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Report on downscaling of nationwide and regional scenarios to local / sub-basin level

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List of Abbreviations

AFD	Agence Francaise de Développement / French Development Agency
ATEEC	Arab Technologists for Economic and Environmental Consultancies, Jordan, partner in SMART
CBS	Central Bureau of Statistics, Israel
CWR	crop-water requirement
DAISY	SMART's Data and Information Management System
DoS	Department of Statistics, Jordan
GDP	Gross domestic product
HCP	Higher Population Council of Jordan
IWA	Water Authority of Israel
JICA	Japanese International Cooperation Agency
JSETs	Israeli-Palestinian Joint Supervisions and Enforcement Mechanisms
JVA	Jordan Valley Authority, public water utility in the Jordan Valley
JWC	joint Israeli-Palestinian Water Committee
l/c/d	litres per capita and day
LACS	Local Aid Coordination Secretariat, donor coordination in Palestine, Ramallah
MCM	million cube meters of water ($\text{m}^3 \times 10^6$)
MNI	Ministry of National Infrastructures, Israel
MWI	Ministry of Water and Irrigation, Jordan
NGWA	Northern Governorate Water Authority, Jordanian public utility until 2012 (<i>cf.</i> YWC)
NRW	Non-revenue water, network water losses (synonym: UFW)
NWMP	National Water Master Plan (published version, 2004)
PHG	Palestinian Hydrology Group, partner in SMART
PMU	Performance Management Unit, advisory committee at the MWI
PNA	Palestinian National Authority
PWA	Palestinian Water Authority
QUASIR	Office for quantitative analyses of socio-economic systems, investments and resource use, contractor of KIT
UFW	unaccounted-for water, network water losses (synonym: NRW)
UNEP/MAP	United Nations Environment Programme / Mediterranean Action Plan
UoJ	University of Jordan, partner in SMART
WAJ	Water Authority of Jordan, public water utility and coordinator of private utilities in Jordan
WDM	Water Demand Management
WIS	Water Information System
WRM	Water Resource Management
WWTP	Wastewater Treatment Plant
YWC	Yarmouk Water Company (Jordanian public-private utility, former NGWA)

1 INTRODUCTION

The elaboration of the proposal for scenario developments under SMART II in 2009 took place in a situation, where other scientific projects published the first regional scenarios about the Jordan Valley and its surroundings. However, initial discussions with national decision makers in the partner countries showed that these existing scenario exercises and their results were regarded with strong skepticism up to outright rejection. Simultaneously, water sector planning in the partner countries underwent significant and rapid developments during the term of SMART II, which put at least some of the assumptions of the preset scenarios in question.

It coincided well with this situation that SMART team members became simultaneously involved in the implementation process of scenario planning processes by water authorities in Jordan and Palestine. These scenario exercises, which were funded by external sources, took place under the auspices of the respective national authorities, which endorsed their results as the currently authoritative basis for planning and evaluation.

The downscaling of scenarios for the purposes of the SMART research regions in Jordan and Palestine could thus be based on assumptions on drivers and databases, which were developed and compiled by workgroups of the administrative decision makers in Jordan and Palestine. SMART partners from QUASIR, PHG and ATEEC acted as organizers and senior experts of the respective scenario exercises and were authorized by the national authorities to use the developed data bases and information for the specific purposes of SMART. The SMART scenario development required a number of adaptations and additional interpretations of the materials and results from the national scenarios. The results from the basic scenario development process were published in 2011 (AFD *et al*, 2011; MWI/AFD, 2011).

The selected region of the Israeli partners in SMART is a settlement in the occupied areas of Palestine and thus not part of the official Israeli water master planning. The scenario development for this region relied on internal information from the SMART partners of the responsible utility MEKOROT.

The presentation of the scenarios in this report comprises the storylines and selected aggregated figures of results from the SMART scenario calculations. The detailed data were provided to SMART's Data and Information Management System (DAISY, UFZ, cont.) and selected results also published on its wiki-based communication platform DROPEDIA (KIT, cont.).

1.1. Objectives of the scenario development

The objective of the scenario development for research regions of SMART was to develop a comprehensible and transparent framework for the quantitative downscaling of nationwide and regional scenarios to the scale of the concerned sub-basins or even communities. A basic requirement of the developed local scenarios was their compliance to the expected developments, assumptions and planning of the water sector on the national level of the individual partner countries. This requirement was due to the regional situation, where local, i.e. basin or watershed based, water economies are closely intertwined with the national water infrastructure and superordinate water policies.

The aim of the intended functional account of the scenarios was to allow for (1) consistency checks of assumptions on the development of conditions, which impact the use and dynamics of water resources and (2) for analyses of impacts for communal development from changes in the management of water and water resources.

The scenarios should provide researchers from other disciplines with an outlook on alternative developments of the local water sector. Additional aims were the identification of relevant sources for information and data on developments in the water sector in the partner countries and successive updates with regard to the regional dynamics of developments in water sector planning, which was expected to speed up considerably during the term of SMART II.

1.2. Material and Methods

Several projects with international funding came up with scenarios on regional development of the Lower Jordan Valley over the last decade. Most of these scenario exercises centered on different major topics, such as e.g. effects from the regional peace process (e.g. The Millennium Project, 2009) and Climate Change (e.g. GLOWA, 2011), but all of them considered developments in water availability and water resource management as a crucial element in their reflections.

The initial intention of SMART II was to use these regional scenario exercises, which were based on substantial funding over three to nine years, as the basis for downscaling of results to the basin-based research regions of SMART II. However, this approach turned out to be not feasible due to the following reasons:

- 1) The considered regional scenarios used either information about aggregated, national developments in the water sector or extrapolations of findings from selected areas. However,

the representativeness of the latter was not proven in any of the existing scenario analyses. Individual analyses of regions in Jordan by the scenario developers in SMART II gave a strong indication that the extrapolations are not justified and downscaling or transfer of the results from the respective scenarios would lead to uncontrollable bias and errors (*cf.* annex 1).

- 2) Downscaling from aggregated, national developments in the water sector failed due to the significant heterogeneity of basins and administrative districts in the Lower Jordan Valley (*cf.* annex 1).
- 3) None of the regional scenarios was considered as realistic or a guideline by the decision makers in the water authorities of the participating countries, despite the stated participation of at least some members from these authorities in the scenario exercises (*pers. comm.* at MWI and PWA, cross checking of policy documents from MWI, PWA and IWA).

A repetition of full-scaled scenario exercises in the SMART research basins and the related collection of local primary data were not budgeted. However, this scientifically desirable alternative would also not correspond to the expectable conditions for the transfer and implementation of SMART's technical findings in other than the current research areas. The choice of the finally applied methodological alternative arose from the simultaneous involvement of SMART partners in scenario exercises and planning processes of the Jordanian and Palestinian water authorities, which were funded by the French development cooperation. This involvement offered three advantages:

- The scenario exercises took part on behalf of the concerned national water authorities, which attributed a high relevance to their results for further national planning and secured their acceptance by the client,
- Detailed data and information, which was collected and created during these exercises, became available to the SMART scenario developers. The responsible water administrations authorized the use of obtained data and information for SMART research areas.
- The adoption of national assessments about (1) driving forces of developments in the water sector and (2) linkages and interdependencies between elements in the water economies facilitated the calibration between local and national prognoses.

However, the most disaggregated level of data from the national accounting systems and statistical offices are - in the case of Jordan and Palestine - governorates. The boundaries of these administrative entities do not coincide with hydrological basins. This "problem of fit", which

was also reported from other BMBF-funded IWRM-projects (cf. e.g. Horlemann *et al.*, 2010), required another step in downscaling of water consumption. The applied downscaling routines varied according to the sector of water use (cf. annex 1).

The specific situation of the Israeli settlement Kalya required a different approach to scenario development. Work package 9 of the preceding phase of SMART provided initial data and information and updates during SMART II were provided by Mekorot. Estimations on possible developments were based on references of the Israeli Water Authority (IWA), the Israeli Central Bureau of Statistics (CBS) and other organizations (cf. chapter 4). The sequential results of the scenario development process were cross-checked with Israeli partners in SMART during the biannual scientific committee meetings.

Water sector planning in the partner countries underwent, as expected, significant and rapid developments during the term of SMART II. The scenario developers met this challenge by updates of the scenarios through incorporation of information from new reports, studies and references. The presented scenarios in this report are the latest version of spring 2013.

However, the regional process of changes in assumptions and driving forces still continues. This holds in particular for areas, which are affected by changes in the political situation, e.g. through the influx of refugees and changes in access to resources, or which may experience abrupt, significant changes in water infrastructure. Such potential changes include the prospective catchment areas of water mega-projects - i.e. the contemplated Red Sea-Dead-Sea channel, the alternative Jordan Red Sea project and the West-East conveyors of desalinated water from the Mediterranean – as well as comparatively smaller projects such as e.g. local desalination plants. The specific dynamics of the region, the international interest in its developments and the related funding mechanisms showed in the past that such changes may be planned and realized on short notice. This indicates the temporally limited validity of the calculated figures and underscores the necessity of continuous cross-checks and updates of the underlying scenario assumptions.

2 Jordan

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2.1. Sources of information about the water sector

Professional publications and pages in the internet provide a large amount of data on the Jordanian water sector, but such data often do not match. Dozens of national, international, bi- and multilateral projects, programs, agencies and organizations worked and still work on the water sector in Jordan. Not all of them harmonize their work with the Jordanian Water Authorities and many of them have an own agenda, which may not be necessarily scientific or otherwise obliged to "true" information.

It is advisable to check applied secondary data, i.e. data that do not originate from own research, with the Jordanian SMART counterparts from Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ) and Jordan Valley Authority (JVA). Selected standard references, which give a general overview and provide quotable "standard" figures for scientific publications include:

- 1 The National Water Master Plan (NWMP), which was initially published within the MWI in 2004 (MWI, 2004). The NWMP is subject to continuous updates by an MWI workgroup. However, these updates are not published, but provide the basis of up-to-date calculations by the MWI, WAJ and JVA.
- 2 Jordan's Water Sector Strategy for the period 2008-2022 (MWI, 2009). This strategy paper represents the results of the MWI workgroups until 2009. Reference to information from this source requires a cross-check with the MWI, since there were more recent changes in the assumptions, e.g. on water for agriculture and water losses.
- 3 The continuously updated web pages of DoS (Department of Statistics, Jordan, continuous update), which provide at least aggregated data on demographic, economic and other indicators. More detailed data on selected parameters are accessible on specific request, but specific queries of the DoS databases require a high-level authorization first.
- 4 The current standard book reference on Jordan's water sector is "Water resources in Jordan", edited by a former Jordanian minister of water (Haddadin, M.J., 2006).

Figures from these references are at least free of suspicions about hidden agendas and usually accepted in the Jordanian water administration. However, even those figures make a cross-

check with the Jordanian counterparts advisable with regard to all calculations and in particular estimations about the future, which are supposed to help in local decision making.

2.1.1 Water administration

The NWMP provides a detailed description of the water administration, its organizations and advisory committees and their respective responsibilities. The comments here below summarize the most important elements in this set-up for research teams in SMART.

- The MWI develops and coordinates water strategies. WAJ and JVA are responsible for the implementation of these strategies and management of the related water infrastructure in their respective fields.
- The Performance Management Unit (PMU) provides strategic and political guidelines, which were then translated into applicable policies and programs by the MWI. Those guidelines are released in irregular time intervals and overrule statements in e.g. the NWMP.
- JVA is responsible for water and irrigation infrastructure in the Jordan Valley.
- WAJ is basically responsible for all water supplies and provision. Jordan's three large semi-private utilities act with a certain degree of independence under the guidance of WAJ.
- The three utilities are Miyahuna (municipal water supply, governorate Amman), AWC (Aqaba Water Company, municipal water in governorate Aqaba) and NGWA (Northern Governorate Water Administration, municipal water in Ajloun, Irbid, Mafraq and Jerash). NGWA is in a process of transformation into the limited liability company YWC (Yarmouk Water Company).

Most important sources for information on water related issues in SMARTs research areas are thus:

- Wadi Arab (governorate Irbid): NGWA/YWC
- Wadi Shueib (governorate Al Balqa): WAJ
- Jordan Valley floor, East Bank (governorates Al Balqa, Madaba, Karak): JVA, WAJ

2.1.2 Water accounting

The designation of national water accounts is basically related to the responsible organizations and may lead to some misunderstandings. Important pitfalls are:

- Municipal water includes not only domestic water use but also water consumption by commercial, governmental, health, and other urban infrastructure. It may even include water for light industries and touristic installations within municipalities if not stated otherwise.
- Water losses, i.e. UFW/NRW stand for the sum of water that leaves the water heads but is not paid for by customers. UFW/NRW are usually (but not always) stated as percentage of the total municipal water supply.
- UFW/NRW consist out of administrative and physical water losses. Administrative water losses have a negative impact on the profits of the utilities, but this water is still part of water consumption and wastewater production. Physical losses are "real" water losses due to leakages in water supply systems.
- The NWMP states an assumed distribution of UFW/NRW between administrative and physical losses of 2/3 to 1/3. This assumption was replaced in current analyses of the utilities by an equal share of both types of losses (50% : 50 %).
- Figures on water for irrigation (agriculture) rely on the information from JVA and WAJ billing systems. Theoretical water requirements of observed crops on cultivated areas exceed the stated amounts by 40 to 50%. The largest parts of the differing amounts concern agriculture in the highlands, i.e. are not of primary interest for the SMART research areas.
- There are currently no reliable quantitative data for the distinction of reasons for this discrepancy between physical crop-water-requirements (CWR) and recorded water supply for irrigation. Potential reasons are (1) replacement of some of the crop water requirement by precipitations, (2) unrecorded water extraction from groundwater or other sources and (3) reduced yields or crop failure.
- The "missing" water in agriculture is not part of the UFW/NRW stated in the references.
- The best basis for estimations on irrigation water demand are the CWRs of the major crops rather than figures and records on past water consumption in a certain area.

Table 1 maps the relations between sectors of water demand and the usual terms that are used for the respective water accounts in literature and at the MWI.

Table 1: Definition of sectors and Jordanian categories of water demand

Water Account:	Municipal	Industry	Tourism	Nuclear	Agriculture / Irrigation
Water Demand Sector:					
Domestic					
Commercial, governmental, health, and other urban infrastructure					
Landscape (communal green areas, tree nurseries etc.)					
Tourism					
“Light” industries					
Water losses (UFW, NRW)					
“Large” industries ¹					
Irrigation					

¹ water supply usually from own wells or own connections to nationwide water supply systems

2.2 Sources of data

2.2.1 General

The Department of Statistics (DoS) publishes the official statistics about Jordan on its website. Data sources are own surveys of DoS and contributions from other ministries. There is a certain delay between data delivery from the latter and publication by DoS due to technical requirements, but also due to the process of data authorization.

The published data are mostly on a high level of aggregation. The underlying, detailed primary data are confidential and the property of the Jordanian state. The respective authorities may allow researchers to access and use the underlying, detailed primary data, but this process requires a written authorization in each individual case. The right to authorize data access is in all cases located on the highest level of the concerned ministries, i.e. can be supported, but not be decided and granted by functionaries below ministerial level.

The primary data (i.e. results from queries to such data bases) remain confidential and the exclusive property of Jordan even with an access authorization for research purposes. Researchers are usually allowed to publish the results from data analyses and modelling. The most disaggregated level of data availability is usually the governorate. Data series on a lower level are mostly not available at central data collection bodies, such as DoS or MWI and remain subject to extrapolations in downscaling from nationwide scenarios. SMART's choice of research areas is based on hydrological water sheds instead of administrative units, which makes such extrapolations unavoidable (*cf.* annex 1).

The work of Riepl (2013) showed that more detailed and updated data may be obtained through contemporary data collection at individual administrative offices and water users in specific locations. However, the gain in data precision for a specific location comes at the cost of higher requirements in time for data collection and, even more important, the lack of a suitable national workgroup on contextual data interpretation and scenario development. Workgroups of local stakeholders lack the knowledge on the superordinate developments and planning in the water sector, which have significant effects on local developments in Jordan, where areas are strongly interlinked via man-made water infrastructure and natural geological and hydrological conditions. Mixed workgroups that include local and national stakeholders, i.e. bottom-up local scenario development instead of the chosen downscaling approach from national scenarios, require much higher investments in scenario development exercises than considered adequate for the current purposes of SMART.

2.2.2 Data on water

The MWI maintains a central Water Information System (WIS) in ORACLE®-format. The Minister's office and the MWI decided that this WIS is the only authoritative data base on water for Jordan. Access and queries to the WIS is restricted to internal use. Inputs and data transfers from other data bases, e.g. from data systems of the utilities, requires authorization by the MWI.

Specific data sets for the scenario development were obtained from WAJ and JVA. However, the same authorization requirements and restrictions applied as with the MWI WIS and all other governmental data bases.

Detailed information on the components of "municipal water" is currently only accessible for areas under the administration of the 3 large private-public utilities. This covers within the SMART research areas the governorate of Irbid only. However, experts from the utilities considered the settlement structure and related municipal water demand in the governorates of Balqa, Madaba and Karak as acceptably comparable to the situation in Irbid (pers. communication with experts from YWC and WAJ). This justified the assumption of corresponding proportions of the components in municipal water supply for all mentioned governorates.

The basic data for the scenario analyses on water in Jordan were sent to SMART's DAISY workgroup.

2.2.3 Estimations on future developments

Assumptions on future developments for the scenario calculations comprised three types of estimations: (1) drivers, (2) deduced information and (3) development estimations. The resulting quantitative estimations until 2025 were provided to the workgroup on DAISY and are accessible from there. The following chapters provide background information on these estimations.

2.2.3.1 Drivers

2.2.3.1.1 Estimations on demographic development:

- The last census in Jordan took place in 2004. Data on the population in different locations were taken from the respective tables of the "DoS Housing & Population Census" (DoS, 2010).
- The Higher Population Council (HPC) provides demographic forecasts. These figures are the result of demographic models, i.e. go beyond a mere extrapolation of trends from the past. The forecasting from HPCs demographic models implies different growth rates per year, i.e. a wavelike growth curve. The smoothed growth curve corresponds to an expected average increase of 2.14% p.a. between 2010 and 2025 (minimum assumption: 2.06% p.a., maximum assumption 2.62% p.a.).
- HPCs estimates of proportions of the population living in each of Jordan's 12 governorates assumes no significant differences to the findings of the last census in 2004 (source: DoS, data per governorate from 2001-2009). This assumption was adopted for the extrapolation of population estimates per governorate until 2025.
- The data from HPC allow for downscaling to the level of governorates. Further downscaling to the level of SMART research areas was based on the identification of population centres, which are located in these areas. The centres and their population in each governorate are listed in the pages of the DoS housing survey.
- Population figures for the SMART research area of Wadi Shueib were based on the last census (DOS 2004) and extrapolated with the demographic growth rates as indicated by the HCP.
- Population figures for the SMART research area of Wadi Arab were estimated based on information on population centres in the governorate of Irbid by DOS (2004).
- The respective data for the scenario analyses were sent to SMART's DAISY workgroup.

2.2.3.1.2 Estimations on economic development:

Links between economic development and water resource management exist on a number of levels in different sectors. Reducing the driver "economic development" to a single parameter or index, such as e.g. the gross domestic product (GDP), renders statements on impacts on water balances to a large extent arbitrary and insubstantial. The MWI scenario exercise on Water Demand Management yielded comprehensible and by far more significant results through the use of a set of outcome-related indicators on economic development. These indicators focus directly on consequences from economic growth for water supply and demand rather than on aggregated parameters of the national economy.

Downscaled indicators included:

- Municipal water consumption, excluding industry, tourism and landscape: This includes water consumption by resident households, commerce, private and governmental offices, hospitals and clinics ("health") and worship.

A strong economic development allows for the realization of MWIs target value of a nationwide average of 112 l/c/d (PMU internal concept note, MWI). The proportional target values for the relevant governorates of SMART would amount to 113 l/c/d in Irbid, 102 l/c/d in Karak and 110 l/c/d in Balqa and Madaba. The proportions are based on past differences in municipal water supply. The scenario assumption is that these levels of consumption will be reached by a continuous increase until 2025.

The estimation of municipal water demand under a weak economic development is equal to the estimation under the assumption of the baseline scenario (scenario zero) and corresponds to the "natural" growth of municipal water demand according to the trend estimations by the utilities. The basic reflection is that current water consumption is still below the standard requirement of at least 100 l/c/d and must be aspired in any case for the sake of social peace. The target values for the relevant governorates of SMART would amount to 91 l/c/d in Irbid, Balqa and Madaba and to 84 l/c/d in Karak in 2025.

- Industrial water demand: There are only "light" and "small" industries, i.e. industries that are supplied via the municipal water supply network, in the governorates where SMART research areas are located. The estimated demand under "most likely" conditions corresponds to the proportions in the governorate of Irbid, which amounts to between 0.4 to 0.5% of the municipal water consumption.

The historical growth rate in industrial water demand varies considerably (NWMP, 2004, vol. 3, chapter 2.5.2). The quantification of a weak and strong development resorts to an aggregated, statistical approach for the definition of boundaries. Growth rates of the total industrial water demand over the period from 2001 to 2008 varied between -0.8% and 24%. The confidence interval of the mean value of the growth rates ranges, at a probability of 95%, between about $\pm 50\%$.

A strong economic development would involve higher water demands by industries due to e.g. a higher number of enterprises and increasing output-related amounts of water. The comparison of the past development of Jordan's industrial gross output with the related industrial water consumption supports this argument. Scenario calculations under the assumptions of a strong development consider a growth rate of industrial water demand, which is 50% higher than the assumed growth rate under the baseline scenario.

A weak economic development would yield reverse effects from a lower growth in the number of enterprises and lower production. Scenario calculations for such situations consider a growth rate of industrial water demand, which is 50% lower than the current average growth rate.

- Water demand by tourism: Water demand of most touristic infrastructure, such as hotels and restaurants, is part of the municipal water demand. The data from the utilities and impacts from economic growth were considered by the same assumptions as applied for industrial water demand. The estimated demand under "most likely" conditions (scenario zero) corresponds to the proportions in the governorate of Irbid, which is between 0.1 to 0.15% of the municipal water demand.
- Water demand for landscape: Water required for the maintenance of public and touristic green spaces and related horticultural activities amounts to about 0,3 to 0,4% of the municipal water supply. Changes to this part of water consumption due to economic growth are not likely.
- Water losses: Water losses, usually abbreviated in documents by the synonymous acronyms UFW and NRW, consist out of administrative and physical losses. Only physical losses are relevant for water balances. Administrative losses represent utilized water, which is just not paid for. However, administrative water losses add to the wastewater flows and thus to the potential of water recycling.

Jordan will in each case dedicate substantial efforts in particular to the reduction of physical UFW, since the reduction of such system losses ranges among the less expensive approaches towards the mobilization of additional water. The baseline scenario and scenarios with weak economic development consider the reduction of losses according to the current planning assumptions of the utilities.

The MWI sees the potential of a more efficient loss reduction (PMU policy note and public presentations by secretary general M. al-Zoubi and Eng. Ali Subah of the MWI in 2011), but this may require higher investments in the upgrade of elements in the water infrastructure. It was assumed that only scenarios with a strong economic development would provide the suitable framework.

2.2.3.2 Deduced information

The assumptions on the development of water demand and consumption determine the resulting amount of wastewater.

- Wastewater formation: The current working assumption on the potential amounts of treated wastewater, i.e. effluents to wastewater treatment (WWT) plants presumes a share of about 50% from municipal water, i.e. water for residents, industry and tourism. The other 50%, which do not re-enter the water balance, are water losses due to consumptive use, conveyance after primary use and WWT (cf. table 2). Wastewater formation, i.e. potential influents to WWT plants after deduction of consumptive use and losses in sewers, amounts to between 35% and 40% of the primary water use.

Table 2: Losses between primary water use and treated wastewater

Water use	Consumption or loss	Wastewater
Municipal water	15%	85%
Water for industry and tourism	10%	90%
Landscape	100%	0%
Agriculture	100%	0%
Physical NRW	100%	0%
Administrative NRW	15%	85%
Sewer system	5%	95%
Wastewater Treatment Plant	Loss (evaporation and sludge)	Treated wastewater
Fuheis ¹	15%	85%
Irbid Central ¹	15%	85%
Wadi Arab ¹	6%	94%

¹ source: MWI/WAJ 2010

2.2.3.3 Development information

Development information comprises additional planning data, assumptions and findings on water infrastructure and water use that are independent from (1) potential innovations from SMART or (2) changes due to a shift in water resource management towards IWRM. This information shapes the framework for a "with-without" evaluation of potential impacts from SMART approaches.

Wastewater treatment capacities: Jordan runs currently 19 mid- to large-scale wastewater treatment plants. Another 17 plants are in different states of construction, whereby some of them will go into operation already during the research period of SMART II. Wastewater treatment plants in governorates, where research regions of SMART are located, are compiled in table 3.

The design capacity of the current treatment plants in Wadi Arab amounts to 11.680.000 m³/year. An additional, new treatment plant (Kofur Asad) with a design capacity of 2.190.000 m³/year is currently under construction. The efficiency of wastewater treatment (outflow/inflow) in this area is currently up to 91% (MWI, datafiles). Amounts of treated wastewater that are not used in agriculture infiltrate into the groundwater, but are not diverted to the Wadi Arab dam, which serves for the storage of freshwater from the Yarmouk river.

The design capacity of the current treatment plants in the area or vicinity of Wasi Shueib, i.e. Salt and Fuheis, amounts to 3.686.500 m³/year. The efficiency of wastewater treatment (outflow/inflow) in this area is currently up to 95% (source: MWI, datafiles). Amounts of treated wastewater that are not used in agriculture go to the Wadi Shueib Dam, i.e. add to water exports from Wadi Shueib to the adjacent part of the Jordan Valley floor.

The estimated costs per m³ of treated wastewater from newly established wastewater treatment plants in currently applied (non-SMART) standard designs amount to 0.82 JD/m³ including costs for the installation of collection and distribution systems (WRG 2030, 2011). Costs per m³ for treated wastewater from the already existing plants are up to 0.35 JD/m³ (MWI, datafiles).

Water consumption by agriculture: The estimation and interpretation of figures on water demand and/or consumption by agriculture consider the following information:

- All figures on water for agriculture have to be interpreted as controlled, i.e. measured, water for irrigation. Precipitations for rainfed agriculture are not included.

Table 3: Existing and planned wastewater treatment plants in Irbid and Balqa

		2000	2005	2010	2015	2020	2025
Governorate Balqa		Figures in MCM (m ³ x 10 ⁶)					
<i>existing:</i>							
Baqa	inflow	4,09	7,55	8,76	10,28	11,84	13,15
	effluent	3,89	6,80	8,32	9,76	11,24	12,49
Fuheis	inflow	0,44	0,82	0,99	1,16	1,34	1,49
	effluent	0,38	0,74	0,90	1,05	1,20	1,34
Salt	inflow	1,25	2,68	3,12	3,65	4,19	4,65
	effluent	1,21	2,41	2,81	3,28	3,77	4,19
<i>planned</i>							
Dair Alla	inflow	0,00	0,00	2,34	2,69	3,07	3,38
	effluent	0,00	0,00	2,22	2,55	2,91	3,21
Shuna South	inflow	0,00	1,18	1,50	1,73	1,98	2,19
	effluent	0,00	1,12	1,43	1,65	1,88	2,08
Dead Sea East Coast	inflow	0,00	0,19	0,47	0,88	1,10	1,12
	effluent	0,00	0,17	0,43	0,80	0,99	0,99
Governorate Irbid							
<i>existing</i>							
Irbid (Central)	inflow	1,68	3,02	4,36	5,02	5,69	6,22
	effluent	1,65	2,87	4,14	4,77	5,41	5,91
Ramtha	inflow	0,86	2,59	3,34	3,98	4,68	5,00
	effluent	0,68	2,33	3,01	3,58	4,21	4,50
Wadi Arab	inflow	2,19	5,01	7,33	8,44	9,57	10,47
	effluent	2,05	4,76	6,96	8,02	9,09	9,94
Wadi Hassan	inflow	0,00	0,55	0,71	0,82	0,94	1,03
	effluent	0,00	0,50	0,64	0,74	0,84	0,93
<i>planned</i>							
Al Mazar Al Shamali	inflow	0,00	0,00	0,99	1,14	1,30	1,43
	effluent	0,00	0,00	0,94	1,08	1,23	1,36
Dair Abi Said	inflow	0,00	0,00	0,00	1,20	1,37	1,51
	effluent	0,00	0,00	0,00	1,14	1,30	1,43
Kofur Asad	inflow	0,00	0,00	2,82	3,25	3,70	4,07
	effluent	0,00	0,00	2,68	3,09	3,51	3,87
North Jordan Valley	inflow	0,00	0,00	2,42	2,76	3,13	3,42
	effluent	0,00	0,00	2,30	2,63	2,97	3,25
Torra	inflow	0,00	0,00	0,00	1,36	1,56	1,72
	effluent	0,00	0,00	0,00	1,29	1,48	1,63
Wadi Shallala (Irbid East)	inflow	0,00	4,13	4,81	5,54	6,29	6,89
	effluent	0,00	3,71	4,33	4,99	5,66	6,20

Source: MWI/WAJ files, scenario planning on sanitation, 2005

- Recording and control of private wells, springs and drill holes is still in its planning phase, i.e. no measured data are available.
- Water for agriculture in the future will be in all cases subject to an imposed cap at a level, which is still under discussion. Current figures of intended water allocation to agriculture

range between 700 and 1000 MCM nationwide, whereby most of the cap will affect agriculture in the highlands, i.e. not in research areas of SMART. However, impacts on the areas which are located in the wadis of the Jordan Valley may still be affected to a currently unknown extent by the intended caps.

- Water supply for agriculture by the JVA is recorded according to the Jordan Valley irrigation infrastructure and its basins, not according to governorates or natural watersheds.
- Agricultural water supply differs highly between areas within the governorates. This holds in particular for those governorates that include parts of the Jordan Valley, i.e. all SMART research locations.
- Agricultural water consumption in Jordan was about stable over the last decade, which indicates that there are no relevant impacts expected from changes in demographic or economic growth.

The resulting major scenario assumptions for agricultural water demand are:

- Irrigated areas will only increase if additional local treated wastewater is not supposed to be channeled in the dams or groundwater of Wadi Arab or Wadi Shueib.
- Irrigated areas will decrease if the status of private wells changes and/or an administrative water cap will reduce irrigation water supply.

The preliminary estimation of irrigated areas in Wadi Fuheis considers the area mentioned in DROPEDIA. Estimations for Wadi Arab are based on a very rough estimate, since the published data of the agricultural census 2007 are not detailed below governorate level.

Irrigation water demand depends on the crops. Table 4 shows the average crop water requirement (CWR) for the main group of crops. The current estimation of the average CRW per dunum (= 1/10 ha) in the research areas relies on the proportion of these major groups of crops in the Jordan Valley.

Table 4: Water demands in irrigation, Jordan Valley 1994-2008

Type of crop	average	median
	m ³ per dunum	m ³ per dunum
Field crops	422.5	416.8
Vegetables	358.3	356.1
Perennials (trees)	1006.0	1006.7
All crops	581.5	583.3

Source: UoJ, 2009

Water values: The MWI/AFD study on water demand management (MWI/AFD, 2011) is the only comprehensive and nationwide analysis of water values in the different sectors of Jordan's economy. Other references on water valuation for specific cases and areas exist, but are neither comprehensive nor do they allow for the transfer of results to the research areas of SMART.

Water values in the AFD study reflect the gains for Jordan's national economy by using water for a specific purpose. This does not necessarily coincide with the gains of the individual water user, i.e. may not determine the decision making of water end users. Values from the AFD study are mostly based on the "operation surplus", i.e. profit before taxes, which goes beyond water productivities and describes the economic utilization of water.

Downscaling of current average nationwide values to the appropriate values in SMART research locations relied on access to the detailed databases of the AFD study. The values did not affect the scenario calculations itself, but were provided to all other SMART research team in order to provide a baseline to start with in respective calculations (*cf.* tab. 5).

Table 5: Water values, Jordan 2011

Water use	Jordan (avg.)	Irbid, Balqa	Remark
	JD/m ³	JD/m ³	
Domestic water	1,490	1,610	opportunity & replacement costs under the assumption of alternative use for non-residential purposes
			Difference between Jordan average and Irbid & Balqa: opportunity costs
Industry	77,631	110,970	Operation surplus (profit before taxes), 6-year average (2003-2008) based on indexed values with 2008 = 100
			Difference between Jordan average and Irbid & Balqa: without industries "mining", "oil&gas", "tobacco" and "coke, petroleum products, nuclear fuel"
Tourism	38,000	38,000	Operation surplus, profit per m ³
Landscape	1,490	1,610	no own valuation, equal to domestic water (opportunity & replacement costs)
Agriculture			
vegetables	0,789	0,562	Operation surplus, profit per m ³
field crops	0,288	0,288	Operation surplus, profit per m ³
fruit trees	0,149	0,149	Operation surplus, profit per m ³
Livestock	18,060	18,060	Value added per m ³
Shadow values for the current crop mix in the Jordan Valley (2010):			
freshwater	0,389	0,389	shadow value (value of the next m ³ above current availability)
Treated Wastewater	0,240	0,240	shadow value (value of the next m ³ above current availability)

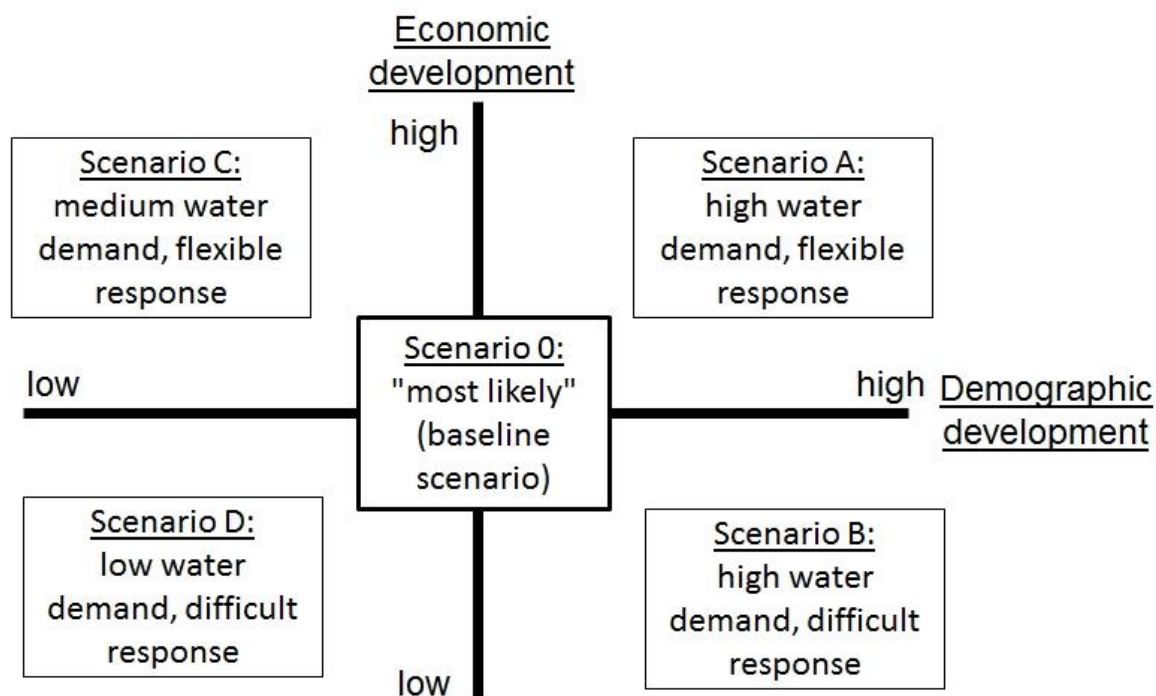
Source: MWI/AFD 2011, downscaling calculations by the authors

Climate Change: Significant impacts from Climate Change are not expectable until the time horizon of the scenarios in 2025 (Smiatek *et al*, 2011; Samuels *et al*, 2011).

2.3. Scenarios

Scenario exercises rely on a set of so called "drivers", i.e. overall conditions that determine the general shape the potential future. The local scenarios in SMART adopt the drivers "economic development" and "demographic development" as major drivers, which correspond to the approaches by (a) the MWIs water demand management scenarios and (b) the downscaling of the IPCC Special Report on Emissions Scenarios (IPCC, 2000). Figure 1 displays the resulting 5 scenarios. The naming of the scenarios was adopted from MWIs Water Demand Management scenario exercise.

Figure 1: Scenario drivers Jordan



Each scenario requires the elaboration of a coherent qualitative narrative, which gives an overall picture about the situation, and the respective calculations with regard to developments in the water sector. Scenarios under the combinations of drivers (1) strong economic development with low demographic development and (2) low economic development with high demographic development were not pursued in SMART. Indicators from these scenarios, which were relevant for IWRM strategies, did not differ sufficiently from the indicators of the three considered scenarios and thus would not justify the additional calculation efforts of other work packages.

Discussions during the scientific committee meetings of SMART led to the reduction of the number of considered scenarios for SMART purposes from 5 to 3 in order to stay within a realistic frame for the scenario calculations.

It is important to keep in mind that Jordan's official Water Strategy (MWI, 2009) and the goals defined therein are the authoritative guidelines for planned developments under all scenarios. The scenario narratives do not repeat the elements and goals of this strategy, but assume them as known by research teams on IWRM. Contribution to the goals of Jordan's Water Strategy is also the yardstick for the evaluation of alternative strategies within the different scenarios (cf. Wolff et al., 2012)

Basic explanations on the situation and assumptions with regard to water demand and supply, which hold for all scenarios, are described in the chapter on scenario Zero ("most likely"). Figures on the development of its individual components are compiled in appendix 2. All figures may also be found on the web-pages of DAISY and DROPEDIA.

2.3.1 Scenario Zero (0): "Most Likely", baseline scenario

Scenario Narrative: Water consumption, demand and supply develop according to the estimates of Jordan's water authorities. Responses of supply to additional demands rely on the development of new water resources (desalinization, wastewater treatment, water imports), the reduction of water losses in conveyance systems and caps of water provision to agriculture. Investments in the reduction of current UFW allow for the rate of success according to the estimations by the utilities, which are lower than the stipulated rate in Jordan's water strategy (MWI, 2009). The stated goal, i.e. to provide all cities and small towns with adequate wastewater collection and treatment facilities, will happen with or without inclusion of SMART technologies.

Development of water demand: Water demand includes water for urban areas (domestic demand), industries, agriculture, tourism, maintained landscapes and expected physical and administrative water losses. Agriculture was assumed constant over the years with 2.835 MCM/year in Wadi Shueib and 10.125 MCM/year in Wadi Arab. Additional water supply that goes beyond of this demand can be put to economically effective use in this sector, whereby water for agriculture may consist out of treated wastewater, too. Table 6 displays the development of the aggregated water demand in the SMART research areas of Wadi Shueib and Wadi Arab.

Table 6: Development of water demand under scenario Zero ("most likely"), all sectors

year	Wadi Shueib	Wadi Arab
	m ³ /year	m ³ /year
2010	7.631.590	25.936.468
2011	7.826.085	26.588.071
2012	8.025.183	27.257.922
2013	8.228.988	27.946.565
2014	8.437.579	28.654.450
2015	8.650.893	29.381.501
2016	8.862.603	30.094.181
2017	9.079.668	30.826.922
2018	9.302.215	31.580.286
2019	9.530.332	32.354.687
2020	9.764.083	33.150.463
2021	9.988.206	33.920.758
2022	10.217.721	34.711.848
2023	10.452.734	35.524.233
2024	10.693.350	36.358.422
2025	10.939.678	37.214.935

Source: calculated by the authors

Development of water supply: water supply comes from local freshwater resources, local water recycling and water imports through Jordan's nationwide freshwater conveyor system. Local freshwater resources include springs and wells, whereby the latter tap on the groundwater base flow. The expected amounts do not vary under different demographic and economic developments and are displayed in table 7 and are valid for all scenarios. The MWI assumes that a maximum of 20% of water from these resources is used for domestic water supply. The rest goes to other sectors, i.e. agriculture and industry, or remains unused.

Table 7: Water supply from local freshwater resources, all scenarios

Location	Gross Capacity	Therefrom for human supply
	MCM/year	
Wadi Shueib	9,4	1,9
Wadi Arab	1,5	0,3

Source: MWI 2004, MWI pers. comm.

The contribution of local water recycling to planned water supply depends on the recycling capacities. However, also untreated wastewater adds to the water balance, either by uncontrolled use in agriculture or infiltration to soils and groundwater. Table 8 shows the

potential wastewater inflow to wastewater treatment plants, i.e. the part of water use from municipal, industrial and touristic water use that would be available for recycling under the assumptions on consumption and losses (*cf.* tab. 2).

Table 8: Development of collectable wastewater under scenario Zero ("most likely")

year	Wadi Shueib	Wadi Arab
	m³/year	m³/year
2010	3.132.907	10.155.031
2011	3.280.017	10.618.341
2012	3.431.997	11.097.328
2013	3.589.004	11.592.512
2014	3.751.185	12.104.380
2015	3.918.615	12.633.183
2016	4.079.670	13.140.843
2017	4.245.835	13.664.801
2018	4.417.263	14.205.560
2019	4.594.089	14.763.561
2020	4.776.442	15.339.218
2021	4.953.806	15.901.274
2022	5.136.578	16.480.684
2023	5.324.906	17.077.938
2024	5.518.944	17.693.539
2025	5.718.850	18.328.003

Source: calculated by the authors

Differences between freshwater from local sources and the expected water consumption require water imports through Jordan's freshwater conveyor system. This holds for the consumption in all sectors except agriculture and landscape. Freshwater used in irrigated agriculture comes from local freshwater sources only, i.e. the difference of 80% between estimated water capacity of local springs and wells and the use of water from these springs and wells for domestic, industrial and touristic water demands. Table 9 shows the required water imports under scenario "most likely".

Table 9: Required freshwater imports under scenario Zero ("most likely")

year	Wadi Shueib	Wadi Arab
	m ³ /year	m ³ /year
2010	2.896.679	15.511.786
2011	3.091.174	16.163.389
2012	3.290.272	16.833.240
2013	3.494.077	17.521.883
2014	3.702.668	18.229.768
2015	3.915.982	18.956.819
2016	4.127.691	19.669.499
2017	4.344.757	20.402.240
2018	4.567.304	21.155.604
2019	4.795.421	21.930.004
2020	5.029.172	22.725.781
2021	5.253.295	23.496.076
2022	5.482.810	24.287.166
2023	5.717.823	25.099.551
2024	5.958.439	25.933.740
2025	6.204.767	26.790.253

Source: calculated by the authors

2.3.2 Scenario MAX: High Demands to Water Sector Development

Scenario Narrative: Water consumption in the domestic sector increases more than expected due to higher population growth combined with a higher water demand per capita due to better household incomes. Industrial and touristic water demand develops on the upper bound of estimations, too. This leads to the respective higher amounts of wastewater and the related requirement of treatment capacities. Strategies to cope with the additional demands to water supply and wastewater treatment may anticipate a favourable situation for fund raising and may also count on a higher coverage of total water costs by water users. This may weigh compromises between financial reflections and goal achievement towards the latter. The improved economic development allows also a more efficient reduction of UFW, which will reach the anticipated level of 25% in 2025 according to Jordan's water strategy (MWI, 2009)

Development of water demand: The explanation on general assumptions with regard to water demand corresponds to those in the description of scenario Zero (cf. chapter 2.3.1). Table 10 displays the development of the aggregated water demand under scenario MAX.

Table 10: Development of water demand under scenario MAX, all sectors

year	Wadi Shueib	Wadi Arab
	m ³ /year	m ³ /year
2010	7.769.316	28.017.047
2011	8.051.536	28.970.857
2012	8.342.238	29.940.528
2013	8.643.682	30.933.915
2014	8.955.170	31.947.589
2015	9.277.253	32.982.854
2016	9.618.317	34.093.859
2017	9.971.642	35.232.544
2018	10.337.766	36.400.086
2019	10.716.964	37.596.646
2020	11.109.613	38.822.739
2021	11.513.350	40.141.658
2022	11.931.351	41.497.313
2023	12.364.206	42.891.206
2024	12.812.300	44.505.777
2025	13.276.139	46.203.068

source: calculated by the authors

Development of water supply: The explanation on general assumptions with regard to water supply corresponds to those in the description of scenario Zero (cf. chapter 2.3.1). Table 11 displays the development of the aggregated water flows, which vary between the scenarios, under scenario MAX.

Table 11: Variable water flows under scenario MAX

	Water imports		Collectable wastewater	
Region:	Wadi Shueib	Wadi Arab	Wadi Shueib	Wadi Arab
year	m ³ /year			
2010	3.034.405	17.592.364	3.222.862	10.446.611
2011	3.316.625	18.546.174	3.438.747	11.160.123
2012	3.607.327	19.515.845	3.663.078	11.902.468
2013	3.908.771	20.509.233	3.897.175	12.678.179
2014	4.220.259	21.522.907	4.140.885	13.486.785
2015	4.542.342	22.558.172	4.394.685	14.329.955
2016	4.883.406	23.669.177	4.659.047	15.205.184
2017	5.236.731	24.807.862	4.934.217	16.117.032
2018	5.602.855	25.975.404	5.220.664	17.067.117
2019	5.982.053	27.171.964	5.518.725	18.056.619
2020	6.374.702	28.398.056	5.828.802	19.086.929
2021	6.778.439	29.716.976	6.151.452	20.159.982
2022	7.196.440	31.072.631	6.486.968	21.276.808
2023	7.629.295	32.466.524	6.835.880	22.439.245
2024	8.077.389	34.081.095	7.198.621	23.648.807
2025	8.541.228	35.778.386	7.575.693	24.907.250

source: calculated by the authors

2.3.3 Scenario MIN: Low Demands to Water Sector Development

Scenario Narrative: The lower than expected demographic growth and the economic stress on household incomes lead to the lowest increase in domestic and municipal water demand compared to all other scenarios. Also water demand from industry and tourism develops on the lower bound of estimations. The leeway for water tariffs for water consumers remains limited and may require divergences from the goals of full cost coverage. Economic aspects in compromises between financial reflections and goal achievement get a stronger weight. Investments in the reduction of current UFW still achieve the rate of success according to the estimations by the utilities.

Development of water demand: The explanation on general assumptions with regard to water demand corresponds to those in the description of scenario Zero (cf. chapter 2.3.1). Table 12 displays the development of the aggregated water demand under scenario MIN.

Table 12: Development of water demand under scenario MIN, all sectors

year	Wadi Shueib	Wadi Arab
	m ³ /year	m ³ /year
2010	7.609.135	25.862.447
2011	7.781.239	26.496.352
2012	7.953.720	27.132.540
2013	8.126.301	27.734.126
2014	8.298.750	28.339.108
2015	8.470.784	28.946.459
2016	8.643.905	29.589.908
2017	8.817.291	30.241.992
2018	8.990.799	30.902.468
2019	9.164.261	31.570.995
2020	9.337.478	32.247.122
2021	9.514.091	32.913.759
2022	9.691.168	33.588.164
2023	9.868.574	34.269.995
2024	10.046.163	34.958.874
2025	10.223.779	35.654.390

source: calculated by the authors

Development of water supply: The explanation on general assumptions with regard to water supply corresponds to those in the description of scenario Zero (cf. chapter 2.3.1). Table 13 displays the development of the aggregated water flows, which vary between the scenarios, under scenario MIN.

Table 13: Variable water flows under scenario MIN

	Water imports		Collectable wastewater	
Region:	Wadi Shueib	Wadi Arab	Wadi Shueib	Wadi Arab
year	m ³ /year			
2010	2.874.224	15.437.765	3.118.241	10.107.492
2011	3.046.328	16.071.670	3.261.858	10.559.582
2012	3.218.809	16.707.858	3.410.204	11.026.899
2013	3.391.390	17.309.444	3.563.358	11.509.716
2014	3.563.839	17.914.426	3.721.427	12.008.400
2015	3.735.873	18.521.777	3.884.500	12.523.243
2016	3.908.994	19.165.225	4.041.002	13.016.327
2017	4.082.380	19.817.310	4.202.310	13.524.751
2018	4.255.888	20.477.786	4.368.560	14.048.965
2019	4.429.350	21.146.313	4.539.886	14.589.400
2020	4.602.567	21.822.440	4.716.413	15.146.463
2021	4.779.180	22.489.077	4.887.736	15.689.211
2022	4.956.257	23.163.482	5.064.116	16.248.205
2023	5.133.663	23.845.313	5.245.691	16.823.893
2024	5.311.252	24.534.192	5.432.599	17.416.732
2025	5.488.868	25.229.707	5.624.984	18.027.189

source: calculated by the authors

2.3.4 Preliminary indications from scenario results

The major intention of the scenario exercise was to provide SMART experts with an evaluation framework for impact analyses based on "with-without" comparisons for of their specific field of innovation development. However, the comparison of the three scenario themselves allows for some conclusions, which help in the estimation of potentials of changes in water resource management. More detailed analyses are possible, but go beyond the current assignment of the workgroup on scenario development in SMART.

Initial observations:

- The potential of wastewater recycling would cover the current agricultural water demand in Wadi Shueib as well as in Wadi Arab already nowadays. However, it is likely that the availability of more water would lead to an extension of irrigation areas. An evaluation of these effects and interdependencies would require an analysis of farming systems and enterprises, e.g. their potentials for investments and spatial expansion. The amount of

treated wastewater, which may alternatively go to aquifer recharge, depend at least as much on the aforementioned capacities of farming systems as on its quality.

- Observations in the area indicated that at least a part of the untreated wastewater is used for irrigated agriculture. The interdependencies between growing, and more expensive amounts in treated wastewater and the reduced availability of cheap wastewater will need closer analysis in order to minimize local resistance against innovations in water treatment.
- The increasing amounts of wastewater are the result of increasing water imports in both areas. Potentials from wastewater treatment will thus depend on the overall development of Jordan's freshwater conveyor infrastructure and water production in other regions. Any sustainable planning of local wastewater treatment coverage will crucially rely on the inclusion of these supra-regional interdependencies in the planning process.

3 Jericho

(H.-P. Wolff, A. Tamimi, A Jarrar)

3.1. Sources of information about the water sector

The Palestinian Water Law assigned the responsibility of building and developing the institutions in the water and sanitation sector, the construction and the rehabilitation of the depleted infrastructure and the improvement of water and wastewater services to the Palestinian Water Authority in 1996. However, the situation in the occupied Palestinian territories and its administrative set-up remained unstable and a verifiable centralized collection of information on the water sector is still only in its development stage. A first strategic water sector plan for Palestine was developed in 2010, but at least two different versions were published (cf. PWA, 2010; LACS, 2010). The comparatively short period of this plan, which covers the period from 2011 to 2013 only, indicates the insecurity of assumptions on the development of the water sector under the given political situation in the West Bank.

Information about the Palestinian water sector is a politically sensitive issue and any obtained information requires intensive cross-checking. This holds for secondary information from references and international organizations as well as for primary information from files and databases. It is advisable to cross-check data requirements for limited local research questions by own observations if possible. The most important sources for information on the water sector are

1) Administrative bodies of the Palestinian National Authority (PNA)

- Palestinian Water Authority (PWA)
- Ministry of Agriculture
- Environmental Quality Authority / Ministry of the Environment
- Ministry of Local Government
- Ministry of Health The Association of Water Service Providers
- Ministry of Industry The Water Consumers Association
- Palestinian Central Bureau of Statistics (PCBS)

2) Regional Water Institutions:

- West Bank Water Department
- Coastal Water Authority
- Jerusalem Water Undertaking
- Environmental and Water Research Centres at local universities

3) Non-governmental organizations (NGOs)

(A large number of NGOs is active in Palestine. The following list is by no means complete, but mentions the largest and most knowledgeable local NGOs with regard to water)

- Palestinian Hydrological Group (PHG, located in Ramallah)
- Palestinian Agricultural Relief Committee (PARC, located in Ramallah)
- Agricultural Research Institute Jerusalem (ARIJ, located in Bethlehem)

4) International support organizations

- Local Aid Coordination Secretariat (coordinates all donor activities, located in Ramallah)
- Website of FAO-Aquastat (<http://www.fao.org/nr/water/aquastat/main/index.stm>)
- World Bank (World Bank 2009a, 2009b)

5) Local administrations and local private associations

- Offices of the municipalities
- Farmers' associations
- Local offices of the above mentioned NGOs

3.1.1 Water administration

The "National Sector Strategy for Water and Waste Water in Palestine" provides a description of the water administration of the Palestinian Authority, its organizations and advisory committees (*cf.* PWA, 2010; LACS, 2010). However, the specific history and situation of the West Bank impeded so far the development of comprehensive centralized administrations such as e.g. in Jordan. Intended organizations, such as e.g. a National Water Utility, are still in the stage of planning.

Planning and implementation of local water resources management depends strongly on the municipal authorities and administrations of the 16 governorates. Water users associations or equivalent civil representations of water users do not exist until now (*cf.* Lamaddalena et al., 2012). Farmers' associations focus mostly on agricultural production and include only in a few cases components of joint water systems management. A part of the wells and shallow boreholes belong to private owners, which renders the situation for water management more comparable to the situation in the Jordanian highlands than to the situation in the Jordanian East Bank.

A very important factor – and a major obstacle to purely engineering approaches – is the right of say by the joint Israeli-Palestinian Water Committee (JWC) and the Joints Supervisions and Enforcement Mechanisms (JSETs). Authorization by this committee is required for basically all

construction of water infrastructure, such as e.g. wastewater treatment plants, wells etc. This holds not only, but in particular, for areas B and C, where Israel retains the control of security and, in the case of area C, also the administrative control.

3.1.2 Water accounting

Water accounting in Palestine, i.e. the attribution of water flows to categories and their inclusion of flows in the water balance, depends on the situation in a specific location. The following waster accounts hold for the area of Jericho, i.e. the research area of SMART.

- Domestic water includes only water for private households. Other municipal water demands fall into the categories public water demand (public demand centres such as security, governmental, religious and municipality centres) and commercial water demand (shops, small industries, private offices).
- Water for tourism is currently included in commercial water demand. A constant distinct recording of water demand by tourism does not exist and estimations rely on sample surveys only.
- Industrial Water includes only large industries. The only large industry in the area is the planned agro-industrial zone in Jericho, which will – according to planning – receive water from Jericho only during its start-up phase. Industries in the park will need to cover their water demands afterwards by purchase from Mekorot as long as Palestine acquires no additional water rights.
- Water use for agriculture is composed out of water (1) from water conveyors under the supervisions of the municipalities and the PWA and (2) from wells and springs in the ownership of farmers. Statements on the former rely on the measurements at the water heads (i.e. inflow to conveyors), statements on the latter mostly on rough estimations based on standard CWRs. Metering of privately owned wells and springs is rare.
- Refugee camps receive water in bulks from the local water providers, e.g. mostly the municipalities. A distinction between different uses in the camps is not officially recorded.

The amount of water conceded to the Palestinian Authority in the Oslo II accords does not even cover the current Palestinian water consumption (cf. FAO, 2008; World Bank, 2009a). Additional amounts have to be purchased from Israeli water companies. Any evaluation of additionally created amounts of water through IWRM measures has thus to consider not only the potential benefit from this water, but also the potential compensation effects with regard to the Israeli-Palestinian water balance.

3.2 Sources of data

3.2.1 General

The Palestinian Central Bureau of Statistics (PCBS) publishes the official statistics of the PNA in aggregated tables on its website <http://www.pcbs.gov.ps/default.aspx> . Data sources are contributions from other ministries, which by themselves receive information from their offices in the governorates. This implies a certain delay and more up-to-date records may be accessed at the local offices, provided a respective authorization from the central authorities.

Non-governmental organizations (NGOs), such as e.g. PHG, played an outstanding role in the representation and fulfilment of needs of the Palestinian population before the founding of the PNA in 1994. They continue to do so until today and possess a substantial amount of data on all issues of water and water resource management. However, these data are the result of projects, which became possible due to long-term international and national fund raising, as well as from self-funded programmes of the NGOs. Consequently, these data are not "common property". All rights to these data remain with the NGOs and access to these data depends on agreements between the NGOs and researchers on an individual basis.

Data on past developments for the SMART scenarios were provided by PHG from own surveys, by the municipality of Jericho from municipality records of 2009 and analyses on tourism development by the Japanese International Cooperation Agency (JICA). The assumptions and calculations follow the basic analyses of the scenario development exercise of PHG, which constitute the current authoritative scenario assumption of the PWA and the Municipality of Jericho.

3.2.2 Data on water

The municipal utility collects data on water supply and consumption and communicates them to the PWA. Major bottlenecks to the reliability of these data are problems with the metering of water outlets due to missing or damaged metering equipment. Cross-checks with standard consumptions per sector indicate that the recorded data may be considered as realistic, even if the exact share and magnitude of water consumption per sector stays unknown.

The scales of these cross-checks and supporting information on water use from sources outside of the utility's network, i.e. privately operated groundwater wells, are results from data collection (e.g. surveys), data compilations and analyses by PHG.

Access to this information requires direct requests and permissions by the PWA and PHG.

3.2.3 Estimations on future developments

Demographic growth: The Palestinian Central Bureau of Statistics (PCBS) calculates with a population growth of about 2,7% in the Jericho area until 2030 and considers variations of the rate as highly unlikely. The stated growth rate was consequently unchanged in all scenarios. However, water demand per capita differs between the scenarios.

Economic growth: Expectations on the basic economic growth in Jericho City are directly related to demographic growth. The increase in water demand for the commercial sector develops from its current status proportional to the increase in population. Increases in water demand above average arise from the expected installation of an agro-industrial park and the development of the touristic sector. However, the development of both of these water consuming sectors depends on the respective scenario.

Water Supply: The main water source for Jericho City and surrounding areas are the Ein As Sultan springs with an average discharge of about 5,67 MCM/year, wherefrom about 80% reaches the supply sides nowadays. Water from Ein As Sultan feed the current domestic water network and the separate agricultural water network. The agricultural water network supplies all agricultural areas with the exception of the majority of areas east of Jericho city. The latter depend on water supply from local groundwater wells, which currently provide decreasing water quantities with a growing degree of salinity.

Additional water supply in the future under all scenarios is expected from the upcoming wastewater treatment plant in Jericho East. Further potential water sources, which depend on the scenario assumptions, are groundwater from Samed Well and Jericho New Well, water purchases from Ed Dyke At Tihta Spring and stormwater harvesting by storage earth pools. The potential construction of desalination plants for brackish water is part of the long term perspective but considered unlikely until 2025.

Water Demand: The current structure of water demand and consumption by individual households offers a number of options for reduction through water demand management. The implementation of these options depends on the development of the frame conditions, i.e. the scenario, and includes changes of cooling systems, modification of tariff systems and institutional reforms.

Water management: The water system of Jericho city is currently composed of two water components. The Ein As Sultan spring supply water for the domestic network, the agricultural network and Ein As Sultan Camp. Groundwater wells supply water for farms located outside the

Jericho city and are not connected to the water infrastructure of the other both networks. Connecting both systems would allow for a significantly more effective combination and management of water supply, but has to overcome restrictions from well ownership and investments first. Advantages would be possibilities for blending waters, a wider leeway in allocating water to areas with temporary bottlenecks in water supply and a better integrated use of treated wastewater from the wastewater treatment plant, which is currently under construction in Jericho East.

Water shares from Ein As Sultan springs are in private ownership. The current institutional set-up for water trades does not match the given physical water infrastructure. Implementing a solution to these problems depends on the assumed frame conditions in the future, i.e. the respective scenario.

Wastewater: The amount of generated wastewater remains constant in all scenarios and is up to 65,5% in domestic water use, 45% in public water use and 50% in commercial water use. A wastewater treatment plant is under construction in Jericho East with funding from JICA and will go, according to planning, into operation in 2015. The JICA project also includes the construction of the necessary infrastructure for wastewater collection in Jericho City. The design volume of this plant is 9.900 m³/day. i.e. around 3.6 MCM/year (JICA, 2010). Further extensions of wastewater treatment capacities are desired when wastewater formation exceeds this volume, but no planning exists on how such extensions will be achieved. However, collectable amounts of wastewater in Jericho City will not reach this limit until 2025.

Water Losses: All prognoses and planning assumptions consider the rate of losses of currently 23,7% as constant due to the continued maintenance of the network by the municipality of Jericho.

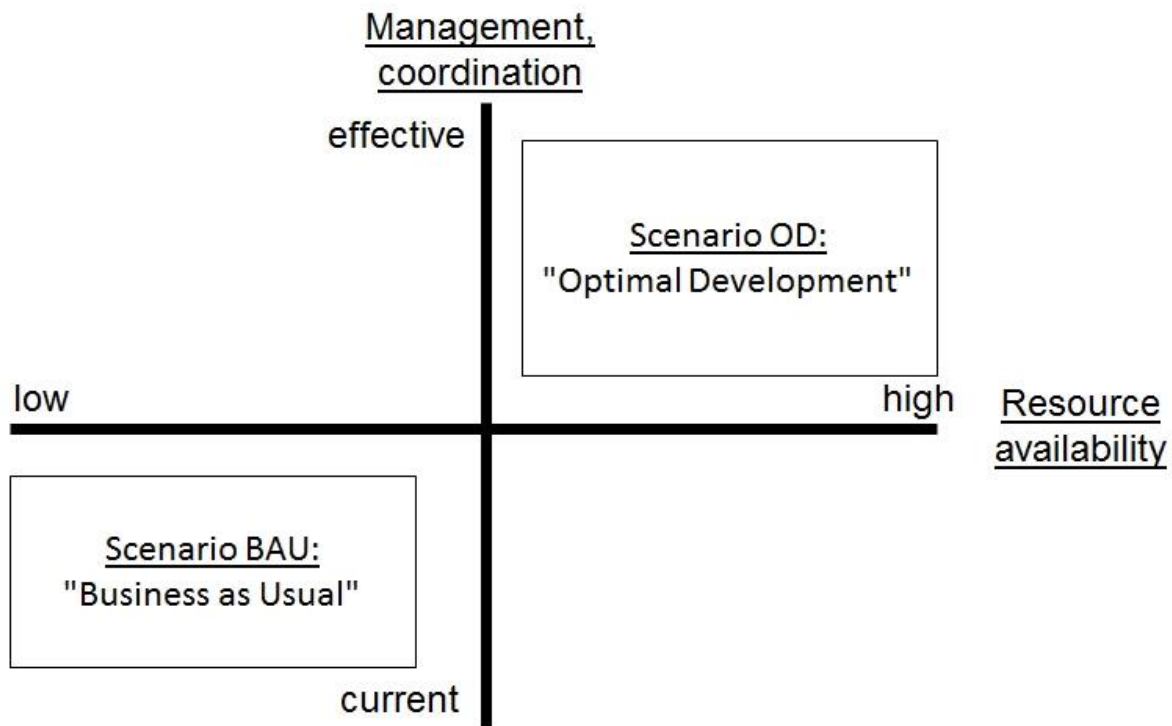
3.3. Scenarios

Existing results from regional scenario exercises are too highly aggregated for meaningful results from direct downscaling due to the distinct diversity of situations between the areas in the Palestinian West Bank. However, scenario development for Jericho could resort to data, agreed-upon assumptions and findings from the recent design of the Water Master Plan for Jericho City (AFD et al., 2011), which was organized and implemented by PHG.

The stakeholders in Jericho identified "management and coordination among stakeholders" and "resource availability under Climate Change" as the two most significant factors for future developments in the water sector (*cf.* fig. 2). Assumptions were that (a) a further deterioration in

the drivers themselves is not likely and (b) variations in demographic growth may arise due to immigration, but not from changes in the natural growth within the governorate. However, migration due to external causes was considered as a non-quantifiable event in terms of size and timing under the given political situation. This excluded demographic growth as a suitable driver of frame conditions for water sector scenarios.

Figure 2: Scenario drivers, Jericho



The scenario exercise boiled down the vast amount of potential developments to 2 most probable scenarios, which represent

- The worst case scenario without progress in water resources management and coordination among actors as well as under limited resource availability and
- The best case scenario, which reflects a competent management, an improved coordination and the availability of additional water resources (without additional, potential contributions from SMART developments).

The water-related results from all other scenarios fell between these both extremes. Figures on the development of the individual components are compiled in appendix 3. All figures may also be found on the web-pages of DAISY and DROPEdia.

3.3.1 Scenario BAU: "Business as Usual"

Scenario Narrative: Negotiations with holders of private water rights and wells fail and investments in water infrastructure above the preservation of existing tanks, conveyance and meters do not take place. The current water supply system remains unchanged with two separated set-ups of the both major water resources (1) Ein As Sultan springs and (2) groundwater wells east of Jericho. Poor household incomes and a lack of donor-supported promotion of water saving devices and techniques leave domestic water demand unchanged at the current level of 250 l/c/d. However, this demand can only be partially satisfied with the available water supplies. The same factors lead to a lack of improved irrigation infrastructure and the related applicability of irrigation methods in agriculture. Results are increasing water demands from agriculture under a decreasing supply of water for irrigation. A further reason for this increase in demand of water for irrigation is the lack of alternative employment for citizens in the area. The creation of new job opportunities, like the expected construction of the agro-industrial park and substantial increases of business in tourism, fail in this scenario. Established but inefficient structures in communal water management do not change under the given situation, which lacks incentives for administrative improvements.

Development of water demand: Water demand rises in all sectors, but cannot be met by the available water supply. Table 14 displays the realizable water use. Water use is the sum of water consumption and remaining wastewater. Water use rises in particular due to the increase in domestic, public and commercial water demand by demographic growth. Agricultural freshwater use decreases in all areas with the decreasing water supply through Jericho's conveyor infrastructure for water from the Ein As Sultan springs. However, agricultural use of treated wastewater over-compensates this effect, but agriculture in the eastern part of Jericho relies on pumping of increasingly saline water from private groundwater wells in this area. Water supply to the refugee camps Ein As Sultan Camp and Aqbat Jaber remains constant on the current level.

Table 14: Development of water use under scenario BAU, Jericho City

year	All sectors	Therefrom: Agriculture
	m ³ /year	m ³ /year
2010	8.935.479	6.187.000
2011	9.043.454	6.231.310
2012	9.153.217	6.275.689
2013	9.264.816	6.320.138
2014	9.378.298	6.364.657
2015	9.493.715	6.409.249
2016	9.911.118	6.453.915
2017	10.030.559	6.498.655
2018	10.152.092	6.543.470
2019	10.275.774	6.588.363
2020	10.401.662	6.633.334
2021	11.229.814	6.678.385
2022	11.360.290	6.723.516
2023	11.493.153	6.768.730
2024	11.628.467	6.814.027
2025	11.766.295	6.859.409

source: calculated by the authors

Development of water supply: Water from the Ein As Sultan springs and water from groundwater wells and their distribution networks remain separated under the conditions of scenario BAU. Treated wastewater from the new treatment plant provides additional water for agricultural purposes, but increases in its potential through blending with saline water are not possible due to the missing network link. Table 15 displays the assumed supply from these sources.

Differences between supply and demand, i.e. un-met demand, will have to be covered either by water purchase or by reducing water consumption. The latter holds in particular for agriculture, where unmet demand most likely results in reduced production due to decreasing cultivated areas.

Table 15: Development of water supply under scenario BAU, Jericho City

year	Ein As Sultan springs (delivery at supply sites)	Groundwater wells	Treated Wastewater
m ³ /year			
2010	4.530.000	2.860.000	0
2011	4.540.000	2.735.000	0
2012	4.550.000	2.610.000	0
2013	4.560.000	2.485.000	0
2014	4.570.000	2.360.000	0
2015	4.580.000	2.235.000	1.413.393
2016	4.590.000	2.110.000	1.411.229
2017	4.600.000	1.985.000	1.409.066
2018	4.610.000	1.860.000	1.406.902
2019	4.620.000	1.735.000	1.404.739
2020	4.630.000	1.610.000	1.402.575
2021	4.630.000	1.539.000	1.416.909
2022	4.630.000	1.468.000	1.431.242
2023	4.630.000	1.397.000	1.445.576
2024	4.630.000	1.326.000	1.459.909
2025	4.630.000	1.255.000	1.474.243

source: calculated by the authors

3.3.2 Scenario OD: "Optimal Development"

Scenario Narrative: Negotiations with private water rights and wells succeed and new investments in water infrastructure, such as well rehabilitation, new tanks and conveyance infrastructure, take place. The hitherto separated water structures of the Ein As Sultan springs and groundwater wells east of Jericho are connected and allow for a joint management of all available water resources. The development of job opportunities leads to increasing water demands from the industrial and touristic sector, but creates simultaneously higher household incomes, too. This and extended donor-supported propagation of water saving techniques and devices allow for investments by households, which leads to decreasing water demands per capita. The overall domestic water demand decreases until about 2020, consequently. Afterwards, impacts from the more sensitive use of water in households become fully compensated by demographic growth and restarts to increase.

Water from new and rehabilitated wells is used for agriculture with more sophisticated irrigation technologies and approaches. Additional water for agriculture comes from storm water

harvesting in earth pools and a new tank for blending treated wastewater with brackish water from the groundwater wells. This allows for a stronger increase of cultivated areas with smaller additional demands to water supply. The creation of job opportunities in industry and tourism puts additional demands to freshwater supply. The municipalities' water network will supply the planned agro-industrial park with 100.000 m³/year of water during its installation phase of from 2012 until the end of the scenario horizon. Additional water for tourism increases the amount of required commercial water within Jericho city.

Development of water demand: Total water demand from urban areas decreases until 2020 due to the successful introduction of measures from water demand management. It reaches and exceeds the current level of total water demand again after 2020 due to demographic growth. The development in water consumption by agriculture corresponds to scenario BAU, but reflects a higher coverage of water demands due to the use of improved irrigation techniques and respective cropping patterns (*cf.* tab. 16). This becomes possible due to the better quality, i.e. lower salinity, of water provided to agriculture. Water supply to the refugee camps Ein As Sultan Camp and Aqbat Jaber remains constant on the current level.

Table 16: Development of water use under scenario OP, Jericho City

year	All sectors	Therefrom: Agriculture
	m ³ /year	m ³ /year
2010	8.915.500	6.187.000
2011	8.955.410	6.231.310
2012	8.995.389	6.275.689
2013	9.035.438	6.320.138
2014	9.075.557	6.364.657
2015	9.215.749	6.409.249
2016	9.556.015	6.453.915
2017	9.596.355	6.498.655
2018	9.636.770	6.543.470
2019	9.677.263	6.588.363
2020	9.717.834	6.633.334
2021	10.487.985	6.678.385
2022	10.558.216	6.723.516
2023	10.628.530	6.768.730
2024	10.698.927	6.814.027
2025	10.769.409	6.859.409

source: calculated by the authors

Development of water supply: The distribution networks for water from the Ein As Sultan springs and water from groundwater wells will be linked and allow for an optimization of water allocation in terms of quantity and quality. Improvements in the infrastructure, such as pumps and tanks, allow for increases in the amount and reliability of water supply from these sources. Treated wastewater from the new treatment plant provides not only directly additional water for agricultural purposes, but is also available for blending with otherwise unsuitable saline water.

Additional freshwater comes from the mobilization of new water resources, such as new and rehabilitated wells and stormwater harvesting as well as from the institutionalization of trading contracts with well owners outside of Wadi Quilt. Table 17 displays the assumed supply from these sources.

Table 17: Development of water supply under scenario OP, Jericho City

year	Combined Network (Ein As Sultan Springs & new developed wells)	Mixing Tank (blending treated wastewater + saline water, for agricultural use only)	Earth pools (stormwater)
m ³ /year			
2010	4.530.000	0	0
2011	4.540.000	0	0
2012	4.812.800	0	0
2013	4.822.800	0	0
2014	5.270.800	0	0
2015	5.280.800	2.000.000	0
2016	5.290.800	2.000.000	0
2017	5.300.800	2.000.000	0
2018	5.310.800	2.000.000	1.000.000
2019	5.320.800	2.000.000	1.000.000
2020	5.330.800	2.000.000	1.000.000
2021	5.330.800	2.000.000	1.000.000
2022	5.330.800	2.000.000	1.500.000
2023	5.330.800	2.000.000	1.500.000
2024	5.330.800	2.000.000	1.500.000
2025	5.330.800	2.000.000	1.500.000

source: calculated by the authors

3.3.3 Preliminary indications from scenario results

The governorate of Jericho is not ridden by natural water scarcity *per se*. Water consumption in urban areas is significantly higher than in comparable communities on the East Bank, but also significantly lower than in Israeli settlements. However, water availability restricts the potential of agricultural production and forces Palestinian farmers to leave large areas of cultivated land as fallow land.

The start of operations of the large-scale wastewater treatment plant in Jericho East, which is in its final phase of construction, will provide sufficient capacity for the full sanitation of the Jericho governorate even beyond the scenario period until 2025. Current planning foresees only the connection of Jericho City to this treatment plant, but this will leave still some capacity for the potential connection of water users in adjacent areas. However, plans for the extension of the wastewater collection infrastructure beyond Jericho City do not exist yet.

Water demand management (WDM) and the success of the foreseen WDM measures will be a significant factor in obtaining a neutral water balance. However, the success will strongly depend on the investment capacities of individual commercial enterprises as well as of private and public households.

Water purchases from the Ed Dyke At Tihta Spring, which is located in Wadi Nuweima, play a role for covering gaps between demand and supply in both scenarios. Any water planning in Wadi Nuweima will not have to consider these water exports to Jericho City only, but also the implications of this possibility for local water trade. Potential implications include e.g. water pricing in Wadi Nuweima as well as competition between sectors of local water use and water exports.

The current estimations of the stakeholders in Jericho indicate that desalinisation of groundwater from wells in Jericho East will become a potential contributor to local water supply only after 2025. This estimation relies on the current technological state of the art of desalinisation plants and may change, if technical innovation leads to economically sound solutions before that date.

4 Kalya

(H.-P. Wolff, J. Guttman)

4.1. Sources of information about the water sector

All water controlled by Israel belongs to the state and is handled through the Israeli Water Authority via contractors. Water supply and water infrastructure in the area of Kalya are provided by the public water company Mekorot. Mekorot acts in accordance with the Israeli Water Authority and under the specifications of the planning by the Ministry of National Infrastructures (MNI). MNI published a transitional water master plan in 2002, which stated the requirement of updates in 3-year periods (MNI, 2002). A new formulation of the master plan is currently under way, but was not officially approved by the time of this manuscript. The Israeli consulting company *Tahal Group International B.V.* develops this plan on behalf of the Israeli Water Authority and published the intended baselines in 2012 (IWA, 2012). The responsible policy body for decisions on implementations in the water sector is the Water Authority Council, which consists out of leading representatives from all concerned ministries.

More detailed information on selected topics of current water use efficiency in Israel are accessible from the planning department of the Ministry of National Infrastructure (Rejwan, 2011a), the websites of Israel's Central Bureau of Statistics (CBS, http://www1.cbs.gov.il/reader/cw_usr_view_Folder?ID=141) and the regional water program of the UNEP/MAP regional activity centre "Plan Bleu" and (Rejwan, 2011b).

Kalya is an Israeli settlement beyond the green line, i.e. Israel's border before the 6-days war. Settlements are included in Israel's water master plan, but the design and implementation of water supply and infrastructure for a specific area is in the responsibility of Mekorot, which acts as the direct contact between water users and the Israeli water authorities. An official local water master plan for Kalya does not exist, but Mekorot works on a comparable internal planning for its service areas.

Initial information on the water sector in the Kalya settlement was retrieved from the work of SMART-partners during both phases of SMART (Milgrom *et al.* 2009, Bensabat *et al.* 2010). Additional information and updates were provided from SMART-partner J. Guttman of the Israeli water company Mekorot during the term of SMART II.

4.2. Development information

Kalya is part of the Ihud HaKibbutzim movement and mainly based on income from agriculture and tourism. Freshwater supplies from the Mizpe-Jericho springs cover the compulsory freshwater requirements for domestic, public and touristic water consumption far beyond 2025, i.e. the considered period of the scenarios. In addition, Mekorot plans to drill a new well in Mizpe-Jericho with an annual capacity of about 2 MCM in 2014. Temporary water scarcity and needs for the mobilization of additional water resources are related to agriculture and environmental services, which may affect tourism in the area.

Agriculture, which relies mainly on the production of dates, cherry tomatoes and condiments, may be extended to additional areas if additional water would become available or include other profitable crops if water quality would be improved in terms of salinity. However, the currently predominant problem of water scarcity in agriculture concerns water shortages during peak days of water demand (*cf.* Milgrom et al. 2009). Dairy production as the main element in local livestock husbandry depends on the availability of fresh water, which is no limiting factor yet.

Environmental services include three natural parks and seven natural reserves (*cf.* Milgrom et al. 2009). Water scarcity will become a particular problem in the touristic part around the Feshkha spring due to the reduced discharge of the existing pumping station as a result from the decreasing level of the Dead Sea. The Israeli Natural reserve authority, which operates the area, plans to build an intake on one or two streams in order to bring water to the open swimming pools for tourists. However, this project is just in the phase of an early suggestion and may be considered as an alternative. Its realization and extent will depend on the deliberations between IWA and Mekorot as well as on potential partners in investments and water allocation.

Resources of water with lower quality, i.e. brackish water, for agricultural and environmental purposes comprise Feshkha springs, Kane & Samar springs and the Og reservoir. The latter receives sewage from the north-eastern neighborhoods of Jerusalem and from the settlements Ma'aleh Adumim, Adam, Anatot and Mizpe Jericho. The quality of the effluent from Og reservoir is considered suitable for irrigation purposes due to the effects from primary treatment during its flow to the reservoir (Haghion, 2011). Parts of the water from the Og reservoir are allocated and transferred to the settlement Moshav Fazaal, north-east of Jerusalem.

The ground- and surface water resources of the Kalya area exceed the actual water consumption of local municipal needs and economic activities. However, remaining waters serve either environmental purposes (national parks, Dead Sea) or are exported to other settlements. Inflows from Israel's water infrastructure to the Kalya area are restricted to the

above mentioned sewage to the Og reservoir. Outflows from the area comprise the water transfer from the Og reservoir to the Fazeel settlement and the unused discharge of saline water from the Feshkha, Kane and Samar springs that flows into the Dead Sea. Table 18 shows the existing and potential water resources of the Kalya research area

Table 18: Existing and potential water resources of Kalya

Source	Annual discharge (MCM)	Water quality	Users
Mizpe-Jericho wells (current)	4,04 – 4,71 ¹	freshwater	All sectors
Mizpe-Jericho well (new, expected start: 2014)	2,00	freshwater	All sectors
Kane & Samar springs	0,31-0,45 ¹	saline water	Agriculture, environment
Feshkha springs	60 – 65 ²	saline water	Agriculture (1-2 MCM), environment, tourism (pools)
Potential new Feshkha pumping station (max.)	10 ¹	saline water	Tourism (pools), Agriculture
Og reservoir	Effluent: 5,0 ¹	Treated sewage (influent: 7,3 MCM/year ³)	Agriculture (partially exported)

¹ source: Mekorot

² source: Bensabat et al., 2010

³ source: Hagihon Company Ltd, 2011

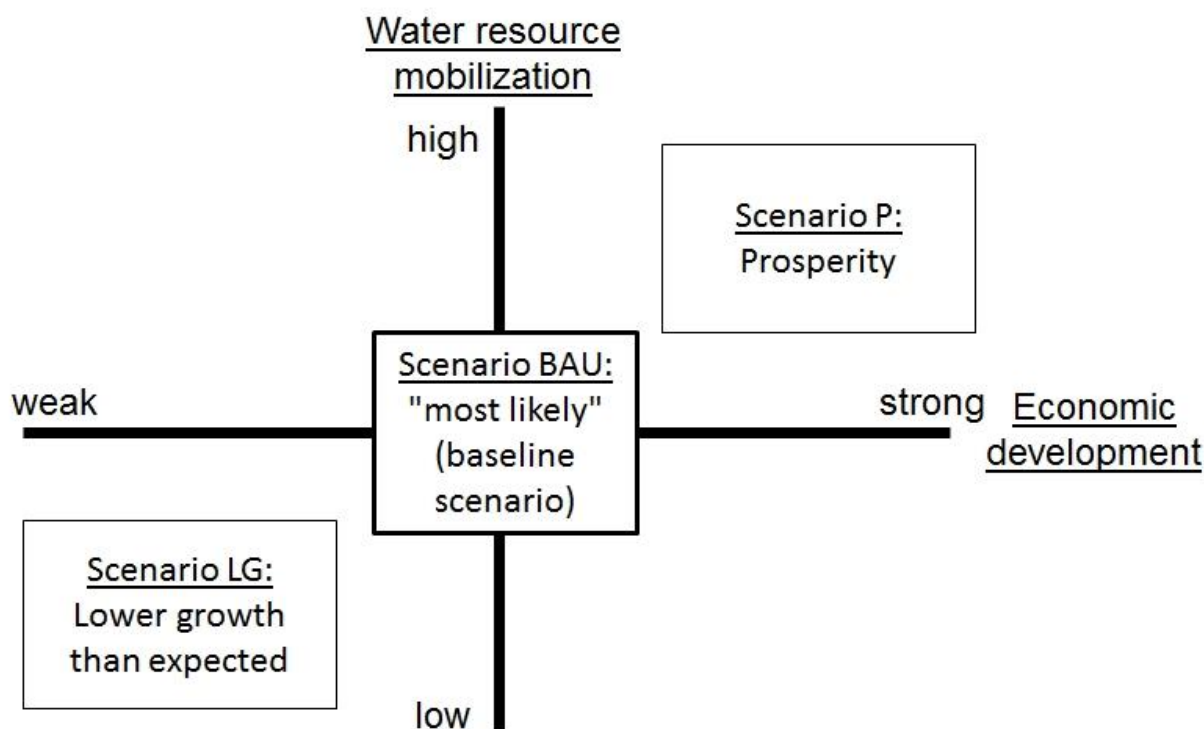
4.3. Scenarios

The situation of Kalya suggests "water resource mobilization" and "economic development" as the both major drivers for the development of the local water sector until 2025. However, the choice of these drivers depends on an "educated guess" of the scenario developers only. Recent local scenario exercises were not available. Figure 3 displays the resulting scenarios.

The outline of the scenarios "Prosperity" and "Lower growth than expected" combined the extreme developments in water resource mobilization and economic development. All other combinations yielded results between the outcomes of these both scenarios. Scenario "Business as usual" considers the current prognoses on water demands and assumes the realization of already decided changes in water resource mobilization.

Figures on the development of the individual components are compiled in appendix 4. All figures may also be found on the web-pages of DAISY and DROPEDIA.

Figure 3: Scenario drivers, Kalya



4.3.1 Scenario BAU: "Business as Usual"

Scenario Narrative: The demographic and economic development of the Kalya area continues according to available prognoses and expectations. Demographic growth corresponds to the expected annual rate of 7.9%, and tourism increases by about 1% per year (estimation based on average development of tourism in Israel, CBS, 2012). This is, beside natural growth, linked to an arrangement between Israel Nature and Parks Authority and Mekorot, which allows for replenishing natural pools in the Ain Feshkha nature reserve by an additional well in the area. The agricultural cooperative achieves arrangements with Mekorot which allow for the successive reduction of water scarcity during peak days and a moderate, but continuous extension of agricultural production.

Development of water demand: The water consumption per capita stays at the current 548 l/c/d, which includes domestic consumption as well as additional water consumption in the localities. Water demand by visit sites remains constant, while water demand by tourism increases by annually 1%. The development of water supply capacities for irrigation allow for an increase in water consumption of 1% p.a. by agriculture (cf. table 19).

Table 19: Development of water use under scenario BAU, Kalya

year	domestic, public and tourism sectors (freshwater)	Agriculture and Environment (water of different qualities)
	m ³ /year	m ³ /year
2010	311.623	16.623.540
2011	330.611	16.682.040
2012	351.042	16.741.125
2013	373.031	16.800.801
2014	396.700	16.861.073
2015	422.180	16.921.949
2016	449.614	16.983.433
2017	479.157	17.045.532
2018	510.974	17.108.252
2019	545.244	17.171.599
2020	582.161	17.235.579
2021	621.932	17.300.200
2022	664.783	17.365.466
2023	710.956	17.431.386
2024	760.714	17.497.964
2025	814.338	17.565.208

source: calculated by the authors

Development of water supply: Local freshwater water production from the existing Mizpe Jericho wells will continue on the current level (extrapolated based on moving average over three years). A new well at Mizpe Jericho will contribute an additional amount of 2 MCM/year from 2014 onward (*cf.* table 18).

Saline water supply remains constant from the existing Feshka wells and the Kane and Samar springs (Kane and Samar wells extrapolated based on moving average over three years). The National Nature and Parks Authority drills a new well in 2015 with a capacity of 2.400 m³/hr, but extracts only 600 m³/hr during 12 hours per day, which is required for replenishment of the pools. Agreements with prospective clients for the potential surplus water, i.e. the agricultural cooperative or the Palestinian water authorities in Jericho fail. The amounts of treated wastewater from the Og reservoir remain on the current level (*cf.* table 20).

Table 20: Development of water supply under scenario BAU, Kalya

year	Mizpe Jericho (freshwater)	Feshkha wells, Kane & Samar springs (saline water for agriculture)	Feshka wells (saline water for natural reserve) ¹	Og reservoir (treated wastewater, effluent) ²
2010	4.280.000	1.840.000	10.773.540	5.000.000
2011	4.030.000	1.840.000	10.773.540	5.000.000
2012	4.090.000	1.810.000	10.773.540	5.000.000
2013	4.133.333	1.830.000	10.773.540	5.000.000
2014	6.084.444	1.826.667	10.773.540	5.000.000
2015	6.102.593	1.822.222	10.773.540	5.000.000
2016	6.106.790	1.826.296	10.773.540	5.000.000
2017	6.097.942	1.825.062	10.773.540	5.000.000
2018	6.102.442	1.824.527	10.773.540	5.000.000
2019	6.102.391	1.825.295	10.773.540	5.000.000
2020	6.100.925	1.824.961	10.773.540	5.000.000
2021	6.101.919	1.824.928	10.773.540	5.000.000
2022	6.101.745	1.825.061	10.773.540	5.000.000
2023	6.101.530	1.824.983	10.773.540	5.000.000
2024	6.101.732	1.824.991	10.773.540	5.000.000
2025	6.101.669	1.825.012	10.773.540	5.000.000

¹ includes 2.628 MCM/year of water from new well from 2015 onward, the new water compensates for decrease of discharge from the old pumping station

² parts of the treated wastewater may be transferred to the Fazaal settlement
source: calculated by the authors

4.3.2 Scenario P: "Prosperity"

Scenario Narrative: Development of tourism significantly exceeds the growth rate over the last 5 years and increases by annually 2%. The related direct and indirect job opportunities attract more residents to the area and lead to a demographic growth of 8,9% per year. As under scenario BAU, the Israel Nature and Parks Authority and Mekorot achieve an agreement, which allows for replenishing natural pools in the Ain Feshkha nature reserve by an additional well in the area. The increased economic activities also stimulate further investments in agriculture (e.g. installation of private desalinization plants, extension of cultivated areas, changes in cropping patterns and greenhouse installations) and induce the agricultural cooperative to invest in additional water supply.

Development of water demand: The water consumption per capita stays at the current 548 l/c/d, which includes domestic consumption as well as additional water consumption in the localities. Water demand by visit sites remains constant, while water demand by tourism

increases by annually 2%. The development of water supply capacities for irrigation allow for an increase in water consumption of 5% p.a. by agriculture (cf. table 21).

Table 21: Development of water use under scenario "Prosperity", Kalya

year	domestic, public and tourism sectors (Freshwater)	Agriculture and Environment (water of different qualities)
	m ³ /year	m ³ /year
2010	311.623	16.623.540
2011	333.727	16.916.040
2012	357.686	17.223.165
2013	383.662	17.545.646
2014	411.833	17.884.252
2015	442.391	18.239.787
2016	475.548	18.613.099
2017	511.531	19.005.077
2018	550.589	19.416.654
2019	592.995	19.848.810
2020	639.043	20.302.574
2021	689.054	20.779.025
2022	743.379	21.279.300
2023	802.399	21.804.587
2024	866.529	22.356.140
2025	936.221	22.935.270

source: calculated by the authors

Development of water supply: The development of local freshwater water production corresponds to the development under scenario BAU. Supply from the existing Mizpe Jericho wells will continue on the current level and the new well will contribute an additional amount of 2 MCM/year from 2014 onward. Saline water supply remains constant from the existing Feshka wells and the Kane and Samar springs.

The National Nature and Parks Authority finds not only an agreement with Mekorot on its intended new well at Feshkha, but also with clients for the surplus water. The amounts of treated wastewater from the Og reservoir remain on the current level (cf. table 22).

Table 22: Development of water supply under scenario "Prosperity", Kalya

year	Mizpe Jericho (freshwater)	Feshkha wells, Kane & Samar springs (saline water for agriculture) ¹	Feshka wells (saline water for natural reserve) ²	Og reservoir (treated wastewater, effluent) ³
2010	4.280.000	1.840.000	10.773.540	5.000.000
2011	4.030.000	1.840.000	10.773.540	5.000.000
2012	4.090.000	1.810.000	10.773.540	5.000.000
2013	4.133.333	1.830.000	10.773.540	5.000.000
2014	6.084.444	1.826.667	10.773.540	5.000.000
2015	6.102.593	20.218.222	10.773.540	5.000.000
2016	6.106.790	20.222.296	10.773.540	5.000.000
2017	6.097.942	20.221.062	10.773.540	5.000.000
2018	6.102.442	20.220.527	10.773.540	5.000.000
2019	6.102.391	20.221.295	10.773.540	5.000.000
2020	6.100.925	20.220.961	10.773.540	5.000.000
2021	6.101.919	20.220.928	10.773.540	5.000.000
2022	6.101.745	20.221.061	10.773.540	5.000.000
2023	6.101.530	20.220.983	10.773.540	5.000.000
2024	6.101.732	20.220.991	10.773.540	5.000.000
2025	6.101.669	20.221.012	10.773.540	5.000.000

¹ includes 18,396 MCM/year from the new well at Feshkha that will be sold to the agricultural co-operative and/or Jericho

² includes 2,628 MCM/year of water from new well from 2015 onward, the new water compensates for decrease of discharge from old wells

³ parts of the treated wastewater may be transferred to the Fazaal settlement

source: calculated by the authors

4.3.3 Scenario LG: "Lower growth than expected"

Scenario Narrative: Regional developments cause a decline in international tourism and lead to a decrease in tourism at Kalya by annually 1%. The impacts on job opportunities decelerate demographic growth down to 5% per year. Analyses of effects and consequences of the contemplated new well at Feshkha yield disadvantageous results and the Nature and Parks Authority refrains from the construction. The agricultural cooperative continues with production on the level of the current extent and water demand.

Development of water demand: The water consumption per capita stays at the current 548 l/c/d, which includes domestic consumption as well as additional water consumption in the localities. Water demand by tourism decreases by annually 1%. Water demand by visit sites remains constant, but supply and consumption decreases by 2,628 MCM/year from 2015

onwards due to reductions in the discharge of the existing pumping station at Feshkha. The water consumption by agriculture remains on the current level. (cf. table 23).

Table 23: Development of water use under scenario "Lower Growth", Kalya

year	domestic, public and tourism sectors (Freshwater)	Agriculture and Environment (water of different qualities)
	m ³ /year	m ³ /year
2010	311.623	16.623.540
2011	322.308	16.623.540
2012	333.577	16.623.540
2013	345.457	16.623.540
2014	357.979	16.623.540
2015	371.175	13.995.540
2016	385.078	13.995.540
2017	399.722	13.995.540
2018	415.145	13.995.540
2019	431.384	13.995.540
2020	448.481	13.995.540
2021	466.477	13.995.540
2022	485.417	13.995.540
2023	505.348	13.995.540
2024	526.319	13.995.540
2025	548.382	13.995.540

source: calculated by the authors

Development of water supply: The development of local freshwater water production corresponds to the development under scenario BAU. Supply from the existing Mizpe Jericho wells will continue on the current level and the new well will contribute an additional amount of 2 MCM/year from 2014 onward.

Saline water supply remains constant the Kane and Samar springs. Supply from the Feshka wells decreases due to the lower discharge of the existing pumping station. The drop of discharge is in reality most probably a continuous process, but considered in the actual scenario calculations as a discrete event in 2015 due to the lack of more precise information on the process. The amounts of treated wastewater from the Og reservoir remain on the current level (cf. table 24).

Table 24: Development of water supply under scenario "Lower Growth", Kalya

year	Mizpe Jericho (freshwater)	Feshkha wells, Kane & Samar springs (saline water for agriculture)	Feshka wells (saline water for natural reserve)	Og reservoir (treated wastewater, effluent)¹
2010	4.280.000	1.840.000	10.773.540	5.000.000
2011	4.030.000	1.840.000	10.773.540	5.000.000
2012	4.090.000	1.810.000	10.773.540	5.000.000
2013	4.133.333	1.830.000	10.773.540	5.000.000
2014	6.084.444	1.826.667	10.773.540	5.000.000
2015	6.102.593	1.822.222	8.145.540	5.000.000
2016	6.106.790	1.826.296	8.145.540	5.000.000
2017	6.097.942	1.825.062	8.145.540	5.000.000
2018	6.102.442	1.824.527	8.145.540	5.000.000
2019	6.102.391	1.825.295	8.145.540	5.000.000
2020	6.100.925	1.824.961	8.145.540	5.000.000
2021	6.101.919	1.824.928	8.145.540	5.000.000
2022	6.101.745	1.825.061	8.145.540	5.000.000
2023	6.101.530	1.824.983	8.145.540	5.000.000
2024	6.101.732	1.824.991	8.145.540	5.000.000
2025	6.101.669	1.825.012	8.145.540	5.000.000

¹ parts of the treated wastewater may be transferred to the Fazeel settlement
source: calculated by the authors

5 Conclusions

- Downscaling of aggregated regional or national scenarios requires additional information on the subordinate areas. The individual sub-regions in the Lower Jordan Valley are too heterogeneous for downscaling by regression. The possibility of direct transfers of findings to other than the examined sub-regions is limited.
- The calculated scenarios represent the closest estimation on the examined basins that can be achieved by the available, aggregated information on sub-regional level. Improvements in the underlying data base are possible by primary data collection as proven by Riepl (2013) for Wadi Shueib, Jordan, but would simultaneously be more expensive. A justification of such additional costs will require a problem analysis in each individual case.
- The presented scenarios correspond to the national guidelines and assessments, i.e. match the assumptions of national decision makers on further developments on the national level.
- The specific dynamics of the region, the international interest in its developments and the related funding mechanisms may lead to changes in assumptions and implementations on short notice. This indicates the temporally limited validity of the calculated figures. and underscores the necessity of continuous cross-checks and updates of local scenarios.
- The situation and key aspects of the water sector in the examined regions 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.
- Water availability from local resources is one of the major distinctions between the examined areas. The scenarios indicate that water from local sources cannot cover the future water demand of the SMART research regions in Jordan, but could or already do so for the regions west of the Jordan River. However, a generalization of this finding for all regions on the respective side of the Jordan River would be incorrect, since representativeness of the selected region is not proven.

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APPENDIX 1: Scenario Downscaling – selection of methodological approach

A1.1 Methodological alternatives for scenario downscaling

(H.P. Wolff)

Research on approaches to scenario downscaling gained prominence around the end of the last century. The need arose in particular from models on Climate Change, which allowed for estimations on global trends but had difficulties with statements on regional consequences. Wilby *et al.* (1997, p.530) described the situation by *"So-called 'downscaling' techniques have subsequently emerged as a means of bridging the gap between what climate modellers are currently able to provide and what impact assessors require."* This challenge arises, in generalized terms, for regional scenarios on developments of other topics, too. The area of the Jordan Valley was subject to a number of regional scenario exercises, which included assessments on the development of water resources (e.g. The Millennium Project 2009, GLOWA Jordan River 2011). However, none of these scenarios helps planners in the identification and evaluation of local measures for water resources management.

Wilby *et al.* (1997) categorized downscaling tools under the four headings: regression methods, weather pattern (circulation)-based approaches, stochastic weather generators and limited-area climate models. This classification of the methodological tool-box still holds today, even if the denominations and specifications may differ for other fields than climate science. The generalization of these categories beyond the scope of climate science may read as: regression methods, normative modelling, stochastic modelling and limited-area models, i.e. modelling based on local empirical data and local assumptions.

Scenario downscaling in SMART tested the application of regression methods and limited area models due to the following reasons:

- Regression methods are the approach of choice in many situations due to their comparatively low requirements in local data and thus budget for research. However, a general weakness of regression methods is the difficulty of including impacts from developments in the future, which have no analogy in the past.
- Limited area models have significantly higher requirements with regard to local data, but computation processes and results are much easier to comprehend by clients and lead to a higher acceptance of prognoses and their interpretation. The limits in funding for local data collection for scenario development under the umbrella of SMART II could be compensated by external funding through projects of other donors.

- Normative and stochastic modelling was not considered due to the extensive requirements of research and development, which stood against the reflection that such models would exceed the requirements of SMART's overall research programme.

A1.2 Regression approach

The utility of regression methods for scenario downscaling depends on a sufficient degree of homogeneity between the subordinate units, i.e. areas, which make up for the aggregated, superordinate scenario. Regional experience of the scenario developers already doubted this possibility for water consumption by large industries and agriculture, which are unevenly distributed in the area of the superordinate scenarios. However, the possibility of a certain homogeneity in the development of water consumption for municipal purposes, i.e. domestic and other water use in urban and semi-urban areas, required closer analysis. Municipal water use is the local sector with the third-largest "blue water" consumption in the Lower Jordan River Valley after the environment and agriculture.

The hypothesis of the analysis was: *Municipal water consumption as a function of population size and income per capita develops in a comparable manner in all sub-regions.* The hypothesis was tested for areas in Jordan, where relevant data on the national (superordinate scenario) and governorate (subordinate units) level could be obtained already in the beginning of the SMART scenario development exercise. (cf. table A1.1).

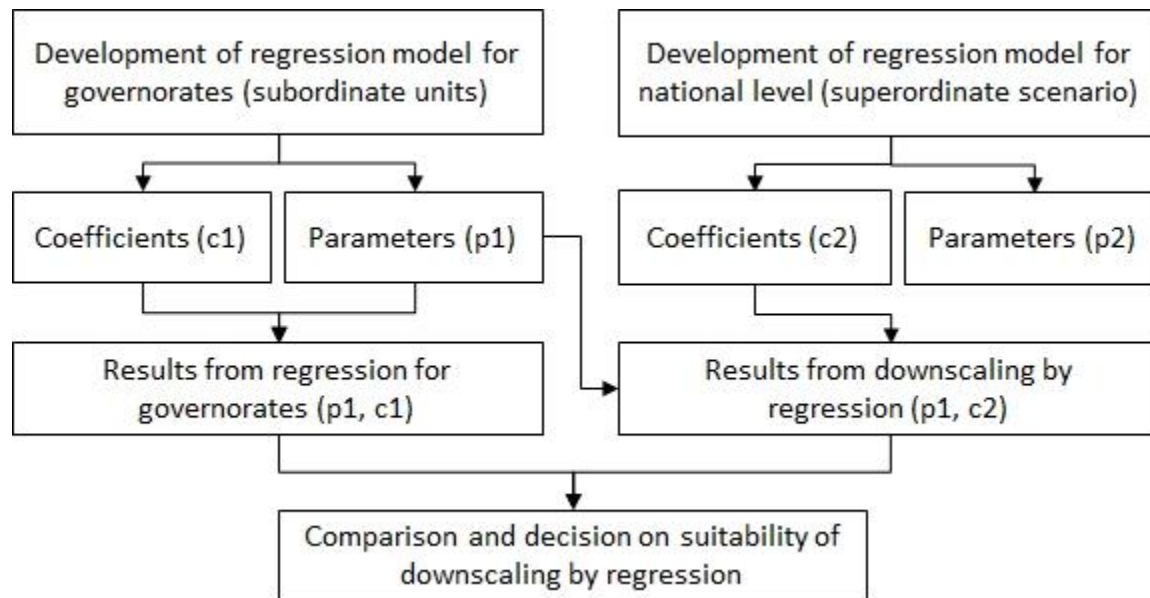
Table A1.1: Data and Sources

Information	Source	Remarks
Demographic growth	DoS / HCP	2001-2009 / 2010-2025 (proportional distribution between governorates for 2010-2025 based on distribution 2009)
Municipal water (supply, billed, non-resident water supply)	MWI / WAJ	2001-2009
Annual Income of household members (JD/yr)	DoS	2001-2009

First steps in the analytical process were the development of regression models for the governorates and the national level. This allowed for the assessment of the obtained models' quality (model fit) and provided the required explanatory variables and respective coefficients of

the models on both levels. The next step was the calculation of results from (1) the regression models on the level of governorates and (2) the regression model of the combination between coefficients from the national model and parameter values from the governorate level. The comparison between the results served as the criterion for decisions on the hypothesis (cf. fig. A1.1).

Figure A1.1: Flow chart of suitability analysis of downscaling by regression



A1.2.1 Regression models for subordinate units

The applied modelling procedure followed the sequence:

- 1) Initial selection of probable model variables: The selection of explanatory, exogenous variables for water consumption and water demand came from workshops with decision makers at MWI, WAJ and JVA under the umbrella of the Water Demand management study, funded by AFD
- 2) Selection of functional form: Based on professional knowledge on expectable developments in a given case over time. Three alternative models with varying explanatory variables were tested for the five Jordanian governorates, which cover the area of the Jordan Valley north of the Dead Sea and contain the research sites of SMART in Jordan. (cf. table A1.2)

Table A1.2: Result of regression models for scenario downscaling, municipal water demand on governorate level, data base: variables from 2001 – 2009, n = 9

Model 1: municipal water (MW, m³) = β1+β2 population (Pop, persons) + β3 billed water per capita (BW, m³)							
Gover-norate	Coefficients				R²	Violation of Assumpt. ¹	Sign. of Model
Irbid	MW = -17200000 + (se) (8806515)*	39.69429 Pop + (11.15929)**	571831.4 BW (204427.1)**		0.91	Hetero-skedasticity	***
Ajlun	MW = -1116476 + (se) (1079559)	37.8324 Pop - (10.7524)**	7421.315 BW (59733.52)		0.76	none	**
Balqa	MW = -22700000 + (se) (6530768)**	64.81985 Pop + (24.77207)**	729070.4 BW (387729.2)		0.88	none	***
Madaba	MW = -10300000 + (se) (853872.3)**	134.6617 Pop - (8.212463)***	79852.9 BW (19564.82)***		0.99	none	***
Karak	MW = -30900000 + (se) (3241652)***	188.0467 Pop + (14.00438)***	70390.21 BW (47152.05)		0.96	none	***
Model 2: municipal water (MW, m³) = β1 + β2 population (Pop, persons) + β3 billed water per capita (BW, m³) + β4 average annual income per capita (CI, JD/year)							
Irbid	MW = 6937159 + (se) (23800000)	5.183108 Pop + (35.47457)	420842.5 BW + (277316.8)	13677 CI (15457.54)	0.92	Heteroskd. Collinearity	***
Ajlun	MW = -3796918 + (se) (4246919)	75.1476 Pop – (58.08297)	58052.76 BW – (99595.26)	1224.453 CI (1869.481)	0.79	Collinearity	**
Balqa	MW = -45000000 + (se) (11300000)**	237.1311 Pop + (80.23905)**	423767.7 BW – (331972)	34738.1 CI (15701.83)*	0.94	Collinearity	***
Madaba	MW = -6429888 + (se) (2534274)*	91.81006 Pop - (27.84455)**	79740.87 BW+ (17447.86)***	2431.985 CI (1524.637)	0.99	Collinearity	***
Karak	MW = -26800000 + (se) (12400000)*	161.0877 Pop + (78.42746)*	75368.35 BW + (52971.22)	1559.552 CI (4451.421)	0.97	Collinearity	***
Model 3: municipal water (MW, m³) = β1+β2 population (Pop, persons) + β3 billed water per capita (BW, m³) + β4 unaccounted-for water (UFW, %)							
Irbid	MW = -57100000 + (se) (8740208)***	47.25438 Pop + (5.676223)***	1179755 BW + (217329.6)***	50900000 UFW (10400000)***	0.99	none	***
Ajlun	MW = -4644071 + (se) (400233.1)***	31.11773 Pop + (2.438231)***	130583.4 BW + (18196.14)***	5400161 UFW (493818.8)***	0.99	none	***
Balqa	MW = -37700000 + (se) (1642040)***	61.887 Pop + (4.514678)***	605847.1 BW + (71186.72)***	37100000 UFW (2796702)	0.99	none	***
Madaba	MW = -11600000 + (se) (525416)***	98.43251 Pop + (9.288089)***	71249.38 BW + (36089.12)***	5629200 UFW (1293977)***	0.99	none	***
Karak	MW = -28800000 + (se) (1148345)	96.45594 Pop + (14.25149)***	386841 BW + (49100.08)***	18700000 UFW (2745983)***	0.99	none	***
Jordan Total	MW = -320000000 + (se) (85600000)**	52.07624 Pop + (7.881929)***	7134623 BW + (1849367)**	255000000 UFW (121000000)*	0.99	none	***

¹ tests for autocorrelation, heteroskedasticity, collinearity and model misspecification, cf. table A1.3 (se) = standard error, * significance at probability levels (* 90%, ** 95%, *** 99%)

3) The model specifications, i.e. the significance of explanatory variables and overall models as well as violations of mathematical model preconditions, were then checked by statistical testing. The applied statistical tests are compiled in table A1.3

Table A1.3: Applied statistical model validation

Task	Method	Result
Check for collinearity	Correlation coefficient between exogenous variables	Consideration of extreme correlations (>0.8) in interpretation of results
Check for auto-correlation	Durbin-Watson test	Prais-Winsten transformation, estimation by generalized least squares (GLS) instead of OLS
Check for heteroskedasticity	Cook-Weisberg-test	estimation by generalized least squares (GLS) instead of OLS (robust standard errors)
Check for model misspecifications	Ramsey Regression Equation Specification Error Test (RESET)	adjustment of included variables and/or functional form
Calculation of model coefficients	OLS or GLS according to results from preceding tests	Final model
Check for significance of model and individual variables	F-test, t-test, coefficient of determination (R^2 , explanatory value of model)	Interpretation of model and coefficients

Results showed that all tested regression models yielded results with a sufficient precision, i.e. a coefficient of determination (R^2) close to 1. However, only the variations of considered explanatory variables in the first and third model showed sufficiently significant impacts in more than 50% of the cases and only the third model yielded significantly precise results for all governorates. In addition, the first and second model suffered from violations of the methodological pre-conditions of regression analyses, i.e. estimations by these models may contain uncontrollable bias. Consequently, the third model was the best choice for downscaling by regression analysis. Table A1.4 compiles the individual results of this evaluation.

Table A1.4: Selection criteria for scenario models “Municipal Water Use”

Criterion	Dependent variable: scenario assumption for municipal water demand (MW, m ³)		
Explanatory variables	Constant, population size, billed water per capita	Constant, population size, billed water per capita, average annual income per capita	Constant, population size, billed water per capita, water losses
Theoretical foundation	+	+++	++
Significance of models (1-α = 95%)	4 out of 5 +	4 out of 5 +	5 out of 5 +++
Significance of explanatory variables (1-α = 95%)	8 out of 15, 53% ++	4 out of 20, 20% +	18 out of 20, 90% +++
Violation of mathematical model requirements in Governorate models:			
(multi-)collinearity	0	5	0
heteroskedasticity	1	1	0
autocorrelation	0	0	0
misspecification	0	0	0
Total: Mathematical problems due to data	1 +	6 ++	0 +++
Average R² over all governorates	0,90 +	0.92 ++	0.99 +++
Other advantages	MWI estimates for all explanatory variables available		MWI estimates for all explanatory variables available
Other disadvantages		Income requires separate prognoses or scenario assumption	
Advantage/disadvantage	+++	+	+++
Evaluation Result:	++	+	<u>+++</u> (selected model)

N.B.: a fourth model under simultaneous consideration of all 4 explanatory variables was no alternative due to the identified correlations of the variable “income”.

A1.2.2 Regression model for superordinate unit and comparison of results

The model, which yielded the best results on the level of governorates, was calculated for the national level, where it showed the same quality (cf. tab. A1.5).

Table A1.5: Result of regression model, municipal water demand on national level, data base: variables from 2001 – 2009, n = 9

Model 3: municipal water (MW, m³) = β1+β2 population (Pop, persons) + β3 billed water per capita (BW, m³) + β4 unaccounted-for water (UFW, %)								
Coefficients						R²	Violation of Assumpt. ¹	Sig.
Jordan	MW =	-320000000 +	52.07624 Pop +	7134623 BW +	255000000 UFW	0.99	none	***
Total	(se)	(856000000)**	(7.881929)***	(1849367)**	(121000000)*			

¹ tests for autocorrelation, heteroskedasticity, collinearity and model misspecification, cf. table A1.3
(se) = standard error, * significance at probability levels (* 90%, ** 95%, *** 99%)

However, the comparison between the results from regression estimation by the governmental models (c1, p1, cf. fig. A1.1) and those from the combined models with national coefficients and governmental parameters (c2, p1, cf. fig. A1.1) showed strong discrepancies (cf. tab. A1.6). The rural character of the examined governorates explains these differences. Governorates with distinctive urban areas, e.g. Amman and Aqaba, which were not part of the analysis, distort the coefficients of the national model in a way, which does not allow for downscaling, i.e. the drawing of conclusions from the national average situation to individual governorates.

Table A1.6: Divergence between prognoses from downscaling regression models and governorate-based regression models for municipal water use, Jordan

year	2010	2015	2020	2025
Governorate				
Irbid	91%	77%	67%	59%
Ajlun	907%	685%	598%	523%
Balqa	287%	240%	205%	174%
Madaba	1006%	734%	566%	441%
Karak	445%	339%	265%	206%

The results of the analysis did not support the initial hypothesis. Regions in Jordan are not homogenous enough for regression downscaling. This lead to the rejection of the regression approach for scenario downscaling in SMART and opted for the adoption of a "limited area" approach.

A1.3 Limited area approach

The application of limited area models became possible due to the access to more detailed data and information about the subordinate areas. The chapters on the different research areas explain the sources and type of this information. However, the most disaggregated level of data from the national accounting systems and statistical offices are - in the case of Jordan and Palestine - governorates. The boundaries of these administrative entities do not coincide with hydrological basins. This required further downscaling of water consumption to the basin level.

Downscaling in those cases relied on relationships between different types of water consumption and land use. Table A1.7 compiles the estimation procedures for the different types of water consumption.

Table A1.7: Downscaling approaches from the level of administrative areas to basin level

Sector	Downscaling approach
Municipal water	
domestic water use	Multiplication of household water consumption per capita by estimated population in basin <u>Household water consumption per capita</u> : average consumption/capita on governorate level <u>Population</u> : estimation based on information about population centers in basin <u>Demographic growth</u> : growth estimation by national office for statistics
other municipal water use, tourism and small industries	Proportion of these types of water use in comparison with domestic water use on the governorate level, multiplied by domestic water use in basin
Large industries	Direct data of specific enterprises if available, otherwise proportion of in comparison with domestic water use on the governorate level, multiplied by domestic water use in basin
Agriculture	Estimation of irrigated areas in basin based on references or aerial images, multiplication by crop-water requirements for field crops, vegetables and perennials, estimation of proportion of cultures based on governorate figures, if no other references available
Water losses	Municipal water use multiplied by loss rates as stated by utility for the governorate

APPENDIX 2: Detailed scenario results, research areas in Jordan

Table 2.1: Development of municipal water demand, all scenarios

Region:	Wadi Shueib			Wadi Arab		
Scenario:	MIN	Zero	MAX	MIN	Zero	MAX
	MCM			MCM		
year						
2010	3,115	3,130	3,220	11,794	11,850	12,190
2011	3,259	3,277	3,435	12,312	12,379	13,009
2012	3,408	3,429	3,660	12,846	12,926	13,863
2013	3,561	3,586	3,894	13,397	13,491	14,753
2014	3,719	3,749	4,138	13,965	14,074	15,680
2015	3,883	3,916	4,392	14,551	14,676	16,646
2016	4,039	4,077	4,656	15,114	15,256	17,652
2017	4,201	4,244	4,931	15,694	15,855	18,698
2018	4,367	4,415	5,218	16,292	16,472	19,788
2019	4,539	4,592	5,516	16,908	17,108	20,922
2020	4,715	4,775	5,826	17,543	17,764	22,102
2021	4,887	4,952	6,149	18,160	18,403	23,329
2022	5,063	5,135	6,484	18,794	19,061	24,606
2023	5,245	5,323	6,833	19,448	19,739	25,933
2024	5,432	5,518	7,196	20,120	20,437	27,314
2025	5,624	5,718	7,573	20,812	21,156	28,749

source: calculated by the authors

Table 2.2: Development of industrial water demand, all scenarios

Region:	Wadi Shueib			Wadi Arab		
Scenario:	MIN	Zero	MAX	MIN	Zero	MAX
	MCM			MCM		
year						
2010	0,015	0,015	0,016	0,057	0,057	0,059
2011	0,015	0,016	0,017	0,058	0,059	0,063
2012	0,016	0,016	0,017	0,059	0,061	0,066
2013	0,016	0,017	0,018	0,061	0,063	0,070
2014	0,017	0,017	0,019	0,062	0,065	0,073
2015	0,017	0,018	0,020	0,064	0,066	0,076
2016	0,018	0,018	0,021	0,066	0,068	0,080
2017	0,018	0,019	0,022	0,068	0,070	0,084
2018	0,019	0,019	0,023	0,070	0,072	0,088
2019	0,019	0,020	0,024	0,072	0,075	0,093
2020	0,020	0,021	0,026	0,074	0,077	0,097
2021	0,020	0,021	0,027	0,076	0,079	0,102
2022	0,021	0,022	0,028	0,078	0,081	0,107
2023	0,022	0,023	0,029	0,080	0,084	0,112
2024	0,022	0,023	0,031	0,083	0,086	0,117
2025	0,023	0,024	0,032	0,085	0,089	0,122

source: calculated by the authors

Table 2.3: Development of water demand of tourism, all scenarios

Region:	Wadi Shueib			Wadi Arab		
Scenario:	MIN	Zero	MAX	MIN	Zero	MAX
	MCM			MCM		
year						
2010	0,005	0,005	0,005	0,018	0,018	0,018
2011	0,005	0,005	0,005	0,018	0,018	0,020
2012	0,005	0,005	0,005	0,018	0,019	0,020
2013	0,005	0,005	0,006	0,019	0,019	0,021
2014	0,005	0,005	0,006	0,019	0,020	0,022
2015	0,005	0,005	0,006	0,020	0,020	0,023
2016	0,005	0,006	0,006	0,020	0,021	0,025
2017	0,006	0,006	0,007	0,021	0,021	0,026
2018	0,006	0,006	0,007	0,021	0,022	0,027
2019	0,006	0,006	0,007	0,022	0,023	0,028
2020	0,006	0,006	0,008	0,022	0,023	0,029
2021	0,006	0,006	0,008	0,023	0,024	0,031
2022	0,006	0,007	0,008	0,024	0,024	0,032
2023	0,007	0,007	0,009	0,024	0,025	0,033
2024	0,007	0,007	0,009	0,025	0,026	0,035
2025	0,007	0,007	0,010	0,025	0,026	0,037

source: calculated by the authors

Table 2.4: Development of water demand for landscaping, all scenarios

Region:	Wadi Shueib			Wadi Arab		
Scenario:	MIN	Zero	MAX	MIN	Zero	MAX
	MCM			MCM		
year						
2010	0,012	0,013	0,013	0,047	0,047	0,049
2011	0,013	0,013	0,014	0,048	0,049	0,053
2012	0,013	0,013	0,015	0,049	0,051	0,055
2013	0,013	0,014	0,015	0,051	0,053	0,059
2014	0,014	0,014	0,016	0,052	0,054	0,062
2015	0,014	0,015	0,017	0,054	0,056	0,065
2016	0,015	0,016	0,018	0,056	0,058	0,068
2017	0,015	0,016	0,019	0,058	0,060	0,072
2018	0,016	0,017	0,020	0,059	0,062	0,076
2019	0,016	0,017	0,021	0,061	0,064	0,080
2020	0,017	0,018	0,022	0,063	0,066	0,084
2021	0,018	0,018	0,023	0,065	0,068	0,088
2022	0,018	0,019	0,024	0,067	0,070	0,092
2023	0,019	0,020	0,026	0,070	0,073	0,097
2024	0,019	0,020	0,027	0,072	0,075	0,102
2025	0,020	0,021	0,028	0,074	0,077	0,107

source: calculated by the authors

Table 2.5: Development of network water losses*, all scenarios

Region:	Wadi Shueib			Wadi Arab		
Scenario:	MIN	Zero	MAX	MIN	Zero	MAX
	MCM			MCM		
year						
2010	1,627	1,635	1,681	3,822	3,840	3,950
2011	1,672	1,681	1,728	3,936	3,958	4,060
2012	1,716	1,727	1,770	4,051	4,077	4,161
2013	1,760	1,772	1,808	4,167	4,196	4,251
2014	1,803	1,817	1,842	4,283	4,317	4,331
2015	1,846	1,862	1,870	4,400	4,438	4,398
2016	1,893	1,911	1,909	4,523	4,566	4,532
2017	1,941	1,960	1,945	4,648	4,696	4,661
2018	1,988	2,010	1,976	4,775	4,827	4,785
2019	2,036	2,060	2,002	4,903	4,961	4,903
2020	2,084	2,110	2,023	5,033	5,096	5,015
2021	2,127	2,155	2,056	5,153	5,222	5,144
2022	2,170	2,200	2,085	5,275	5,350	5,267
2023	2,212	2,245	2,110	5,398	5,479	5,385
2024	2,255	2,290	2,130	5,523	5,610	5,497
2025	2,297	2,335	2,144	5,648	5,742	5,601

* Includes physical (losses due to leakages) and administrative (not billed water) losses

source: calculated by the authors

APPENDIX 3: Detailed scenario results, Jericho

Table 3.1: Development of domestic and public water demand, all scenarios

	Domestic demand		Public demand	
Scenario:	BAU	OD	BAU	OD
year	m ³ / year		m ³ / year	
2010	1.794.979	1.782.000	425.000	420.000
2011	1.843.443	1.781.300	436.475	417.100
2012	1.893.216	1.780.600	448.260	414.200
2013	1.944.333	1.779.900	460.363	411.300
2014	1.996.830	1.779.200	472.793	408.400
2015	2.050.744	1.778.500	485.558	405.500
2016	2.106.114	1.777.800	498.668	402.600
2017	2.162.980	1.777.100	512.132	399.700
2018	2.221.380	1.776.400	525.960	396.800
2019	2.281.357	1.775.700	540.161	393.900
2020	2.342.954	1.775.000	554.745	391.000
2021	2.406.214	1.788.700	569.723	397.800
2022	2.471.181	1.802.400	585.106	404.600
2023	2.537.903	1.816.100	600.903	411.400
2024	2.606.427	1.829.800	617.128	418.200
2025	2.676.800	1.843.500	633.790	425.000

source: calculated by the authors

Table 3.2: Development of commercial water demand and water demand by refugee camps

	Commercial demand		Refugee camps (Ein As Sultan and Aqbat Jaber)	
Scenario:	BAU	OD	BAU	OD
year	m ³ / year		m ³ / year	
2010	138.000	136.000	190.500	190.500
2011	141.726	135.200	190.500	190.500
2012	145.553	134.400	190.500	190.500
2013	149.483	133.600	190.500	190.500
2014	153.519	132.800	190.500	190.500
2015	157.664	132.000	190.500	190.500
2016	161.920	131.200	190.500	190.500
2017	166.292	130.400	190.500	190.500
2018	170.782	129.600	190.500	190.500
2019	175.393	128.800	190.500	190.500
2020	180.129	128.000	190.500	190.500
2021	184.992	132.600	190.500	190.500
2022	189.987	137.200	190.500	190.500
2023	195.117	141.800	190.500	190.500
2024	200.385	146.400	190.500	190.500
2025	205.795	151.000	190.500	190.500

source: calculated by the authors

Table 3.3: Development of touristic water demand and water demand of agro-industrial zone

	Touristic demand		Agro-industrial zone	
Scenario:	BAU	OD	BAU	OD
year	m³ / year		m³ / year	
2010	200.000	200.000	0	0
2011	200.000	200.000	0	0
2012	200.000	200.000	0	0
2013	200.000	200.000	0	0
2014	200.000	200.000	0	0
2015	200.000	200.000	0	100.000
2016	500.000	500.000	0	100.000
2017	500.000	500.000	0	100.000
2018	500.000	500.000	0	100.000
2019	500.000	500.000	0	100.000
2020	500.000	500.000	0	100.000
2021	1.200.000	1.200.000	0	100.000
2022	1.200.000	1.200.000	0	100.000
2023	1.200.000	1.200.000	0	100.000
2024	1.200.000	1.200.000	0	100.000
2025	1.200.000	1.200.000	0	100.000

source: calculated by the authors

Table 3.4: Development of agricultural water demand

	Areas of current agricultural network		Jericho East	
Scenario:	BAU	OD	BAU	OD
year	m³ / year		m³ / year	
2010	2.567.000	2.567.000	3.620.000	3.620.000
2011	2.565.310	2.565.310	3.666.000	3.666.000
2012	2.563.689	2.563.689	3.712.000	3.712.000
2013	2.562.138	2.562.138	3.758.000	3.758.000
2014	2.560.657	2.560.657	3.804.000	3.804.000
2015	2.559.249	2.559.249	3.850.000	3.850.000
2016	2.557.915	2.557.915	3.896.000	3.896.000
2017	2.556.655	2.556.655	3.942.000	3.942.000
2018	2.555.470	2.555.470	3.988.000	3.988.000
2019	2.554.363	2.554.363	4.034.000	4.034.000
2020	2.553.334	2.553.334	4.080.000	4.080.000
2021	2.552.385	2.552.385	4.126.000	4.126.000
2022	2.551.516	2.551.516	4.172.000	4.172.000
2023	2.550.730	2.550.730	4.218.000	4.218.000
2024	2.550.027	2.550.027	4.264.000	4.264.000
2025	2.549.409	2.549.409	4.310.000	4.310.000

source: calculated by the authors

Table 3.5: Development of wastewater

	Wastewater production		Wastewater Treatment (influent)	
Scenario:	BAU	OD	BAU	OD
year	m³ / year		m³ / year	
2010	1.435.961	1.424.210	0	0
2011	1.474.732	1.422.047	0	0
2012	1.514.550	1.419.883	0	0
2013	1.555.443	1.417.720	0	0
2014	1.597.440	1.415.556	0	0
2015	1.640.570	1.413.393	1.640.570	1.413.393
2016	1.684.866	1.411.229	1.684.866	1.411.229
2017	1.730.357	1.409.066	1.730.357	1.409.066
2018	1.777.077	1.406.902	1.777.077	1.406.902
2019	1.825.058	1.404.739	1.825.058	1.404.739
2020	1.874.335	1.402.575	1.874.335	1.402.575
2021	1.924.942	1.416.909	1.924.942	1.416.909
2022	1.976.915	1.431.242	1.976.915	1.431.242
2023	2.030.292	1.445.576	2.030.292	1.445.576
2024	2.085.110	1.459.909	2.085.110	1.459.909
2025	2.141.408	1.474.243	2.141.408	1.474.243

source: calculated by the authors

Table 3.6: Development of freshwater supply from wells and stormwater collection

	Freshwater from wells		Stormwater	
Scenario:	BAU	OD	BAU	OD
year	m³ / year		m³ / year	
2010	4.530.000	4.530.000	0	0
2011	4.540.000	4.540.000	0	0
2012	4.550.000	4.812.800	0	0
2013	4.560.000	4.822.800	0	0
2014	4.570.000	5.270.800	0	0
2015	4.580.000	5.280.800	0	0
2016	4.590.000	5.290.800	0	0
2017	4.600.000	5.300.800	0	0
2018	4.610.000	5.310.800	0	1.000.000
2019	4.620.000	5.320.800	0	1.000.000
2020	4.630.000	5.330.800	0	1.000.000
2021	4.630.000	5.330.800	0	1.000.000
2022	4.630.000	5.330.800	0	1.500.000
2023	4.630.000	5.330.800	0	1.500.000
2024	4.630.000	5.330.800	0	1.500.000
2025	4.630.000	5.330.800	0	1.500.000

source: calculated by the authors

APPENDIX 4: Detailed scenario results, Kalya

Table 4.1: Development of water use in sectors with exclusively freshwater consumption

Sector:	Domestic and public demand			Tourism		
Scenario:	LG	BAU	Prosperity	LG	BAU	Prosperity
	m ³ /year			MCM		
year						
2010	230.023	230.023	230.023	81.600	81.600	81.600
2011	241.524	248.195	250.495	80.784	82.416	83.232
2012	253.600	267.802	272.789	79.976	83.240	84.897
2013	266.280	288.959	297.067	79.176	84.073	86.595
2014	279.594	311.786	323.506	78.385	84.913	88.326
2015	293.574	336.417	352.298	77.601	85.762	90.093
2016	308.253	362.994	383.653	76.825	86.620	91.895
2017	323.665	391.671	417.798	76.057	87.486	93.733
2018	339.849	422.613	454.982	75.296	88.361	95.607
2019	356.841	455.999	495.475	74.543	89.245	97.520
2020	374.683	492.023	539.573	73.798	90.137	99.470
2021	393.417	530.893	587.595	73.060	91.039	101.459
2022	413.088	572.834	639.891	72.329	91.949	103.489
2023	433.743	618.088	696.841	71.606	92.868	105.558
2024	455.430	666.917	758.860	70.890	93.797	107.669
2025	478.201	719.603	826.398	70.181	94.735	109.823

source: calculated by the authors

Table 4.2: Development of water use in sectors with water of different qualities

Sector:	Natural reserves and visit sites			Local agriculture		
Scenario:	LG	BAU	Prosperity	LG	BAU	Prosperity
	m ³ /year			MCM		
year						
2010	10.773.540	10.773.540	10.773.540	5.850.000	5.850.000	5.850.000
2011	10.773.540	10.773.540	10.773.540	5.850.000	5.908.500	6.142.500
2012	10.773.540	10.773.540	10.773.540	5.850.000	5.967.585	6.449.625
2013	10.773.540	10.773.540	10.773.540	5.850.000	6.027.261	6.772.106
2014	10.773.540	10.773.540	10.773.540	5.850.000	6.087.533	7.110.712
2015	8.145.540	10.773.540	10.773.540	5.850.000	6.148.409	7.466.247
2016	8.145.540	10.773.540	10.773.540	5.850.000	6.209.893	7.839.559
2017	8.145.540	10.773.540	10.773.540	5.850.000	6.271.992	8.231.537
2018	8.145.540	10.773.540	10.773.540	5.850.000	6.334.712	8.643.114
2019	8.145.540	10.773.540	10.773.540	5.850.000	6.398.059	9.075.270
2020	8.145.540	10.773.540	10.773.540	5.850.000	6.462.039	9.529.034
2021	8.145.540	10.773.540	10.773.540	5.850.000	6.526.660	10.005.485
2022	8.145.540	10.773.540	10.773.540	5.850.000	6.591.926	10.505.760
2023	8.145.540	10.773.540	10.773.540	5.850.000	6.657.846	11.031.047
2024	8.145.540	10.773.540	10.773.540	5.850.000	6.724.424	11.582.600
2025	8.145.540	10.773.540	10.773.540	5.850.000	6.791.668	12.161.730

source: calculated by the authors

Table 4.3: Development of water supply which remains constant under all scenarios

Source:	Mizpe-Jericho, existing well	Mizpe Jericho, new well	Feshkha, current extraction for agriculture	Kane & Samar springs	Og reservoir
quality:	freshwater	freshwater	saline	saline	treated wastewater
	m ³ /year				
year					
2010	4.280.000	0	1.500.000	340.000	5.000.000
2011	4.030.000	0	1.500.000	340.000	5.000.000
2012	4.090.000	0	1.500.000	310.000	5.000.000
2013	4.133.333	0	1.500.000	330.000	5.000.000
2014	4.084.444	2.000.000	1.500.000	326.667	5.000.000
2015	4.102.593	2.000.000	1.500.000	322.222	5.000.000
2016	4.106.790	2.000.000	1.500.000	326.296	5.000.000
2017	4.097.942	2.000.000	1.500.000	325.062	5.000.000
2018	4.102.442	2.000.000	1.500.000	324.527	5.000.000
2019	4.102.391	2.000.000	1.500.000	325.295	5.000.000
2020	4.100.925	2.000.000	1.500.000	324.961	5.000.000
2021	4.101.919	2.000.000	1.500.000	324.928	5.000.000
2022	4.101.745	2.000.000	1.500.000	325.061	5.000.000
2023	4.101.530	2.000.000	1.500.000	324.983	5.000.000
2024	4.101.732	2.000.000	1.500.000	324.991	5.000.000
2025	4.101.669	2.000.000	1.500.000	325.012	5.000.000

source: calculated by the authors

Table 4.4: Development of water supply which change according to scenario

source	Feshkha new well			therefrom for agriculture			therefrom for reserve		
	LG	BAU	Prosp.	LG	BAU	Prosp.	LG	BAU	Prosp.
	MCM/year			MCM/year			MCM/year		
year									
2010	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0
2015	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2016	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2017	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2018	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2019	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2020	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2021	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2022	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2023	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2024	0	2,628	21,024	0	0	18,396	0	2,628	2,628
2025	0	2,628	21,024	0	0	18,396	0	2,628	2,628

source: calculated by the authors