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Understanding the Economics of Water in Israel: the Multi-Year Water Allocation System Model

by

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1. Abstract

The objective of this project is to develop a tool, called MYWAS (Multi-Year Water Allocation System), as an analytical instrument for assessing the economic efficiency of the Israeli water sector, to quantify the effects of various policies and changes in external factors, and to formulate recommendations with respect to future water management and policy. MYWAS incorporates detailed supply and demand information for the various users and regions of Israel, a constrained optimization model and an interface module that facilities simulations (using the Water Evaluation and Planning (WEAP) software). The natural water sources within each region in Israel are specified along with the cost of extraction and the sustainable yield. The model incorporates regional demand functions of different types of water use, including households, agriculture, and industry, as well as information on water infrastructure and its operational and capital costs (wastewater treatment plants, desalination plants, storage facilities, and conveyance infrastructure). MYWAS enables the user to impose constraints that reflect her views of social values for water, including the specification of amounts of water to be set-aside for environmental purposes. Water management policies, such as the prices at which water is to be sold to farmers, can also be set if desired; MYWAS takes these inputs and calculates the water flows that maximize the system-wide net benefits received from the available water. These consist of the gross benefits (measured by the areas under the different demand curves) less the costs. We present two applications of the model: (1) a short-run static analysis of water pricing schemes, which was conducted in response to a request by the Israeli Ministry of Agriculture and Rural Development (IMARD); (2) long-run dynamic runs, conducted to compare an optimal water management path to the results of keeping the current (2014) water prices. Under both scenarios MYWAS suggests a much slower desalination-capacity development than the schedule proposed in the Master Plan of the Israeli Water Authority (IWA, 2011). We also report dissemination activities and discuss the potential of the model to become an analytical tool in decision making processes in the Israeli water and agricultural economies.

2. Introduction

In recent years, the water sector of Israel has been experienced significant changes in almost all aspects: physical, structural, legislative and organizational. Decision makers in Israel came to an understanding that the only possible way to cope, on one hand, with the natural water shortage, and on the other, with growing population and quality of life standards, is to adopt and implement as the national policy an Integrated Water Resources Management approach.

During the last decade Israel has been facing an extremely severe drought. The annual precipitation levels have been decreased far beyond the multi-annual average. The sequences of dry years have accelerated the cumulative loss and degradation in the natural water supplies. This drought status, combined with increasing demands from a growing population, has resulted in depletion from all natural water sources. Thus, there is a growing urgency for increased water conservation and use-efficiency, and the development of supplemental sources. A review of the updated quantities and qualities of the major water resources and of the recent efforts to improve the efficiency of water use can be found in Rejwan (2011). The successive droughts have been creating a severe water shortage that incentivizes a major policy reform. Decisions have been made concerning construction of large scale sea water desalination plants, sewage collection and construction of effluents reuse treatment plants for agricultural needs, implementation of water tariff reform based on cost recovery principles, reorganization of the municipal water sector, preparation of a National Water Master Plan to 2050 (Israeli Water Authority, 2011), initiation of water saving programs and media campaigns, preparation of rehabilitation of contaminated water resources plans, and more.

Our objective in this project is to develop a tool, called MYWAS (Multi-Year Water Allocation System), as an analytical instrument for assessing the economic efficiency of the above, to quantify the effects of various policies and changes in external factors, and to formulate recommendations with respect to future water management and policy. MYWAS incorporates detailed supply and demand information for the various users and regions of Israel, a constrained optimization model and an interface module that facilities simulations (using the Water Evaluation and Planning (WEAP) software created by the Stockholm Environment Institute). The natural water sources within each region are specified along with the cost of extraction and the sustainable yield. The model incorporates demand functions of different types of water use, including households, agriculture, and industry, as well as information on water infrastructure and its costs (wastewater treatment plants, desalination plants, storage facilities, and conveyance infrastructure). MYWAS enables the user to impose constraints that reflect her views of social values for water. For example, the user can specify an amount of water to be set-aside in a district for environmental purposes. Water management policies, such as the prices at which water is to be sold to farmers, can also be set if desired; MYWAS takes these inputs and calculates the water flows that maximize the system-wide net benefits received from the available water. These consist of the gross benefits (measured by the areas under the different demand curves) less the costs.

In the next section we describe the structure of MYWAS and its various elements. In sections 3 and 4 we present two applications of the model: (1) a short-run static analysis of water pricing schemes, which was conducted in response to a request by the Israeli Ministry of Agriculture and Rural Development (IMARD); (2) long-run dynamic runs model, conducted to compare an optimal water management path to the results of keeping the current water prices. We then report dissemination activities and discuss the potential of the model to become an analytical tool in decision making processes in the water and agricultural economies in section 5. Section 6 provides a summary.

3. The Model Structure

MYWAS is the multi-year extended version of the original one-year steady-state WAS (Water Allocation System) model; the latter was created in the mid 1990s by the Water Economics Project — a joint venture of Israeli, Jordanian, Palestinian, American, and Dutch experts, facilitated by the government of The Netherlands (Fisher et al., 2005). MYWAS is a dynamic non-linear programming model that searches for optimal water allocation and infrastructural investments along time and space, while taking into account a range of economic data and physical factors and constraints. The development process incorporates determination of the model's topology and the physical constraints, and calibration based on economic data and functions. We calibrated the model based on data for 2010, and then conducted simulations for analyzing the effects of various changes related to exogenous factors and policies. This section describes the model's elements.

The model topology

The topology specifies the water sources (aquifers, natural surface water, desalination plants and wastewater treatment plants), the regions of demand for agricultural and non-agricultural (domestic and industrial) water uses, and the connecting lines between the sources and the demand zones. The model elaborates on 46 water sources, including 16 underground aquifers, 19 wastewater treatment plants, 3 surface reservoirs, 4 sea-water desalination plants, 4 desalination plants for saline water, 183 pipelines for fresh water and 58 pipelines for marginal water. For each water source, the data include annual recharge, maximum hydrological and technical extraction capacities, detailed cost data and linkages to demand regions. Schemes of the topology are presented in Appendix A.

Supply-side data

The data were purchased from Tahal Inc. based on a cost-minimizing model of the Israeli water system, which was developed for the Israeli Water Authority (unlike MYWAS, this model does not incorporate demand functions, and therefore cannot provide socially optimal water allocation and shadow values of the various constraints). Tahal ensured the reliability and accuracy of the data and guaranteed that the Israeli Water Authority approves the topology of the modeled water system and the data. The data are reported in Appendix B.

Urban water demand functions

Demand functions for the urban sector are based on recent estimates by Bar Shira, Cohen and Kislev (2005). Using updated data on average incomes and water prices (both are discounted to the represented year in the study of Bar Shira, Cohen and Kislev (2005)), and water consumption, we calculated the demand elasticity for each urban-demand zone specified in the topology, and calibrated the MYWAS's constant-elasticity urban demand function accordingly. Appendix C reports the parameters of the urban demand regions.

Agricultural water demand functions

For each agricultural-demand zone we calibrated a demand function that incorporates the different water qualities supplied to the region. The function represents the value of marginal product of freshwater, where non-fresh water sources (treated wastewater and brackish water) have factors applied to convert to units of "freshwater equivalents." The conversion factors are calibrated based on the administrative conversion factors that are applied by the Water Authority and the Ministry of Agriculture and Rural Development to convert freshwater quotas to quotas of non-freshwater sources. One could also calibrate the conversion factors based on the prices of the various water sources (see Appendix D for a formal description). The latter is based on the assumption that the quotas of non-freshwater sources are not binding; i.e., that farmers equate the value of marginal product of non-fresh water to their prices. Given the consumption patterns of recent years, this assumption is not realistic, and therefore we prefer the administrative factors. Appendix E reports the calibrated parameters of the agricultural demand functions.

Infrastructural investments

To treat endogenously the extension of infrastructure throughout long-run simulations we specified the level of investment required for extending the capacity of each infrastructure element, the lifetime of each element and the interest rate. We assume that investments in expansions of infrastructural capacities increase linearly with the increased capacity. This is elaborated further in Appendix F.

Interface and optimization process

MYWAS uses WEAP (Water Evaluation And Planning system) as an interface. WEAP is linked to the optimization software GAMS through the program Python, which feeds the data from WEAP into GAMS, runs the optimization process, and finally introduces the optimization results back into WEAP. This triple linkage provides both a user-friendly interface for data upload, results analysis and presentation, combined with a state-of-the-art optimization engine.

Simulations

MYWAS can conduct two types of scenarios, one we call the *optimal* scenario and the other the *policy* scenario. Under the *optimal* scenario, MYWAS maximizes the present value of net benefits over a specified time period (Fisher and Huber-Lee, 2011). MYWAS allows the user to specify a menu of possible infrastructure projects, such as desalination plants, conveyance lines, treatment plants, or dams, their capital and operating costs and their useful life. The program then yields the optimal infrastructure plan, specifying which projects should be built, in what order, and to what capacity. It also can be used to study the effects of changes in relevant exogenous factors; for example, the impact of climatic uncertainty and climate change on natural water resources and the associated extraction plans. Under the policy scenario, a pricing scheme dictates the water consumed by the various consumers, and then MYWAS searches for the solution that minimizes the costs associated with supplying the water demanded by each consumer. This enables MYWAS to analyze various policies associated with water management; for example, setting block-rate pricing, employing cost recovery pricing mechanisms (as is now the case with respect to urban water corporations in Israel) and permitting intra-agricultural trade in irrigation water quotas; the model enable analyzing the impact of such policies on water-use patterns and net benefits in the economy.

4. Static Analyses of Water Policies

Our objective in this chapter is to illustrate the static analysis of water pricing schemes based on the calibration year (2010). This analysis was the basis for a Policy Paper produced by Feinerman, Finkelshtain and Kan in response to a request by the IMARD (December 2014).

We compare five scenarios:

1. Actual 2010: The amount of water according to 2010 Tahal data (for agriculture, the data were taken directly from the Water Authority).
2. Simulation, 2010 prices: This is a policy-scenario simulation where we employ the price structure that existed in 2010. Three price levels are applied in each area in agriculture: three rates for fresh water; a price for treated wastewater (actually two rates, one for treated waste water and one for the Dan Region Wastewater Treatment Plant [SHAFDAN]) water, and a price for brackish water. We put in place a uniform price for industry, and two price tiers for urban consumers (a basic [social] price of NIS 8.37 per m^3 for the first 2.5 m^3 per month per person and NIS 12.18 for larger amounts).
3. Simulation, 2014 prices: This policy-scenario simulation is similar to 2010, but with water prices that existed in 2014. In agriculture, a uniform price of NIS 2.45 was applied per cubic meter for fresh water (2.15 before VAT and an additional average NIS 0.30 cost of distributing water to the fields); for treated wastewater, NIS 1 per cubic meter, for SHAFDAN water, NIS 1.07 per cubic meter; and for brackish water, the price remained the same as in 2010. The industry price remained the same as in 2010, as did city price levels according to 2014 rates (a basic [social] price of NIS 8.37 per m^3 for the first 3.5 m^3 per month per person and NIS 12.18 for larger amounts).
4. Simulation, IWA proposed prices for 2015: This is a policy-scenario simulation where we use the prices suggested by IWA for 2015 during their negotiation of agricultural water prices with the IMARD. In this case, for agriculture: a flat rate for fresh water is applied, NIS 3.1 per cubic meter (NIS 2.8 before VAT plus 30 agorot to distribute water to the fields); treated waste water and SHAFDAN water NIS 1.1 per cubic meter; and brackish water the same as in 2010. Again, industry kept the same as in 2010; city price levels according to those proposed for 2015 show a slight change: (a basic [social] price of NIS 7.98 per m^3 for the first 3.5 m^3 per month per person and NIS 12.86 for larger amounts).
5. Simulation, optimal allocation: Allocation of water by the model under the objective of maximization of the economic welfare of the country from the production and consumption of water (the total of "consumer surplus" of urban water consumers and "producer surplus" of agricultural and industrial water users less water production and supply costs)

Table 1 shows the results for consumption, amount of desalination and welfare differences, and Table 2 present the results.

Table 1. Water consumption, desalination quantities, and welfare differences

Scenario	Urban MCM	Ind. MCM	Ag Fresh MCM	Ag Rec. MCM	Ag Brk. MCM	Ag Total MCM	Total MCM	SW Desal. MCM	GW Desal. MCM	Welfare loss $\$10^6$/yr
Actual 2010	794	129	491	390	181	1062	1985	320	44	
Simulation, 2010 prices	794	129	501	390	113	1004	1927	308	35	120
Simulation, 2014 prices	781	129	356	390	146	892	1802	174	19	130
Simulation, IWA proposed prices for 2015	790	129	273	390	146	809	1727	98	20	110
Simulation, optimal allocation	871	128	380	453	173	1007	2006	261	37	0

The main conclusions from Table 1 are as follows:

- Mekorot's price for fresh water for agriculture in 2014 is NIS 2.15/m^3, and it costs farmers approximately an additional NIS 0.30/m^3 to distribute water to the fields. An increase in the cost of fresh irrigation water from NIS 2.45/m^3 (2.15 + 0.30, third row in the table) to NIS 3.1/m^3 (2.80+0.30, fourth row in the table) will result in a significant decrease of close to 23% of fresh water consumption in agriculture (down from 356 million cubic meters (MCM) to 273 MCM) and a negligible change in the total sum the farmers payments for water (from 2.15×356= NIS765 million to 2.8×273= NIS 764 million). In other words, the increased price per cubic meter will be counterbalanced completely by the decline in consumption.
- The increase in cost of fresh water for agriculture to NIS 3.1/m^3 (Mekorot price NIS 2.8/m^3) will cause an approximately 76 MCM per annum reduction in the amount of desalinated water.
- Relative to the water allocation under the actual 2014 water prices, according to the optimal solution, fresh water consumption should be higher both in the agricultural sector (by approximately 24 MCM per year) and in the urban

sector (by approximately 90 MCM per year) and agricultural treated wastewater consumption should increase accordingly.

- The optimal amount of desalinated seawater, 261 MCM per year, is 59 MCM per year less than the amount desalinated in 2010 (320 MCM per year), the amount the model was calibrated to.
- The quantities of water supplied by the various water sources and the "scarcity rents" of the limited resources are presented in Table 2. For example, the $0.39 scarcity rent for Kinneret Western groundwater (GW) means that increasing the supply available for pumping of this aquifer water by 1 cubic meter (and allocating it optimally to an appropriate consumer) increases the objective function value (= total economic welfare) by 39 cents. It should be noted that as long as there are sources of water whose scarcity rents exceed 40 cents (such as the Southern Mountain Aquifer), it is economically worthwhile to desalinate seawater at a marginal cost of 40 cents. Indeed, the desalination level selected in the optimal allocation is 261 MCM per year.
- The last column of Table 2 presents the shadow prices of transmission capacity constraints – which are a measure of a need to increase capacity.

Table 2. Supplied quantities and shadow values (scarcity rents) of water sources

	Quantity (MCM)		Shadow Values ($/CM)	
Source	**Observed - 2010**	**Optimal**	**Scarcity Rent ($/CM)**	**Capacity-Constraint Shadow Value ($/CM)**
Golan GW	10	17		0.18
Golan Local Streams	23	30		0.38
Western Kinneret GW	56	49	0.39	
Sea of Galilee	165	247	0.29	
WG Aquifer	90	105	0.43	
Lower Galilee GW	13	23	0.39	
Eastern Aquifers	41	90		0.37
Northern Mountain Aquifer	85	87	0.39	
Central Mountain Aquifer	146	161	0.32	
Southern Mountain Aquifer	38	20	0.45	
Carmel Aquifer	18	22		0.40
Northern Coastal Aquifer	85	76	0.41	
Central Coastal Aquifer	29	27	0.42	
Southern Coastal Aquifer	193	66	0.40	
Negev Coastal Aquifer	22	17	0.45	
Negev Aquifer	2	3		0.46
Arava GW	13	12	0.36	
Total	**1029**	**1051**	**Average 0.36**	**Average 0.36**

It is worth mentioning that in the empirical application of the model, we assume that **the marginal cost (the cost of purchased inputs) of desalination at the gate of the desalination plant is 40 cents (NIS 1.5**), which is the amount that the State would have been required to pay for desalinating 1 cubic meter of seawater at the gate of the desalination plant. This is actually the weighted marginal cost of desalination of all desalination plants. It is important to note that this cost is higher than the marginal cost of desalination according to the price determined at the most efficient (and newest) facility at Sorek— about 25 cents.

Welfare losses (last column of Table 2) are calculated relative to total welfare in the optimal allocation (equal to the value of the objective function of the optimization model with the optimal allocation).

4. Dynamic Analyses of Water Policies

As in the short-run analyses, to examine long-run water management we developed two scenarios in MYWAS: (1) the socially *optimal* scenario, where MYWAS searches for the optimal solution, and (2) the *policy* scenario, in which, first, a pricing scheme dictates the water consumed by the various consumers throughout the country, and second, MYWAS searches for the solution that minimizes the costs associated with supplying the water demanded by each consumer. However, under the long-run analyses infrastructures are no longer considered constant. That is, in addition to allocating the various water sources to the consumers, MYWAS considers investments in infrastructure such as desalination plants, wastewater treatment plants, pipes, pumping stations, etc. Expanding the capacity of these infrastructural elements is considered by MYWAS while accounting for a wide range of constraints and factors that affect the objective function, including the initial operative storage in the aquifers, the annual natural recharge rates of the aquifers, temporal shifts in the demand due to population growth, the level of investment required for extending the capacity of each infrastructure element, the life-time of each element and the interest rate.

Our assumptions with respect to the long-run scenarios are the following:

- The initial storage in the aquifers is based on levels in 2010; that is, the operative storage was zero due to the severe drought, and any pumping would have driven the water levels below the "red lines", causing irreversible damage to groundwater storage.
- The annual natural recharge rates equal the long-run countrywide average (1,200 MCM) throughout the whole planning period.
- The population grows at a rate of 1.8% per year. This assumption implies a shift in the water demand for domestic use, and therefore in the sewage amounts that need to be treated and are available for agricultural use.
- Investments in the expansion of infrastructural capacities increase linearly with the increased capacity (see Appendix F).
- Agricultural and industrial water demand functions remain constant throughout the simulation period. This assumption is based on historical trends of water consumption by these sectors (Kislev 2011), which points at increasing efficiency in the use of water in these sectors.

We ran MYWAS under the *optimal* and *policy* scenarios for 29 years, starting in 2010 (the calibration year), until 2038. The results are presented in Figures 1-7, showing countrywide summations of water quantities and averages of shadow values, values of marginal product (VMP) in the agricultural and industrial sectors, and the social welfare gains (representing marginal utility) of the consumers in the urban sector.

Figure 1 shows the amounts of water consumed by the urban, industrial and agricultural sectors, and the statewide average VMP of the agriculture and industrial sectors and the social welfare gains of the urban sector. Given the constant demand functions for industrial and agricultural water uses over time, the amounts delivered to these two sectors remain almost unchanged throughout the simulation period, whereas, driven by the population growth, the consumption of the urban sector steadily increases. Agriculture can consume the treated wastewater produced by the urban sector, and, indeed, corresponding to the increase in the urban consumption of freshwater, the agricultural consumption of treated wastewater rises. This phenomenon is seen in Figure 2, which shows the composition of water sources consumed by the agricultural sector. At the same time, however, freshwater consumption in the agricultural sector declines, so as to free freshwater for the urban sector. These general trends prevail under both scenarios, however, with scale differences: under the *optimal* scenario water consumption is larger in both the urban and agricultural sectors. In view of the urban sector's marginal level of social welfare gains (about 1.5 $/cm, see Figure 1a) and price (3.8 $/cm, see Figure 1b), we conclude that the freshwater price for the urban sector under the *policy* scenario is too high, and therefore the water consumption in the urban sector falls short of its optimal level. Moreover, as a consequence, the treated wastewater available for the agricultural sector is also lower. Figure 2 further indicates that the price of freshwater in the agricultural sector is too high: 0.62 $/cm (Figure 2b) compared to the freshwater's VMP of about 0.5 $/cm (Figure 2a).

In Figure 3 we present the paths of the total freshwater stored in the freshwater aquifers in comparison to the overall storage capacity. As mentioned previously, the aquifers are effectively empty (zero operative stock) at the beginning of the simulated period (2010). Overall, under both scenarios the natural recharge exceeds the extraction until about 2034, and from that point, the stored amounts generally augment, and decline afterwards, but not to the lowest levels of 2010. Also presented in Figure 3 are the statewide average shadow values of the constraint put on the lower level of groundwater in the various aquifers (also known by the name "scarcity rent"). This constraint is effective, hence its shadow value is positive, and generally increases in response to the increased demand for freshwater by the urban sector. Figure 4 sheds light on the sources of the scarcity by presenting the variation in the stored water amounts at the various aquifers. Apparently, during most of the simulated years, most of the storage occurs in four aquifers -- Eastern Aquifers, Golan, Negev and Carmel (and the Lower Galilee GW under the *policy* scenario) -- where the natural recharge exceeds the extraction capacity, and MYWAS finds increasing these extraction capacities as a suboptimal strategy. At some of the aquifers, at least during part of the simulated period, the optimal extraction falls between the natural recharge and the extraction capacity, such that the scarcity rents there are zeroed (e.g., Sea of Galilee and Western Kineret GW). In all other aquifers extraction equals recharge, the operative storage is zeroed, and the scarcity rent is positive. On average, the scarcity rent is higher under the *optimal* scenario, and rises from about 0.3 $/cm in 2010 to 0.5 $/cm at the end of the simulation period.

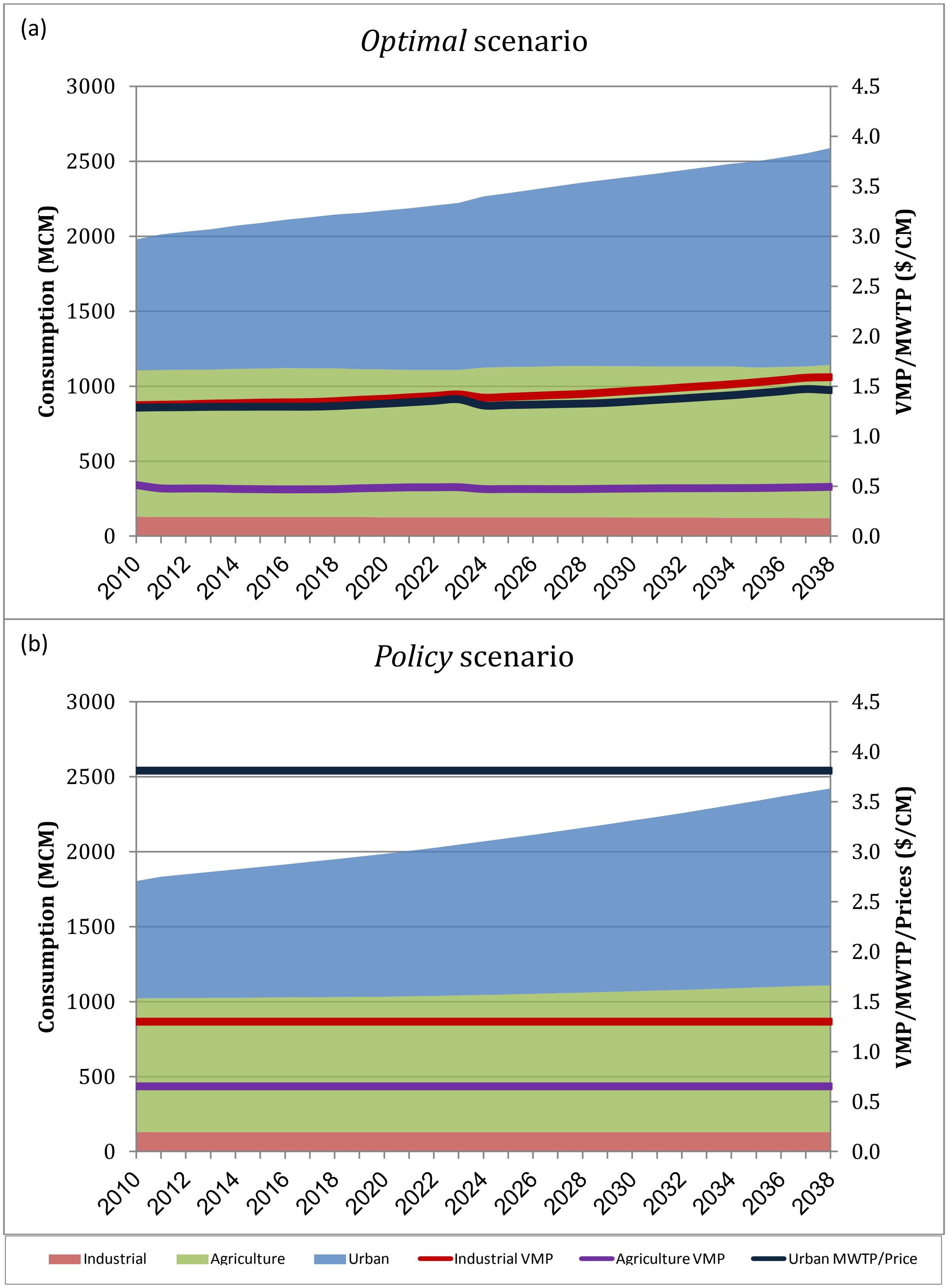

Figure 1 – Statewide total water consumption and average VMP under (a) the *optimal* and (b) *policy* scenarios

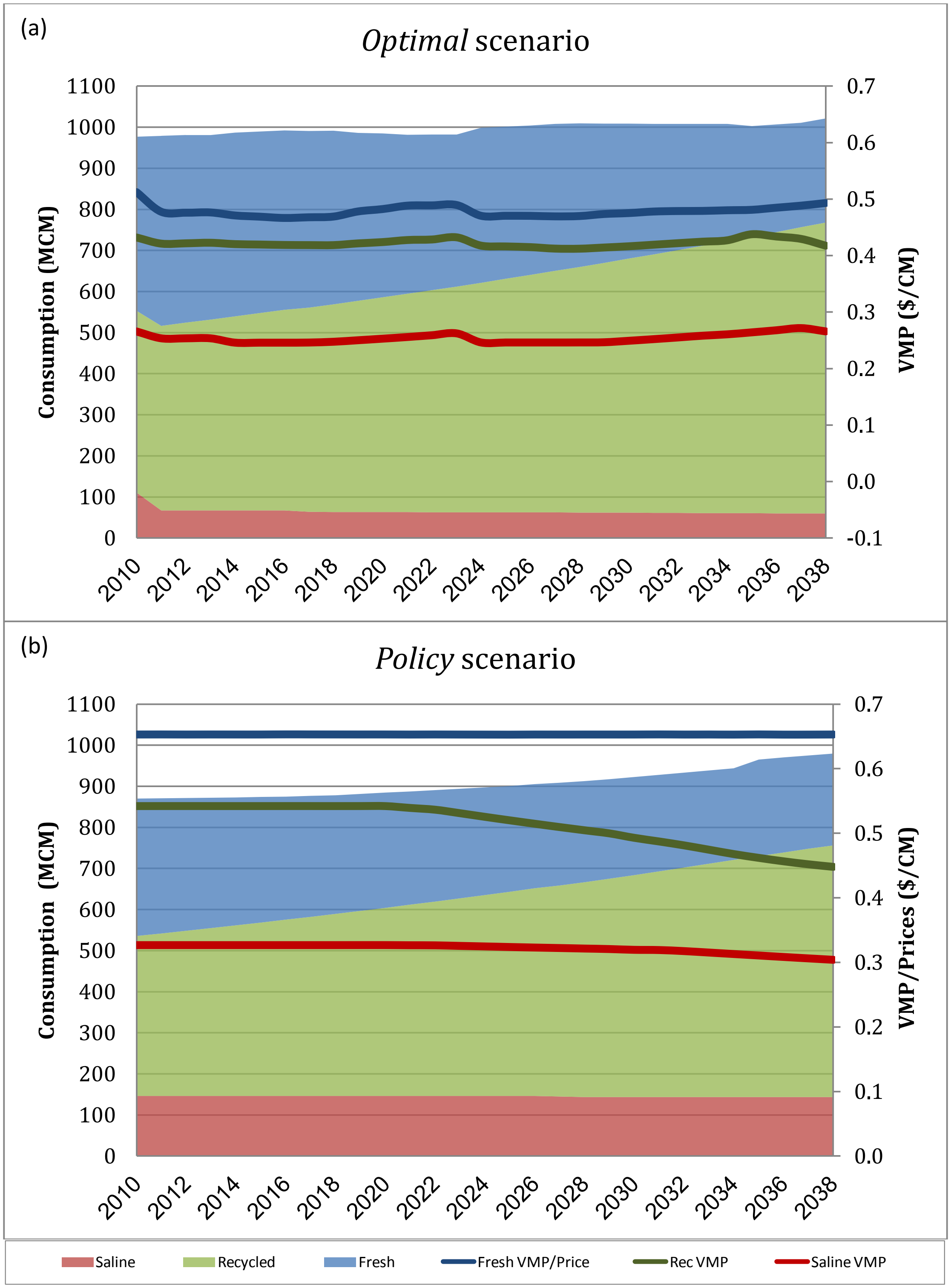

Figure 2 – Statewide agricultural consumption of water sources and average VMPs under (a) the *optimal* and (b) *policy* scenarios

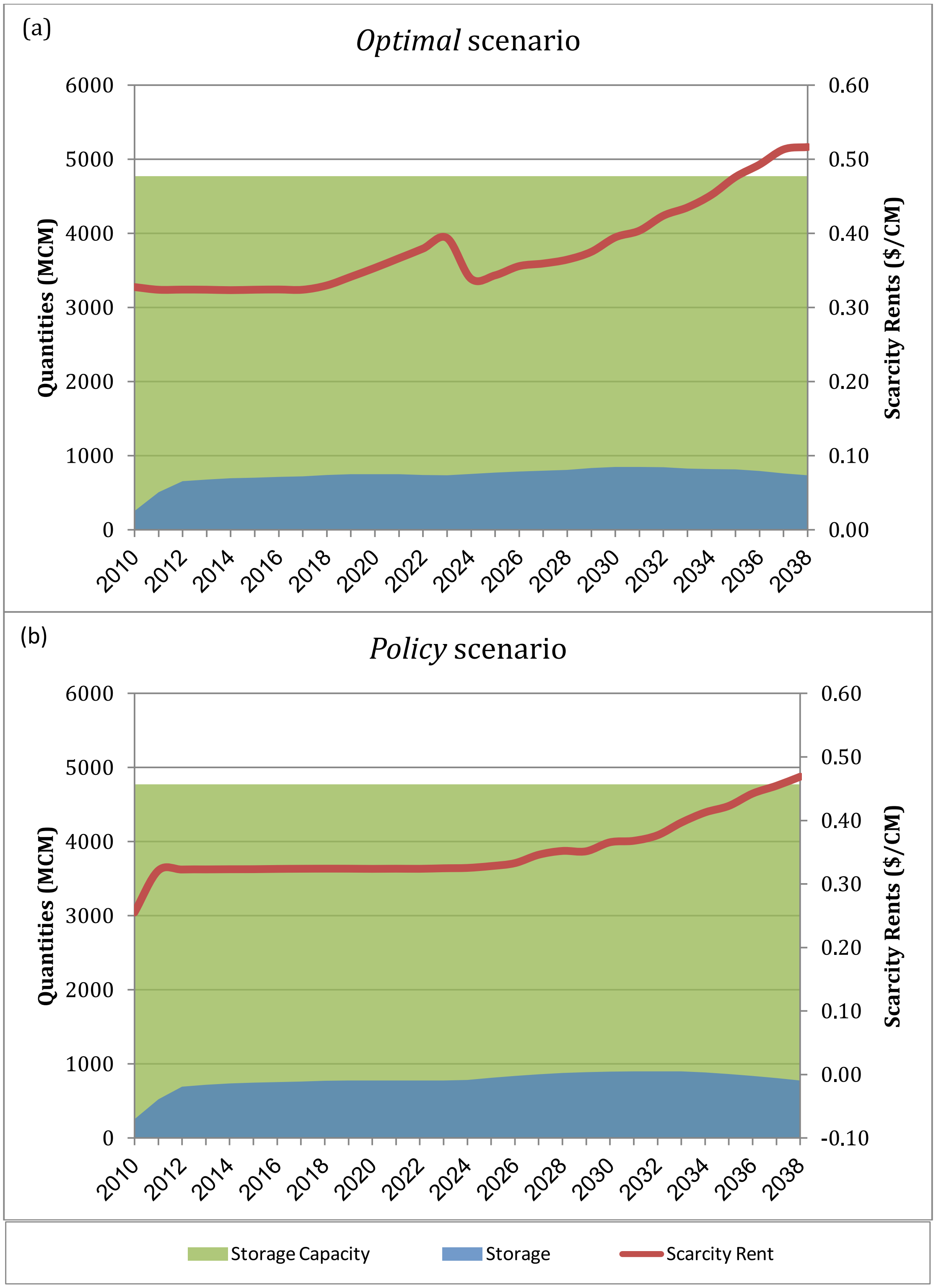

Figure 3 – Statewide storage capacity, stored volumes and shadow values of lower-level constraints in freshwater aquifers under (a) the *optimal* and (b) *policy* scenarios

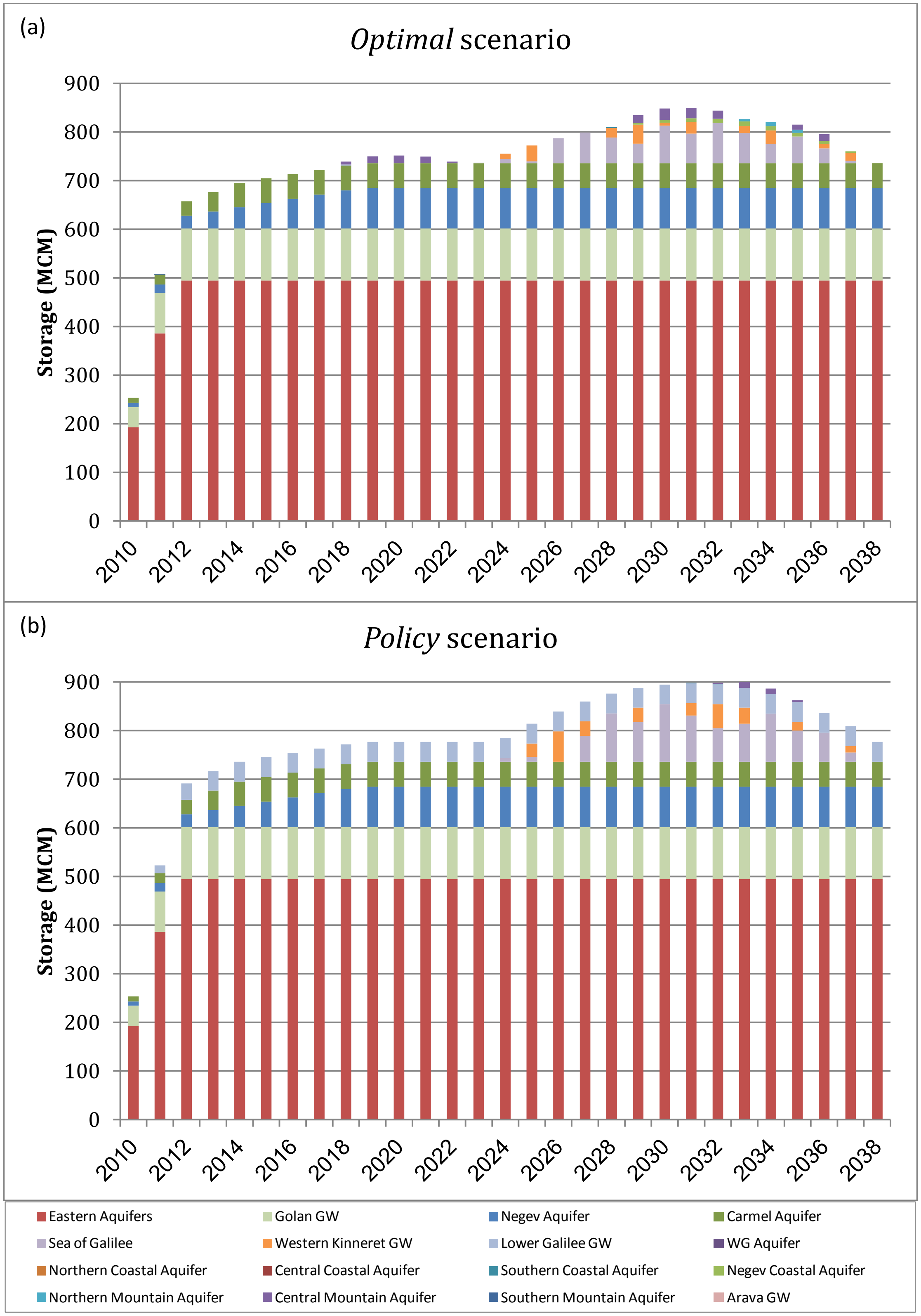

Figure 4 – Stored volumes in freshwater aquifers under (a) the *optimal* and (b) *policy* scenarios

Optimal trends of desalination are presented in Figures 5 and 6. Under both the *optimal* and *policy* scenarios the desalination capacity (Figure 5) increases from 303 in 2010 to 450 with the construction of the Sorek plant. However, under the *optimal* scenario, the Sorek plant is built at full capacity in 2024, whereas under the *policy* scenario the capacity gradually increases from none in 2010 until its full capacity at 2024. Note that under both scenarios MYWAS refrains from establishing the plant in Ashdod. This solution suggests a much slower desalination-capacity development than the schedule proposed in the Master Plan of the Israeli Water Authority (IWA, 2011); according to the latter, desalination capacity should reach 750 MCM at 2020.
To farther examine the desalination plan, we've simulated a "worst-case scenario" under which natural recharge throughout the whole period equals the lowest recorded level, 750 MCM. In this case, the Sorek plant is built at 2012 and the plant in Ashdod at 2024, and the overall desalination capacity gradually increases until stabilizing at about 600 CMC in 2033.

The amount of desalinated water (Figure 6) gradually increases under both scenarios, as desalination constitutes a source available for supplying additional freshwater for domestic uses, which is assuming to grow. Since freshwater consumption under the *policy* scenario is lower, so is the desalinated amount. The internal allocation of production among the desalination plants varies along time, and also differs between the two scenarios. In effect, once the Sorek plant is launched (in 2011 and 2024 under the *policy* and *optimal* scenarios, respectively), production in the Hadera plant completely stops, and then gradually increases when Sorek attains its full capacity (this scheme is not merely theoretic, as the contracts with the desalination plant operators enable shutting them down while covering fixed costs only). Desalination in the Ashkelon plant is lower under the policy scenario, and, unlike the optimal one, does not reach the plant's capacity constraint in the time horizon of the scenario.

Optimal management paths of the country's overall wastewater treatment and treatment capacity are presented in Figure 7. The capacity of the wastewater treatment plants increases constantly with an expansion rate almost equal to that of the treatment levels, such that the plants generally work at their full capacity throughout the entire simulation period.

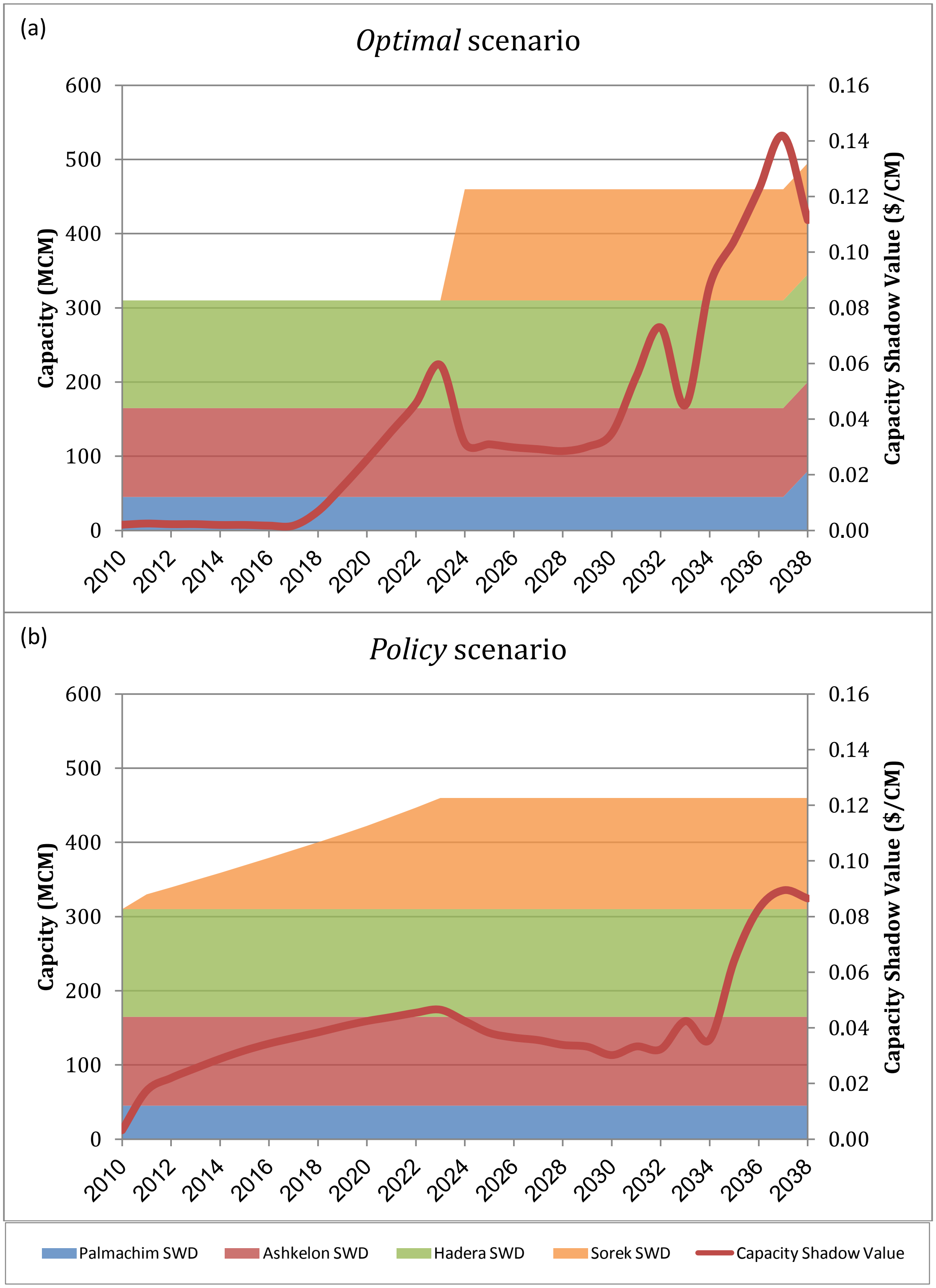

Figure 5 – Desalination capacities and average shadow value of desalination-capacity constraints under (a) the *optimal* and (b) *policy* scenarios

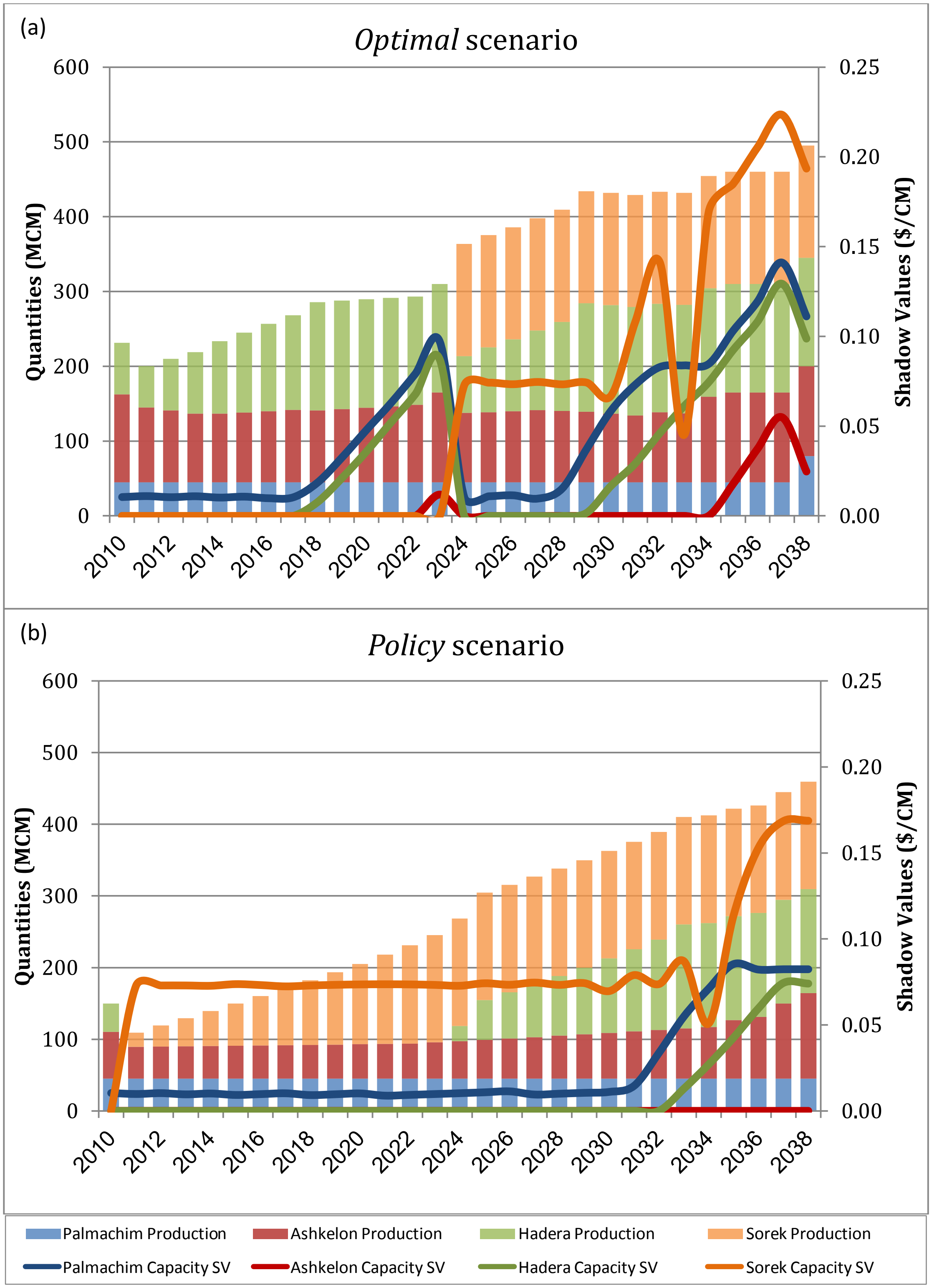

Figure 6 – Desalination levels and shadow values of desalination capacity constraints of the various desalination plants under (a) the *optimal* and (b) *policy* scenarios

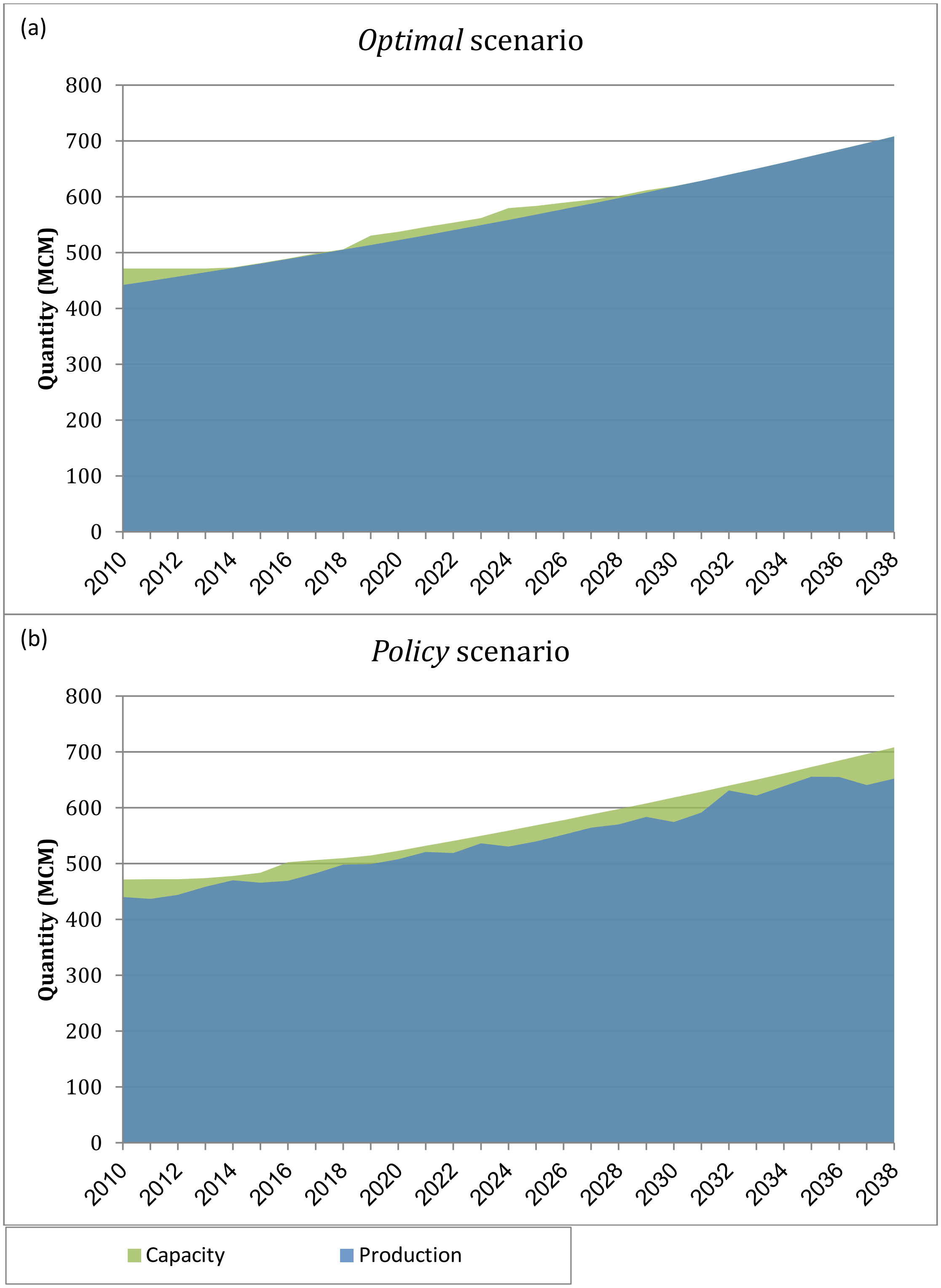

Figure 7 – Treated wastewater production and capacity under (a) the *optimal* and (b) *policy* scenarios

5. Presentation and dissemination

The team has started a process of disseminating the results with key stakeholders, both via private meetings and more public meetings as demonstrated in the two meetings discussed below.

Meeting with Ministries of Agriculture, Finance, Farmers Association and Water Authority

On August 27th, the Hebrew University team held a meeting with the following participants:

Ministry of Agriculture and Rural Development (MoA)

- Mr.Uri Zuk-Bar, Deputy Director General, Head of the Research, Economy and Strategy Division.
- Dr. Yael Kachel, Head of Research, Research, Economy and Strategy Division.
- Mr.Tzvika Cohen, Deputy Director General, Head of the Investment and Finance division.
- Dr. Assaf Levi, economic and marketing advisor for the Director General.
- Mr. Amir Antler, Director of the Galilee-Golan District
- Hana Tubi, Planning Authority, responsible for water planning and quota allocation.
- Mr.Erez Osman, economist, Research, Economy and Strategy Division.

Ministry of Finance (MoF)

- Mr Alon Messer, Coordinator water and agriculture, budgetary division.

Israeli Farmers' Federation (IFF)

- Rachel Boroshak, Chief economist, Israeli Farmers' Assocation.

Water Authority (WA)

- Eng. Shimon Tal, Consultant (former Head of Water Authority)

The objectives of the meeting were twofold:

1. Present the Israel MYWAS economic and hydrologic model
2. Discuss how the model can be used to support the proposed policy reform in the pricing of fresh and recycled water for agriculture

Israel Finkelshtain presented the main features of MYWAS. He described the objective function (maximizing net social water associated welfare in the country); the inputs (various scarce water resources, hydrological and engineering constraints, topology of the water sector, the demand functions of the agricultural, industrial and urban consumers) and the outputs (optimal allocation over space and time from the various resources to the various consumers, scarcity rents of the resources, shadow values of water and more).

He pointed out that the model's results are clearly relevant and valuable for the litigation process being conducted now between the MoA and the MoF and the Water Authority. The MoF and the Water Authority are planning to raise the agricultural freshwater tariff by approximately 50% in the near future, equating it to the **average cost** (**AC**) of water supply. The shadow values of water for the various agricultural regions clearly show that the planned tariff increase should not take place. In fact, the economically efficient tariff should be equal to the **marginal cost** (**MC**) and **not the AC** (which is higher than MC), which is even lower than the current tariff.

The representative from the MoF (an economist) commented that a tariff equal to MC will not cover the full cost of supply. We agreed with them and offered a couple of policy instruments that can be applied in order to achieve full-cost recovery (like levying a fixed annual payment on each user independent of their water consumption, namely, a two-part tariff). We emphasized that "imposition" of all the costs on the tariff per cubic meter yields sub-optimal allocation and significant welfare loss which can be calculated by MYWAS.

The model's results and our explanations were very interesting for all the participants. They asked to learn more and we gladly agreed to meet again within a month or two. In the follow up meeting, we will present additional and more detailed results and ask their opinion, what are the most important water projects we should simulate (check out their profitability and priorities) in MYWAS.

Meeting with the Ministry of Agriculture and Farmers Association

The Hebrew University team held a subsequent meeting with the following participants October 28, 2014:

Ministry of Agriculture and Rural Development (MOAG)

- Mr.Uri Zuk-Bar, Deputy Director General, Head of the Research, Economy and Strategy Division.
- Dr. Yael Kachel, Head of Research, Research, Economy and Strategy Division.
- Two assistance of Uri Zuk Bar

Israeli Farmers' Foundation (IFF)

- Mr. Avshalom (ABU) Vilan, Head of IFF and former Knesset Member
- Rachel Boroshak, Chief economist.

The objectives of this meeting were twofold:

1. Short presentation of the updated (since the previous meeting) results of MYWAS

2. In- depth discussion on the economic and policy implications of the results for the agricultural sector

Eli Feinerman presented the main features of MYWAS, its key results and explained in a relative length the economic principles of water allocation to competing activities from various limited resources differing in quantity, quality and supply costs as well as the principals of efficient water pricing.

The participants were highly impressed by the potential of the model to simulate and predict the results and economic impacts of relevant policies. They asked us to simulate the impacts of the 2015 agricultural water prices proposed by the MOF and IWA during their negotiations with MOAG and IFF. We did so a couple of days after the meeting. <u>The results were presented to the General Director of MOAG and to the other above mentioned negotiators and have already influenced the negotiation process.</u>

Additional dissemination activities

In addition to the formal activities described above, the team has carried out several other activities:

- We wrote a detailed report (in Hebrew) to MOAG which included: (i) discussion of the economic principles of allocation of limited water resources and of economically efficient pricing, (ii) the main results of MYWAS simulations of static analysis of water policies, and (iii) recommendations for the two-part tariff for irrigation water.
- Following the request of the editor of the formal journal of the Israeli Fruit Growers Association, "*Alon Hanotea* " (*The Planter Bulletin*), and for the benefit of the Israeli Farmers, we wrote a short version (in Hebrew) of the report submitted to MOAG that will be published soon (on January 2015) in this journal.
- The principles and the results of MYWAS will be presented soon to the General Director and representative from the Economic Division of the IWA.

6. Summary

The Water Economics Project and Hebrew University team have successfully created a model of the water economy of Israel that for the first time includes not only fresh and recycled sources of water, but brackish sources as well. The model comprehensively allows users to evaluate the impacts of different price policies, their impacts on different water users, as well as how that shifts infrastructure planning over time.

The project has already had some influence over the negotiation process between various ministries on pricing of water for agriculture in the future, reaching the level of the Director General for the Ministry of Agriculture and the negotiation team. Future meetings are planned for the Water Authority.

It is clear that MYWAS has a role to play in Israel in thinking about water policies. It is our hope that there is continued investment in the tool to provide clear economic knowledge and awareness as critical decisions are being made in the face of tremendous uncertainty – both climatically and politically – around water.

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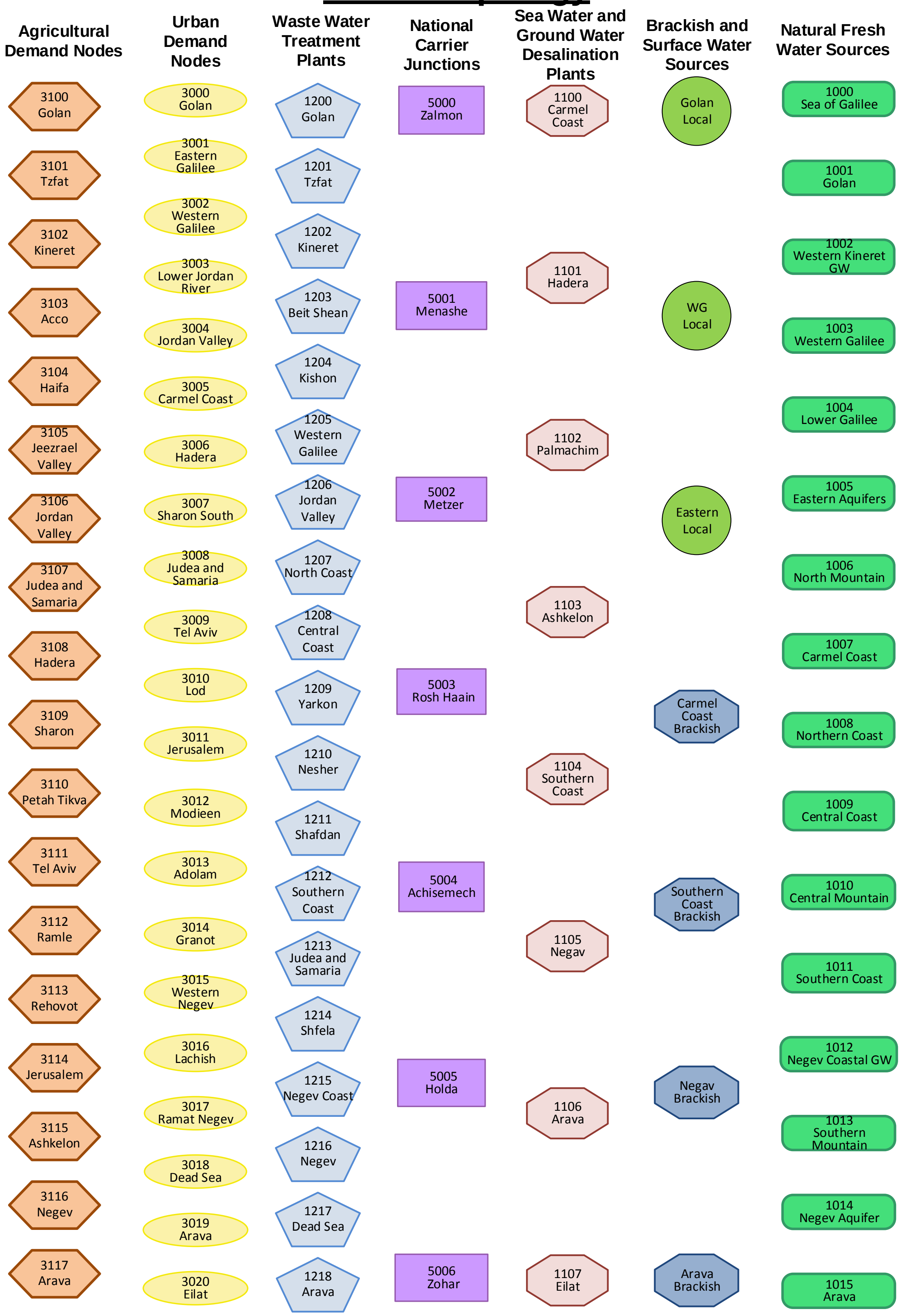
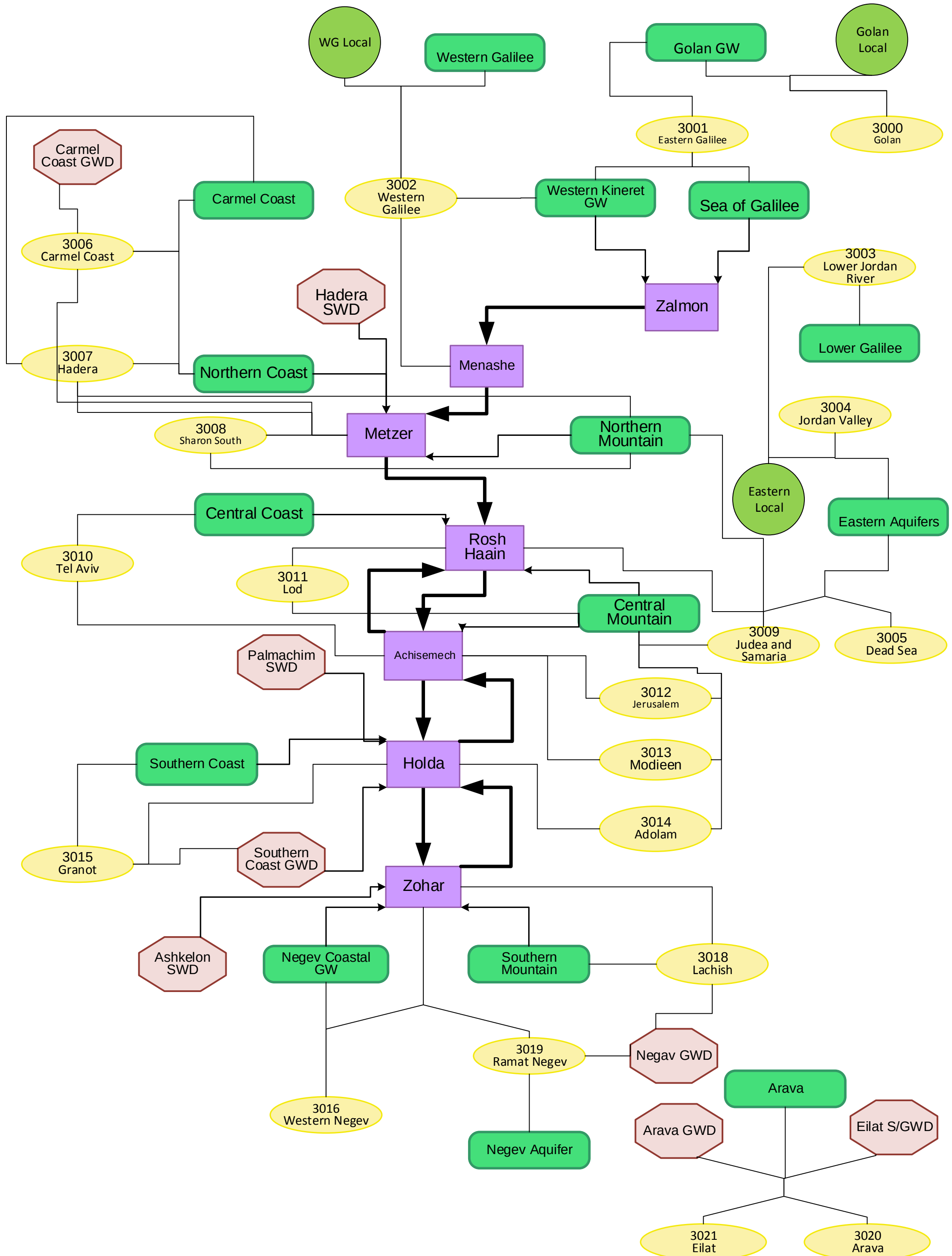
Appendices

Appendix A – Topology Schemes

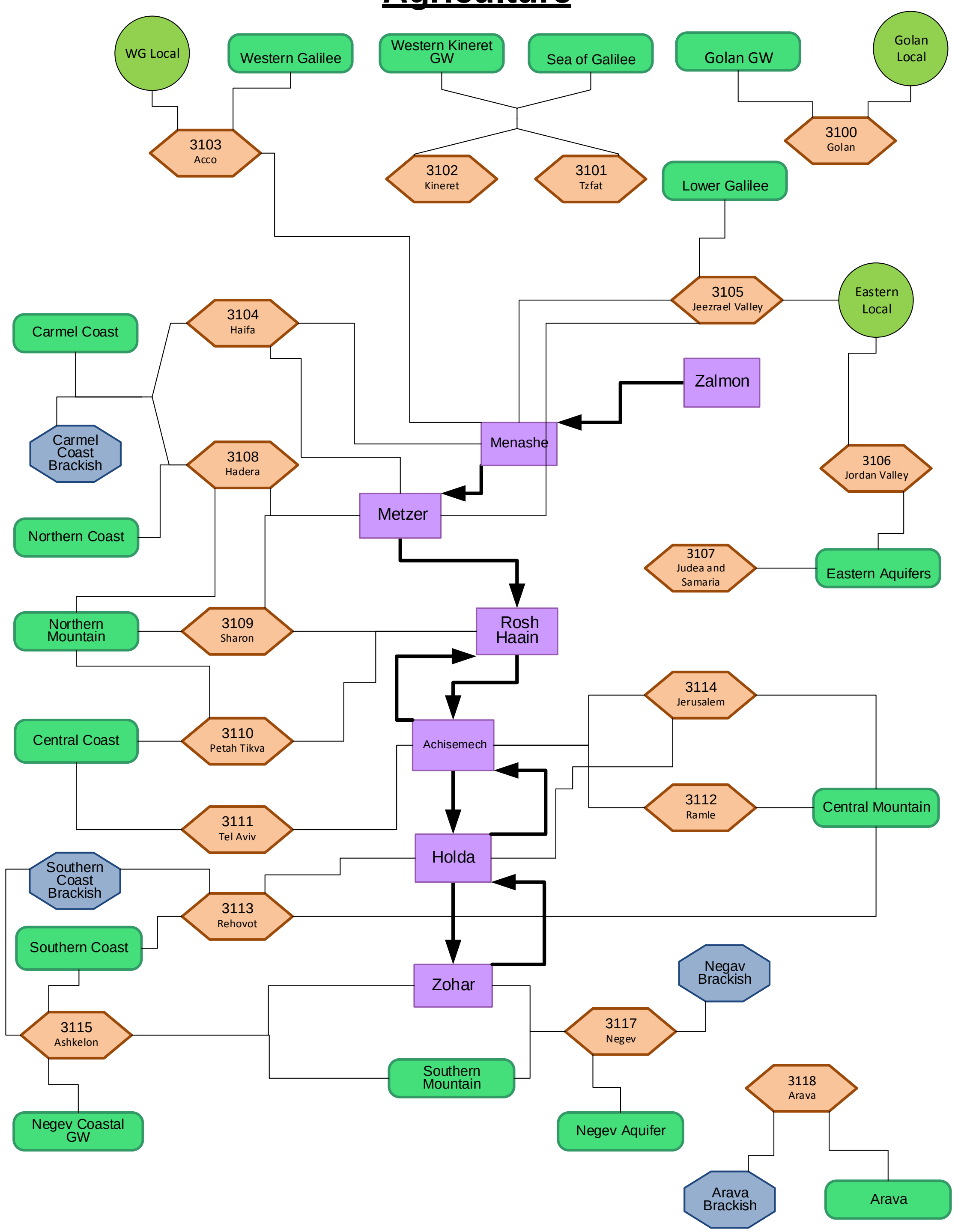
Model Topology



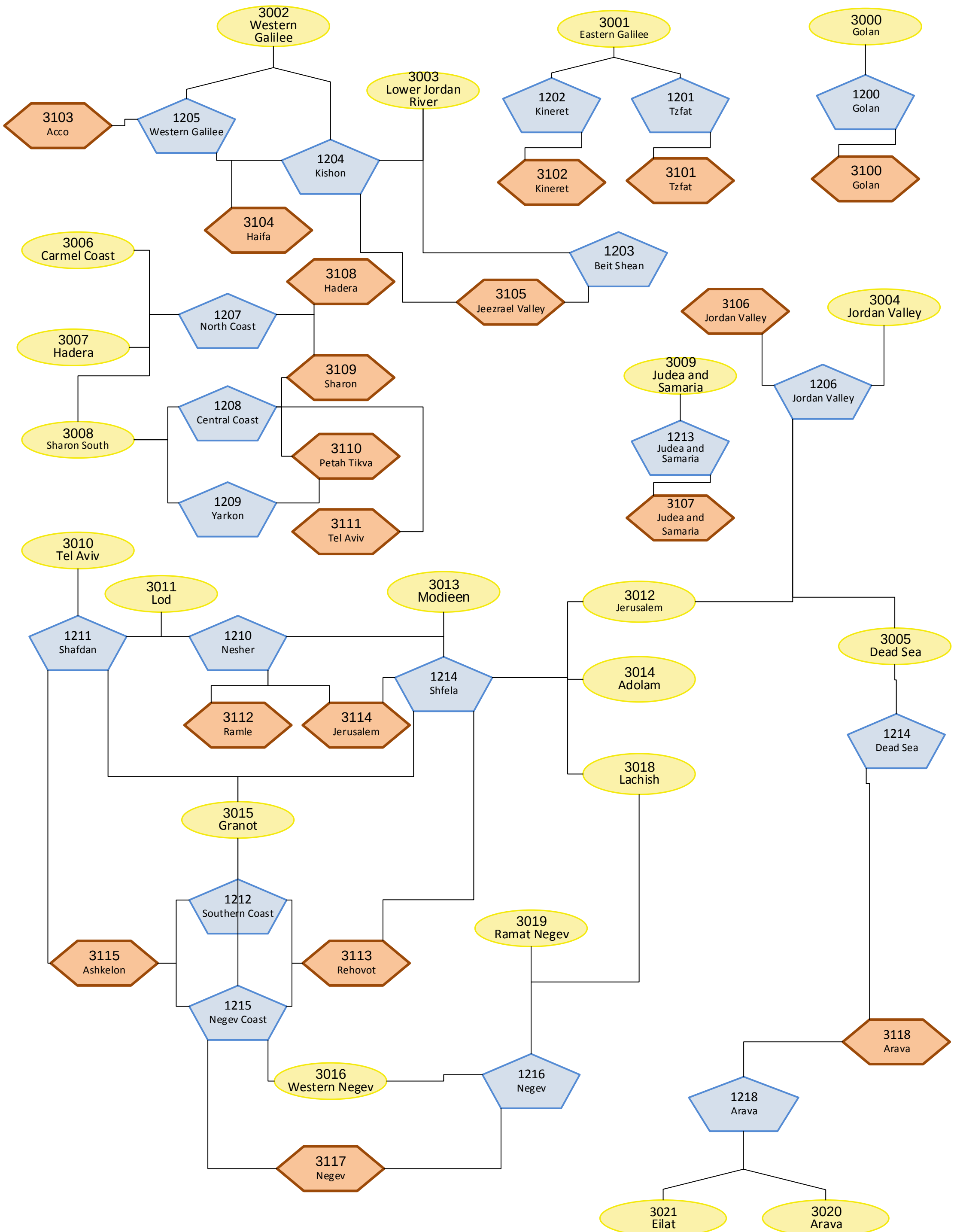
Fresh water system



Fresh and Brackish water for Agriculture



Waste water system



Appendix B – Supply Data

Potable Water Sources				
Name	Capacity (MCM)	Extraction in 2010 (MCM/Year)	Average Annual Recharge (MCM/Year)	Cost of Extraction ($/CM)
Sea of Galilee	692	165	317	0.096
Golan	107	10	75	0.18
Western Kinneret GW	128	56	63	0.0775
Western Galilee	215	90	135	0.045
Lower Galilee	40.6	13	29	0.06
Eastern Aquifers	495	90	365	0.0654
Northern Mountain Aquifer	442	85	111	0.0334
Carmel Coast	51	40	41	0.0254
Northern Coastal Aquifer	585	85	97	0.025
Central Coastal Aquifer	251	29	35	0.027
Central Mountain Aquifer	654	146	206	0.121
Southern Coastal Aquifer	614	203	85	0.0275
Negev Coastal Aquifer	250	28	22	0.032
Southern Mountain Aquifer	98	38	25	0.151
Ramat HaNegev	83	3	35	0.04
Arava	67	13		0.0385

Desalination Plants			
Name	Capacity (MCM)	Desalination in 2010 (MCM/Year)	Cost of Desalination ($/CM)
Carmel Coast GWD	16.7	16.7	0.226
Hadera SWD	145	127	0.4
Palmachim SWD	45	45	0.4
Southern GWD	14	14	0.226
Ashkelon SWD	120	120	0.4
Negev GWD	2.5	2.5	0.226
Arava GWD	11.3	11.3	0.226

Eilat	26	26	0.4

*SWD and GWD stand for "Sea Water Desalination" and "Saline Ground Water Desalination" respectively

Waste Water Treatment Plants			
Name	Capacity (MCM)	Water Treated in 2010 (MCM/Year)	Treatment Cost ($/CM)
Golan	3.7	3.3	0.260
Tzfat	10.7	9.6	0.266
Kinneret	8.1	7.3	0.272
Beit Shean	2.8	2.5	0.313
Kishon	59.8	53.8	0.291
Western Galilee	28.6	25.7	0.294
Jordan Valley	8.5	7.7	0.244
Northern Coast	21.5	19.4	0.299
Central Coast	45.8	41.2	0.293
Yarkon	11.7	10.5	0.320
Nesher	18.8	16.9	0.314
Shafdan	127.8	115.1	0.320
Southern Coast	6.1	5.5	0.287
Judea & Samaria	5	4.5	0.266
Shfela	42.1	37.9	0.317
Negev Coast	30.7	27.6	0.311
Negev	30.7	27.6	0.299
Dead Sea	1.5	1.3	0.298
Arava	8.1	7.3	0.312

*Costs are levied on urban & industrial demand sites

Transmission Links to Urban Demand Nodes			
Potable Water Sources			
Source Name	**Destination Name**	**Transfer & Distribution Cost ($/CM)**	**Sewage Removal Cost ($/CM)**
Golan GW	Eastern Galilee	0.432	0.68
	Golan	0.308	0.642
Sea of Galilee	Eastern Galilee	0.42	0.68
Western Kinneret GW	Eastern Galilee	0.372	0.68
	Western Galilee	0.354	0.646
WG Aquifer	Western Galilee	0.344	0.646
Lower Galilee GW	Lower Jordan	0.31	0.66
Eastern Aquifers	Dead Sea	0.306	0.661
	Jordan Valley	0.306	0.66
	Judea and Samaria	0.303	0.67
Northern Mountain Aquifer	Hadera	0.3	0.61
	Judea and Samaria	0.303	0.67
	Sharon South	0.297	0.642
Central Mountain Aquifer	Adolam	0.456	0.66
	Jerusalem	0.58	0.8
	Judea and Samaria	0.303	0.67
	Lod Lowland	0.28	0.634
	Modieen	0.35	0.51
Southern Mountain Aquifer	Lachish	0.294	0.583
Carmel Aquifer	Carmel Coast	0.306	0.66
	Hadera	0.3	0.61
Northern Coastal Aquifer	Carmel Coast	0.306	0.66
	Hadera	0.3	0.61
	Judea and Samaria	0.303	0.67
	Sharon South	0.307	0.642
Central Coastal Aquifer	Tel Aviv	0.31	0.797
Southern Coastal Aquifer	Granot	0.28	0.6
Negev Coastal Aquifer	Western Negev	0.315	0.585
Negev Aquifer	Ramat Negev	0.33	0.73

Arava GW	Arava	0.306	0.66
	Eilat	0.336	0.66

*Removal costs are levied only on the share of consumption that's being discharged from the city

Transmission Links to Urban Demand Nodes			
Desalination (Ground, Surface & Sea Water)			
Source Name	**Destination Name**	**Transfer & Distribution Cost ($/CM)**	**Sewage Removal Cost ($/CM)**
Eilat SWD	Arava	0.336	0.66
	Eilat	0.336	0.66
Jordan Valley	Lower Jordan	0.36	0.66
	Jordan Valley	0.356	0.66
Western Galilee	Western Galilee	0.394	0.646
Carmel Coast	Carmel Coast	0.246	0.66
South Coast	Granot	0.28	0.6
Negev	Lachish	0.314	0.583
	Ramat Negev	0.3	0.73
Arava	Arava	0.346	0.66
	Eilat	0.346	0.66
National Carrier Junctions			
Source Name	**Destination Name**	**Transfer Cost ($/CM)**	**Sewage Removal Cost ($/CM)**
Menashe	Western Galilee	0.384	0.646
Metzer	Carmel Coast	0.356	0.66
	Hadera	0.32	0.61
	Sharon South	0.287	0.642
Rosh Haain	Judea and Samaria	0.49	0.67
	Lod Lowland	0.27	0.634
Achisemech	Jerusalem	0.48	0.8
	Judea and Samaria	0.623	0.67
	Lod Lowland	0.29	0.634
	Modieen	28.08	0.51
	Tel Aviv	0.295	0.797
Holda	Adolam	0.596	0.66
	Granot	0.27	0.6
	Jerusalem	0.69	0.8
	Judea and Samaria	0.633	0.67
	Modieen	0.36	0.51
Zohar	Judea and Samaria	0.603	0.67
	Lachish	0.434	0.583
	Ramat Negev	0.3	0.73
	Western Negev	0.335	0.585

Transmission Links to Agriculture Demand Nodes		
Potable Water Sources		
Source Name	**Destination Name**	**Transfer Cost ($/CM)**
Golan GW	Golan	0.01
Sea of Galilee	Kineret	0.01
	Tzfat	0.01
Western Kinneret GW	Kineret	0.01
	Tzfat	0.01
WG Aquifer	Acco	0.01
Lower Galilee GW	Jeezrael Valley	0.01
Eastern Aquifers	Jordan Valley	0.01
	JS Settlements	0.01
Northern Mountain Aquifer	Hadera	0.01
	Petah Tikva	0.02
	Sharon	0.02
Central Mountain Aquifer	Jerusalem	0.01
	Ramle	0.01
	Rehovot	0.01
Southern Mountain Aquifer	Ashkelon	0.01
	Ramat Negev	0.01
Carmel Aquifer	Hadera	0.01
	Haifa	0.01
Northern Coastal Aquifer	Hadera	0.02
Central Coastal Aquifer	Petah Tikva	0.02
	Tel Aviv	0.02
Southern Coastal Aquifer	Ashkelon	0.01
	Rehovot	0.04
Negev Coastal Aquifer	Ashkelon	0.01
Negev Aqufer	Ramat Negev	0.01
Arava GW	Arava	0.01

Transmission Links to Agriculture Demand Nodes		
Waste Water Treatment Plant		
Source Name	**Destination Name**	**Transfer Cost ($/CM)**
Golan	Golan	0.01
Tzfat	Tzfat	0.01
Kineret	Kineret	0.01
Beit Shean	Jeezrael Valley	0.01
Jordan Valley	Jordan Valley	0.01
Western Galilee	Acco	0.09
	Haifa	0.09
Kishon	Haifa	0.13
	Jeezrael Valley	0.13
North Coast	Hadera	0.03
	Sharon	0.03
Central Coast	Petah Tikva	0.02
	Sharon	0.02
	Tel Aviv	0.02
Yarkon	Petah Tikva	0.02
Shafdan	Ashkelon	0.09
	Ramat Negev	0.16
Shfela	Ashkelon	0.06
	Jerusalem	0.06
	Rehovot	0.06
Nesher	Jerusalem	0.06
	Ramle	0.06
Judea & Samaria	JS Settlements	0.01
South Coast	Ashkelon	0.04
	Rehovot	0.04
Negev Coast	Ashkelon	0.02
	Ramat Negev	0.03
	Rehovot	0.02
Negev	Ramat Negev	0.03
Dead Sea	Arava	0.02

Arava	Arava	0.02

*Transfer costs at each WWTP are similar due to aggregation level

Transmission Links to Agriculture Demand Nodes		
Brackish/Saline Ground & Surface Water		
Source Name	**Destination Name**	**Transfer Cost ($/CM)**
Jordan Valley	Jeezrael Valley	0.01
	Jordan Valley	0.01
Western Galilee	Acco	0.01
Carmel Coast	Hadera	0.01
South Coast	Ashkelon	0.01
	Rehovot	0.04
Arava GW	Arava	0.01
Negev GW	Ramat Negev	0.01
Treated Brackish/Saline Ground & Surface Water		
Source Name	**Destination Name**	**Transfer Cost ($/CM)**
Jordan Valley	Jeezrael Valley	0.06
	Jordan Valley	0.06
Western Galilee	Acco	0.06
National Carrier Junctions		
Source Name	**Destination Name**	**Transfer Cost ($/CM)**
Menashe	Acco	0.05
	Haifa	0.05
	Jeezrael Valley	0.05
Metzer	Hadera	0.03
	Haifa	0.06
	Jeezrael Valley	0.03
	Sharon	0.01
Rosh Haain	Petah Tikva	-
	Sharon	-
Achisemech	Jerusalem	0.13
	Ramle	0.02
	Tel Aviv	0.005
Holda	Jerusalem	0.34
	Rehovot	0.01
Zohar	Ashkelon	0.06
	Ramat Negev	0.05

Appendix C – Urban Water Demand Function Parameters

	Urban Demand		Industrial Demand	
Name	Constant Term	Consumption in 2010 (MCM)	Constant Term	Consumption in 2010 (MCM)
Golan	5.08	4.517	0.41	0.372
Eastern Galilee	87.94	78.148	3.02	2.765
Western Galilee	141.77	125.982	27.78	25.464
Lower Jordan	7.56	6.716	1.98	1.816
Jordan Valley	7.69	6.830	0.04	0.039
Dead Sea	7.09	6.298	43.61	39.975
Carmel Coast	8.56	7.604	0.80	0.731
Hadera	28.26	25.114	6.99	6.407
Sharon	97.67	86.787	4.47	4.097
Judea and Samaria	64.22	57.065	0.77	0.702
Tel Aviv	127.89	113.646	4.25	3.895
Lod Lowland	42.19	37.494	2.76	2.531
Jerusalem	70.86	62.963	2.51	2.301
Modiin	16.84	14.965	4.27	3.913
Adulam	1.19	1.056	0.24	0.224
Granot	79.34	70.498	13.62	12.482
Western Negev	31.16	27.686	5.15	4.726
Lachish	51.75	45.989	9.89	9.069
Ramat Negev	4.12	3.657	2.30	2.108
Arava	12.33	10.956	5.72	5.240

We assume demand elasticity of -0.1 for domestic use and -0.33 for industrial use. Prices for Urban and Industrial uses are administrated by the Water Authority and are assumed equal to all users (~3.26 $/CM and ~1.3 $/CM for urban and industrial uses, respectively).

Appendix D - Calibrating Agricultural Demand Function

Let the agricultural revenue function be:

(1) $$R = A\left(w^f + \gamma w^r\right)^{\alpha}$$

where w^f and w^r are freshwater and treated wastewater, respectively, and A, α and γ are parameters. The parameter γ converts wastewater into freshwater equivalents.

Assuming that prices bind freshwater and treated wastewater consumptions, the *VMP* functions with respect to w^f and w^r are:

(2) $$VMP_{w^f} = \alpha A\left(w^f + \gamma w^r\right)^{\alpha-1} = p^f$$

(3) $$VMP_{w^r} = \alpha A\left(w^f + \gamma w^r\right)^{\alpha-1}\gamma = p^r$$

Thus, the parameter γ is given by:

(4) $$\gamma = \frac{p^r}{p^f}$$

The parameter α can be estimated based on observations that consume freshwater only. In such observations:

$$VMP_{w^f} = \alpha A\left(w^f\right)^{\alpha-1} = p^f \Rightarrow$$

(5) $$w^f = \left(\frac{1}{\alpha A}\right)^{\frac{1}{\alpha-1}}\left(p^f\right)^{\frac{1}{\alpha-1}} \equiv B\left(p^f\right)^{\beta}$$

The parameter β has been estimated by Bar-Shira et al. (2006): 0.3 and 0.5 for the short- and long-run, respectively .

Then, having $\alpha = \frac{1+\beta}{\beta}$ and the γ parameter from Eq. (4), one can calibrate A based on Eq. (2). The calibrated Eq. (2) can then be used as the demand function for freshwater.

Note that, ultimately, we didn't apply this calibration procedure, because it yields unrealistic freshwater-equivalent conversion factors.

Appendix E - Agricultural Demand Function Parameters

Agricultural Demand						
Name	Constant Term	Potable Water Consumption in 2010 (MCM)	Treated Waste Water Consumption in 2010 (MCM)	Brackish Water Consumption in 2010 (MCM)	Fresh Water Equivalent (MCM)	Potable Water Prices ($/CM)
Golan	415.32	29.94	0.53	-	30.38	0.50
Tzefat	2913.42	76.18	5.16	-	80.46	0.38
Kineret	1081.58	43.67	4.79	2.76	49.03	0.36
Acco	753.76	26.50	13.90	5.78	40.93	0.38
Haifa	65.28	4.35	9.27	-	12.04	0.38
Jeezrael Valley	10641.62	75.89	39.24	90.64	153.78	0.34
Judea & Samaria	48.98	4.57	7.06	-	10.43	0.44
Jordan Valley	487.17	21.56	12.16	2.50	32.90	0.45
Hadera	1055.51	38.26	10.17	3.46	48.43	0.36
Sharon	1438.24	36.78	23.80	-	56.53	0.33
Petach Tikva	444.10	25.97	6.56	-	31.41	0.33
Tel Aviv	4.13	1.80	1.48	-	3.03	0.35
Ramla	111.95	11.44	5.22	-	15.77	0.43
Rehovot	452.26	11.39	23.37	1.83	31.70	0.39
Jerusalem	411.48	5.48	29.83	-	30.24	0.43
Ashkelon	3112.33	34.00	55.74	5.80	83.16	0.41
Ramat Negev	10181.71	34.32	133.65	10.34	150.42	0.45
Arava	626.29	2.68	8.17	55.69	37.31	0.35

Administrative conversion ratios applied by the ministry of agriculture are: 1 treated wastewater CM = 0.83 CM of freshwater; 1 CM of brackish water = 0.5 CM of freshwater.

Appendix F - Investments in Infrastructures

Investments in Wells by Regions

Source	Capacity (MCM/Y)	Investment ($/well)
Northern Coastal Aquifer	0.69	91,794
Central Coastal Aquifer	0.51	102,082
Southern Coastal Aquifer	1.22	107,663
Negev Coastal Aquifer	1.36	126,433
Northern Mountain Aquifer	1.00	255,148
Central Mountain Aquifer	1.96	425,832
Southern Mountain Aquifer	1.65	691,298
WG Aquifer	1.51	269,436
Carmel Aquifer	0.63	87,204
Western Kinneret GW	1.32	454,300
Golan GW	0.53	512,383
Eastern Aquifers	0.80	403,804
Arava GW	1.64	322,508
Negev Aquifer	0.83	281,811
Lower Galilee GW	1.04	229,536

Data were provided by TAHAL. The capacity represents the increased extraction per well, computed based on the regional capacity in each region, where the number of wells in each region were taken from the Hydrological Service.

Investment in Desalination Plants

Plant	Investment (million $)
Hadera SWD	425
Palmachim SWD	100
Ashkelon SWD	212
Sorek SWD	400
Ashdod SWD	423

Source: Spiritos and Lipchin, 2014.

Investments in Wastewater Treatment Plants by Regions

Name of Plant	Size of representative plant (1=big, 4=small)	Investment per plant (10^6 $)
Golan WWTP	3	6.31
Tzfat WWTP	3	6.68
Kineret WWTP	3	6.15
Beit Shean WWTP	3	6.94
Kishon WWTP	2	31.57
WG WWTP	2	23.11
JV WWTP	2	20.17
NC WWTP	2	20.68
CC WWTP	2	31.48
Yarkon WWTP	2	21.24
Nesher WWTP	1	32.42
Shafdan	1	37.33
SC WWTP	3	7.03
JSS WWTP	4	5.01
Shfela WWTP	1	33.74
Negev C WWTP	2	31.07
Negev WWTP	2	20.01
Dead Sea WWTP	3	5.61
Arava WWTP	2	20.24

A representative plant size was computed for each region according to the average size of the pants in the region. The investments were computed based on data supplied by TAHAL (Table A3).

Investments in Treated Wastewater by Size

Size	Capacity	Investment (10^6 NIS)
Large (1)	40-60 TCM/day	140
Medium (2)	10-30 TCM/day	65-115
Small-Medium (3)	3-10 TCM/day	28-60
Small (4)	100 – 1000 m^3/day	2-15

Appendix G – Interface of MYWAS for Israel