Karlsruhe Institute of Technology

Integrated Water Resources Management (IWRM)
in the Lower Jordan Valley

SMART

Sustainable Management of Available Water Resources with Innovative Technologies

Institute of Applied Geosciences
Division of Hydrogeology

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

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: Data base, waste water 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 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 waste water 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

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Project Coordination

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Issued by: Karlsruhe Institute of Technology (1st edition, Karlsruhe, 2012)
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Sponsored by: Federal Ministry of Education and Research (BMBF)

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1 Introduction

IWRM FUNDING PROGRAM AND MODEL REGION

Supply of the growing global population with sufficient clean drinking water under changing environmental conditions is one of the crucial challenges of mankind. In many regions of the world, groundwater from wells and springs is the quantitatively most important and qualitatively best water resource. Water is not only used for drinking, but also and increasingly for irrigation in agriculture, in the energy sector, and for many other purposes. Ecosystems need water of sufficient amount and quality, at the same time they protect and contribute to the natural cleaning and storage of water in many ways. Under the funding program "Integrated Water Resources Management" (IWRM), the Federal Ministry of Education and Research (BMBF) supports the development of adapted planning instruments for a sustainable use of water as well as the adaptation of water management strategies to variable climatic, economic, and social conditions in developing and threshold countries. In total, 18 IWRM projects are sponsored by the BMBF.

The SMART project is one of them. It has been sponsored by the BMBF since 2006. SMART stands for "Sustainable Management of Available Water Resources with Innovative Technologies", the investigation area is the Lower Jordan Valley. SMART is a multilateral, interdisciplinary research project of 25 partners from universities, research establishments, and decision-relevant institutions in the target region, e.g. water ministries and water suppliers, as well as companies and external experts from Germany, Israel, Jordan, and Palestine. It is the paramount objective to develop concepts for an integrated water resources management (IWRM) in the Lower Jordan river catchment area. As the Jordan Valley is an arid region it suffers under natural conditions from water scarcity. In the future, this situation will even be aggravated by climate change and population growth. The SMART project has the objective to increase the amount of available water significantly and sustainably. All available water resources, i.e. groundwater and surface water as well as processed wastewater, salt water, brackish water, and flood water, are investigated by the project.

2 Project 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-Institut

DVWG- 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 Sheba

Mekorot Water Company Ltd., Tel Aviv

Environmental & Water Resources Engineering, Haifa

Map of the model region with the riparian states of Jordan and Israel and the Palestinian territories. The sub-catchment areas on which SMART research concentrates are colored green (Layout: H. Neukum / J. Klinger 2012, KIT)

The Lower Jordan Valley extends over length of about 100 km and from the Sea of Galilee in the north to the estuary of the Jordan river into the Dead Sea in the south. The SMART project area is 5.000 km² and limited by the mountain rigdes along the Irbid-Amman-Madaba ridge in the east and the Nablus-Ramallah-Jerusalem-Hebron ridge in the west. With its topographic elevation down to 420 m below sea level, the Lower Jordan Valley, together with the Dead Sea, represents the lowest area on the Earth's surface. The adjacent mountain ridges have a height of up to 1.200 m above sea level. Among the larger urban areas are those of Jerusalem as well as Hebron, Nablus, and Ramallah in Palestine, and Amman, Irbid, Salt, and Madaba in Jordan.

In the Lower Jordan Valley arid climate prevails with precipitation of less than 150 mm and potential evaporation rates of up to 2.600 mm per year. Recharge of groundwater takes place only on the elevated areas east and west of the Jordan Valley with Mediterranean climate and annual precipitation rates of up to 650 mm. The climatically induced natural scarcity of water is increased by extensive agriculture and high population growth. Drastically decreasing groundwater levels indicate that aquifers are overexploited already. Pharmaceutical residues and other pollutants in the groundwater and spring water reveal that these valuable resources are endangered by wastewater.

4 Research Objectives and Project Structure

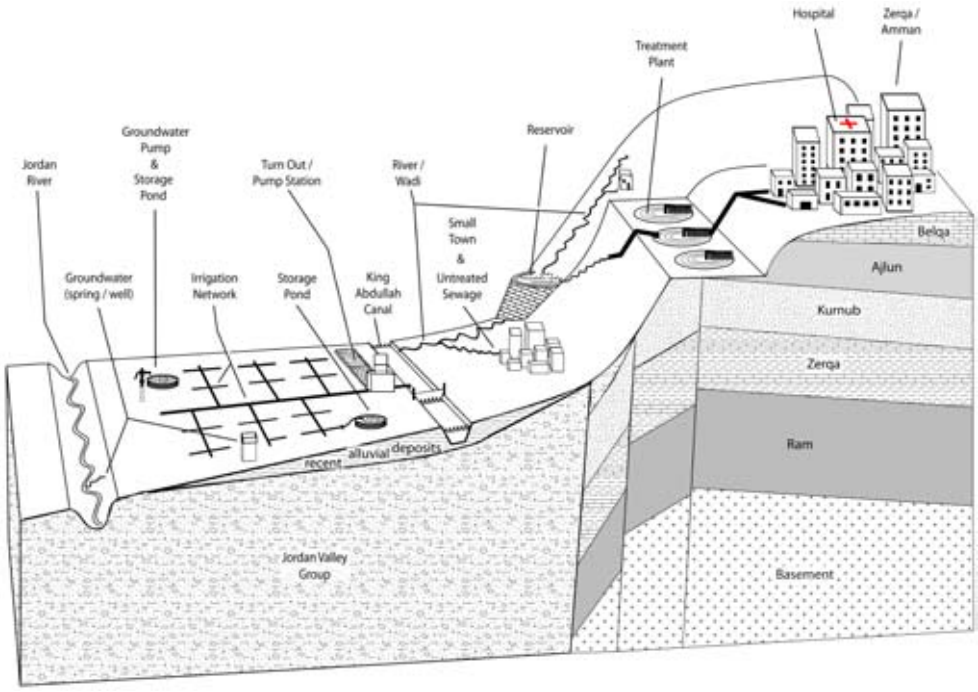
OBJECTIVE

The paramount objective of SMART is the optimized and sustainable use of all water resources in the region. This also includes treated wastewater, brackish groundwater, and flood water. To reach this objective, a comprehensive and integrated water resources management and use approach is pursued. Depending on further use and local conditions, appropriate processing techniques and intermediate storage solutions are developed. Their implementation does not only require the establishment of infrastructure facilities (e.g. waterworks, drinking water pipelines, wastewater treatment, and irrigation systems), but also the development of administrative framework conditions for regional water management.

METHODS AND PROJECT STRUCTURE

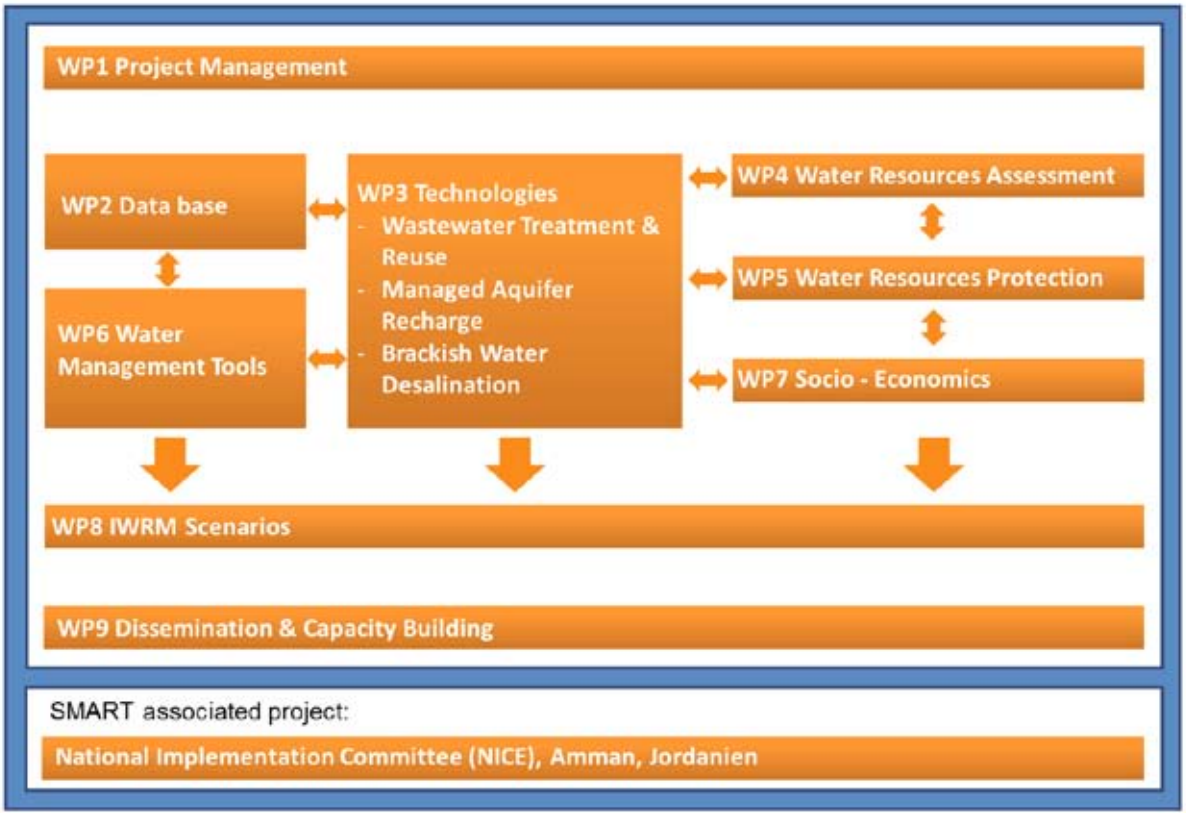
The second funding phase of the SMART project supplies scientific fundamentals for implementing technologies in the existing water management system. This includes e.g. operation of decentralized sewage treatment plants, desalination of highly mineralized groundwater and managed aquifer recharge, intermediate storage, and recovery. For this purpose, the following objectives are pursued:

- Further development of decentralized wastewater treatment and adaptation to local requirements (processed wastewater can be used for irrigation in agriculture)
- Hydrogeological and geophysical field studies to identify appropriate locations for controlled long-term groundwater enrichment and interim storage (managed aquifer recharge)
- Mapping of brackish water resources in the Jordan Valley and adaptation of desalination technologies to the temporally and spatially varying groundwater quality



Schematic representation of water resources in Wadi Shueib, Jordan (L. Wolf, A. Pöschko, KIT)

- Development of groundwater protection concepts and their incorporation in legislation
- Development of computer-based knowledge management systems
- Socio-economic assessment of alternative scenarios for water resources management based on interviews of the citizens and cost-benefit analyses
- Development of an IWRM concept that can be transferred to other areas as well
- Build-up of institutional capacities by training and qualification



Structure of the SMART project and individual work packages (WP) as well as the associated implementation office in Amman, Jordan

PARTICIPATION OF STAKEHOLDERS AND KNOWLEDGE TRANSFER

An important element of IWRM is the participation of stakeholders in planning and decision processes, with a holistic water resources management considering the varying requirements. Success of IWRM concepts is also based on knowledge and technology transfer, because the research results obtained can only be applied sustainably by well-trained local staff.

ADAPTED PROCESSING TECHNOLOGIES

Demonstration and test site for decentralized water treatment in Fuheis, Jordan (Foto: M. v. Afferden, UFZ)

Decentralized Wastewater Treatment and Reuse

- Use of a GIS-based planning instrument to establish a decentralized wastewater infrastructure
- Fundamentals for the design of various ecotechnologies (cleaning efficiency, energy, water balance)
- Demonstration and training platform for different technologies, inclusive sequenced batch reactors, extended aeration systems and sludge humification and screening systems
- Test of decentralized sewage treatment and reuse technologies on the pilot scale („Fuheis", Jordan)
- Implementation of decentralized plants in suburban areas and villages

Managed Aquifer Recharge

- Transport modeling of trace substances and hygienically relevant microorganisms during soil passage for groundwater recharge
- Analysis of wastewater, surface water, and groundwater samples from the Lower Jordan Valley (among others for pharmaceutical residues, bacteria, viruses)
- Balance of available flood- and treated wastewater for artificial recharge
- Development of appropriate infiltration techniques as well as identification of adequate aquifers

Wadi Wala (Jordan) with dam and reservoir for flood water storage (Foto: A. Sawarieh, KIT)

Brackish water desalination equipment (Foto: F. Saravia, KIT)

Brackish Water Desalination for Drinking Water Production and Irrigation Purposes

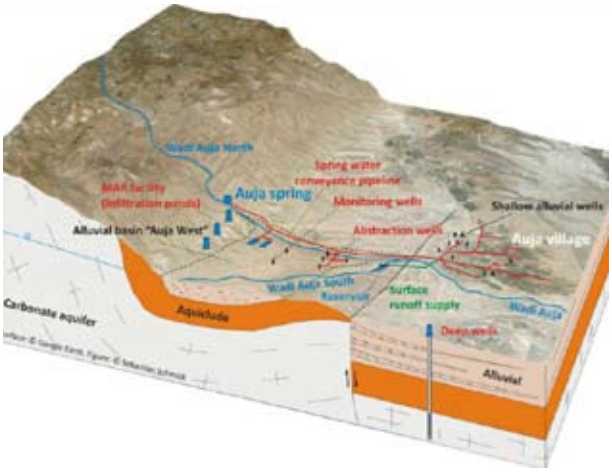
- Investigation of potentials and limits of nanofiltration for brackish water processing (low energy consumption)
- Test series with various membranes for optimizing brackish water processing and adaptation to local framework conditions
- Palestine: Evaluation of two potential locations for brackish water desalination (Jericho and Auja)
- Jordan: Operation of an energy-efficient pilot plant with innovative pretreatment stages, photovoltaics modules, and energy recovery systems
- Environmental impact assessment for brackish water desalination and improvement of brine disposal practice

EXPLORATION OF WATER RESOURCES AND GROUNDWATER PROTECTION

Exploration of Water Resources

- Identification, delineation, and evaluation of all water resources available on the local and transboundary regional level
- Calculation of surface runoff and numerical modeling of regional groundwater flow
- Water balancing of catchment areas
- Development of sub-basins management scenarios and their evaluation with respect to groundwater quality and quantity
- Simulation of runoff scenarios by using combined hydrological flow models
- Exploration risks and benefits of runoff harvesting

Monitoring of water quality at an infiltration well, Wadi Wala (Foto: M. Gabi, KIT)



Conceptual representation of the conjunctive use of surface and groundwater resources, Wadi Auja / Jericho region, Westbank (S. Schmidt, University of Göttingen)

Combined Management of Surface- and Groundwater Resources

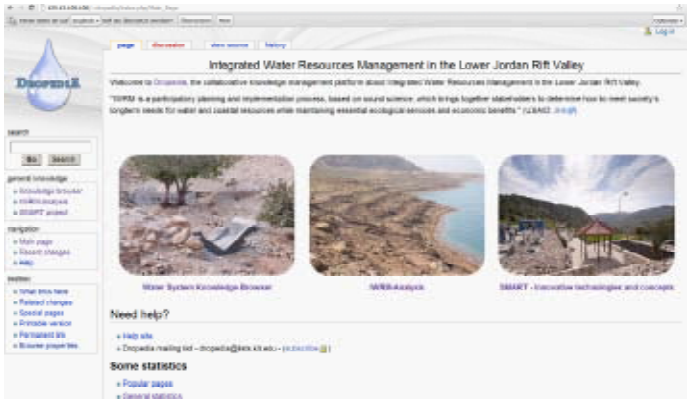
- Development of a platform for an IWRM knowledge management system
- Evaluation of alternative IWRM strategies applying cost-benefit analysis and assessment of the financial feasibility
- Sustainable groundwater management as part of the conjunctive use of surface runoff (flash floods), deep karst and alluvial groundwater, spring discharge, brackish water and treated domestic effluent
- Implementation of Managed Aquifer Recharge as control element for conjunctive use and underground storage of water
- Involvement of end users in the planning process
- Summary of the transferable findings for IWRM in semiarid areas

Groundwater Protection

- Development of an adapted concept and application of methods to define groundwater protection zones (continuous source monitoring, monitoring of pharmaceutical substances)
- Assessment of the risk associated with the seepage of treated and non-treated wastewater based on microbiological parameters
- Participation and support of local authorities in the development of protection zone concepts
- Evaluation of economic impacts of protection zone concepts

Tap water capture at the Hazzir Spring, Salt, Jordan (Foto: F. Grimmeisen, KIT)

TRANSBOUNDARY PROJECT DATABASE AND IWRM TOOLS



Introductory page of the DROPEDIA website (D. Riepl, KIT)

Database:

- Availability of latest and relevant environmental data is the key to sustainable water management
- More than 1.5 million data sets in the project database
- Graphic user interface: DAISY Harvester
- Spatial data analysis via WebGIS link
- The database is available to all members of the SMART project and can also be used outside of SMART (www.ufz.de/daisy)

Regionally adapted decision support system:

- Detailed description of water and substance balances
- Link to SMART database
- Programming of the DROPEDIA semantic knowledge management system (http://www.iwrm-smart2.org ⇨ DROPEDIA)

DISSEMINATION & KNOWLEDGE TRANSFER

- Implementation of the IWRM tools developed and strengthening of institutional capacities
- Training program for teachers and awareness building at primary schools (WATER FUN brochure and teaching material in English and Arabic)
- Training courses, e.g. workshop on tracing techniques and groundwater protection at the Al-Balqa University, Jordan
- Ph.D. program (16 scholarship holders from Israel, Jordan, Palestine, and Germany) and further training on academic level
- Scientific advanced training (SAT): Program for exchange of information among researchers from the region and Germany
- Updated and informative website: www.iwrm-smart2.org

Participants of a KIT scientific training course on tracing techniques at the Al Balqa' University in Salt, Jordan (Foto: Jordan press, Salt)

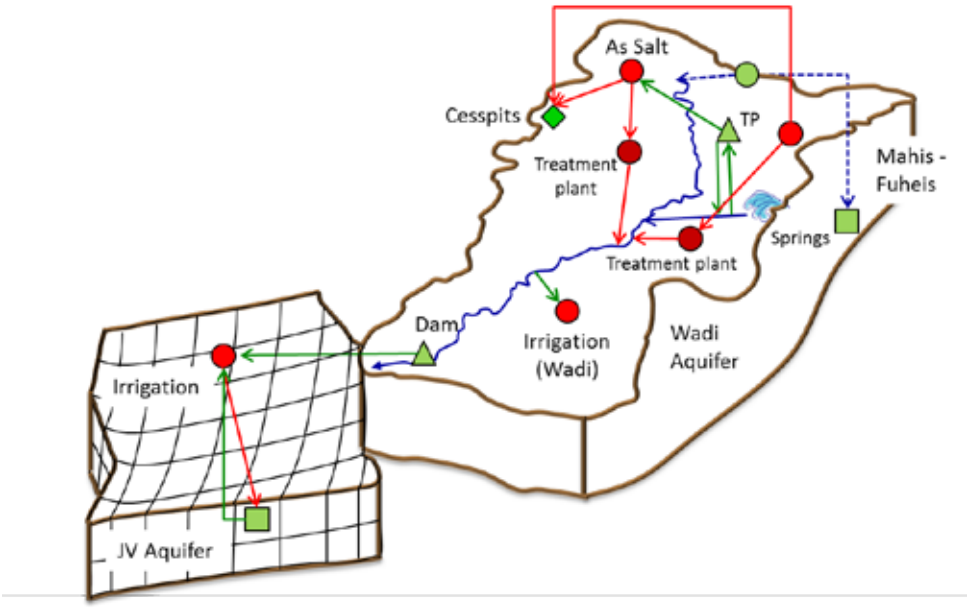
Cover page of the handbook and training program WATER FUN for teachers (M. v. Afferden, UFZ)

PILOT STUDIES OF IWRM IN SUB-BASINS

The countries bordering the Jordan Valley have realized the urgent necessity of an integrated management of scarce water resources and made it their political priority objective. But, for the translation of national goals into local applications, however, neither readily available solution approaches nor clear institutional decision paths exist. SMART develops planning and decision instruments bridging the gap between the objectives of state-wide water strategies and specific needs on the local level. The IWRM concepts developed were tested for applicability in Wadi Shueib on the Jordanian side and a wadi cluster on the Palestinian side (Auja, Jericho, Quilt).

IWRM CONCEPT FOR THE WADI SHUEIB CATCHMENT AREA, JORDAN

Wadi Shueib is a densely populated tributary wadi of the Jordan valley near the capital Amman. Here, inappropriate wastewater treatment and discharge as well as insufficiently implemented groundwater protection lead to a pollution of the scarce water resources, which exceeds the maximum allowable concentrations. The pilot study investigates established approaches that are already being implemented (e.g. extension and repair of sewers), as well as innovative technical solutions (e.g. demand management, decentralized wastewater treatment, brackish water desalination, etc.).



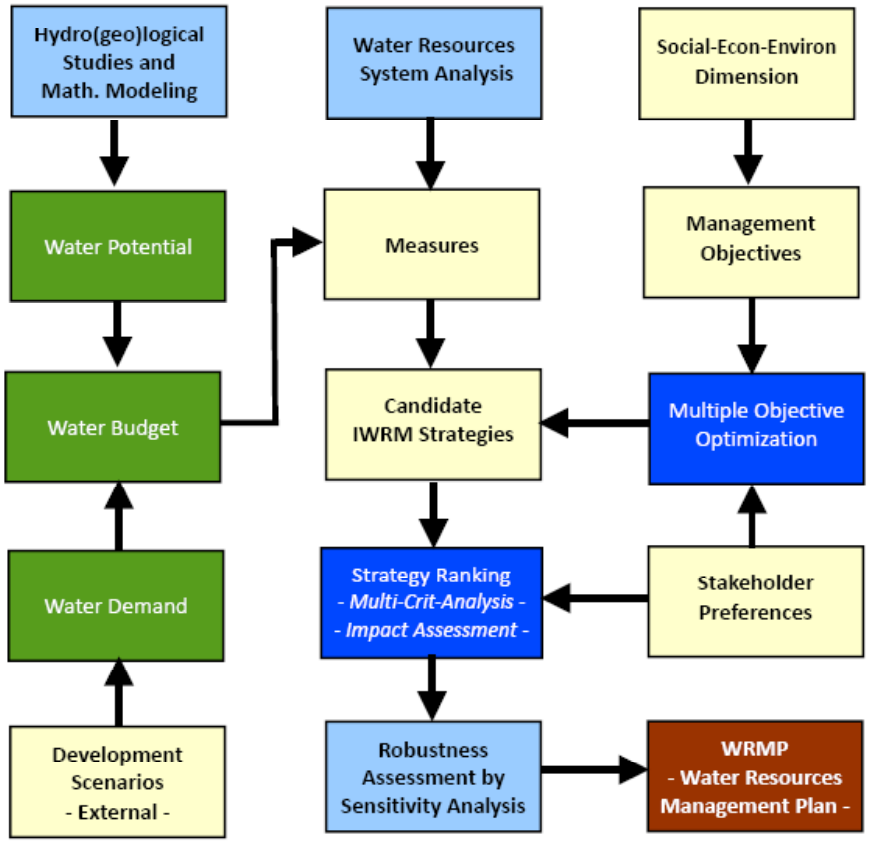
IWRM approach for the Wadi Shueib, Jordan (P. Alfaro & D. Riepl, KIT)

The approach pursued is based on classical planning processes that are combined with simulation models, IWRM-specific scenario planning, and an innovative knowledge management module. In order to allow rapid implementation, internationally tested software (WEAP, MODFLOW, MediaWiki), partly already used in Jordan, was applied. To ensure compliance of the recommended actions with the local reality, a set of planning scenarios were derived directly from the national strategic objectives and agreed upon with representatives of national authorities and research institutions. For the Wadi Shueib, the most efficient measures suggested comprise the reduction of supply losses, adapted demand management, and cost-efficient centralized and decentralized wastewater processing technologies.

IWRM CONCEPT FOR THE WADI AUJA AND JERICHO REGION, PALESTINE

The region around the city of Jericho and Auja village in the Lower Jordan Valley (LJV) offers excellent conditions for irrigated agriculture due to its fertile soils and favourable climate and is known as the Palestinian "Food-basket". The mountainous areas of these Wadis near Ramallah with a difference in elevation of around 1.000 m refered to valley floor present steady urban and industrial development and, therefore, increasing water demand. The springs which arise from the karst groundwater system present a great water potential which is not being efficiently managed and which requires protection measures. The number of water related conflicts is constantly rising. In contrast, the extension of the irrigated agricultural land in the LJV is a basic requirement for the sustainable socio-economic development of the region.

In the context of the Jericho-Auja case study a methodological approach has been developed which permits the identification of IWRM strategies as combined measures and accordingly the adequate "mix" of water and environmental technologies to ensure sustainable development. Water resources system analysis, water budget and multi-criteria decision support is being used to identify so-called "candidate" IWRM strategies and to rank them. The water potential is being determined by means of hydro(geo)logical studies and modeling. For the evaluation of alternative IWRM strategies, besides economic and environmental criteria, social factors are considered. The social dimension is of major relevance in the region, especially in the rural areas, due to the traditional grown structures.



SMART IWRM approach towards the development of a Water Resources Management Plan
(B. Rusteberg & J. Bensabat 2012)

The approach is strictly participative. The development of compromise solutions for the joint management of the scarce water resources in the LJV, according to the suggested approach, requires close cooperation between Israelis and Palestinian. This is being successfully conducted within SMART, contributing to the peace process.

7 Implementation and Further Research Demand

IMPLEMENTATION

Scientific findings made under the SMART project are applied and have already been incorporated in the Jordan national water strategy. Pilot plants for decentralized wastewater treatment, artificial groundwater recharge, and brackish water desalination are being operated or implemented at the moment. Progress has also been achieved in education, training, and capacity building. Examples are training courses for experts of water authorities and qualification courses for the technical staff as well as the highly successful "Water Fun" program for pupils. The water problems of the region require continuous, solution-oriented research. This also includes fundamental research, as basic process understanding is the prerequisite for viable solutions in the water and environmental sector. But also fundamental research should be aimed at solving problems in order to improve the living conditions of the people. As these solutions will have to be supported and applied by local population and decision-makers, the latter are strongly integrated in the development of further project ideas: Our research is tailored to the needs of the region. Under the SMART project, the decision-makers from the neighboring countries are asked regularly to formulate current research needs and to technically implement novel technologies. Research of the consortium extends beyond the SMART project and is adapted to these needs. It is the basis of long-term cooperation. The phrase "thinking globally, acting locally" also applies to the Jordan region and the SMART project: The integrated, transboundary approach and the resulting dialog have turned out to be highly valuable. At the same time, solutions often are of local and technical character. Here, the following questions have to be answered: How can underground storage of flood water in combination with dams be optimized? How can brackish spring water be used for drinking water supply without affecting the associated groundwater-dependent ecosystems?

FURTHER RESEARCH NEEDS

Future research in the region should therefore be concentrated more than ever on specific, local solutions, while maintaining the integrated approach developed under SMART. Among the integrating elements to be enhanced in the future are the further development and regional implementation of latest environmental measurement technology and coupled environmental information systems. This approach will offer good opportunities for German companies, supply the database for solution-oriented research and its application, and contribute to the sustainable management of water resources in the Jordan Valley.

Installation of monitoring system at the Hazzir spring, Salt, Jordan (Foto: N. Goldscheider, KIT)

Ein Feshkha, spring area in the Palestinian territories: An ecosystem worth protecting and drinking water source at the same time (Foto: J. Hasan; Al-Quds University)

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