

**Integrated Water Resources Management in the
Lower Jordan Rift Valley**

**Sustainable Management of Available Water Resources with
Innovative Technologies**



SMART

Executive Summary

FKZ 02WM1079-1086 and FKZ02WM1211-1212

Status: May 14, 2014

Edited by Jochen Klinger, Felix Grimmeisen, and Nico Goldscheider

Karlsruhe Institute of Technology (KIT)

Institute of Applied Geosciences

Division of Hydrogeology



Project Coordination:

Main Coordinator:	Assistant Coordinators	
Prof. Dr. Nico Goldscheider & Dr. Jochen Klinger Institute of Applied Geosciences Karlsruhe Institute of Technology	Prof. Dr. Martin Sauter Department of Applied Geology Göttingen University	Dr. Roland Müller & Dr. Stefan Geyer Helmholtz Centre for Environmental Research (UFZ)

Partners:**Germany**

Karlsruhe Institute of Technology (KIT), Institute of Applied Geosciences, Division of Hydrogeology

Helmholtz Centre for Environmental Research - UFZ

- Centre for Environmental Biotechnology (UbZ)

- Department Catchment Hydrology

- Department of Economics

University of Göttingen, Geoscience Centre, Department Applied Geology

Karlsruhe Institute of Technology (KIT), DVGW - Research Center at the Engler-Bunte Institute

DVGW- Water Technology Center (TZW), Karlsruhe

Heidelberg University, Institute of Earth Sciences

Training and Demonstration Centre for Decentralized Sewage Treatment – BDZ e.V.

ATB Umwelttechnologien GmbH, Porta Westfalica

Huber SE, Berching

Stulz-Planaqua GmbH, Bremen

Jordan

Ministry of Water and Irrigation, Amman

Jordan University, Amman

Al-Balqa' University, Salt

ATEEC, Amman

ECO-Consult, Amman

NAW - Nabil Ayoub Wakileh & Co., Amman

Palestine

Palestinian Water Authority, Ramallah

Al-Quds University, Department of Earth & Environmental Sciences, Jerusalem

Palestinian Hydrology Group, Ramallah

Israel

Tel Aviv University, Department of Geophysics and Planetary Sciences

Ben Gurion University of the Negev, J. Blaustein Institute for Desert Research, Beer Sheva

Mekorot Water Company Ltd., Tel Aviv

Environmental & Water Resources Engineering, Haifa

Scientific Coordination Meetings

- Kickoff Meeting - Amman, Jordan, March 16-18, 2010
- 2nd Scientific Coordination Meeting - Karlsruhe, Germany, November 22-24, 2010
- 3rd Scientific Coordination Meeting, (Specific Strategy Meeting) in Malta, May 09-12, 2011
- 4th Scientific Coordination Meeting – Dresden, Germany, October 10-11, 2011, together with the BMBF IWRM Conference, Dresden, October 12-13, 2011 - Management of Water in a Changing World: Lessons Learnt and Innovative Perspective
- 5th Scientific Coordination Meeting - Istanbul, Turkey, March 26-29, 2012
- 6th Scientific Coordination Meeting – Karlsruhe, Germany, November 18-20, 2012
- 7th Scientific Coordination Meeting – Larnaca, Cyprus, April 13-15, 2013

Upcoming Events

Status Seminar – Karlsruhe, Germany, June 26, 2014

INFORMATION: Website, Publications, Deliverables, Final Report

The website of the SMART II project, maintained by the KIT coordination team, includes a complete list of publications as well as all accomplished deliverables and the draft final report:

<http://www.iwrm-smart2.org/>

All SMART members and the reviewers of the SMART MOVE proposal have full access to this information when using the following log-in information: User Name: partner, Password: peace

The deliverables and the draft final report are available under the Project Office. For the sake of conciseness, this Executive Summary does not include a reference list and a list of project deliverables, as this information can be obtained from the project website.

Additional information can be obtained from jochen.klinger@kit.edu or goldscheider@kit.edu

Photo of cover: View in SW direction from the lower Wadi Kafrein towards the Jordan Valley and the Dead Sea

(Grimmeisen 2011)

Cooperative Research Project: IWRM Israel (ISR), Jordan (JOR), Palestine (PAL):**Integrated Water Resources Management in the Lower Jordan Rift Valley: 2nd Project Phase of SMART - Sustainable Management of Available Water Resources with Innovative Technologies**

Sub-project 1: Coordination, capacity building, aquifer recharge; Karlsruhe Institute of Technology (KIT), Institute of Applied Geosciences, Division of Hydrogeology; grant number: 02WM1079

Sub-project 2: Database, wastewater treatment and reuse, socio-economy; Helmholtz Centre for Environmental Research - UFZ, Centre for Environmental Biotechnology (UbZ); grant number: 02WM1080

Sub-project 3: Water resources assessment, aquifer recharge; University of Göttingen, Faculty for Geoscience and Geography, Geoscience Centre, Department Applied Geology; grant number: 02WM1081

Sub-project 4: Elimination of emerging pollutants by a membrane bioreactor and groundwater recharge processes, DVGW German Technical and Scientific Association for Gas and Water - Water Technology Center (TZW); grant number: 02WM1082

Sub-project 5: Technologies - Brackish water; DVGW German Technical and Scientific Association for Gas and Water at the Engler-Bunte Institute, Chair of Water Chemistry and Water Technology, Karlsruhe Institute of Technology (KIT); grant number: 02WM1083

Sub-project 6: Membrane bioreactor; Huber SE, Berching; grant number: 02WM1084

Sub-project 7: Decentralized sewage treatment systems by SBR technologies, ATB Umwelttechnologien GmbH, Porta Westfalica; grant number: 02WM1085

Sub-project 8: Gaza, assessment of wastewater treatment and reuse, Heidelberg University - Faculty of Chemistry and Earth Sciences - Institute of Earth Sciences; grant number: 02WM1086

Sub-project 9: Membrane pilot plant for brackish water treatment and desalination, STULZ-PLANAQUA GmbH, Bremen; grant number: 02WM1211

Sub-project 10: National Implementation Committee (NICE) Amman, Jordan, Helmholtz Centre for Environmental Research - UFZ, Centre for Environmental Biotechnology (UbZ); grant number: 02WM1212

CONTENTS

1	Introduction	1
2	Database management	7
3	Decentralized Wastewater Systems	12
4	Managed Aquifer Recharge	14
5	Brackish Water Usage	17
6	Water Resources Assessment	20
7	Water Resources Protection	23
8	IWRM Tools	28
9	Socio-economics	30
10	IWRM Scenarios	34
11	Dissemination & Capacity Building.....	36
12	Summary & Conclusion	37

1 Introduction

The Lower Jordan Valley

The Lower Jordan Valley (LJV) (Figure 1-1) comprises parts of Israel, Jordan, and the Palestinian Territories and is, in terms of per capita freshwater availability, among the water-scarcest regions worldwide. The current overexploitation of the natural surface water and groundwater resources already has severe impacts on the environment and society. According to the observed trends of population growth and demand, the conditions are likely to be aggravated in the coming years.

On a regional scale, capacious seawater desalination and import schemes are presently discussed as potential solutions. However, even if political and economic constraints and environmental concerns relating to such mega-projects can be overcome, the effective management and protection of the basin's internal resources still remain key requirements for the future water security in the LJV.



Figure 1-1 The Lower Jordan Valley (view to the West Bank, photo: J. Klinger)

In response to this situation, the responsible governments have already expressed their commitment to fostering IWRM as well as to adopting the required major water sector reforms. However, each of the riparian states is vastly different in terms of institutional setting and capacity, awareness, economics, and water policy. For this reason, a universally applicable basin-wide IWRM implementation concept is still lacking for the Lower Jordan Valley. In spite of this situation, there are common denominators that unite the different riparian states. Apart from the need for reliable and comprehensive information on the temporal and spatial availability of the regions' conventional water resources, the understanding of treated wastewater, brackish groundwater, and stormwater runoff as genuine parts of the water management cycle is of

particular importance to IWRM in such water-stressed regions. The critical challenges in this respect are the establishment of measures that are technically adapted to local physical conditions and conceptually adapted to the respective socio-economic realities.

The multilateral SMART (Sustainable Management of Available Resources with Innovative Technologies) research initiative investigated these topics in a series of local pilot studies and at demonstration sites in sub-catchments in Israel, the Palestinian Territories, and Jordan. The focus of these studies laid on decentralized wastewater treatment, brackish water desalination, managed aquifer recharge, and groundwater protection. Central objectives were the investigation of feasibility, costs, and effectiveness of adapted solutions as well as the provision of necessary decision support tools and institutional capacity building initiatives. Finally, the local findings were scaled up to form a basin-wide framework by means of a regional trans-boundary water budget model and a regional data- and knowledge base.

While SMART provides a set of adapted technologies for water treatment, the objective of this chapter is to specifically highlight the developed and applied concepts addressing the problems of current and future water management in the LJV. The concepts take the basic principles of IWRM into consideration. Socio-economic and environmental impacts of various water management developments are assessed.

Geographic, Hydrogeological, and Climatic Setting

The Lower Jordan Valley (LJV) in the Middle East is part of an extensive geological transform fault system and is shared by Israel, Jordan, and the Palestinian Territories. It extends over a length of approximately 100 km from Lake Tiberias in the north to the mouth of River Jordan at the Dead Sea in the south. As part of the Lower Jordan Valley, the SMART project region comprises an area of approximately 5,000 km², including the valley floor with a width of 8 to 15 km as well as numerous tributary sub-basins (Wadis) east and west of the River Jordan (Flexer et al. 2009). The project area is bordered by mountain ridges in the east along the axis Irbid-Amman-Madaba and on the western side along the axis of Nablus-Ramallah-Jerusalem-Hebron (Figure 1-2).

The Dead Sea topographically is the lowest area and currently is located at about 420 m below sea level, while the surrounding mountain ridges reach altitudes of 1,200 m above sea level.

Only few urbanized areas can be found in the Jordan Valley due to the hot and dry climate prevailing close to the Dead Sea. An example is Jericho (population 20,000). Larger urbanized areas are located on top of the escarpments, such as Amman, Irbid, Salt, and Madaba in Jordan on the eastern side and Jerusalem, Hebron, Nablus, and Ramallah on the western side.

The climate in the project region is arid to Mediterranean. Arid conditions prevail in the Jordan Valley with precipitations below 150 mm/a, whereas the potential evaporation can exceed 2,600 mm/a. Along the mountain ridges, Mediterranean climate predominates with precipitation rates of 600 to 800 mm/a and a potential evaporation of 1,600 to 1,900 mm. The transition zone along the slopes is characterized by a semi-arid climate with precipitation rates of 200 to 300 mm/a and a potential evaporation of 1,900 to 2,400 mm/a (Flexer et al. 2009).

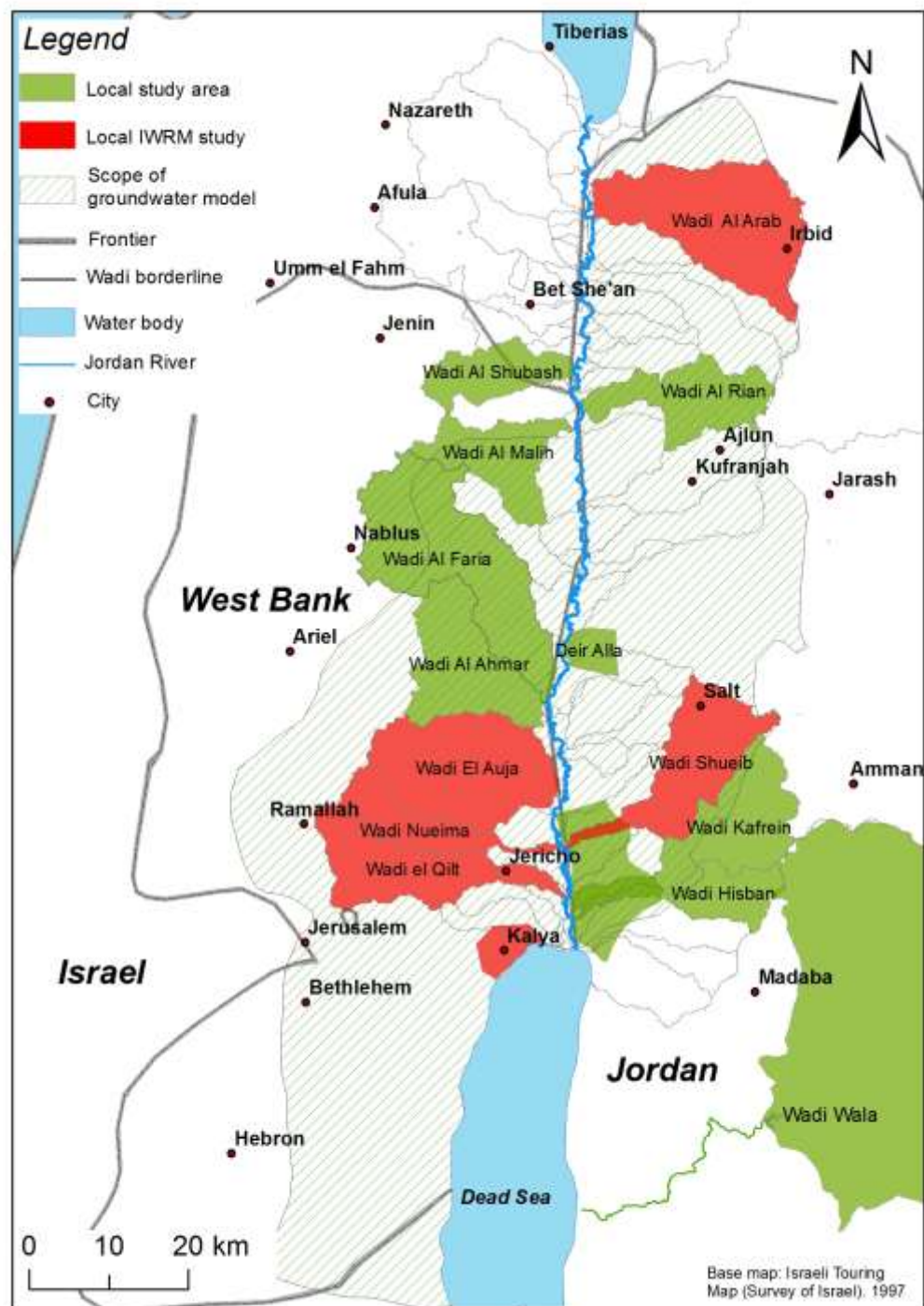


Figure 1-2: Overview of the SMART project area in the LJV (Klinger et al. 2014, submitted)

Water Scarcity in the Lower Jordan Valley

The LJV lies in a region where water demands frequently exceed the availability of resources. Hence, especially in dry periods, water shortage is a problem of daily life. Generally, it is referred to absolute water scarcity, if the freshwater availability is below 500 m³/a per person (UN 2012, FAO 2012, Falkenmark & Widstrand 1992). Based on this indicator, Jordan and the Palestinian Territories may well be considered regions suffering from extreme water shortage. This situation is aggravated by declining natural groundwater recharge and constant population growth. Table 1 lists the water budgets for both present and future conditions in the riparian states of the LJV.

Table 1: Lower Jordan River Valley: Water availability and demand in the adjacent countries

	Israel		Jordan		Palestine (West Bank)	
Year	2010	2020	2010	2025	2010	2022
Freshwater resources [MCM/year]	1,170 ⁽³⁾	1,170 ⁽³⁾	780 ⁽⁷⁾	483 ⁽⁸⁾	127 ⁽⁴⁾	> 127 ⁽⁶⁾
Inland brackish water desalination [MCM/year]	25	75 ⁽¹⁾	57	82	0.5	22
Seawater desalination [MCM/year]	270	650 ⁽²⁾	--	370	--	--
TWW reuse in agriculture [MCM/year]	400	570 ⁽¹⁾	100	247	--	30.6
Population (million)	7.7	9.1	6.1	8.5	2.65 ⁽⁵⁾	5.7
Total water demand [MCM/year]	1,994	2,596	1,315	1,652	125 ⁽⁵⁾	712 ⁽⁹⁾
Deficit of water (demand – resources) [MCM/year]	129	131	361	470	2	>>2

Abbreviations: TWW=Treated Wastewater; MCM=Million Cubic Meters

Superscript numbers: ⁽¹⁾ 2015 value, ⁽²⁾ 2017 value, ⁽³⁾ Pumped water, ⁽⁴⁾ Domestic and agricultural water supply, including purchases from Mekorot utility, ⁽⁵⁾ 2012 value, ⁽⁶⁾ Depends on the access to water resources, ⁽⁷⁾ Estimated natural groundwater and surface water resources, ⁽⁸⁾ Renewable and non-renewable groundwater only, ⁽⁹⁾ Long-term water strategy as of 2022.

Sources: Guttman, J. (2011), Rosenthal, G., and Katz, D. (2010), Palestinian Water Authority (2012), RCW & MWI (2009)

The table reflects that the water resources management strategies of all riparian states take future water demand into account. It is planned to increase the reuse of treated wastewater, inland brackish water desalination, and seawater desalination to mitigate the situation. The deficit of water demand and water availability already is significant and will increase in the next ten to fifteen years.

In case of Israel, reuse of treated wastewater is being practiced on a large scale, and the government is currently implementing a huge seawater desalination program along the Mediterranean coastline.

In Jordan, water reuse, especially for irrigation purposes in agriculture, is being practiced as well, and major infrastructural projects like the Disi water conveyance pipeline or the Red Sea – Dead Sea water conveyance project represent two of the main future options. Particularly in the northern part of Jordan, the water situation is getting worse due to the crisis in Syria. According to current figures published by the UNHCR (October 2013), there are 2.0 million Syrian refugees in total, and more than 640,000 of which are officially registered in Jordan. In contrast to this, Jordan's Ministry of Water and Irrigation refers to an unofficial number of up to 1.3 million Syrian refugees in Jordan by the end of 2014. The country experienced a population growth of more than 20 % within the last two years, the total population being 6.45 million in 2013.

The situation in the Palestinian Territories, especially in the West Bank, is characterized by limited access to natural resources and ongoing rivalries with Israel. The availability of water per capita ranges from 29 to 150 l/d, but is mostly below 80 l/d, with widespread seasonal water cut-offs, mainly during dry summers. 30% of the communities or 700,000 people are currently not served by any water network. In these areas, purchasing water from trucks and hauling water from standpipes are typical practices. Due to the lack of water, many people use untreated gray wastewater to irrigate their farms and gardens without taking into consideration health and environmental risks especially to children and pregnant women. The gap between supply and demand will increase dramatically in the coming years.

By changing the allocation of water among the three riparian countries, together with additional measures, such as water reuse, brackish water desalination, and stormwater harvesting, the insufficient water supply in this area could be improved radically.

The development and application of an approach to IWRM in the Lower Jordan Valley may result in an efficient, equitable, and sustainable development and management of the scarce water resources in that area. The SMART project provides a suitable framework to address the above objectives.

Integrated Water Resources Management in the Lower Jordan Valley

SMART - IWRM in the Lower Jordan Valley

SMART is a multilateral and interdisciplinary research project of 25 partners from universities, research centers, water authorities, decision-relevant institutions, external experts as well as industry partners in Germany, Israel, the Palestinian Territories, and Jordan. The SMART initiative is in its second project phase, the investigations of SMART I from 2006 to 2010 being documented in the project report of phase 1 (Wolf & Hötzl, 2011). The SMART project itself was based on the German-Israeli-Jordanian-Palestinian (GIJP) project which was also funded by the BMBF from 1997 – 2004 and concentrated on a regional hydrological, hydrogeological, and hydrochemical database as well as on exemplary detailed studies along a section from Jerusalem to Amman crossing the Jordan rift valley (Hötzl, Möller & Rosenthal 2009).

In SMART II, which was initiated in 2010, the overall goal was to develop an IWRM concept for the Lower Jordan Valley to ensure an optimized and sustainable use of all water resources in the region (DoW, 2010). Ideally, the developed, applied, and validated concepts were to be transferable to other regions suffering from natural and/or man-made water scarcity.

Besides conventional water resources, unconventional water resources are taken into account, such as treated wastewater, temporally stored surface water, and desalinated brackish groundwater. To ensure a sustainable exploitation and use of the results gained through the investigations, involvement of decision-making stakeholders was one of the basic requirement in planning the project.

Structure and Objectives of the SMART Initiative

Due to its size and the wide scope of research activities, SMART was divided into sub-projects and work packages (WP) addressing IWRM-relevant issues. The IWRM character of SMART is reflected by the structure of the project (Figure 1-3) showing the work packages and their interdependencies.

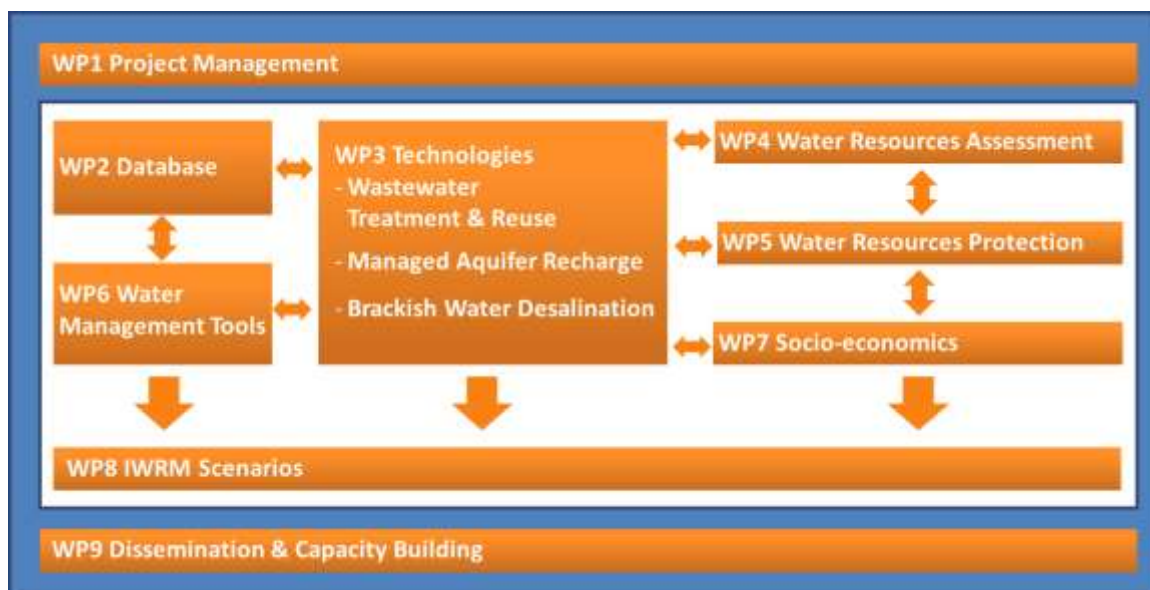


Figure 1-3: Project structure of SMART II

Although the project was dominated by technology demonstration and implementation, it included substantial components of research and development, education, dissemination, and capacity building. It was one of primary goals that the stakeholders and local authorities receive all necessary information and data needed for a sustainable decision-making process.

At first glance, the technologies in WP3 built the backbone of the project and included wastewater treatment and reuse, managed aquifer recharge, and brackish water desalination. It was assumed that the appropriate way to provide for additional water is to develop resources for procedures of extensive recovery, adapted treatment, reuse of effluents, and brackish water desalination.

The objectives of the other work packages were to provide tools for the management and operation of the LJV water resources. This included a platform for trans-boundary data management and exchange, with data from all riparian states being actively stored and queried. The assessment of the water resources and groundwater vulnerability supplied fundamental information about the overall yield of available resources in the LJV and the current deficits concerning its protection.

Socio-economic effects of technology implementation and groundwater protection were evaluated in WP7 and the institutional feasibility of alternative water treatment technologies was proven. All data and information of the research activities gathered in the course of the project were compiled in WP8. By taking the respective water strategies into consideration, a guideline for an IWRM strategy implementation was developed.

The frame around all WP was capacity development which was performed on all levels – pupils in schools were taught as were teachers and technicians. Furthermore, academic capacities were built within a separate doctorate program and a scientific advanced training course for researchers from the region to maintain a sustainable development.

2 Database management

WP2: Spokesman Stefan Geyer, UFZ

Introduction

The Integrated Water Resources Management (IWRM) project SMART takes into account environmental conditions, ecosystems, socio-economy, water provision, and demand management to conserve the water resources for future generations. Besides different socioeconomic and technological aspects, the IWRM also covers the physical characteristics of the neighborhood, such as climate, geology, hydrology (surface and subsurface), and soil screening. All these variables are often linked to each other. For decision-making in natural resources management, a profound database of all available variables and measurements is essential. Data and information management is a key issue for IWRM. The database allows for people and institutions with different backgrounds and from various political environments to talk the same language. Querying capabilities as well as visualization tools are necessary ingredients. The information here includes spatially distributed systems, temporally varying data, and geo-referenced information (maps and point data).

The resulting SMART comprehensive database management system (DBMS) was designed to efficiently supply all partners with input data for establishing the required systems (modeling, geographical information systems - GIS). The Helmholtz Centre for Environmental Research – UFZ technologically advanced this tool and named it DAISY (Data and Information System).

The DBMS is designed to serve as a platform for collecting and storing data and sharing them among the partners to ensure proper, effective, and quick supply of data and information required for the execution of the various project tasks.

Consequently, the project (basin) area and scope were determined and subdivided into sub-areas of more homogeneous problems and characteristics for the work to focus on more specific local problems. The findings were then to be incorporated in the project stream.

An integral part of the work package was to gather, compile, and organize all data available on the JRV, which were considered relevant to and necessary for the project, including:

- Agriculture: Current status of activities, crops, irrigation practices and applied technologies, irrigation schedules, efficiency (crop production per unit area of cultivated land per unit volume of irrigation). Link/interface to: WP4 –spatial characterization of soil cover by satellite images, results: Information about the evolution of agriculture (temporary and long-term crop rotation/changes with regard to the necessary amount of irrigation, changes in recharge, soil erosion)
- Socio-economy: Inventory of the cities and small towns in the JRV, their current population and expected growth trends, water ingestion (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 with respect to density and kind of communities by aerial photographs).

- 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 complement time-dependent remote sensing data from the work area or special areas.
- Morphology: Up-to-date digital elevation models in GIS-readable base (e.g., grid, image) for study area/particular areas (e.g. Israel Geological Survey base) or produced out of aerially corrected remote sensing data from the stereographic sensor on the ASTER-platform.
- Wells: Well characteristics (well location, depth, position of perforation, diameter, pump depth, etc.); well time series of piezometric head and quality, such as concentrations of chloride, nitrate, and other elements, which may exist in any of the institutional data warehouses have to be gathered for the 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).
- Climatic data: Characteristics measured by rain gauges (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.) under specific and regional climate 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 wider areas to characterize the evolution of urban/rural regions.
- Water distribution system: Layout and characteristics (diameter, discharges, and so on).
- 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 projects and those provided by project partners were and are still being reviewed and classified according to database regulations and their relevance to the project. The aim was to produce a logical information structure (variables, units, parameters), to avoid redundancy, and to guarantee data quality.

In cooperation with project partners, gaps of knowledge and information that need to be bridged under the project were identified. The newly designed and updated data and information system then assisted the project partners in determining additional needs for investigations (including field work) necessary to reach the strategic aims of the project.

Structure of the Database

All implemented data are incorporated in the integrated relational DBMS (Figure 2-1), which is based on an Oracle system of the Helmholtz-Centre for Environmental Research - UFZ. The DBMS makes the data available via a personal internet portal and an interface of a GIS platform. A web-based graphical user interface (GUI) for data queries was established.

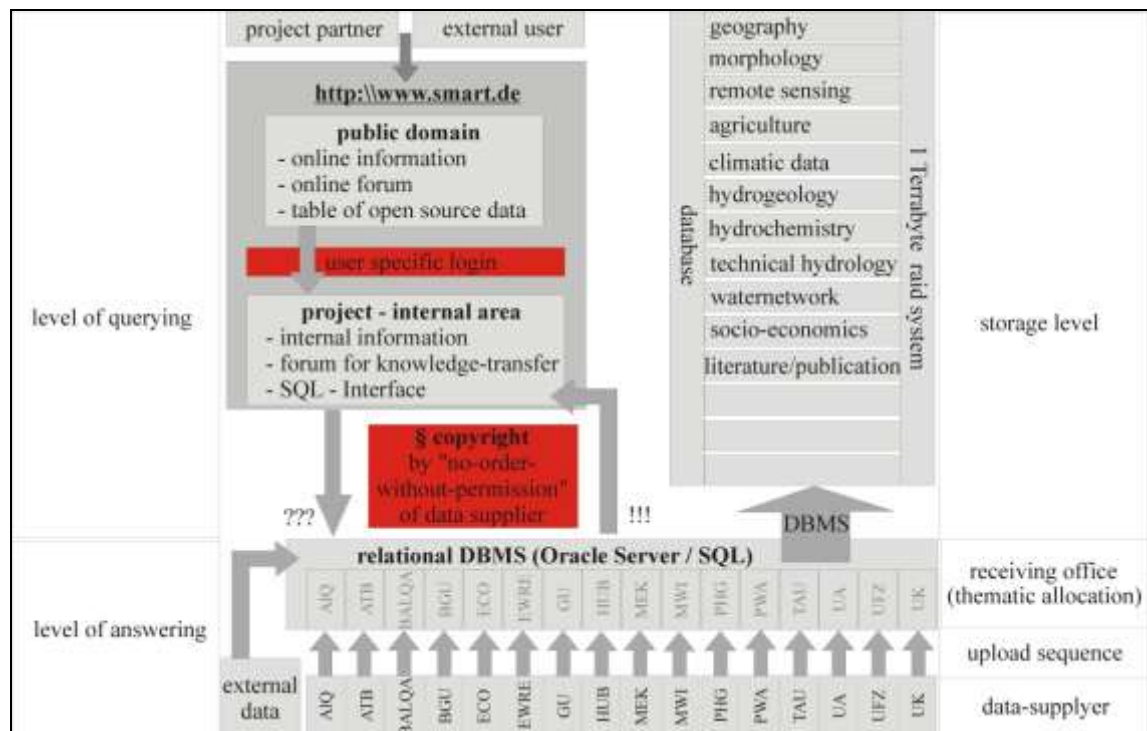


Figure 2-1: Conceptual flowchart of the relational database management system (RDBMS)

The DAISY data and information system is designed to answer with respect to different matters:

- DBMS – Oracle: Storage and provision of alphanumerical data
- ArcSDE: Storage and supply of raster and vector data
- Transfer drives: Secure platform for transfer, , storage, and exchange of all types of data among 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

Database Entry and Usage

The entry to the system is easily found on the internet (<http://www.ufz.de/index.php?de=31527>). An easy-to-use and web-based graphical user interface (Figure 2-2) was developed to make access to DAISY for all users as easy as possible. Based on this mask, every user decides what he is interested in. One of the main topics is an open public Web-Gis to generate thematic queries and maps for the SMART region (<http://www.ufz.de/webgis-daisy/>), where the visitor sees the locations of all relevant data available in the database management system (RDBMS), but not the data themselves. If the user wants to search for alphanumerical data, he has to enter the second main topic, the Daisy data harvester (https://www.ufz.de/daisy_harvester/, partly free or Log-in required) or raster/vector data sets, incl. metadata (<http://www.ufz.de/datalog/>, Log-in required).

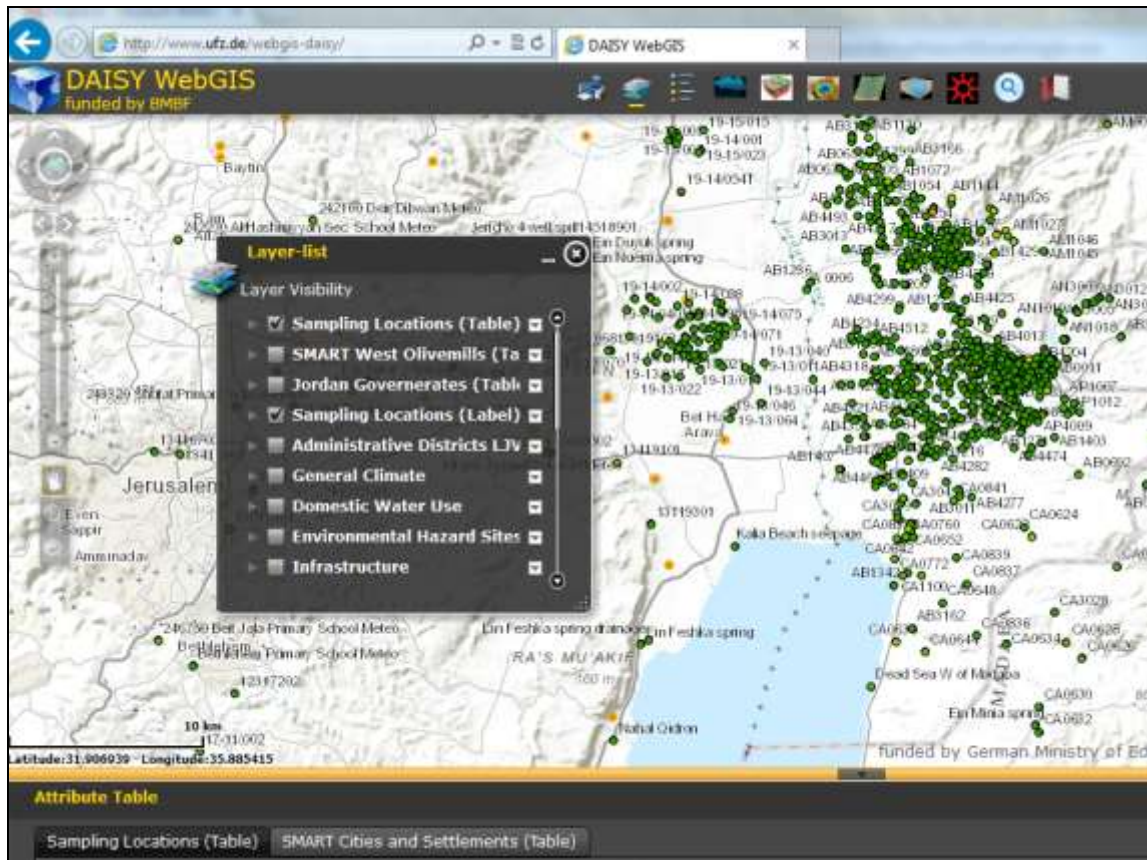


Figure 2-2: Public domain DAISY WebGIS starting page

Based on the experience of the first project years, the first DAISY data harvester was revised completely to make the queries more stringent and faster.

Transfer Drive

Usually, spatial data sets like maps, digital evaluation models, etc. have a huge size of several hundreds of megabytes. RDBM systems like that of SMART are highly sensitive and have to be administrated carefully in order to continuously provide users with information. Such databases have no standardized file system. For this reason and because of security and content restrictions, a partner who wants to upload data sets to the RDBMS cannot connect directly to the database. This is one of the reasons transfer-drives were implemented. Each working group is given its own password-locked drive to prevent problems relating to information protection. From there, the database administration takes the data, checks them with respect to logics and consistency (file formats, units, coordinate systems, etc.) and afterwards, the data sets will be uploaded to the RDBMS.

An additional advantage of the transfer drives is to quickly exchange and store huge amounts of data (each set has up to 1 GB) in a very safe manner. The stored data can be accessed easily from all over the world, because the drives are web-based. They are hosted by the UFZ and twice a week, a backup of each drive is made. Neither the content nor the size of the drive are subject to any restrictions. Nevertheless, the size of a single file (or archive) should not be larger than 1 GB.

To reach the drive, the URL www.transfer.ufz.de has to be written into the address list of a standard internet browser (e.g. Firefox, Mozilla, Safari).

Security of Data

In DAISY, already published data sets are public knowledge and are visible to everybody. Nonetheless, data that are sensible (e.g. unpublished data) can be made invisible by a declaration of the data owner. Only metadata like the type of data and the owner of the data are visible. Hence, every user can reach the owner and ask whether he may obtain and use the information. This security system is important to enhance reliance on the database providing the data.

The relational database management system (RDBMS) is strongly protected by various firewalls within the Helmholtz Centre for Environmental Research – UFZ. Every user who wants to access the protected, non-public domain area needs a personal password, which is made available via e-mail to the administrator. The administrator checks the rights of the potential user (SMART project member) and starts an automatic process. The new password is generated and sent to the new user. Only the personal user knows this password. It is checked, how often the user logs in. After several months without action, the user is automatically sent a warning to renew his log-in. If there is no reaction, the password is deleted. In this way, only active members can log in and the administrator knows how many people and who uses the database. On the other hand, it is no problem to get a new password.

The database itself is updated every day and mirrored at different storage locations within the database management system of the Helmholtz Centre for Environmental Research – UFZ. A secure access to the database is guaranteed to all partners also after the completion of regional projects.

Data Input in the DBMS

The long-lasting experience of the group shows that an automatic input via the internet is not appropriate. The reason is that all data lists still have to be checked for consistency to keep the reliability of the stored data high. Another big problem was the different names for e.g. sampling locations by the partners. Alphanumerical data are sent in the form of ASCII files or Excel files and then checked by the administrator before incorporation in the database. The same is the case for raster/vector data.

A huge amount of data from former projects, such as GIJP, GLOWA, from literature and the internet, from local and foreign databases was screened, selected, evaluated, compiled, and finally included into the RDBMS and DAISY. Data from project partners, such as the Ministry of Water and Irrigation, Mekorot, Tel Aviv University, etc., or from foreign partners, such as BGR, were collected and incorporated as well.

Use and Awareness in the Region and Science Community

In the meantime, 2 million data of the region have been made available in the information base. By the end of April 2014, a database update will provide access to about 750,000 more data sets. The number of users and daily access counts are rising constantly as the DAISY data consciousness grows.

3 Decentralized Wastewater Systems

WP3-1 Spokesman: Roland Müller, UFZ; Bassim Abassi, Al'Balqa University, Jordan

Introduction

Since 1978, the Jordanian government has gradually implemented the reuse of treated wastewater (Haddadin and Shteivi 2006). The country's 28 wastewater treatment plants presently serve about 68% of Jordan's households and capture around 118 MCM sewage per year (WAJ 2013), of which nearly 90% are reused mainly in agriculture in the Jordan valley. However, the quantitative potential for wastewater treatment and reuse has yet not been fully exploited. As stated in "Jordan's Water Strategy 2009-2022" that has been prepared with input of the SMART team, the Ministry of Water and Irrigation (MWI) aims at reusing 200 MCM of treated wastewater by 2022. The Strategy defines the implementation of decentralized wastewater treatment (DWWT) infrastructure to be a measure to alleviate Jordan's permanent and growing water scarcity and to significantly improve sanitation. Therefore, one major focus of the previous research activities was the development and implementation of innovative Decentralized Wastewater Treatment and Reuse (DWWM) systems as a flexible tool for Integrated Water Resources Management (IWRM).

Research Activities and Implementation Research

Decentralized Wastewater Management (DWWM) systems are defined by their technical components, namely, a wastewater treatment plant coupled with the reuse of treated effluents at or near to the point of their generation, which creates added benefits and contributes to sustainable water management in the region. Under Jordanian topographical and building development conditions, the sizes of such facilities range from solutions for individual buildings (onsite) to solutions for several houses or small villages (cluster) up to a maximum size of approximately 5,000 population equivalents (PE) (semi-centralized; see Figure 3-1).

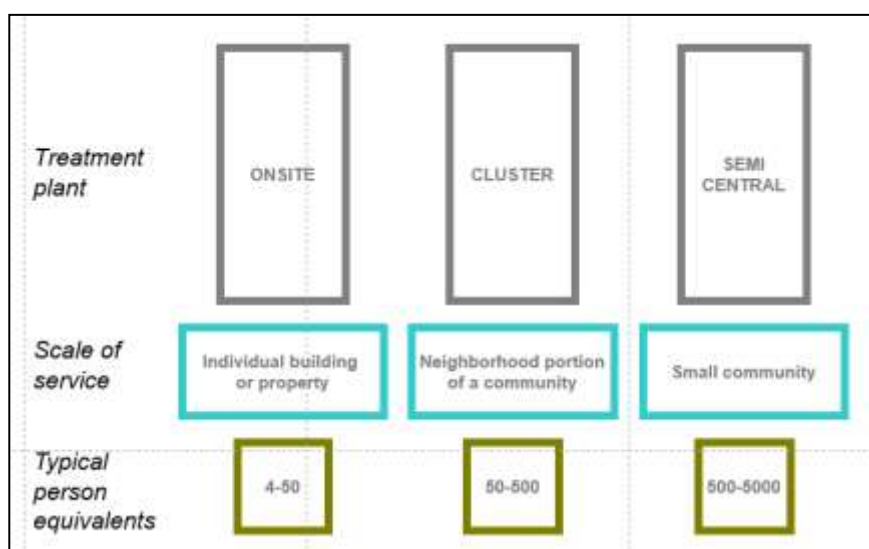


Figure 3-1: Sizes and classification of DWWT solutions (Within the scope of this project, WWTPs with a capacity exceeding 350 m³/day are considered 'centralized' solutions)

Within the SMART project, the research strategy “Implementation Research” was developed with the goal to establish resilient infrastructure for managing water resources under scarcity conditions using an integrated water resources management approach. This interdisciplinary research strategy is based on three pillars: a) Technology adaptation to local requirements, b) decision support focusing on economic efficiency, and c) capacity development for different educational levels and academic fields.

Results

The core element of the SMART project is “innovative technologies”. In the area of decentralized wastewater management, the following results were achieved:

Technology adaptation to Jordanian requirements

- Establishment of a research and demonstration site for DWWM systems in Jordan (see Figure 3-2). The fact that infrastructures are tailored to local conditions makes them important modules in the implementation process. Furthermore, the site was established not only as a research platform stimulating cooperation between researchers, thus generating cross-disciplinary synergies, but also as a location for technical and educational capacity development as well as measures to enhance public awareness of wastewater issues.
- Development and adaptation of 5 different DWWM technologies towards a treatment performance that complies with the Jordanian Standard (JS 893-2006) for the reuse of wastewater.
- Implementation of 7 DWWM systems on the real scale for individual households and group solutions.
- Introduction of the wetland and SBR technologies on the Jordanian market by our industrial partners.

The implementation of the developed technologies on the regional scale requires an easy-to-apply “decision support tool” that will enable practitioners, i.e. public authorities, consulting companies, etc., to compare different decentralized and centralized wastewater management scenarios in order to identify best solutions under local conditions.

Development of a decision support tool to secure economic efficiency

- A new and innovative methodology for site analysis was developed, which allows integrating highly diverse data, i.e. economic, social, physical, topographic, institutional data, along with satellite imaging and a digital land elevation model in order to effectively assess DWWM system solutions under local conditions.
- Based on this methodology, a GIS-based decision support tool with which scenario and feasibility analyses can be performed taking into account local conditions. In close cooperation with government officials, stakeholders, industry, and development banks, GIS-based wastewater management scenarios on the regional scale in Jordan were generated and assessed both economically and technologically. The application of this tool has great potential to enhance the access of German consulting companies to new markets in the water sector.

In order to overcome further societal and political barriers that impede implementation and to set impulses for a sustainable development on different social strata, capacity development activities targeting different and essential stakeholder groups were realized.



Figure 3-2: Research and demonstration site for DWWM systems at Fuheis

4 Managed Aquifer Recharge

WP3-2 Spokesman: Andreas Tiehm, TZW; Amer Marei; QUDS, text summarized by Nico Goldscheider, KIT

Introduction

Managed Aquifer Recharge (MAR) is a key technology to mitigate water shortage in areas characterized by high freshwater demand, limited water availability, and high temporal variability. The basic idea is to store excess water, such as stormwater or treated wastewater, in aquifers and use it in periods of limited water availability. Additionally, by using the natural filter capacity of soils and aquifers, MAR is intended to improve the quality and safety of the freshwater. A wide range of MAR technologies is available on different scales and for different purposes – ranging from small-scale wastewater infiltration to the large-scale infiltration of surface water into regional aquifers.

Several technologies were tested and further developed in the SMART II project region. Activities in WP3-2 included implementation-oriented research on selected test sites, an evaluation of relevant biogeochemical processes during the soil passage as well as socio-economic considerations concerning the feasibility of MAR implementation.

The following six test sites were studied during SMART:

- Wadi Wala, Jordan
- Deir Alla, Jordan
- Wadi Kafrein, Jordan
- Wadi Ishe, Jordan
- Al Uja (or Auja), West Bank
- Bani Zaid, West Bank

Only results from Deir Alla and Wadi Wala are presented in this summary, because these two contrasting examples demonstrate the potential and challenges of MAR in different hydrogeological settings. The summary also highlights the most relevant results in terms of water quality and contamination problems, biogeochemical processes, and socio-economic aspects.

Wadi Wala, Jordan

Wadi Wala is an example of a successfully operating large-scale MAR facility in a karst hydrogeological setting (Figure 4-1). The Wala catchment is about 1600 km² large. During storm rainfall events, flashfloods occur in the valley. The stormwater is first captured in the Wala reservoir from where it infiltrates into the underlying regional karst aquifer, partly by natural infiltration processes, partly via injection wells. Approximately 7 km downstream of the dam, groundwater from the aquifer is recovered via several pumping wells in the Hidan well field.

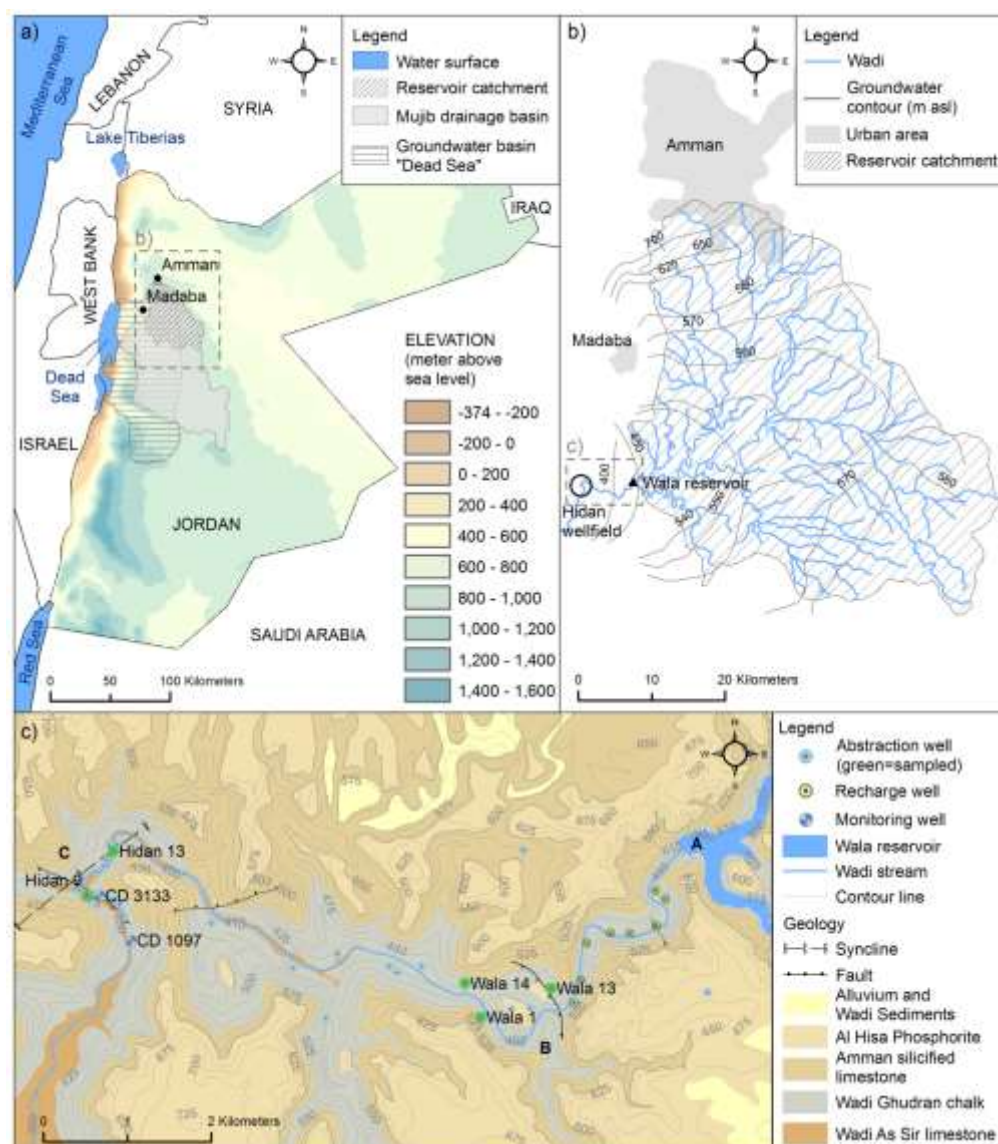


Figure 4-1: Geographical setting of Wadi Wala. (b) Wala catchment with groundwater flow direction and location of the reservoir and well field. (c) Geology of the Wala area with locations of recharge, abstraction, and observation wells (KIT, Julian Xanke et al., submitted paper)

Since 2002, about 11.7 million cubic meters per year (MCM/a) have been abstracted from these wells. Based on water balances, hydrochemical and isotopic data, it is possible to estimate that 63 % (7.4 MCM/a) originate from MAR. Therefore, this MAR facility has amortized itself from an economic point of view. However, sedimentation problems in the reservoir and water quality problems in the groundwater pumped by the wells are major challenges concerning this MAR infrastructure. Research in SMART II has contributed to establishing water balances and improving the management of the Wadi Wala MAR system by hydrological monitoring, tracer tests, and numerical modeling (FEFLOW).

Deir Alla, Jordan

Deir Alla is a potential MAR site in an alluvial aquifer in the Lower Jordan Valley that could essentially contribute to improving the drinking water supply situation in Amman. The idea is to deviate water from the King Abdullah Channel in water excess periods and infiltrate it into the adjacent and underlying alluvial aquifer. In periods of increased water demand and water storage, water from this aquifer could be pumped to Amman. Activities in SMART included geological field work and geophysical measurements, the goal being to develop a conceptual hydrogeological model and propose a general hydraulic and technical design of a possible large-scale MAR facility at Deir Alla (Figure 4-2).

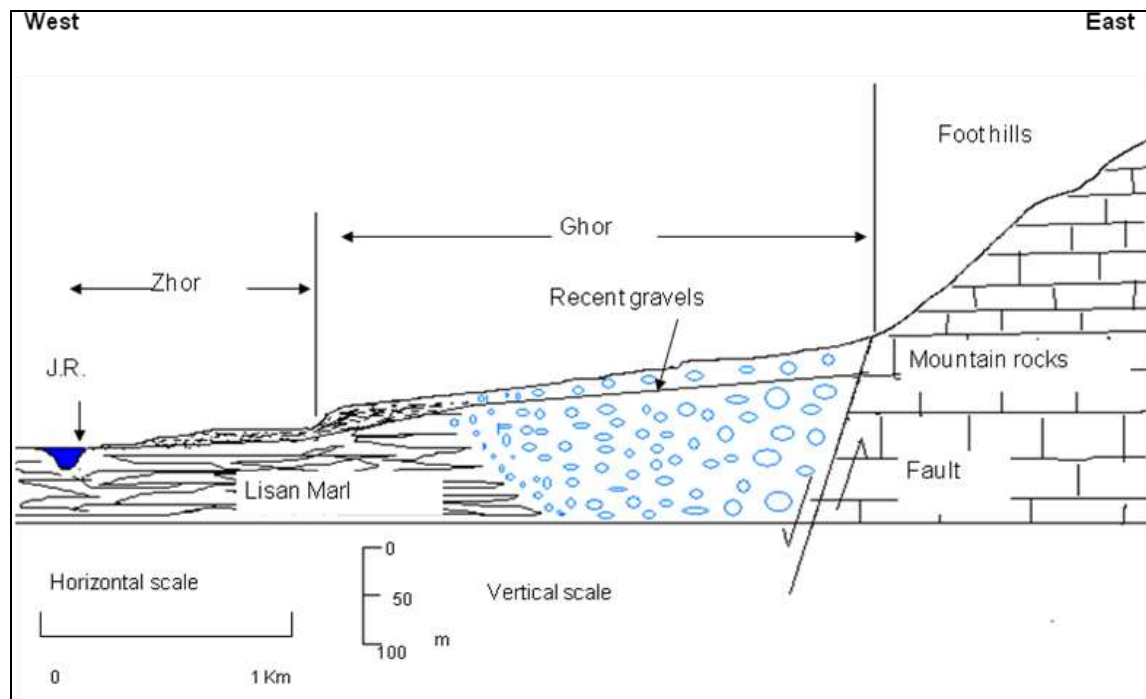


Figure 4-2: Conceptual hydrogeological model of the alluvial aquifer at Deir Alla (gravel, highlighted in blue) that could be used for managed aquifer recharge based on water from the King Abdullah Channel (sketch: Elias Salameh, JUA)

Water Quality: Elimination of Emerging Pollutants

In the European Union (EU), about 3,000 different substances are used in human medicine, but the fate and transport of these substances in the environment are still poorly understood. In the context of MAR, it is crucial to evaluate the transport and degradation of such substances mainly in connection with the use of treated wastewater for MAR, but also when storm water flow is used as a source of recharge. Within the framework of SMART, numerous column and batch experiments were performed at the TZW laboratory in Karlsruhe in order to better understand the relevant biogeochemical processes during MAR. These experiments revealed a high potential for the elimination of emerging pollutants due to natural degradation processes within the unsaturated zone and during storage in the underground. The combination of the redox condition, adaptation time, and concentration of the respective substances was identified to be crucial to the effective removal of trace substances. Some compounds showed a high recalcitrance towards natural degradation and are expected to prevail and accumulate in the water cycle. However, since the X-ray contrast agents are thought to have no therapeutic activity, the presence of diatrizoic acid might be of advantage if used as a possible anthropogenic tracer for hydrogeological investigations. From the results of the batch and column experiments, a classification scheme was deduced, which can support the planning, implementation, and monitoring of MAR systems in terms of water quality aspects (Schmidt 2014, Schmidt et al., submitted).

Economic Aspects of MAR

A cost-effectiveness analysis of alternative technologies for the mobilization of additional water was also made under SMART. Among other technologies, Managed Aquifer Recharge was evaluated for the use of treated wastewater as a resource. The analysis showed that the combination of decentralized treatment units for wastewater with subsequent surface infiltration and storage in the underground is the most beneficial option from an economic perspective. Due to the high remediation potential of the soil passage for trace pollutants and the advantage of storage in the underground (minimizing evaporation losses and additional enhancement of water quality), decentralized treatment options with aquifer recharge systems operating via surface infiltration are recommended for the study region.

5 Brackish Water Usage

WP3-3 Spokesman: Fritz Frimmel, EBI; Akiva Flexer, TAU

Introduction

Access to freshwater is becoming a critical issue in many areas of the world. To contribute to solving the freshwater problem, to reducing over-exploitation of water sources (such as groundwater), and to decreasing the impacts of climate change and extreme weather, alternative water sources, such as wastewater and brackish water, have to be considered.

The Low Jordan Rift Valley has relatively high quantities of non-exploited brackish water sources which can be treated to generate freshwater. They can be found in the shallow and deep aquifers, mostly coexisting with freshwater.

A detailed study was carried out to integrate the amount, locations, and quality of brackish water resources in the study area based on previous studies as well as on an exploration of sites for brackish water utilization.

Efforts were made to locate sites for utilization of brackish water from the various sources and to forecast and recommend the volume and salinity of water that can be extracted on each site.

The following potential resources of brackish water were found within the framework of the current study (see Figure 5-1):

- The regional Judea Group aquifer in the area of the Feshcha springs as well as the Uja and Fazeel areas;
- The alluvial shallow basin-fill sediments in the Jordan Valley (Jericho and Uja regions);
- Direct pumping from the Jordan River.

The table in Figure 5-1 summarizes the preliminary recommendations for each of the sources.

The study did not cover the question of how many desalination plants and/or facilities are needed for the utilization of brackish water as well as potential solutions for brine disposal.

Membrane filtration is a promising option for brackish water treatment and freshwater supply. Reverse osmosis systems were improved considerably during the last decade, resulting in the development of high-performance membranes which require less pressure and, thus, less energy, have better rejection properties and larger fluxes, possess a longer lifetime, and are associated with lower costs. Additionally, the application of energy recovery systems (e.g. Francis turbines or Pelton wheels) and the use of renewable energy sources (e.g. wind and photovoltaics) contribute to the propagation of membrane technologies in countries with non-fossil energy sources.

Studies in Palestine

The studies in Palestine focused on two main areas (Jericho and Uja) in the western part of the Jordan valley. From these two areas, more than 50 water samples were characterized. According to the water data, application of nanofiltration (NF) membranes to treat the brackish water sources was investigated. The use of NF filtration for desalination of low-salinity brackish water sources offers two main advantages: High permeability and, thus, lower operating costs in comparison with RO. Commercially available NF-membranes have very different retention properties and permeability values. The NF90 membrane reaches the highest rejection and a relatively high permeability and seems to be appropriate for desalination processes of low-salinity waters (salt concentration < 3 g/L, depending on the concentration of the individual ions). The next step for the evaluation of nanofiltration performance in general should be the upscaling of the pilot plants from the lab-scale setup used in this project to spiral modules (pilot scale) as applied in industry-scale systems. This will allow conclusions to be drawn with respect to large-scale applications.



Site	Well/station	Yearly pumping [MCM]	Expected salinity [mg/L]
Feshcha Sp.	2	30	1,500-2,000
Jericho	5	4	1,600-2,000
Uja	2	1.6	1,600-2,000
Fazael	3	3	2,000-2,500
Jordan River	3-5	5	1,000-6,000

Figure 5-1: Proposed sites for utilization of the brackish water in the LJR and table with potential water sources in the Low Jordan Rift Valley

Karameh Desalination Plant

Within the framework of SMART II, an innovative water treatment plant using elaborate cutting-edge techniques to treat the groundwater from the test site (Karameh) in Jordan was built by STULZ-PLANQUA (SPA) in cooperation with the Engler-Bunte Institute (EBI) (Figure 5-2).

The plant can generate about 10 m³/h of treated water – enough to irrigate a large area or to supply a small village. The input of well water is 16 m³/h. In March 2014, the last and successful attempt was made to take the water treatment plant into operation. After some obstacles in the first days, the plant went into operation (see Figure 5-2). The yield was approximately 50%. The quality of the well water still varied strongly, especially after pump stops. This issue needs to be solved for a stable operation of the plant. The staff of the Water Authority Jordan (WAJ) was extensively trained and shown how to run the plant and how to do trouble-shooting.

One of the most important environmental issues of desalination is the generation of the saline “by-product” brine. The concentrate does not only have a high concentration of salts, but also contains residual chemicals (such as antiscalants and cleaning chemicals). The treatment or disposal of brine is one of the challenges associated with the application of membranes in in-land

desalination and must be covered by further research activities. The scarcity of freshwater, the availability of large volumes of unused brackish water resources, the availability of renewable energy sources, and the geographical location makes the LJR a highly suited region for efficient membrane-based desalination technologies. However, the application of membrane technologies should not be considered a separate solution, but part of an IWRM (integrated water resources management) approach, which includes freshwater use and availability, wastewater treatment and reuse, education, socio-economic evaluation, quantification of the regional water balance, etc.



Figure 5-2: a) Desalination plant in Karameh (Photo: Klinger, 2014). b) Pilot plant producing water in Karameh (Photo: Amri Chouba, 2013)

6 Water Resources Assessment

WP4 Spokesman: Martin Sauter, GU; Yossi Guttman, MEKOROT

Introduction

The assessment of surface water and groundwater resources is the most important component in the long-term planning of an integrated water management scheme, since it provides information on the sustainable average available input on the supply side, its hydrochemical properties as well as its temporal variability. Generally, two main methodologies are employed to quantitatively determine available water resources. These are:

- a) *Direct measurement* of discharge (surface / groundwater / wastewater) components and water budgeting.
- b) *Forward modeling* with hydrological models.

While the *direct measurement* provides the most detailed information and data on the water budget of a local catchment and, hence, represents the optimal basis for local planning, the results mostly cannot be generalized to a larger region because of the generally large variability of natural catchment characteristics and local catchment precipitation and evapotranspiration patterns. Furthermore, long-term measurements of the water budget components of precipitation, evapotranspiration, as well as surface and groundwater discharge are required. Especially in (*semi-*) *arid areas*, such as the Lower Jordan Valley, the required detailed spatially distributed long-term records are not readily available. A main reason is the characteristic episodic nature of

precipitation and discharge, massive floods, technical challenges, and the uncertain political situation.

Forward modeling with process models is a powerful tool for the determination of surface water and groundwater discharge, since, once calibrated and validated, they allow for the prediction of the temporal and spatial variability of the discharge components. However, they require a large amount of detailed spatially distributed data on the catchment, e.g. hydrological soil and vegetation characteristics, relief, etc. that are not readily available. Furthermore, the above-mentioned large climatological and hydrological variability, the episodic nature of precipitation events as well as the extreme heterogeneity and contrasts in catchment characteristics (hill slope, thin soils and bare rock, spotty vegetation) aggravate the application of forward models.

The general answer under such conditions is to expand the region of investigation to a larger spatial and temporal scale in order to be able to obtain quantitative information for water resources assessment purposes. While this type of approach compromises the level of detail of the information, it can still provide the basis for long-term regional assessment. However, a prerequisite for using the spatial-temporal large-scale approach is the availability of spatially and temporally integrating signals, i.e. continuous discharge via perennial rivers. In semi-arid regions this large-scale approach unfortunately is subject to limitations because of the above-described natural episodic climatological patterns and the extreme spatial variability of the catchment characteristics in the Lower Jordan Valley with discrete short-lived winter surface runoff via wadis and groundwater discharge at individual springs.

The hydrochemical quality of the aquifers in the Lower Jordan Valley is affected by the presence of evaporites and brines originating from the precursors of the Dead Sea. This affects the alluvial aquifers as well as the carbonate aquifers in parts of the Lower Jordan Valley floor. In contrast to this, the groundwater of the carbonate aquifer in the mountain region is fresh, but increasingly affected by anthropogenic pollution sources, such as infiltration of treated and untreated wastewater.

Approach

In SMART, an integrated strategy was pursued, which covers the complete spectrum of methodologies described above. Detailed catchment-based physical models were built for those catchments, where favorable conditions with respect to catchment characteristics and measurement logistics existed. Furthermore, massive effort was undertaken in the last 6 years to set up a detailed climatological and hydrological measurement network to cover seasonal as well as the event variability in order to be able to evaluate long-term fragmentary records with long measurement intervals with respect to their short-term information content. These detailed long-term records were the basis for the setup of hydrological and hydrogeological models of the Jericho-Auja catchments, the Wadi Kafrein and Wadi Al-Arab areas. The problem associated with the catchment-scale models in the Lower Jordan Valley is the uncertainty of the position and the size of the catchments, since the surface catchment cannot be expected to match the subsurface groundwater catchment because of the specific geological geometry and karstification processes. In addition to hydrological models, alternative methods for the assessment of recharge, such as the chloride mass balance method, were therefore employed to reduce ambiguity in recharge assessment.

The large-scale transboundary model reduces the problem of catchment size considerably. However, it cannot simulate the local spring discharge on a detailed event basis, because it does not include the specific karst characteristics. Nor does the transboundary model calculate surface runoff. Therefore, both transboundary models and local catchment models are necessary for the assessment of water resources for the semi-arid conditions and the physical catchment characteristics in the Lower Jordan Valley.

For most catchments, distributed hydrological forward models were applied: J2000g for sub-basins Al-Arab and Qilt, TRAIN-ZIN for sub-basins Auja and Kafrein. These models were mainly calibrated using time series of surface runoff. Recharge is calculated as a residual component in those models, next to the output of the extremely temporally and spatially variable runoff. The latter is a major challenge to simulate for the semi-arid and highly heterogeneous physical catchment characteristics of the Lower Jordan Valley. The water balance of sub-basin Shueib was assessed employing a conceptual water evaluation and planning model (WEAP21). The water balance of the Auja spring catchment was assessed by calculating long-term average recharge using a chloride mass balance, and a long-term time series of daily recharge could be derived by a combined lumped soil water balance and reservoir model.

Selected Results

The calculated water balance components display considerable differences among the sub-basins (Table 2). Whereas mean long-term precipitation is relatively uniform (approx. 400–550 mm a⁻¹), surface runoff and groundwater recharge exhibit larger differences. The lowest fraction of surface runoff was measured to be about 1% for the surface catchment of Wadi Auja for the hydrological years of 2011–2013 (Ries, 2013). However, this period did not cover a very wet year. As the main reason for the low volume of surface runoff, a high infiltration capacity of the karstified limestone and dolomite outcrops in the catchment was identified. For the other catchments, surface runoff fractions between 3–7% were obtained. These higher runoff values are likely due to catchments characteristics with a relatively high fraction of impermeable rocks at the surface (e.g. Upper Cretaceous chalk).

Groundwater recharge ranges between 13% and 33% for the analyzed catchments. Comparatively low recharge was found for catchment Al-Arab, the actual reason of which still needs to be investigated. For most other catchments, long-term recharge is in the range between 23% and 33%. However, the water budget calculations are obviously highly influenced by differences in hydrometeorological conditions during the different reference periods, with longer periods providing more reliable estimates compared to shorter ones.

Figure 6-1 displays the results of the 45-year hydrogeological model of individual hydrological years. Recharge is highly variable for individual years, mainly due to the overall annual precipitation depth and different annual rates of evapotranspiration. A considerable amount of the long-term recharge is provided by a small number of high-recharge years.

Table 2: Modeled water balance components for the different sub-basins.

	Auja spring	Auja surface	Qilt surface	Qilt subsurface	Arab	Shueib	Kafrein
Period (hydr. years)	1968–2012	2011–2013	1978–2000	1978–2000	1980–2008	1996–2009	2003–2009
Method ^a	CMB+M	DEM	DEM	DEM	DEM	WEAP	DEM
Reference	Schmidt et al. (2014)	Ries (2013)	Rödiger and Siebert (2012)	Rödiger and Siebert (2012)	Rödiger et al. (2014)	Riepl (2013)	Alkhoury (2011)
Area (km ²)	49	55	163	761	300	198	161
Precipitation (mm)	544	392	403	481	489	442	336
ETa (mm)	364	278	311	345	413	382	221
ETa (%)	67	71	77	72	84.5	86	66
Surface runoff (mm)	neglected	4	15	24	15	16	23
Surface runoff (%)	neglected	1	4	5	3	4	7
Recharge (mm)	180	109	77	112	61	70	93
Recharge (%)	33	28	19	23	12.5	16	28

Abbreviations: CMB+M: Chloride mass balance and lumped soil water balance and reservoir model; DEM: Digital Elevation Model; WEAP: Water Evaluation And Planning System

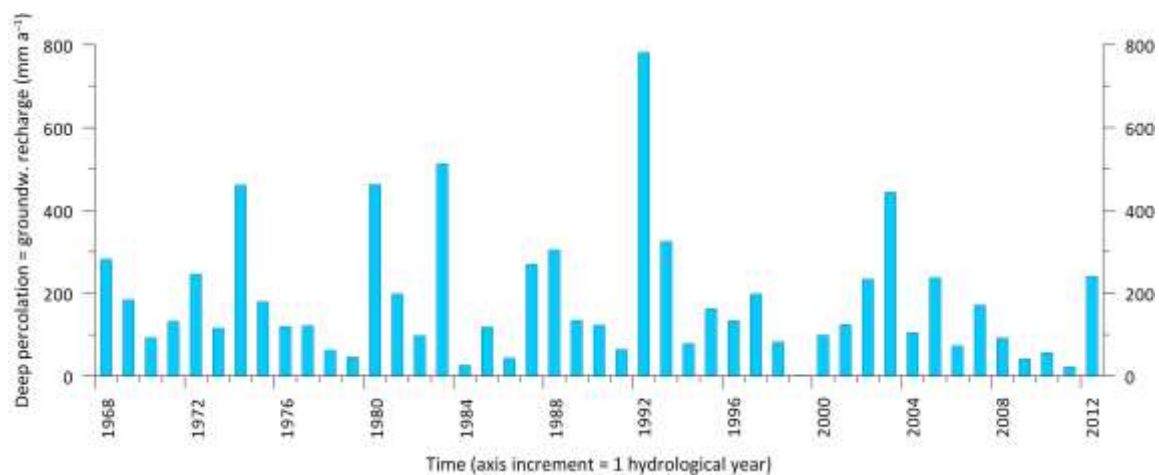


Figure 6-1: Time series of annual groundwater recharge in the catchment of Auja spring calculated by a reservoir model (Schmidt et al., 2014)

7 Water Resources Protection

WP5 Spokesman: Nico Goldscheider, KIT-HYD; Yossi Guttman, MEKOROT

Introduction

The protection of freshwater for human use and ecosystems requires a holistic approach, encompassing surface water and groundwater resources in terms of both quality and quantity. Agriculture is often the largest freshwater consumer, while drinking water requires the safest quality and should be assigned first priority. This applies particularly to arid and semi-arid regions with high population density and intense agriculture, such as the Lower Jordan Valley (LJV). In this and many other regions of the world, groundwater is the most important freshwater resource by volume and the preferred source of drinking water, with several advantages compared

to surface water. The provision of safe drinking water requires a multi-barrier approach, including the following elements:

- General reduction of polluting activities;
- Implementation and enforcement of appropriate protection zones;
- Continuous monitoring of water quality and contamination problems;
- Adapted drinking water treatment.

All of these elements were addressed within the framework of the SMART project. For instance, decentralized wastewater treatment (WP 3.1) contributes to the general reduction of contaminant releases into the environment. WP 5 addressed the following main aspects:

- A detailed evaluation of water quality and trace contaminants in the Lower Jordan Valley and side wadis, with a focus lying on wastewater impacts on groundwater resources.
- Evaluation of chemical and biological surface water quality, including the development of a bioindicator approach using aquatic invertebrates, specifically adapted to the LJV region.
- The development and initial implementation of continuous monitoring techniques at a karst spring in Jordan that is connected to the regional drinking water network.
- The advancement of groundwater protection zoning concepts, with initial implementation in the Palestine territories, including a socio-economic assessment.

Water Quality and Trace Contaminants in the Lower Jordan Valley

The region of the Lower Jordan Valley features high evapotranspiration rates and almost complete reuse of treated wastewater for irrigation farming. A detailed investigation program within SMART I and II focused on water transfer schemes and the presence, spreading, and potential accumulation of pharmaceutical residues in the local water resources based on findings of a five-year monitoring program. 16 pharmaceuticals and 9 X-ray contrast media in total were monitored in groundwater, surface water, and treated wastewater. 95 samples were taken to cover all geographical settings and flow paths from origin (wastewater) to target (groundwater). Results are summarized in Table 3.

Nine substances were detected in groundwater, with concentrations between 11 and 33,000 ng/L. In some cases, detection rates (i.e. % of positive detections) were higher than in comparable studies: Diatrizoic acid 75 %, iopamidol 42 %, iopromide 19 %, iomeprol 11 %, carbamazepine and iothalamate 8 %, ibuprofen 6 %, fenofibrate and iohexol 3 %. Concentrations in groundwater generally increase from north to south, depending on the application of treated wastewater for irrigation. Almost all substances occurred most frequently and with highest concentrations in treated wastewater, followed by surface water and groundwater. As an exception, diatrizoic acid was found more frequently in groundwater than in treated wastewater, at similar concentration levels. This indicates the persistence of diatrizoic acid with long residence times in local groundwater systems, but may also reflect changing prescription patterns, which is in accordance with increasing iopamidol findings by surveys at local hospitals. Trend analyses confirm this finding and indicate a high probability of increasing iopamidol concentrations, while other

substances did not reveal any trends. The high spatial and temporal variability of the concentrations measured calls for further systematic studies to assess the long-term evolution of organic trace substances in this reuse setting.

Table 3: Pharmaceuticals and X-ray contrast media in groundwater (GW), surface water (SW), and treated wastewater (TWW) in the Jordan Valley. The LODs for ground- and surface water are 10 ng/l for X-ray contrast media, 50 ng/l for the pharmaceuticals, and 50 ng/l each in TWW (Zemann et al. 2014).

Substances	Samples above LOD			Median concentration of samples above LOD			Maximum concentration		
	GW	SW	TWW	GW	SW	TWW	GW	SW	TWW
	[%]	[%]	[%]	[ng/l]	[ng/l]	[ng/l]	[ng/l]	[ng/l]	[ng/l]
Diatricoic acid	75	42	0	120	140		940	850	
Iopamidol	42	79	100	59	1,300	3,950	36,000	78,000	33,000
Iopromide	19	67	75	24	660	876	250	4,500	1,700
Iomeprol	11	58	0	39	2,700		790	6,900	
Carbamazepine	8	58	75	74	900	7,150	500	2,100	17,000
Iohexol	8	67	25	31	620	130	180	1,600	130
Ibuprofen	6	38	75	56	80	280	59	430	340
Fenofibrate	3	0	0	74		260	74		260
Iotalamic acid	3	8	25	10	21	42	10	23	42
Bezafibrate	0	13	25		89	91		120	91
Clofibric acid	0	8	0		32			33	
Diclofenac	0	8	50		78	350		140	430
Etofibrate	0	0	25						0
Gemfibrozil	0	50	25		270	100		2,100	100
Naproxen	0	13	0		70			82	
Ioxaglic acid	0	0	25			28			28
Ioxithalamic acid	0	17	0		19			51	
Total number of samples	36	24	4	36	24	4	36	24	4

Surface Water Quality and a New Bioindicator System for Jordan

Within the scope of SMART II, surface water quality and contamination problems in the LJV and side wadis were monitored using two biological methods, accompanied by chemical analyses:

- Biofilm monitoring for the assessment of water pollution by heavy metals;
- Macro-invertebrate survey to evaluate the overall ecological status.

The advantage of biological methods is their integrative character, as they reflect long-term water quality and the combined effects of many different contaminants.

Biofilms have the ability to adsorb and incorporate material, including heavy metals and other contaminants; they can be found at almost any surface exposed to water and they represent a microbial community with various inhabitants, such as sessile bacteria, protozoa, fungi, and algae. Biofilm monitoring in the SMART project region revealed highly variable water quality, rang-

ing from nearly unpolluted to highly contaminated. Biofilm results are generally in accordance with chemical analyses.

The method of using aquatic macro-invertebrates as bioindicators to characterize surface water quality is more than 100 years old and is regularly applied to many European rivers, lakes, and streams. However, the approach is not directly transferable to the LJV region with its different aquatic fauna. Therefore, an adapted bioindicator approach was developed and applied to evaluate several streams in the region, accompanied by measurements of physical and chemical parameters, including temperature, pH, conductivity, nitrate, phosphate, trace elements (e.g. copper, iron, zinc, boron), BOD, and COD. Samples of invertebrates were collected from 24 sites at 8 locations from December 2011 to April 2013. The freshly collected organisms were identified in the laboratory of the University of Jordan using a stereomicroscope. The study concluded that aquatic biota can be used effectively as bioindicators of water quality in the LJV region. Gastropods turned out to be very good bioindicator candidates of water quality in Jordan.

Novel Monitoring Approaches

Three karst springs in Wadi Shueib are used for drinking water supply of the city of As-Salt, but their catchment is highly urbanized, resulting in generally high, but also highly variable contamination levels. To better understand the dynamics of water quality and contamination, a detailed monitoring program was established, including continuous monitoring of spring discharge, electrical conductivity (EC), temperature (T), nitrate (NO_3), turbidity, DOC, and TOC, accompanied by water sampling and subsequent chemical and microbiological analyses.

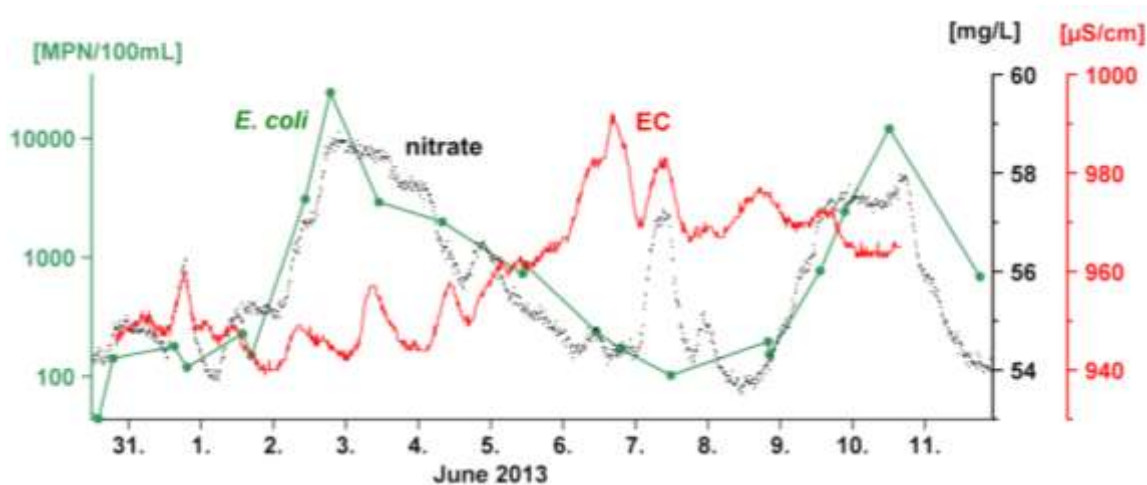


Figure 7-1: Example of monitoring results obtained at Hazzir spring in Wadi Shueib, showing good correlation between nitrate and *E. coli*, suggesting that these two contaminants originate from the same source, most probably wastewater

The levels of fecal bacteria, such as *E. coli*, are extremely high at these three karst springs, mainly at Hazzir spring, where *E. coli* levels often exceed 10,000 per 100 mL (see Figure 7-1), while the WHO standard for drinking water is 0 per 100 mL. Based on these findings from the SMART project, the Jordanian Water Authorities disconnected this spring from the water supply network.

Another important finding of this study was that water quality at Hazzir spring exhibits systematic weekly variations which can be attributed to leakages of pipelines of the water supply network in its urban catchment area. Freshwater losses reach 50 %, which is almost as high as the

amount of imported water. These findings illustrate the urgent necessity to rehabilitate both the freshwater supply network (to avoid losses) and the sewage network (to avoid groundwater contamination). The results also underline the usefulness of detailed water quality monitoring.

Groundwater Protection Zoning – from Concepts to Implementation

The SMART project has greatly advanced the awareness of the regional water authorities concerning the importance of groundwater protection zones. Based on SMART results, the first groundwater protection zones on Palestine territory were implemented and enforced. The legislations in Israel, Jordan, and the Palestine territories (and in many other countries, including Germany) define three types of protection zones around drinking water abstraction points, such as wells or springs:

- In Zone A (or I), all land use not directly related to the well or spring is prohibited.
- In Zone B (or II), all potentially contaminating activities are forbidden.
- In Zone C (or III), all activities or infrastructure that can cause significant contamination is forbidden, such as major effluent pipelines or irrigation with treated effluents.

Besides this universal concept, the detailed procedure to delineate the three types of zones is different in the three countries. Mainly in Jordan and Palestine, the enforcement of effective protection zones is often not feasible for different reasons, such as urbanized spring catchments.

The Wadi al-Qilt springs (west of Jericho) were studied as an example in SMART II. Results showed that the most vulnerable zones are located along the wadi stream, where poorly treated effluents infiltrate underground at many places. Therefore, treating the urban wastewater before releasing the effluents into the wadis is a priority measure to improve and protect the spring water quality.

In the Palestine territories, great progress has been achieved in the field of groundwater protection zoning initiated by SMART and in cooperation with the SWMED project. Due to the overlap of institutional mandates, a committee of representatives of all ministerial bodies was established on the technical level in cooperation with Al-Quds University and an NGO (PHG). The committee has already organized stakeholder workshops, field trips to relevant drinking water springs and their catchments, and round-table discussions concerning the legal requirements of protection zones. A pilot study dealing with the Delineation of Wellhead Protection Zones for Groundwater Wells in the Tulkarem Area was carried out using MODPATH backward tracking and GIS tools. Based on this study, the Palestinian authorities (Palestinian Water Authority, Ministry of Health, Ministry of Agriculture, Ministry of Industry, Ministry of Environment, and the municipalities) see the need to fulfill their responsibilities and take immediate actions to prevent and control groundwater contamination.

SMART activities also included a socioeconomic study concerning the costs and benefits of water protection zoning. For the catchment of the Ein Sultan spring (near Jericho, Palestine), it was possible to demonstrate that protection zoning also is economically beneficial, i.e., the costs related to the enforcement of land-use restrictions (estimated 500,000 USD/year) are substantially lower than the benefits resulting from improved freshwater supply (estimated 1,090,000 USD/year), thus resulting in an estimated added value of 590,000 USD/year. Although these figures are subject to substantial uncertainties and cannot be directly transferred to other

springs and wells in the region, the results suggest that groundwater protection zoning is economically beneficial.

As a general conclusion, the reduction of polluting activities, the implementation of protection zones, continuous monitoring of water quality, together with adapted water treatment technologies, can contribute to improving the provision of safe drinking water and, thus, enhancing the quality of life.

8 IWRM Tools

WP6 Spokesman: Jacob Bensabat, EWRE

Introduction

WP06 focused on the development, deployment, and application of state-of-the-art tools for IWRM, including 1) a web-based set of visual tools for water resources management – the SMARTDSS platform developed by EWRE, 2) a web-based visual platform for knowledge management – the DROPEDIA application (developed by KIT), 3) a platform for risk assessment (developed by EWRE), and 4) a comparative analysis of the performance and applicability of software applications for the simulation of variably saturated flows and reactive transport (prepared by EWRE).

The SMART DSS Application

This web-based application consists in a number of decision-making and reporting tools aimed at facilitating the derivation of water plans. SMARTDSS can be deployed from the internet (www.ewre.com/smartdss/publish.htm). It comprises the following tools:

- 1) A graphical user interface;
- 2) An application for storing data and information relevant to the inventory of water resources of various qualities on any spatial aggregation scale (HYDROBUDGETS, see Figure 8-1);
- 3) Decision-making tools, such as the implementation of the AHP and ELECTRE-III approaches;

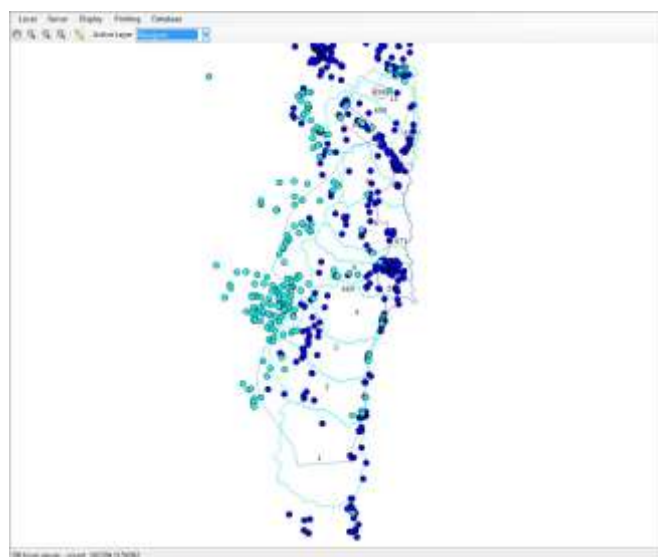


Figure 8-1: General view of a HYDROBUDGET graphical user interface

4) Multi-criteria optimization based on the derivation of the Pareto set of non-dominated solutions using a number of algorithms (weighted sums, normal boundary intersection, normalized normal constraint, and enhanced normalized normal constraint); and

5) Scenario Generator, implementing an approach to the derivation of optimal water plans using a combination of multi-criteria optimization and decision-making procedures (AHP and or ELECTRE-III). SMARTDSS was applied extensively to and demonstrated for the Wadi Nueima, Kalya, and Wadi Auja basins.

The DROPEDIA Application

DROPEDIA (<http://www.dropedia.iwrm-smart2.org/>) is a web-based knowledge management system based on the WIKI paradigm (see Figure 8-2). It enables integrating collected data and information on various levels of refinement (informative data, modeling data through WEAP, etc.). It can be used for documenting a specific project or test case and for the analysis of new project areas based on the experience and knowledge acquired from areas previously investigated. DROPEDIA relies on the knowledge management system for collaborative documentation and sharing of planning- and decision-making-relevant knowledge for integrated water resources management. It is coupled to the WEAP software and was demonstrated at Wadi Shueib basin in Jordan. DROPEDIA is linked to the DAISY database platform developed by UFZ and can mine the data and information required for subsequent analysis.

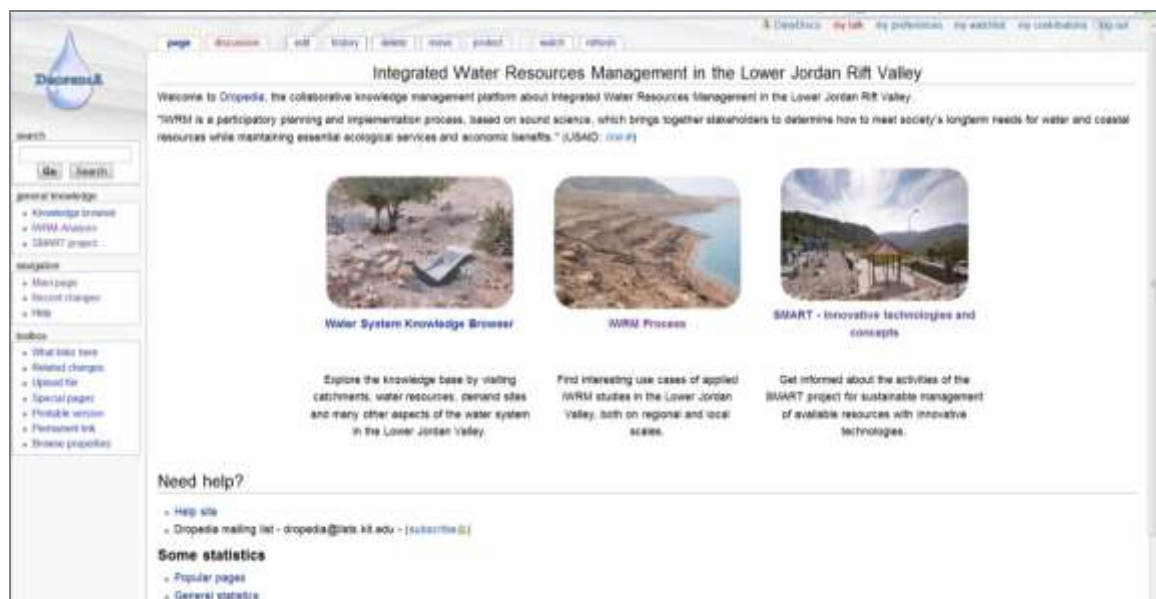


Figure 8-2: Dropedia welcome screen (by D. Riepl and B. Kämpgen, KIT)

Platform for Risk Assessment

Risk assessment is a crucial activity in the definition of measures for water resources protection and for the delineation of the protective zones for water bodies, wells, springs, and rivers. We suggested to adopt the widely used RBCA (Risk Based Corrective Action) paradigm developed by the American Society for Testing and Materials (ASTM) and implemented a rather large number of areas and environmental problems (soil pollution, groundwater pollution, etc.). It relies on the Sources-Pathways-Receptors (RPS) approach, which basically claims that a risk is identified when

a pollution source can connect a sensitive receptor (a freshwater body, a well, a spring, population, etc.) with a sufficient damage potential. The identified risk is then quantified and protection measures can be suggested accordingly. Tools for risk analysis and the determination of mitigation levels (RBCA toolkit, IRBCA, etc.) were reviewed in the context of the project area and demonstrated for a test case of characteristic importance.

Software Codes for the Simulation of Variably Saturated Flows and Reactive Transport

Artificial recharge is one of the key IWRM measures that are particularly suitable for the project area. It allows for the storage of water surpluses generated during rainy seasons for further use during high-demand periods either on a seasonal and / or multi-year basis. While the practice of artificial recharge is not new and practiced extensively, modern design and planning of artificial recharge require a close look at treatment processes occurring during the infiltration in the unsaturated zone, including the highly non-linear flow processes and chemical reactions that take place both in the unsaturated zone and in the aquifer. Three software codes were reviewed, Hydrus, TOUGHREACT, and PFLOTRAN. Hydrus is a commercial software with a highly sophisticated user interface, but limited capabilities with regard to the modeling of reactive transport. TOUGHREACT is the most comprehensive software, but has a primitive user interface, requires substantial computer resources, and is extremely slow. PFLOTRAN has smaller capabilities than TOUGHREACT, but still provides flow and reactive transport with a relatively simple user interface and is natively parallel, running fast on multi-processor machines. Codes were compared for a characteristic case of flow and reactive transport.

9 Socio-economics

WP7 Spokesman: Ingo Heinz, KIT; Abed Tamimi, PWA; Nele Lienhoop, UFZ

Introduction

The work package 7 “Socio-economics” addresses a broad range and great variety of IWRM domains, such as water demands, water scarcity, costs and benefits of water projects, water pricing, institutions, poverty, and governance. It consists of 11 studies. As the reports are comprehensive, a synopsis was made, with the following list and subsequent abstracts providing an overview of the results and conclusions of each study (cf. also Heinz I. 2013):

- Cost-benefit analysis of decentralized wastewater treatment (DWWT) and reuse in Jordan: An application in Maghareeb and Ma’addi (N. Lienhoop).
- Environmental and socio-economic benefits of decentralized wastewater treatment in Palestine (A. Tamimi).
- Assessing the impacts of different water qualities and quantities on the farmers’ income and their economic situation in Palestine (A. Tamimi).
- Assessing the impacts of different water qualities and quantities on the farmers’ income and their economic situation in the Jordan Valley (A. Salman).
- Cost effectiveness of decentralized wastewater treatment (DWWT), water reuse, managed aquifer recharge (MAR), and brackish water treatment (BRT) (N. Korf).
- Cost-benefit analysis (CBA) of alternative IWRM strategies and their financial feasibility on the basin level in Palestine and the Lower Jordan Valley (I. Heinz).

- Costs of different IWRM technologies in the West Bank (A. Tamimi).
- Social acceptability of different IWRM technologies in the West Bank (A. Tamimi).
- Institutional feasibility of alternative IWRM technologies in the West Bank (A. Tamimi).
- Assessment of multiple water qualities in Israeli municipalities (T. Milgrom).
- Framework for decentralized wastewater treatment and water reuse in Jordan (M. Lee).

Results

Cost-benefit Analysis of Decentralized Wastewater Treatment (DWWT) and Reuse in Jordan: An Application in Maghareeb and Ma'addi

The following options were subject of the cost-benefit analysis (CBA): 1. Wastewater treatment and reuse through Sequencing Batch Reactors (SBR) and 2. Wastewater treatment and reuse through Constructed Wetlands (CW). By using the present value analysis, the time streams of future costs and benefits can be diverted ('discounted') to two single values. The difference between both is the net present value (NPV): If greater than 0, the investment would be worthwhile. If there are several optional projects, the one with the highest net present value should be chosen. Since not all costs and benefits can be quantified directly in economic terms, surrogates are used. A commonly applied approach is to estimate the amounts of money the people are ready to pay – the Contingent Valuation (CV) method. Typical examples are odor, groundwater contamination, insects, and health risks. In Ma'addi the net present value (NPV) of the different options is larger than zero, resulting in considerable economic values added. In Maghareeb, however, the negative NPV can be explained by the low productivity in agriculture and the high treatment costs due to the high requirements on the reclaimed water.

Environmental and Socio-economic Benefits of Decentralized Wastewater Treatment in Palestine

Due to the lack of water in many regions of Palestine, untreated gray wastewater is used to irrigate farms and gardens without taking into consideration health risks. Especially gray wastewater treatment and reuse is acceptable and cost-efficient for agricultural use. The reclaimed water can be used for irrigation, where economic benefits arise in terms of increases in agricultural revenues. Further economic benefits are cost savings in wastewater drainage and use of fertilizers. Moreover, the households save costs, because they can reduce the consumption of freshwater, which was used for irrigation purposes before. The sum of the economic benefits is compared with the installation costs of different treatment techniques. Finally, the potential environmental benefits resulting from the reduced water pollution are evaluated in economic terms by assuming that the (unit) cost of wastewater treatment reflects the minimum willingness to pay for protecting the environment. Decentralized wastewater treatment (DWWT) is an important component in the national wastewater strategy, but institutional legal arrangements are still missing.

Assessing the Impacts of Different Water Qualities and Quantities on the Farmers' Income and Their Economic Situation in Palestine

The study focuses on the following water management options: 1. Wastewater reuse: The El-Bireh treatment plant exists already and another plant in Jericho is planned. A water volume between 1 and 3 million cubic meters per year is estimated to be available for irrigated agriculture and artificial recharge. 2. Desalination of brackish water: The potential availability is approx-

imately between 4 and 6 million cubic meter per year. It can be obtained by drilling a cluster of shallow wells, which are proposed to be located along the wadi Al-Qilt. 3. Stormwater harvesting: A potential water volume of about 4 million cubic meters per year is estimated. The water is to be collected by a pond, and small wadis can be used for harvesting. When comparing the costs and revenues of different water management options, water harvesting is most economical for vegetables, banana, palms, and greenhouses. As regards palms, other options, such as drilling and rehabilitation of groundwater wells, desalination of brackish water, artificial recharge, and wastewater reuse, are cost-effective as well. Wastewater reuse is important to the expansion of cultivated land. Brackish water should be blended with harvested rainwater. The use of treated wastewater and brackish water for palm cultivation is highly recommended. Multi-quality water mixing will increase the resources and will allow expanding cultivated areas.

Assessing the Impacts of Different Water Qualities and Quantities on the Farmers' Income and Their Economic Situation in the Jordan Valley

Water reuse is one of the major options to tackle exhaustion of natural resources and overuse of aquifers particularly in the Jordan Valley. Crops produced by using blended treated wastewater (BTWW) have higher yields (kg/du), lower water consumption, and higher water productivity (kg/m³) compared to those produced with freshwater. The average profitability of one cubic meter for vegetable crops irrigated by BTWW was 1.439 JD/m³, while it was 1.280 JD/m³ for those vegetables irrigated with freshwater. The average yield for cereals irrigated by using BTWW was 1.41 ton/dunum in the Middle Jordan Valley (MJV), while it was 1.29 ton/dunum for those irrigated by using freshwater in the Northern Jordan Valley (NJV). It has to be noted that citrus is considered the only exceptional case, which has a higher net profit in the NJV (208 JD/dunum). Finally, the costs of irrigation water relative to the total production cost range between 7% for freshwater and 9% for BTWW. The water costs are determined by the price and the amount of water consumed. In the Jordan Valley, however, there is no price discrimination between freshwater and BTWW. In Jordan, increasing water scarcity will cause more freshwater to be diverted from agriculture to domestic uses, thus generating more treated wastewater.

Cost Effectiveness of Decentralized Wastewater Treatment (DWWT), Water Reuse, Managed Aquifer Recharge (MAR), and Brackish Water Treatment (BRT)

By applying the cost effectiveness analysis (CEA), three different technologies were ranked. However, the analysis did not focus on certain communities in the Lower Jordan River Basin. Instead, it offered a decision tool for any location in the study region. Depending on the specific local conditions, the most cost-effective technologies were selected. Not all technology options were feasible and cost-efficient. Two DWWT systems were considered: Sequencing batch reactor (SBR) and vertical flow-constructed wetlands (VFCW). As shown by the results, the decentralized technologies VFCW, SBR, and BRA do not differ significantly in terms of their cost effectiveness. The specific treatment costs to produce one cubic meter of water quality "A" range from 0.53 JD/m³ (SBR) and 0.59 JD/m³ (BRA) to 0.62 JD/m³ (VFCW). The two MAR options, however, differ considerably from the other technologies. The least cost-effective option is MAR by treatment & infiltration with 1.19 JD/m³ and the most cost-effective option is MAR by infiltration with 0.03 JD/m³ only. BRT is only useful, if brackish water is available in sufficient quantities. However, it is important to keep in mind that the infiltration of treated wastewater is illegal in Jordan.

Cost-benefit Analysis (CBA) of Alternative IWRM Strategies and Their Financial Feasibility on the Basin Level in Palestine and the Lower Jordan Valley

The study focused on two areas: The Jericho basin in Palestine and the Eastern Lower Jordan River Valley. The basin of Jericho was divided into three sub-areas characterized by different utilization rates of water resources, infrastructures, and water demands. For each of these areas having specific problems, water management options were identified, which were supposed to be appropriate for improving the water situation. As obvious from the results of the study, the economic benefits of water management options exceed the costs in most cases. For example, in the Jericho east sub-area a maximum of additional water supply can be reached by desalination of brackish water, rainwater harvesting from Al Qilt, and water reuse. As not all the management options considered were to be implemented at the same time to meet the water demand, they were prioritized according to their cost efficiency in terms of values added. Time-referenced CBAs can advise water managers who have to decide in which year different projects should be constructed and which capacity they should have. Such an IWRM approach helps to maximize the economic added values and to ensure financial feasibility of water projects.

Costs of Different IWRM Technologies in the West Bank

The report first provides a broad overview of the current socioeconomic and hydrological conditions in the West Bank. The situation is characterized by high unemployment rates (average 19%), low family incomes, water shortage, and poor water management. The availability of water per capita in the West Bank ranges from 29 to 150 liters per day, but is mostly below 100 liters. Seasonal water cut-offs occur rather frequently, mainly during dry summers. 30% of the municipalities currently are not served by any water network. There, purchasing water from trucks and hauling water from standpipes are typical. In the West Bank, the gap between supply and demand will increase dramatically in the coming years. Recommendations address better governance of water management, improvements in spring water conveyance, stormwater harvesting and artificial recharge, promotion of wastewater treatment and reuse. Pricing policy and tariff structure are the keys to improving the efficiency of water management.

Social Acceptability of Different IWRM Technologies in the West Bank

The report deals with the main drivers of social acceptance, such as water and poverty, water pricing and tariff structure, willingness to pay and affordability. The Jericho case study focuses on the socio-economic implications of IWRM strategies in a specific basin. In agriculture, water harvesting is often preferred, because it is a cheap option. Many of the farmers prefer drilling of own wells to keep the water costs low and to be independent of other sources. The readiness to use treated wastewater (TW) is low; a huge public awareness campaign to promote the concept water reuse is needed. Since the tariff systems for the domestic, commercial, and agricultural users appear to be somewhat unbalanced, the report contains some recommendations of how to improve them. With respect to the water tariffs for municipal users, the block rate settings should be revised in order to align them to the actual water consumptions, to encourage water saving, and to ensure social equity and cost recovery.

Institutional Feasibility of Alternative IWRM Technologies in the West Bank

The IWRM approach needs adequate institutional structures to achieve an effective and equitable governance of water problems. In particular, it shows what happened before and after the Oslo Agreement II of 1995. The current state institutions and non-governmental organizations in

the West Bank are described. Then, the goals and challenges in the Palestinian water policy are described and the progresses and the constraints in improving the governance are pointed out. For instance, a new form of Irrigation Water Association at Jericho is suggested. Suggestions are made of how to establish new institutional frameworks and how to apply more effective water management instruments in the West Bank. Some legal and institutional reforms are strongly recommended.

Assessment of Multiple Water Qualities in Israeli Municipalities

The water situation in Israel is described with special regard to socio-economic characteristics (e.g. water pricing). In the selected case study area in the Lower Jordan River Valley (LJRV), there are substantial sources of residual waters, such as brackish water of various degrees of salinity and treated effluents. A proper mixing of these waters can be channeled for the irrigation of different crops, thus releasing freshwater for other uses (domestic, tourism, and industry). Various IWRM alternatives are ranked to facilitate complex decisions in situations with several conflicting objectives, such as aquifer sustainability, maximizing the economic profit, and reliability of water supply. The study applies the Multi-Criteria Analysis (MCA), particularly the AHP approach, which was developed by the mathematician Thomas Saaty in the 1980s. Especially from the socio-economic point of view, the trade-offs between the IWRM alternatives are important to know, so that the stakeholders can change their preferences and revise their previous ranking of alternatives in an iterative way.

Framework for Decentralized Wastewater Treatment and Water Reuse in Jordan

At present, households in Jordan are not closely involved in water management planning processes. However, a close cooperation with the people concerned throughout the entire planning process is important in order to attain acceptance. Participatory planning is one of the keys to successfully implementing IWRM. The Household-Centered Environmental Sanitation (HCES) approach was chosen as the blueprint for the participatory planning concept. It aims at providing stakeholders on every level, but particularly on the household and neighborhood level, with the opportunity to participate in the planning, implementation, and operation of the local water resources management. It is recommended to discuss and to further develop this participatory planning approach in the context of the framework setting process of the National Implementation Committee for Decentralized Wastewater Management in Jordan (NICE).

10 IWRM Scenarios

WP8 Spokesman: Heinz-Peter Wolff, QUASIR; Jochen Klinger, KIT; Ali Subah, MWI; Abed Tamimi, PWA; Yossi Guttman, Mekorot

Introduction

WP8 focused on the provision of planning criteria on the sub-basin level and the integration of results from other work packages into combined IWRM approaches. Nation- and region-wide scenarios resulting from several international research projects were used as starting points for prognoses concerning the water sector development in the research areas of SMART.

Downscaling of these aggregated scenarios by regression analysis revealed the necessity of additional local information due to the distinct heterogeneity of the selected research regions. The

finally established quantitative and qualitative local scenarios combined the framework of national assumptions on the water sector with the specific constraints at the selected locations. Results show that the situations and key aspects of the water sector of the West Bank and Jordan differ significantly between the basins. The scenarios indicate that such differences will become even more distinct in the future. Scenario assumptions and quantitative results were input into SMART's public IWRM-wiki DROPEdia.

Scenarios on Wadi Shueib, which include potential innovations tested by SMART, were provided as a sub-module to the responsible department of the Jordanian Ministry for Water and Irrigation (MWI). The translation of the findings into the WEAP format contributed to the WEAP models for water resources development and water use in the Jordan Valley already developed and maintained by the responsible water authority.

IWRM Strategies

An aggregated report on IWRM strategies on the local sub-basin level, sensitivity analysis, and performance assessment focused on two different SMART engineering and scientific approaches to identifying priority interventions (measures) in terms of new hydro-infrastructure and water technologies on the local case study level to cover increasing water demands on both sides of the Jordan river. Alternative IWRM strategies, as combined measures, are compared to each other based on performance indicators.

For the Palestinian study area, a generalized conceptual approach has been developed and applied in an exemplary manner to Wadi Auja. The participative approach is based on hydrogeological investigations, water budget studies, water resources systems analysis, strategy development by multi-objective optimization, sensitivity analysis, and strategy comparison based on the multi-criteria analysis taking social, economic, and environmental aspects into account.

The SMART approach applied to Wadi Shueib is mainly based on dynamic water budget assessments by WEAP for different development scenarios and alternative sets of interventions taking performance indicators into account, which rely on the Jordan water development policy.

Results

The scenarios as well as the experience from SMART working groups in different sub-regions showed that the most suitable approach to an IWRM strategy for the LJR is a modular development of local IWRM concepts, which align the developed technical solutions with site-specific particularities as well as with the guidelines of the respective national water sector strategies. The technical solutions developed and examined by SMART have the potential to provide a solid backbone of such local strategy modules. Particular advantages are not only their direct contribution to the alleviation of stress on water resources and to the sustainable functionality of hydrological cycles, but also their comparatively low political profile. The mobilization of additional water is a central issue of IWRM strategies in all examined areas, but its acceptance and success is intimately linked with acceptable responses to the question of its distribution within and outside of the respective basins.

Experience of the SMART working groups showed that IWRM solutions affect a number of areas which are not always obvious in the beginning. Such areas range from constraints by existing – or currently missing – stakeholder representation and participation, to land tenure and building

laws, to politically sensitive decisions. Obstacles encountered during the implementation of SMART activities as well as proposals for overcoming them in future IWRM implementation processes were documented.

11 Dissemination & Capacity Building

WP9 Spokesman: Wasim Ali, KIT, Manfred v. Afferden, UFZ

Knowledge Transfer

In SMART, a focus was placed on building a strategic network from the very start of the project. This was done inter alia through a project-related program in which a total of 26 doctoral students from Israel, Jordan, Palestine, and Germany participated. The setting and the maintenance of this network reflect a sustainable use of the SMART project, as many of the former graduate students now work in decision-making leadership positions in government agencies and ministries.

In addition, a scientific exchange program (Scientific Advanced Training) was established to promote ongoing scientific exchange between partners from the region and Germany. In SMART II alone, ten scientists from the three countries visited Germany under the above program.

The publication and dissemination of the results are documented by more than 35 papers in international journals. Furthermore, SMART can look back on more than 80 contributions to international conferences and, for example, was the co-organizer of the IWRM conference in Dresden and Karlsruhe.

Capacity Development

In order to overcome further societal and political barriers that impede implementation and to set impulses for a sustainable development on different social strata, capacity development activities targeting different and essential stakeholder groups were realized.

Capacity Development for Sustainable Development in the Areas of Water Quality & Consumption and Wastewater and Reuse

- Development of a complete primary school teaching unit “Water Fun – Hands, Minds, and Hearts on Water for Life?” addressing core aspects of water quality, water consumption, wastewater treatment and reuse in Jordan and Palestine (see Figure 11-1).
- The teaching unit was introduced to 118 teachers/schools from North, Central, and South Jordan and the Palestinian territories, covering school projects for nearly 5,000 primary school students.
- An «implementation office» in the Jordanian Ministry of Water and Irrigation has been established. Its main tasks are to facilitate and mediate an inter-ministerial and multi-stakeholder “National Implementation Committee for Decentralized Wastewater Management – NICE” that has set out to develop a regulatory and institutional framework for DWWM implementation in Jordan.
- Based on input and feedback of SMART sub-project 3.1, DWWM systems were integrated into “Jordan’s Water Strategy 2009-2022” and its associated “Action Plan”.



Figure 11-1: a)-c) Development of “Water Fun – Hand, Minds, and Hearts on Water for Life?”

12 Summary & Conclusion

By Heinz Hötzl (KIT)

After eight years of very constructive cooperation with the partners from Israel, Jordan, and Palestine, the SMART consortium can look back proudly on very successful results regarding the adoption of the IWRM concepts in the target-oriented regional planning in the Lower Jordan Rift system. The manifold requirements of a sustainable water management were taken into account, not only with respect to the availability of the resources, but also with regard to the socio-economic conditions in order to satisfy the demands of the diverging groups of the society. The reorganization from a sectoral projection to an integrated water development approach needs a long time. Within SMART, new scientific models for sub-catchments were developed, which improved the entire understanding of regional water systems and the connected land use. This may help solve and locally secure the water situation. These concepts can be transferred step by step to the whole region. On the basis of the strong connection with the governments and stakeholders, certain elements of the new concepts have already been integrated into the current state water programs, such as the approaches to groundwater protection in Palestine or the conversion of the main IWRM concepts into the new water strategy plan for Jordan. In addition, improved technologies, such as decentralized wastewater treatment or desalination of brackish water, could be adapted, tested in pilot and demonstration plants, and partly have already been implemented locally.

The large involvement of all responsible groups, from the government with the responsible ministries, to the water and environmental authorities, to stakeholders, to local consultants and companies, to scientists from universities and other scientific organizations finally gave rise to a huge corporation which initiated and supported the rethinking of the previous reckless water utilization policy. This development was additionally supported by a gradual capacity development program with specific water curricula for pupils at schools, training programs for technicians, or specific scientific programs for PhD students. We are proud of the fact that many of our former students now assume important positions in the water domain in their country.

Last, but not least, the close cooperation of partners from different countries in this politically unstable region confirmed that water resources are not restricted to political boundaries, but need the joint efforts of all riparian owners. Such a fruitful cooperation as was demonstrated in

the SMART project by all partners might contribute to a peaceful understanding between the countries involved.