water systems. The outcomes are documented in the internal section of the SMART homepage.

In addition, a separate consultation was carried out at the MWI, Jordan with representatives of MWI, WAJ, JVA, BGR and GTZ. All major discussion results were immediately visualized during the meeting and revised by the expert group until a consensus and common knowledge base on the topic was reached. The chosen method has the advantage, that the recommendations & conclusions derived from the consultation are based on the actual positions & needs of the responsible actors in the Ministry.

As an example, an overview of IWRM instruments identified in Jordan during the stakeholder consultation is given below:

Planning tools
- National Waster Master Plan, digital version, updated according to need
- Strategic Plans of WAJ, JVA and MWI, updated each period (2 - 3 years)
- Investment Program
- Strategic Plan for the Implementation of Water & Wastewater Projects 2007 - 2015 for WAJ, including cash flow for the planning period
- National Agenda/ Jordan first
- Water Information System, planned with more telemetry/ online measurements, online/ offline, see JICA project
- Project Information System (under construction)
- State of the environment in Jordan (Ministry of Environment), under discussion

Implementation tools
- Law, By-Laws, Regulations
- Guidelines and standards for marginal (including reclaimed and brackish) water / bio-solids
- Protection guidelines

Public participation tools
- Water users (e.g. farmers union).
- Public awareness programs

Control instruments
- Water quality & quantity monitoring programs

Finally, the requirements of an additional SMART DSS for the areas were jointly discussed. While the existing Water Information System and the newly build Project Information System provide good access to raw data sources, there is a lack of interpreted information and meta-knowledge.

Especially ranking procedures, cause-effect chains and knowledge sharing between different sectors are currently underdeveloped. A system which increases the transparency of the IWRM process is highly welcomed.

10.2.3 Employment and testing of existing water management software

Besides the development of completely new DSS software, SMART was also employing existing decision support software.

To address these concerns, a first attempt to simulate water supply and demand in the Jordan Valley region, thereby explicitly accounting for the use of treated wastewater in relation to agricultural production was carried out (Alfarra et al, 2009). The study capitalizes on extensive primary and secondary spatial data sets that constitute the empirical basis for yield function that reproduces geographically-specific agricultural production patterns under different water availability levels. Information sources are processed in the Water Evaluation And Planning system (WEAP) model to evaluate the impact of various water allocation scenarios for agricultural production (Figure 10.2). The results show that treated wastewater can successfully complement existing fresh water resources, especially in years of extended droughts, and is more profitable in areas with annual crops than in perennial orchards. The work is fully documented in Alfarra (2010).

In addition, a prototype area to test the practical applicability of the WEAP-Modflow coupling was identified. The alluvial aquifer system downstream of the Wadi Shueib reservoir is an ideal test case for surface-groundwater interactions and questions of water distribution. The combination of surface runoff and treated wastewater is stored in the Shueib reservoir, from where it is either used directly for irrigation purposes or seeping into the alluvial aquifer beneath the dam. Downstream of the reservoir, water is abstracted from the aquifer using wells. It is obvious, that changes in the reservoir operation do not only impact on the surface water distribution, but also on the irrigation and domestic supply wells downstream. A steady state numerical groundwater flow model was therefore set up using Modflow (Leicht, 2008). In addition, a draft WEAP model has been setup for Wadi Shueib and the downstream agricultural area. Unfortunately, up to now, lack of human resources has prevented the further testing of the coupled WEAP-Modflow application.

10.2.3.1 Multicriteria tools

Two methods had been used for defining and ranking the various alternatives of water management scenarios. The methods were Multi Criteria Decision Making (MCDM) methodology, and the Analytical Hierarchy Process (AHP, Saaty 2005). MCDM aims at highlighting these contrarieties and deriving a way to come to a compromise in a transparent process, mainly led by the decision maker. The AHP method is designated to assist the decision maker to rank predefined alternatives according to a set of predefined criteria, following a pair-wise comparison process. It is important to note that some combinations of alternatives are contrary to the others and these tools are aiming in defining and selecting the proper alternative (combination).

In order to make decisions in the complex environment of multiple criteria, we need to know the problem, the need and purpose of the decision (the goal), the criteria with which we screen the decisions, to define a set of sub-criteria, consult the stakeholders and other affected groups and finally, to define a set of alternatives or scenarios that can meet the stated goal.

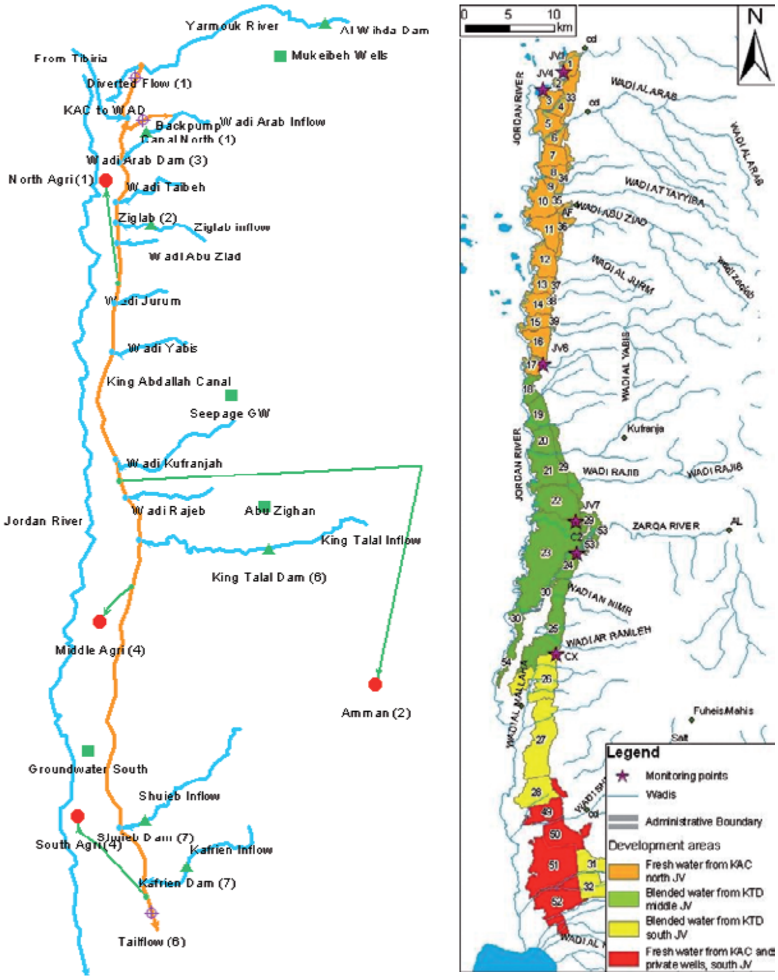

Figure 10.2
WEAP Application to the LJV (Alfarra 2011)

We then try to determine the best alternative, or in the case of resource allocation, we need priorities for the alternatives to allocate their appropriate share of the resources. The decisions involve many intangibles that need to be traded off. Through tradeoffs it clarifies the advantages and disadvantages of policy options under circumstances of risks and uncertainty (Saaty, 2008). Decisions are typically characterized by a large set of alternatives and multiple, conflicting and incommensurate evaluation criteria. **MCDM** is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations (criteria). This methodology aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process, mainly lead by the decision maker. The AHP is a mathematical theory of value, reason, and judgment, based on ratio scales for the analysis of multiple-criteria decision-making problems (Saaty, 2008).

The AHP is a systematic procedure to construct and represent the elements of a problem in a hierarchy format. The basic rational of AHP is organized by the breakdown of the problem into smaller constituent parts at different levels. An AHP model typically consists of an overall **goal**, a set of **criteria** to specify the overall goal decomposed to sub-criteria, and finally, at the lowest level of the hierarchy, the decision **alternatives** to be evaluated. In AHP, each element in the hierarchy is considered to be independent of all the others. The hierarchy can be visualized as a diagram like the one below (Figure 10.3).

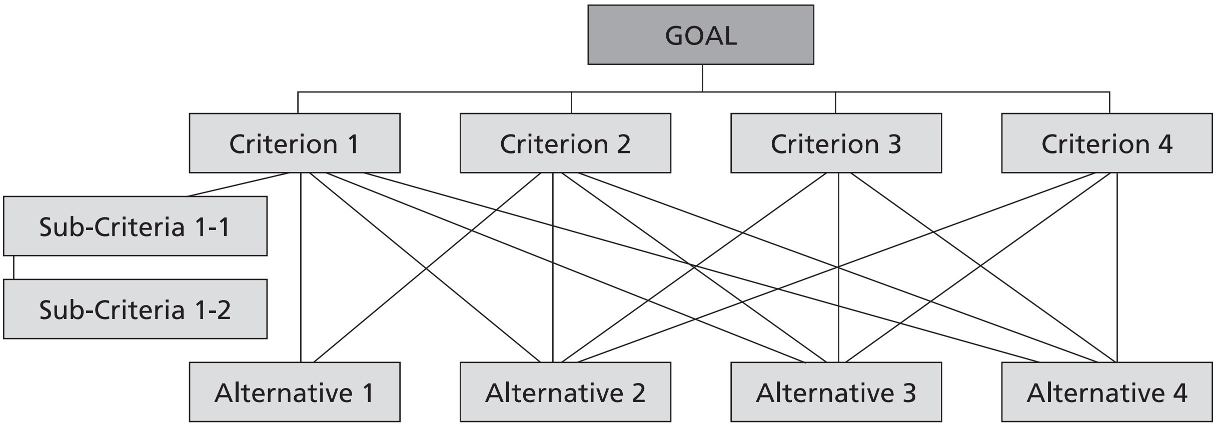

Figure 10.3

Illustration of the Analytic Hierarchy process

Beyond the decomposition principle, the AHP is based on pair-wise comparisons of elements in a decision hierarchy with respect to the parent element at the next higher hierarchical level (i.e. among criteria and lower level elements). The pair-wise comparison is aimed in providing a cardinal scale to evaluate objects according to some subjective preference criteria. Pair-wise comparisons are made on a scale of relative importance (see Table 10.1) where the decision maker has the option to express the preferences between two elements on a ratio scale from equally important (i.e. equivalent to a numeric value of one) to absolute preference (i.e. equivalent to a numeric value of nine) of one element over another.

Ratings of decision makers are arranged as numerical numbers in a comparison matrix. Based on this, relative weights for all elements of the hierarchy are calculated with the eigenvalue method (see Figure 10.3), indicating the priority level for each element in the hierarchy (Saaty, 2001). Accordingly, priorities for the alternatives are gained by judgments with respect to each above-level element of the hierarchy. Their performances are weighted with the relative weights of criteria and sub-criteria, and added to an overall priority for each alternative (i.e. how they contribute to the goal), which allows a cardinal ranking of the alternatives (Saaty, 2006).

Table 10.1

A nine point scale for pair-wise comparison

Intensity of Importance	Definition	Explanation
1	Equal Important	Two elements contribute equally to the objective.
3	Weak Importance	Experience and judgment slightly favor one element over another.
5	Strong Importance	Experience and judgment strongly favor one element over another.
7	Very Strong Importance	One element is favored over another; its dominance is demonstrated in practice.
9	Absolute Importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intermediate values used to interpolate between adjacent scale values		

Ideally the judgment matrix should have the following properties:

$$a_{ii} = 1$$

$$a_{ij} = \frac{1}{a_{ji}}$$

$$a_{ij} = a_{ik}\, a_{kj}$$

According to these properties, the ideal structure of the judgment matrix is:

$$1\& \frac{w_1}{w_2} \& \frac{w_1}{w_3} \& \frac{w_1}{w_4} \& \frac{w_1}{w_5} \& \frac{w_1}{w_6} \&\&\&\& \frac{w_1}{w_n} @ \frac{w_2}{w_1} \&1\& \frac{w_2}{w_3} \& \frac{w_2}{w_4} \& \frac{w_2}{w_5} \& \frac{w_2}{w_6}$$

$$\&\&\&\& \frac{w_2}{w_n} @ \frac{w_3}{w_1} \& \frac{w_3}{w_2} \&1\& \frac{w_3}{w_4} \& \frac{w_3}{w_5} \& \frac{w_3}{w_6} \&\&\&\& \frac{w_3}{w_n} @ \frac{w_4}{w_1} \& \frac{w_4}{w_2} \& \frac{w_4}{w_{\square}}$$

Here, the vector $w_t = (w_1, w_2, w_3, w_4, w_5, w_6, \ldots\ldots\ldots\ldots w_n)$ denotes the weights of the alternatives resulting from the judgment. The ideal judgment matrix has the following property:

$A*m = nw$

Where n denotes the number of alternatives. This means that under ideal conditions, the vector of the weights is equal to the principal eigenvector.
In practical situations, the judgment matrix does not respect the transitivity condition, i.e. the condition $a_{ij} = a_{ik}\, a_{kj}$ is usually violated. Saaty suggests that the principal eigenvector of the real matrix should be the weights vectors. In the case of non-ideal judgment matrix, this vector is given by:

$$w = \lim_{k \to \infty} \left(\frac{A^k e}{e^T A^k e} \right)$$

$e^T = (1,1,1,1,1,1,\ldots\ldots,1)$

An alternative calculation of the weights called the logarithm least squares method (LLSM) has been suggested and is given by:

$$w_t - \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n} \left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}, \; i - 1, \ldots.., n$$

The same procedure can be applied to rank criteria too.

There is substantial debate regarding the most suitable way to calculate the weights (the eigenvector method (EM) or the LLSM method). Many papers have been indicating their advantages and shortcomings, but so far there no clear cut recommendation regarding the best method. This technique was applied to the Kalya site and the results of the evaluation will be presented in the report of next year.

The AHP tool was distributed to all project partners but is also available from the project coordination or EWRE at request.

10.2.3.2 Knowledge management system

Following the principles of IWRM, the impact of a planning scenario has to be collectively evaluated from various viewpoints, corresponding to the knowledge of experts in different domains, as well as to the interests of various stakeholders. This makes IWRM decision support to an intensive knowledge management process. Unfortunately, this aspect is lacking adequate support in state of the art approaches on IWRM-DSS, thus, hampering the efficient selection of decision relevant information from the available knowledge pool and considerably amounts for the significant gap between scientific modelling and the actual planning practice.

This study focuses on the development of a flexible knowledge-management framework for IWRM-related problem analysis and impact assessment in the Lower Jordan Valley. The interaction of various DSS components is shown in Figure 10.4.

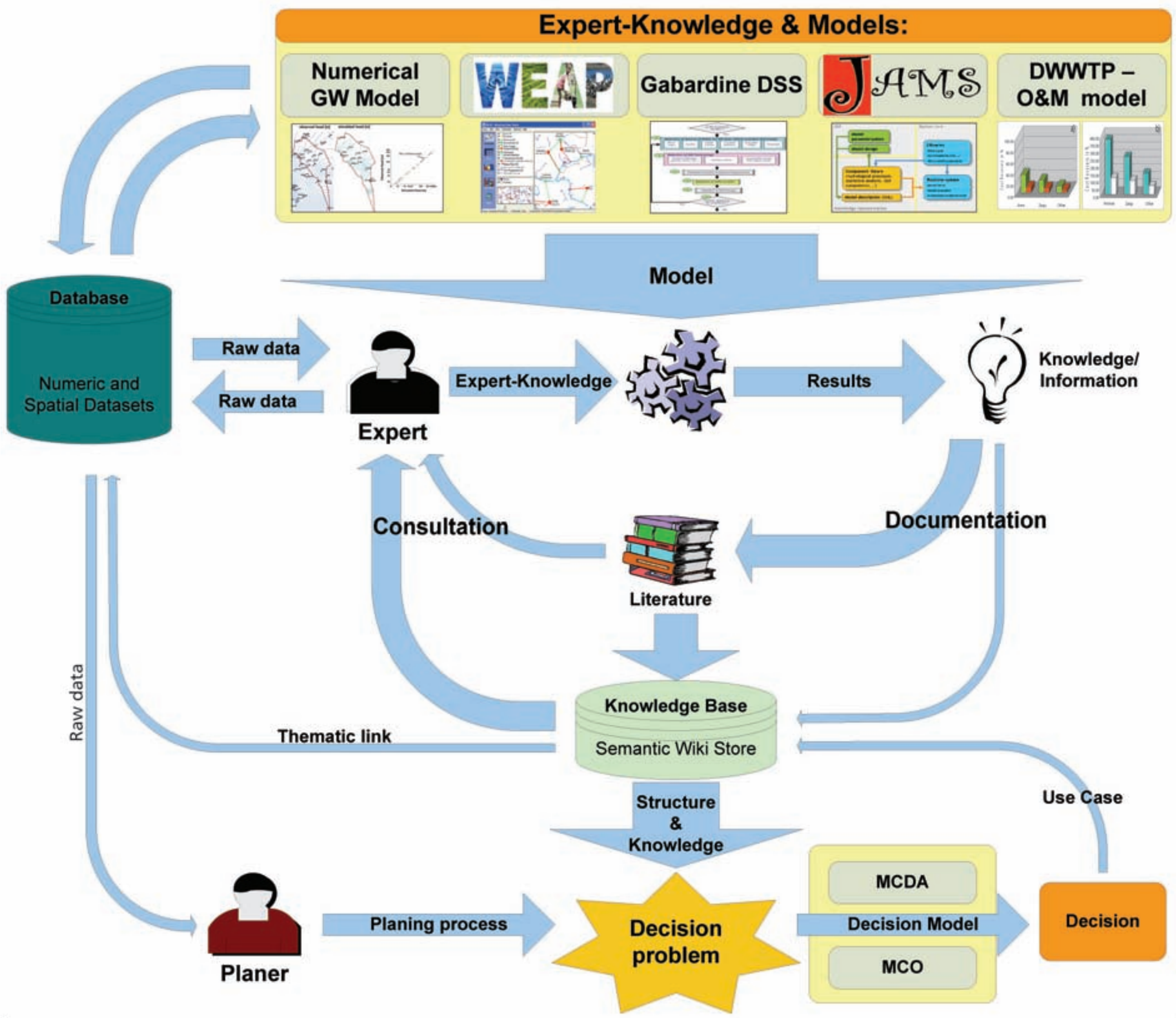

Figure 10.4

Flowchart of the SMART Decision Process

In order to provide the necessary functionality, the SMART Knowledge Management Tool is based on a "Semantic Wiki System" and embedded in the framework of a decision support process. By combining the advantages of the popular Wiki approach with semantic web technologies the SMART Knowledge Management supports users to

- easily gather, structure and edit available and newly generated IWRM knowledge,
- establish meaningful links between related information elements,
- detect and address critical knowledge gaps,
- efficiently query for necessary and related information, and
- allow for flexible presentation of information according to the contents context

The implemented basic knowledge structure allows experts to model their domain knowledge within an interdisciplinary context and link information elements through an evolving network of cause-effect relationships and related background information, thus, supporting the user during problem analysis and planning. This results in a highly flexible and adjustable, yet easy to use SMART Knowledge Management tool, which will contribute to make IWRM decision processes more informed, more transparent and more reusable.

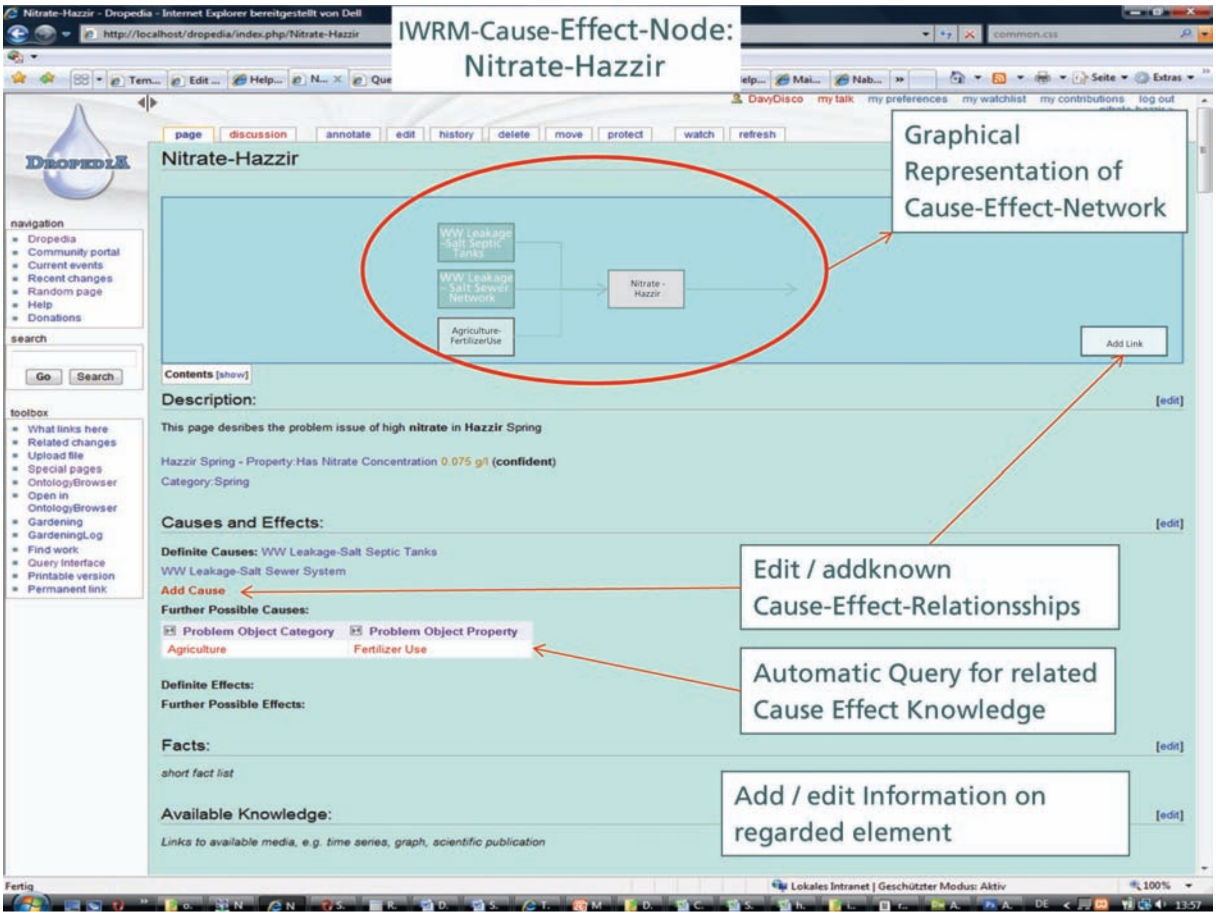

Figure 10.5

Prototype screenshot of the new SMART Knowledge Tool based on semantic wiki technology

Ontologies have been developed in artificial intelligence research to facilitate knowledge sharing and reuse. They are a popular research topic in various communities, such as knowledge engineering, natural language processing, cooperative information systems, information integration, software agents, and knowledge management. In general, ontologies provide:

- a shared and common understanding of a domain; this domain can be communicated among people and across application systems
- an explicit conceptualization (i.e., meta information) that describes the semantics of the data

Ontology-based Knowledge Management is fundamentally different to traditional databases.
A database structures and stores data using tables with rows and columns, defined by data types. In contrast, a knowledge base contains information on the meaning of data. It contains logical rules to define the semantic relationships within and between the single data elements.

A prototype of the SMART Knowledge System that is still under lively development (Figure 10.5) is build for a side wadi of the Jordan Valley, where management conflicts arise from insufficient wastewater treatment and leakage, nitrate pollution of spring waters, groundwater overpumping and lacking groundwater protection zones. Within interdisciplinary discussions with partners from governmental agencies, research facilities and development cooperation institutions, the SMART Knowledge Base is structured and filled with content from project partners. A set of scenarios of different management options for the Wadi provides a use case for proving the functionality of the knowledge management concept within the decision support framework.

10.2.4 Towards integrated impact assessments

Based on the Wadi Shueib area, it is demonstrated how many different activities may be ongoing at the same time (Figure 10.6), all related to the water sector and many without consideration of the mutual benefits or conflicts. In the Wadi Shueib area, information density is comparatively high:

- Vulnerability-, Hazard-, and Riskmapping (GIJP-SMART)
- Delineation of spring protection zones (MWI-BGR)
- OMS (Operations & Management Support)-Program (GTZ/KfW)
- Modelling of groundwater recharge from Wadi Shueib dam (SMART)
- Demonstration plant for decentralised wastewater treatment (SMART)
- Feasibility studies for decentralised wastewater treatment of the villages Ira and Yarqa (SMART)
- Preparation of holistic water balances including all water sources (surface water, runoff, wastewater, groundwater) (SMART)
- Stakeholder consultation and problem screening exercise according to the DPSIR concept (SMART)
- Organizing and classifying the available knowledge

The following scenarios have been identified for further quantifications by the stakeholders:

- Baseline (continuation without change)
- Implementation of decentralized wastewater treatment plants
- Enforced implementation of spring protection zone concepts
- Sewer rehabilitation in Salt

The integrated analysis especially includes the prospects for more decentralized wastewater treatment which is treated in detail by WP5 and WP7 for the two villages Ira and Yarqa which are situated in the Wadi Shueib.

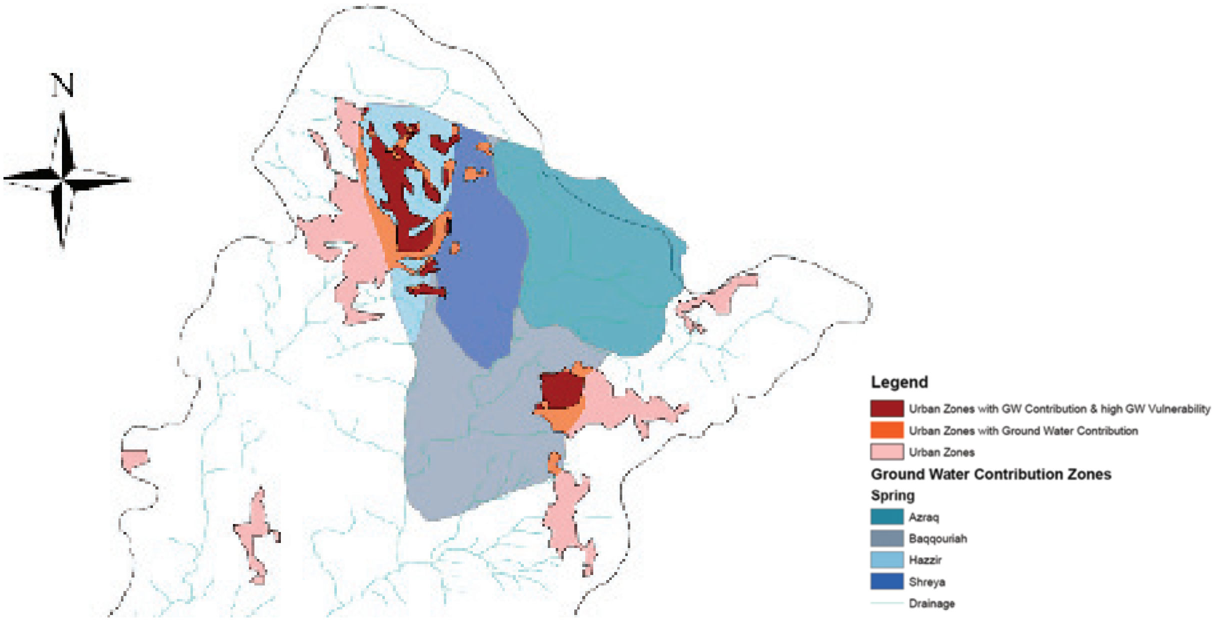

Figure 10.6

Improved prioritization of sewer rehabilitation in the Shueib area considering an overlay of landuse, intrinsic vulnerability and groundwater contribution zones

10.3 Expected impacts

The decision support tools developed in WP9 and WP10 serve to visualize the complexity of the integrated management.

Joint analysis of water related investments in different sectors is expected to save considerable costs by ensuring long term operation. Further on, the inclusion of environmental and health benefits into the project planning stage promotes an economical sustainable operation.

10.4 Future research

The development of new and innovative software products is a rewarding but time consuming task. Future research should be directed towards an improved utilisation of the semantic wiki technologies on one hand, especially with regard to the actual task of introducing the SMART DSS into the daily routines of key stakeholders in the region.
On a second field, specialised DSS-sub modules which represent the relevant expert knowledge need to be enforced for each of the technologies considered in SMART (e.g. artificial recharge, decentralized wastewater treatment).

Thirdly, the application of the Multi Criteria Decision Making (MCDM) methodology and the Analytical Hierarchy Process (AHP) which is currently explored for the Khalya subregion needs to be demonstrated on a sub-domain in Jordan.

11 DISSEMINATION, TRAINING AND TECHNOLOGY TRANSFER

Involved Institutions: UKA, UFZ, WP-Speaker: W. Ali (UKA)

11.1 Introduction

The activities of WP11 were focused on the fulfilment of the following deliverables:

- D1101 Organizing project workshops open to interested people
- D1102 Technology and know-how transfer
- D1103 Establishment of the internet site
- D1104 Training of end-users

11.2 SMART coordination meetings and workshops in 2008 (D1101)

Compiled by: W. Ali (UKA)

11.2.1 Coordination Meeting in Aqaba

The 3rd SMART Scientific Coordination meeting (jointly with GLOWA project Meeting) took place between the 24th and 29th of June 2008 in Aqaba, Jordan (Figure 11.1). Around 120 participants attended both meetings out of which more than 60 participants attended the SMART project meeting. In the opening session H.E. Khaldon KHASHMAN, the general secretary from the Ministry of Water and Irrigation in Jordan and Prof. Heinz Hötzl, SMART project main coordinator welcomed the participants (Figure 11.1). In addition to the individual SMART and GLOWA project coordination meetings, a one day joint meeting of both projects took place, followed by two field trips to the Aqaba Region and to Sinai, Egypt.

A detailed program of this meeting is available at the project webpage (http://www.iwrm-smart.org/).

Figure 11.1
3rd SMART scientific coordination meeting, **Left:** Prof. Heinz Hötzl, main scientific coordinator opening the meeting
Right: H.E. Khaldon KHASHMAN the general secretary from the MWI, Jordan welcomes the participants in Aqaba and presents the water situation in Jordan (Pictures: W. Ali)

11.2.2 Coordination Meeting in Amman

The 4th SMART Scientific Coordination meeting took place from 24th to 27th of November 2008 in Amman, Jordan (Figure 11.2). The meeting mainly involved the WP speakers of the SMART project and the stakeholders of the region with the purpose to present recent results of the SMART project. In addition to the presentation days of the SMART-project, a 1-day field trip was undertaken to the SMART-project test sites and to Wadi Wala Dam south of Amman.

A detailed program of this meeting is available at the project webpage (http://www.iwrm-smart.org/).

11.2.3 Meeting in Ramallah, Palestinian territories

Dissemination activities were conducted in the Palestinian Territories between November 19th and 22nd 2008. The focus of the meetings was the divulgation of the capacity-building program for the local stakeholders including the Ministry of Education of Palestine, the Palestinian Water Authority (PWA) and the Palestinian Hydrologic Group (PHG).

11.2.4 Meeting at the Palestinian Water Authority

In order to provide the main context about the dissemination and capacity-building activities, a meeting on the 19th of November took place in the installations of the Palestinian Water Authority in Ramallah, Palestinian Territories. The meeting was an opportunity to introduce the SMART project to important authorities in Palestine as well as to initiate an approach to the teachers designated to attend the training.

11.2.5 Meeting at the Palestinian Hydrologic Group (PHG)

The PHG is an active organizations involved in the water framework in the Palestinian Territories. The objective of the meeting was the presentation of the training program “Water Fun” within the framework of the SMART project. The meeting also provided the opportunity to contextualize the capacity-building program into the local water resources problematic. For this reason, the PHG organized a presentation concerning the wastewater problematic and the role of alternative technologies for grey-water treatment (Figure 11.3).

Figure 11.2
4th SMART scientific coordination meeting, **Left:** Dr. Khair Hadidi (MWI) and Dr. A. Yellin–Dror (TAU)
Right: Dr. Leif Wolf (UKA) and Dr. Abdulrahman Tamimi (PHG). (Pictures: W. Ali).

Figure 11.3
Meeting Palestinian Hydrologic Group, **Left:** PHG co-worker present their activities in the grey water field
Right: General discussion with SMART project members (Pictures: M. Van Afferden).

11.3 Technology and know-how transfer (D1102)

Compiled by: M. van Afferden (UFZ)

11.3.1 Introduction and methods

Know-how transfer is a fundamental issue in order to achieve an integrated water resource management concept for the Jordan River Valley. The WP1102 incorporates a know-how transfer strategy through the development of a Demonstration and Training Site (DTS; Johansson, Klemedtsson et al. 2003) for decentralized wastewater management and irrigation in Wadi Fuheis, close to the capital of Amman. In the DTS, different technologies for decentralized wastewater treatment will be constructed and tested. Furthermore, a research program including adaptations of relevant design components towards the climatic conditions and hygienic treatment efficiency will be carry out by the UFZ and the Al-Balqa Applied University. The research program will be linked to an agricultural test site where the different technologies will be optimized and evaluated considering their potential to provide suitable irrigation water.

Regarding training/dissemination, the DTS will be designed as an interpretive center with integrated showroom that allows presenting the technologies and will give a general overview on decentralized wastewater treatment and reuse options. The DTS will be the platform to provide training and capacity building programs and will contribute to promote the transfer of innovative decentralized wastewater treatment and reuse technologies. Furthermore, it should encourage reuse-oriented wastewater management among stakeholders, decision makers and technical staff. The DTS will be dedicated to fostering public awareness and knowledge of the inherent values and necessities of locally reusing reclaimed water throughout Jordan.

11.3.2 Results

The primary result of the know-how transfer deliverable 1102 is the development of the concept and the design of the Demonstration and Training Site that will elucidate the complex issue of technical, environmental, economic and cultural factors which define decentralized wastewater system solutions. In particular, the outcomes consist in:

- Overall concept/design of the DTS drawing especial attention to the fundamental project idea to demonstrate decentralized wastewater system solutions
- Detailed design of the "wastewater treatment and reuse trail"
- Detailed concept of the demonstration/training area for decentralized wastewater treatment technologies
- Detailed concept of the demonstration/training area for the decentralized reuse of treated wastewater

11.3.2.1 Design of demonstration and training site

As the main design element of the DTS a "wastewater treatment and reuse trail" was developed linking the treatment area with the irrigation field. As seen in Figure 11.4, the predominant sub-elements of the trail are two pavilions connected by a straight pathway with a blue axis (e.g. water canal or stone pavement) that leads from the "wastewater treatment site" to the "wastewater reuse site". This interrelation concept reflects the flow of the treated wastewater to the different reuse options and is intensified by the elevation profile of the terrain between the two pavilions, where the first pavilion directs the visitor's view to the lower pavilion surrounded by the agricultural research plots. As it is important to incorporate shade – the visitors can view the surroundings comfortably from the vantage point of the open arbor structure – interpretive material will be provided under shaded cover.
The first pavilion (Figure 11.5) therefore primarily functions as an entry and orientation area for the visitors, where the overall concept of the site (including research) and the general concepts of decentralized wastewater treatment can be explained. This pavilion, designated as "treatment pavilion", is located in the centre of the wastewater treatment area and, if needed, allows direct access to the demonstrated technologies.
Consecutively, the visitors walk down the trail, tracking the wastewater flow to the "reuse pavilion". Following the trail several wastewater reuse options are showcased as plant beds flanking the pa-

thway on the way down to the "reuse pavilion" where interpretive signs directing his attention to plant materials, irrigation technology, etc. In the "reuse pavilion" examples and general concepts as well as specific aspects such as "irrigation components" will be explained and demonstrated. Two sites of the DTS will be fenced by a row of cedars. The young trees ideally define the dimension of the centre and frame views inward (towards the demonstration site) and outward (towards the existing WWTP and landscape). Cedar trees were chosen not only for their robustness regarding water shortage, but also to encourage the reuse of treated wastewater for landscaping in general.

The following figures give an impression on the overall design of the DTS:

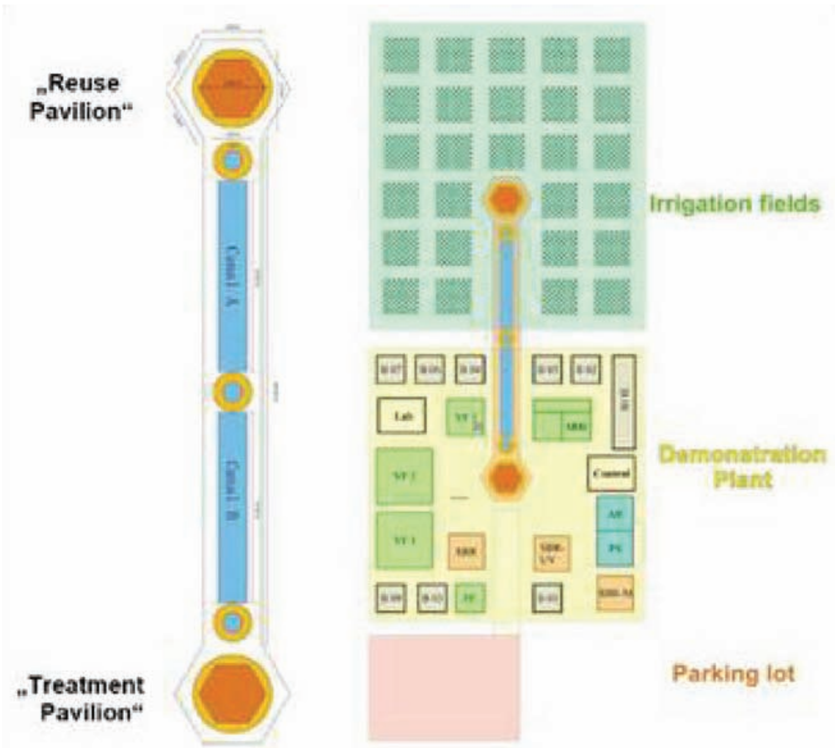

Figure 11.4
Overall concept of the "wastewater treatment and reuse trail"

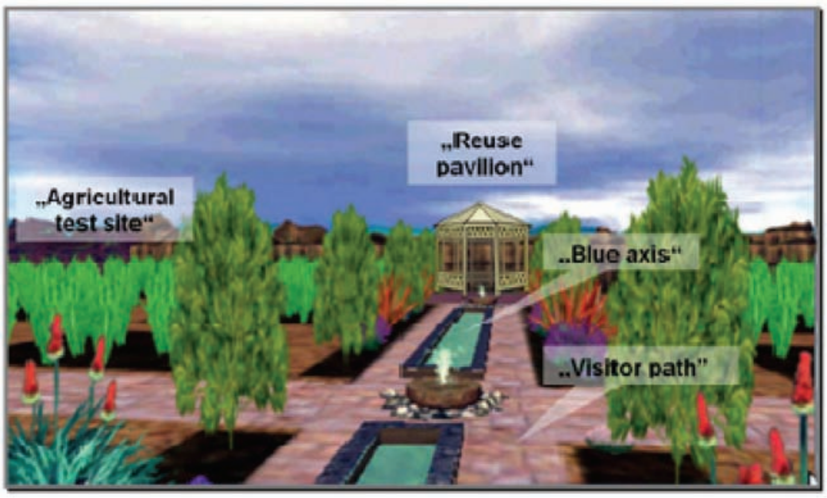

Figure 11.5
Spatial simulation of the demonstration and training site

11.3.2.2 Site selection

The demonstration and training site for decentralized wastewater treatment and reuse is situated at the wastewater treatment plant (WWTP; Figure 11.6), in a distance of around 18 km from the centre of the Jordanian capital Amman. The following figures give an impression of the building plot. The surrounding (200 m) of the demonstration site consist of non-cultivated arid grass and shrub land and the nearest residential area is located in a distance of approximately 400 m, separated by a west branch of Wadi Fuheis. The available construction plot is a polygon with a maximum length of 140 m and a maximum width of 70 m. The surface area is approximately 8500 m^2. It is located at the perimeter of a Wadi Fuheis branch. The access of the site is through an existing street passing the WWTP. The distance from the entrance gate of the WWTP to the building plot is about 430 m. The road has an asphalt pavement and is 4.5 m wide, so that it can be used by visitor busses, provided that the construction of a turning circle will be considered. The total area of the existing WWTP is fenced including the building plot so that no additional need exist for safety measures.

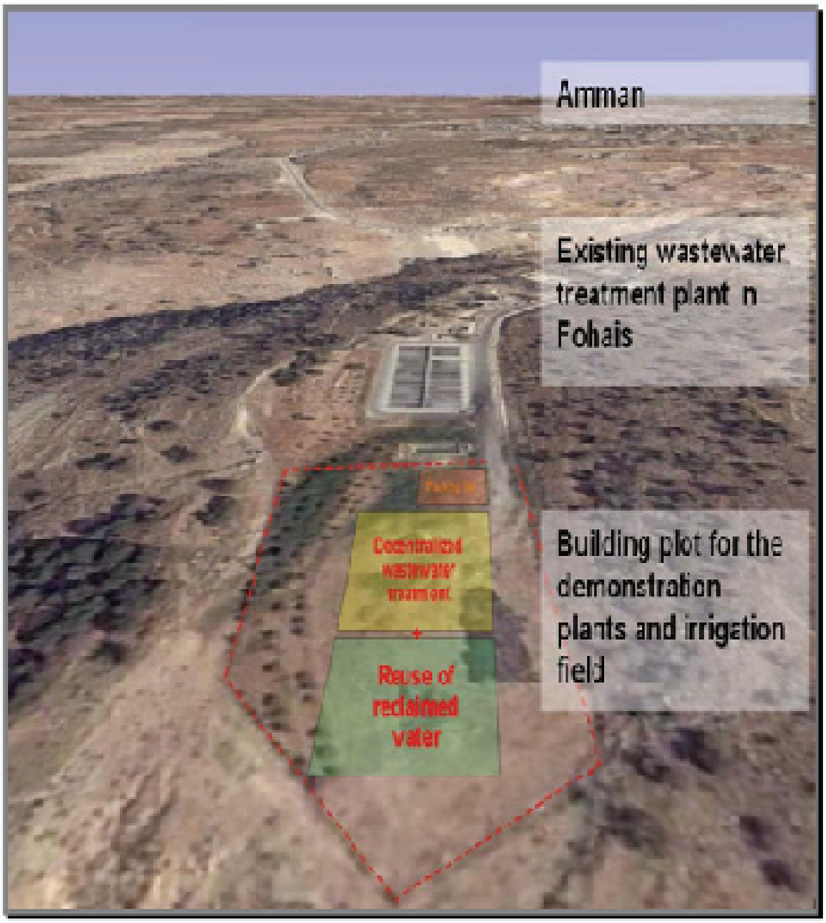

Figure 11.6
Site for the demonstration plant

11.3.2.3 Technical approach of treatment train

The demonstration site should include the following wastewater treatment trains, Fig. 11.7 and Tab. 11.1:

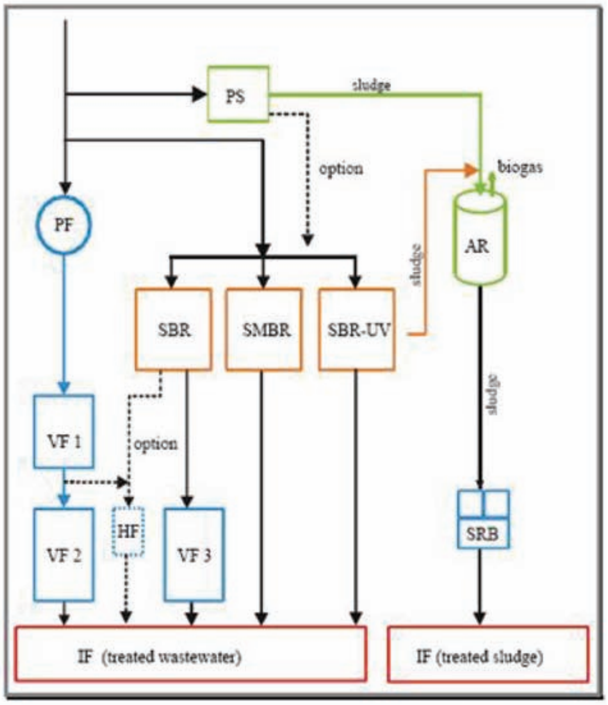

Figure 11.7
Scheme of treatment trains for decentralized wastewater treatment and reuse at the research and demonstration site

Table 11.1
Technical component of the research and demonstration site

Technology	Abbreviation	Developer
Fine screen "pipe strainer" (pretreatment)	PS	Hans Huber AG
Anaerobic reactor (biological secondary treatment)	AR	Hans Huber AG
Sequencing Batch Reactor (SBR) (biological,secondary treatment)	SBR	ATB Environmental Technologies Ltd.
SBR (biological secondary treatment) with, Membrane (post-treatment)	SBR-M	ATB-Environmental Technologies Ltd.
SBR (biological secondary treatment) with UV, (post-treatment)	SBR-UV	ATB-Environmental Technologies Ltd.
Organic prefilter (pretreatment)	PF	Helmholtz Centre for Environ-mental Research (UFZ)
Planted vertical flow soil filter (constructed wetland) (biological secondary treatment)	VF1	Helmholtz Centre for Environ-mental Research (UFZ)
Unplanted vertical flow soil filter with permanent, unsaturated flow (biological secondary treatment)	VF2	Helmholtz Centre for Environ-mental Research (UFZ)
Unplanted vertical flow filter (post-treatment)	VF3	Helmholtz Centre for Environ-mental Research (UFZ)
Sludge reed beeds (sludge treatment)	SRB 1 - 3	Helmholtz Centre for Environ-mental Research (UFZ)
27 agricultural plots with drip irrigation	IF	Al-Balqa' Applied University

11.3.3 Expected impacts

One of the principal tasks of the SMART-project is to encourage reuse-oriented wastewater management. Considering this, the design of the DTS should reflect this strong link between wastewater treatment and reuse. Thus, the following key impacts can be expected from the know-how transfer strategy:

- The DTS should serve the public at several levels as an educational site. Users are perceived to be Jordanian and foreign specialists on decentralized wastewater management as well as politicians, local stakeholders and students. Design elements should appeal to both, the local community and the international audience (e.g. language).

- The DTS should integrate the needs and requirements for the research program as well as the technical research and treatment equipment.

- The DTS, once installed, should be reliably operated and maintained (sustainability). The Al-Balqa Applied University will operate the site as a project partner and is willing to integrate the site into the graduate study program when the project will be finished. Therefore, the DTS should represent a progressive teaching site and an outstanding facility to be proud of and that in turn enhances the attractiveness and prestige of Al-Balqa Applied University.

- The realization should be integrated in the existing technical overall budget of the demonstration site. Therefore, the DTS should not be extravagant, but should achieve its beauty through a sophisticated design. Furthermore, the maintenance and operating costs should be moderate facilitating the continuation of the centre for the time after the project has ended.

Since Muslim sensitivity to issues of purity are an important factor in the acceptance of new wastewater treatment technologies, and wastewater in general has a negative image and is associated with dirtiness and malodor, a green garden aspect of the demonstration site should dominate the first optical impression of the site. For this reasons the DTS is to acquaint its users with the concept of aesthetically pleasing, but technically and scientifically sophisticated designs. This will be achieved through a garden design combined with the utilization of clear examples of wastewater treatment plants, wastewater reuse technologies and comprehensible interpretive information.

11.3.4. Future research

As described above, the general concept of the DTS, which is actually under construction, consists in a "wastewater treatment site" and a "wastewater reuse site" connected by a "wastewater treatment and reuse trail". Other than the mentioned architectural perspective, the design of the "DTS" should include clear technical examples and comprehensible interpretive information for both of the thematic units.

The technological design of the demonstration treatment plants is mainly defined by the research requirements of the involved SMART-project partners and do not necessarily reflect the whole spectrum of examples for decentralized treatment technologies for a direct implementation in rural or suburban communities. Furthermore, it is not yet clear which technologies or combination of technologies will be the most suitable for a successful implementation in Jordan and the surrounding regions. Therefore, the didactical concept of the "wastewater treatment site" should be supplemented by additional technologies and documentations of treatment systems already implemented in other regions. The required set of additional interpretive material should include exhibition walls, touchable technology, fact sheets and visual as well as olfactory impressions of the water quality before and after the treatment.

11.4 Training of end-users (D1104)

Contact Person: Jaime A. Cardona (BDZ), M. Van Afferden (UFZ)

11.4.1 Introduction

Capacity building oriented towards sustainable management of available water resources can play a significant role in the alleviation of water constrains in the Lower Jordan Rift Valley. Thus, in the framework of the project Sustainable Water Management in the Lower Jordan Rift Valley (SMART) a training program based on demonstration, technology transfer and capacity building in the field of Decentralized Wastewater Systems Solutions (DWWSS) was designed, developed and tested as a pilot teaching unit for primary schools in Ramallah, Palestine.

A summary status report on capacity building activities undertaken by the Training and Demonstration Centre for Decentralised Sewage Treatment (BDZ) within the SMART Project is presented. The report focuses on activities undertaken between 2008 and 2010, and principally contains the results for the accomplishment of the Deliverable **D1104 Training for end Users**. The report aims to assess the results of a pilot training project conducted in primary schools during November 2008 in Ramallah, Palestine, and April 2009 in Al-Salt, Jordan. In addition, the document looks at the essential challenges involved in developing the programme on a national scale in Jordan and Palestine, incorporating it into the official curriculum, and evaluating its local impact with the overall aim of more effective and equitable use and allocation of water resources.

11.4.1.1 Training Objectives

The goals of the training programme were to raise public awareness and understanding of water issues; provide pupils with the opportunity to conduct experiments in water and wastewater analysis; and build wastewater filters and constructed wetland models. The specific objectives of the workshop were for the participants to:

- Understand the conceptual framework of ecological engineering as a new teaching material for primary schools in Jordan and Palestine.
- Build awareness of teachers and children for water quality, treatment and reuse.
- Become familiar with various wastewater management concepts such as water quality, treatment and reuse; that may be used in the classrooms steps within a stakeholders involvement process.
- Build analytical capacity concerning water quality and ecological engineering wastewater treatment options.

11.4.1.2 Training components and traget group

Students from 9 to 11 years old are the main target group of the teaching unit. The training approach adopted was based on the 'Training-for-Trainers' technique and participants in the workshops included primary school teachers, undergraduate students and water authority personnel from Ramallah in Palestine and Amman in Jordan.

11.4.1.3 Coordination and preparation of the activities

In order to introduce the main context of the capacity building activities, organizational meetings were conducted at the Palestinian Water Authority in Ramallah, Palestine and the Al-BALQ University in Amman. The meetings were an opportunity to introduce the SMART project to key authorities in Palestine and to induct participating teachers to the training course.

Figure 11.8

Left: Palestinian Water Authority meeting, Ramallah 19th November 2008. Plenary panel with participants of the training program. **Right:** Presentation Teaching Unit Water Fun in Al-BALQ Applied University in Amman. 24th April 2010

11.4.1.4 Meeting with local organizations

The Palestinian Hydrologic Group (PHG) is one of the active organizations involved in the water sector within the Palestinian Territories. The objective of the meeting was to present the training program "Water Fun" within the framework of the SMART project (Figure 11.8). The meeting also provided the opportunity to conceptualize the capacity building program within local water resource issues. For this reason, the PHG organized a presentation concerning issues associated with the management of wastewater and the role of alternative technologies to treat greywater.

11.4.2 Methodology

The training encourages reflection about wastewater components and educates the participants about the advantages of wastewater treatment and its potential for reusing wastewater from decentralized systems. Additionally, the experiments help students to understand wastewater as a resource particularly in the SMART study area where water shortages are a common occurrence.

The students build a constructed wetland model which helps them to recognise constructed wetlands as a modern and ecological treatment technology that blends in well with the environment and can provide treated wastewater for irrigation purposes.

The development and implementation of the teaching unit “Water Fun” enhances the capacity building dimension in IWRM. As a key element, the program explores the development of human resources as a strategy to address the sustainable management of water in the Lower Jordan River Basin. The main importance of capacity building is directly associated with the increasing need and value of water. Particularly in the West Bank in the Palestinian territories where only less than 6% of the population is connected to treatment plants (Mahmoud et al. 2003), the implementation of such capacity building programs in schools has a direct impact on the value associated to water as a resource and will therefore assist with facilitating the sustainable management of water into the future.

11.4.2.1 Development of teaching unit Water Fun

The teaching unit sensitizes both pupils and teachers for the basic and essential concepts of sustainable development related to water value and scarcity. Most of the water analysis experiments promote the reflection and behaviour change of water management, wastewater treatment, low-cost treatment technologies and reuse alternatives and enhance a vision of considering wastewater as a resource and not as a waste (see Figure 11.9).

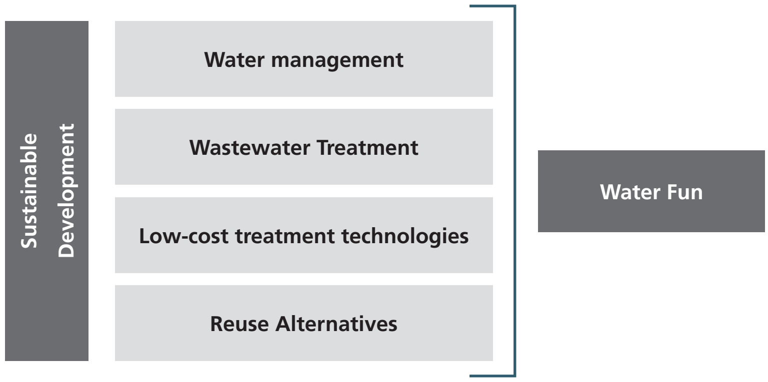

Figure 11.9
Sustainable development approach through the Water Fun teaching unit

As a capacity building strategy, the training program provides the possibility for pupils to conduct experiments in water and wastewater analysis and to build wastewater filters and constructed wetland models. The training enhances the reflection process of wastewater components and assists students in understanding the possibilities of wastewater treatment and its reuse purposes in decentralized systems. Additionally, through the experiments, students understand wastewater as a resource; especially in regions with water shortages. Moreover, by building a constructed wetland model, students recognise constructed wetlands treatment systems as a modern and ecological treatment technology that fit in well with the environment and can provide treated wastewater for irrigation.
The central methodological tool of the teaching Unit “Water Fun” is the Learning by Doing Principle. The pupils are provided with activities designed to reflect on wastewater as a valuable resource and the clear need of wastewater treatment solutions for reuse purposes. This is achieved through the hands-on contact students have in the program, from conducting water and wastewater analysis experiments through to the construction and monitoring of a constructed wetland model (see figure 11.10).

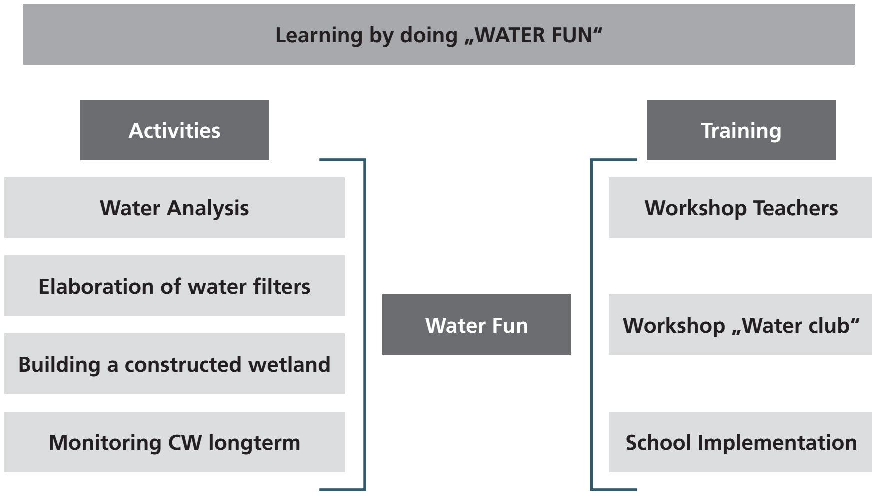

Figure 11.10
Methodological approach for the implementation of the water fun program

11.4.2.2 Development of didactical materials

The teaching material is based on the primary school teaching unit “Constructed Wetland” (Van Afferden et al. 2008), that was developed for European primary schools within the European Community funded project “Play with Water”. This teaching unit was translated and modified according to suggestions from our local Palestinian and Jordanian partners. One of the important modifications was related to the teaching unit’s name. Originally the teaching unit was presented in Ramallah under the name “Play with Water”. After the pilot activities it was realized that modifications in the name were necessary. Considering the water constrains in the Lower Jordan Rift Valley, children should avoid “playing” with water.
For this reason the name “Water Fun” has been adopted for future activities (See Figure 11.11).
A special booklet was designed including illustrative drawings on the activities developed in the teaching unit. The booklet contains minimal explanations in the Arabic language and is based primarily on visual orientation for the development of the workshop (See Figure 11.12)

Figure 11.11
In cooperation with ECO-Consul in Jordan and PWA in Palestine the training handbook for teachers was translated into the Arabic language

Figure 11.12

Developed didactical materials for implementing the Teaching Unit Water Fun in the SMART study area

11.4.3 Results

The pilot training activity denominated Teaching Unit "Water Fun" was conducted in November 2008 in Ramallah, Palestine and in April 2009 in Al-SALT, Jordan. Primary school groups of 21 students between 9 and 11 years old attended the teaching unit. The CB activity initiates with training for trainers where teachers from different Palestinian and Jordan primary schools as well as Palestinian and Jordan water administration authorities took part in the activity (see Figure 11.11, 11.14, 11.15, 11.16, 11.17). The selection of the participants was coordinated with the Palestinian Water Authority (PWA) and the Palestinian Ministry of Education (PME) in Palestine and from the AL-BALQ applied University in Jordan. The training for trainers activity was attended by teachers from nine different Ramallah Schools (RSCH) and two different schools in Jordan. Additionally, Palestinian and Jordanian representatives from the PWA, PME and the MWI (Ministry of Waster and Irrigation of Jordan) also attended the training session (see ANNEX II Workshop list of participants.

Nine different zones from the central west part of Ramallah were covered by the CB program. The teaching unit was conducted considering the schools located in the selected areas presented in Table 11.2. From each of the selected areas, a school was represented by one teacher, who was taking part in the training for trainers.

Table 11.2

Schools covered by the training program

Code	**Ramallah selected areas**
1	Dir Bzea'
2	Betoneyia
3	Biet lieqiah
4	Al-janiah
5	Raskarkar
6	Bani Zaid
7	Kharbath Musbah
8	Kafer Neama
9	Bait Serah

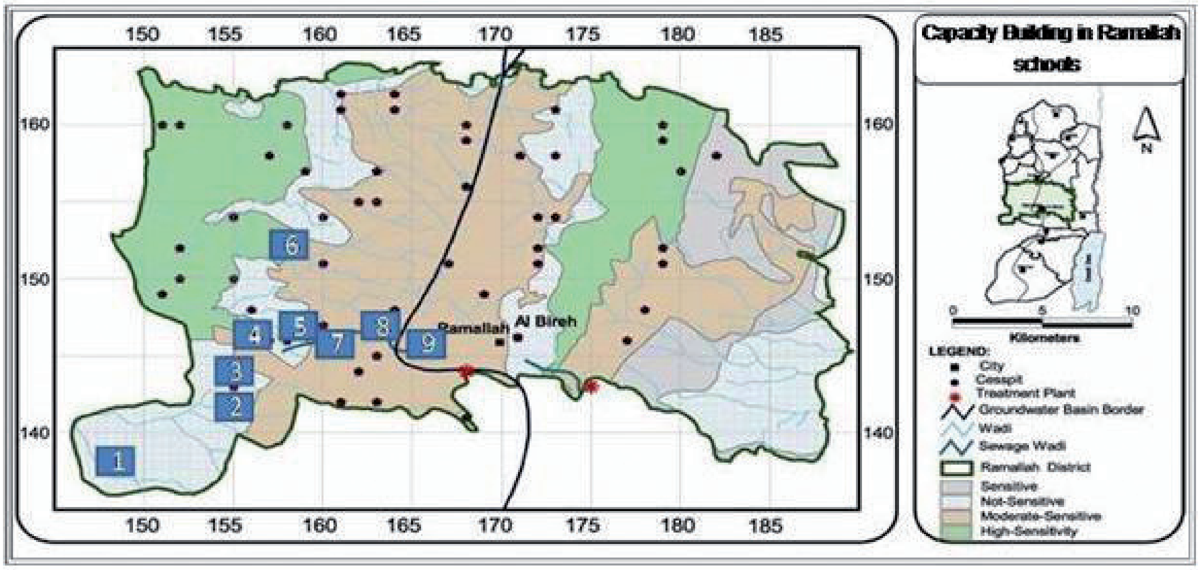

Figure 11.13 Zones covered by the capacity building program in Ramallah City, adapted from (Mimi & Assi 2009).

Figure 11.14 Teaching Unit Water Fun applied in Al-SALT primary school at the 26 of April 2009

Figure 11.15

Teaching unit Water Fun applied in Ramallah, Palestine at 19.11.2008. **Left**: children from Al-Shurook school build a constructed wetland model. **Right:** teachers from different Ramallah schools attend the CB activity in the Palestinian Water Authority PWA

Figure 11.16
Capacity Building Activities teaching unit “Water Fun” in Palestine 20.11.2008. Right: Training for Trainer in Al-BALQ University April 2010

11.4.4 Expected impacts

The teaching unit “Water Fun” as a capacity building strategy represents an adequate tool to empower local communities and organizations in the implementation of water policy and management initiatives through education. The direct impact of the CB strategy on IWRM in the research area is associated with a common lack of basic knowledge of water resources management in the population. Thus, the development of water resources knowledge at the primary school level is a sustainable strategy to establish effective water management programs in the future.
The teaching unit sensitizes pupils but teachers as well for the basic and essential concepts related to water value and scarcity. Most of the water analysis experiments promote reflections and behaviour changes concerning water consumption and enhance a vision of considering wastewater as a resource and not as a waste.

11.4.5 Future research

The fundamental challenges to enhance the program at a national scale in the Palestinian territories, Israel and Jordan is the central point to be explored in the dissemination of strategic capacity building in SMART II. Incorporating the teaching unit “Water Fun” into the official curriculum of primary schools in these countries will have a local impact in water management and water valuation behaviour can be achieved. As a consequence, a more effective and equitable use and allocation of water resources will be promoted.

Figure 11.17
Left: Training conducted in AL-SALT, Jordan. Comparison of different water qualities
Right: Example of real constructed Wetland in Rural areas of Jordan

11.4.5.1 Perspectives for SMART II

Together with our partners from the Jordanian Government, in SMART I, we developed a promising strategy for the implementation of decentralized WWT&R systems in Jordan. Subsequently it is feasible to achieve a high coverage of sanitary systems in the rural and suburban sector by a central governmental initiative that involves funding organizations and strive for a privatization of the decentralized wastewater sector.

This situation is completely different for Palestine. In the West Bank only less than 6% of the population is connected to WWTPs. The unstable political circumstances in the region hinder private investments and impede the long term engagement of international companies in the water sector. While in Jordan the tendency of a successful implementation favors small treatment plants at village level (with an externally contracted operation and maintenance service), in Palestine the implementation strategy for the rural sector should focus at the household level. This strategy has the advantage that the population will be involved in the operation and maintenance of the technologies (community based approach).

In Palestine more than 200 onsite treatment plants are operating at household level, mainly for the treatment and reuse of greywater. The planned activities include the categorization of the applied technologies, an assessment of the treatment performance and reuse potential of the treated water, the economical balance of the technologies installed and their acceptance by the end user. The outcomes of these activities will contribute to the need of the government to define implementation strategies of WWT&R-technologies and operation and financing models to improve the sanitary situation in Palestine. For SMART II, the activities will be carried out in close coordination with the capacity building activities of WP 9 that have a direct impact on the water value attitudes in the population and will contribute to a sustainable water recourses management in the long-term.

11.5 PhD students program and PhD student meeting (D1101)

Compiled by: W. Ali, H. Hötzl (UKA)

11.5.1 PhD student program

The definition of the PhD student program has become an important issue for the SMART partners. The majority of the PhD students are originally from the study area, giving a particular local point of view to their proposed research questions. The majority of the PhD students started their thesis at the beginning of the SMART project in 2006. Few PhD students started in 2007, one only in 2008. Table 11.3 lists the names and research topics of PhD students participating in the SMART PhD program.

Table 11.3

PhD Students of the SMART project.

PhD students	Country	Theme of the PhD	University
Abdel R. Abueladas	Jordan	Integrated geophysical and geological interpretation of the Jordan Valley/ Dead Sea Rift, Jordan	Al-Balqa Applied University / University of Karlsruhe
Amani Alfara	Palestine	The potential role of treated wastewater in the agricultural development of the Lower Jordan Valley	University of Karlsruhe
Suha Al-MaDbouh	Palestine	Social impact assessment (SIA) of Integrated Water Resource Management in the Lower Jordan Valley	University of Bielefeld
Wiliam Al-Khoury	Jordan	Rainfall-runoff relationships in Wadi Kafrein	University of Göttingen / Jordan University
Betty Al-saqarat	Jordan	Hydrogeology of Wadi Kafrein	Jordan University
Ibrahim Awad	Palestine	Paths to sustainable water solutions in West bank and the estimation of environmental and resource cost, in arid environment with highly competing water uses	University of Leipzig / Al Quds University
Nimrod Inbar	Israel	The evaporatic subsurface body in Kinnaret Basin: structure and geophysical aspects	University of Karlsruhe / Tel Aviv University
Hind Jasem	Jordan	Groundwater vulnerability in Wadi Kafrain catchment area and surroundings	Jordan University
Yuval Laster	Israel	Trans-border integrated water management in conflict zones	Hebrew University
Jaime Nivala	Germany	Decentralized wastewater plants in Jordan	University of Halle
David Riepl	Germany	Ontology-based knowledge management in the SMART DSS	University of Karlsruhe
Julia Sahawneh	Jordan	Geology and structure – east of Jordan Valley	Jordan University / University of Karlsruhe
Subhi Samhan	Palestine	Tracing the fate and transport of bio-contaminants and organics due to wastewater effluent in the Wadi Al Qilt catchment (Palestine)	University of Halle
Natalie Schmidt	Germany	Elimination of anthropo-genic organic trace compounds and hygienical relevant microorganisms during soil passage – wastewater reuse and groundwater recharge in the Jordan Valley	University of Karlsruhe
Sebastian Schmidt	Germany	Temporal and spatial variability of groundwater recharge in the Auja catchment area (West Bank)	University of Göttingen
Sabine Sorge	Germany	Operational and financial model of decentralized wastewater treatment plants	University of Leipzig
Moritz Zemann	Germany	Spreading behaviour of xenobiotics	University of Karlsruhe

11.5.2 PhD student meeting, march 2009

A SMART PhD student meeting takes place in Karlsruhe from March, 30th to April, 04th 2009. The meeting includes external and internal presentations, a workshop, as well as a field trip to southern Germany (Black Forest, Kaiserstuhl, Landautunnel test site, Danube springs) and the northern part of Switzerland (Rhine Falls, etc.).

11.6 Establishment of the web site (D1103)

Compiled by: D. Riepl (UKA)

The website of the SMART project (Figure 11.18) was established to promote and share the results provided from the associated partners. It is updated on a regularly basis and contains information for public (e.g. interested stakeholders) and for internal users (i.e. SMART partners). Thus, it is a tool to provide current information about research and implementation activities, results of the work packages and information concerning the project evolution, meetings and other news. Due to the main project coordination of the SMART project, the webpage is situated in Karlsruhe.
It is accessible via http://www.iwrm-smart.org.

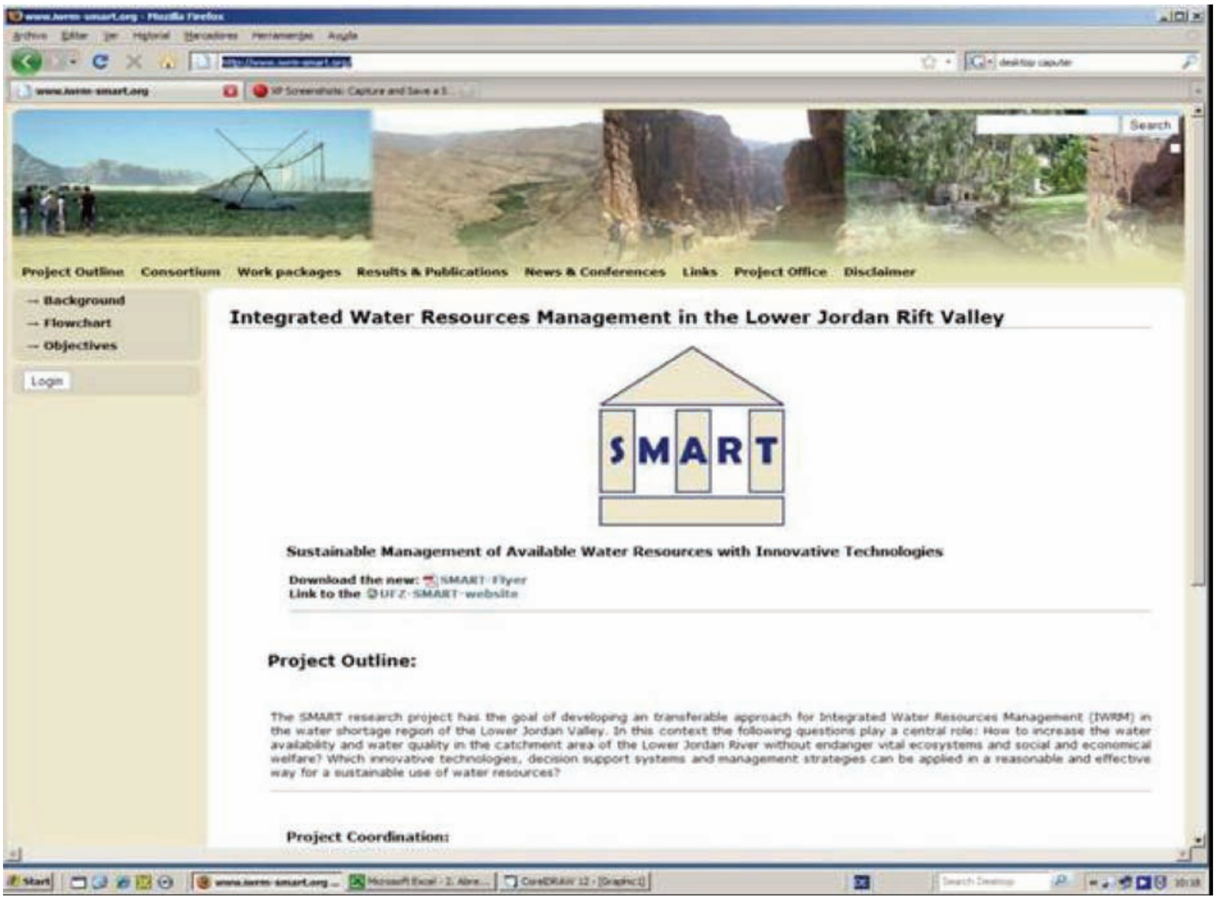

Figure 11.18
SMART website

PART C

LIST OF PUBLICATIONS

12 SMART documentation

12.1 Publications

ABU-RAHMA, A. R., GHANEM, M., ALI, W. (2010):
Grey water treatment and reuse experience in the Palestinian rural areas. Proceedings IWRM 2010 Karlsruhe, Germany. p. 207 - 213

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