Global Issues in Water Policy 4

Nir Becker *Editor*

Water Policy in Israel

Context, Issues and Options

Springer

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GLOBAL ISSUES IN WATER POLICY

VOLUME 4

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This book is dedicated to the memory of late Professor Dan Yaron: a teacher, mentor, and a friend, but most of all, a true gentleman and one of the most sensitive individuals I have ever met. His knowledge and modesty serve as a permanent light to my path. Dan introduced me to the complex issues of water policy in Israel; it is only a small thanks compared to what is due that I dedicate this book to his memory.

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Chapter 1
Introduction

Nir Becker

> Taking into account the range of issues, the number of alternative management strategies, the complex structure of governing institutions and the unavoidable interplay between values, interests and power, it has been argued that public policy processes are anything but linear, organized or coherent arenas (Teschner et al. 2012).

This book aims to focus on the policy of the water sector in Israel. It brings together 16 chapters written by experts in their field. Each chapter deals with a different aspect of the policy dimension. In this introduction chapter, I draw the linkage among them besides providing the justification for this book and describing the water sector in Israel in a concise way.

It should be noted that there is no chapter about water policy in Israel, per se. The topic is complex enough that it cannot be dealt with within a single chapter. Water policy refers to the aspects of the water sector with which the government deals. These may include supply and demand management, pricing, water conflict resolutions, and the international water policy dimension. It is important to remember that policy does not define actions so much as it defines the rules. The implementation of these rules is later implemented in Israel by what is called the "master plan."

Water policy in Israel changed over time as a result of two major forces (Alatout 2008). On one side, this is not a good indication since policy needs to address changing conditions. On the other, it demonstrates the flexibility that one can observe in cases where significant changes in some exogenous conditions have occurred. Was this really the case in Israel? Several committees formed by the government, the parliament, and the state comptroller have indicated that the first force dominated the second (Magen Committee 2002; Milgrom and Schwartz 2008; Bain Committee 2010). These committees plus some internal ones under the Water Authority were abundant (19 according to Fischandler 2008). But these committees

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are looking backward, while policy needs to look forward and, as such, always faces some uncertainty (Tal 2006). Thus, a good or bad outcome is not necessarily correlated with a good or bad policy (Fischandler and Heikilla 2010). The situation is more complex and hence deserves a special attention. This is a major reason for the appearance of this book.

This is the first chapter in this book and it is divided into three parts. The first one describes some basic statistics and estimates regarding the water sector in Israel. The interested reader can find parts of those estimates in chapters along the book, but it might be useful for the reader to get a fuller picture. The second part deals with the policy questions the water sector in Israel faces and why it is a unique experience as well as a challenging one. The third part briefly describes the different chapters and relates them into the policy aspects that need to be addressed.

1.1 General Background on the Water Sector in Israel[1]

Israel currently has renewable freshwater available sources of some 1,300–1,400 million cubic meters (MCM) annually, representing a per capita supply of some 180 m^3 of water annually. The current annual consumption of water is about 2,100 MCM. This represents per capita consumption of 268 m^3. The definition of the UN for water scarcity is less than 500 m^3 water per capita annually.[2]

1.1.1 Supply Sources

Israel's main natural renewable sources of water supply include the Sea of Galilee (Lake Kineret) and Jordan basin springs and rivers, the Mountain Aquifer, and the Coastal Aquifer. Several smaller aquifers constitute the rest of the natural supply. Figure 1.1 below presents the distribution of water natural sources. Figures on the chart are in MCM and percentage from the total of 1,392 MCM of renewable supply sources. A general insight into the water system in Israel is given in Map 1.1.

As can be seen from Figure 1.1 and Map 1.1 below, almost all the water resources are based on three major sources: two groundwater aquifers and one lake. It can be also noted that they are connected by what is called the National Water Carrier (NWC). The importance of each one of these resources is crucial for policy

[1] An up-to-date overview of the water sector in Israel can be found in Kislev (2011). A more general overview, less technical but more detailed, is given in Gvirtzman (2002). Figures here are based on Waslekar (2011).

[2] When annual water supplies drop below 1,000 m^3 per person, the population faces water scarcity, and below 500 m^3 "absolute scarcity." Source: website page of UNDESA (United Nations Department of Economic and Social Affairs)
http://www.un.org/waterforlifedecade/scarcity.shtml

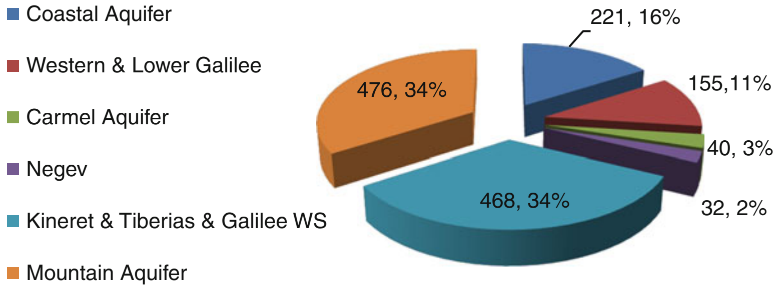

Fig. 1.1 Distribution of water resources in Israel – 2010 (in MCM and %)

purposes. The Sea of Galilee and the coastal aquifers are subject to pollution, and the Sea of Galilee also serves as a recreational site. The Mountain Aquifer is a resource in dispute between Israel and the Palestinian Authority (PA).

1.1.2 Demand[3]

The demand for water in Israel originates from three major sectors – agricultural, industrial, and domestic use (households). A fourth sector is becoming more and more relevant in the last few years, water for nature in the form of in-stream flow into the different rivers. Total consumption in 2010 was 2,013 MCM, while some 100 MCM were allocated to Jordan and the PA. Figure 1.2 below presents the distribution of water consumption by the different sectors.

Worth mentioning is the fact that most of the water allocated to agriculture is reclaimed and treated water, and in general, no more than 500 MCM of freshwater are allocated to agriculture. This was a result of a major change in Israel's water policy to be discussed in several chapters along this book.

1.1.3 The Gap Between Supply and Demand

Figure 1.3 below represents the trend of water consumption vs. water availability in the last 30 years. As can be seen from this figure, the utilization rate has increased from 108% in 1980 to some 150% in 2010. This utilization rate was possible due to the use of marginal water, mainly treated wastewater and desalinated water. Projections indicate that the demand will increase to 2,500 MCM in 2020 and close

[3]Data are taken from water authority website – http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/Allocation-Consumption-and-production/20091/by-goals.pdf

Map 1.1 Israel's water system (*Source*: Feitelson and Rorenthal 2012)

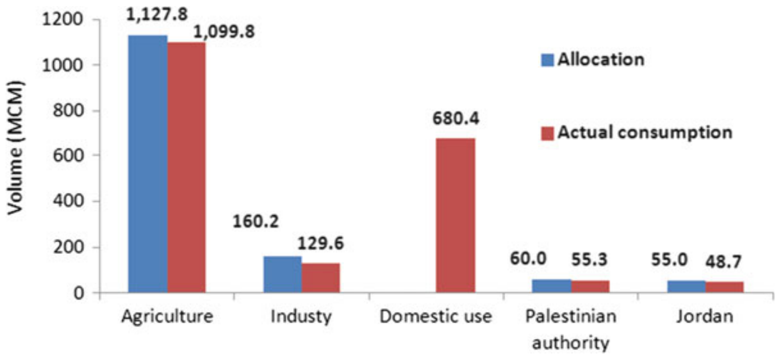

Fig. 1.2 Major beneficiaries of water consumption in Israel (in MCM) – 2010

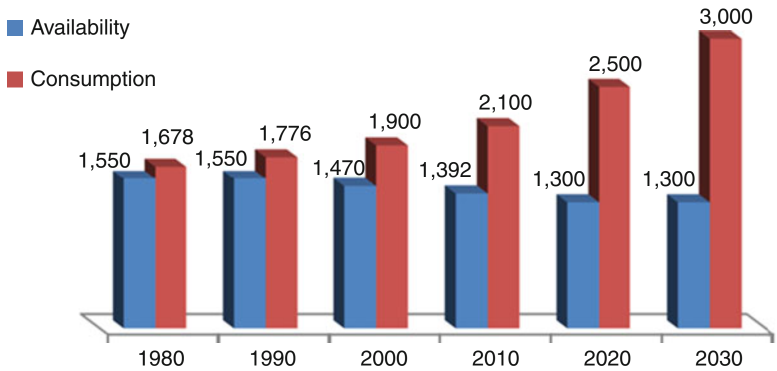

Fig. 1.3 Water consumption vs. availability

to 3,000 MCM in 2030, while supply of available freshwater will slightly shrink, resulting in a utilization rate of almost 200% in 2020 and more than 230% in 2030. This trend is what consist the "water crises" in Israel.

1.1.4 Marginal Water

As seen in Fig. 1.3, the gap between supply and demand for water is increasing over time. In order to reduce the gap, Israel's major policy goal was to increase the supply available, on one hand, and to reduce demand on the other.

From the supply side, Israel has increased its use in marginal water, including using means of desalination, wastewater treatment, and water harvesting. Each is indicated below:

Desalination – n 2011, 296 MCM of water were desalinated out of sea water, and some 45 MCM were desalinated out of brackish water. There are currently three active desalination plants, working in reverse osmosis technique – in Palmachim,

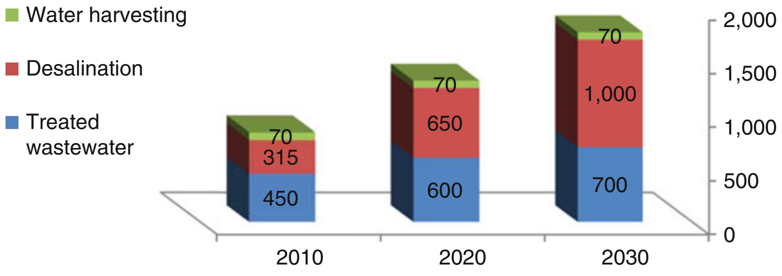

Fig. 1.4 Current and future marginal water use

Ashkelon, and Hadera, producing 46, 120, and 127 MCM, respectively. Few other plants are in construction, designated to increase annual desalination capacity to 700 MCM by 2020 and then an additional 100 MCM every 4 years.

Treated wastewater – Israel is one of the leading countries in the world in managing (treated and reclaimed) wastewater. In 2007, 92% of the wastewater in Israel was treated, and over 75% was going to be reused in irrigation. Currently, some 450 MCM of wastewater are reclaimed for agriculture, and this figure was supposed to increase to 600 and 700 MCM in 2020 and 2030, respectively.

Water harvesting – The current estimate is about 70 MCM. Water harvesting generally includes capturing runoff from rooftops and local catchments, capturing seasonal floodwaters from local streams, and conserving water through watershed management.

Figure 1.4 above presents the current and projected volume of marginal water supply.

As can be seen from Figs. 1.3 and 1.4 above, the increase in marginal water supply corresponds to the increase in the gap between the supply and the demand of renewable freshwater. Seemingly, it should be enough. However, this change in water mixture did not come without a fight, and, moreover, it was recently found that climate change can add more pressure on the already semiarid climate of Israel (Alpert et al. 2008). The Water Authority is trying to close the potential gap by treating the demand side as well (Lavee et al. 2011). This was done by several methods to be explored in this book. They include both changes in the water tariffs as well as non-price measures.

The gap between supply and demand is one of the main concerns for water policy makers in Israel. But it is necessary to view water policy as a broader sense than this gap alone – hence the need for this book.

1.2 The Need for Water Policy

The need for water policy is not restricted to Israel, of course. Every country deals with water problems by initiating its own policy on the subject. Why is a special book needed about Israel's water policy? There are several reasons which I can think of. The first is that no such book was written in such a comprehensive effort by many leaders in their field. Second, it provides up-to-date information while not neglecting the past events that have led to the current situation. But the most important reason is that Israel can serve as an example to a country that has to deal with so many aspects of its water sector that it can be a good starting point for other countries that face part of the problems that Israel is facing by learning how to cope with these issues from past experience.

Not all the water sector issues are unique to Israel of course, but it is the sum of all those aspects that makes Israel a unique case study. Here are some of issues that together make Israel's water sector issues unique:

- *Mixture of private and public aspects*: Water is consumed by households, farmers, and industry; however, it also carries public good characteristics by providing high elevation in the Sea of Galilee, in-stream flaw in rivers, and by creation of desirable landscape arising by farming. Those last values do not carry a price tag, but certainly have a value associated with them. How can this be reconciled by the free market? It cannot and therefore there is a role for a policy.
- *Water as a social good*: Despite the fact that water can be thought of as a commodity (either private or public), it can also be served as a tool to achieve social goals that cannot be quantified. Those goals have no direct value attached to them, but rather serve as constraints. Examples of such are water diverted to the periphery to sustain living conditions to settlers, water to farmers in a minimum amount to sustain heritage, and water as a basic good that every person has the right to get a minimum amount regardless he/she can afford it or not. All those elements of water do not have a direct value, but they have an indirect value. This indirect value can be defined as the opportunity cost of achieving those preset goals. Water policy should take those costs into account when defining such goals.
- *Common property resource problem(CPR)*: The main water sources in Israel (there are 3 such sources) can be characterized as CPRs. In such resources, there exists the quazi-public good problem. Hence, the consumption of the good is private (You get what you pumped), but the cost of the extraction and the quality of the resource are both determined by the action of all users involved. In such situation, there is a market failure known as the tragedy of the commons. Without some governmental policy, there would be inefficiency involved which may result not only in higher extraction costs but also in morbidity and mortality due to increased pollution which is not regulated.
- *Increasing return to scale*: Most of the water resources extraction and diversion as well as distribution are associated with large infrastructure facilities. In a nonregulated market, this may result in too many firms operating with high upfront costs. Therefore, natural monopoly is the common way of water activities that we may find. However, without public regulation, a natural monopoly will act as a regular monopoly, thus creating a deadweight loss.
- *Shift in demand and supply*: Changes in both demand and supply have been happening very fast in Israel during the last two decades. On the demand side, we can observe a large increase in the urban population and standard of living.

We also observe a change in preferences which results in more weight given to water that serves nature conservation. On the supply side, we observe a downward slide in the precipitation level annually. Since precipitation is the major water supply source, the gap between demand and supply increases dramatically from both ends. While in a regular market this is not a cause of worry (from a policy point of view) since the price rise will adjust accordingly, this is not the case here. The market is regulated hence price does not necessarily reflect scarcity, and as such, policy makers should decide what is best to do. Augment supply and how or reduce demand and how? A good policy formation should not be changed according to those shifts but rather set up a known in advance rules that will allow the regulators to act accordingly.

- *Uncertainty*: Water can be thought of as a flow variable, but also as stock. The three main water sources in Israel are being used as buffers. As such they can be used to smooth fluctuations in supply to serve a constant demand as much as possible. However, depleting stock does not come without a cost and might be thought of as going on the verge. A good policy should form some well-defined rules that can associate extra use of water with the cost of doing so.
- *The international dimension*: A significant amount of water that Israel uses originates in disputed areas. Israel is not an isolated island, and considering water policy which does not take into account Israel's neighbors is not serving the overall assessment of efficiency, equity, and justice. The Hashemite Jordanian Kingdom and the Palestinian Authority are striving for water and are having even a stressful water conditions than Israel. Part of Israel's water resources are shared with those neighboring entities, and it is expected that more will be given up when peace process will be more dominant in the region. Internal policy needs to take those factors into account in its overall assessment.

These points are only a partial list of policy questions in Israel which need be addressed. Since the policy instruments may be diverse but not as many as the policy issues, as such they cannot fulfill all goals in a perfect way. But they can give an answer which can be thought of as the best policy considered all things that need to be taken into account. As long as the policy is spelled out openly and is based on a solid and scientific ground, it can be defined as a successful one. Based on the previous list of issues and the instruments that are available (water pricing, standards, public-private sectors relationships, etc.), is it possible to achieve a successful water policy in Israel? I hope that after reading this book, a better understanding of the topic will be at hand.

1.3 Structure of the Book

This book is composed of 18 chapters. Besides this chapter and the last one, which summarizes the book, the remaining 16 chapters were assembled to make a logical sequence of reasoning.

Feitelson (Chap. 2) examines the history of water policy and divides it into several different eras. The first shift occurred in the early 1960s, when the emphasis shifted from development and access to allocation. The second shift was toward greater sensitivity to water quality issues. Since the late 1980s, the Israeli water sector has moved toward more economic rationing of water, and this was followed by the current era which contains large-scale desalinization on the Mediterranean coast as well as wastewater reuse. The chapter will describe the external and internal forces that drove the country from one era to another.

Menahem and Gilad (Chap. 3) concentrate on the reasoning which explains policy stalemate for long periods, especially in situations where the risks generated by prolonged policy impasse are obvious. This chapter attempts to explain the stalemate in Israel's water policy during the two decades between 1980 and 2000, a stalemate that persisted despite a general consensus on the gravity of the status quo, the inadequacy of existing policy, and the risks of the continuing impasse. The chapter also tries to identify the factors that account for policy changes in the 2000s. It addresses questions regarding both policy impasse and policy change and analyzes them using two joint theoretical frameworks, namely, the Advocacy Coalition Framework (ACF) and the constructivist Narrative Policy Analysis (NPA).

The next two chapters contain policy issues that relate to two important sectors, namely, agriculture and nature. The reason is that the agricultural sector was the largest water consumer for many years and was accused of being a major course of the water crises, by significantly increasing the price gap between supply and demand. Water for nature, on the contrary, was not given much attention until about 15 years ago. However, in the last period, it was identified as a major driver for public preferences change. Kislev (Chap. 4) surveys recent developments in the use of water in agriculture and related policy issues. Among the topics covered are the shifts from freshwater to recycled effluent, the water and food balance of the country, and growth of water productivity and its explanation, allocation, and price policy. Katz and Tal (Chap. 5) take a closer look on the water as a source for nature conservation. They claim that by the 1960s, the intermittent streams that crisscrossed the country, emptying either into the Mediterranean or into the Dead Sea, were little more than a putrid system of sewage conduits, with the local aquatic habitat decimated or changed beyond recognition. Yet, during the past two decades, initial signs appeared that suggest that this ecological misfortune might be reversible. Recent advances in the construction of Israel's desalination infrastructure, however, have added substantial quantities of freshwater to Israel's national grid and have raised the prospects for a new deal for Israel's streams. Questions as to who shall pay for rehabilitation, what level of clean up is acceptable, and what the in-stream standards and uses that should drive restoration efforts ought to be remain unanswered. The chapter traces the different stages in Israel's efforts to bring its streams back to life, maps the different positions of stakeholders, and offers a strategy for future restoration efforts.

Chapters 6 and 7 deal with the two most significant water supply augmentation sources, namely, waste water reuse and desalination. Lavee and Ash (Chap. 6) explore the issue of reusing domestic sewage production. Such a source can substitute conventional water used for irrigation. The chapter addresses the trends and changes that took place in Israel's wastewater management, in the treatment quality, and in the politics of reusing water for different purposes. It offers a view of the sectors that initiate demand for this kind of water and examines how the question of water quality can influence the future trends and users of water reuse in Israel. The chapter outlines the economic benefits of wastewater reuse and the place of Israel's "WaTech" both locally and globally. Spiritos and Lipchin (Chap. 7) conduct a comprehensive assessment of the impact of desalination in Israel. The chapter includes a comprehensive assessment, including an evaluation of the social, economic, and environmental impacts of current and planned desalination activities in the region. Specifically, they identify in what ways the proliferation of water desalination technology may affect a water-scarce country and region given its growing demand for water, assess the environmental impacts of desalination technologies on a region that is already under severe anthropogenic stress, and determine the political, governmental, and economic ramifications of the potentially plentiful water that desalination may provide. They also present the social costs and benefits of desalination for Israel in particular, and for the region in general, with specific attention directed at contrasting socioeconomic contexts that exist across the region in particular and explore and propose institutional policy and legal arrangements for addressing the environmental and social impacts that may be associated with expanded desalination.

In the next chapter, Furman and Abbo (Chap. 8) look at groundwater management in Israel. Since groundwater is (still) the main source for Israel's water supply system and its main long-term water storage, it can serve as a better understanding of Chaps. 6 and 7 in retrospect (Feitelson 2005). Furthermore, Israel uses the groundwater system as part of its wastewater treatment system, uses it for limited flood water storage, and more. Thus, both quantity and quality issues are important in that sense. The chapter starts with an overview of the aquifer system and the way the different aquifers relate to the national water supply system. The recent history of the major aquifers is then reviewed, and different processes are identified. Unique usages of the aquifer system are also discussed in detail, focusing on the role of aquifer systems in a dry region country. Last, operational management practices are discussed both in terms of quantity and of quality.

Chapters 9 and 10 deal with the economic approach taken toward dealing with water allocation and issues. DiSegni (Chap. 9) deals with price mechanisms and their application within the Israeli water sector. The chapter outlines the long-run profile of market-based regulations that have been adopted by Israel over the years. These regulations were implemented in an attempt to cope with water scarcity on one hand and with the increase in water demand on the other. Particular attention is given to the relative efficiency of applying pricing mechanisms and quotas to regulate use in the agricultural sector, a dominant user of water resources. The chapter also discusses the consequences of these market regulations on the development of water-saving technologies in the agricultural and industrial sector and the development and penetration of alternative water resources, such as saline water, desalinated water, and effluents that are used predominantly in the agricultural sector. Katz (Chap. 10), on the other hand, concentrates on non-price instruments in order to regulate the water sector. For many reasons, water is not priced as an ordinary commodity. In Israel, the government regulates water pricing, and so changes to water prices often entail long hard-fought political battles. As such, the current pricing mechanisms are often unable to address many water demand issues, such as quick responses to drought. Instead, a variety of non-price mechanisms have been utilized to complement pricing policies. These include, inter alia, quotas, educational and informational campaigns, and government buyback of water rights. Such non-pricing mechanisms often avoid many of the political hurdles that price increases face, and are thus easier to implement. This chapter briefly reviews the water pricing policy in Israel and the political obstacles that price reform has encountered over the recent past. The chapter also presents a description and analysis of the non-pricing mechanisms that have been utilized in the past.

Chapters 11 and 12 deal with two significant water resource bodies that hold specific and important roles in Israel's perspective of water resource management. These two water resources are the Sea of Galilee and the Dead Sea. The Sea of Galilee is one of the three major water supply sources in Israel and the only one which is not a groundwater source. As such, it holds many conflicts in its management since it serves as both water source as well as an ecological and recreational one. Managing the lake with these two (possible) conflicting goals is one of the most challenging issues. Parparov, Gal, and Markel (Chap. 11) claim that quantifying water quality and its incorporation into a management objective function is a major step in the establishment of natural-water, resources management policy. They show how a quantified system can be integrated into a methodological framework, developed for the management of the unique social-ecological ecosystem of the Sea of Galilee.

The Dead Sea is not a water supply source but rather a terminal lake. Its value it totally derived from recreation and heritage. However, since it is located downstream the Jordan River, it was considered last in line with respect to priorities causing its level to decrease by about 1 m annually. One of the more ambitious projects that is being considered is the Red-Dead Canal that aims at bringing water from the Red Sea in the south, up north to the Dead Sea. Markel, Alster and Beyth (Chap. 12) discuss the relevant options: one is to let the sea reach a new equilibrium. Another one is to release water from the Jordan River to feed the Dead Sea again. That means releasing water to flow again through the Jordan River instead of being diverted through the "national carrier." The last solution suggested is to divert water from the Red Sea in the south in what is called the Red-Dead conduit. This last option will raise the Dead Sea level by desalinating sea water, primarily for use by Jordan and the Palestinian Authority. The chapter presents an overview of the Dead Sea problems and its possible solutions and concentrates on the advantages and disadvantages of each of the three alternatives listed above.

The next four chapters deal with two kinds of uncertainty. The first two chapters deal with climate change and its effect on the Israeli water sector. The next two chapters deal with the international dimension of Israel's water policy.

Climate change and its impacts are summarized in Chaps. 13 and 14. Kan and Zeitoni (Chap. 13) explore the effects of varying annual rainfall patterns on the profitability of winter crop production in Israel. Rainfall distribution functions, and yield-water response functions, are used for simulating regional net-benefit expectations under a future projected scenario of changes in precipitation patterns. Simulations indicate a future decline in net-benefits relative to those in the latter part of the twentieth century. Although most of the effects are seen in the semiarid southern region, some reduced profitability is detected in the Center and in the North of the country. One of their conclusions is that risks for annual economic losses increase because of the larger variability in rainfall events. Issar and Livshitz (Chap. 14) deal with two kinds of uncertainties which Israel may face due to climate change. The first deals with temperature uncertainty and the second with energy sources. It is predicted that the ongoing global warming will cause a reduction in precipitation in the Mediterranean region, including in Israel. Yet lately, this prediction is faced by a big question mark, as a new factor may act in the opposite direction of global warming. According to scientists at the National Solar Observatory (NSO) and the Air Force Research Laboratory of the USA, the number of sunspots is forecast to decline to a minimum. This may cause a cooling of our planet. Which of the two factors will emerge? Another uncertainty factor deals with the sources of energy needed to desalinate sea water. Currently and in the planned future, desalination plants receive energy from power stations and burning fossil fuels, thus producing greenhouse gases. In order to ensure Israel's safe supply of water in the face of these and other types of uncertainties explored in the chapter, the authors suggest creating groundwater storages capable of supplying, at least for a few years, about 50% of the domestic water supply.

Chapters 15 and 16 deal with the international dimension of water policy in Israel. While Chap. 15 deals specifically with a microlevel river basin analysis, Chap. 16 takes a more general picture and looks at the overall context of water issues, mainly conflicts but also resolutions between Israel and its neighbors. Laster and Livney (Chap. 15) depart from the lack of a comprehensive peace plan to resolve the Israeli/Palestinian conflict in the near future. In the chapter, they suggest that preparation of a master plan for a trans-boundary watercourse can serve as a touchstone for cooperation between two conflicting entities. It enables decision making under any scenario: coexistence, cooperation, or partnership. It weighs the value of each scenario and allows policy makers to make decisions based on value judgments. It improves tools for grass-roots democracy, stakeholder involvement, and collaborative decision making. In the worse case, it serves as a platform for discussion instead of acrimony and in the best case, a platform for river restoration, improved planning, and biological diversity. Shmueli and Aviram (Chap. 16) assume that the allocation of the water resources of the Jordan River Basin and the Mountain Aquifer of the West Bank and Israel are key issues in any lasting settlement of the Arab-Israeli conflict. Over the past decade and a half, two agreements have been negotiated. The first is addressed in the October 1994 Israel-Jordan Peace Treaty. The second was incorporated within the September 1995 Oslo II Interim Agreement between Israel and the Palestinian Authority. This chapter reviews these accords, relating them to international standards of water quality and waste water agreements, considering the feasibility of water imports, and assessing the regional political implications of water allocation proposals in peace negotiations.

Feinerman, Frenkel, and Shani (Chap. 17) deal with the reaction of the Water Authority to the issues mentioned above. The Water Authority was established in 2007. Until that year, water management in Israel was divided among seven governmental ministries, hampering efficient management, planning and development. The Water Authority serves as an executive arm, and the Council functions as the legislative arm for Israel's water economy. Both arms are responsible for the management and regulation of the water sector, in accordance with governmental policy. The Authority was established in the midst of a severe water crisis which forced it to devote a substantial amount of time and resources to develop short-term supply and demand mitigation policies. However, the Authority did manage to enter the process of implementing a series of far reaching reforms, including the following: (1) achieving governmental approval for a significant increase in supply via the development of large-scale seawater desalination plants (750 MCM until 2020) and hastening its construction processes, (2) reducing demand via a significant increase in nonagricultural water charges (by an average of 40%) that comply with the law requiring full cost recovery and restructuring water tariffs that distinguish between a basic rate for water and a rate for high consumption, and (3) shifting urban water provision from the control of municipal authorities to the control of local water corporations. This chapter is aimed at analyzing the economic and social motivations for the above significant reforms and evaluating the impacts of the intervention of members of parliament and of various consumers' interest groups in the decision making process. It points out the advantages and disadvantages of each one of the major decisions and offers a vision for the future design of supply-side and demand-side management schemes in the Israeli water economy.

Finally, Becker (Chap. 18) concludes this book by providing an interpretative summary and synthesis of the previous chapters, as well as by identification of a more specific research and policy agenda for Israeli water sector.

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Chapter 2
The Four Eras of Israeli Water Policies

Eran Feitelson

Israel is considered by many as a paragon of sound water management (e.g., Postal 1997). Due to the severe water scarcity Israel faces and the relatively high levels of human and social capital it can muster, Israel has successfully implemented policies that are at the forefront of the water policy field. These policies enabled Israel to develop an advanced postindustrial economy and to supply a burgeoning population with high-quality water at the tap on the basis of scarce and contested water resources. Moreover, Israel has succeeded in providing water to an advanced agricultural sector whose product per unit of water has risen rapidly in the past 30 years.

Yet, the seemingly successful water policies have been criticized within Israel as being outdated, inefficient, and environmentally detrimental. In the past 15 years, there have been increasing calls for an overhaul of Israel's water policies, as can be seen in the formation and recommendations of a series of governmental and parliamentary inquiry commissions.[1] These calls, coupled with the new options opened by large-scale desalination and the shifting intra-Israeli power structures, suggest that such a structural change may be underway (Feitelson and Rosenthal 2012).

Two of Israel's main water sources are shared (see Fig. 2.1). Consequently, Israel has been embroiled in some of the most widely discussed international water conflicts in the world. Actually, it is safe to suggest that the number of words written about water in the Israeli–Arab context, per unit of water, is significantly higher than for any other water conflict. Most of the studies on the Middle East water

[1] Invariably named after their chairs, these are the Arlosoroff committee (1997), the Magen committee (2002), the Gronau committee (2005), and the Bein committee (2010).

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Fig. 2.1 The Water resources of Israel and the NWC (*Source*: Author)

conflicts analyze Israel as a unitary player. Yet, as many studies of international affairs suggest, foreign policy is often driven by domestic concerns. Thus, most negotiations are conducted concurrently between countries and within countries (Putnam 1988). However, the internal mechanizations of Israeli water policies have remained largely opaque for the international audience. Hence, this chapter focuses on the shifts in Israeli water policies from an intra-Israeli perspective, though it does note the interplay between intra-Israeli policies and the international scene.

Israel lies between the Mediterranean and arid climatic zones. Rainfall ranges from 1,000 mm/year in a small part of the north to 100 mm/year and less in the southern half of the country, most of it within 5 months (November–March). As a result water has historically been a critical aspect of human habitat. However, until the technological innovations that were introduced in the late nineteenth century, most of the human habitation was based on springs, wells, and cisterns. At the time Israel gained independence, in 1948, water resource development was still largely limited to local and regional systems (Feitelson and Fischhendler 2009; Seltzer 2011). At that time only 20,000 ha were irrigated, and municipal systems barely supplied the domestic demand, which was low by today's standards (Weiner 1993).

The history of Israel's water policies since independence can be divided into four eras, differentiated by the issues, goals, discourse, means, and actors that framed the policies. A systemic shift in all these parameters occurred between each period and the subsequent one. Hence, the history of the Israeli water sector can be told as a story of eras and the transformations between them. The purpose of this chapter is to outline these four eras and the factors that led to the restructuring of the water policies from one era to the next.

Each era is described according to the main concerns that drove policies, the main actors that affected those policies, and the main issues that arose, and ultimately led to the next transformation. Clearly, transformations take time and cannot be seen as clean breaks from the past. Hence, while the periods can be delineated time-wise, there are overlaps between them.

2.1 The First Era: The Hydraulic Mission Period (1948–1964)

Immediately after independence, Israel was faced with three critical concerns: One, to accommodate the large immigration wave over one million new immigrants within 3 years; two, to provide food for the burgeoning population, as much of the previous production potential was damaged in the war and imports from neighboring countries were cut off; and three, to establish control over all the area of the state and prevent a return to the 1947 UN partition lines. Agricultural settlement was seen as the primary mean to address all three concerns, as it allowed immigrants to move quickly into the labor force, thereby increasing domestic food production at a time the country faced food and capital shortages, while establishing a stable presence in the contested areas (Bein 1982; Reichman 1990).

The three practical reasons for giving priority to the agricultural sector were augmented by a fourth, ideological, factor. The Zionist movement, and particularly the labor party dominating it at the time, was strongly committed to a rural ideal. An agrarian-based rural existence was viewed as an element for increasing the productivity and changing the employment base of the Jewish people and contributing to nation building by creating closer links between the recently arrived new immigrants and their ancient homeland (Willner 1969).

As most of the irrigable land is in the water-scarce south, and the settlement program, driven in part by geopolitical considerations, targeted areas where local resources were deemed insufficient, the settlement and agricultural development plans were contingent upon national water resource development and conveyance. To this end, a national water master plan was prepared by 1950. This plan was a continuation of earlier plans prepared by the Zionist movement for settlement purposes (Schwartz 2010) and in response to British attempts to limit Jewish immigration according to the "absorptive capacity" of the country, which was largely based on its food production capacity.[2]

The hydraulic mission of the early state period was to develop all available water resources and convey them to where they were needed for agricultural and settlement purposes (Blass 1973). This mission was driven by a nation-building agenda, and hence, the projects which were advanced to carry it out were not subject to strict economic criteria (Galnoor 1978). Based on the earlier plans (most notably Hay's 1948 plan, entitled TVA on the Jordan), the 1950 national water plan prescribed that water will be conveyed from Lake Kinneret in the north to the northern part of the arid Negev in the south, thereby combining all the main aquifers and streams into one comprehensive national water system (see Fig. 2.1). This was achieved with the completion of the National Water Carrier (NWC) in 1964. In the interim period, until the completion of the NWC, regional systems were gradually consolidated, and water from the Yarkon River was conveyed to the south through the Yarkon–Negev pipeline (Fig. 2.1). This pipeline was later incorporated in the NWC.

Development of water in the upper Jordan River, and particularly Israel's plan to divert water out of the Jordan River basin, was contested, mainly by Syria. Though the skirmishes that occurred around the Huleh drainage project in 1951 and the tensions surrounding the beginning of diversion works for the NWC around the Bnot Yaacov bridge in 1953 (as well as the skirmishes around the Syrian diversion plans in 1965–1966) were driven by geopolitical concerns, they were presented as confrontations over water.[3] Thus, water came to be viewed as the bone of

[2]Essentially, the Zionist movement claimed that with irrigation, food production can increase, and hence, the absorptive capacity is higher than in the British calculations. Reichman et al. (1997) provide a detailed account of this argument.

[3]The drainage of the Huleh lake and swamp were viewed at the time as a direct continuation of earlier Zionist drainage projects that were intended to eliminate malaria and create new farmlands. In reality, however, malaria was already eliminated at the time. The skirmishes in both this case and the Bnot Yaacov bridge area 2 years later, however, were largely over the control of the demilitarized zones between Syria and Israel, and particularly whether Israel could conduct works

contention, with important national security dimensions, thereby contributing to the symbolic importance of water in the national ethos of the time. To diffuse the upper Jordan River issue, President Eisenhower sent Ambassador Eric Johnston to the region. After four shuttle trips in 2 years, Ambassador Johnston drafted in 1955 an agreement, whereby the Arab states will receive all the water they could demonstrate a need for, while Israel got the "residual flows" without specifying any limitations on the location of use (Phillips et al. 2007a). While this agreement was never ratified due to the Arab States' refusal to recognize Israel at the time, it served as a basis for legitimizing the construction of the NWC and the conveyance out of the basin.

The extensive and rapid development of water resources in this formative era was carried out by a small cohesive highly capable policy community, largely composed of water engineers affiliated with the labor movement and the agricultural sector. Their success can be partly attributed to the direct access they had to centers of power, not least because several of the leaders of the labor movement previously held positions in the water sector.[4] The leadership of the policy community was largely associated with the national water planning company, Tahal, primarily due to the emphasis placed on planning and the professional leadership of the engineers in Tahal. However, as Alatout (2008) notes within the technical elite, there were fierce struggles, during which the dominant view shifted from viewing water as an abundant resource that has to be explored and utilized to a limited resource that has to be judiciously managed due to its scarcity. This latter view came to dominate the Israeli water scene and became the main theme of the second era.

2.2 The Second Era: Wise Management? (1959–1990)

Once all the main freshwater sources were tapped, by the mid-1960s, attention shifted toward the untapped potential of the Mediterranean Sea. However, a proposal to advance large-scale seawater desalination in the mid-1960s was scrapped due to the expected cost, thereby effectively ending the hydraulic mission era. From this point, and for the subsequent 40 years, the policy emphasis shifted to the management of the existing resources. While the occupation of the West Bank and Golan Heights in 1967 allowed Israel to control an additional headwater of the Jordan River (the Banias spring),[5] to access the eastern aquifer (see Fig. 2.1),

from the eastern bank of the Jordan River, which was contested. The 1965–1966 skirmishes, in contrast, were largely an outcome of the growing rivalry between Egypt and Syria over the leadership of the Arab world. For a more comprehensive overview and discussion, see Feitelson (2000).

[4]The most notable of these were Levi Eshkol, the founding director of Mekorot, the future national water company, who went on to become minister of the treasury and prime minister, and Pinhas Sapir who replaced Eshkol in Mekorot and later in the treasury (Seltzer 2011).

[5]The Jordan River has four sources in the north. The largest, the Dan springs, is within pre-1967 Israel, while the Ajoun and Hasbani streams originate in Lebanon and the Banias spring in the Golan Heights.

and to somewhat increase its intake from the Jordan River, the total amount of additional water made available by the results of the war was limited and did not change the overall picture. This can be seen in the water use patterns that did not change markedly as a result of the war (Grinwald 1989). Hence, since the late 1960s, the emphasis has shifted to the management of the existing resources.

The institutional structure for managing water was set already in the 1959 Water Law. This law nationalized all the country's water and established the post of water commissioner to manage it. Thereby any abstraction of water and any use of water require a permit. This command and control structure was used to determine how much water will be abstracted in each time period from each source and how much water each user will get in this time period. To do so, all water abstractions and uses have to be monitored, and indeed a comprehensive metering system was put in place.[6] The centralized institutional structure, the comprehensive monitoring of all abstractions and uses, and the existence of a national conveyance system allowed Israel to establish and operate a highly centralized and sophisticated water management system. This system is a natural monopoly. Mekorot, the water company established by the Zionist organizations, was designated in the 1959 Water Law as the National Water Company to operate this system.[7]

As noted above, once the possibility to embark on new large-scale projects was curtailed, the emphasis increasingly shifted to the optimal management of the water system. As water conveyance requires considerable energy, water is conveyed during off-peak energy use hours to higher altitudes and supplied by gravity during the rest of the day. Based on extensive monitoring of the water resources and weather patterns, water abstractions are determined after extensive deliberations within the water agencies (Feitelson et al. 2005). However, this decision-making process is largely opaque from the public's point of view, as no record of it is made public. A factor that received increasing attention in this era is water quality. Following the introduction of improved treatment processes, water quality at the tap improved over time.[8]

The institutional structure that was established in Israel was extended to the occupied territories through military orders. Hence, all the water resources of the upper Jordan,[9] Mountain aquifers, and coastal aquifer have been managed since 1967 by Israel as one system.

The change in emphasis had important fiscal ramifications. Capital expenditures on the water infrastructure were reduced from 3 to 5% of the total national capital

[6]The requirement to measure and monitor was made already in the 1955 Water Measurement Law.

[7]See Seltzer (2011) for a detailed history of Mekorot.

[8]See Seltzer (2011) for discussion of the different facets of water quality concerns addressed by Mekorot.

[9]An exception is the Ajoun stream, the westernmost source of the Jordan River, whose water is used primarily in Lebanon, and is not seen thus as part of the Israeli system. In contrast, most of the Hasbani water, which also originates in Lebanon, flows into Israel and is seen as part of the Israeli water potential.

outlays (which made water development one of the major development priorities during the 1950s and early 1960s) to less than 1% by the late 1960s, and the role of planning declined (Galnoor 1978). Despite ongoing planning activity, no new master plan was prepared for the water sector until 1988 (Schwartz 2010). Moreover, the 1988 plan was rejected by the acting water commissioner, without any public disclosure, as it contradicted his ongoing policies. This contributed to the decline in the share of Tahal's income from public sources in Israel. Until the completion of the NWC, national water projects in Israel accounted for over 75% of Tahal's activities, while after 1964 they fell to less than 30%. At the same time the share of Tahal's activities abroad increased. As Tahal increasingly became an international planning and consulting firm, its role in the Israeli national water policy making declined, leading to its eventual privatization in 1996.

The lack of a long-term plan after the termination of the desalination project in the mid-1960s could not mask, however, the increasing stress on the water system. Already in 1966 the State Comptroller issued a report that forewarned of excessive groundwater abstraction. Similar warnings were issued by various expert panels and planning teams in subsequent years. However, these warnings did not have an impact on policies (Kartin 2000). This can be partially attributed to the water commissioners that were appointed in the late-1970s and the 1980s, which were closely associated with the agricultural sector (Feitelson et al. 2007). Hence, they strived to maintain the supply of subsidized freshwater to the agricultural sector, despite the growing demand from the burgeoning domestic sector. This resulted in an overdraft from the natural resources, both the Sea of Galilee and the aquifers (Gvirtzsman 2002).

Regardless of the political impasse, which precluded any major policy change, several innovations and actions helped alleviate the water stress. Perhaps the most important is the widespread introduction of drip irrigation. As a result of this technological innovation, the agricultural product per unit of water increased dramatically. Essentially, agricultural production was decoupled from water use or irrigated acreage. As can be seen in Fig. 2.2, agricultural production was highly correlated with water use and irrigated area until the early 1970s. Since then, however, agricultural product increased almost irrespective of the changes in water used in irrigation or the amount of irrigated land. A second factor that contributed to this decoupling was crop substitution in agriculture. Essentially, crops with a higher value per unit of water gradually replaced crops with lower water productivity.

A third factor that helped to decouple the trends is the increasing reliance on recycled water (Shelef 1991). Following a cholera outbreak in Jerusalem in 1970, wastewater treatment and water quality issues came to the public attention. In the subsequent years, a major advanced secondary treatment plant, the Shafdan, was built to treat most of the Tel Aviv metropolitan area's sewage, as part of the World Bank-financed National Sewage Project. The recycled wastewater is then conveyed to the northern Negev in the so-called third line (the first two being the two branches of the NWC below Rosh Haayin – see Fig. 2.1). A second advanced treatment plant was built in the Haifa metropolitan region. With the improvement in treatment levels, the range of crops that can be safely irrigated with recycled

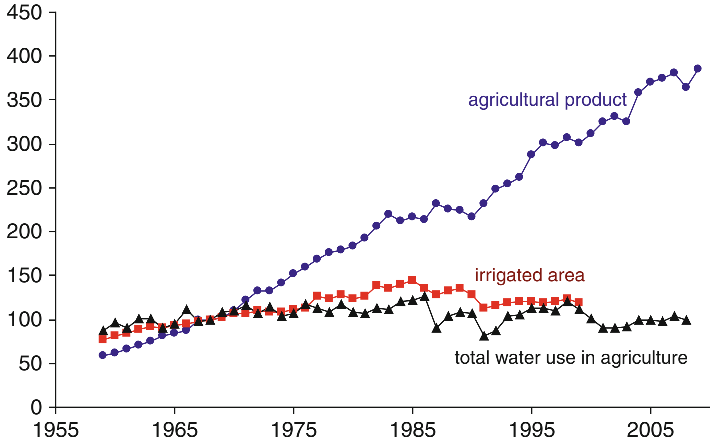

Fig. 2.2 Agricultural product, irrigated area,* and total water use in agriculture** in Israel 1959–2008 (index: 1968 = 100) [*Data on irrigated area was collected only until 1999. **Total water in agriculture includes freshwater, brackish water, and recycled wastewater] (*Source*: Central Bureau of Statistics, Annual Yearbooks)

water increased, thereby increasing the attractiveness of recycled water for farmers. Additional factors that increased the attractiveness of recycled water for farmers were the improvements in drip irrigation technology, which allowed recycled water to be used in drip irrigation, and the high nitrate levels in recycled water, which allowed farmers to save on fertilizers.

One of the effects of the increasing use of recycled water and of the conveyance of water from the relatively saline Lake Kinneret southward was the increasing salinity of water used for irrigation. Irrigation with recycled wastewater and Kinneret water resulted in increasing salinity levels in the unsaturated zone. The salinity in the unsaturated zone has over this period become an increasing source of concern, not only from an agricultural production perspective but also for the unconfined coastal aquifer (Kass et al. 2005). To reduce the salinity of Kinneret water, a bypass canal was built to divert water from saline springs in its vicinity to the lower Jordan River, thereby circumventing the intake to the NWC.

The increasing concern over water quality led to a change in the water law in 1971, expanding the water commissioner's jurisdiction to include water quality. However, the institutional authority over quality issues remained highly fragmented (National Water Commission 2010).

An additional noteworthy factor that allowed Israel to thrive, despite the decreasing amount of water available per capita, is the shift in agricultural policies. During the first era, the main goal of agricultural policies was to assure food self-sufficiency for Israel. By the mid-1960s, however, it became increasingly apparent that this was an infeasible goal. Hence, the agricultural policy shifted to a market-based agriculture, thereby signaling the general shift from a statist centrally planned to a more liberal market-oriented sector. The main ramification of this shift, from a water perspective, is that the main water-intensive staples, most notably wheat, are largely imported, while the domestic production shifted toward crops which produce a high marginal value per unit of water (Fig. 2.2). This increasing reliance on "virtual water"[10] is one of the least acknowledged factors that allowed Israel to develop an industrial, and later postindustrial economy, without suffering from food shortages, despite the rising number of people dependent on the meager water resources.

2.3 The Third Era: Reflexive Deliberations (1990–2005)

The early 1980s were marked by a steady increase in freshwater consumption in irrigation, resulting in a steady increase in abstraction rates. Consequently, when droughts occurred in the late 1980s, most notably 1989–1990, water levels dropped to the "red lines" prescribed for Lake Kinneret and the Mountain Aquifer. Amidst the public outcry, a highly critical State Comptroller report was published (State Comptroller 1990). This report led, for the first time, to the dismissal of a water commissioner due to his perceived failure to manage the water resources judiciously. The State Comptroller report and subsequent dismissal of the water commissioner received wide public attention. As a result the debate over the direction that Israel's water policies should take, which previously was limited to a small technocratic elite, became public. This episode marks, thus, the beginning of the third era in the Israeli water policies, an era marked by increasing fragmentation within the policy community, and the rise of a series of new issues to the fore.

The first issue to arise was the deterioration in water quality in the aquifers and the validity of the brinkmanship policies pursued by the water commissioners. As Dery and Salomon (1997) point out, it became increasingly apparent that the overdrawing of the water resources in the mid-1980s was not an aberration, but rather the governing policy. Following Mosenzon's (1986) work, an increasing number of economists called for full-cost pricing in order to manage demand and hence prevent excess water drafts (Kislev 1991; Yaron 1991).

The increasing prominence of pricing issues in the water policy discourse was, however, only one of the changes in the sanctioned water discourse, the discourse seen as politically acceptable, that occurred since the early 1990s. In his review of the Israeli newspaper articles in three selected years between 1995 and 2000, Feitelson (2002) identified several story lines in addition to the scarcity and conservation themes, which predominated in the earlier periods, and the somewhat more recent water quality and pricing themes. These include water for nature, privatization, and desalination. These new themes reflected the widening and diversifying set of issues that became part of the water policy discussions since the early 1990s.

[10]"Virtual water" is the water embedded in food. As Allan (2001) shows, it has become the main de facto source of water in the Middle East since the early 1970s.

While water quality concerns were recognized for more than 20 years, their prominence rose since 1990, as part of the growing interest and attention paid to environmental issues in Israel in general over this period (not least due to the establishment of a Ministry of Environment in 1988) and within the professional elites in particular. During this period, several new environmental concerns gained prominence, as the widespread externalities of water development and use were increasingly recognized. The issue that perhaps gained the most attention was the implications of water policies for natural systems. This issue became prominent after several well-known highly visited nature reserves were almost desiccated in the 1999–2000 drought. Thus, while in-stream flows were seen largely as "wasted water" in previous eras, as manifest in the absence of nature from the list of uses to which water can be allocated under the 1959 Water Law, they increasingly were recognized as important for aquatic ecosystems and stream rejuvenation. Consequently, in 2004 the water law was modified, and nature was recognized for the first time as a legitimate use to which water should be allocated.

Other, closely related, environmental issues that gained prominence since 1990 were stream rehabilitation and wastewater treatment. The situation whereby wastewater flow untreated in streams was no longer seen as tenable, especially as streams became a mainstay for open space corridors in the coastal plain region. Such corridors were incorporated into all the national and regional master plans prepared during the 1990s. Moreover, following the statutory national plan for development and immigration absorption, ratified in January 1993, secondary level wastewater treatment became a requisite for housing development. As a result, a large number of new secondary and advanced secondary level wastewater treatment plants were built since 1993. Within a decade, almost all towns and cities were connected to an advanced secondary level treatment plant, driven by environmental concerns rather than recycling goals. The increase in quantities of treated wastewater allowed for a gradual substitution of freshwater in agriculture by recycled wastewater as well as use of recycled water for stream rehabilitation (Friedler 2001). By the end of this era, most of the irrigation in central and southern Israel was supplied by recycled wastewater.

These new "story lines" in the policy discourse did not lead, however, to policy change until 2000. During this period, the policy impasse that emerged in the 1980s remained (Feitelson 2005). In essence, the treasury demanded that water subsidies for agriculture be eliminated, as a condition for funding desalination. However, the agricultural lobby in the Knesset blocked any attempt to raise agricultural water tariffs. Hence, water tariffs remained too low for them to become effective demand management tools, while desalination, the main potential for augmenting water supply, was blocked by the treasury. Consequently, the water commissioner was forced to lower the water levels in the reservoirs, infringing previous "red lines" (Feitelson et al. 2005).

As a result of the severe drought of 1999–2000, which forced the water commissioner to lower the "red lines" in Lake Kinneret to the level of the intake for the NWC, and a change in the stance of the agricultural lobby, desalination was raised again as a realistic option. In the summer of 2000, the minister of finance reversed the position of the treasury by issuing the first tender for large-scale desalination (in Ashkelon), thereby breaking the impasse and setting in motion a plan for large-scale seawater desalination.[11] This breakthrough was allowed for by the technological innovations that led to a dramatic drop in desalination cost.

This era in water policies within Israel coincided with the peace process initiated in Oslo. Water was one of the issues that were raised as part of this peace process, which lasted throughout the 1990s. As a result transboundary water issues gained once again a high public profile during this period. These issues were dealt with extensively in the two main agreements reached during this period: the Israeli–Jordanian peace accord in 1994 and the 1995 Israeli–Palestinian interim agreement (the so-called Oslo B agreement). The Israeli–Jordanian agreement is a multifaceted agreement, whereby Israel provides additional water to Jordan in the north, as well as storage services for 20 MCM from the Yarmouk River, and can continue utilizing the Arava aquifer on the Jordanian side in the south. The interim Israeli–Palestinian agreement requires that Palestinians in the West Bank receive additional water from the northeastern and eastern Mountain Aquifers and establishes a Joint Water Committee to manage water resources in the West Bank. This committee has been subject, however, to increasing criticism by Palestinians (i.e., Nassereding 2001). Following this agreement, Israeli and Palestinian water supply systems in the West Bank were gradually separated.

However, the most significant difference between this era and the previous one is the widespread dissatisfaction with the institutional structure of the water sector. This dissatisfaction is manifested in a number of committees that were asked to review Israel's sector since the mid-1980s and their recommendations. The first among these was the Arlosoroff committee, which submitted its report in 1997. This committee suggested that major policy shifts were needed – real cost pricing of both end use and abstractions and a reduction in government involvement. This reduction was to be achieved by a breakup of the national water supply company (Mekorot), through privatization and the establishment of a public service authority for water. The Arlosoroff commission also proposed to strengthen the water commissioner's office by increasing his independence and improving his planning capacities. In 2001 a parliamentary inquiry commission (the Magen committee) was formed, which reached similar conclusions.

Some of the recommendations made by the Arlosoroff and Magen committees, such as increasing the planning capacity of the water commissioner and increasing private sector participation in water supply and wastewater treatment, have been adopted. However, these modifications were deemed insufficient, resulting in the

[11] The decision to issue the tender is considered here as the turning point. However, it was one of several governmental decisions that moved desalination forward. Earlier government decisions to plan for desalination were made in January 1997 and March 1999. Decisions to widen the scope of desalination were made after the tender was issued in 2001 and 2002. But these were only partially implemented (National Water Commission 2010).

establishment of a national inquiry commission, the Bein committee. But this committee convened against a different background than previous committees, as by 2010 large-scale desalination was already underway.

2.4 The Fourth Era? Desalination and Privatization

The inauguration of the first large-scale desalination plant in Ashkelon, in 2005, arguably marks the beginning of a new era. While the discussions and disagreements that marked the previous era continue, the advent of large-scale desalination marks several fundamental shifts from previous eras.

The advent of large-scale desalination allows for the first time since the mid-1960s to substantially augment the quantity of available freshwater. Hence, it allows for an increase in the total amount of freshwater for all sectors. Desalinated water also reduces the salinity of wastewater, thereby allowing for wider wastewater recycling (Tal 2006). Since higher wastewater treatment standards were promulgated, a wider array of crops can be irrigated by such recycled water. As wastewater is generated from the urban sector, it is not affected by weather or climate change. Hence, the combination of desalination and higher-quality wastewater reduces the vulnerability of Israel to weather vagrancies and climate change. Yet, desalination increases energy use in the water sector, and hence its carbon footprint, and may have some detrimental effects on coastal seawater.

Desalination also alters the basic water geography, as it is generated along the seashore and conveyed inland (Feitelson and Rosenthal 2012). Hence, north to south flows along the NWC are expected to decline, as additional water desalinated along the Mediterranean shore reduces the need to convey water from the Kinneret basin (IWA 2011). This shift in flow patterns has wide ramifications (Feitelson and Rosenthal 2012). It allows additional water to be retained in the natural systems, hence potentially allowing for rejuvenation of natural resources (IWA 2011). As desalination has been advanced through public–private partnerships, and Mekorot was barred from these tenders (with the exception of the Ashdod plant), it advances the treasury’s intent to reduce Mekorot’s monopoly power. However, most of the tenders have been won by consortiums that included a single leading firm (IDE), thereby raising the prospects of substituting a state company monopoly for a duopoly (Feitelson and Rosenthal 2012).

The emphasis on incorporating private capital is part of a wider neoliberal agenda that came to predominate the Israeli policy scene since the 1980s (Ben Porat 2008). A second facet of the neoliberal agenda in the water sector has been the reform of municipal water. Following a government decision in 1997, the Water and Sewage Corporation Law was passed in 2001, whereby these services were to be corporatized, rather than being supplied directly by the municipalities. By 2009 the majority of the population is supplied through such corporations, though there are increasing critiques of these corporations (Ben-Elia 2009). These critiques largely focus on the rise in water rates to consumers. These have become a focal point for public unrest for the first time in Israel in 2010 and were one of the issues raised in the widespread public protests on costs of living in the summer of 2011.

Large-scale desalination also raises several issues in the wider Israeli–Palestinian scene. Essentially, Palestinians claim additional water due to Israel's ability to substitute desalinated water for water from the contested Mountain Aquifer (Phillips et al. 2007b). Israel counters that the desalination does not substitute for the need for storage capacity, as desalinated seawater serves as a base supply, while the natural reservoirs are necessary to address fluctuations in natural replenishment (IWA 2009).

Several additional features differentiate this era from the previous one. The first is the establishment of a water authority in place of the previous position of the water commissioner. The establishment of this authority, with wider purview than the water commissioner, was an outcome of pressures by the empowered treasury. However, the treasury had to make significant compromises in this process (Zinger 2011), thereby arguably not making the difference it sought to make (Fischhendler and Heikkila 2010).

A second feature that, arguably, differentiates this era from the previous one is the return of long-term planning. Following an interim emergency plan that was formulated in 2002 (IWA 2002), a long-term plan has been prepared, which is in an advanced draft form as this lines are written (IWA 2011). Both of these plans advance desalination as the major long-term prospect, seeking add capacity in the short run above the rise in demand in order to replenish the aquifers (IWA 2011). This plan is a partial response to the findings of the Bein committee, which was established to examine the factors behind the continuing crisis, resulting from the multiyear drought. Other recommendations of this committee pertained to the need to use pricing for demand management and for a more open decision-making process in the water sector (National Inquiry Commission 2010).

2.5 Overview and Conclusions

Sixty-four years after independence, Israel's water policies are now in their fourth phase, or era. This reflects the extraordinary dynamism of Israel's water policies. Such dynamism is indicative of the high level of adaptive capacity exhibited by the Israeli water sector, allowing Allan (2001) to suggest that Israel is the only country in North Africa and the Middle East (MENA region) to adapt to impeding water scarcity without the benefit of vast oil resources. However, this adaptation is fraught with internal struggles, as each transformation from one era to the next is an outcome of a crisis in previous policies.

Table 2.1 summarizes the four eras according to the main factors that were used to define them: the concerns or goals that the policies sought to address or advance; the main actors that affected and implemented the water policies (by their weight in making these policies); the main policies advanced; and the main issues with which these policies had to contend.

Table 2.1 Overview of the four eras

Era	Hydraulic mission	Wise management	Reflexive deliberations	Desalination and privatization
Main concerns/goals	Supply to rural settlements	Optimize water management	Whether to manage demand or augment supply	Supply to urban sector
	Integrate system	Increase water productivity in agriculture		Reduce dependency on weather
Main actors (by order of importance)	Tahal	Mekorot	Treasury	Treasury
	Mekorot	Water commissioner	Water commissioner	Private capital
	Settlement bodies	Tahal	Mekorot	Water authority
			Agricultural lobby	
Main issues	What is the water potential	Water quality	Political impasse	Pricing
	Ability to convey Jordan River water out of basin		Negotiations over water with neighbors	Water for nature
				Funding desalination
				Monopolies
Main policies	Augmentation by accessing all possible resources	Water saving in agriculture	Brinkmanship in water abstractions; Extensive wastewater treatment and recycling	Desalination
	Large-scale water conveyance	Algorithms to manage water resources		Privatization
		"Red lines" for Kinneret and westerns Mtn Aquifer		
		Extension of management rules to West Bank		

So far I have described each era. In this section, I present an overview focusing on the actors, as the actors are those that determine policies, and thus, the shifts between eras should be seen as an outcome of shifting power relations between the actors.

The hydraulic mission era was dominated by engineers. Two engineers in particular stand out. The first is Simcha Blass, who was the main figure behind the initiation of the NWC and who sought to develop all possible water resources as rapidly as possible (Blass 1973). The second is Aharon Weiner, who often clashed with Blass, arguing that water has to be managed judiciously, as it is a scarce resource. Between the two of them, and despite the clashes among them, they established Tahal as the lead agency in water resource planning, as it was the agency which planned the Israeli water system according to the settlement needs.[12] These needs were defined by the settlement bodies. Hence, the settlement bodies were central in defining the emerging water geography. In essence this was a geography whereby water was extracted from the natural water bodies into a pipe-determined geography, increasingly conveyed from north to south, out of the natural basins (Feitelson and Fischhendler 2009), thereby creating a national integrated system (Fischhendler and Heikkila 2010). The two main issues that had to be addressed in order to establish this system were to determine the water potential, that is, how much water can be extracted and conveyed, and whether water can be conveyed out of the Jordan basin. Both of these issues were settled in the mid-1950s, as the water potential was realized to be lower than Blass suggested, and the Johnston accords provided the legitimization necessary to convey water out of the Jordan basin.

As all the basins were essentially closed by the mid-1960s and desalination was blocked due its cost, the emphasis shifted to the management of the existing system (Weiner 1993). As a result decision-making power shifted and Mekorot increasingly became the lead agency, as it managed the integrated water system. While the position of the water commissioner was formed, expertise remained during this second era largely in Mekorot and Tahal. But as the funds for planning were cut, Tahal increasingly oriented itself to the international market.

The main focus of water management shifted during this era toward quality issues. A bottom red line was established in the Kinneret in 1968 to protect the quality of the lake’s water. The red line has since been the focal point in public discussions of water in Israel (Feitelson et al. 2005). The red lines, however, are only one of the quality issues. Other issues pertained to the level of wastewater treatment and the extent to which wastewater can be recycled. The main concern with regard to this issue was the danger of salinization of groundwater and soils.

Yet, water issues were largely absent from the public debate during this era. This can perhaps be explained by relatively high levels of rainfall during the late 1960s

[12]In its first 4 years, between 1952 and 1956, Tahal was also in charge of operating the water system. In 1956 following the resignation of Blass, the operation elements were transferred to Mekorot, which subsequently became the National Water Company.

and 1970s and the evident success of the Israeli agriculture to raise the marginal value product of water through conservation and crop substitution, thereby allowing also to accommodate the rising domestic demand.

Following the series of droughts since the late 1980s, water issues rose again in the public eye. The third era, however, was largely marked by a political impasse, whereby the treasury prevented large-scale augmentation (mainly desalination), while the agricultural lobby precluded any significant cut in subsidies for water in agriculture (hence preventing further demand management). Thus, the water commissioner (whose role became gradually more central) was forced to draw down the water levels in Lake Kinneret and the aquifers (Feitelson 2005; Feitelson et al. 2005). However, the extent to which the water commissioner agreed to extract from the water reservoirs was a function of the identity of the water commissioner. Essentially, water commissioners who came from the agricultural sector and were aligned with it tended to take a brinkmanship approach, whereby they allowed for a greater drawdown from the aquifers and lake, while water commissioners who were part of the professional elite took a more precautionary approach (Feitelson et al. 2007). The flexibility of the water commissioner to determine water policies was, however, increasingly constrained by the international obligations of Israel in the peace agreement with the Kingdom of Jordan, and the interim agreement with the Palestinians, as well as by the increasing share of the domestic sector of water consumption. As domestic consumption is inelastic relative to the agricultural use, the buffer that could be drawn upon in multiyear droughts has shrunk.

Since successful 1985 stabilization plan, the power of treasury officials increased with widespread effects on water policies. Initially, the treasury mainly pushed for higher water rates in agriculture. The pressures to raise water rates for farmers were followed in the past 15 years by a series of additional policy initiatives that were successfully advanced by the treasury. However, these policies cannot be discussed in separation from the general ideological shift toward neoliberal policies. This shift is perhaps best seen in the calls to break up the Mekorot monopoly.

The drought of 1999–2001 opened the policy window for desalination. Feitelson and Rosenthal (2012) suggest that this was allowed to move forward, albeit in fits and starts, due to a change of view within the treasury. Increasingly the treasury has come to see desalination as a way to break the Mekorot monopoly, by advancing desalination through tenders, from which Mekorot was barred. In the past 10 years, the treasury advanced and implemented two additional reforms. The first forced municipalities to corporatize their water and sewage services. The second restructured the water commissioner's office, which became now the water authority, with a somewhat wider regulatory scope.

The long-term master plan, currently being prepared by the water authority, calls for the rapid expansion of desalination. However, the tender issues so far have allowed for the emergence of a duopoly, as a single leading firm (IDE) is involved in most of the desalination plants. Hence, new issues arise regarding the institutional structure of the water sector, which question whether it will be able to adapt as flexibly and effectively as it has in the past. These issues cannot be disassociated from the wide ranging calls to decentralize the tycoon-dominated economy, the increasing opposition to higher water tariffs in the urban sector, which led also to calls to de-corporatize the municipal water sector, coupled with the realization that the Palestinians in the West Bank need additional freshwater and calls, echoed by the Bein commission, for greater transparency in water decision making. The question how will these new emerging issues be addressed is at the forefront of the Israeli water discourse today.

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Chapter 3
Israel's Water Policy 1980s–2000s: Advocacy Coalitions, Policy Stalemate, and Policy Change

Gila Menahem and Shula Gilad

3.1 Introduction and Theoretical Considerations

Water policy in Israel was characterized by a stalemate for two decades between the 1980s–2000. This policy stalemate persisted despite deteriorating situation on the ground (and under it) and scientists' warnings regarding the extreme risks and the likelihood of severe and irreversible damage to the water system. The prolonged impasse was especially perplexing in light of the consensus about the gravity of the situation, the urgent need for change on one hand and readily available ideas and technical solutions on the other. Lengthy debates over approaches to resolving the problem produced no agreement and no changes until 2000. However, the new millennium introduced a major transformation in governmental decisions about Israel's water policy.

Policy deadlock and policy change have been of much scholarly as well as practical interest. In the case of the Israeli water sector, where the damaging results of the stalemate were considered at least partially irreversible, the question becomes even more relevant. This chapter attempts to describe the process and explain the 1980–2000 policy stalemate in Israel's water sector and the eventual breakthrough in 2000, using the Advocacy Coalition Framework (ACF) (Sabatier and Jenkins-Smith 1993, 1999; Sabatier 1999; Sabatier and Weible 2007).

Primary data on which the following analysis is based were collected from more than one hundred interviews of key players in the Israeli (as well as

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Palestinian and Jordanian) water domain, of which 20 were in-depth interviews (Gilad 2003). Additional data were obtained from official government documents, reports, position papers, and conference proceedings published between 1970 and 2010.

3.2 The Context of the Research: Water Scarcity in Israel

The climate in Israel is semiarid; the desert in the south, which covers more than half of the country, has an arid climate. Only 17% of the total area is arable land.

As early as 1972, an international team of renowned water experts submitted a report to the Minister of Agriculture stating that " . . . Israel very clearly appears to be on the collision course which will result in a very serious water crisis . . . " (Woleman et al. 1972 in Mossenson 1991: 479). A drought in 1979 did indeed result in a severe water shortage and led to additional somber reports. By the 1980s, consecutive droughts made it clear that the existing water policy was not addressing the chronic problems of shortage, declining quality, and rapid depletion and deterioration of the sources (Cantor 1984, 1995, 1997). Natural population growth, massive immigration, a rising standard of living, and urbanization generated mounting demand for water, which increasingly exceeded the limited and diminishing renewable supply.

The World Bank defined the water situation in the Middle East at the beginning of the 1990s as "precarious" and presumed that the situation would only worsen and reach a crisis unless immediate actions were taken. According to the World Bank, in 1990 about 20 countries (in the world) were suffering more or less severely from water scarcity, as indicated by a commonly used index of vulnerability: an annual per capita water availability of 1000 cubic meters or less. ". . . . Israel (including the Palestinian territories) had less than half the scarcity amount – 461 cubic meters/year" (World Bank 1994: xii). Moreover, given the trends of population growth, consumption patterns, and the overextension of the restricted natural water resources, these societies were doomed to remain in crisis mode.[1] In this context, the question of policy responses to the severity of the water situation is of much interest.

Until 1990, agricultural use had generally been above 60% of Israel's total water consumption, and industrial use about 6%. The Israeli Water Law of 1959 set the foundation for water policy; it determined that water is the property of the public, under the control of the government, to be used for the benefit of its citizens and the development of the country. Since in 1959 agriculture was by far the

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[1]World Resources Institute 1996; using WB terminology on per capita availability of fresh water: below 1,700 = stress; below 1,000 = scarcity; below 800 = crisis. Some add: below 500 = absolute scarcity. Hinrichsen, D., Robey, B., and U.D. Upadhyay, *Solutions for a Water-Short World. Population Reports*, Series M, No. 14. Baltimore, Johns Hopkins, Chapter 3.2, http://www.jhuccp.org/pr/m14edsum.stm

biggest consumer of water, the law conferred nearly all of the authority and power on the Minister of Agriculture. The law stipulated the Water Commission's role and authority, as well as the responsibilities of other governmental agencies, and recognized three user sectors: urban (including household and public municipal), agricultural, and industrial. It defined priorities for allocation among them: first urban, then industry, and finally agriculture. However, in practice, the agricultural water quota system, established by law in 1959–1960 and revised in 1989, guaranteed the agricultural sector a minimum quantity of fresh water.[2] In drought years, these regulations benefiting agriculture stood in direct conflict with the 1959 Water Law's designation of the urban sector as having the highest priority. Although agricultural quotas could be reduced on a yearly basis if the Water Commission stipulated that there was not enough water to address total demand, a reduction in the agricultural quota was always difficult to implement and damaging to the farmers. Hence, water was provided to the agricultural sector (and to industry) by an administrative allocation scheme, but there were no quotas – either guaranteeing or limiting – urban uses. Until 2000, the law did not recognize nature as a legitimate user of water.

3.3 The Advocacy Coalition Framework (ACF) Approach: Coalitions and Belief Systems

The Advocacy Coalition Framework (ACF) claims that within each policy domain (or policy subsystem), "actors can be aggregated into a number of advocacy coalitions composed of members from various governmental and private organizations who share a set of normative and causal beliefs and who often act in concert" (Sabatier and Jenkins-Smith 1993: 18). These "[c]oalitions seek to translate their beliefs into public policies or programs" (Ibid.: 28). The actors within a coalition share basic values and search for means to accomplish them.

The belief system of actors within the coalitions is conceived as a three-tiered model. At the top of the belief system lie deep core beliefs, which are the broadest and most stable among the beliefs and are predominately normative in nature and usually cross policy domains. Examples of deep core beliefs include liberal vs. conservative beliefs; beliefs about the role of government, human nature, or desired relations between humans and nature; or present- versus future-oriented worldviews. Policy core beliefs are in the middle of the belief system hierarchy, and are in most cases specific to a policy area such as the water domain. Policy core beliefs are resistant to change but are more likely than deep core beliefs to adjust in

[2] Noga Blitz, director of consumption and licensing in the Water Commission, Protocol 5, 4: the basis of the agricultural allocation and the internal divisions among farmers and cooperative farms has not changed since 1960. Only the total quantity allocated to agriculture was reduced after the 1991 drought using 1989 as a reference year.

response to such factors as changes in the environment, new evidence, experiences, and information. At the bottom of the belief system are secondary beliefs, which, compared to policy core beliefs, are more substantively and geographically narrow in scope, more empirically based and include specific strategies to advance policies (Weible et al. 2009).

3.4 Coalitions and Belief Systems in Israel's Water Sector

Our analysis identifies three advocacy coalitions in the water policy domain that were active during the study period of 1980–2000: the agro-water coalition, the professional economists' coalition, and the newer environmentalists' coalition (Gilad 2003). Each was bonded by a specific combination of core beliefs, which are discussed below and synthesized in Table 3.1.

3.4.1 The Agro-Water Coalition

Ever since Israel was founded in 1948, an agro-water coalition dominated the water policy subsystem. Several factors combined to fortify its dominant position: its core beliefs embodying the Zionist ideas and ethos; its wide representation in the political arena, with many of its members holding central political positions; and finally the formal water policymaking institutions that gave farmers a key role in decision-making. The supreme authority for the formulation and implementation of water policy in Israel was the Minister of Agriculture. The Water Commissioner was appointed by the government upon the recommendation of the Minister of Agriculture. Two additional major actors were the Parliamentary Committee for Water and the Water Council, in both of which the agricultural sector had a majority as representatives of the main water consumers. Additional members of the agro-water coalition included the Farmers Association, the Agricultural Association, the Unified Kibbutz Organization, and the Agricultural Center, all representing the various agricultural sectors in the country.

The agro-water coalition held several distinguishing core beliefs that were centered on basic goals and values of Israeli society (see Table 3.1, left columns). This coalition's deep core beliefs were anchored "religiously" in a nation- and land-building and land acquisition version of Zionism (Eisenstandt 1967). Referring to the early years of the state when the agro-water coalition was dominant, Galnoor (1978) claims that policymakers regarded the development of water resources as a vital part of the nation-building efforts, in particular settlement of the land and agricultural development. Feitelson (2002) also claims that the discourse over water in the first years after independence was a direct continuum of the way water was referred to by the Zionist movement in the prestate period. Water was not conceived as a factor of production, but rather as a crucial mean for furthering national goals.

Table 3.1 Advocacy coalitions in Israel's Water Sector 1980s–2000s: beliefs, strategies, and policy goals

Criterion	Agro-water coalition	Economists	Environmentalists
Deep core beliefs			
Paramount value/s	National security, sovereignty, land settlement	National economic growth, market economy, personal liberty, efficiency	Sustainability, equity
Scope of government/private role sector	Large-scale government involvement, public funds; centralist approach for planning, development, and management	Minimal government intervention; privatization; market systems guarantee individual freedom of choice and support democracy	Large-scale government role & large-scale citizen participation
Natural resources perceived as	Strategic national assets	Economic commodity	Public good
Approach to development	Proactive	Economic criteria; cost/benefit analysis	Cautious and regulated sustainable development
Nature/human consideration	Humans, as a group, use nature	Individual welfare; humans, as individuals, use nature	Humans are part of nature
Public versus/private sphere?	Public > private	Private > public	Universe > private; public > private
Policy core beliefs			
Water perceived as:	Strategic asset, ensuring autonomous supply and control	Economic commodity	Public good
Cause of problem defined as:	Shortage of natural resources & government resistance to financing development	Quota-based allocation system and subsidies leading to irrational use; central administrative management system	Abuse, disregard and exploitation of nature and resources
Solution	Proactive development of resources: conventional and new nonconventional resources	Adopt (optimal) economic allocation pricing scheme; water development limited by cost-benefit considerations	Conservation, long-term planning; sustainable development based on ecological impact considerations

(continued)

Table 3.1 (continued)

Criterion	Agro-water coalition	Economists	Environmentalists
Management boundaries	Political, nation-states	International markets	Regional, natural – defined by water basin
Enforcement mechanism	Regulatory instruments	Economic incentives	Regulatory and judicial precedents
Scarcity: striking a water balance	Expand supply	Manage demand	Modify supply and manage demand
Role of agriculture	Primary	Should be treated like any other production sector	Favorable
Secondary instrumental beliefs			
Need for institutional reform	Reduce power of Finance Ministry	Reduce power of agricultural lobby	Enhance stakeholders power, mainly the public
Immediate steps to alleviate the crisis	Create new sources of water: desalination; import water; household conservation	Reduce quota for agriculture, in particular to high water consuming sectors for export, as an immediate interim solution; household conservation	Increase recycling; household conservation; rainwater harvest

Cultivating the land and establishing agricultural communities on the borders were building blocks of the agro-water coalition's core beliefs. Within these core beliefs, agriculture was viewed as a major means for assuring security and sovereignty.

The dominance of this coalition resulted in a water development paradigm that was embedded in the belief system shared by the members of the coalition and was implemented with relatively broad consensus and sound internal coordination, giving priority in water allocation to the agricultural sector (Menahem 1998).

The paramount values of national security, sovereignty, and land settlement were related to other agro-water coalition core beliefs: the need for central government involvement in the development of natural resources and large-scale publicly funded programs; a centralist approach to planning, development, and management; primacy of the public sphere over the private one; and a view of natural resources, including water, as strategic assets in the national struggle and of nature as a reservoir of resources to be deployed for human use and economic development. These deep core beliefs and policy beliefs shaped the actual water policies that were geared to protecting the agricultural sector. As the 2010 State Inquiry Commission appointed to examine the water crisis stated, in retrospect, the Ministers of Agriculture and the Water Commissioners who were in charge of water policy were in fact following the deep core beliefs of the agro-water coalition. "[T]he Ministers of Agriculture over several decades gave preference to the agricultural sector's needs, ignoring effects on the total water situation . . . water commissioners in fact were also driven by the ideological motive of expanding settlements along the borders, thus aggravating the water crisis" (State Inquiry Commission 2010: 10, authors' translation from Hebrew).

The coalition's policy beliefs led it to a focus on the supply side of the water balance equation and support policies that were geared toward increasing the existing supply: in the early years, searching for water, drilling wells, and pumping and building sophisticated conveyance systems; and later, in view of water shortages, desalination, treating or recycling wastewater, and developing state of the art water technology and water import. Within this framework, guaranteeing the agricultural sector a generous quota of subsidized water was essential. Therefore, a major aspect of the agro-water coalition's strategy was to block economists' attempts to adopt a market allocation system (which would automatically increase water prices to agriculture), as discussed in the following section.

3.4.2 The Rise of the Economists' Coalition in the Water Sector

During the 1980s, with the rise of globalization, privatization, and efficiency-oriented thinking in the Western world, the economists' coalition emerged as a second major player in Israel's water sector. Its members were mainly professional economists, located mostly in the Ministry of Finance or in academia.

Keren (1993) claims economists became more important in Israel in the context of the making of Israel's 1985 stabilization policy, which followed a period of economic instability, low growth rate, and accelerated inflation. The acknowledged success of the stabilization program enhanced the role of economists in Israeli policymaking. As Keren shows, they became partners in a coalition with the prime minister and sought new rules of economic and social conduct that included advancing a quest for efficiency, privatization, and less government intervention. Their professional deep core and policy beliefs had major impacts in many policy domains, including the water policy subsystem. These core beliefs were grounded in a paradigm of efficient market management of the private and public sectors, and natural resources like water were no exception (Hochman and Hochman 1991). Economists viewed economic stability and growth as a major determinant of national security and market systems as ensuring stability and growth. Where the agro-water coalition held that central planning was essential for protecting national needs, the economists' coalition viewed the market mechanism as guaranteeing efficiency. They favored minimal government intervention and promoted privatization. Development of natural resources should be considered only in terms of cost-benefit analysis. In accordance with these core beliefs, the economists' policy core beliefs viewed water as an economic commodity and not a strategic asset. Rather than enhancing water supply, they focused on curbing demand. They defined mismanagement of water demand, encouraging overuse and irrational use, as the source of the problem; their policy solution, therefore, was adopting optimal allocation of water based on prices and on cost-benefit analysis, rather than investing in projects to enhance supply. The relevant boundaries for applying cost-benefit analysis were international markets, not national boundaries. Where the agro-water coalition viewed regulation as the major enforcement mechanism, the economists' coalition depended on economic incentives, using pricing as the major enforcement mechanism. Hence, a major component of their policy was to reform prices of water for agriculture and to block investments for developing additional and nonconventional sources of water until such reforms materialized (Gilad 2003).

3.4.3 The Environmental Coalition

During the 1990s, a third coalition emerged and became a "mature" political player in Israel's water sector – the environmental coalition. Proponents of sustainability, the environmentalists gave a voice to nature, the silent player in the water sector, and spoke on behalf of future generations. The environmentalists' policy objectives focused on preservation of resources through both water conservation and water production, achieving the latter primarily by recycling. Consistent with environmental coalitions elsewhere in the world, this coalition shared some of the policy preferences of both the agro-water coalition and the economists, but their motivation sets them apart from either.

3.4.4 Clash of Coalitions in Israel's Water Sector Leads to Policy Stalemate

Many reports published by the State Comptroller since the end of the 1970s (State Comptroller 1979, Report #30; 1986, Report #37; 1988, Report #39) confirmed the severity of Israel's water situation and called for policy change. In 1985 another water crisis created political pressure which led the Water Commissioner to commission the Israel Water Planning Authority (Tahal) to prepare a comprehensive water management master plan. The 1990 State Comptroller's report asserted that the master plan, submitted in November 1988, "... was discussed neither by the Water Commission nor by the government, in spite of its findings and conclusions which indicated a need for a real and immediate change in the management of the Israeli water economy and in the allocation of water to agriculture. The Water Commission had restricted the distribution of this master plan ..." (State Comptroller 1990: 176). At the same time, during the three years which followed the submission of the Tahal report, 1988–1990, the water allocation to agriculture exceeded the available resources (State Comptroller 1990).

The severity of the water situation, as publicized by the comptroller's reports, was accompanied by intense struggle over the direction of change in Israel's water policy. During the period, each of the two major coalitions failed to implement its own policy goals but was successful in blocking the other coalition. While the situation on the ground continued to deteriorate rapidly, the economic coalition was able to thwart any proposals to desalinate, import, or produce unconventional water, and the agro-water coalition frustrated all efforts, even incremental, to implement price policies. In fact, in 1995 and again in 1999, the Ministry of Finance torpedoed two attempts to launch desalination projects unless price reform was introduced, despite the severe water crisis (State Inquiry Commission 2010: ch. 4 item 5 and item 1.5.2).

Following the logic of ACF, policy persistence or stalemate within a policy domain can be the result of one very dominant coalition. Alternatively, an impasse can occur when deeply held core beliefs within each coalition make compromise with an opposing coalition difficult or impossible. This is especially true when two or more coalitions with conflicting beliefs and strategies are able to maintain equally strong positions and block each other's efforts to change the status quo.

In fact, we found that despite agreement that the status quo policy was detrimental to the water sector, each of the two strong coalitions perceived the preferred policies of the other as opposed to its own and harmful to its basic beliefs and interests. The bone of contention, in essence, was the refusal of the economists to approve any projects for developing unconventional water resources prior to a reform in water prices, while the agro-water coalition fiercely resisted any increase in water prices to the agricultural sector which would reflect "real" prices. The two coalitions found themselves diametrically opposed. Each coalition therefore spent most of its energies on blocking the other from implementing its policy, despite the pressure for change.

Based on the Israeli case, we propose that in democratic countries, policy stalemates, especially with high-risk consequences in the policy domain, may not necessarily reflect the dominance of one coalition, but the ability of each coalition to block the other's attempts to advance a preferred course of action. In the case of water policy in Israel, each of the coalitions, driven by its deep core and policy core beliefs and derived strategies, espoused a course of action that directly opposed the other coalition's desired actions.

3.5 The Policy Breakthrough at the Beginning of the 2000s and the Factors Explaining It

3.5.1 External Perturbations and Policy Change: ACF

ACF theory proposes that major changes in external forces, the emergence of new players and new technological solutions, may produce the necessary preliminary conditions for policy transformations. We examine this proposition to determine the role that major societal changes had in precipitating and advancing policy change in Israel's water sector.

However, according to ACF, such external perturbations create only necessary but not sufficient conditions for policy change. Several additional factors may be needed to provide the sufficient conditions to ripen such external perturbations into actual policy change. Two of them will be discussed in this chapter: policy-oriented learning and the existence of policy brokers.

According to ACF, one possible outcome of a prolonged contest among advocacy coalitions is a "policy-oriented learning" process, by which some components of the coalitions' belief systems, more specifically policy beliefs or secondary strategic aspects, may be modified through a cognitive process that coalition members experience. "Policy oriented learning refers to relatively enduring alterations of thought or behavioral intentions that result from experience and are concerned with the attainment (or revision) of policy objectives" (Sabatier and Jenkins-Smith 1993: 19).

As observed by Sabatier, "In situations in which all major coalitions view a continuation of the current situation as unacceptable, they may be willing to enter negotiations in the hope of finding a compromise that is viewed by everyone as superior to the status quo. This is not a zero-sum game but rather a search for a win-win solution" (Sabatier 1998: 119). This change in perspective is a process of policy learning. In the next sections, we explain how external changes, policy learning, and the emergence of policy brokers culminated in governmental decisions that defined a new water policy in Israel.

3.5.2 External Perturbations and Policy Change in Israel's Water Sector

Three major external changes took place in Israel in the early 1990s with implications for the water sector:

1. Demographic change: an influx of immigration from the former Soviet Union that started in 1989 and led in the early 1990s to about a 20% population increase.
2. Climate change: an additional series of severe droughts in the years 1999–2001 that significantly reduced water availability and quality and caused unprecedented shortages and contamination of the water resources.
3. Geopolitical change: of no less importance, the Oslo Accords signed in Washington in September 1993 and the peace treaty between Israel and Jordan signed in 1994 included important components regarding regional water resources; it was understood that under any potential agreement, Israel would have to cede fresh water, further reducing its supply.

Supplementing these external changes, within the water domain, surprising technological developments at the turn of the decade reduced the price of desalination considerably.

These external developments drastically increased the demand for water and reduced the available supply, thus intensifying the problem in Israel's water sector in terms of water shortage (annual and cumulative), water quality, condition of the sources (lake, rivers, and aquifers), and tension with the neighbors (primarily Palestinians, Jordanians, and Lebanese). The need to find a solution became much more obvious and more urgent.

Yet as mentioned above, ACF theory holds that when external factors create necessary conditions for policy change, additional factors are still required to bring about actual change. We suggest that two such conditions played a major role in the Israeli case: policy-oriented learning and the existence of policy brokers.

3.5.3 Policy Learning and Policy Brokers: ACF

Weible et al. (2009) acknowledge that an additional path to change, as alternative dispute resolution (ADR) literature suggests, occurs through negotiated agreements involving two or more coalitions (Susskind et al. 1999). Such agreements can take place, the ACF claims, when conditions facilitating cross coalition learning exist. "Professional forums" that provide an institutional setting that allows coalitions to safely negotiate, agree, and implement agreements are important conditions to create cross coalition learning (Weible et al. 2009). "Policy oriented learning across belief systems is most likely when there exists a forum that is: (1) prestigious enough to force professionals from different coalitions to participate and (2) dominated by professional norms" (Sabatier and Jenkins-Smith 1999: 124).

The second condition that is conducive to policy change is the presence of policy brokers. Policy brokers are defined as a third group of actors whose principal concern is to find some reasonable compromise that will reduce intense conflict (Sabatier and Jenkins-Smith 1993: 72).

We will examine the role of these two factors in our analysis of the breakthrough in water policy in Israel.

3.5.4 Policy Change in Israel's Water Sector

Resolution #8211 (18 July 2000) of the Ministerial Committee on Economics under the leadership of the Finance Minister (approved by government decision #2117 on 3 August 2000)[3] deals primarily with the development of nonconventional water sources and signifies the beginning of a breakthrough in the policy impasse. The committee made a series of decisions, the major one being initiation of desalination. (In fact, this decision is commonly referred to as "the decision to desalinate.") It was decided to issue a tender for a 25-year contract to desalinate 50 mcm/year in Ashkelon (on the southern Mediterranean coast) by BOT (build, operate, and transfer) by private companies. The resolution also included other sources for augmenting the supply of water that were to be developed: brackish desalination, reclaiming wells, and recycling and conservation in urban and industrial sectors. Import of water was to be considered after conducting a feasibility and cost/benefit study. Finally, the resolution ordered the allocation of 50 mcm/year for nature.

In presenting his resolution, the Finance Minister, who acted as a policy broker, said that it was "the first comprehensive national water policy in decades."[4] Yet one of the most important things about this package was not only what was included but also what was omitted: this comprehensive policy originating in the Finance Ministry did nothing to alter water subsidies for the agricultural sector or attempt to introduce even a minor price increase and thus seemed like a concession by the economists to the agro-water coalition.

Once the trend began, additional projects followed. In April 2001, under the leadership of Minister of Infrastructure and Water Commissioner Shimon Tal, the government approved an increase in the amount to be produced by desalination. This time, they granted a turnkey contract to the national water company, Mekorot. In addition, in May 2001 BOO (build, operate, and own), tenders were issued for the production of an additional 65 mcm/year by small plants along the coastline, and the winners of the Ashkelon tender were granted permission to double the original

[3]Final report of the Parliamentary Inquiry Commission for investigation of water crisis, June 2002, 93.

[4]Opening remarks by Minister of Finance, Shochat, in the public announcement of the government's decision on 3 August 2000.

amount, bringing the total potential amount of desalinated water to 200 mcm/year. Table A.1 in the appendix below summarizes anticipated amounts of water from the various potential sources and technologies, target years, and financial resources required for each technology.

During that period another major step was under preparation and was adopted two years later. On 28 April 2002, the government approved the new agricultural policy – reform in water prices, replacing water subsidies by land subsidies, that is, shifting government subsidies from water to land cultivation. The main component of the plan, surprisingly supported by the Ministry of Agriculture, consisted of a price increase for agricultural water. This was to be achieved gradually by annual increases beginning 1 July 2002 and continuing through 1 October 2005, with the objective of reaching a uniform price of fresh water for all sectors (urban, industrial, and agricultural) by 2006. The graduated price system would then be replaced by a single price for each water quality, with prices for lower-quality water set at a fixed proportion of the price of potable water.

What explains this breakthrough? We propose that the external events that shocked the water system and triggered action moved the players into a process of policy learning and urged some leaders to assume the role of policy brokers in promoting conditions for change.

3.5.5 Policy Learning and Policy Brokers in Israel's Water Sector

For the ten years of policy impasse in the 1990s, it seemed as if proponents of opposing points of view were conducting a "dialogue of the deaf." But analysis of the changes reveals a process of policy learning, which culminated eventually in policy change. First, economists realized that they could initiate a process of privatizing the water market through desalination and could expand water resources without imposing on the public budget directly. They targeted the production of nonconventional water as an area that could attract private investment and advance efficiency in the water sector. Hence, although the economic coalition's policy core objectives were not transparent in the July 2000 proposal, it in fact made gains consistent with its deep core belief in privatization across all the new steps included in the government decision.

Another rationale for making a seeming concession by the economists' coalition can be understood from the words of Ohad Marani, who explained that desalination and imports would drive the country to adopt a price mechanism: "For years the Budget Division opposed desalination, but that has changed and we are also willing to import water . . . I prefer desalination and importing water, even if we lose a little money on it, **because there is enormous importance in the fact that we**

will all know, once and for all and precisely, the cost paid by the economy for continuing to subsidize water for agriculture."[5]

From the agro-water coalition's perspective, agriculture, still legally administered by quotas, suffered substantial reductions in the quantity of allocated water.[6] These annual cutbacks were made by administrative decision and did not indicate an actual change in policy. Yet they did affect farmers' understanding of the secondary aspects of their policy strategy. Farmers came to see that in the new reality of the Israeli water sector, administrative allocations worked to their detriment rather than to their advantage. Becoming completely reliant on the annual water allocation, they could no longer plan their farming business and many farms collapsed.

While moving toward a uniform price for water seemed to hurt the farmers, Minister of Agriculture Shalom Simhon pointed out its advantages from the farmers' point of view: "[T]he program is rational and balanced, and will make it possible to reach the goal of conserving water in agriculture without causing financial losses to farmers." He added, "The reform plan is an agricultural revolution. At its basis is the shift from water subsidies to land-cultivation subsidies."[7] According to Simhon, the agro-water coalition had not lost a battle. On the contrary, the value of the new policy for farmers was threefold: it guaranteed that agricultural lands would continue to be subsidized and farmed, water would be saved by efficient use, and water supply would be predictable – an essential ingredient for long-term agricultural planning.

The environmental coalition was less significant in the two major policy changes, but its influence in the water policy subsystem was not inconsequential. Environmentalists made an important contribution by emphasizing the dangers of the status quo, the urgent need for policy change, and the possible irreversibility of the damage. They helped push the two rival coalitions out of stalemate by pointing out the potentially disastrous role of the zero-sum game they were playing in blocking each other from making progress away from the unsustainable status quo.

Indeed, the Israeli government decided in 2000 on one more significant policy change: for the first time in history, it considered "nature" a consumer sector, and

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[5]Amiram Cohen, "**Finance Ministry reverses its opposition to desalination and water importation**," *Ha'aretz*, 7 June 2001 (emphasis added).

[6]In 1999 the Water Commissioner ordered a 40% reduction from the official 1989 quota (which is effectively less than a 40% cutback from actual use). Farmers received the instructions late and did not trust the government's promise of compensation, so they ignored the order. In 2000, farmers reduced use of water from the national system by 50% of the 1989 quota (effectively less than 40% of the previous year's use). In 2001, the Water Commissioner recommended a reduction of 56%, but only 50% was approved. Farmers adhered to regulations and were compensated for losses. The 1999–2000 attempt to reduce agricultural allocations failed because compensation was not implemented. Attempts to reduce urban consumption in 2000–2001 by mandating behavior (such as forbidding lawn and park watering during summer months) also failed.

[7]Raveh, "The government approved reform in prices to agriculture – prices will be equalized to municipalities," *Globes*, 29 April 2002.

"at the height of the water crisis, the government took a decision to allocate 50 million cubic meters of water to nature."[8]

We further claim that the role of policy brokers was important in leading from policy learning to governmental decision. In promoting the above impasse-breaking governmental decisions, a major role was played by Avraham Shochat, then in his second term as Minister of Finance (1999–2001). According to Shochat, he was assured that the package he put forward would be supported by all the other ministers and by other vital players in the water domain, even though similar proposals were ignored or turned down in the past.[9] In addition to the personal and professional relations between Shochat and Minister of Agriculture Haim Oron at the time, the Minister of Finance was able to affect the Ministerial Economic Committee's work. Unlike former bodies, this committee was not dominated by one ministry; it provided a forum for experts from the Water Commission, the National Water Company, the National Security Council, and the Ministries of Agriculture, Infrastructure, Finance, and Environment to express and defend conflicting views.[10] Ad hoc subcommittees composed of representatives from the Prime Minister's Office and the Ministries of Health, Industry, Foreign Affairs and Interior, and others conducted specific research and information-gathering tasks for the committee. The Finance Ministry's spokesperson's public statement indicated, "The final proposal submitted by the Minister of Finance was based on a careful synthesis of drafts offered by the Ministers of Infrastructure, Agriculture, Environment and the Water Commissioner... after prolonged discussions."[11] As the ACF proposes, such a process, incorporating substantive input from various agencies, created a forum prestigious enough to force professionals from different coalitions to participate and provided an institutional setting that allowed coalitions to negotiate, thus increasing the likelihood of reaching agreement.[12] The proposal drafted as a result by the Minister of Finance offered something for everyone and became a government decision.

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[8]Ministry of Environment – http://www.sviva.gov.il/bin/en.jsp?enPage=bulletin&infocus=1&enDisplay=view&enDispWhat=object&enDispWho=News%5El1628&enZone=february_bull04&enVersion=0&

[9]Avraham (Baiga) Shochat, phone interview to Gilad, May 2002.

[10]Substantiated by interviews with Gideon Shaffer (Interim Director of the National Security Council), Haim (Jumes) Oron (Minister of Agriculture), Mordechai (Kedmon) Cohen (Director of Planning in Agriculture Ministry), Moshe Izraeli (consultant to the Water Commission), and by copies of draft proposals provided to the author by interviewees (Gilad 2003).

[11]Finance Ministry spokesperson's announcement on 16 April 2000 and 18 July 2000, Internet: http://press.info.gov.il/dover_show.asp

[12]In a May 2002 phone interview, former Minister of Finance Shochat emphasized that at the point of decision, it was clear to him that all the ministers were 100% supportive.

3.6 The Gap Between Decisions and Implementation and the Role of Persistent Core Beliefs

In spite of the breakthrough in the early 2000s that the governmental decisions cited above represented, implementation was slow and incomplete. While some of the decisions regarding reforms in agricultural water prices were implemented, the 2010 State Inquiry Commission set up to investigate the water crisis concluded that most of the steps that should have been taken to increase water supply were not carried out. According to the Inquiry Commission's report (State Inquiry Commission 2010: item 18 and item 1.5.2), the main responsibility for this inaction lay with the Ministry of Finance, more specifically with the Ministry's Budget Office. The Budget Office, according to the commission, adhered to the concept it held during the stalemate period that desalination should not be promoted as long as other and less expensive sources of water could be used, such as catching rain drainage or brackish desalination. The commission criticized the Budget Office for not allocating the resources needed for such alternatives as desalination. As a result, the water crisis was again aggravated during the first decade of the twenty-first century.

3.7 Discussion and Concluding Remarks

The preceding analysis of processes in Israel's water sector during the recent decades attempted to explain the gap between the publicly acknowledged need to change policy in order to prevent accelerating damage to water resources and the persistent policy stalemate that dominated the water sector during that period, as well as the breakthrough in the early 2000s. Our main line of explanation of the policy process in the Israeli water sector from the 1980s through 2010 is based on the existence of two rival advocacy coalitions, the agro-water coalition and the economists' coalition, holding differing and incompatible deep core beliefs. Each coalition was represented among governmental policymakers who adhered to the coalition's deep core beliefs and attempted to implement them as government policy. The result was a policy stalemate, as each coalition was able to block the other, but not to advance its own preferences.

As ACF theory posits, a series of major external changes including severe droughts, a 20% population increase, and geopolitical changes in the form of the Oslo agreement and the peace treaty with Jordan created pressures for change. These external shocks generated a process of policy learning during the years of impasse that led each coalition to look for ways to resolve the standoff. The emergence of a policy broker made possible agreements over desalination in 2000 and reforming water prices for agriculture in 2002.

What both these major shifts in policy, as represented in governmental decisions, had in common was that while each of the coalitions seemingly "gave in" and acceded to the demands of the other, in fact each was able not to relinquish its core beliefs. In 2000, the economists' coalition, while agreeing to initiate desalination processes before reforming the system of subsidized water for agriculture, implemented a core belief by introducing the private market as the main source of financing for projects to augment water resources. The 2002 reform that changed agricultural water subsidies to subsidies for land cultivation still accepted and supported the societal value of agriculture, in line with a core belief of the agro-water coalition.

As above mentioned, a decade later only a fraction of these reforms was implemented, although the dire water situation did not change. As the 2010 Inquiry Commission stated, the Ministry of Finance and more specifically the Budget Division did not allocate the funds necessary for most of the approved projects. We propose that one way to attempt to understand the failure to implement the proposed governmental reforms is to restate what we previously pointed out: the policy learning process did not lead the rival coalitions to change or abandon their core beliefs. Instead, we showed that the coalition leaders viewed the reforms as an opportunity enabling them to adhere to and implement their core beliefs. Thus, it may be suggested that the combination of external conditions, policy brokers, and policy learning may lead to changes in governmental decisions. At the same time foot-dragging in implementing the changes raises further questions as to the role of policy beliefs in implementing policy change. These questions should be investigated in further research.

Appendix

Table A.1 Expected increase in water supply by governmental decisions

Enhancing water resources		
Government decisions to increase water resources	Quantity yielded	Target year
Seawater desalination plants	400 mcm	2006
Brackish water desalination plants	50 mcm	2005
Rehabilitation of saline-polluted and depleted wells	50 mcm	2005
Treatment and reuse of sewage effluents for irrigation	Up to 500 mcm	
Water import	50 mcm	

Supply development plan: required investments (2002–2010)	
Project	In millions of US dollars
Desalination	1,600
Sewage treatment and reuse systems	1,000
Water supply	600
Renovations and improvements	800

Source: Ministry of Foreign Affairs website: http://www.mfa.gov.il/mfa/go.asp?MFAH0mb00

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Chapter 4
Water in Agriculture

Yoav Kislev

The provision of water to agriculture, as well as to the other sectors of the economy, rests mainly on two principal foundations. The first is the 1959 Water Law, stipulating that all the water sources in the country are publicly owned and indicating that there are no private property rights over water or its use. The second foundation is the national system and the North-South Carrier around which the water system is built. Based on these constructs, Israel managed to provide water to agriculture, since its early days, not only in the rainy north, but also in the dry southern parts of the country.

Most of the water supply to agriculture in its early days was of freshwater (Table 4.1). The quantities grew gradually and peaked in 1985 (partly overdrafting); since then, the quantity the sector receives has decreased. Recent changes reflect both reduced precipitation—perhaps due to global warming—and expansion of the urban population: freshwater was diverted to urban consumption, with additional quantities of desalinated seawater, and treated sewage was returned to agriculture as recycled effluent. The legal regime of public ownership and the structural interconnectedness of the national system enabled a relatively smooth transformation of the water economy: the quantity of freshwater in agriculture in 2010 was less than 40% of the 1985 allotment. It would have been much more difficult and a lot more costly to achieve such a transformation under a completely decentralized infrastructure and a legal doctrine of private property rights in water.

The chapter draws on *The Water Economy of Israel* prepared for the Taub Center www.taubcenter.org.il. (Kislev 2012).

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Table 4.1 Water in agriculture, million cubic meters

	Freshwater	Recycled	Marginal	Total
1962	1,039		105	1,144
1985	1,235	43	155	1,433
2010	476	414	210	1,100

Source: Central Bureau of Statistics and the Water Authority
Note: Marginal is saline and floodwater

Examination of the agricultural water sector brings forward, not only successful allocation and reallocation, but also problem areas. This chapter will open with a review of developments and then turn to several policy issues.

4.1 Consumption and Production

Today, 40% of the water used in agriculture is supplied from its own facilities, mainly owned by regional and local cooperatives; the rest is provided by Mekorot. In the early days of the state, the supply to agriculture was limited to water from local sources—from the Sea of Galilee, wells, and rivers to irrigated fields close by. With the completion of the national carrier—one of the largest projects of the young state—the supply to agriculture quadrupled and expanded to all parts of the country. Yet, in the past 50 years, as can be seen in Table 4.1 and Fig. 4.1, the quantity supplied to this sector has not grown significantly.

The period beginning in the mid-1980s is characterized by a gradual shift from freshwater to recycled effluent and other marginal water, as well as by supply fluctuations. Despite the fact that the water quantity did not increase, the output of crops—vegetables, field crops, and orchards, agriculture's water consumers—steadily grew. In the past four decades, output of crops per unit of water has grown sevenfold, and once again, as can be seen in Fig. 4.1, this halting of the expansion of water supply has not slowed the expansion of agricultural production.

Many view the increase in agricultural production per unit of water as a measure of the success of Israel's irrigation technology. An OECD report (2010, Executive Summary) referred in this context to "an innovation culture spanning several decades." Israel's technology shows impressive achievements, but water is not the only factor responsible for the development of agricultural production. Among the other factors are the following: since the 1960s, the quantity of fertilizer used in agriculture has increased 50%; the quantities of fuel and oil used for machinery have doubled; and herbicide and pesticide use has tripled. Moreover, in the past decade, the area covered by greenhouses has doubled, and foreign labor has been added to the labor force, mostly excellent workers from Thailand. In contrast, the number of self-employed farmers has dropped, concentrating production into the hands of a relatively small number of professionals who can manage large farms.

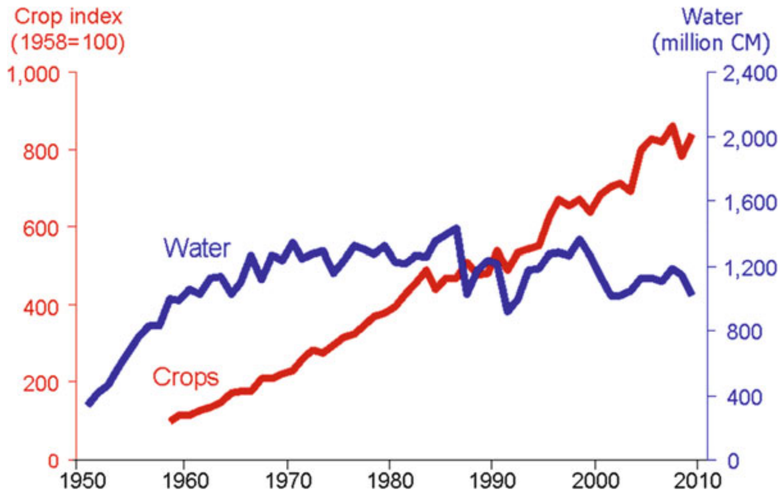

Fig. 4.1 Water and crops, 1950–2009 (*Source*: Central Bureau of Statistics)

These factors and others were combined with the technological achievements that have brought about a marked increase in agricultural production. Improvement in water technology has not been its only cause.

4.2 The Food-Water Balance

The quantity of water available in Israel does not suffice for production to cover the entire food needs of the country's population. A simple computation will demonstrate this, even if only with approximate figures. The computation is based on an approach developed by Tony Allan (2000) according to which food trade, or trade in other products, is actually trade in water used in the production process. While the products themselves are dry or contain only tiny quantities of water, their production requires water; consequently, export and import of food can be regarded as if they were trade in water. The term coined is virtual water.

In approximate terms, the quantity of water needed for producing 1 kg of grain seed (wheat, barley, and so forth) is 1 CM (precipitation or irrigation), and the quantity of food needed to feed one human is the equivalent of 1 ton of wheat per year or 1,000 CM of water. Therefore, in the first part of Table 4.2, the quantity of water needed to feed Israel's population (including foreign laborers and tourists) is written as 7,800 million CM of water per year. Add to that water for the urban sector and industry, and the total quantity of water needed is 8,600 million CM a year. Israel's available water, again in rough terms, is 1,500 million CM a year in the soil (from precipitation that wets the ground of fields and gardens) and 2,000

Table 4.2 Water balance and food import in approximate figures

Needs (water, million CM/year)		Resources (water, million CM/year)	
Food	7,800	In soil (from rain)	1,500
Home and urban	690	Extraction and recycled	2,000
Industry	110	Export	−500
		Total	3,000
		Import of virtual water	5,600
Total	8,600	Total	8,600

Main food imports	Thousands of tons	Virtual water, cubic meters per ton	Virtual water, millions of cubic meters
Grains	3,200	1.0	3,200
Oilseeds	394	1.3	512
Sugar	492	1.5	738
Beef	63	16.0	1,008
Total			5,458

Sources: Water – my estimates; food – 2009 Central Bureau of Statistics figures for foreign trade; virtual water – www.waterFootprint.org and my adjustments

million CM a year provided from natural and other sources. Subtract water for export crops—citrus, flowers, and others—estimated as 500 million CM a year, and one reaches the total available quantity of 3,000 million CM a year; hence, the yearly deficit is 5,600 million CM.

The second part of the table shows virtual water imports. For example, in Israel there is an import of 63,000 tons of beef a year. The quantity of water needed to raise 1 kg of beef is 16 CM, so that the imported beef contains a billion CM of virtual water. The aggregate quantity of the four main food groups in the table is 5,458 million CM of water a year.

Israel imports and exports many products containing virtual water. Although the balance in Table 4.2 is not complete, as even the food sector is not covered fully, it leads to a clear conclusion: we cannot be independent in our food supply, as Israel's water resources suffice to produce less than half of the quantity of food needed to feed its population; even large-scale desalination will not change this conclusion. The additional food that we consume is produced abroad, and we import it against exports of industrial products, services, and knowledge (virtual water can also be quantified in imported and exported industrial products).

Other countries in our region also need to import food, that is, virtual water. Tony Allan found that the Middle East is more dependent than any other region on virtual water imports. He remarked that this import added in the prevention of war: if we did not import food, the region's inhabitants would have fought desperately for every drop of water. Here is a contribution of globalization to peace.

4.3 Costs, Prices, and Levies

About 60% of water for agriculture is supplied by Mekorot. The prices that Mekorot charges are set in rules determined by the Water Authority. The prices charged by other suppliers—mostly regional associations—are not made public, but the Central Bureau of Statistics publishes aggregate data on the cost of water for all users, both Mekorot customers and others. These cost figures will be presented below.

The water law distinguishes between the cost of water and water fees. Cost refers to the cost of extraction and supply, on the "production" side (as distinct from the cost to users referred to at the end of the previous paragraph), and it was set in the past in regulations issued by the Minister of Agriculture. Today this is the responsibility of the Water Authority. Fees are prices paid by the users of water, which the law allows to be set based on various considerations, among them the users' ability to pay (the government has recently adopted a policy of cost-recovering prices). The law also sets extraction levies that are to reflect water scarcity and may differ from place to place.

In the past, water prices were determined with the approval of Knesset committees with no explicit connection to the cost of provision. When the Water Authority was established, it was tasked with price setting. Yet, just before its establishment in fall 2006, the government signed an agreement with farmers' representatives according to which water prices for agriculture would be set based on the average Mekorot cost of water supply to the sector, including agriculture's share of desalinated water. (The agreement also stipulated support for investment in agriculture, but this aspect will not be reviewed here.) According to the agreement, Mekorot's costs were to be agreed upon by a joint committee following a comprehensive study. The committee apparently completed its work, but its findings have not been published yet. Nevertheless, water prices for agriculture have risen and will continue to rise in the coming years.

Mekorot's tariffs for freshwater to agriculture are block rate prices. Each agricultural consumer, whether moshav, kibbutz, or individual farmer, has a basic water quota (also called 1989 quota and basically set administratively), and the prices paid are set according to demand relative to the quota in the following manner:[1]

Block I, Quantity A, 50% of quota	NIS 1.650 per CM
Block II, Quantity B, 30% of quota	NIS 1.902 per CM
Block III, Quantity C, 20% of quota	NIS 2.411 per CM

These prices do not include value-added tax.

The rules also set forth increments to the tariff for the coming years accordingly by 2016, the prices for all blocks will rise by 60 agorot per CM.

[1]The average exchange rate for 2011 was NIS 3.60 to US$1.

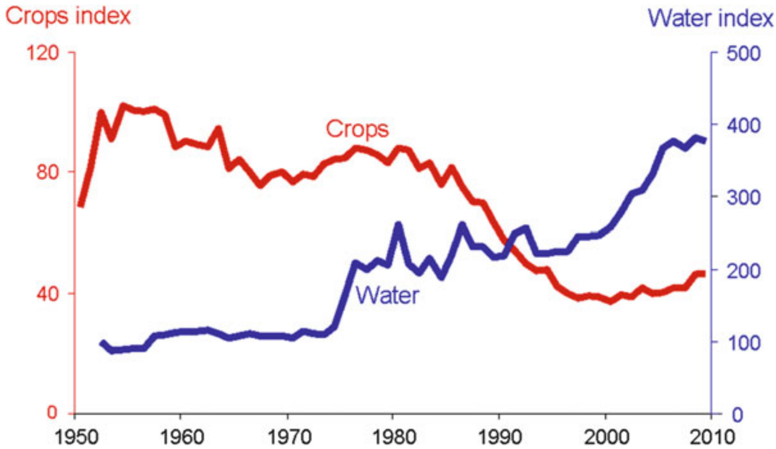

Fig. 4.2 Water cost index for agriculture and crop price index (*Source*: Central Bureau of Statistics)

In some special cases prices are different.
The charge for brackish water is lower, a decreasing function of salinity level.
An extra charge is set for consumption above the quota, termed irregular quantity.
The prices for recycled water supplied by Mekorot were set to be between NIS 0.80 and NIS 1.00, depending on quality.

By law, since 1999, water suppliers are required to pay extraction levies—aimed to reflect scarcity values—and they are allowed to pass them on to their customers. The levies differ depending on the water's end use, its locale, the season—winter or summer—and whether the year was rainy or dry. In fact, the levy does not apply to Mekorot and its customers. The levies will be presented in the discussion on policy below. All of the prices and the levies are linked to indices reflecting changes in the cost of water provision.

According to the letter of the law, water supply for agriculture is done by administrative allotment, in quotas: each consumer has a quota that was historically set by the planning authorities (1989 quota). The quota is supposed to be the maximum quantity that the consumer will receive. In fact, in recent years—until the recent crisis—the farmers have not used their full quotas, and the quotas served only to determine the price blocks (the quotas are reduced in periods of shortages and crises).

A few factors may affect agricultural water consumption. Figure 4.2 shows two of these: (1) the index of the cost of water and (2) the index of the price of crops (field crops, vegetables, and orchards). The indices are real, discounted by the consumer price index. The cost of water is the average cost per unit (cubic meter) of all types of water from all sources—not only payments to Mekorot—and it is the cost to the farmers. For those purchasing water, the cost is the buying price, and for those supplying water themselves, the cost is of self supply.

The average cost in Fig. 4.2 was stable for Israel's first two decades, then rose sharply in the 1970s together with energy prices (in the wake of rising energy prices, the cost of self-extraction rose, as did prices paid by farmers to Mekorot), and then rose again gradually from the 1990s until today. Over a 50-year period, the real cost of water quadrupled. In contrast, the trend in crop output prices has been a downward one, despite a temporary increase in the 1970s.

Today, product prices are approximately 40% of the real price that applied at the beginning of the 1950s. That is, in the period following the establishment of the state, prices were two-and-a-half times higher than what they are today. The reduction in price of Israeli agricultural products reflects a rise in productivity and a reduction in world market prices, both of Israeli exports and imports that compete with local products.

Water constitutes only a fraction—and frequently not a large one—of the total cost of producing agricultural products; therefore, a reduction in produce prices likely had a stronger effect on the demand for water than the rise in the cost of the water itself. Indeed, when agricultural product prices were relatively high, in the 1970s, farmers used their water quotas fully and even surpassed them, while later, when prices decreased, agriculture did not utilize all its allocations.

4.4 Policy

Examining agricultural water policy raises four issues: allocation to the sector and diversion of freshwater for urban uses, allocation among agricultural subsectors, tariffs, and levies in the country's regions, and cross-subsidization.

4.4.1 Allocation to Agriculture

In Israel's early years (the first decade after its establishment in 1948), particularly following the wave of immigration and mass settling of the land, agriculture was the main consumer of water, and the large water projects—the national carrier and the mains to the mountains, Negev and Arava—were laid to provide for the needs of agriculture. As the water sector developed, allocation to agriculture increased and peaked in the mid-1980s, as we saw in Table 4.1. Yet, over the years, Israel's population grew, urban water consumption increased, and freshwater was diverted from agriculture to the urban sector, partly replaced by recycle effluent.

The reduction of water allocation to agriculture came under criticism that was not always justified. The gradual diversion of freshwater from agriculture to urban consumption is one aspect of Israel's general and economic development, as well as that of world markets. For comparison, one can look at parallel changes that have taken place in the numbers of workers in agriculture. These changes were accepted uncritically: more than 120,000 people were employed in agriculture at the beginning of the 1960s; today fewer than 70,000 are employed in the sector, many of them are foreign workers. The number of Israelis employed today in agriculture is less than a third of what it was 40 years ago, although over that period, the population of the country tripled. The main cause of the reduction in the number of workers in agriculture—both self-employed and laborers—is the rise in income and salaries in other industries. Farmers and their children have shifted to occupations and income sources outside agriculture. At the same time, increased productivity—including improvements in water utilization—has enabled maintaining and even expanding the supply of fresh food to the growing population with a small and diminishing number of workers.

The gradual shift of freshwater from agriculture to other sectors is therefore part of the growth process and the change in the structure of Israel's economy. The freshwater goes over to the urban sector and is replaced, though only partially, by recycled water. It is likely that this shift would have been accepted uncritically if it had been accompanied by a sharper rise in the price of water than that which actually occurred. The farmers would then have voluntarily reduced the quantities of water that they took. Yet, the policy was one of price supports for agricultural water—because of appreciation of the difficulties of the sector, for the sake of maintaining a green environment, and due to agriculture's political power. Since the directing of water is in the hands of the state, and the decisions of government agencies have been to reduce supply to agriculture, the changes in water use have been perceived as coercive and arbitrary, thus generating sharp criticism on the parts of the farmers.

The gradual diminishment in the quantity of water supplied to agriculture was accompanied by another phenomenon, which generated even sharper criticism: that of repeated reductions in the water allocated to agriculture in dry periods (the fluctuations in the water graph in Fig. 4.1). Agriculture has borne the burden of the crises in the water sector, and according to its spokespeople, it has become "the fourth aquifer" to which the authorities came running every time there was a shortage. This phenomenon stemmed from the inability to reduce significantly and instantly water supply to urban consumption, from the fact that when all sources were tapped the water sector became tight, all development possibilities were practically exploited, and, above all, due to intense overdrafting that depleted the quantities of water in the reservoirs, leaving no reserves for hard times.

4.4.2 Allocations to Subsectors Within Agriculture

Households, institutions, offices, and others in the urban sector are not restricted in their water consumption; they are free to take as they please in exchange for paying the tariffs. As explained previously, a combined method prevails in agriculture: initial water allotment is administrative—each consumer has a basic quota—and the payment for the water is a function of quota utilization.

Water allotment, the quota, affects the farm economy in four main ways:

Initial allotment determines the structure of the farm and the farmer's ability to develop water-intensive crops or others.

Tariff setting: With block rate prices, a farmer who has a large quota can receive a greater quantity of water at the lower price of Quantity A.

Conversion to effluent: A farmer converting freshwater quota receives a quota of effluent of 1.2 CM for every CM of freshwater given up (for the high-quality Shafdan, the ratio is 1:1).

Mainly felt today, the quota is the basis for the reduced quantity of water to be used in times of emergency.

There are considerable differences in allocations to the agriculture subsectors. The most recent detailed numbers that I found are for 1998–1999. The quantity of water used then in agriculture was more than 25% larger of today's provision, yet there have been no significant changes in the proportional allocation to the subsectors since.

The data are presented in Table 4.3. Looking at the quotas (column 2), for 270 kibbutzim, the quota was 678 million cubic meters a year, whereas 411 moshavim were awarded only 519 million cubic meters a year. Neither the kibbutzim nor the moshavim used all of their quotas in 1999 (column 3). Only the non-Jewish sector used all its allocated water.

Looking at the allotment per land unit (column 4), the kibbutzim had more water than the moshavim; and the two sectors had a much larger quantity than did the non-Jewish sector. The land area of a farm community is practically a set size, whereas in contrast, labor input varies, and as such, it makes sense to associate it not with the quota, but rather to the actual water use (column 5). Here the differences between the sectors are large: six workdays per 1,000 CM in the kibbutzim; in the moshavim 23 workdays per 1,000 CM; and in the non-Jewish sector 50 workdays per 1,000 CM. Farmers who had at their disposal smaller quantities of water used them for labor-intensive crops, they "squeezed" the water more.

One explanation for the differential allocation to the subsectors is that it reflects a basic planning approach: kibbutz agriculture was built for large areas and mechanization. In the figures in Table 4.3, the average land area of a kibbutz in 1999 was 4,700 dunams, with water allotted commensurately. The average land area of a moshav was 2,600 dunams, and water allocation was accordingly smaller, on the assumption that the moshavim would engage in labor-intensive agriculture (the communal moshavim fell in between). Although this explanation is historically correct, these planned assignments led to differing allocations, with the kibbutzim still being able, if they so desired, to go over to labor-intensive crops, but the moshavim do not have the corresponding option of growing land- and water-intensive crops. A moshav farmer who wishes to expand has to collect means of production from others in the community or the region. The planning-based explanation for land and water distribution to Jewish communities does not apply to the non-Jewish sector; here the explanation appears to be clear-cut discrimination.

Table 4.3 Water in the agricultural subsectors, 1999

	No. of communities	1998 quota in millions of cubic meters	Use in millions of cubic meters	Quota in cubic meters per dunam	No. of workdays per 1,000 cubic meters used
	(1)	(2)	(3)	(4)	(5)
Kibbutzim	270	678	601	532	6
Communal moshavim	42	61	50	478	11
Moshavim	411	519	414	493	23
Non-Jewish	131	36	36	063	50
Urban/rural	55	216	140	763	16
Education/research	45	21	13	470	8
Sum/average	954	1,531	1,254	456	14

Source: Ministry of agriculture 2001
Notes:
(a) Urban/rural = noncooperative villages
(b) In column (4), dunam (one tenth of an hectare), physical area, field crops, vegetables, and orchards
(c) Workdays, in crop production

Recently, the Ministry of Agriculture has permitted quota trading. Although this option does relieve certain difficulties, the relief is only partial because trading is restricted, and—perhaps needless to say—only a farmer who was awarded a quota in the past can now transfer it in exchange for payment or for free.

4.4.3 Regional Tariffs and Levies

The data on water allocation point to differences between subsectors. The main differences in tariffs and levies are between regions. They reflect, however, not only regional conditions but also differences in organization and internal politics within agriculture. To focus, we consider only freshwater. As has been explained previously, in setting the tariffs that Mekorot's agricultural customers pay, the Council of the Water Authority follows the 2006 agreement. Farmers who are not Mekorot customers pay extraction levies set forth in the water law upon recommendation of the Water Authority Council. Thus, the farmers are divided (in paying for freshwater) into two groups: those who pay Mekorot tariffs and those who cover their own cost of supply and pay extraction levies. The tariffs of Mekorot are identical, uniform tariffs (though block rate prices) almost everywhere; the levies differ from place to place and season to season.

The schedule of levies in use today was first set as the second addendum to the water law in the fall of 2006, at the same time that the agreement with the farmers was formulated. Thus, the price agreement and the second amendment are, in fact, a single package. Regarding extraction levies, Israel is divided into three regions: disconnected (the Harod Valley, the Beit Sh'ean Valley, the lower Jordan Valley, the Dead Sea, and the Arava), the Sea of Galilee area (Mìgdal, Tiberias, the Jordan Valley, Yavniel Valley, the Golan, and the Upper Galilee), and the country system (all other places). The levies are defined in different values for extraction from aquifers and from surface water. Regarding the latter, a distinction is made between upper, mid-level, and downstream, as well as three hydrological conditions. (I did not manage to obtain from the Water Authority the geographical definition of the surface water regions.)

Table 4.4 shows the tariff and the levies for the country system in round numbers. The Mekorot tariff is repeated here for comparison. The extraction levies in the table are my calculations, using values from the tables in the second addendum to the water law, for mid-level surface water, for an average hydrological condition; extraction of downstream water is not levied. Table 4.5 shows selected extraction levy values for the disconnected and the Sea of Galilee region. Extraction to reservoirs in the Golan during the winter is exempt from levies; a levy does apply to pumping freshwater from these reservoirs, at a rate of 40% of that applying to surface water in the Sea of Galilee region.

As the values in the tables show, the highest price is the tariff for Mekorot freshwater, the next highest are the extraction levies in the country system; far behind are the extraction levies in the disconnected and Sea of Galilee regions. The differences are large by any measure.

Table 4.4 Mekorot tariff and extraction levies in the country system agorot per cubic meter

	Mekorot freshwater	Extraction levy	
		Aquifer	Surface water
Quantity A	165	5	21
Quantity B	190	102	118
Quantity C	241	150	150
Average	188	63	76

Source: Water Authority website
Note: Mekorot's tariff applies to all regions, with the exception of a few unique cases

Table 4.5 Extraction levies in disconnected and Sea of Galilee regions agorot per cubic meter

	Disconnected	Sea of Galilee
Aquifer		
Quantity A	1	5
Quantity B	3	13
Quantity C	4	21
Average	2	11
Mid-level surface water		
Quantity A	0	4
Quantity B	1	11
Quantity C	2	17
Average	1	9

Source: The second addendum of the water law

Examination of the tables leads to several observations. The first is that there are two aspects to the regional extraction levy: (1) the allocation aspect and (2) the equality aspect. To begin with the former, the levies affect the national water system only in cases in which they are imposed in places that are connected—directly or indirectly—to the national water economy. This is the case in the Sea of Galilee region. Water taken in the Golan or the Upper Galilee does not reach the Sea of Galilee, thereby subtracting from the water balance of other parts of the country. With exceptionally low extraction levies, farmers in the Sea of Galilee region receive economic signals that differ markedly from those sent to others who also share water resources in the national system. The situation is different regarding water in the disconnected region. There allocation is internal and the decision on extraction is regional, without affecting the national system.

Considering intra-sector equality, it may be argued that all farmers should bear similarly structured levies, for example, in each region a levy reflecting local water scarcity. This view leads to another point that arises when examining the tables, which is agriculture's internal political organization. The lion's share of water supply in the north, the disconnected, and the Sea of Galilee regions is the responsibility of water associations that are regional cooperatives whose members are kibbutzim and moshavim. Naturally, these associations are also platforms for political activity, not in the partisan sense, but in the sense of negotiations with the public officials. The representatives of the associations bring the requests and needs of their member to the table. In contrast, Mekorot customers and farmers in the national system usually stand alone, each one and his connection to the national supplier or local provider; they have no collective voice. The organized farmers have more power than the others, and this may be the root of the great differences in users' water cost seen in Tables 4.4 and 4.5.

Another issue relates not to Tables 4.4 and 4.5, but to the underlying law. As already indicated, the Water Authority Council sets tariffs in rules, whereas extraction levies are considered a tax, and therefore, they are set forth in the water law itself (not in rules that are bylaws). Amendments to the law are made only after a decision by the Water Authority Council is presented for discussion and approval in the Knesset Finance Committee.

The levies themselves are not quoted in the law; in their stead, the law specifies a series of tables whose figures are multiplied by each other in order to get the actual values of the levies. In fact all the levies could have been printed out on a single sheet, but this was not done and the information was not presented in this simple way to the Water Authority Council or to the Knesset Finance Committee. It is hard not to reach the conclusion that the Water Authority has an interest in hiding the levies and the differences between them. Indeed, it has succeeded in doing so: the members of its council and of the Knesset Finance Committee approved a clearly inequitable tax without bothering to learn what it actually was.

4.4.4 Subsidies and Cross-Subsidization

The term subsidy applies generally to support by the public at large, by the state budget, to a sector or commodity. Cross-subsidization is support of one group of the public by another.

For a long time the state budget supported Mekorot and water prices for consumers, particularly for agriculture, that were lower than the cost of supply. Beginning in 2008, water prices have been set such that consumers' entire payment cover Mekorot's cost in full. Household and other consumers in the urban sector cross-subsidize water prices in agriculture. The Water Authority estimated this support to be at 90 agorot per CM of urban consumption (for 2011). As explained earlier, the price of freshwater in agriculture will rise, and cross-subsidization will decrease; some subsidy will however remain to cover the cost of the recycled Shafdan water and the effluents.

Another cross-subsidy will be applied within the farm sector: by the 2006 agreement, future freshwater prices of Mekorot will be set to cover the cost of provision to agriculture. This means that farmers in low-cost areas will cross-subsidize supply to high-cost regions; that is, some farmers, Mekorot's consumers, not all farmers and not the country's public at large, will carry the burden of supporting irrigation in the mountains and in the Southern Arava valley.

At this point, it should also be mentioned that the state budget supports various activities in the water economy, among them, sewage treatment and effluent recycling. This dimension of government support is not reviewed in the current chapter.

4.5 Looking Ahead

As seen earlier in the chapter, after growing for several decades, the supply of water to agriculture has been characterized, over the last 30 years, by a decreasing and fluctuating trend. Crop planning was uncertain and provision was sometimes curtailed in mid-season. Judging from recent developments of seawater desalination in Israel, barring climate catastrophes, agriculture can expect stable supply of water in the coming years. The provision of recycled effluent may even increase as population grows and treatment facilities expand.

Ample supply is costly and in the coming years farmers will have to pay increasing prices for water. Although agriculture is still regarded highly in Israel as the supplier of fresh food and the guardian of the environment, contributing barely 2% of net national product, it cannot expect to master in the future the political power that had enabled it to enjoy in the past heavily subsidized water tariffs.

The water economy of Israel is mature in the sense that most of its facilities—networks, desalination plants, sewage treatment, and recycling systems—are in place or being constructed these days. But maturity is not stagnation: urban population is growing, health and environmental regulations are tightened, and equipment and infrastructure have to be replaced and updated. The water sector will undergo substantial changes in the future, changes that may affect agriculture significantly. The central authority responsible for the governance and the regulation of the sector has been strengthened since the establishment of the Water Authority in 2007, and the share of the largest single utility, Mekorot, in service provision is growing as supply is augmented with desalinated water. These developments call for increasing public participation in the leadership of the sector: deliberations and decisions have to be transparent, information disseminated, and stakeholders in agriculture, town, and industry has to be routinely consulted. The water sector has still a long way to go in this direction.

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Chapter 5
Rehabilitating Israel's Streams and Rivers

David Katz and Alon Tal

5.1 Introduction

For the first several decades of Israel's existence, water left in streams was considered a waste of a precious resource. Streams themselves were seen as hazards to be managed, with little perceived value other than serving as convenient conduits for disposal of sewage and other unwanted effluents. As a result, the country's streams were largely denuded, polluted, and rerouted to reduce flood risks. Legal, institutional, and political frameworks that have emerged over the past 20 years promoting rehabilitation of the country's streams signal a shift in public perception and public policy. In addition, recent advances in desalination infrastructure adding substantial quantities of freshwater and improved sewage treatment standards further raise the prospects of a new deal for Israel's streams. After years of intensive development and chronic water scarcity, however, several challenges still stand in the way of stream rehabilitation. This chapter reviews the causes of degradation of Israel's streams, recent policy measures to promote their rehabilitation, and the primary obstacles still facing actual rehabilitation.

5.2 A Brief History of Degradation of Israel's Streams

Sixteen primary streams flow into the Mediterranean while another 15 reach the Jordan River or the Kinneret Lake (Israel Ministry of Environment 2012). Before the modern period, these local streams contained healthy aquatic ecosystems that

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were habitats for fish, turtles, and even crocodiles. They also provided innumerable "ecosystem services" including watering holes for terrestrial wildlife and grazing, power for mills, and a myriad cultural services for local communities.

Already prior to the founding of the State of Israel, these streams were being channelized to prevent flooding, and their waters diverted to supply water to nascent cities and a burgeoning agricultural sector. When Israel codified its Water Law in 1959, the law was considered progressive for its time, specifying that water was a public good and that the government had a responsibility to manage it for the public's benefit. However, it turned out to be detrimental to the ecological integrity of the country's streams. Section 6 of the law defined those activities for which water could be utilized. These were (1) household needs; (2) agriculture; (3) industry; (4) industry, commerce; and (5) public services. Legally at least, nature was not a legitimate user of water. This oversight reflected not so much a cavalier attitude toward Israel's streams as a reflection of values that prioritized economic development with little regard for ecological matters.

Israel adopted an aggressive national strategy of water infrastructure development. In the 1950s Israel was still an indigent country, with enormous economic stress associated with both maintaining a large military and absorbing a huge influx of refugees that doubled the nation's population in a decade. During the 1950s and 1960s, massive water projects such as the Yarkon-Negev pipeline and the National Water Carrier, symbols of great national pride, more than doubled the amount of available water across the country. The water went to stave off the thirst of a population undergoing geometric growth and to supply irrigation water for rapidly expanding agricultural activity.

The exploitation of the nation's existing freshwater sources resulted in overpumping which, in turn, led to drastic declines in aquifer levels to the point that several of the springs supplying the nation's streams ceased to flow. Streamflow is considered by many aquatic ecologists to be a master variable (e.g., Poff et al. 1997), as it effects not only the size of available habitat but its temperature, its ability to process nutrients, stream geomorphology, and numerous other aspects of ecological functioning. A recent report stated that flow in a full two-thirds of all springs monitored were severely reduced and/or actively witnessing declines (Stutolsky and Perlmutter 2012). Several streams that had perennial flow became intermittent streams. Some that had been intermittent or ephemeral ceased to flow altogether. Streamflow in the lower portion of the Jordan River – Israel's only river – declined by over 95% relative to natural flows, with current streamflow consisting primarily of agricultural runoff and semi-treated sewage (SPNI 2008). Flow in the Yarkon stream, which runs through the heart of Tel Aviv, Israel's largest metropolitan area, is less than 2% of historic flows (ibid. 2008). Of all of Israel's streams, only the headwaters of the Jordan remained with significant shares of natural flow and functioning natural ecosystems.

Other surface water resources were also damaged irreparably. The Huleh wetlands and lake were home to an extraordinary collection of biodiversity that included the greatest concentration of aquatic plants in the entire Near East, 18 species of fish, and countless local and migratory bird species (Zigelman and Gershuni 1954).

In order to free up more arable agricultural lands, the marsh was completely drained and the ecosystem extirpated. This was the largest of the major "swamp draining" projects conducted by Zionist land agencies which together erased some 97% of Israel's natural wetlands (Glazman 2006).

In addition, to the decline in flows, Israel's streams became repositories for sewage, industrial wastes, heavy organic discharges from fish ponds, and even trash. While most municipal and industrial sewage now receives some treatment, the beds of these streams still house decades worth of residues containing heavy metals and organic chemical compounds. The streams have also suffered from a range of nonpoint pollution sources, including agricultural and urban runoff.

Not all of the pollution in Israel's stream originates in Israel. There are 15 streams that cross the Palestinian/Israeli border. Twelve of these are major streams that flow year-round in a westward direction toward the Mediterranean Sea, carrying sewage and other pollutants from the Palestinian Authority, or from lands that will probably be outside Israeli jurisdiction. Only 30% of the Palestinian population in the West Bank is connected to a sewage network, with the remainder relying on cesspools (PHG 2010). Similarly, there are three major streams with easterly flow that cross into the Palestinian Authority. At least part of each of these streams can be defined as highly polluted, posing a health hazard to users, endangering flora and fauna, and unfit for recreational or consumptive uses.

The toll of decades of intensive development of water resources, combined with lax pollution regulation, predictably took a large toll on the country's natural ecosystems. Environmental conditions in ephemeral or low-flowing streams tend to be particularly fragile. Ecosystems are naturally under stress due to the short rainy season and the high annual losses due to evapotranspiration during the dry summer months (Gasith and Hershkovitz 2010). Some ephemeral streams stopped receiving water altogether, while others with ecosystems developed around periodic dry periods, began receiving effluent discharges year-round. These shifts affected vegetation cover, bank and bed stability, and sediment transport and storage.

The aquatic ecosystems, already vulnerable due to the high variability of stream flow, were decimated. Natural vegetation and fauna were often replaced by invasive species better adapted to contaminate to the new environments. In some cases, opportunistic flora so thrived on organic loadings that natural flow became clogged and floods ensued due to impaired drainage during winter rains. Almost a quarter of endemic fish are endangered and five are already extinct (Goren 2002). Of the six indigenous amphibian species in Israel, none enjoy a stable population, and four are either endangered (two critically) (Gafny 2002).[1]

In sum, the systematic overexploitation of Israel's natural water sources, intense industrial and agricultural development, and copious quantities of inadequately treated sewage placed a severe burden on the nation's streams and the native wildlife that depended on them. For decades these impacts were either overlooked or deemed

[1]Nature lovers rejoiced in November 2011 when the painted frog, for 50 years thought to be extinct globally as a result of the Huleh drainage, miraculously reappeared (Rinat 2011). But their future is not clear, as the wetland habitat that supported the species has virtually disappeared.

the price the nation had to pay for progress. Beginning in the 1990s, however, a gradual shift toward recognition of the value of stream ecosystems and a desire to rehabilitate them began.

5.3 A Change in Perspective

A combination of increasingly pernicious environmental conditions in Israel's streams, a decline in the economic and political influence of the agricultural sector in Israel,[2] and an increasingly concerned environmental awareness among the public all converged to initiate a change in the government's approach to stream management. Initial changes beginning in the 1990s were both regulatory, establishing bodies to promote stream rehabilitation, and financial, including financing upgrade of sewage treatment infrastructure. The decade also witnessed the country's first large-scale ecological rehabilitation project, the reflooding of part of the Huleh wetlands, a project that proved both potential environment and economic value of ecological restoration.

5.3.1 Statutory Amendments: Necessary but Not Sufficient

Israel had long had in place statutory authority that ostensibly could be used for purposes of protection and rehabilitation of streams. Israel's Water Law of 1959 obligated the government to protect the quality of the nation's water sources. However, as mentioned, it does not explicitly mandate protection of the aquatic ecosystems dependent on these water sources. As early as 1965 Israel passed the Streams and Springs Authorities Law that empowered the Minister of Interior (now Environment) to create an independent authority to coordinate the oversight of activities to protect a stream or river. Such authorities are empowered to undertake steps to protect and conserve the stream and its banks as well as abate nuisances and prevent pollution. However, it took 23 years for the first authority to be declared in the Yarkon Stream in 1988, with the Kishon Authority, the only other stream authority, following suit only in 1994.

In 1993, the government founded a national Stream Restoration Administration,[3] with representatives from several governmental agencies as well as

[2]According to Israel's Central Bureau of Statistics, as of 2011, agriculture accounted for only 1% of the national gross domestic product and less than 2% of employment (Central Bureau of Statistics 2012). This is down from nearly 25% of employment in the 1950s and early 1960s.

[3]In Hebrew, the word "shikum" can be interpreted as restoration or rehabilitation. Ecologists tend to reserve the term "restoration" for instances in which normal or historical ecological functioning has been restored to an ecosystem without the need for outside help. In the case of Israel, plans are generally for "rehabilitation" which represents only partial restoring of ecological functioning.

nongovernmental organizations. The new administration, however, served mostly has an ad hoc advisory body and did not create a clear national strategy or establish a clear division of responsibilities. The vacuum at the national level was filled by several initiatives by regional agencies. Numerous stream and drainage basin authorities began to coordinate rehabilitation work as well. The first was the Yarkon Stream Authority with a 50-million-dollar effort over the years, which was followed in the Kishon and others. A critical first step in rehabilitation efforts involves creating a master plan that can serve as a blueprint for the myriad activities which need to be part of a restoration program. By 2012, rehabilitation master plans had been developed for 27 different streams or stream segments, and work was under way to prepare one for the lower Jordan River as well. Ultimately, however, statutes and master plans cannot create the funds and political will that is necessary to ensure water supplies, upgrade sewage treatment, enforce discharge standards, or provide the resources to bring the public to the streams.

5.3.2 Financing Wastewater Treatment

Perhaps the most significant improvement to the quality of streams in Israel in the 1990s came as a result of upgrading of sewage treatment. Between 1990 and 2010, Israel invested nearly $2 billion in wastewater treatment facilities (Israel Ministry of Environment 2010). In 1995 there were 15 advanced wastewater treatment facilities in Israel. By 2005 32 plants were fully operational, treating 80% of the nation's total wastewater at at least a secondary level (Inbar 2006). Much of the wastewater was delivered to farms as recycled effluent, and the wastewater that was released in the streams contained significantly lower organic loadings and pathogens than previously. The investments produced substantial dividends in terms of environmental quality as measured by several water quality parameters in the country's major streams. Between 1994 and 2000, levels of organic carbon, total nitrogen, and total phosphorus inputs into major streams all declined by more than 40% (Shapira and Mazor 2001).

5.3.3 Reflooding the Huleh: Israel's First Major Ecological Rehabilitation Project

Reducing pollution loads is a critical step in rehabilitating streams, but merely reducing the level of damage in highly impaired ecosystems is not sufficient to restore ecological functioning. In fact, little progress was made in actually rehabilitating stream ecosystems in the decade following the establishment of the Stream Restoration Authority. Israel's first progress toward actual restoration of aquatic habitat came about not as a result of the authority's work, but rather, at the site of the first and largest land reclamation (i.e., wetland drainage) project, in the Huleh Valley. The Huleh wetlands, located at the northern-eastern tip of Israel, covered 60 km^2 including a 14-km^2 lake. Early state leaders viewed the wetlands as a source of malaria and an impediment to agricultural production. By 1958, the Huleh Valley was entirely drained, with only a small 310-ha area reflooded and kept as a reserve and reminder of the original landscape. Agriculture in the valley was dramatically expanded.

However, soon after the draining, it became clear that the benefits of the project were much less than predicted, and the costs much higher. In the southern and central parts of the valley, the agricultural dividend that the project was supposed to create never materialized. As the groundwater table dropped, the peat soil began to degrade. Subsurface oxidation became a problem. The peat became black dust which was basically infertile. The dry summer months produced dust storms, while during the winter, fields were often flooded and unworkable, as the soil surface dropped by as much as three meters in some areas. The farmers in the area stopped cultivating the soils and sought alternative livelihoods (Hambright and Zohary 1998). In addition, the combination of soil degradation, agricultural activities in the northern part of the valley, and channelized flow led to increasing erosion and nutrient loading into the Kinneret Lake, Israel's primary source of surface water.

In order to improve water quality downstream and make use of the degraded land, authorities decided to reflood a portion of the valley. The project was completed in 1994 by the Jewish National Fund – the same organization that had led the drainage project 40 years earlier. The "Agmon" or mini-lake is only one square kilometer and, at an average of half a meter deep, far shallower than the original lake. Yet the new ecosystem quickly became a major tourist venue with an astonishing array wildlife, including tens of thousands of migrating cranes that winter on the site. In terms of broader policy significance, the project offered a "proof of concept" for advocates of stream rehabilitation who could now demonstrate that their efforts had both clear environmental and economic value.

5.4 The Potential for Genuine Progress

Recent years have seen several developments which bode well for the long-term prospects of improved surface water quality and stream rehabilitation. These include amendment of the Water Law to include environmental goals among the list of legitimate uses of water, a policy of large-scale desalination that should offset at least some of the pressures on natural water supplies, and significantly improved sewage treatment standards requiring tertiary treatment levels for nearly all municipal wastewater facilities. These policy changes have been accompanied by several initial projects designed to restore or rehabilitate streams and wetlands, including multimillion dollar efforts dredging and removing contaminants from the Kishon River.

5.4.1 Legal Recognition of Nature as a Legitimate Water Consumer

As mentioned, when passed, Israel's Water Law did not recognize nature as a legally legitimate recipient of water. This essentially meant that streams and wetlands were essentially left with whatever water, if any, remained after other legally recognized beneficial uses received their shares. In 2003, the Water Law was amended, adding environmental objectives as a legitimate objective for water allocations and stipulating that the Water Commission (now the Water Authority) submit a report about allocations to nature each year to the Knesset (Knesset 2004). The authority has since committed to finding water for stream restoration, called for proposals for determining water needs for environmental purposes, and included stream restoration in its long-term master plan for national water management (Israel Water Authority 2011).

5.4.2 Desalination

Israel's current commitment to desalination on a massive scale, as documented elsewhere in this volume, may reduce pressure on natural water resources, allowing water tables to rise and springs to flow again. As of 2011, nearly 300 million cubic meters (mcm) of water were desalinated annually, accounting for over half of all water supplied for domestic uses and nearly a third of all freshwater consumption for all uses. This amount is expected to increase to over 550 mcm by 2015 and to 750–1,000 mcm by 2020 according to various plans laid out by the Water Authority. Moreover, because currently over 70% of wastewater is treated and reused, each cubic meter desalinated actually adds 1.7 m^3 of water to the overall water supply. And given plans to increase the share of wastewater reused, these quantities can be expected to increase even further.

As a result, Israel's dependence on natural (rainfed) sources of water should significantly decline in the future. Current policy is to recharge aquifer levels in order to build a strategic reserve for future needs. While this will not raise water tables high enough for most springs to flow naturally again, it may help in isolated cases and should at least stunt the current trend of declining flows from springs (Stutolsky and Perlmutter 2012).

5.4.3 Effluent Standards

As Israel's sewage treatment improved, it became clear that meeting the existing standards would not be sufficient to bring its degraded streams back to life. The Ministry of Environment spearheaded an initiative to upgrade the existing standards for biological oxygen demand (BOD) and total suspended solids (TSS). New standards for wastewater reuse were adopted in 2005 which establish a two-tiered criterion for sewage treatment: one for effluents discharged into streams and another for treated effluent delivered to agriculture. Though formally approved, a long phase-in period was allowed to allow for the necessary investment in upgrading sewage treatment infrastructure (Lawhon and Schwartz 2006). The standard replaces the 20/30 BOD/TSS standard with a uniform 10/10 BOD/TSS requirement. But many standards for other water quality parameters are bifurcated. Fecal coliform requirements are more stringent for irrigation (10 per 100 ml) than for streams (200 per100 ml) which presumably can benefit from dilution dynamics. At the same time, the standard for total nitrogen and phosphorus is tougher in effluent bound for streams (10 and 1 mg/l) than it is for irrigation (25 and 10 mg/l) in order to reduce the risk of eutrophication. No sewage treatment plant specifically designs its facilities for irrigation or stream release, but the very fact that special standards were designed to improve instream ecological integrity sent an important policy message about the seriousness with which Israel intends to pursue stream restoration.

5.4.4 Initiating Stream Protection and Rehabilitation Projects

In addition to the above-mentioned policy changes, Israel has also embarked on several projects of various scales designed specifically to rehabilitate springs and streams. Small projects include securing agreements to supply modest amounts of water to individual springs in the Galilee and an agreement that resolved a high publicized controversy over water from the Ein Gedi springs – a small but ecologically and historically significant desert oasis. In the case of the latter, the bulk of the waters were being captured directly from the springs for use by a bottled water company and for agricultural and domestic purposes in a nearby settlement. Today most of the waters are now captured downstream after flowing through a protected nature reserve.

A project to rehabilitate the Kishon stream, which flows through Israel's most industrialized area, represents Israel's first large-scale stream rehabilitation project. The stream has served for decades as the drainage canal for industrial effluents from large chemical industries, oil refineries, and other heavy industry in the Haifa region. Its waters have long been toxic and rancid. Beginning in the mid-1990s, tighter regulations on effluent discharges and upgrading of the local sewage treatment plant, as well as concerted action by the Kishon Stream Authority, resulted in significant reductions in inflows of major pollutants, including organic loads, ammonia, oils, and suspended solids (Nissim and Gutman 2011).

Reduction in pollution inputs, however, has not been sufficient to compensate for decades of accumulated stocks of pollution in the streambed sediments. A master plan for the rehabilitation of the Kishon was developed which has as its centerpiece a plan to dredge and treat the contaminated soil along the streambed. In order to accomplish this, the course of the stream will be altered, adding a large meander downstream. Once in place, the contaminated land will be treated biologically and the soil used to create an urban park along the stream's new banks. This project is expected to be completed by 2015. Other elements of the master plan include acquiring additional water allocations for the stream as well as reintroduction of native flora and fauna. The master plan's price tag of nearly $60 million makes it the most expensive effort to date at stream rehabilitation in Israel. Roughly 60% of the funding for the rehabilitation project is to be paid by the oil refinery and chemical companies that are responsible for much of the historic pollution, with the national government footing the bill for another 30% and local authorities the remainder (Darel 2011b).

In sum, streams in Israel are no longer solely viewed as open sewage canals. There is growing recognition of the importance of streams from both an environmental and economic development perspective. The removal of certain statutory obstacles to stream rehabilitation and dedication of significant funding for desalination and wastewater treatment bodes well for the future of the ecological integrity of the streams in Israel, and some progress is being made in implementing aspects of many of the 27 master plans prepared for stream rehabilitation in Israel. The way forward, however, is not without substantial challenges.

5.5 Challenges and the Road Ahead

5.5.1 Administrative Obstacles

In a 2011 report on the state of stream rehabilitation policy in Israel, the nation's State Comptroller office noted that nearly 20 years after the establishment of the national Stream Restoration Administration, not one stream had actually been restored (State Comptroller 2011). The report cited numerous policy obstacles that remain to effective implementation of rehabilitation policy, among these overlapping policy mandates across government agencies, conflicts of interests within government agencies responsible for rehabilitation, and insufficient funding.

Over a dozen government agencies are responsible for some aspect of stream rehabilitation, including national ministries, local authorities, and specific agencies tied to the streams, such as drainage basins or stream authorities. The Stream Rehabilitation Authority – an interagency body – acts in an advisory capacity only and has no statutory authority. Among those with genuine operational powers, it is often unclear who is responsible for coordinating policy and what the hierarchy of decision-making is when agencies do not see eye to eye, as is often the case.

The Comptroller's report also criticized government policy for not taking a watershed basin approach to stream rehabilitation, even though it is widely recognized that such an approach is necessary for effective implementation. While the Ministry of Environment is authorized under the Streams and Springs Authority

Law to establish stream basin authorities, it has been reluctant to do so, in most cases conferring the responsibility for developing and implementing rehabilitation plans to the local drainage authorities. Its rationale for doing so has been not to create redundant bureaucracies. Yet it raises clear conflicts of interests.

The primary responsibility – and legally binding obligation – of drainage basin authorities, which operate under the auspices of the Ministry of Agriculture, is to prevent damage from flooding. To this effect, they tend to focus their efforts on channelizing streams and ensuring that the water flows quickly through them. However, floods are a necessary element in freshwater aquatic ecosystems, fulfilling numerous ecological functions such as replenishing wetlands and dispersing seeds. While the drainage basins can be held liable for failing to prevent flood damage, they have no such obligation to implement specific rehabilitation projects. This creates a clear prioritization of incentives with water quality and ecosystem rehabilitation lower on the hierarchy. In addition to the conflict of interests, there is also a conflict of cultures, as drainage authorities have tended to seek engineering fixes to stream issues, rather than taking more ecologically based watershed approaches (State Comptroller 2011). Efforts to place the drainage authorities under the mandate of the Ministry of Environment, in order to change both the conflicts of culture and of interests, have been met with significant resistance (Darel 2011a).

5.5.2 Financial Obstacles

According to estimates by the Ministry of Environment, rehabilitation of the nation's streams will demand over $1 billion dollars, including an additional half billion dollars for upgrading sewage treatment facilities and another half billion for actual projects in and along the streams (Israel Ministry of Environment 2010; State Comptroller 2011). The average amount of funding allocated by the government for rehabilitation projects between 1998 and 2010, however, was only roughly $2.5 million, leading the Comptroller's office to declare that at the current pace, rehabilitation efforts would take a century to complete (State Comptroller 2011).

Many economic assessments have found the economic value of stream rehabilitation in Israel is quite high, often outweighing the costs (e.g., Yarkon Stream Authority 2002; Barak 2010). Yet much of the benefits are in the form of public goods and, therefore, do not necessarily generate revenues that can be used to fund the rehabilitation projects. Additional cases such as the Kishon, in which large industries with deep pockets can be coerced to foot the bill, are not foreseen. This leaves the government to appropriate the necessary funds. For streams in urban areas, some of the revenues can be raised through property taxes on areas expected to see an increase in property value; however, this is not likely to raise sufficient funds for all rehabilitation needs. Other economic policies to generate revenue, such as a dedicated tax on water consumption, have been resisted by various parties who maintain that water prices are already high and that such a tax would be regressive in nature.

A small abstraction levy which charges more for users to pump upstream than downstream, in an effort to incentivize letting water flow in natural channels, has been implemented by the Water Authority on a small scale. However, such a policy is effective primarily in areas such as the tributaries to the upper Jordan River, in which water still flows naturally from springs. Potential to utilize this policy in coastal streams is limited, as water tables too low to affect spring flows.

5.5.3 Obtaining Necessary Environmental Flows

Even if policymakers were to sort out regulatory and financial issues, several other challenges stand in the way of stream restoration in Israel. First and foremost, perhaps, are the scientific questions of what is needed to restore or rehabilitate rivers. Under pressure from the Water Commission (now the Water Authority) to detail the water needs of streams, an interagency team led by the Nature and Parks Authority and the Ministry of Environment, produced a policy brief entitled "Nature's Right to Water," detailing the minimum amounts of water necessary for ecologically functioning streams (Nature and Parks Authority and Ministry of Environment 2003). The report cited a need for over 600 mcm per year for nature reserves and coastal streams, and an additional 200 mcm per year for restoration of the Jordan River. This amount is above and beyond the amount of water flowing in the streams already. To put this quantity in perspective, it constitutes more than half of the annual renewable freshwater resources of the country.

Taking desalination costs as a shadow price, a "back of the envelope" calculation puts the annual expense of supplying such amounts at roughly half a billion dollars. Knowing that such a request would be summarily dismissed, the report specified that, because water could be captured downstream, net water needs for nature reserves and coastal streams (i.e., losses to evaporation and unrecoverable seepage) could be satisfied with only about 50 mcm.

While the policy document played an important role in pushing forward the debate on the water needs for nature, it is deeply problematic. First of all, the policy of encouraging capture of the streamflow downstream, while certainly better from an ecological perspective than capturing it upstream, and perhaps politically necessary in order to be taken seriously, inherently sacrifices flows into estuaries – deltas where fresh- and seawater mix. Estuaries are important habitats in and of themselves and often play an important role in ecological functioning upstream as well.

Secondly, the quantities needed were calculated based on a dated methodology that failed to take into consideration important nuances in flow regimes that are vital to ecosystem health, such as the timing, duration, and rate of change of flows (Poff et al. 1997). The methodology is widely used because it is inexpensive and easy to implement (Katz 2006), yet it is unlikely to actually bring about restoration of ecological functioning.[4] Furthermore, that method, like most other methods for determining ecological needs for streams, was based on how much water must be left in streams to avoid irreparable damage. It assumes a reasonable existing ecological integrity. Much less is known about how much flow must be returned to streams in order to overcome damage already inflicted by decades of dewatering and toxic discharges, as is the case in Israel. This is especially challenging in Israel, as no coastal stream is in good enough ecological health to serve as reference case and a basis for restoration plans.

While the exact quantities needed to rehabilitate streams are still unknown, it is clear that they are significant. In 2000 the government committed to allocating 50 mcm of water for nature preservation and rehabilitation. However, as of 2011, only 10 mcm was actually been allocated for such purposes, almost exclusively to the Yarkon stream. Policymakers still struggle with finding the needed waters. As Israel presently uses 100% of its renewable precipitation, until the country's desalination network grows appreciably, water for streams will have to come at the expense of other uses. Various government proposals call for treated wastewater – treated to the Inbar standards – to account for much of the future allocations for streamflows. Yet ecologists and environmental organizations argue that the standards are insufficient to bring about actual ecological restoration and that water at these standards may cause more harm than good (e.g., Gasith and Hershkovitz 2010; Stutolsky and Perlmutter 2012).

5.5.4 Water Quality

Additional improvements in water quality are still needed as well. The Inbar standards have already decreased the amount of pollutants and improved water quality in streams, from effluents, the primary point source of contamination. But many streams still suffer significant loadings from nonpoint source pollution from agricultural, urban storm water, or other non-discrete sources. In fact, the few studies that actually characterize the full profile of stream pollution suggest that nonpoint sources from runoff are the single greatest source of nutrients and other pollutants to the streams (Tal et al. 2010). Moreover, periodic treatment plant "failures" or accidents along the stream are not unknown and can cause considerable damage even when they occur far away from the stream but within the basin. Several such accidents have occurred in recent years resulting in massive fish kills and other water quality damages that literally wiped out years of rehabilitation efforts.

[4]The present criteria were proposed as a rule of thumb in the 1970s by Donald Tennet, an American hydrologist who examined rivers in the western USA and who himself has stated that many better, more sophisticated methods have been developed since then (Instream Flow Council 2002).

5.5.5 Land Use

Changes in land use within stream basins also complicate rehabilitation efforts. Development, especially in floodplains, decreases recharge areas and increases runoff, exacerbating floods and increasing the need for flood prevention, which, as stated, can contradict restoration goals. Furthermore, such development can prevent projects such as the reintroduction of meanders, which may be necessary for restoration of ecological functioning in streams. Proposals to establish funds to purchase land for purposes of stream restoration, including open spaces to preserve floodplains, have been put forward, but, to date, have not been implemented (State Comptroller 2011).

5.5.6 Public Perception and Understanding

Despite important shifts in policy that reflect a new appreciation of streams' value, significant rehabilitation will still require additional change in public opinion, both among policymakers and the public at large. Given national water shortages, many citizens still view water left instream as a luxury or a waste of precious resources. Editorials and declarations of politicians bemoaning the "wasted" water left to flow unexploited to the sea are still commonplace, as are calls for development of additional reservoirs to capture surface water flows.

In theory, the production of large quantities of desalinated water should reduce pressure on natural water resources; nonetheless, because of the high cost of desalination, many people object to desalinating seawater, for the seemingly "frivolous" purpose of allowing additional freshwater to run in streams. Similarly, theoretically, increasing standards for wastewater treatment can produce more water for instream flows. However, once sewage is treated to a high level, local authorities and utilities tend to see it as an economic resource that can be sold to farmers and are reluctant to release it without payment to streams. Indeed, for many years the Water Authority expected the Nature Reserves to "pay" for water – though the reserves had little ability of producing income to compete in a national market. Thus, both desalination and high-quality wastewater standards – which potentially could supply additional water to streams – may end up working against such allocations.

The Israeli public consistently expressed a desire for stream restoration, especially in urban areas. Still, it lacks the associated recreational culture. After living through decades of putrid conditions, stream-based recreation activities are minimal. Whole generations have grown up viewing streams as an environmental hazard, not a resource to be enjoyed. A recent study on public willingness to pay for stream-based recreation found that it was divided roughly equally between instream activities such as fishing and swimming, and off-stream activities, such as bike trails along the banks and picnic areas (Barak 2010). Yet much of the public is seemingly content with creation of recreational areas alongside of streams and still widely views the streams themselves as dangerous or as beyond repair.

Case in point, one of the more developed stream rehabilitation projects is for the Alexander, along the country's Mediterranean coast. Its "restoration plan" won an international prize. The parks along its banks and the rare soft-back, giant turtles (*Trionychoidea*) which live in its estuarial sections attract thousands of tourists each year. And yet, despite over a decade of "rehabilitation," the Alexander Stream is still a toxic canal having experienced little meaningful improvement in terms of biological and chemical indicators (Tal et al. 2010). It may be economically rational to begin with the inexpensive "low hanging fruit" of development of recreation along stream banks. Yet there is concern that many rehabilitation efforts will end there and not continue on toward comprehensive ecological rehabilitation of the streams and their ecosystems (State Comptroller 2011).

5.5.7 Necessity of Transboundary Efforts

Given that 12 streams originate in the West Bank and that Jordan River system is shared with Jordan, Lebanon, Syria, and the West Bank, restoration efforts are dependent on policies outside Israel's boundaries, as well as international policy and diplomacy. In terms of water quantity, the challenge is to convince those upstream to forego water so that it can flow downstream – a considerable hurdle given existing political tensions, regional water scarcity issues, and attitudes that tend to see ecological goals as luxury items. But there is some empirical basis for optimism regarding cooperation in transboundary restoration efforts. In a recent public opinion survey, Palestinians reported a higher willingness to pay for restored streams than did the richer Israeli public (Abramson et al. 2010). Furthermore, several Jordanian policymakers, including members of parliament, publicly supported rehabilitation of the lower Jordan River.

In terms of quality, the most immediate challenges needed to improve water quality in transboundary streams involve improved treatment of urban wastewater and policies to abate nonpoint discharges, especially from agricultural sources. Given the costs of building and operating high-quality wastewater treatment facilities, and the limited economic capacity of Israel's neighbors, especially the Palestinians, they are unlikely to be built without substantial assistance from international donors.

5.5.8 Climate Change

Finally, the cloud of climate change casts additional shadows over the potential efficacy of any rehabilitation efforts. Already facing chronic water scarcity,[5] the

[5]Chronic water scarcity is commonly defined by water managers as renewable water supplies of less than 500 mcm per capita per year (based on the Falkenmark index. For a comparison of water

region is experiencing a measurable negative trend in precipitation. This includes longer periods between rainfall events, increasing storm intensity, and more extended droughts; trends that are expected to continue into the future (e.g., Alpert et al. 2008). Various models predict decreases in precipitation of between 10 and 30% by mid-century and by up to 50% by 2080.

5.6 Conclusions

Stream rehabilitation is a prolonged process that requires considerable stamina on the part of society and decision makers, even under ideal circumstances. After more than half a century of overwithdrawals, contamination, and neglect, rehabilitation in Israel requires a considerable investment in removing pollution sources, landscaping, and infrastructure. Not less important is a change in public perception of streams and an understanding of their importance to the country. Israel is home to streams that literally flow through the heritage and traditions of four major religions, providing both spiritual and economic (touristic) reasons to pursue a new deal for its streams. Offering pilgrims from around the world, the opportunity to hold Baptism ceremonies in the River Jordan as Jesus did in days of old is not just good business; it also constitutes an ethical responsibility that goes along with being a steward of a holy land.

In water scarce regions, a surfeit of water must become available to release anew to the nature reserves and parks as part of a process that meets the competing demands for agricultural irrigation and rising consumer consumption. Hence, one can argue that Israel's streams' time has finally come. The advent of massive desalination is changing the perspectives of the general Israeli public as well as the country's robust environmental movement about water resources. For Israel's beleaguered surface waters, it offers an opportunity and a fresh lease on life.

Israel's attitudes toward its streams have changed significantly over the course of the country's short history. Once viewed primarily as a convenient means for evacuating sewage, with little inherent value, streams are now increasingly recognized as a beneficial asset to local communities and the nation as a whole. For an increasingly urban country, they can provide "green ways" and parks that allow crowded citizens and visitors to enjoy some direct connection with nature and the historic countryside. Laws have been amended, rehabilitation plans developed, and some preliminary projects initiated. The challenges to meaningful rehabilitation of the country's streams, however, remain numerous and formidable. The pervasiveness of past neglect makes it a long-term, expensive prospect. But it appears that the country has turned a corner and that lip service has finally

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poverty indices, see Lawrence et al. (2002)). Between 1990 and 2010, Israel's renewable rate was less than 200 mcm/cap/year (Weinberger et al. 2012). Even with massive desalination and wastewater reuse included, this amount was less than 300 mcm/cap/year.

begun to be replaced by actual commitments. If the country can stay the course and implement the many rehabilitation master plans, the outlook for the future of Israel's streams is hopeful.

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Chapter 6
Wastewater Supply Management

Doron Lavee and Tomer Ash

6.1 Introduction

Wastewater reuse for agricultural irrigation is becoming a common and rapidly increasing practice in arid and semiarid regions around the world (Friedler 2001). This new water source is particularly important in regions with limited water resources where increased urban demand is met by reducing water supply for irrigation, causing economic and cultural stress in the agricultural sector (Volkman 2003). The introduction of reclaimed wastewater in the water balance of a country is subjected to three main issues from the supply side:

- *Quantity* – The link between the sewage treatment systems to the agricultural sector
- *Quality* – Health and environmental issues and wastewater standards
- *Technology* – The need of technological solutions and innovation

The basic assumption of this chapter is that the demand side is a known constant subjected to external changes (e.g., population growth, geographical location), while demand management policy tools are efficient only in the short term. The supply side can be engaged through policy actions intended to close a negative water balance when all conventional water resources are exploited to their maximum capacity. This chapter is divided into three main sections:

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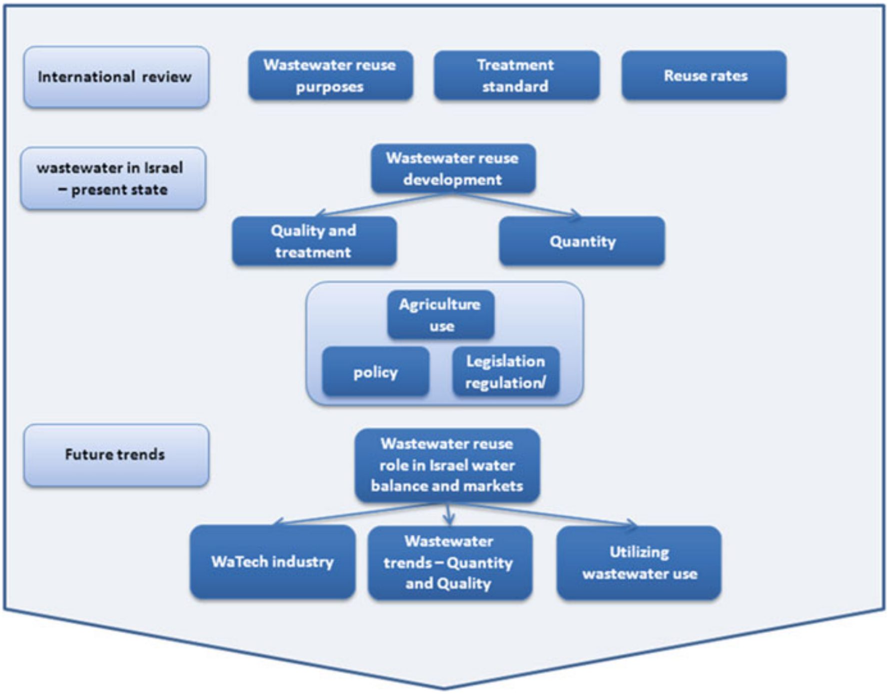

Fig. 6.1 Methodology taken in this chapter

International review: Characterizing the main trends of international use of wastewater
Wastewater in Israel: Wastewater reuse and wastewater quality in Israel
Future trends: Local and global future trends in wastewater use and policy (Fig. 6.1)

6.2 International Review: Wastewater Use

Both developed and developing countries share some common water problems (e.g., water shortages, increasing population, or concerns about environmental pollution), which turn reclaimed water into a potentially valuable resource (Winpenny et al. 2010). Wastewater use can have many types of applications, including agricultural irrigation, urban and industrial uses, and artificial groundwater recharge (Asano et al. 2007). The most established and longest worldwide application for wastewater is agricultural irrigation, particularly in arid and semiarid countries (Scheierling et al. 2010), and has been reported in no less than 44 countries (Jiménez and Asano 2008).

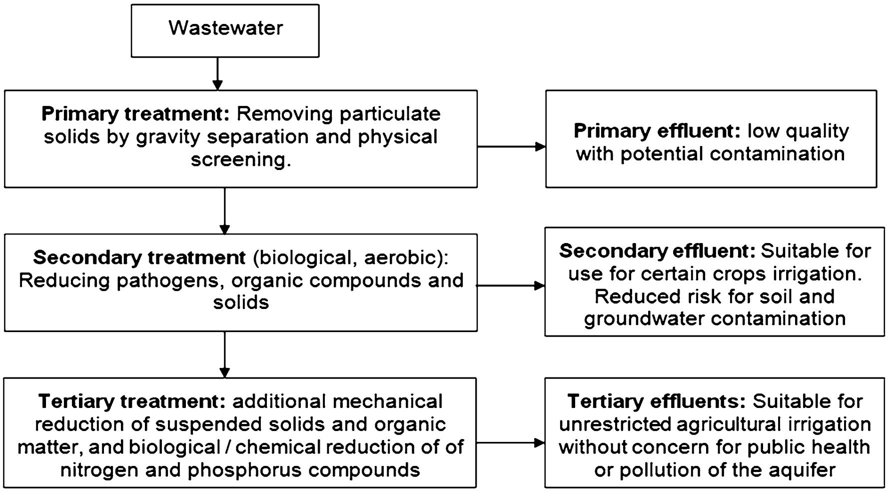

Fig. 6.2 Main wastewater treatment levels

The use of wastewater as a part of the water resources may be justified by two main reasons (Friedler 2001):

1. *Closing the water balance* – Treated wastewater may be considered as a new water resource and substitute conventional water (potable water) used for irrigation and other purposes. This may assist to close a negative water balance in a country in which all conventional water resources are exploited to their maximum capacity.
2. *Protecting water resources from pollution* – Water resources exploited to their maximum capacity results in small water bodies and short retention times, generally accompanied by deterioration of water quality and water pollution. Wastewater reuse enhances the quality of conventional water resources by (a) reducing the demand pressure on conventional resources and (b) preventing pollution by municipal sewage.

However, irrigation with wastewater may cause environmental and sanitary hazards such as water and soil pollution and decline in crops (Israel Ministry of Environmental Protection 2005c). These risks primarily depend on the wastewater quality. Therefore, many countries set standards and requirements for wastewater treatment and effluent use (Jiménez and Asano 2008). According to the Scheierling et al. (2010), given proper treatment and reliable operation, wastewater can be use for all purposes for which freshwater is used.

According to a recent comprehensive survey, there are approximately 3,300 water reclamation facilities worldwide, applying various treatment levels and applications (Winpenny et al. 2010), as described in the following illustration (Fig. 6.2).

Most developed countries treat wastewater to at least a secondary level, and use is restricted to non-potable uses or at least to indirect potable uses (Drechsel et al. 2010; Scheierling et al. 2010). Many countries have guidelines on water quality for irrigation, and where wastewater use is allowed, the legislation requires compliance with certain quality conditions, based mostly on a combination of the California guidelines and the WHO recommendations (Drechsel et al. 2010).

6.3 Wastewater in Israel: Present State

6.3.1 Israel's Water Management System

Water scarcity is a major concern in Israel, a country subject to arid and semiarid climate conditions. *Human and external factors* such as high population growth, rapid industrial growth, bilateral agreements, and extensive economic development have placed a continuous growing demand on Israel's scarce water resources (OECD 2011b). Israel relies mostly on its natural renewable water resources, and as such, the country's water planning, policies, and management are highly challenged by *physical factors* which are climatic fluctuations and uncertainty in water availability due to multiple multiyear droughts. In the last decade, Israel experienced almost 7 consecutive years of drought as water consumption exceeds the natural rate of replenishment. Groundwater is being used unsustainably and constitutes a potentially serious pollution problem, particularly in the coastal aquifer (Ministry of National Water Authority 2006).

Since the 1950s, following the establishment of Israel, one of the government's main tasks was to develop water resources and build infrastructures to mobilize water, especially from north to the south. The national water carrier was built in 1964 along with extensive construction of associated facilities and infrastructure. Water management has improved in 2007 with the creation of the Water Authority which is responsible for the regulation of the entire supply-recovery cycle of water and oversees the national water grid (OECD 2011b).

6.3.2 Water Demand Policies

Water demand policies were developed to improve efficiency in the agriculture, domestic, and industry sectors. These policies used economic tools and incentive mechanisms such as water tariffs, regulations and its enforcement, penalty mechanism for municipalities for reducing water losses, water saving education, training, and campaigns (OECD 2011a). The Water Authority is responsible for setting tariff levels and their structure to recover supply costs and reflect scarcity. Charges for all water in Israel are determined according to the volume metered in all regions, and municipalities are subject to fines if unbilled water quantities exceed 12% of the water consumed by the local authority. Moreover, increasing regulatory and enforcement of water production and its use was initiated with an emphasis on public gardens and agriculture. In addition, media campaign instructs the public of the correct use of water (Water Authority 2011).

The demand for water in 2010 was about 2,130 MCM, out of which 1,044 MCM was used for agriculture, 764 for private use, 143 for regional use (transfer to the Hashemite Kingdom of Jordan and the Palestinian Authority in the framework of political agreements), 120 for industrial uses, and about 60 MCM for natural and landscape uses (e.g., enhancing flow of rivers) (Israel Water Authority Planning branch 2011).

A significant issue that is worth noting is the division of the water allocated to the various consumers according to types. It is apparent that for private uses, namely, domestic and regional uses, only potable water is allocated, while for industrial and natural and landscape uses, both potable and brackish water are allocated, and the agricultural sector receives treated effluents, brackish water, and potable water (Water Authority 2011).

6.3.3 Supply Management Policies

As the water crisis deepened, more emphasis has been placed on increasing water supply. Intensity of freshwater use in Israel is extremely high by OECD standards, consuming more water than its natural supply, which is essentially provided by rainfall (OECD 2011b). As a result, *supply-side management policies* are taken into effect. An ambitious policy of seawater desalination has been proposed with the aim of supplying 750 MCM (about half of the expected potable water needs of the urban, industrial, and agricultural sectors) by 2020 (resolution number 3533, June 2008). Previously, since 2005, a large-scale desalination plant located by Ashkelon has produced about 120 MCM/year (Dreizin 2006), and since 2007, an additional production of 30 MCM/year of desalinated seawater was performed in Palmachim. In addition, the current water system integrates treated sewage (effluents). In 2004, about 470 MCM of sewage was collected of which 428 MCM was treated and of that 395 MCM has been reused (Water Authority 2008).

The water supply in Israel in 2010 was about 2,130 MCM. Out of this, about 70% was potable water – 1,200 MCM from natural recharge of aquifers and additional 300 MCM from desalination of sea and brackish water. The water supply is completed by 450 MCM of effluents and brackish water, supplied annually at various qualities and used for agricultural and industrial purposes (Water Authority 2011).

Table 6.1 Future water supply trends

water supply							
year	Potable	Brackish	Effluent	Desalin Brackish	Desalin	Additional	Total Supply
2010	1,200	174	450	23	280	4	2,131
2020	1,140	150	573	50	750	9	2,672
2030	1,080	140	685	60	750	50	2,765
2050	1,020	130	930	70	750	671	3,571

Source: Israel Water Authority Planning Branch (2011) p. 10

6.3.4 Wastewater Treatment

6.3.4.1 Quantity

The rate of wastewater reuse in Israel is approximately 75%, mostly for agricultural use, and considered among the highest in the world. Treatment is performed by about 135 facilities which supply approximately 355 MCM a year. This quantity represents about 31% of the total water supplied for agriculture and about 18% of the total water supplied in the country for all uses. According to the Water Authority's master plan, within 5 years, 95% of the wastewater will be used for various purposes, allowing more freshwater to be allocated for domestic use. Part of the Water Authority's plans is to continue and develop more facilities for wastewater reuse for agriculture so that their scope by 2020 will reach approximately 600 MCM/year (Water Authority 2011). In fact, as the table below shows, there are increasing targets for the year 2030 with 685 MCM and for the year 2050 up to 930 MCM based on the projections of the Water Authority's master plan (Table 6.1).

An assistance plan for sewage treatment plants, which currently operates under the Water Authority, began its operation in 2000. The financial assistance is granted in return for converting from potable water use to effluents use, as well as for improving the quality of the outflowing effluents to the level required by the regulations. As part of the assistance procedures for private entrepreneurs, establishment of plants for effluents in agriculture that was approved in the plan will be provided a financial assistance of up to 60% of the total investment in the project and is incorporated in a master plan prepared by the planning division in the Water Authority. As part of these plans, inter-factory guidelines with the full funding of the state are made, allowing the mobility of excess effluents from over populated areas to sparsely populated peripheral areas that are based on agriculture and are in need of effluents (Water Authority 2011). The main advantages of this initiative are as follows:

Broadening the water supply and freeing potable water from the agriculture sector to be used for household purposes.

Converting a nuisance into a resource and protecting the environmental.
Encouraging agriculture by allocating is relatively inexpensive water with high availability and reliability.

6.3.4.2 Wastewater Quality

Since commencing the use of reclaimed water in Israel, a regulatory framework began to evolve, aimed initially to prevent health risks. In 1977, water quality standards for irrigation of different crops were set by the Shelef Commission (Sagi and Shisha 1999). In 1981, the Public Health Law limited wastewater irrigation to specified crops, and a permit was required for all wastewater reuse projects (Scheierling et al. 2010). Two of the most common measured components representing the quality of treated wastewater are biochemical oxygen demand (BOD) and total suspended solids (TSS) (Akpor and Muchie 2011). In 1992, the Ministry of Health set a secondary 20/30 standard (BOD < 20 mg/l and TSS < 30 mg/l) due to a demand for better wastewater quality for irrigation and for preventing pollution of streams and further environmental risks (State Commission of Inquiry of Water Management in Israel 2010). This standard helped reduce the environmental and health impacts arising from the use of wastewater. However, wastewater treatment plants in Israel continued to discharge effluents containing various pollutants and high levels of salt, raising various issues which prompted the need for introducing more stringent standards (Israel Ministry of Environmental Protection 2005c; Lavee 2011).

Therefore, in the year 2000, a special committee (Inbar Committee) was established to set new standards for wastewater quality. The committee was to address aspects of health, soil, plant, and hydrology, so that wastewater use will not constitute a hazard on the one hand and will be economically worthwhile on the other (Pareto-Engineering Ltd. 2003). The committee experts had differed as to the required standard. Therefore, it was determined that assistance measures for the decision makers would be put to action as cost-benefit analysis (CBA) for the final standards. The CBA was conducted at a national and regional level, in order to identify the optimal standard for the economy. A further analysis examined the funding distribution required for the regulations implementation (Pareto-Engineering Ltd. 2003).

6.3.5 An Economic Measure

A CBA examined a number of alternatives for introducing stringent standards for wastewater treatment in Israel, including a "business as usual" (BAU) scenario, in order to determine the optimal standards for the economy. The analysis was based on an extensive survey of both wastewater treatment technologies and the economics of wastewater use (Pareto-Engineering Ltd. 2003).

The examined standards referred to sanitary (TSS, BOD etc.) and salinity (chlorides, boron, SAR, etc.) standards (removal of hazardous materials is the sole responsibility of the industrial sector before entering the wastewater system).

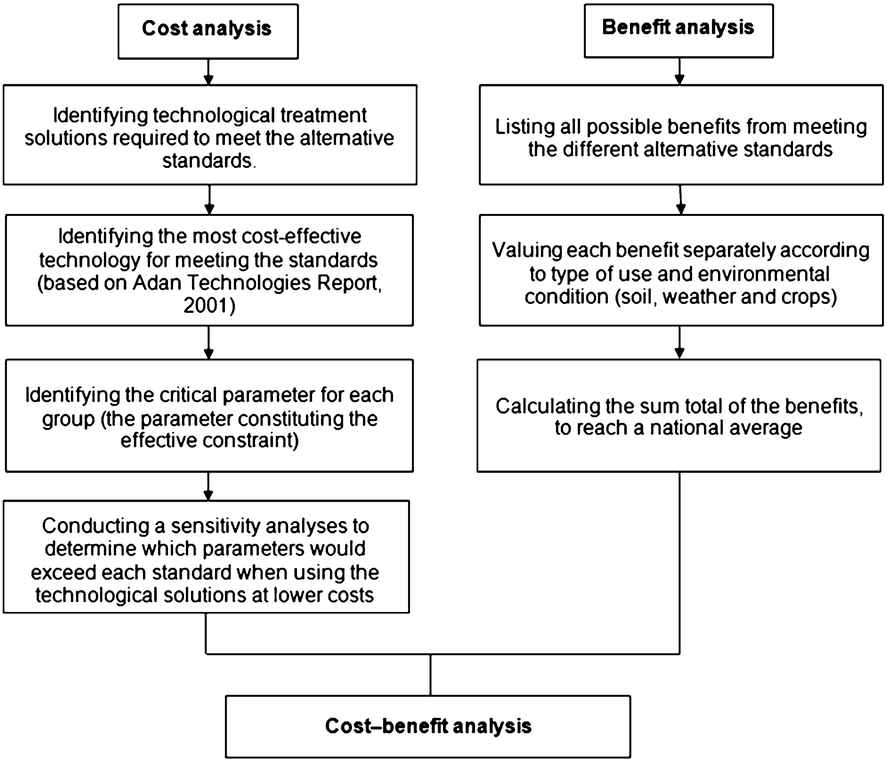

Fig. 6.3 A cost-benefit analysis for the proposed standards

The sanitary group was tested for basic (the existing standard), intermediate, and stringent standards, while the salinity group was tested for basic and stringent standards (Lavee 2011).

The cost-benefit analysis was carried out for all proposed standards according to the methodology presented in Fig. 6.3:

According to the best available technologies, the sanitary group would be treated by biological wastewater treatment, while the salinity group would be treated by desalination.

The benefits identified and evaluated from the transition from the basic to the proposed standards are presented in Table 6.2.

6.3.5.1 Regional Aspects

Since there are significant differences in the main parameters between Israel's various regions, which may change the appropriate standard, a comparison of a uniform national standard versus a regional standard was conducted. The analysis was carried out separately for 12 regions in Israel.

Table 6.2 The identified and evaluated benefits from the proposed standards

Proposed standard	Benefits
Intermediate sanitary standard	Growth of more profitable crops
	Lower costs of filtration equipment
	Less need for chlorination
	Less wear to irrigation systems
Stringent sanitary standard	Reducing maintenance costs in reservoirs
	Water savings due to lesser need of washing the filters
	Benefits from nutrient removal
	Improved aquifer water quality (relevant only to areas above aquifers)
Stringer salinity standard	Prevention of decline in crop yield
	Reduction in aquifers salinity levels
	Soil conservation
	Benefit from the reduction in boron
	Benefit to households and industry

A quantification of all costs and benefits resulting from the proposed standards was carried out. In addition, the costs and benefits were calculated according to the unique characteristics of each region: the type of existing/possible crops; the presence of an aquifer, its depth and characteristics (freshwater, brackish, etc.); the level of rainfall; soil type; source water quality; and proximity to environmentally sensitive areas.

It was found that in some regions it is not economically feasible to meet all of the standard parameters; therefore, these parameters were modified and given ease in those regions (Israel Ministry of Environment 2005a,b).

According to the CBA, implementing the more stringent standards (tertiary level), with some relief in certain regions, will result in the highest net benefit for the national economy, resulting in a cost-benefit ratio of about 1:5, estimated at approximately $120 million a year (Lavee 2004, p. 19).

On the basis of the CBA, the committee determined a tertiary standard of 10/10 (BOD/TSS) and provided 37 various parameters, as opposed to 2 so far (20/30), which will allow the use of treated wastewater for unlimited irrigation and improve the quality of wastewater released into rivers and sea (Inbar 2007). The recommendations were approved in 2005 and took effect on 25 July 2010, placing Israel on par with other developed countries regarding strict values protecting the environment, with an emphasis on preventing pollution of water resources.

6.3.6 Dividing the Financial Burden

Following the approval of the new standards, it was necessary to determine the *distribution of the financial burden* of the effluents upgrade between the various factors – the manufacturers and the consumers of the treated wastewater effluents.

On the one hand, according to "polluter pays" principle, wastewater producers are required to pay in order to reach a quality level that allows discharging them into the rivers or sea without creating an environmental damage. On the other hand, according to the principle of "beneficiary pays," treated wastewater is a water source that the consumers – the farmers – should pay for its production costs.

When examining the economic contributions of the various types of crops, a large heterogeneity is evident. While many crops will barely be affected by changes in water prices, other crops will be affected more significantly. Therefore, for most crops, a unified *elasticity* of the market *demand curve* was assumed, while exceptions were made for the following crops: tomatoes grown for industries, certain citrus varieties, and cotton – since they depend on global prices and therefore have high demand flexibility – and for corn since it is used primarily as feedstock for animals and canned food and therefore has no direct relationship with the end consumer. In addition, the contribution per cubic meter of these crops is low. Therefore, it may be assumed that the market conditions of these crops will be different in the case of rising water prices.

In industry equilibrium analysis, the equilibrium point is determined by the "weakest" consumer, and so even if there are many crops that can bear higher water prices, such a price determination will result in a decrease in demand and the creation of excess supply of water. However, agricultural water prices will not be set uniformly, but rather different rates will be set for treated water at several levels according to their quality. Thus, farmers can adjust their crops according to the water quality at their disposal.

The analysis conducted was based on assumptions and data that may change in the future and therefore considered a *percent deviation*. Since it was found that wastewater at a price of NIS 0.7 will cause excessive water demand and a price of NIS 1.2 will cause excess supply, in order to take a conservative approach, and due to a preference for excessive demand over excess supply, it was decided to recommend a price closer to the lower range.

It was therefore decided to divide the burden of financing: the farmers will pay an extra cost of 0.15 NIS/m^3 (i.e., 0.75 NIS/m^3 for a tertiary level instead of 0.60 NIS for a secondary level), and the city and the government will finance the remainder (Lavee 2006b).

The farmers opposed to this decision on the basis of two main arguments: (1) The benefits of the farmers from upgrading the effluents are lower than 0.15 NIS/m^3. (2) The farmers are unable to finance the upgrade due to the low level of profitability.

Consequently, an additional analysis was conducted by Pareto-Engineering Ltd. (2003), examining these claims. The analysis demonstrated that the farmers will benefit from the upgraded standards since (1) converting from freshwater to reclaimed water lowers the cost of water for their crops and (2) farmers previously using treated wastewater benefit from upgrading the effluent quality by 0.28 NIS/m^3. According to the analysis, the farmer's net benefit will be 0.35 NIS/m^3 (Lavee 2006b, p. 6).

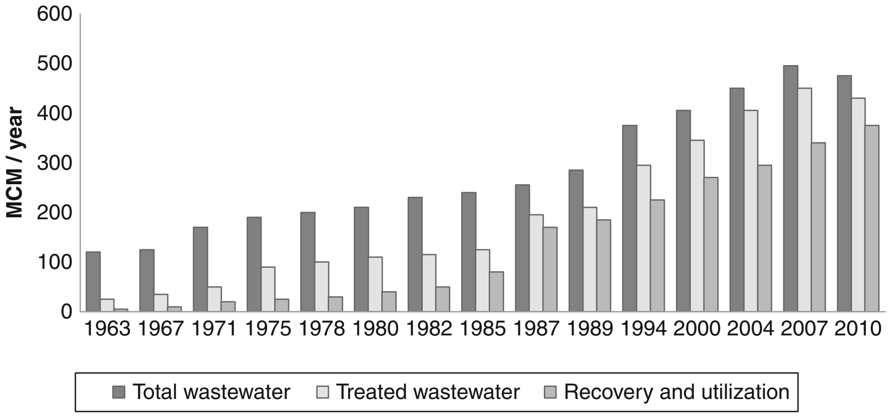

Fig. 6.4 Wastewater collection and treatment and effluent utilization (*Source*: Israel Nature and Parks Authority 2012) p. 18

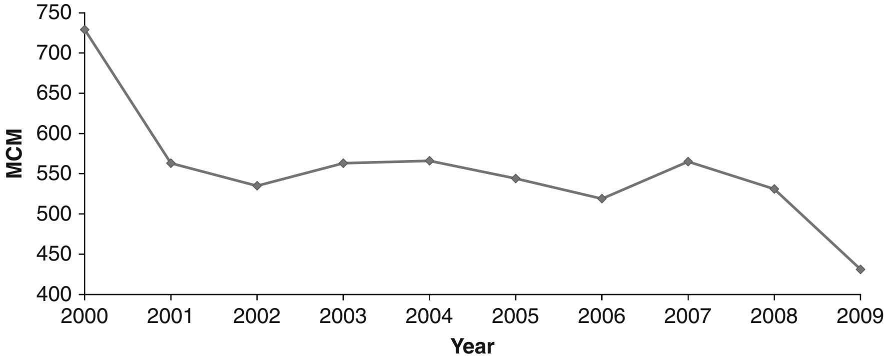

Fig. 6.5 The reduction in potable water use in agriculture, 2000–2009 (*Source*: Israel Nature and Parks Authority 2012)

6.3.7 Current State

6.3.7.1 Trends in the Use of Treated Wastewater

As of 2008, there are approximately 80 large- and medium-sized wastewater treatment facilities (treating over 1,000 m^3/day) in Israel, performing primary to tertiary treatments (Israel Ministry of Environmental Protection 2008). In recent years, there has been a significant increase in wastewater treatment and use of reclaimed water, as can be seen in Fig. 6.4.

As a result of utilizing treated wastewater for irrigation, a considerable reduction in potable water use in agriculture has occurred, as shown in Fig. 6.5.

By the year 2015, a significant increase in the amount of land irrigated with wastewater is expected, mainly due to reductions in the quotas of freshwater as well as to the many recovery projects that have been made in recent years (Ministry of Health 2011).

Treated wastewater quality: Currently, the treated wastewater sector provides about 490 million cubic meters per year of various qualities. Treated wastewater qualities currently used for irrigation are divided into five levels of quality, though most (59%) of the treated wastewater used for irrigation is of high quality (effluents containing no more than 20 mg/l BOD and 30 mg/l TSS) (Ministry of Health 2011, p. 5).

Wastewater tariffs: The largest player in the treated wastewater industry is "Mekorot," a government company, as the "Shafdan" provides the largest amount of treated wastewater, about 130 million cubic meters per year, at a fixed rate of about 1 NIS/m^3. In addition, "Mekorot" provides through additional recovery plants about 63 million cubic meters of additional treated wastewater (of varying quality) each year, at a rate of about 0.85 NIS/m^3.

There are also private wastewater treatment facilities, providing approximately 200 million cubic meters per year. Currently, private treated wastewater facility tariffs vary, often significantly, between facilities. The reasons for these differences are varied and depend on several factors, primarily due to capital costs required for the establishment and ongoing operational requirements. Currently, the possibility of requiring all facilities to provide tariffs based on the weighted average cost of all facilities is being considered. In addition, publication of private treated wastewater facility tariffs, in a similar format of publishing freshwater tariffs, is being considered as well. Such a publication will lead to full transparency in the prices of treated wastewater and reduce the possibility of significant deviation from acceptable rates.

Financing: The Water Authority is engaged in promoting the treated wastewater sector, including assistance for recovery projects providing financial liabilities totaling at 4.6 billion NIS in the last decade. In parallel, "Mekorot" is investing in developing its main facilities (e.g., the "Shafdan").

The treated wastewater sector is deeply subsidized by the domestic consumer. Private recovery facilities receive a *financial assistance* of 15–60% of the construction costs. In addition, some inter-facility infrastructure has been constructed with 100% *financial assistance*. Treated wastewater tariffs provided by "Mekorot" are set below the cost of service provision, and the total subsidy for this sector was estimated at about 170 million NIS per year.

6.3.7.2 Operational Structure

The reclamation sector is directly related to the treatment sector. In most cases, an operational functionality exists between the treatment facility and reclamation facility, in the geographical and physical aspect.

Following the wastewater treatment, the reclamation facility receives the reclaimed wastewater from the treatment facility and transmits them to the various agricultural consumers.

Main barriers and constraints of wastewater utilization: The government's decision to assistance reclamation facilities was not backed by an organized planning process and largely dictated the development of the effluent sector in the last decade.

During this period, several master plans were conducted in order to implement the comprehensive approach in the treated wastewater sector. In practice, an unwritten policy was accepted, of connecting local recovery facilities for the transfer of surplus treated wastewater from areas of production to areas of consumption.

At present there are wide inter-sectoral and interregional gaps, as initiative comes mostly from the organized agriculture sectors, and at wastewater intensive areas.

Several large areas and quite a few private organizations lack the financial ability to raise the remaining capital required for establish recovery facility, even after receiving grants of up to 60% of the country and the establishment of reserves by the Jewish National Fund.

The government policies prevented from "Mekorot" to build additional recovery facilities, and thus, the pace of development was determined by the ability of the private parties (mostly agricultural associations), while this ability is limited, even with assistance from the fund. The Water Commission and the Water Authority acted slowly in matters under their responsibilities, the Israel Land Administration made it difficult for farmers to build reservoirs on land intended for agriculture, and the Ministry of Finance delayed the approval of investment plans and the release of the approved budget funds.

Thus, despite plans to reach in 2010 a supply of 509 MCM of reclaimed water, in practice, only 395 MCM was provided for agriculture, and of this amount, about 30 MCM of potable water was added as reinforcement to the "Shafdan" (Taub Center 2011, p. 6).

6.4 Wastewater: Future Trends

Future trends in the Israeli water consumption and production industry are highly correlated to local as well as worldwide trends. Rapidly growing world population implies increasing pressure on water resources (OECD 2008). Hence, it is estimated that the proportional weight of the produced water will grow with time. The direct result will be higher operational and management cost of the water industry. This situation has led to a continued search for implementing new technique and produced methods to guarantee reliable water supply in a reasonable economic and environmental cost.

Israel strives to become a worldwide center for collaboration in developing new and innovative technologies in the field of water systems and a pioneering example to water resources management under scarce conditions (Israel Water Authority

Planning branch 2011). The path for this vision goes through CleanTech industry. Economical literature outlined the positive effect of R&D investments for economic growth. The same principle applies for environmental and CleanTech investment (Ayalon and Lavee 2007).

Clean technologies are the variety of technologies, products, goods, and services that are meant to increase productivity and efficiency while decreasing costs, materials and energetic inputs, pollution, and waste.

A report written by the Israeli parliament in 2008 (Knesset Research Center 2008) shows that Water Technologies are considered to be at the lead among the Israeli CleanTech industry. Israel is well known for innovative industry and technology in the field of water technology. Israel recycles 75% of its wastewater, invented drip irrigation, and is home to the world's largest reverse osmosis desalination plant. These inventions have earned Israel the title of the "Silicon Valley" of water technology (CleanTech 2010) and a fast becoming CleanTech incubator to the world. However, Israel is yet to fulfill the expectation which promised to be a world's leading entrepreneur in water technology confronting the world challenges for years to come.

Israel's national plan for promoting environmental technologies (Pareto Group 2008) indicates that wastewater treatment technology is one of the fields where Israel has a relative advantage to become a leader of innovation. Worldwide market potential is estimated at 15 billion with an annual growth rate of 3.5% (Pareto Group 2008, p. 198). The demand for goods and services is mostly located at developed countries. The nature of the demand in those markets is ideal for Israeli water technology industry ability. The need is for specific solutions, mainly in upgrading existing infrastructures and operational cost saving.

Wastewater has a great interface with water technology where Israel enjoys an excellent international reputation. There is a critical mass of Israeli companies that can perform as an integrator for Israeli sewage and wastewater technology in enterprises abroad.

In 2008, the Israeli market totaled at approximately $150 million a year. That is, the Israeli production was only about 1% of the global market, similar to the average volume of the total environmental technologies. However, the growth rate of the Israeli market is significantly higher than the global growth rate. This means that Israel is expected to take an increasing share of the global market in the future (Pareto Group 2008, p. 198).

Israel's knowledge and experience in wastewater use may help relieve the world's water shortage. On the other hand, Israeli companies are facing difficulties in introducing new products to the local market, even if new technology is expected to be more efficient than existing ones, especially on the ground of meeting regulatory demand and the concern of liability. This difficulty becomes a major obstacle in marketing a complete and operationally proven product to foreign markets (Pareto Group 2008).

In contrast to Hi-Tech, Wa-Tech initiatives require high equity. It is more difficult to raise the resources needed and demonstrate the technologies implementation. Another difficulty is the introduction of new technologies in developed countries.

In order to encourage this industry, several policy measures should be taken:

- Establishing a verification center for new wastewater treatment technology, to ease the decision of potential consumers and enable the entry of the Israeli product to local and foreign markets.
- Regulatory solution, encouraging the use of innovative technology, and long-term policy to enable the technology developers to prepare for policy and regulation changes. This will give local industries an advantage over foreign competition. Collaboration between the development and production sector to consumer and policy makers will ensure the adoption of the new technology at the local markets and prevent possible liability legal claims.
- Public sector financing aid, in order to help developers and producers demonstrate the implementation of the technology.
- Public sector assistance in construction of treatment facilities. Encouragement of the demand side and increasing the need for improved and innovative technology.

6.5 Conclusions

Israel suffers from water shortages and therefore must implement water management policy in order to develop alternative water sources. Israel has been practicing wastewater reuse for many years and is known worldwide for innovation and leadership in this matter, reusing approximately 75% of the total produced wastewater, mostly for agricultural irrigation.

Over the years, the use of reclaimed wastewater has gone through various changes, concerning both quantity and quality. New and more stringent treatment standards have been introduced following an economic feasibility, further improving wastewater quality and reducing environmental and health negative effects, as well as allowing additional uses of wastewater.

The demand for produced water is expected to continue to grow worldwide, resulting with higher operational and management cost of the water industry. Hence, new techniques and methods are needed in order to guarantee reliable water supply with reasonable economic and environmental costs. Israel plans to meet this need through the Wa-Tech industry, yet Israeli companies are facing difficulties in introducing new technologies, requiring further policy measures to encourage this industry. By doing so, Israel would act to maintain its position and reputation in the field of water systems and continue to set an example for water resources management under scarce water conditions.

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Chapter 7
Desalination in Israel

Erica Spiritos and Clive Lipchin

7.1 Desalination Technology in Israel: Introduction and History

Desalination was first developed in Israel in 1965, when Mekorot, Israel's national water utility, established the first seawater desalination facility using vaporization technology in an effort to address the chronic thirst of the city of Eilat, located at the extreme southern tip of Israel on the Red Sea. A highly energy-intensive process, Mekorot looked for an alternative, energy-saving process, which it found in the reverse osmosis (RO) technology developed in the United States. In the early 1970s after the energy crisis of the Yom Kippur War, Mekorot began installing small-scale brackish water RO-desalination plants and, within the decade, established 15 desalination plants that supplied water to the Arava valley residents. Increasing demand and decreasing supply of freshwater in the coming years encouraged Mekorot to develop seawater desalination as an additional source, and the first plant (which desalinated a mixture of seawater and the reject brine from desalinated brackish water) commenced operation in 1997 in Eilat (Mekorot 2006).

The motivation behind desalination of seawater in Israel stems from the fact that current demand and projected future demand cannot be met by natural freshwater sources alone – a disparity that results from population growth, overconsumption, misallocation, and pollution.

This chapter discusses the development of desalination in Israel and the evolution of desalination as a pivotal means to securing a sustainable water supply in Israel. The chapter covers desalination policy, technology, pricing, energy needs, and the health and environmental impacts of desalination.

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7.1.1 Desalination Master Plan for 2020

The Desalination Master Plan was first conceived in 1997 in an effort to bridge the gap between an increasing demand and limited supply of freshwater resources in Israel within the next 20 years, through the introduction of a potentially unconstrained source of water. As stated in the Plan, the overarching goal of the Israeli Water Authority is to "assure that water will be sustainable, available, and reliable in the required quantities, locations, and qualities." In regard to desalination, the Water Authority has undertaken a program designed to meet all of Israel's domestic water needs with desalinated seawater by expanding existing facilities, constructing new facilities, encouraging technology improvements in pretreatment and posttreatment, and promoting energy-saving technologies (Tenne 2011).

The Plan itself involves the estimation of desalinated water needs and the optimal sizes and distribution of plants required to satisfy this need. From an economic perspective, the Plan considered the costs of the desalination process and delivering it to the national water supply grid, as well as expenses relating to storage capacity, energy requirements, and operation. Benefits derived from increased water-consuming economic activity and from the improvement in water supply quality and quantity were examined and optimized (Dreizin et al. 2007). The Plan did not include an environmental or social impact assessment, leading to much criticism from those who would prefer a more precautionary or demand-management method of addressing Israel's water shortages.

7.2 Israel's Desalination Plants

7.2.1 Seawater Reverse Osmosis

In the past, desalination production was limited to the southern resort town of Eilat and the surrounding agricultural communities, where no alternative existed. Today, modern membrane technologies, increased energy efficiency, and decreased overall cost from US$2.50 per cubic meter in the 1970s to slightly more than US$0.50 by 2003 have allowed for widespread implementation of desalination facilities along the Mediterranean coast (Becker et al. 2010).

In Israel today, all large-scale desalination plants operate using the reverse osmosis technology – the most energy and cost efficient of current desalination methods – consisting of four major processes: (1) pretreatment, (2) pressurization, (3) membrane separation, and (4) posttreatment stabilization. In the initial pretreatment stage, suspended solids are removed from the feedwater, the pH is adjusted, and a threshold inhibitor is added for membrane protection. Next, the electric pumping system increases the pressure of the pretreated water to a level appropriate for the membrane capacity and seawater salinity. For seawater

Table 7.1 Existing industrial-scale desalination facilities in Israel

Facility	Inauguration	Production (MCM/year)	Contractor
Ashkelon	Sept 2005	119	VID, a special purpose joint-venture company of IDE Technologies, Veolia and Dankner-Ellern Infrastructure
Palmachim	2007 (April 2010)	30 (45)	Via Maris Desalination Ltd. consortium
Hadera	2009	127	H2ID, a consortium of IDE Technologies (IDE) and Shikun & Binui Housing and Construction
Sorek	2013	150	SDL, owned by IDE Technologies and Hutchison Water International Holdings Pte.
Ashdod	2013	100	ADL, subsidiary of Mekorot

desalination, operating pressures range from 800 to 1,000 psi. In the third phase, the increased pressure is used to separate the concentrated seawater into two streams: the permeable membrane allows solvent (water) to pass through, leaving behind the solute (salts and other non-permeates) in a highly concentrated form known as brine. A small percentage of salts do, however, remain in the freshwater product stream, as no membrane system is 100% efficient in its rejection of dissolved salts. Finally, freshwater passes through a posttreatment phase that includes boron removal and remineralization, among other stabilization processes required to meet drinking water quality standards. Unlike in thermal desalination processes, no heating or phase change takes place. Rather, major use of energy is for pressurizing the feedwater, and so the energy requirements for RO depend directly on the concentration of salts in the feedwater.

7.2.2 Existing Facilities and Plans for Future Expansion

At the start of 2012, Israel is home to three major seawater reverse osmosis (SWRO) desalination facilities located along the Mediterranean coastline at Ashkelon, Palmachim, and Hadera. In May 2011, the financing agreement was signed for the construction and operation of a desalination plant in Sorek, 2.2 km from the Mediterranean coast and 15 km south of Tel Aviv. Three months later, the Ministry of Finance signed an agreement for the construction of a fifth SWRO plant in the northern industrial zone of Ashdod. Production and construction details of the five major desalination plants (existing and planned) are presented in Table 7.1.

In total, the five desalination plants along Israel's Mediterranean coast will produce 540 MCM annually by 2013, accounting for 85% of domestic water consumption. By 2020, expansion of existing plants will increase the total production capacity to 750 MCM annually, accounting for 100% of Israel's domestic water consumption (GLOBES 2011).

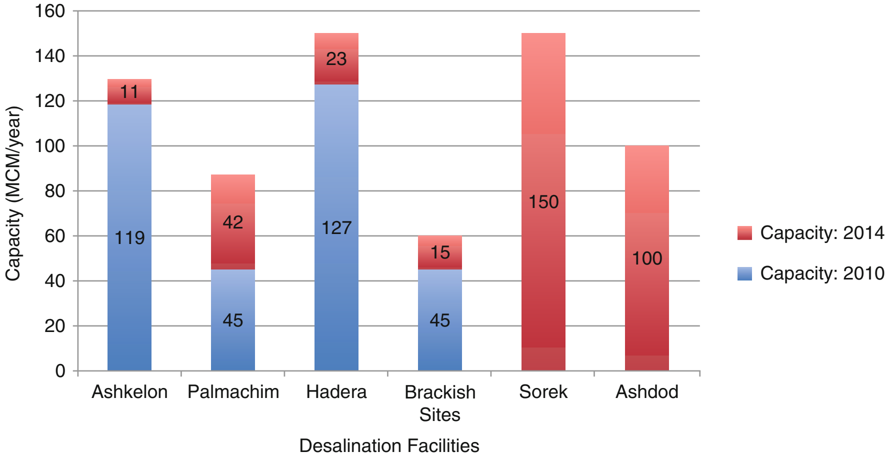

Fig. 7.1 Israel's desalination capacity (*Source*: Adapted from Tenne 2010)

Several smaller desalination facilities desalinate brackish water from groundwater wells or a combination of brackish and seawater. The largest of these facilities is located in Eilat and produces roughly 13 MCM annually from combined brackish and seawater sources (Dreizin et al. 2007). In total, brackish water facilities in Eilat, the Arava, and the southern coastal plain of the Carmel produce 30 MCM/year. In the future, production is expected to reach 60 MCM/year in 2013 and 80–90 MCM/year by 2020 (Tenne 2010). The total production capacity is presented in Fig. 7.1.

Beyond the 2020 goal of 750 MCM, a second stage of the master plan, recently announced, provides for the establishment of five more desalination plants between 2040 and 2050. These facilities, which account for the needs of both Israel and the West Bank, will each have a production capacity of 150–200 MCM/year for a grand total of 1.75 billion cubic meters of desalinated water. The first of these plants is planned for the Western Galilee in northern Israel and will likely begin its production in 2017. Total cost of the plants and related infrastructure is estimated at US $15 billion, with 80% of the budget coming from water tariffs and 20% from the state. The National Planning Council has stated, however, that there is uncertainty regarding the construction of any of these five proposed plants, as it is difficult to predict future water demands.[1] In the meantime, any supplementary desalinated water that becomes available during the coming years will be used to aid in replenishing Israel's natural water systems.

[1] http://www.globalwaterintel.com/archive/12/5/general/israel-build-five-new-desal-plants-2050.html

7.3 Water–Energy Nexus

7.3.1 Energy Consumption for Current Desalination Production

In Israel, electricity is generated, transmitted, and distributed by the Israel Electric Corporation – the sole integrated electric utility and 99.85% owned by the State. In the decade from 1999 to 2009, the national cumulative electricity demand grew at an average rate of 3.6%. In 2009, 64.7% of the electricity produced by the IEC was generated by coal, 1.2% by fuel oil, 32.6% by natural gas, and 1.5% by diesel oil. All fuels used are imported from outside of Israel, with a proportion of natural gas, coming from Egypt (Israel Electric Corporation 2010).

The volatility of obtaining natural gas from Egypt cannot be underestimated, especially as Egypt supplies 43% of Israel's natural gas and 40% of the country's total electricity. Eight times in 2011, Sinai Bedouin and terrorists halted the flow of natural gas from the Sinai Peninsula to Israel in protest of the export, resulting in losses amounting to US$1.5 million per day. Israel's lack of control over the availability of fuels, and the dependence of desalination plants on the national grid, means that any disruption in the supply (due to political or other reasons) would impact the State's ability to provide water for residents and industries.

Alternatively, recent natural gas discoveries in the offshore Tamar (9.1 trillion cubic feet) and Leviathan (twice as big) fields will mitigate the potential for harm by consolidating a greater fuel supply within Israel's borders, and the government is working quickly to develop this resource (Israel Electric Corporation 2010). In January 2012, Delek Drilling signed a US$5 billion agreement to supply Dalia Power Energies Ltd. with Tamar natural gas for 17 years, and production is set to begin in 2013 (Solomon 2012). A summary of Israel's electricity generation and consumption are presented in Table 7.2.

Given Israel's energy insecurity, it is critical to consider how much energy is required to desalinate roughly 300 MCM/year or the 750 MCM/year expected by 2020. The cost, quantity, and source of energy consumed at each desalination facility are paramount in the design process, as the combined energy demand for all of Israel's desalination facilities places a non-negligible burden on the energy sector. To reduce the impact, Israel's Desalination Master Plan stipulates that all plants utilize "advanced energy-recovery devices to reduce specific energy consumptions to below 4 kWh/m^3" (Dreizin et al. 2007). According to Abraham Tenne, Head of Desalination Division and Water Technologies and Chairman of the Water Desalination Administration (WDA), the country has exceeded this goal by reducing the national average energetic cost of desalinated water to 3.5 kWh/m^3 (Tenne 2010).

Table 7.2 Israel's electricity landscape

Generating system	Installed capacity	11,664 MW
	Peak demand	9,900 MW
	Electricity generated	53,177 million kWh
Electricity consumption	Total consumption	48,947 million kWh
	Average consumption growth (1997–2009)	3.6%
	Total revenues	18,704 million NIS (4,955 million USD)
	Average electricity price	38.21 agorot/kWh (10.12 cents)
	Total consumers	2.4 million
Fuel consumption (millions of tons)	Fuel oil	0.2
	Coal	12.3
	Gas oil	0.2
	Natural gas	2.7

Source: Israel Electric Corporation (2010)

In regard to the design and construction process for desalination plants, natural gas power generation is preferable to coal generation, and this is reflected in the bidding system for project developers. Natural gas power generation produces only 20% of the CO_2 emissions generated by coal power plants and is also approximately 7–8% cheaper than the energy provided by the national (coal-driven) power system. This savings reduces the cost of producing the desalinated water, thereby raising the bid score further (since cheaper water scores higher). Contractors for a desalination facility are also permitted to build a power plant that not sells additional energy to the national grid. This allows further reductions in the costs of the desalinated water product (thereby increasing the bid score further) (Tenne 2010).

Electricity is provided to the Ashkelon desalination plant from two redundant sources. A dedicated combined cycle cogeneration power station (built adjacent to the plant) runs on natural gas from the Yam Tethys reserve. Of the plant's 80-MW capacity, 56 MW are used for desalination and the surplus is sold to private customers and/or the Israel Electricity Company (Delek Group 2010). Additionally, a 161-kW overhead line provides supply from the Israeli national grid (Water-Technology.net, Ashkelon).

According to the numbers in Table 7.3, the roughly 1,100 million kWh required in 2010 and 2,100 million kWh required in 2020 for desalination account for 2.06 and 3.91% of the 53,177 million kWh of the electricity generated by IEC in 2009. For comparison, Mekorot consumes 6% of Israel's total electricity production (Plaut 2000). Of that 6%, the National Water Carrier consumes two-thirds – approximately 100 MW/h (Meisen and Tatum 2011). The energy demand from desalination is therefore a central issue when designing a national master plan for water supply.

Table 7.3 Annual energy consumption at existing desalination plants

Facility	Capacity (MCM) 2012	Capacity (MCM) 2020	Energy consumption (kWh/m^3)	Total energy (million kWh) 2010 (2020)	Energy source
Ashkelon	119	130	3.85	454 (454)	Power plant and IEC grid connection
Palmachim	45	87	2.91 (2.38 post-retrofit)	131 (107)	IEC grid
Hadera	127	150	3.5	445 (525)	IEC grid
Sorek	0	150	3.5	0 (525)	Natural gas power plant and IEC grid
Ashdod	0	100	3.5	0 (350)	
Brackish	45	80	1.5	68 (120)	
Total	335	697		1,098 (2,081)	

7.3.2 Cost of Energy for Desalination and Associated Impact on Energy Markets

Currently, energy consumption constitutes approximately 30–44% of the total cost of water produced by an optimized RO-desalination plant (Semiat 2008). At the Ashkelon plant, energy amounts to US \$0.21 of the \$0.53 total cost (40%): it takes 3.5 kWh to purify 1 m^3 of water and power costs \$0.06/kWh (Zetland 2011).

But the cost of energy is dynamic, and this volatility will surely affect the cost of desalination in the future. Desalination may compensate for reliability risk from drought, but corporate managers of desalination plants must account for risk in the form of energy price, regardless of whether the user pays a predetermined price for the water. On-site energy production from reliable sources is one way to address the energy price unpredictability.

7.3.3 Increasing Efficiency of the Desalination Process

The laws of thermodynamics set an absolute minimum limit for the energy required for separating water from a salt solution – approximately 1 kWh/m^3 of water – and modern RO technology has come close to reaching this theoretical thermodynamic minimum. Efficiency has been achieved through large pumps that use modern turbines and other energy-recovery devices known as “turbochargers,” “pressure exchangers,” or “work exchangers,” which recover the energy content of the high-pressure brine leaving the membrane module. Additional savings are possible with the use of higher permeability membranes that do not compromise rejection capabilities – a technological advancement that would lead to a reduction in operating pressure. By improving the RO membranes, it will be possible to further reduce energy consumption by 10–30% or roughly 15% for the overall desalination process. Improved pretreatment and fouling control measures would also create more optimal conditions for desalination, but there is a threshold to efficiency (Semiat 2008).

The Hadera plant, for example, utilizes energy-recovery devices produced by Energy Recovery Inc., known as PX-220 pressure exchanger devices. These reduce CO_2 emissions by 2.3 million tons per year and are expected to save approximately 60% (700 MW) of power consumption at the plant annually, allowing for a lower price of the final product (Water-technology.net 2010).

In the future, desalination may reach a point where energy is no longer consumed, but produced. In November 2011, chief executive of IDE Technologies, Avshalom Felber, commented in a BBC broadcast: "Ten years from today, we can actually see seawater desalination . . . . turning the dice around and actually starting to produce energy – to produce renewable energy through forward osmosis process. That would mean, the same energy we invest now during the separation of water, we can create by merging streams of saline and non-saline water. This is the future of this industry, and it's going to be a real break-through on the kind of service water desalination can give to the world" (BBC 2011).

7.3.4 Role of Renewable Energy in Desalination

Growing concern over the effect of greenhouse gas emissions on global climate change, and the volatility of externally sourced fossil fuels, has drawn attention to the possibility of using renewable energy sources (RES) for desalination in Israel. Two options exist for the use of renewable energy in desalination. Indirect use involves using RES to generate electricity used for desalination. Direct use involves the utilization of solar thermal energy for distillation by evaporation, for example, geothermal energy to power multistage flash desalination. Feasible sources of energy include wind, geothermal, solar thermal, and photovoltaic, although not all renewable sources can be used for each type of desalination process. Direct use of RES requires that the source be matched to its appropriate desalination process.

7.3.4.1 Solar Desalination

The combination of reverse osmosis desalination and solar energy is not only a promising field of development but also a highly appropriate one for a water-scarce, coastal country with high solar radiation. Interestingly, large-scale solar-driven RO desalination is still in its conceptual stage (as of 2009).

On a small and medium scale, however, solar desalination has been effectively carried out in three forms: (1) photovoltaic-powered reverse osmosis (PV-RO), (2) solar thermal-powered RO, and (3) hybrid solar desalination. In Kibbutz Maagan Michael (30 km south of Haifa), a brackish water RO-desalination system powered by 3.5 kWp PV and 0.6 kWp wind produces 3 m^3/day at a cost of US \$6.8/m^3. The system includes a diesel generator for backup, which was never used during the entire period of testing (Ghermandi and Messalem 2009).

Currently, several roadblocks still exist to commercial use of renewable energy in desalination. The first obstacle that must be overcome is the issue of energy storage for solar and wind, as desalination plants must operate continuously and at full capacity: 24 h a day, 365 days a year. Until a solution for the storage of this energy is developed, utilization of solar and wind power for large-scale desalination is limited. The second constraint is in regard to cost, an issue of primary importance to private developers of desalination plants. Because solar power is available only 25% of the time, the cost of desalination using solar energy is at least four times more expensive than conventional desalination powered by fossil fuels (Adu-Res 2006). Though solar-powered desalination has been researched for over 50 years, no commercial solar desalination plant is currently in operation – either small or large scale (Semiat 2008).

7.4 Environmental Impacts

First and foremost, seawater desalination is a manufacturing process and, by default, presents environmental concerns of varying nature and degree that must be understood and mitigated. Corporate responsibility, coupled with government regulation, may mitigate potential harm to natural aquatic and terrestrial ecosystems, but associated impact can never be entirely avoided. The question to be answered is whether desalination is still a worthwhile means of meeting Israel's freshwater needs, in spite of these impacts.

7.4.1 Damage to Marine Environment

7.4.1.1 Seawater Intake

Israel's direct (open) intake systems of delivering seawater to the desalination facility are known to increase the mortality rate of marine organisms residing in the vicinity of the desalination plant. Due to the great suction force and increased velocity surrounding intake openings – both necessary for the intake of large quantities of water – organisms may be trapped against intake screens (impingement) or be drawn into the plant with the seawater (entrainment). If starvation, exhaustion, and asphyxiation do not immediately kill impinged marine life, there is a significant possibility that some life-supporting biological function will be damaged, significantly reducing their chances for survival if they happen to be released back into the environment. Entrainment is considered to be lethal for all organisms as a result of extreme pressures within the intake system, collision with parts of the pump, high temperatures, and biocides such as chlorine used to prevent biofouling of membranes. Impingement is of high concern for fish, invertebrates, mammals, and birds, while entrainment affects smaller organisms such as phytoplankton, zooplankton, fish eggs and larvae, spores of kelp, and seaweed. From an economic perspective, trapped organisms increase biofouling of membranes, thereby reducing the life span of these pressure vessels (IAEA 2010).

The issue of marine life mortality is one that can be largely overcome by technological advancements in intake screening equipment. The oldest and most common traveling water screens feature mesh wire panels with 6–10-mm openings and are typically cleaned every few hours by a strong jet of water. An alternative version of this screen, called the Ristroph traveling screen, involves buckets that would trap and then return marine organisms to the sea. Passive wedgewire screens are another new development with a mesh size of 0.5–10 mm to prevent the entrance of smaller organisms into the intake system. Barriers that aim to deter organisms from the intake vicinity – such as strobe lights and air bubbles – have also had positive results when tested in conjunction with screen technologies. It is important to note, however, that technologies intended to address the issue of marine life mortality and biofouling do come at the price of reduced plant efficiency (IAEA 2010). Another alternative altogether involves indirect (subsurface) seawater intake, which avoids contact with marine life that is not nested beneath the ocean bottom. This alternative was considered for the Ashkelon plant, but was ultimately dismissed due to the potential danger of possible leaks into freshwater aquifers (IAEA 2010).

7.4.1.2 Brine Outflow

Perhaps the most worrisome environmental concern associated with desalination is of what to do with the concentrated brine that is a by-product of the treatment process. The brine solution has approximately twice the concentration of ambient seawater and contains a range of chemical additives including chlorine and other biocides to prevent membrane biofouling, antiscalants (polyphosphates, polymers) to prevent salt from forming on piping, coagulants (ferric sulfate, ferric chloride) to bind particles together, and sodium bisulfite to eliminate the chlorine, which can damage membranes (Safrai and Zask 2006). Brine also contains heavy metals introduced into the desalination process as a result of equipment corrosion (Cooley et al. 2006).

In Israel, this brine solution is diluted and pumped into the sea, with the expectation that the dilution of brine will mitigate the ecological harm done. Dilution is not, however, the solution to pollution in this case, as the high specific weight causes the brine to sink to the sea bottom, creating a "salty desert" surrounding the pipeline outlet. In general, brine accumulation in the affected area is generally permanent, continuously compounded by a constant flow from the facility, and not without consequence for the biotic community in the area (Einav and Lokiec 2006). Nevertheless, there are no scientifically documented cases of long-term ecological impact at the point of brine outflow.

Other environmental concerns regarding this concentrated brine solution include (1) eutrophication due to phosphates enrichment if polyphosphates are used in the treatment process and if organic cleaning solutions are added to the brine, and (2) discoloration due to high concentration of iron, with high suspended solids and turbidity levels, and the impact of brine on the composition and distribution of marine life (Safrai and Zask 2006).

The extent of the brine's marine impact is dependent upon its concentration, discharge rate, the outlet pressure, and planning of the pipe system, in addition to natural hydrological phenomena such as bathymetry, currents, and waves. Currently, evaluation of the degree and range of impact is based on mathematical models and a limited amount of field data, so in this regard, we are learning in real time the consequences of our actions. Not to mention, different marine habitats such as coral reefs and rocky beaches will respond differently to the brine (Einav and Lokiec 2006). As such, the precautionary principle is recommended as an integral component in the establishment of new environmental regulations for desalination plants.

As of now, the Law for the Protection of the Coastal Environment (2004) stipulates that any planned facilities for seawater/brackish water desalination will be constructed with a clear plan for the removal of the concentrated desalination discharge. Discharge of brine into sea is permissible only with a valid, interministerial permit issued in accordance with the Prevention of Sea Pollution from Land-Based Sources Law (1988) and its regulations. The main issues considered are marine outfall, marine monitoring program, and discharge composition (Safrai and Zask 2006).

One potential solution to the problem of brine discharge is to utilize the concentrated solution for salt production. As if to solve the issue of energy consumption and brine disposal simultaneously, it turns out that an increase in energy recovery increases brine salinity, thereby reducing the size and cost of evaporation costs necessary for salt manufacturing. Thus, we arrive at the concept of dual-purpose plants for the production of desalinated water and salt. In this model, brine outfall facilities, and the pipe entering the sea used to discharge brine, are avoided.

In Eilat, such a plant (the 80:20 seawater–brackish water plant described above) has been in operation for 9 years, owned and operated by Mekorot. The salt production plant is owned by the Israel Salt Company 1976 Ltd., a private, public sector corporation. Improvements made to the facility have increased the annual production capacity from 118,000 to 150,000 tons in less than one decade. At this point in time, the major shortcoming of this closed-loop solution is that there exist few salt production facilities in the vicinity of desalination plants – there simply is not a large enough market for this product (Ravizky and Nadav 2007).

7.4.2 Expropriation and Land Use Along Coastal Areas

While some may consider desalination plants to be technological masterpieces dotted along Israel's 273-km Mediterranean coastline, others will argue that this land should not be used for such industrialized activity. From an economic and

Table 7.4 Air emissions per m^3 water for reverse osmosis desalination facilities

Emissions per m^3 water	Reverse osmosis
CO_2 [kg/m^3]	2–4
NO_x [g/m^3]	4–8
SO_x [g/m^3]	12–24
Non-methane volatile organic compounds [g/m^3]	1.5–3

Source: IAEA (2010)

engineering perspective, situating a facility closer to the shoreline is advantageous; proximity to the sea avoids the installation of pipes for transporting large amounts of seawater and brine that come with the associated risk of polluting underground aquifers in the event of a leak (Einav et al. 2002). In Israel, however, the real estate, environmental and social value of the shoreline has pressured the desalination industry to build in areas specifically designated for engineering installations in order to preserve land for tourism and recreation. For example, the Ashkelon facility was built 2 km south of the city, extends over an area of 70 dunam, and sits adjacent to the IEC Rothenberg Power Station.

7.4.3 Air Pollution and Increased GHG Emissions due to Energy Consumption

The combustion of fossil fuels for electricity generation is responsible for approximately 50% of Israel's air pollution. In particular, power plants are responsible for 65% of the country's sulfur dioxide (SO_2) emissions, 45% of nitrogen oxide (NO_x) emissions, 38% of particulate emissions, and 60% of carbon dioxide emissions, all of which are known to have adverse health effects (MEP 2009). In this regard, the country's desalination plants – powered predominantly by the national grid that generates electricity from coal and natural gas – present an additional threat to the regional environment. Importantly, direct air emissions from desalination include only oxygen and nitrogen discharges associated with deaeration processes (IAEA 2010).

Assuming a specific energy capacity of 3.85 kWh/m^3, the desalination of 1 m^3 of water produces 3.432 kg CO_2/m^3 of carbon emissions. In 2020, when Israel's desalination capacity reaches its goal of 750 MCM/year, this will amount to 2.574 billion kg CO_2 annually. Illustrated in Table 7.4 and Fig. 7.2 are the GHG emissions per cubic meter of desalinated water with fossil fuels as the energy source.

7.4.4 Restoration of Freshwater Resources

The environmental impacts associated with desalination are surely not all negative. One of the most attractive aspects of this method of water resource management is the potential for restoration of freshwater resources as we begin to rely more

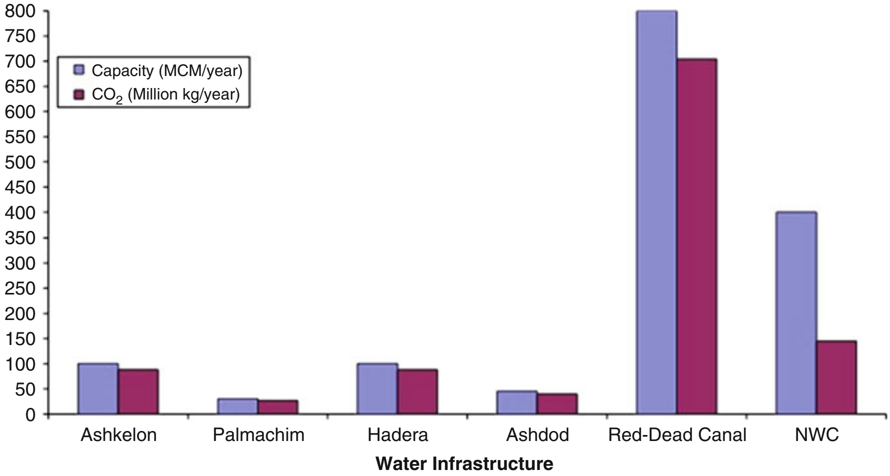

Fig. 7.2 Capacity and CO_2 emissions of water infrastructure in Israel

on seawater and less on fragile aquifers and declining surface water. It is true that overall demand for freshwater is increasing, but the expectation is that desalinated water will more than compensate for the additional consumption so that Israel can begin to manage its freshwater sources as a buffer instead of the primary supplier. This shift will pave the way for natural sources to be allocated for nature, recreation, and aesthetic use.

7.5 Economic Impacts

7.5.1 The Commercial Players

Mekorot: Israel's national water utility operates 31 desalination facilities including the new facility planned for Ashdod and the National Water Carrier that delivers 400 MCM/year of water distributed throughout the country. Mekorot supplies 80% of Israel's drinking water and 70% of national consumption.

IDE Technologies Ltd.: IDE is a publicly owned, joint venture between Israel Chemical Limited and the Delek Group. As a pioneer in desalination technologies, "the company specializes in the development, engineering, production and operation of advanced desalination as well as innovative industrial solutions." IDE has developed over 400 facilities globally and in Israel at Ashkelon, Hadera, and Sorek (IDE Company Profile).

Global Environmental Solutions Ltd.: GES (2010) invests its experience and human capital in the water sector. Most notably, GES played a role in constructing

Table 7.5 Price of desalinated water from Israel plants

Desalination plant	Price (NIS/m^3)
Ashkelon	2.60
Palmachim	2.90
Palmachim expanded[a]	2.07 (D&WR 2011)
Hadera	2.563 (http://www.globalwaterintel.com/archive/7/10/general/ide-takes-hadera-with-rock-bottom-price.html)
Sorek	2.01 (MFA 2011)
Ashdod	2.40 (Shemer 2011)

[a]Following expansion from 45 to 87 MCM

the Palmachim desalination plant in 2005 and was commissioned to carry out the operation and maintenance of the facility. GES has designed, built, and currently operates brackish water and seawater desalination plants in Israel, the Gaza Strip, and Greece (GES Company Profile).

7.5.2 The Price Tag on Desalination

The price of desalinated water is site-specific, depending on total capacity, labor costs, energy sources, land availability, water salinity, and perhaps most significantly today – technological innovation. The price of desalinated water from each of Israel's industrial facilities is shown in Table 7.5.

7.5.2.1 Plant Financing

In Israel, almost all desalination facilities are based on a build–operate–transfer (BOT) contract, under which the concessionaire designs, builds, and operates the plant for a total period of 26.5 years, after which the plant is transferred to state ownership. Both domestic and international banks fund the large-scale plants, for which the total project cost runs between $200 million and $500 million. The financing details for the five major plants are outlined in Table 7.6.

7.5.2.2 Direct Costs

Desalination is undoubtedly the most expensive water treatment process, and the high capital costs of constructing each plant are only compounded by operation and maintenance costs. Energy and equipment are the most costly components of desalination, and all individual pieces of equipment seem to contribute equally to the expense (Semiat 2008). At Ashkelon, for example, about 42% of the price of

Table 7.6 Financing Israel's desalination facilities

Facility	Capital cost (USD)	Contract	Investors
Ashkelon	\$212 M	BOT	23% equity, 77% debt
Palmachim	\$100 M	BOO	Bank Hapoalim
Hadera	\$425 M	BOO	International banks: European Investment Bank (EIB), Credit Agricole, Banco Espirito Santo
Sorek	\$400 M	BOT	EIB, the European Development Bank, and Israel's Bank Hapoalim, and Bank Leumi
Ashdod	\$423 M	BOT	Bank Hapoalim, EIB

water covers energy costs, variable operation and maintenance costs, membranes, and chemical costs, while 58% covers capital expenditures and operation and maintenance costs (Sauvet-Goichon 2007).

Nonetheless, the capital and operating costs of desalination are declining in large part due to technological improvements, economies of scale of larger plants, and increased level of experience among those in the industry. RO membrane technology has made the greatest leap of improvement: salt rejection has increased from 98.5 to 99.7% over the past decade, output from a membrane unit has increased from 60 to 84 m^3/day, and manufacturers are guaranteeing a longer life for their membranes (Cooley et al. 2006). Still, many argue that there is room for increased efficiency and that RO membranes are the low-hanging fruit for cost reduction (Semiat 2008).

According to Avshalom Felber, chief executive of IDE Technologies, the cost of desalinated water is expected to drop to as low as 35 cents in the next 10 years. Just a decade ago, the cost was above the \$2 mark (Becker 2011). Recently, however, a counterforce has emerged to cost reduction of desalination in the form of increases in the cost of raw materials, energy, and rising interest rates (Cooley et al. 2006). As a result of these opposing forces, it is difficult to predict the actual cost of seawater desalination in the future.

7.5.2.3 External Costs

In addition to the direct production costs of desalination, external costs must be considered to determine the comprehensive economic impact of this technology on Israeli society. External costs of desalination are associated with environmental impacts such as air pollution and greenhouse gas emissions, expropriation and land use along coastal areas, and damages to marine life caused by seawater intake and brine discharges.

In a 2010 analysis of the external costs of desalination performed by Dr. Nir Becker, the aforementioned environmental impacts were quantified and factored into the total cost of producing 1 m^3 of freshwater. The study was based on an average energy consumption of 4.25 kWh/m^3 (slightly higher than the national average in 2012) and assessed the costs associated with specific pollutants with estimates from the Israeli Ministry for Environmental Protection (Becker et al. 2010).

Considering that Israel produces roughly 280 MCM/year of desalinated water, the external cost of air pollution exceeds $36 million annually and will rise to nearly $100 million by 2020 when Israel is expected to produce 750 MCM. It should be noted, however, that estimated externalities from air pollution would decrease to 4.8 cents per cubic meter if desalinated water were produced solely with natural gas rather than the current fuel mix that is one third natural gas and two thirds coal (Becker et al. 2010).

Land use presents another significant external cost, as over half of the Israeli population lives along the coast, and this land is very highly valued. As such, the opportunity cost of the land upon which a desalination plant is constructed should be counted when determining the true cost of desalinated water. Using a weighted average of 190 NIS (US $0.50) per square meter of shoreline, and an assumed 100 m of shoreline and 7 ha of territory for every 100 MCM of desalinated water produced, land is worth US $0.034 per cubic meter. At the current desalination capacity, $10 million per year represents the alternative value of this land and nearly $26 million for a capacity of 750 MCM/year (Becker et al. 2010).

Additional externalities also arise from damage to marine resources caused by seawater intake and effluent discharge. Metals found in brine and the higher temperature characteristic of this solution can have adverse effects on the reproductive capabilities of some organisms, but in Israel, impacts on marine life from desalination have yet to be quantified (Becker et al. 2010).

Conversely, positive externalities also result from desalination. Reduced water salinity – from 250 mg Cl/L for freshwater to 100 mg Cl/L for desalinated water – can increase crop yield, improve aquifer water quality, and reduce costs for household and industrial electrical equipment and sanitary systems. Together, positive externalities are estimated at about US $0.10 per cubic meter.

In total, a lower bound on the externalities of desalination (positive and negative, and not including damages to marine life) is found to be US $0.065 per cubic meter. Adding this to the price of water would increase the direct cost by 8% (Becker et al. 2010).

7.5.3 Government Subsidies of Desalinated Water

Government subsidies of desalinated water are often required to increase affordability of the freshwater product. These subsidies are often visible, but may also be hidden as in the water produced by the Ashkelon facility. As the first large-scale desalination plant in Israel (and the world's largest at the time it commenced production in 2005), Ashkelon was able to offer freshwater at a cost of $0.53/$m^3$ because the land on which the plant was constructed was provided at no cost by the Israeli government (Cooley et al. 2006).

7.5.4 *Privatization of Water Supply*

In Israel, the law declares, "The water resources of the State are public property, subject to the control of the state and destined for the needs of the inhabitants and development of the country" (Section 1, Water Law 5719-1959) (MFA 2002a, b). As such, those who advocate for water as a basic human right have raised concern over the commoditization of this resource similar to any other consumption good. At the end of the day, the question is whether private sector control over the production, supply, and management of this resource is in the public's best interest. Those privatizations can be quite beneficial; it is also associated with decreased transparency and accountability, price hikes caused by the introduction of additional profit margins, service deterioration, and noncompliance with health and environmental regulations resulting from a lack of regulation of corporations involved.

With the exception of the Ashdod plant, all of Israel's water desalination facilities involve some sort of public–private partnership, in which governments call upon the expertise of the private sector, and risk is allocated to the sector best equipped to manage it. The result is that Israel is increasingly dependent on the terms of 25-year contracts that are typical for build–operate–transfer (BOT) and build–operate–own (BOO) desalination plants.

Since the construction of the Ashkelon, Palmachim, and Hadera plants, a 7-year drought forced the government to ask manufacturers to increase their production in exchange for higher rates (to cover the costs of expansion and increase their profit margin). No longer in a competitive process with a range of options, Israel is at the mercy of the contracted corporations. As a result, each time there is a water shortage and the government must negotiate to increase production, the agreed upon price is higher (sometimes by 6–7%) than initially offered. Ultimately, Israelis will cover this price increase in their water bills. There seems to be no end in sight for this corporate control: when the Sorek plant commences production in 2013, IDE will produce 75% of the country's desalinated water and 25% of Israel's drinking water (Bar-Eli 2011).

To reconcile the positive aspects of privatization with the potentially adverse aspects, Friends of the Earth – Middle East has outlined the following recommendations (Becker et al. 2004):

1. A municipal corporation may transfer to the private sector in a variety of ways parts of the construction, management, and maintenance of water and sewage systems, as long as ownership and long term control over assets remain in public hands. The complete privatization of water corporations should be avoided.
2. Public participation in the regulation of water and sewage corporations should be implemented, widened and institutionalized so as to strengthen the regulatory agency. Principles of democratic regulation, as are practiced in the regulation of a variety of public utilities in the US, may provide an adequate structure for the regulation of private as well as public monopolies.

3. The disconnection from water services of homes, hospitals, schools and other institutions should be prohibited by law or at least by regulations.
4. In determining the price of water, water saving should be encouraged while safeguarding the access of all residents to a reasonable amount of water. To that end, it is recommended to establish a per capita consumption threshold of water, which should be available at low cost. Any water consumed above that threshold should be priced high enough so as to provide a real incentive to save water.

7.6 Water Quality Impacts

By design, the quality of desalinated seawater is quite high, as RO membranes remove most impurities. There are, however, several concerns associated with this treatment process due to low mineral content. Importantly, desalinated water does get mixed in with other freshwater in the National Water Carrier distribution system, supplementing the remineralization process that takes place during posttreatment.

7.6.1 Health Concerns

High boron concentrations in seawater are perhaps the most talked-about health issue associated with desalination, as boron is known to cause developmental and reproductive toxicity in animals and irritation of the digestive tract. RO membranes remove 50–70% of this element from the seawater where boron concentrations are as high as 4–7 mg/L, and additional boron is removed during the posttreatment process (Cooley et al. 2006). To meet the World Health Organization (WHO) standard of 0.5 mg/L, the Hadera plant uses a Cascade Boron Treatment system that produces water with a boron concentration of 0.3 mg/L. At the Ashkelon plant, the Boron Polishing System constitutes 10% of the overall energy costs (Garb 2008).

Posttreatment presents a second concern, however, as essential nutrients such as calcium, magnesium, and sulfate are found in natural freshwater but missing from desalinated water. Israel's National Water Carrier contains water with dissolved magnesium levels of 20–25 mg/L, whereas water from the Ashkelon plant contains no magnesium. Similarly, calcium concentrations in desalinated water are 40–46 mg/L, compared to 45–60 mg/L found in natural freshwater. Posttreatment processes expected in future desalination facilities – such as dissolving calcium carbonate with carbon dioxide – will further reduce calcium concentrations to 32 mg/L (Yerimiyahu 2007).

There is also concern that lower calcium and carbonate concentrations will serve to degrade the piping system of the distribution network, with public health and financial ramifications. As a result of acidic product water, toxic metals such as nickel, copper, lead, cadmium, and zinc can be leached from the distribution system. Such corrosion may be harmful to human health and reduce useful life of the system. Fortunately, this problem is corrected in the posttreatment stage with the reintroduction of calcium carbonate in the form of lime or limestone, which neutralizes the pH of the water and forms a nonporous film along the pipeline (Yerimiyahu 2007).

7.6.2 Implications for Agriculture

Originally, water produced by the Ashkelon desalination facility was designed for human consumption, and not for agricultural use. However, low population density in southern Israel has allowed for a substantial percentage of the supply to be used by farmers. This shift in irrigation water from natural freshwater sources to purified seawater has had both positive and negative effects on the healthy growth of crops.

The lower salinity of desalinated water is what makes this water so appealing for agricultural use, as high Na^+ and Cl^- concentrations damage soils, stunt plant growth, and alter the environment. The salinity of water produced at the Ashkelon plant – measured by electrical conductivity (EC) – is 0.2–0.3 dS/m, compared to water from the national distribution system that has an EC roughly three to five times higher (Yerimiyahu 2007).

On the other hand, high boron concentrations in seawater have had adverse reproductive and developmental effects on irrigated crops, including tomatoes, basil, and certain varieties of flowers (Yerimiyahu 2007). Citrus species are found to be particularly sensitive, with a boron tolerance threshold of 0.4–0.75 mg/L (Bick and Oron 2005). When water produced at the Eilat plant (without posttreatment for boron removal) caused damage to sensitive crops, Israel became the first country to set a boron limit of 0.04 mg/L. This concentration is similar to that of drinking water from freshwater sources and is achieved only with the additional posttreatment (Garb 2008).

Calcium and magnesium deficiencies described above also cause physiological defects in crops (Yerimiyahu 2007). To meet agricultural needs, farmers may need to incorporate missing nutrients into their fertilizers. Due to mixing of natural freshwater and desalinated water in the National Water Carrier, the quality of irrigation water is unpredictable, and farmers do not have the capacity to prepare for fluctuations. On the other hand, desalinated water is meant for several uses and must simultaneously be optimized for agricultural benefit and for drinking water consumption. At the very least, however, increasing the concentrations of calcium and magnesium in desalinated water will have a positive impact on both agricultural production and on public health (Yerimiyahu 2007).

7.7 Trans-boundary Management with the Palestinian Authority and Jordan

Regional cooperation and trans-boundary management of water resources are viewed as vital to sustainable use of precious resources and for the peace-building process among Israelis, Palestinians, and Jordanians. Currently, industrial-scale desalination facilities do not exist in either the West Bank or Jordan (both landlocked) or in the Gaza Strip due to the lack of resources to invest in this technology. Such a possibility, however, is far from closed for the future.

7.7.1 Red Sea–Dead Sea Conveyance

The Red Sea–Dead Sea Conveyance has been proposed as a means of restoring the declining water level of the Dead Sea. Historically, the surface of the Dead Sea was 392 m below sea level – the lowest point on Earth. In the past 30 years, however, diversion of water from the Jordan River (which feeds the salty lake) to the north has caused the water level of the Dead Sea to drop to 417 m below sea level. The average annual inflow has decreased from 1,200 to 250 MCM/year, and as a result, the surface area has been reduced from 940 to 637 km^2 (Abu Qdais 2007).

Due to the economic, cultural, and touristic importance of this trans-boundary body of water, Israel, Jordan, and Palestine have come together to identify solutions for its restoration while simultaneously increasing water security in the region. To this end, the World Bank and Coyne & Bellier of France, in coordination with the governments of Israel, Palestine, and Jordan, have conducted a feasibility study for the construction of a 250-km conveyance to transport 1,900 MCM/year from the Red Sea to the Dead Sea. Called the Red–Dead Sea Conveyer (RDSC) or "Peace Canal," this project would pump seawater from the Gulf of Aqaba to an elevation of 170 m below sea level in the Arava Desert and then flow by gravity to the Dead Sea. The 570-m head differential would generate 550 MW of electricity, to be used for three purposes: (1) to power the initial pumping, (2) to power 850 MCM/year of seawater desalination based on 45% recovery, and (3) to yield a power surplus of over 100 MW (Hersh 2005).

The opportunity for seawater desalination is particularly attractive to Jordan – one of the top ten water poorest countries in the world – as it would increase national water supply by 50% (Hersh 2005). The desalination plant, located at the southern Dead Sea, will discharge brine into the Dead Sea at a rate of 1,050 MCM/year, with a dissolved solid concentration of 72,220 mg/L – far below the salinity of the Dead Sea (Abu Qdais 2007). This difference in salt concentration (and density) is expected to result in stratification similar to the phenomenon that takes place when brine is discharged into the Mediterranean, except that in this instance, the brine is less salty than the receiving body of water. Additionally, the range of chemicals used in the desalination process is expected to affect the chemistry of the Dead Sea (Abu Qdais 2007).

On May 9, 2005, the 2-year feasibility study was launched by Israel, Jordan, the Palestinian Authority, and the World Bank – costing $US 15million – to analyze the economic, environmental, and social impacts of the project. Environmental concerns are paramount: seawater intake may affect the fragile marine ecosystem and coral reefs of the Gulf, leaks or spills along the pipeline may contaminate freshwater aquifers, and the mixing of seawater from the Red Sea (with a salt concentration of 60–100 ppt) with Dead Sea saltwater (300 ppt) may have adverse effects on the Dead Sea and dependent industries of tourism and potash (Hersh 2005). Conversely, restoration of the Dead Sea will preserve the agricultural land of the Jordan Valley, sustain the tourist and industrial activities of the Dead Sea, and reverse sinkhole formation, a natural phenomenon due to the declining Dead Sea water that has caused serious damage to local infrastructure. In total, capital investment of the project is about US$ 3.8 billion, which includes the costs of the conduit, RO plant, and distribution system (Abu Qdais 2007).

7.7.2 Regional Water and Energy Grids

The future of water security in the region lies in the integrated management of the Jordan River Basin, an 18,000-km^2 watershed that encompasses much of Israel, the Palestinian territory of the West Bank, and parts of Jordan, Lebanon, and Syria. Undeniably a challenge, yet perhaps a blessing in this conflict-ridden part of the world, cooperation on energy and water issues is vital for the sustainable use of resources and could prove to be a grounds for peace-building and reconciliation.

As explored in a previous section, on the water–energy nexus, it is becoming increasingly clear in this water-stressed, energy-poor region in which population is growing that scarce resources must be co-developed. Great amounts of energy are needed to pump, treat, desalinate, and distribute freshwater for agricultural, industrial, and residential use. On the other hand, large amounts of water are needed in the production of energy. Fortunately, both Israel and Jordan have resources that, when combined, would be hugely beneficial for both parties. In Israel, access to the Mediterranean Sea and technological know-how to produce large amounts of desalinated water could be used to improve regional water security. In Jordan, large tracts of unused desert with a high degree of direct solar irradiance may be used to produce solar energy and meet regional energy demands and in particular, to desalinate seawater in Israel. In the Jordan River Basin, solar energy could produce an estimated 17,000 terawatt-hours of electricity annually, 170 times the current regional consumption of less than 100 terawatt-hours (Meisen and Tatum 2011).

Motivation for regional cooperation lies in the climate change models that predict average temperature increases in the Jordan River Basin by up to 3.1°C in winter and 3.7°C in summer. This increase is expected to result in a 20–30% decrease in average rainfall over the next 30 years, causing reduced flow of the Jordan River, desertification of arable land, and increased unpredictability of natural disasters (Meisen and Tatum 2011).

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Chapter 8
Groundwater Management in Israel

Alex Furman and Hila Abbo

8.1 Introduction

In recent years, groundwater (GW) is becoming increasingly important due to population growth, preparation for climate change, flood control, and above all water quality awareness. While in far and recent history most of the water for agricultural and domestic use was of surface origin, in the recent few decades, the portion of groundwater used in many countries is significantly higher than the portion of surface water used. This makes the study of groundwater and related fields such as vadose zone hydrology, subsurface contaminant fate and transport of high importance.

An hydrologists joke nicknames Israel the holy land because it is covered with holes (wells). Groundwater was utilized in this dry region since the biblical times (e.g., Abraham visits Be'er Sheva – seven wells; Genesis 22). During the last several decades, Israel experienced rapid population growth, accompanied by intensive agricultural and industrial development. The water demand is rapidly growing, and Israel, as a modern country, developed advanced methods and tools to maximize water resources utilization. Still, groundwater is the largest natural water resource in Israel.

Therefore, the major goal of this chapter is to review the recent history of groundwater utilization in Israel and to highlight several management practices and their resultant consequences. This chapter will introduce the major groundwater

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resources in the country and their relation to other water resources, review the history of groundwater resources under fast development and the deterioration of water quality, and present several specific management practices utilized (primarily) in the coastal plain aquifer of Israel. None of the authors was personally responsible for the management practices presented here, and likely several of these practices were never officially declared. We look at the reality of groundwater management from the perspective of uninvolved hydrologists.

8.2 The Israeli National Water Resources System and the Role of GW Systems

All water resources of Israel are centrally managed by the Israel Water Authority (IWA). Therefore, the management of each groundwater system is part of the operation of the national system, and it is important to understand the structure of the national system and the external and internal constraints that control its operation. The water supply system is operated mainly by MEKOROT – the Israeli water supply company – and in a lower extent by private well owners and local water distribution organization. Generally speaking, the national system is fed by four major resources: (1) Sea of Galilee (a.k.a. Lake Tiberias or Kinneret), the only freshwater lake in Israel; (2) the Israeli coastal plain aquifer (ICPA), a sandstone aquifer; (3) the mountain aquifer, a carbonate aquifer (Gvirtzman 2002); and (4) an artificial resource, seawater desalination plants (Fig. 8.1). The national water resources also include several smaller aquifer systems, local systems for diverting seasonal flows into groundwater infiltration ponds, several brackish water desalination plants, and treated wastewater.

The overall water consumption in Israel in the last decade is about 2,000 MCM (million cubic meter) of water per year (IWA 2012). About 1,400 MCM is freshwater consumption, 350 MCM is treated wastewater, and about 300 MCM originated from desalinization plants (which, according to the government decision from 2008, supposed to reach 750 MCM by 2020). Of the total consumption, about 55% is used for agriculture (including most of the lower-quality waters), close to 40% for domestic uses, and the remainder for industrial use and nature preservation.

As noted above, the water utilization is mostly centralized, and major water carriers deliver water from the Sea of Galilee toward the center of the country, southward to the northern Negev, and eastward toward Jerusalem, making the three major basins interconnected. Separate system delivers treated wastewater from urban regions to agricultural regions, with the SHAFDAN project, that treats most of the wastewater of the Tel Aviv (Dan) metropolitan, delivering about 170 MCM southward.

Fig. 8.1 Schematic map of Israel (*left*) presenting major aquifer and surface water systems, major wastewater and desalination plants, and closer map of the ICPA (*right*) indicating desalination plants, the SHAFDAN facility, and populated areas

8.3 Historical Overview of GW Utilization in the Modern Era and Resultant Problems

The population of Israel has seen dramatic increase over the last six decades or so, from about 600,000 with its establishment in 1948 to about 7.5 millions today (excluding the Palestinian population of around 4 million today; CIA 2012a, b). Further, in its first years, the economical basis of the country was agriculture, and while water-saving techniques were applied almost from the beginning, the water demand increased very fast to its current figures. Major water supply systems were constructed throughout the country with the Yarkon–Negev line (opened 1955; a parallel line opened 1966) and the national carrier (opened 1964) practically connecting between the three major natural water sources and establishing the “three-basin system” which is the core of the national water policy.

As the agricultural water use increased almost instantly (1950s) while hydrologically balanced supply of water (primarily from the Sea of Galilee) caught up only in the mid-1960s, utilization of the aquifers (and primarily the ICPA) was beyond the natural replenishment (Shavit and Furman 2001). As a result in some regions, significant hydraulic depressions were formed, and occasionally water levels dropped below the seawater level. This point will be further described in the next chapter. Starting in the mid-1960s utilization of groundwater resources became more balanced, and consideration of long-term recharge was applied.

While the development of the two major aquifers reached its natural capacity around the mid-1960s (in terms of pumped volume; but see later for enhanced recharge), development of pumping facilities in smaller aquifers continues to date, especially in the more remote parts of the country, e.g., the Arava valley, lower Jordan valley, Hula Valley, and more. In many of these cases, groundwater is naturally saline, and the pumped water is diluted with less saline water from the national system.

An important point that worth mentioning is that most of the development following the establishment of the country in 1948 was centralized. The “water law” that was made by the government (MoAg 1959) in the late 1950s (following earlier regulations) made all water (including floods, groundwater, and even wastewater) property of the country. That is, most wells drilled and all major water supply lines were designed and constructed by state-owned companies (TAHAL and MEKOROT, respectively), and centralized management under the water authority (then water commission) began.

8.4 General Depletion of GW Quality and Quantity

As described above, in the early years of the country, water was pumped primarily from the coastal plain aquifer and from the mountain aquifer for local use, and starting in the mid-1950s for intensive agricultural development of the southern parts of the country. This led to fast depletion of water levels in those aquifers and, as noted years later, to significant movement of the freshwater–seawater interface land inward. Figure 8.2 depicts water levels at several representative wells in the ICPA. It can be seen that water levels were dropping at times at a rate of 1 m/year. Following the opening of the national water carrier that delivers water from the Sea of Galilee in the mid-1960s, pumping from the two aquifers was balanced and levels/heads recovered significantly, although not to their original values.

For a coastal aquifer depletion of levels means reduction of fluxes toward the sea. This takes the fragile freshwater–seawater interface out of balance (between

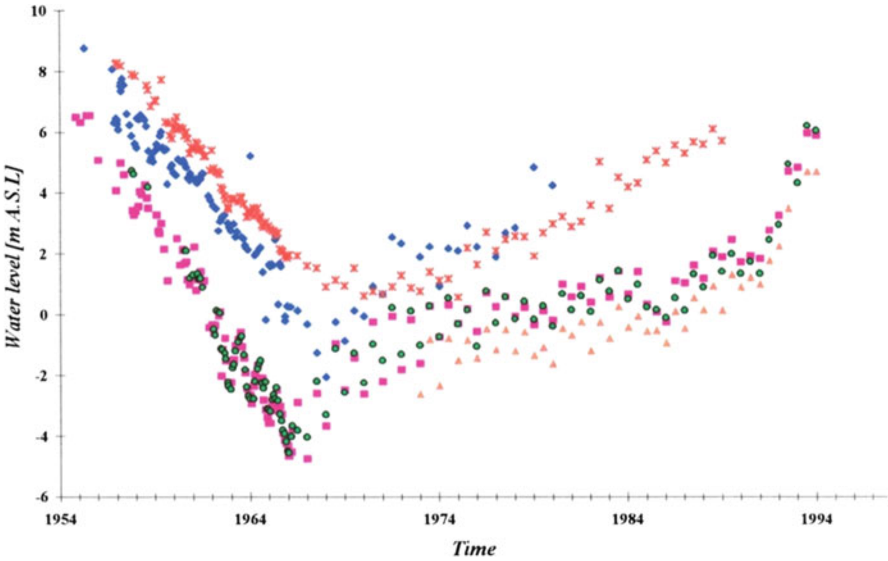

Fig. 8.2 Water levels in several representative wells (*different symbols and colors*) in the ICPA (Be'er Tuvia region; data from the IWA database, figure based on Furman 1998)

advection and diffusion) and causes the interface to disperse and more importantly to move landward. Following the sharp depletion of water levels (at several places and times even below seawater levels), saline water started to appear in several wells, mostly close to the sea (Goldman et al. 1991; Melloul and Goldenberg 1997). Following significant pumping in the 1950s, the seawater–freshwater interface moved about 2.5 km landward in the Tel Aviv area (Goldman et al. 1991). Melloul and Goldenberg (1997) report intrusion (movement of the interface toe) of up to 2 km along the coast elsewhere. It is important to note that the more significant intrusion is associated with the more urban areas. In recent years, it has been realized that contact between fresh and salt water may exist also between a freshwater body and saline water beneath it, as suggested by Paster et al. (2006).

It is a common mistake to directly relate a drop in water levels to depletion in water quality. The complete picture is much more complicated. Other than perhaps the phenomena of up-coning and increased salinity levels in pumping wells near the coast line (The Hydrological Service 2011), drop of water levels in aquifer does not directly contributes to depletion in water quality. However, it may lead to different processes that eventually lead to such depletion and primarily to its acceleration. Groundwater quality deterioration, expressed as increase in salt concentrations, is always due to intrusion of saltier water into the aquifer (by increase of the agricultural backflow, seawater intrusion, point sources due to municipal and industrial activities, and more). The drop of water levels only means that the "mixing volume" (i.e., the aquifer) is smaller and therefore concentrations increase faster. Figure 8.3 presents the trends in water quality for several wells in the

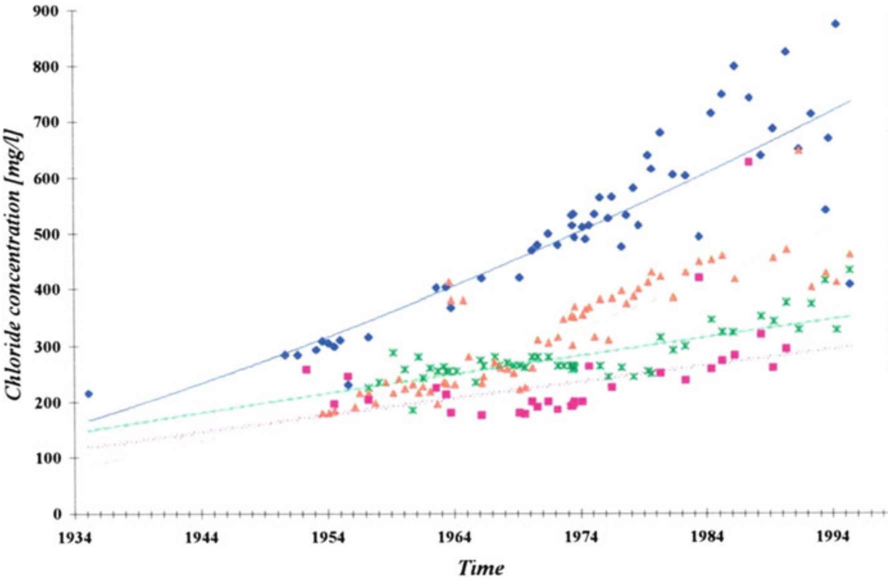

Fig. 8.3 Chloride concentrations in several representative wells (*different symbols and colors*) in the ICPA (Be'er Tuvia region; data from the IWA database, figure based on Furman 1998). *Lines* indicate long-term trends

ICPA as expressed by chloride concentrations. One can note a continuous increase in concentration of the salinity, which is somewhat increasing with time. Similar trends can be seen also for nitrate (The Hydrological Service 2011), indicating that a major source of salinity is agricultural activity.

The salinization of the ICPA was studied by many throughout the years. While the exact weight of the different components is in dispute between scientists, it is clear that the most important processes include (a) backflow from agriculture, (b) introduction of more saline water through artificial recharge (mostly from the Sea of Galilee, see later in the discussion of the aquifer as a storage facility), (c) fluxes from adjacent aquifers and water bodies (The Hydrological Service 2011), (d) reduced aquifer rinse, and (e) spatially imbalanced pumping combined with the role of aquifer thickness (Solomon 2006). Of those only c and d are related to level reduction (due to change in gradients), and even in these cases, the impact is likely small. It is clear that the most important mechanism is anthropogenic activity, mostly but not solely agricultural, on top of the aquifer (Assouline and Shavit 2004).

Nitrate contamination is more complex than general salinity as various biochemical processes (nitrification, denitrification, mineralization, and more) make it difficult to track and quantify nitrogen sources and nitrogen fate in aquifers and in the vadose zone above. Nevertheless, it is clear that nitrogen contamination is primarily due to agricultural activity.

Salinity (and nitrate) increase is often expressed as general increase of the average values (IWA 2010), but careful examination of the spatial distribution indicates the formation of several plumes in the aquifer, mostly in its southeastern parts. The exact formation mechanism was not studied in details for all plumes, but for the few that were studied, it is now believed that they are due to anthropogenic nonagricultural origin. However, geochemical studies, (e.g., Vengosh and Ben-Zvi 1994) suggested that other mechanisms related to entrapped saline water bodies beneath the aquifer are at play. Possibly the formation of the lesser distinct plumes is related to heterogeneity of agricultural activities (source) or of the vadose zone.

While chloride and nitrate contamination is spread over large portion of the aquifer and hence can be regarded as nonpoint source pollution, industrial pollution is regarded as point-source pollution. Since the early 1980s, there is a growing interest in GW industrial pollution. Volatile organic compounds (VOCs), heavy metals, oil residuals, and other industrial pollutants were detected in soil and GW under gas stations and industrial areas, where metal coating, tanning, dry cleaning, and other craftsmen shops were located. As the first drinking water wells were shut due to industrial pollution, the IWA initiated a monitoring program in order to locate other sources, mainly above the ICPA, where the urbanization processes are the most intensive. The growing interest in the field of industrial GW pollution along with the increasing water demand has led to the implementation of site investigation and risk assessment methodologies. The next step was to study remediation techniques and to fit them to the local hydrological characteristics. Currently, about 200 polluted sites, mostly above the ICPA, are under investigation (gas stations, infrastructures, and industrial areas). Almost 800 designated monitoring wells (60 of them were drilled during 2010) are regularly sampled and analyzed by the national laboratory for water monitoring (IWA Annual Report 2010). Groundwater remediation projects are planned or already been carried out in some of the polluted sites. For example, in more than 20 gas stations, an oil lens was pumped and groundwater is treated with different *in situ* remediation techniques, whereas large pump and treat actions are planned in former military sites, accompanied by *in situ* remediation of industrial pollutants such as VOCs and heavy metals (IWA Annual Report 2010). Quality of the treated water is aimed to comply with Israeli Drinking Water Standards (MOH 1995) and therefore designated for public consumption under the supervision of the Ministry of Health.

Along with the investigation and remediation processes, the IWA, as the regulatory authority, has developed legislative and policy barriers to construction projects. These barriers, under the water law, are aimed at implementation of measures to minimize the risk of pollution, control on-site potential pollution sources, and react if pollution occurs.

Looking at the different aspects of water quality and quantity deterioration, and especially in the ICPA, one can easily conclude that the reasons are mostly due to anthropogenic activity over a relatively fragile aquifer system. This includes not necessarily in order of importance (a) intensive pumping of water, at times way beyond the aquifer natural replenishment, and perhaps primarily local increase of demand and production around urban regions; (b) decrease of recharge due to urbanization; (c) insufficient treatment of industrial waste (small- to medium-scale industry); (d) rural untreated wastewater that for many years was left to infiltrate into the aquifer; (e) irrigation with water of lower quality (mostly from the Sea of Galilee); (f) uncontrolled solid waste damps; and (g) minimally controlled intensive agricultural activity.

Many of the above are characteristics of a developing country, and today's image of water quality is mostly the result of less managed groundwater system in the past (or to some degree more accurately phrased, groundwater systems managed for quantity only). Indeed, in the recent decades, many measures were taken to control, reduce, and remediate some of the aspects of groundwater deterioration. Above all this includes reduction of pumpage to safe yield levels. Many polluted sites are now under remediation actions. But perhaps more important, significant measures were taken to reduce pollution at the source. Irrigation over sensitive areas is now limited to higher water qualities; solid waste dumping sites are now controlled and high standards are enforced; industries were connected to specific collection and treatment systems and toxic effluents are treated separately: wastewater from animal slaughter houses (uses high quantities of salt due to religious regulations) and other food industries is treated separately.

8.5 Groundwater as a Short- and Long-Term Storage

Israel is mostly characterized by Mediterranean climate and lies at the desert edge. This means absolutely no summer rains and elevated potential evaporation rates (from 1,500 to 3,000 mm/year; IMS 2012). This makes surface storage of water, although practiced, inefficient. Storage of water in aquifers, and especially in the ICPA that is characterized by (relatively) low hydraulic conductivity and high storativity, is appealing.

Israel uses the ICPA as a storage facility by several means. First, artificial recharge is practiced in several locations with different water sources, and second, the aquifer is considered as a long-term storage, and in sequences of dry years, pumping from that aquifer is increased temporarily beyond its natural replenishment (while in wetter periods, pumping is reduced). This practice can be seen in Fig. 8.4. Note how after the extremely wet winter of 1991/1992 the ICPA portion in the so-called three-basin system drops to around 35%, after much larger portion in the preceding years. Further note the increase in the use of the ICPA following the very dry year of 1998/1999. Similarly, following the wet winter of 2003/2004, the portion of ICPA use drops to 30%.

Artificial recharge to the ICPA is practiced in several ways. First, two facilities for recharge of floodwater were constructed in the aquifer's northern (Menashe) and southern (Shikma) parts, capturing winter flows for summer use. These facilities dam or divert the flow into sandy infiltration ponds, capturing in total between 10 and 20 MCM annually (MEKOROT 2012). Second, several infiltration ponds

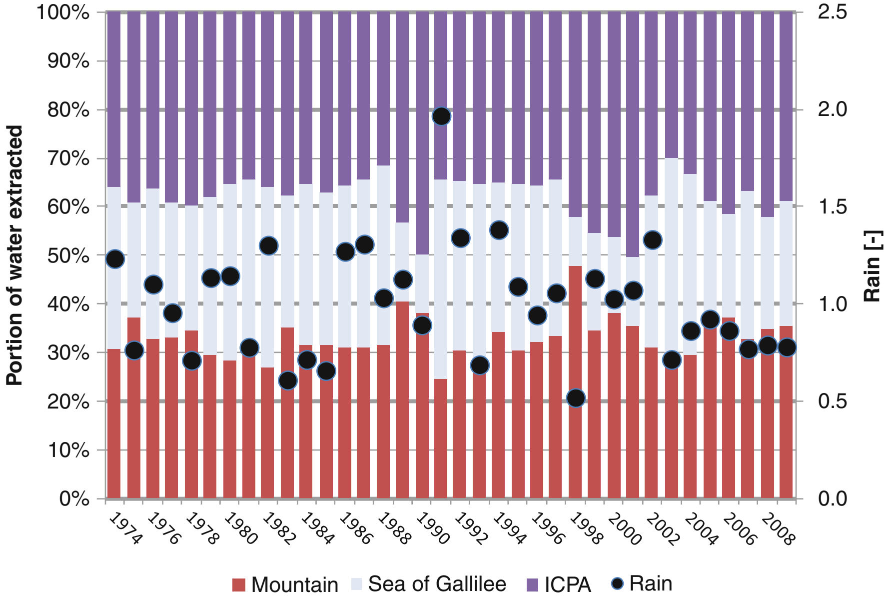

Fig. 8.4 Portion of annual pumpage from the three main sources of the national system, 1970–2006. For Sea of Galilee, pumping is only for the national system and excludes local pumpage. For reference, annual rain is given, normalized by the multiyear station average of 510 mm, for the Mikve Israel rain station (Extraction data based on the Hydrological Service 2011; meteorological data based on the IWA)

were constructed (e.g., near Azrikam) to infiltrate water from the national system (in practice Sea of Galilee water is infiltrated). Third, in few locations, bidirectional wells were constructed so that water can be injected directly into the aquifer (again, almost solely Sea of Galilee water). This was practiced mostly with the mountain aquifer and less in the ICPA as for its favorable hydraulic conductivity. Last, treated wastewater is infiltrated into section of the ICPA. This practice will be discussed further in the next section.

8.6 Groundwater as Part of Wastewater Reclamation System

The need for agricultural water and the decrease in freshwater available (due to increase in the population and the standard of living) led Israel to increasingly use treated wastewater for irrigation. The country is by far world leader in using treated wastewater with about 75% reuse rate (MEKOROT 2012). Most of the treated wastewater is used for agricultural irrigation. The largest facility for wastewater treatment is the SHAFDAN, treating the Tel Aviv metropolitan area's wastewater. The SHAFDAN is located at the south part of the metropolitan and includes three treatment stages, starting with primary and secondary treatment levels which include high-quality activated sludge-based processes, while the third level includes soil aquifer treatment (SAT). The facility's infiltration ponds are surrounded by two rings of recovery wells that abstract the treated water and prevent it from spread to freshwater pumping zones of the ICPA (Abbo and Gev 2008).

By infiltration through an over 30-m sandy vadose zone, the water enjoys seminatural physical, chemical, and biological treatment that includes both aerobic (vadose zone) and anoxic (aquifer) parts and is slightly diluted with the rain that infiltrates into this part of the ICPA. On the average, the treated wastewater resides in the system between half a year and 1 year before pumped by the recovery wells for agriculture in southern Israel, where it is the main agricultural water sources (MEKOROT 2012). Altogether the SHAFDAN facility treats some 150 MCM of wastewater per year and delivers some 170 MCM of high-quality agricultural water (including local natural recharge to the aquifer).

The SHAFDAN facility is using a section of the ICPA. Although the water quality of the SHAFDAN is very high, it is a health concern to nearby wells. To prevent contamination of adjacent sections of the ICPA, the operation of the recovery wells of the facility is targeted at preventing hydraulic gradients toward those sections. In addition, water quality at surrounding wells is intensively monitored.

8.7 Coping with Water Shortage

While the demand for freshwater is constantly growing, the safe supply is decreasing. Water levels of all natural water sources, groundwater as well as Lake Kinneret, are generally depleting and in cases have already dropped below hydrogeologically defined red lines. Further, the Eastern Mediterranean climate is characterized recently by high inconsistency in annual rain and long (5–8 years) periods of drought.

In order to cope with the water shortage, to assure reliable water supply to residents on one hand, and to prevent further deterioration of natural water resources on the other hand, the IWA has taken a series of measures to reduce freshwater consumption and to develop new sources of water. These include water-saving campaign, decreasing freshwater quota for agricultural and municipal irrigation, increasing taxes for overconsumption of water, speeding up the development of new sewage treatment plants and treated wastewater delivery systems, building seawater and brackish water desalination plants, reclamation of polluted GW, drilling groundwater wells in non-utilized section of aquifers, and strengthening enforcement measures to keep proper use of water in the industrial and municipal sectors. Most of these actions are not directly relevant for GW management but are related to general water resources management. GW systems can be used, as described above, as an important part of water resources management at times of shortage, primarily using the slow pace of GW flow for temporal overdrafting. However, one must understand that in order to use an aquifer as backup for dry years, the appropriate surplus storage needs to be considered.

8.8 Summary and Future Challenges

In this chapter, we listed the history of groundwater management in Israel and primarily in its coastal plain aquifer, as reflected by actions. We have seen how excess pumping brought to significant drop in groundwater levels, followed by inland recession of the seawater–freshwater interface. We have seen how intensive agriculture, using local or imported water, caused a decrease in the GW quality, expressed primarily in increase of aquifer salinity and elevated nitrate concentrations. Although these points are now trivial, it seems that planners tend not to consider basic physical processes that lead to these observations.

We have seen also how intensive urbanization over a phreatic aquifer rapidly leads to its pollution. Knowingly and unknowingly, industrial and domestic activities at all levels may and do cause pollution of the aquifer. Aquifer management is not only the appropriate control of pumping operations but also regulating agricultural, domestic, and industrial on-surface activities, monitoring, and remediating existing problems.

The fast pace of the Israeli development caused significant problems to groundwater systems but also derived advanced solutions to these problems. All aquifers in Israel are still operated very close to their boundaries, and likely more problems may arise in the near future. At present, the questions that start to pop up are related to the impact of irrigation and of wastewater irrigation (with solution based on improvement of wastewater quality due to improved treatment and to domestic use of desalinated water), water levels and water quality restoration, the “ticking bomb” of the vadose zone, which contains enormous amounts of salts, nitrates, and other agricultural residues, and the need to share the limited groundwater resources with neighboring countries.

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Chapter 9
Market-Based Regulations on Water Users

Dafna M. DiSegni

This chapter outlines the long-run profile of market-based regulations that have been adopted in Israel over the years in attempting to cope with water scarcity, on one hand, and with increasing water demand, on the other. Particular attention is given to the relative efficiency of applying combined quotas and pricing mechanisms for regulating water use within the agricultural sector, the dominant user of water resources. Finally, we discuss the added benefit from trade when coupled with development of water technologies that increases water resources and water quality and indirect third-party effects of market-based regulations.

9.1 Historical Regulation of Water Use

The debate over the appropriate mechanism for allocating publicly owned resources is relevant for policy makers in a large number of countries, in most of which water resources are controlled by the government. In these countries, the main role of the government is to efficiently allocate the rights to use water while taking into consideration environmental, industrial, and agricultural concerns. Israel is a classical case study in which water is publicly owned and controlled by the government (Israel Water Law 1959) and a case in which water-use regulations are of primary importance.

According to Israeli water law and regulations, water-use rights in the agricultural sector are allocated to private and collectively organized farmers based on their past water use per acre crop (base year 1989). The allocation of water to farmers is also based on the production capacity of the land used and on the size of the community. The allocation of water in the agricultural sector follows a historical trend resembling that of the Western USA, the doctrine of prior appropriation: "first

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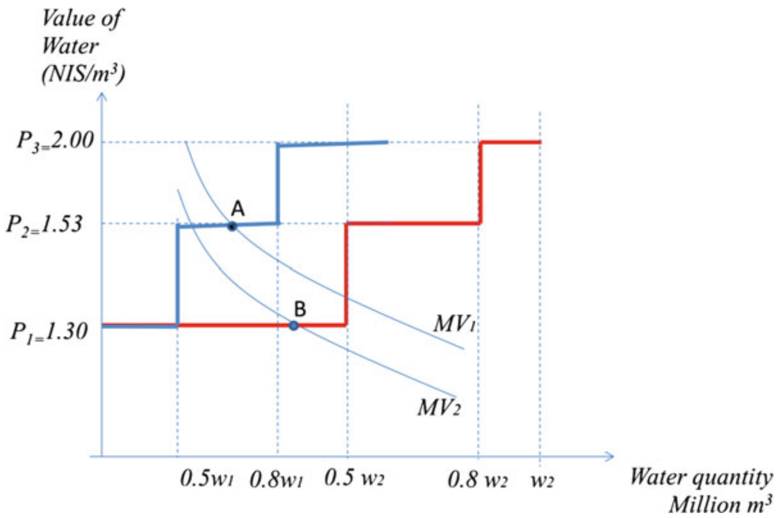

Fig. 9.1 Block rate pricing mechanism. On the horizontal axis, we display quantities in 1,000 m^3, and on the vertical axis, we have set an example of three-stage prices at the levels $P_1 = 1.30$, $P_2 = 1.53$, and $P_3 = 2.00$ (values are close to the values set in Israel during the last decade)

in time, first in rights" and "use it or lose it." This system places a higher value on those users of water that come first, regardless of the ways different uses of water might be valued today.

In principle, the allocation of water to farmers is reset every year. In practice, it has not changed much in several decades and continues to be proportional to land area cultivated by each farmer. Since 1991, the government of Israel has established increasing block rate tariffs for the allocated water. The lowest price block is applied for consumption of up to 50% of the (historically fixed) farmer's quota. The medium tariff is levied on consumption between 50 and 80% of the quota, and consumption above 80% is charged the highest price. Using historical quotas as benchmarks for pricing water creates variation across farmers regarding the price schedules they face, as demonstrated in Fig. 9.1. In the figure, we present the supply functions faced by two representative farmers, 1 and 2, who receive different quotas of water and different marginal valuations for water, presented by the curves MV1 and MV2, for farmers 1 and 2, respectively. The horizontal axis displays the quantity of water used by each farmer, and the vertical axis displays the prices paid by each farmer. For example, we set the allocated quota to farmer 1 as w_1 million m^3 of water per year and the allocated quota to farmer 2 as w_2 million m^3 of water per year, where w_2 is larger than w_1 ($w_2 > w_1$). Setting increased prices per blocks of water results in a situation where farmer 2 uses a larger quantity of water at a lower price than farmer 1, and we have impaired marginal valuations for water at the equilibrium, points A and B. Farmer's 1 marginal value for water is higher than the marginal value of water to farmer 2, and yet, under the block pricing system, farmer 1 uses less water than farmer 2.

In reality, such inefficiency in pricing and allocation has been observed in Israel over a long period of time. A careful examination of the consumption trends in Israel at the regional level reveals inefficiencies in allocation across all regions. Table 9.1 displays the distribution of farmers and water usage over the three block prices. Block 1 (first three columns from the left) details the farmers that used up to 50% of their allocation. These account for about 29% of the farmers. Those farmers received about 12% of the overall water allocated for irrigation. Block 2 details the farmers in various regions that used between 50 and 80% of their quota, and block 3 details the allocation and water use by farmers in Israel that used 80% and above of their quota. In the year 2008, on average, 29% of farmers used up to their first block and consumed a share of 2% of the water, while almost 60% of the farmers reached the highest price block and consumed a share of 87%, of the available water for agriculture, which was higher than the total allocation of water to these farmers. Similar trends have been identified by Bar Shira et al. (2006) for the 1990 decade on a state-level analysis.

A situation in which almost 1/3 of the farmers use less than 50% of their quota while a large share of farmers use their full quota and beyond signals a significant potential for gain from trade among parties. The disparity in payments at the margins is a second symptom of the inefficiency of the adopted combined quota and step pricing regulation.

Inefficiencies in the allocation and the consumption of water in Israel were discussed in more than few studies since the early 1990s and include Back and Zender (1993), Kislev (2001), Tsur (2004), Fischhendler and Feitelson (2005), and Bar Shira et al. (2006). Sources of inefficiencies which we identified in these studies are primarily (i) ignorance of water value: the water does not flow to the farmers who value it most, since the marginal unit is sold at three possible prices with no direct relation to the farmers' valuation of water. (ii) Supply of water is inelastic within the agricultural sector: some farmers are given an allocation of water and do not use all of their allocation, while others need more water than their given allocation. Furthermore, transferring the water is illegal and hence there is no full appropriation of the value of water for agricultural usage. (iii) The allocations are mostly determined on the basis of historical data and do not necessarily reflect with any accuracy current needs and preferences. During dry years, crosswise cuts on all allocations are made, without personal consideration, while the impact of dry weather may vary by region and farmers. Bar Shira et al. (2006) have estimated a 1% loss in welfare when switching to block pricing compared to one fixed price, along with a decline in water use of about 7% and price increase of 20%. Block pricing benefits the less productive at the expense of the more productive.

The underlying rationale for introducing a block pricing system has been to induce water-use reductions without burdening farmers with the full cost of water supply that a simple marginal cost pricing would have entailed. Concerns have been raised that adopting marginal cost pricing approach within the agricultural sector would crowd out family-based farms. In contrast, an increasing price schedule would allow imposing a high, and even a socially optimal price at the margin, while maintaining a lower average price, for keeping small farms in business. Theoretical

Table 9.1 Water use and water allocation in various districts in Israel

Region	1st block % farmers	1st block % allocation	1st block % used	2nd block % farmers	2nd block % allocation	2nd block % used	3rd block % farmers	3rd block % allocation	3rd block % used	Total No. of farmers	Total Allocation (Million m^3)	Total Used (Million m^3)
North	35.1	16.4	2.2	12.4	18.0	14.2	52.5	65.6	83.6	920	145.6	128.5
Galilean Valleys	41.3	4.8	0.7	9.1	9.4	5.5	49.5	85.8	93.8	755	191.0	184.6
Center	27.5	14.5	3.6	12.7	13.5	9.7	59.7	72.0	86.7	2,886	142.4	135.7
Plain and Mountain	17.5	10.7	1.9	7.9	9.2	6.7	74.6	80.1	91.4	831	87.4	85.3
South	27.3	12.9	2.3	7.9	15.2	12.0	64.8	71.8	85.7	693	243.7	225.8
Jordan valley	36.5	22.2	6.5	10.6	13.3	10.0	52.9	64.4	83.5	85	46.6	39.3
Average total	29.1	12.2	2.3	11.0	13.4	10.1	59.8	74.4	87.6	6,170	856.8	799.4

Data Source: Israel Central Bureau of Statistics (2008) support for this assertion is provided by Bar Shira and Finkelshtain (2000) and Bar Shira et al. (2006) that have empirically tested the underlying theoretical hypothesis that increasing block tariffs implements the second-best social objective of maximizing welfare subject to a desired number of small firms in the industry. While conceptually attractive, the implementation of block prices raises several practical difficulties. In particular, to achieve the second-best allocation, each and every farmer should pay, in equilibrium, the socially optimal price at the margin. The potential improvement from a transition to a market-based regulation is discussed in the following sections.

9.2 Efficient Market Mechanisms for the Allocation of Water

The constrains posed by historical allocations and inefficiencies of block pricing for achieving the best allocations of water for the agricultural sector have resulted in the development of an informal trade in water, under which farmers transferred water quotas in bilateral agreements. Such transactions increased in volume during the first decade of the twenty-first century to the point that transfers have been acknowledged by the authorities as a tool to potentially improve water allocation and water use within the agricultural sector. In 2008, the Israeli Ministry of Agriculture had set a formal framework for bilateral water transfers, after a severe year of drought in which a large number of farmers used their full quota of water and asked for additional water for irrigation, while other farmers were left with unused quotas of water. The inefficiency in water allocation was transparent to all and had accelerated the move toward water transfer (WT) regime. The WT regime has been approved subject to the following constraints:

(a) Transfers are allowed only in a bilateral framework to farmers from the same region.
(b) Transfers are subject to hydrological constraints.
(c) Transfer is on an annual basis and will not impact the quota allocated to the farmers in subsequent years.
(d) Transfers are restricted to 30% or less of the transferring farmer's annual quota.
(e) The quota of any farmer plus the water transferred to him will not be larger than the quota set to this farmer in 1989. That is, there exists an upper limit for the quantity a farmer can receive after transfer.

Constraints (d) and (e) are designed to restrict water transfers so that transfers are put into action only to overcome periodical water shortages and do not have an impact on the long-run agricultural activity. Water transfers were approved also in subsequent years and officially included in the Water Act Amendment signed by the Ministry of Agriculture in 2011. After 4 years of water transfers, it is evident that transfers alleviate short-term water constraints among farmers. Figure 9.2 details the transfers of water in each district over the years 2008–2011, the first 4 years of the WT regime in Israel. We observe a clear increasing trend in the volume

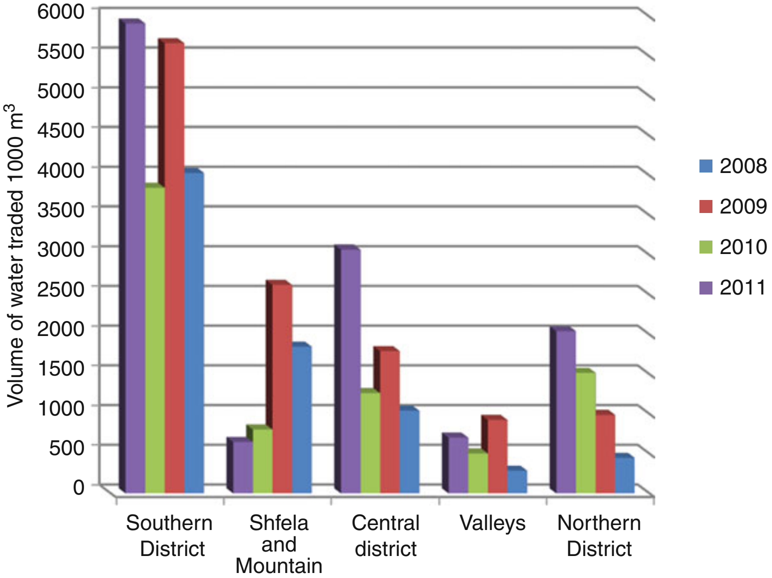

Fig. 9.2 Water transfers over the period 2008–2011 in Israel, by districts

Table 9.2 Water transfers among farmers in Israel

	Year			
Water transfers (in 1,000 m^3)	2008	2009	2010	2011
Total volume of transfers	7,646	11,985	7,925	12,366
Fresh water transfers	5,236	9,363	7,412	5,994
Total fresh water for agriculture	454,000	354,000	430,000	442,000
Percent of water transferred	1.15	2.64	1.72	1.36
Number of transactions	192	470	287	334
Refused transactions	32	32	21	30
Total requests for water transfer	224	502	308	364

Source: Rofe (2012)

of water transferred in the northern district, the valleys (lower Galilee area), and central and southern districts. Over this period, the quantities of water transferred have significantly increased (from 7.646 to 12.366 million m^3), and the number of transactions has almost doubled (from 192 transactions in 2008 to 334 transactions in 2011), but transfers are only 1.15–2.64% of total freshwater allocated to the farmers (Table 9.2).

The WT regime is a clear step forward to efficiency, but the bilateral trading framework and restricted volume of trade do not release the sector from its bureaucracy and inefficiency.

Existing transfers signal that farmers could increase their welfare by reallocating water between users. The authorities have also acknowledged the potential improvement in water allocation using a formal trade system in water but have not yet designed water for markets and methods of trade that would result in optimal water use.[1] It is expected that under a market mechanism, those who value the water most (those with high returns to water) will bargain and receive the water quota for agricultural usage, pending on water availability and payment. Current inefficiencies in water use that result from asymmetric information among farmers and authorities, as well as failures due to lack of use control, fixed prices and unequal pricing with respect to identical users could be reduced when using multilateral trading via well-designed market mechanisms for the reallocation of water for agricultural usage.

In search of an optimal trading mechanism, it is advocated that the adoption of an auction mechanism would generate the highest social welfare. The auction mechanism is expected to reallocate water among users in a more efficient manner. Economic theory outlines the superiority of auctions over other trading institutions (e.g., bilateral bargaining) in different dimensions. In particular, auction results in a transfer of goods from sellers who value them least to buyers who value those most, with reasonably low transactions costs (McAfee and McMillan 1987; Milgrom 1987), and it is characterized by evolutionary stability (Lu and McAfee 1996). Auction theory provides fundamental discussions on the equilibrium properties and relative efficiency of central auctions' designs. However, the multiplicity of equilibria in a multiple-unit trading system does not allow for easy comparison across auction formats.[2]

The potential increase in welfare to farmers and to society from auctioning water has been studied by DiSegni et al. (2012). The study forecasts an 8% increase in social welfare when moving from an allotment allocation at three block prices to a uniform auction mechanism. The increase in welfare is attributed to the rise in consumption (7% higher consumption in auction than in the allotment system), and more efficient allocation among farmers, where water is allocated to farmers who value it most. Under this mechanism, farmers are expected to pay a higher price per unit of water, and on average, farmers' profits are lower. The auction, however, is expected to strengthen market concentration in the agricultural sector. Farmers

[1]Early recommendations to create markets for water were suggested by a special committee report on water prices in Israel, submitted to the office of the Israeli Prime Ministry on 2003 (Feinerman et al. 2003).

[2]In many circumstances, auctions as trading institutions are found to be superior to bargaining institutions. By using a model of monopoly with random matching heterogeneous buyers and the possibility to resell, Milgrom (1987) pointed out that auctions often lead to an efficient and stable outcome. The intuition that auctions have an inherent advantage over bargaining mechanisms with random matching among the players is straightforward. Auctions have the ability to discriminate among buyers and choose the highest value buyer (McAfee and McMillan 1987; Milgrom 1987). However, in the absence of this advantage (e.g., homogeneous environments in which buyers and sellers are all of one type), it is unclear whether auctions remain superior to bargaining. Lu and McAfee (1996) considered an environment of homogeneous buyers and sellers, which eliminates the advantage auctions possess of matching buyers and sellers, showing that both auctions and bargaining are at equilibrium. Nevertheless, only auctions are evolutionarily stable.

that have received a relatively high share of water in the allocation system continue to dominate in shares under the auction system. Farmers with a relatively high demand for water (associated with those farmers who also have a larger agricultural land area) are expected to benefit from the move from block pricing to the auction mechanism. The auction might also accelerate the exit of small farmers from the sector (DiSegni et al. 2012).

Adoption of an auction mechanism should, however, direct attention to existing limitations in setting a national trading mechanism. These include, for example, technical constraints on the transfer of water among regions and within regions, the existence of political, social, and environmental constraints that need to be taken into consideration when adopting a state-level auction, as well as the fact that farmers in Israel use water of different qualities/types (freshwater, saline water, desalinated water, treated water), and where for some farmers, one type of water cannot be substituted by other types of water. These constraints naturally lead to considering a second-best auction carried on a regional level.

The impact on each region may vary, depending on the relative size of cultivated land area and marginal benefits to the farmers from water use. Following the simulation carried in DiSegni et al. (2012), when moving into regional auctions, the bidders in the central district are the most negatively affected, while the bidders in the southern district, the Jordan valley, and the northern districts gain advantages and increase their welfare by about 2–7%.

9.3 Trade in Water and Technological Improvement

Water shortage in Israel, along with water regulations that have imposed limitations on water usage and water transfers, has resulted in raising barriers for maximizing profits. At the same time, however, they stimulate alternative actions that can effectually increase the marginal benefit from the use of water in agriculture. One important category of actions is the development of technologies that increase agricultural yield using the same quantity of water, as for example, by introducing the dropping system technologies, genetically modifying plants that require the use of less water, or different types of water and other cultivation technologies that increase yield altogether by preserving soil and water qualities. These technological improvements in water use and agricultural yield growth have indirectly increased farmers' value of water and have increased efficiency in the use of water. Technology development gains added values when moving into a water trading system. The trading system gives incentives to the farmers to increase water saving and gain from water sale, if allowed, and particularly when the auction is designed in such way that quotas are allocated to farmers as in the past years, and farmers are allowed to freely buy and sell reserves of water. Alternatively, in a system where all water is auctioned by one auctioneer, farmers with high water values are expected to receive a larger quantity of water and increase their overall profits from water use.

Investment in technologies directed to increase water resources like saline water, desalinated water, and effluents have de facto increased water availability for the agricultural sector and others. Increasing the quality of water and bringing it to the stage at which most farmers can use all water types facilitate the move into one trading system in which only one type of water is traded (particularly treated and desalinated water) and where different types of water are equally valued by the farmers. The use of alternative sources of water might also facilitate transfers as allocation can be carried from the nearest source of water, saving transfer costs to the system overall.

9.4 Third-Party Effect When Moving into a Market-Based Regulation

We wrap up the discussion on market-based regulations with few remarks that relate to third-party effects of trade. Beyond the efficiency characteristics of water markets, adoption of the trading mechanism should be weighed against a number of third-party effects which arise as a consequence of markets being incomplete. Third-party effects, which often take the form of externalities or transaction costs spillovers, are associated with economic costs that are not fully reflected in the prices of goods or services. Third-party effects may be vertical (between the farmers and retailers or consumers) or horizontal (between farmers). Three key effects might arise from trade in water and related to (a) reliability of supply, (b) storage and delivery charges, and (c) water quality.

(a) *Reliability of Supply.* Supply reliability is determined by the natural variability of the resource pool and by the trading equilibrium. While the water quotas ensured an allocation of water among farmers and a relative known diffusion of market forces, trade in water might strengthen farmers who possess a relative large agricultural land area and weaken small farmers. Such an outcome would result in lower reliability of supply by small farmers along with increasing probability of pecuniary externalities by big farmers, thus increasing the agricultural product price and decreasing consumers' surplus.
(b) *Storage and Delivery Charges.* Trade among farmers might require storage and delivery that are costly. These costs resulting from transactions might decrease the overall surplus from water trading, if applicable.
(c) *Water Quality.* Trade might not include a clear specification with respect to the quality of water traded and may complicate control over the use of water from different types at a certain landscape (if different types of water are traded). Failing in control for the quality of water traded among parties and used by parties may result in real externalities as a consequence of incompatibility between the water type and the irrigated landscape. This type of third-party effect is likely to be resolved when trade is restricted to one type of water or alternatively, when clear restrictions are imposed on the mix-up of different types of water for irrigation of agricultural landscapes.

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Chapter 10
Policies for Water Demand Management in Israel

David Katz

10.1 Introduction

Facing chronic water scarcity,[1] Israel has invested heavily in supply augmentation, including cloud seeding, reclamation and reuse of wastewater, and more recently large-scale seawater desalination. Given the physical and technological limitations as well as the economic costs of supply augmentation, Israel has also pursued a wide array of demand management policies. While both supply and demand management policies have always been pursued concomitantly, the relative emphasis placed on each has shifted over the course of the country's development.[2] In the early years of the country, emphasis was placed on development of existing supplies and large infrastructure projects such as the National Water Carrier. By the 1970s and 1980s, all renewable freshwater resources were exploited, and the focus was more on demand management. Failure to reduce demand, especially during extended droughts, such as those in the 1990s, led to overwithdrawals and a renewed focus

[1]Chronic water scarcity has been defined differently by different sources. A commonly used reference is the so-called Falkenmark measure (see, for instance, Lawrence et al. 2002), which defines chronic water scarcity at the national level as a supply of less than 500 cubic meters per capita per year (m^3/cap/year). As of the writing of this chapter (in 2012), Israel had roughly 200 m^3/cap/year in natural renewable water resources. If one adds reclaimed wastewater and desalination, the amount grows to roughly 300 m^3/cap/year – still well within the definition of chronic water scarcity.

[2]In some cases, the distinction between supply and demand management is fuzzy. For instance, reduction of water losses due to leakage could be considered both provision of additional water to the end users (supply augmentation), as well as reducing the overall amount withdrawn from the sources (demand management). In general, however, the distinction is a useful one.

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on supply augmentation, which, given declines in the cost of desalination, again took precedence at the beginning of the twenty-first century. However, given the costs of desalination, as well as the various environmental and even security impacts associated with it, demand management is still a critical element in Israel's overall water management strategy.

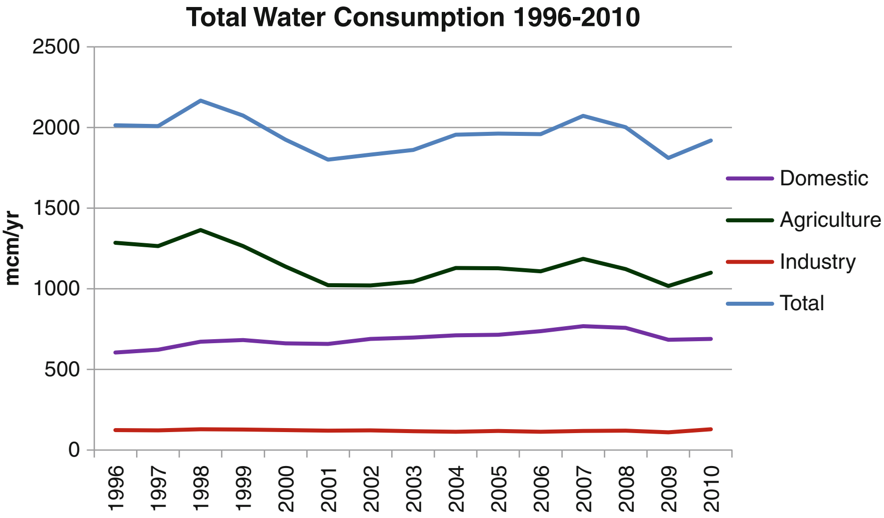
This chapter will review various demand management policies that have been or are currently being implemented in Israel, together with a discussion of the relative advantages and disadvantages of each. Specifically, a distinction will be made between market mechanisms for demand management – such as pricing, water trading, and economic incentives for conservation – and nonmarket mechanisms, which include a wide range of options such as quotas, public awareness campaigns, and various technical fixes. Market mechanisms are often promoted by economists primarily for reasons of efficiency and cost-effectiveness, but also for ensuring the long-term economic viability of water systems, and even at times for reasons of equity. Such mechanisms face several challenges, including often still political resistance. Nonmarket policies are often easier for policymakers to draft and often provide certainty that nonmarket mechanisms do not. The remainder of this chapter will explore how both of these types of policies are applied to management of water demand in different sectors in Israel. It does not attempt to provide a comprehensive overview of use of various instruments but rather to give a general overview of how and why different types of policies have been applied.

10.2 Market Demand Management Mechanisms

10.2.1 Pricing

Pricing of water is the primary means of market mechanism employed by Israel for demand management. Municipal water consumption is now the largest consuming sector of freshwater in Israel (see Fig. 10.1).[3] Few quantitative restrictions are applied to municipal water use. Household consumers, for instance, which make up the bulk of municipal consumption, can use unlimited amounts of water. Until relatively recently, the price of water for urban consumption was subsidized by the government. In recent years, it has begun a policy of full-cost pricing, a policy which it is also currently expanding to freshwater used in agriculture. The objectives of this policy are twofold: (a) to send proper price signals to the public regarding the true costs of water provision and treatment and (b) to ensure that the water sector can cover these costs, thereby eliminating or at least seriously curtailing the need for government financial support for the sector. Under the policy, the average price paid by the consumer is set to cover the average cost of supply (and for the municipal sector, also the average cost of wastewater treatment). Although water to all sectors

[3] Agriculture still consumes more total water; however, roughly half of this is reclaimed wastewater.



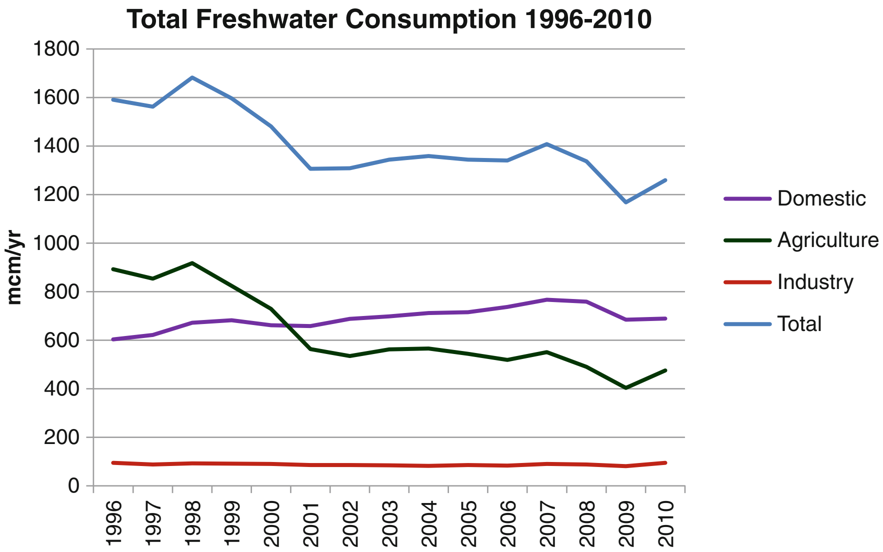


Fig. 10.1 Total water consumption (*above*) and freshwater consumption (*below*) 1996–2010 (*Source*: Israel Water Authority 2012a)

is priced using an increasing tiered tariff, the prices do not necessarily reflect the marginal cost of supply, which for Israel is desalination, nor do they reflect externalities such as pollution from desalination or public good aspects of water consumption such as the decline in in-stream flows and water in natural ecosystems. Rather, average cost of supply is calculated as the cost of production and delivery of water, including amortization of infrastructure investments and other fixed costs.

For purposes of economic efficiency, the price charged for freshwater should be identical across sectors and differ by regions in accordance with variations in cost of supply. In reality, the pricing in Israel has been the opposite. As a matter of public policy, Israel implemented a policy of cross-subsidization, whereby the price of water to the municipal and industrial water sectors was set in order to subsidize the supply of water to agriculture. That policy, common in many countries, is now being phased out – a reflection both of the acknowledgement of the inefficiencies that it caused in the agricultural sector (e.g., cultivation of water-intensive crops whose economic value was less than that of the true cost of water) and of the declining economic and political power of agriculture.

Other types of cross-subsidies continue to exist in Israel's pricing policy, however. The government has adopted a policy according to which prices are not to vary based on geographical location. Thus, the basic price paid for water is the same in the hills of Jerusalem as near the banks of the Sea of Galilee, despite significant differences in costs of supply. As such, cities and farmers near water sources are in effect subsidizing those further away. In the case of municipal water, some geographical differences exist, based on the additional costs of the local water cross-subsidized utility and sewage treatment facilities. However, even here, a cross-subsidy exists, as, in order to ensure relative cost parity across municipal consumers, low-cost utilities are charged more than high-cost utilities or those that require significant infrastructure upgrades. Such a situation has created a disincentive for utilities to increase efficiency (Kislev 2011). The Water Authority expects economic convergence between water utilities, thus, that this cross-subsidy will not be significant in the future; however, it provides little rationale for why this optimistic outlook is likely (Kislev 2011).

Municipal water is provided using a two-tiered increasing tariff that is adjusted for number of persons per household. As of early 2012, this was 8.63 shekels for the first 3.5 m^3/capita/month and 13.89 for any additional water consumed (see Fig. 10.2). In theory, increasing tiered tariffs can provide an incentive to discourage overconsumption while also meeting public policy and humanitarian objectives of providing water for basic needs at affordable prices.[4] In order to serve as an effective demand management tool, however, at least one tier must be higher than the marginal demand for water at the desired quantity, and demand must be at least somewhat elastic. According to available estimates, municipal water demand in Israel is very inelastic. A studies by Nisan (2006) and Dahan and Nisan (2007b) estimated demand in various cities in Israel at −0.17 to −0.2.[5] The implication of

[4]Dahan and Nisan (2007a) demonstrated that the adjustment for number of persons per household is not implemented uniformly across demographic sectors in Israel. They note that groups that do not have Hebrew as the native language, such as Arabs and immigrants, tend to exploit the benefit of additional water at low tariffs less than native Hebrew speakers. They attribute this to the associated costs of information, given the need to fill out a form declaring a change in the number of persons per household.

[5]The meaning of an elasticity of −0.2 is that a price increase of 10 would decrease the quantity consumed by roughly 2%. Analyses of studies of residential and urban water demand from around

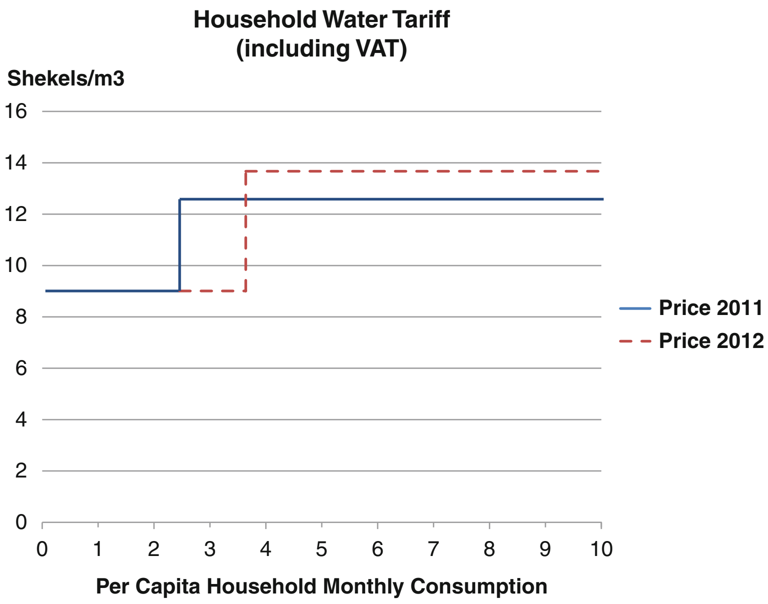


Fig. 10.2 Domestic water and sanitation tariffs (as of 2012) (*Source*: Israel Water Authority 2012b)

the relatively inelastic demand is that price changes need to be significant in order to affect a meaningful change in consumption. Such dramatic price increases tend to bring about public opposition. How much such reactions are justified is a matter of debate. The average price for water in Israel in 2008–2009 was only slightly higher than the average of prices in other OECD nations (OECD 2010), although the average share of disposable income spent on water per household (1.08%) was higher than all but three other OECD countries (OECD 2012 and Central Bureau of Statistics).

Prior to 2010, municipal water was priced using a three tier tariff. In 2009, amidst a multiyear drought and water levels at record lows, the Water Authority initiated an attempt to raise the price of the third tariff – that for relatively large amounts of household consumption – by 40%. The primary goal of the price changes was to reduce excess consumption during drought, while the secondary motivation was to raise extra revenues for highly underfunded water infrastructure. Though the majority of consumers would have been affected by this price reform – as they did not consume enough to reach the third tariff tier – public opposition was

the world found that elasticities tended to be in the range of −0.2 to −0.8 (Dalhuisen et al. 2003; Espey et al. 1997; Hanneman 1997; Nauges and Whittington 2010). Thus, demand in Israel is at the more inelastic end of this range.

vociferous, and politicians rallied to the populist calls for repeal of what was dubbed the "drought tax." In the end, the "drought tax" was frozen and, over 2 years later, has still not been implemented.

The public response to the so-called drought tax indicates another limitation of using price mechanisms as a demand management tool. To be truly effective, consumers must be aware of the prices they pay and adjust accordingly. A survey of the Israeli public conducted around the time of the drought tax found that 77% of those surveyed were unaware of the price they were paying for water (Peled 2009). Furthermore, consumers receive water bills bimonthly, and thus, there is a significant lag time between consumption and the price signal that they get in the form of a water bill. Hence, price mechanisms alone are likely not the optimal demand management tool for situations in which a relatively rapid response is needed, such as during acute drought periods. In order to reduce lag times, as well as public outrage, informational campaigns are necessary. In the case of the drought tax and other changes to water prices in Israel, despite the informational campaigns, many consumers were unaware of the changes as they occurred, realizing them only after receiving substantially higher bills. They then channeled their anger into public protest. Others joined the protests out of fear, even though they were not directly affected by the price reforms.

During the same period, incremental price reforms on the lower tiers of the consumption passed with less public outrage. This occurred despite the fact that such price reforms are regressive in nature, meaning that proportionally they affect poorer populations more than richer ones. As stated, shortly thereafter the third tariff was eliminated completely. Incremental changes to prices are useful for revenue generation; however, they are less so for purposes demand management as consumers tend not to notice and thus not to change behavior.

In the past, water used for home gardening and home irrigation was priced lower than other domestic uses; however, recent price reforms have also raised price of water for gardening to bring it in line with the price for other uses. The rationale for the reform was to reduce inefficient water use. This use of water is likely the most elastic element of residential water demand, and thus price increases are likely to reduce consumption. Because irrigation of gardens and yards is a relatively small share of overall residential demand, however, the overall impact on the national water budget of this reform will be modest. In addition to economic efficiency and demand management, this price reform also had a social element, as the segment of population with yards and gardens tends to be more affluent than average, and the lower prices were seen as a benefit largely enjoyed by the rich. There have been protests over this price reform, based on claims that yards provide public goods, that the water use is nonconsumptive and thus at least partially replenishes groundwater, and that water for home irrigation does not need the level of treatment that other freshwater does, and so should not have to bear the cost. These protests have not been effective, however, and a return to the discounted rate for home irrigation seems unlikely.

While demand for municipal water consumption is highly inelastic, the same is not necessarily true for water consumption in agriculture and industry. These sectors

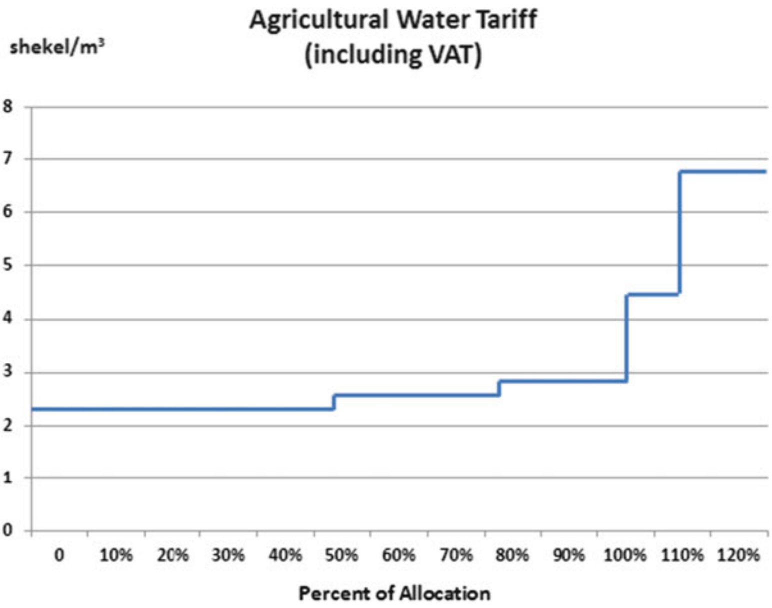


Fig. 10.3 Agricultural Water Tariffs (as of early 2012) (*Source*: Israel Water Authority 2012b)

have what economists refer to as a derived demand for water – that is, they demand water not as a final good as do residential consumers but rather as an input for production. Thus, they can quantify relatively precisely the marginal value of water and adjust demand accordingly. As opposed to municipal demand, these two sectors receive water according to quotas issued by the Water Authority, as will be explained in more detail later. Various research has shown, however, that these sectors are price sensitive. Agricultural users pay for water according to an increasing tariff structure based not on the absolute quantity consumed but rather on the percentage of allocation consumed. The first 50% of their quota is supplied at a given price (2.079 shekels as of 2012), which increases for the next 30%, and increases yet again for the final 20% (see Fig. 10.3).[6] As such, the pricing structure for agriculture is often presented as a three-tiered tariff. In practice, pricing for this sector is actually five-tiered, as farmers are charged significantly higher if they exceed 100% of their allocation (see Fig. 10.3). In addition to the higher tariffs, farmers exceeding their quotas may also see water supply cut and/or risk future reductions in allocations.

Kislev (2011) has shown that many farmers are not exploiting all of their quotas, indicating that the marginal price (the third tier) is likely the limiting factor for their consumption. The real effective price paid by farmers for a cubic meter of water has tripled since the 1970s (Kislev and Vaksin 1997; Margoninsky 2006;

[6]In theory, such increasing block-rate tariffs can be economically efficient, however, Bar Shira et al. (2006) have shown that this is not the case when using a combined quota and block-rate system, as is done in Israel.

Kislev 2011), this despite strong economic lobbying by the agricultural sector (Feitelson 2005; Margoninsky 2006). As a result, many farmers have been priced out of production, especially for low-value crops. The price of freshwater for agriculture is continuing to rise almost yearly as part of government policy designed to raise the price to reflect actual production costs and promote a transition among farmers from irrigation with freshwater to that of reclaimed wastewater (Lavee 2008; Kislev 2011).

Treated wastewater is an increasingly important source of water for agriculture in Israel, as seen in Fig. 10.1. Treated wastewater is priced at levels much lower than freshwater, as the water is of inferior quality (e.g., generally higher salinity and higher risk for pathogens), and uses restrictions both in terms of areas in which it can be used and type of crops to which it can be applied. The true cost of treated wastewater is the cost of treatment plus the cost of storage and delivery, as well as scarcity rent. (Storage in reservoirs or aquifers is necessary as wastewater is produced year-round, while demand for irrigation water is largely restricted to the summer months.) The price of treatment is covered by the sewage charge in the municipal water tariffs. Actual pricing of treated wastewater, including how the costs should be distributed between municipal and agricultural consumers is an ongoing policy controversy. While it is clear that it is a valued resource for agriculture, farmers stress that they are providing a public service by taking the treated wastewater, disposal of which would otherwise be a cost to municipalities. As such, cost sharing between the sectors remains hotly contested. In terms of demand management, the primary goal of the government is to price treated wastewater such that it is an attractive alternative to freshwater, while still reflecting the fact that it too, is a scarce resource.

10.2.2 Extraction Levies

The cost of water to consumers is meant to cover the average cost of supply (and in the case of municipal water, also sewage collection, treatment, and disposal). The national water company Mekorot supplies over 70% of all water in Israel and over 80% of municipal water. The remainder is supplied by various local suppliers. For local suppliers, an extraction levy is assessed in order to ensure cost parity among suppliers. The levy is designed to bridge the gap between the average cost of supply and the cost of an individual supplier and is an effective tool in reducing consumption by consumers who would otherwise have access to low-cost supplies. In recent years, the Water Authority has introduced differential extraction levies within stream basins, whereby levies are higher upstream than downstream. This pricing scheme is an effort to incentivize leaving water for in-stream flows. Such an approach is a welcome use of pricing as a tool for promoting efficiency and is one of the rare instances of internalization of environmental costs of water extraction in water pricing in Israel. Its effect in constraining overall demand is limited, though it may have significant impacts on flows in particular basins.

10.2.3 Water Markets and Trading

Markets for water trade have long been advocated by economists, primarily for their potential improvements in economic efficiency within Israel (e.g., Becker 1995), but also as means of addressing allocation issues between Israel and its Arab neighbors (e.g., Fishelson 1994; Yaron 1994; Zeitouni et al. 1994; Fisher and Huber-Lee 2005). However, as opposed to other countries with established private water rights and active water markets, currently options for trade are limited in Israel. Water quotas for agriculture and industry are, at least in theory, issued to consumers by the Water Authority each year based on a number of factors, including total available resources, historical use, and estimates of the economic productivity of the water. In general, recipients have no rights to trade them. Even if water trade was allowed, it is not clear that given the existing water rights, substantial trade would occur. This is because a willingness to trade water rights could jeopardize future allocations by the Water Authority. That said, however, limited water trade does occur. Some irrigation cooperatives, for instance, get a collective water quota, which they then allocate among members. Some of these cooperatives allow trading among partners.

Water trading markets, while promoting efficiency, do not play a role in reducing overall demand. The exception to this is the policies involving buyback by the government of water allocations, primarily those of farmers, during times of drought. While the Water Authority could simply cut water quotas, buyback of water allocations is considered an economically efficient policy in that it takes water from those with the lowest marginal value at the least cost to the government. In addition, in contrast to simply cutting quotas, buybacks face little political resistance. Still, such buybacks have been implemented infrequently in Israel.

10.3 Nonmarket Demand Management Policies

10.3.1 Water Quotas

Far and away the primary tool used by policymakers for limiting demand for water in Israel has been the use of quotas for water consumption. As mentioned, quotas are not used for regulating municipal water consumption but are used for agriculture and industry. The dramatic decline in consumption of freshwater by the agricultural sector over the past two decades is a direct result of cuts to quotas issued to farmers. As a result of these quantitative restrictions, agriculture has been replaced by municipal consumption as the primary freshwater-consuming sector in Israel, as can be seen in Fig. 10.1. As mentioned above, it can be claimed that water in agriculture is price-rationed given that many farmers do not exploit their full quota allotment. However, it is the quotas themselves that determine the water price, as tariff tiers are a function of percentage of quotas consumed. Thus, a farmer with a quota of 1 million cubic meters (mcm) per year would pay only the lowest tier tariff for consumption of 500,000 m^3, but a farmer with a quota half that size would be charged all three tariff levels for the same amount of water. For this reason, the distinction between price rationing and quantitative rationing of water, often made by economists (see, e.g., Moore and Dinar 1995), is not clear-cut in the case of Israel. Such somewhat academic distinctions aside, there can be no doubt that the issuance of quotas and their reductions, whether absolute or temporary in times of drought, have been the primary mechanism by which the government has attempted to limit demand within the agricultural and industrial sectors.

The contribution of water quotas to further reduction in demand for freshwater in Israel, however, is unclear. While there is no sign that the government is going to abandon the current quota system, quotas to the industrial sector have been relatively constant over time (see Fig. 10.1) and are unlikely to be cut significantly.[7] Quotas to the agricultural have been reduced significantly to only 450 mcm/year from over 1,200 mcm at their peak. The government has determined minimum "iron allocations," below which they will not reduce agriculture's allocations of freshwater. It has failed to live up to this promise and in 2009 reduced allocations below 500 mcm (the then "iron allocation" level). However, it is not clear how much further the government will be willing to reduce agricultural water quotas. The government has indicated that it intends to continue the shift of agricultural water use from freshwater to treated wastewater. However, there are geographical limits to the economic feasibility of such a switch (the bulk of municipal wastewater is produced in the urbanized coastal region, while agriculture is dispersed in rural regions throughout the country). There are also environmental concerns regarding salinization and other impacts on the soil and groundwater in areas irrigated with treated wastewater. Even in such areas, periodic use of freshwater to flush out salts is often implemented. Naturally, farmers have protested fiercely against quota reductions and can be expected to do so even more so in the future, given the government's commitments to minimum "iron" quotas. Furthermore, environmental organizations and others who largely protested against water use by agriculture in the past have toned down such criticism in the past years given both the postreductions of freshwater allocations to farmers and an increasing recognition of the value that agriculture plays in preserving open spaces in Israel.

10.3.2 Nonquota Use Restrictions

In addition to quantitative restrictions on water use, Israel has implemented policies involving a number of other limitations on water use. Such policies include bans on

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[7]The most likely scenario for a decline in industrial water demand is reduced demand by the textile sector. Several such companies face increasing economic competition from abroad, and it is unlikely, should these companies cease production in Israel, that their quotas would be distributed to other industrial consumers.

irrigating or water of lawns during daylight hours and limiting washing of vehicles to water from buckets, rather than hoses. Enforcement of such restrictions, however, tends to be weak. The actual impact of such restrictions is unknown but is likely largely a factor of social pressure and developing of accepted social norms, rather than the strict enforcement of policy.

10.3.3 Technical and Infrastructural Means of Demand Management

Israel has long embarked on numerous measures to reduce the technical demands for water. Significant research and development has been invested, for instance, in developing less water-intensive strains of agricultural crops or new varieties that are capable of growing using higher levels of salinity. Israel is also the originator and a world leader in production and application of drip irrigation systems, which use significantly less water per unit yield than traditional sprinkler systems. Such technical fixes, however, have not, in and of themselves, brought about a reduction in demand. While they make possible achieving the same yields with less water, their effect in Israel has been allowing increased yields with the same amount of water applied. Thus, water use in agriculture did not decrease significantly in the 1960s, when drip irrigation began to be implemented widely, but rather, only as a result of the reduction in quotas and increases in prices that were implemented in the following decades. What the technical improvements allowed for was increased agricultural productivity even during periods in which water supplies to the sector were being cut (Kislev 2011).

Regulation concerning technical standards in the domestic sector has been more consequential. For instance, Israel has long had regulations requiring low-flow and dual-flush toilets in new construction. Toilet flushing is estimated to account for up to 35% of overall household water consumption in Israel (Israel Water Authority 2012c), and thus, reduction of water consumption from toilets can be substantial – up to 20% of household use (Israel Water Authority 2012d). In addition, in 2010–2011, the Water Authority engaged in a campaign distributing “water-saver” faucet attachments to further reduce household water use. According to their estimates, such devices can reduce overall household consumption by up to 30% (Israel Water Authority 2012d). The campaign to distribute such water-savers followed a less successful public campaign and economic subsidy to encourage their use. The extent of actual installation of the water-savers and its impact in terms of water demand reduction, however, are still unknown, as is the extent of the scope for further achievements in demand reduction via such policies.

Israel is home to many private sector initiatives to facilitate water conservation. Some, like Netafim the drip irrigation company, have become world leaders in their field. Others, like the start-up TaKaDu, which developed systems to identify leakages in delivery systems, have won international prizes and contracts around the world. Relatively recently the Israeli government recognized the potential economic value of encouraging such initiatives and has developed a limited number of programs, such as the Ministry of Trade and Commerce's "Israel NewTech" program, designed to assist start-ups in the water sector by providing technical, administrative, and limited economic support – as well as by facilitating beta sites for testing of the technologies.

10.3.4 Standard Setting and Planning as Means of Demand Management

Several bodies in Israel have implemented standards designed to inform consumers as to water consumption of various goods. The Water Authority has implemented a "blue label" for products that are relatively less-water consuming than other similar products – including for the "water-savers" devices just mentioned. The Israel Standards Institute has issued a number of standards concerning water conservation, including several criteria for water conservation included in the standards for the relatively new Green Building Certification. Such standards are meant to incentivize producers and suppliers to offer water-saving products; however, based on the limited adoption of such certifications, their impact has been minimal to date. The increased interest in the nascent Green Building Certification, however, may be a positive indication of change in this respect.

A much larger potential for reducing demand lies in standard setting in national planning regulations. Several authors have noted the potential for water-sensitive planning of building and infrastructure construction, especially in urban areas, to limit water needs (see, e.g., Shamir and Carmon 2007). Actual integration of such considerations into planning, however, has been relatively limited. In some cases, the government itself has implemented policies that prevent adoption of water-saving technologies. For instance, currently the Ministry of Health has blocked regulation allowing installation of gray-water systems in homes due to concerns about public health as well as potential contamination of soil and water should gray water be used for household irrigation purposes.

It should be noted, too, that regulatory policies often entail tradeoffs, and these are not always positive in terms of water demand management – even those with a specific environmental or resource conservation intent. For instance, long-standing regulations on solar water heaters on the roofs of houses and apartment buildings have significantly reduced energy consumption related to heating of water but have resulted in more water consumed as residents wait for the heated water to flow from the rooftops to the faucets. Efforts to reduce water consumption due to waiting for hot water, by means of localized supplement water heaters or even by encouraging cleaning and replacement of old rooftop units, for instance, have been very limited and are almost exclusively done by the private sector.

10.3.5 Public Information and Awareness Raising Campaigns

Public awareness regarding water shortages in Israel is high. The topic is part of every child's school curriculum and receives significant attention in the media. Up-to-date displays of water levels in the Sea of Galilee – Israel's solitary freshwater lake – are displayed prominently on the websites of major news outlets and on the weather pages of major newspapers. The government has led several campaigns at various levels to raise awareness as to the shortages of water and ways to conserve, including use of popular celebrities in television and radio ads in recent years and highlighting water scarcity and conservation as the theme of the national Independence Day celebrations in 2012.

Public awareness campaigns as demand management tools have several advantages over both market mechanisms such as pricing and command and control policy regulation such as quotas and use restrictions. Because they are nonobligatory, they do not produce the public and political resistance that price increases or cuts to quotas do. Nor do they require direct up-front costs to consumers as do installation of water-thrifty appliances or equipment. Furthermore, they do not need to be approved at numerous levels of bureaucracy and thus can be implemented relatively quickly – an important advantage when dealing with acute shortages during droughts, for instance. Several studies have also shown that such campaigns can be cost-effective compared to other policy instruments (e.g., Neiswiaday 1992; Olmstead and Stavins 2009; Renwick and Green 2000).

Research has shown that the Israeli population is very much aware of government campaigns to conserve water and that the potential for conservation is high (Heiman 2002). Kislev and Vaksin (1997) reported that consumption dropped 6% following a campaign in 1986, and, in a stated preference experiment, Heiman found that ad campaigns reduced consumption by 15% (Heiman 2002). However, it is difficult to evaluate the actual impact of an informational campaign, as generally no counterfactual case exists. Also, because such campaigns are almost always done concomitantly with other policies, it is difficult to isolate the specific impact of the campaign itself. Grinstein et al. (2012) conducted an experiment in the summer of 2009 in which some households in Israel were sent messages encouraging conservation, while others in the same neighborhood were not. They found that the campaign reduced consumption by an average of 4.6% over a period of 4 months. Moreover, they found that positive campaign messages were more effective than assertive ones that appealed to a strong sense of moral obligation. The effect of this experiment was above and beyond that of price reforms and national level public campaigns that were being conducted at the time. They also found that the cost of the information campaign was significantly cheaper than the cost would have been to achieve the same reduction via price increases or to produce a similar amount via desalination.

Despite apparent advantages to public awareness campaigns as policy tools for demand management, the government has been reluctant to depend on them too much in terms of overall water policy. Reasons for skepticism include a lack of concrete data on their impacts and a worry that the impact may only be temporary in nature, as people may forget the campaign or become indifferent to campaigns if constantly exposed. Such worries have some empirical support. The study by Grinstein et al. (2012) found that the effect of the experiment was negligible after 4 months, and a survey conducted by Heiman (2002) found that 73% of respondents stated that they were conserving water following a national public awareness campaign, but only 38% indicated that they expected to do so in the future. Worried about the public becoming immune to persistent calls for conservation, the Water Authority published a campaign in 2011 imploring the public to conserve for three more years – until two more large-scale desalination plants are expected to be in use and water scarcity reduced. This campaign was subject to much criticism, as critics claimed that it portrayed a scenario of only temporary water scarcity, rather than the chronic water scarcity that the country faces, and promises a technical fix. They also charged that it would make demand management even more difficult in the future, as the public would claim that they were led to believe that water scarcity would no longer be an issue.

10.4 Conclusions

Alongside supply augmentation, Israel has engaged in numerous types of demand management policies. Different institutions have emphasized different policies. Traditionally the Water Authority (and the Water Commission before it) had relied on reductions in quotas. The Ministry of Finance has encouraged market mechanisms, especially price increases. Outside of the government, environmental organizations have stressed the role of public awareness, while many economists have stressed pricing and options for trade of water rights. As multiple policies are implemented simultaneously, it is often difficult to know what the relative impact of any single policy is. For instance, an 18% drop in municipal water consumption in 2009 has been attributed by various sources as either a result of an extensive awareness campaign or of price reforms (e.g., Darel 2010).

Each type of policy has its relative merits and limitations. Market policies such as price reforms promote efficiency, can send clear price signals to consumers regarding the true cost of water, and can generate funds for continued maintenance and development of water infrastructure. On the other hand, they often face widespread public and political opposition, and, at least in municipal water demand, price changes need to be large to affect significant change in consumption habits. Water buyback has potential but its use is limited, given the lack of permanent water rights and the possibility for the government to simply reduce water quotas. Reduction of quotas is theoretically easy – demanding just the stroke of a pen at the Water Authority – however, heretofore, such policies have face concerted opposition especially by the agricultural lobby.

Given the fact that quotas to agriculture have already been slashed over the past two decades, the relatively small share of water consumed by industry, and the fact that municipal water is now the largest consumer of freshwater and its supplies are allocated by quotas, one can expect increased reliance on market mechanisms such as price reforms, as well as nonmarket mechanisms such as regulations on use as well as public awareness campaigns. One area in which the use of quotas is likely to see an increase is in the allocation of water for environmental needs. This sector has long been ignored (see Chap. 5) but is now benefiting from increased awareness and public support. Given that water in nature is a public good, the government is unlikely to rely on market mechanisms for its supply and has committed to increases minimum guaranteed flows to several streams and other water bodies. In general, however, increased reliance on expensive supply sources such as desalination, problems of underfunding of public water works, and a commitment to include environmental costs in the price of water all indicate an increasing role for pricing policies.

Despite increased supplies from expanded reliance on desalination, Israel will continue to face acute water scarcity. Several factors are likely to contribute to such scarcity including declines in supply due to climate change (Alpert et al. 2008), continued population growth at rates among the highest in the industrialized world, economic growth, and increased demand for sharing of water with neighboring Arab states. Thus, the government will continue to need to implement its whole arsenal of demand management policies into the foreseeable future.

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Chapter 11
Water Quality Assessment and Management of Lake Kinneret Water Resources: Results and Challenges

Arkadi Parparov, Gideon Gal, and Doron Markel

11.1 Introduction

Management of a human-controlled social-ecological system should be based on a set of criteria allowing a compromise between the necessity to conserve the aquatic ecosystem in some predefined "reference" state and the necessity to provide the required ecosystem services such as water supply, a recreational site, and fishery (Wetzel 2001; WFD 2000). The task of water resource management can therefore be formulated (Straskraba and Gnauck 1985) as the optimization of an objective function (Q) of the economic activities (EA): anthropogenic activities in the lake watershed and intensity of water resources uses, water quality (WQ), and economic effectiveness of the management (costs versus benefits, CB):

$$Q = f\,(\mathrm{EA};\ \mathrm{WQ};\ \mathrm{CB}) \tag{11.1}$$

Quantification of various parameters in Eq. 11.1 (EA, WQ, CB) and assessment of the relationships between them should be a central task for establishing a scientifically based water resource management strategy (Jorgensen and Vollenweider 1989; Groffman et al. 2006).

In this chapter, we summarize our experience in assessment of a methodological framework aimed at development of quantitative tools for advanced management of Lake Kinneret (Israel) that will allow conservation of the lake ecosystem and sustaining its WQ while providing required ecosystem services. The framework

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consists of an ongoing monitoring program, a quantified system of water quality, and an aquatic ecosystem model. These tools were implemented to establish the relationships between WQ and economic[1] activities such as nutrient loading and the amount of water withdrawal from the lake, thus outlining a sustainable management policy for the Lake Kinneret water resources. We also discuss some aspects of the economic valuation of the lake water resources management (WRM).

11.2 Description of the System of Lake Kinneret

Lake Kinneret (the Biblical Sea of Galilee) is a subtropical lake located about 210 m below mean sea level in the northern part of the Dead Sea Rift Valley (Fig. 11.1, Table 11.1). The major water inflow to the lake is the Jordan River, which drains the relatively high-rainfall region of the Upper Galilee and the Golan Heights.

In summer, the lake is characterized by surface temperatures above 30°C and an anoxic hypolimnion (Serruya 1978). Lake Kinneret is meso-eutrophic with a mean annual primary production of 650 g C m^{-2} (Berman et al. 1995; Yacobi 2006). A prominent biological feature of the lake has been the spring bloom of

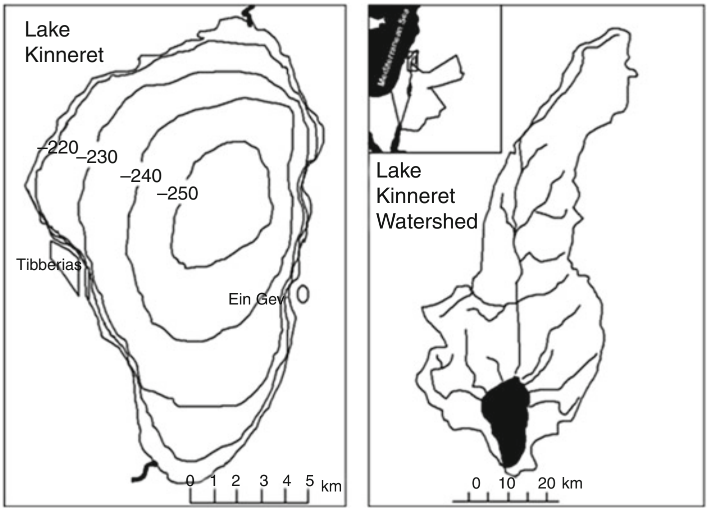


Fig. 11.1 Lake Kinneret and its watershed: an elevation map

[1]Throughout the paper we define "management activities" as "Economic activities". We note that preventing point source pollution, reduction of diffuse source pollution and water resources management at the watershed are not evaluated on ground of their costs and benefits. However, economic considerations should be a major guideline to those activities. We, therefore, recognized the necessity to define them as such.

Table 11.1 Characteristics of Lake Kinneret and its watershed (Serruya 1978)

Watershed		Lake Kinneret	
Surface area (km^2)	2,730	Surface area (km^2)	160–170
Water inflow (km^3 $year^{-1}$)	0.3–1.5	Volume (km^3)	3.3–4.2
TP load (g m^{-2} $year^{-1}$)	0.4–1.6	Water supply (km^3 $year^{-1}$)	0.2–0.6
TN load (g m^{-2} $year^{-1}$)	3.1–12.5	Total phosphorus (TP) (mg L^{-1})	0.02
Population	255,000	Total nitrogen (TN) (mg L^{-1})	0.60
		Fish yield (t $year^{-1}$)	2,000
		Main uses: domestic water supply, fisheries, recreation	

the dinoflagellate *Peridinium gatunense*, though since 1994, the lake has exhibited uncharacteristic developments in the phytoplankton assemblage, including the first-ever bloom of a potentially toxic, N_2-fixing cyanobacteria (Zohary 2004). Moreover, the routine spring bloom of *P. gatunense* was replaced by very rare blooms every few years (Zohary 2004).

The importance of Lake Kinneret stems from its unique socioeconomic role as the principal freshwater resource of Israel (Shamir et al. 1985; Markel and Shamir 2002). Some 200,000 people live in the Israeli part of the basin, under six regional and 25 local authorities and municipalities (Markel 2008). Moreover, according to the Israel Central Bureau of Statistics, there is an annual population increase of 1–2.5% in the cities and communities around the lake, and over two million tourists that visit Lake Kinneret and its basin annually. The total quantity of water supplied in Israel is roughly $2 \cdot 10^9$ m^3 $year^{-1}$, while about $5.4 \cdot 10^8$ m^3 annually is supplied from Lake Kinneret and its watershed ($3.6 \cdot 10^8$ m^3 $year^{-1}$ from the lake and $1.8 \cdot 10^8$ m^3 $year^{-1}$ from the watershed). The economic activity of the water sector, including output and investment, totals over NIS ten billion (Kislev 2010). The output value is close to NIS 3.5 billion or half a percent of Israel's Gross Domestic Product. The large population and annual number of torists result in a significant pollution load reaching the lake. Furthermore, the watershed is primarily used for agriculture including orchards, field crops, fishponds, cowsheds, and cattle-grazing areas. This determines the main pollutants of the watershed: nutrients, herbicides, pesticides, and pathogenic bacteria (Berman 1998; Markel and Shamir 2002). Industrial areas in the basin are few and small in size; hence, they produce only a small fraction of the pollution that enters the lake from its basin. The large increase in human activities in the drainage basin over the past 50 years has led to the appearance of various diffuse sources of pollutants, including anthropogenic sewage, cowsheds' drainage, as well as agricultural and industrial drainage. Superimposed on these were the drainage of swamps in the Hula Valley and the diversion of the Jordan River from its historical route through the 1950s. Accordingly, concern for water quality in the lake has led to the creation of an extensive water quantity and quality monitoring system in both the lake and watershed as well as its reorganization and coordination by the Water Authority (Markel and Shamir 2002).

According to the Water Law, all of Israel's water sources are public property and controlled by the state. The water supply from Lake Kinneret is controlled by the Water Authority; it oversees withdrawal, provision to the agriculture and urban sectors, monitoring of the lake and its tributaries, and development of the supply system, including recycling facilities and desalination plants. Most of the withdrawal and provision of freshwater is done by the state-owned Mekorot water company. In the long-term period, the quantity of the supplied water, initially, for irrigation and then for domestic supply, was the main target of Lake Kinneret WRM (Berman 1998; Kislev 2010). The most recent Management Action Plan (MAP 2011) declares that use of water resources of Lake Kinneret should be accompanied by the conservation of the lake water quality (i.e., basic features of the aquatic ecosystem).

The major uses of Lake Kinneret water resources (Berman 1998; Hambright et al. 2000; Markel 2008) are:

1. *Drinking and irrigation water supply*. In addition, since 1994 Israel also supplies water from the Jordan River at the outlet of Lake Kinneret to the Hashemite Kingdom of Jordan.
2. *Tourism and recreation* – about two million tourists visit the lake many of whom are Christians visiting the numerous sacred sites for Christianity around the lake.
3. *Fishery* – about 800–1,500 t of fish is caught in the lake annually.

The main water quality problems that the lake managers face are (i) *the relatively high salinity of the lake water* – due to the influx of salt springs into the lake, its natural salinity is too high for irrigation of different crops. Furthermore, the relatively high salinity of Lake Kinneret water could drastically accelerate salinization of the irrigated soils on the coastal plain and of the coastal aquifer lying beneath it. Currently, the lake water salinity varies between 220 and 280 mg Cl L^{-1}. (ii) *Cyanobacteria blooms*: since the mid-1990s, the lake faces summer Cyanobacteria blooms of *Aphanizomenon* and *Cylindrospermopsis*, joining the older winter blooms of *Microcystis* (Zohary 2004). These blooms are indicators of a eutrophication process – drastic increase of non-desirable algal production (mainly cyanobacteria), accumulation of organic matter and products of its decomposition in water column, and a decrease in water transparency. This, in turn, causes problems of taste and odor, high turbidity, scums, blockage to filters and pumps, and fouling of shore installations, swimming, and recreation beaches. In very extreme cases, eutrophication can cause the presence of toxic algae with lethal effects on animals and even humans. The increase of the nutrient load (mainly nitrogen and phosphorus) is traditionally considered to be responsible for this process.

The Water Authority utilizes a series of management tools for both the lake and the watershed:

1. Lake Management

   1.1. *Determining Water Level* – The lake water level is managed closely and is dependent on withdrawal volumes and available water which directly

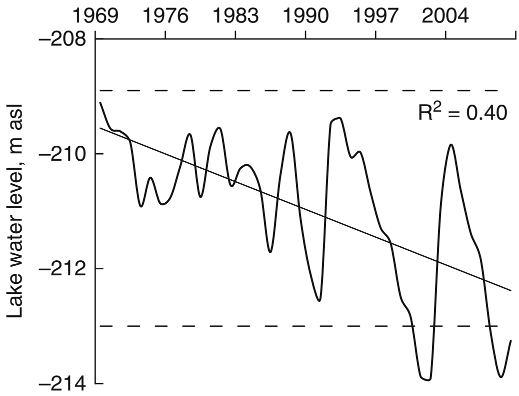


Fig. 11.2 Lake Kinneret levels during the period 1969–2010. Dotted horizontal lines represent *upper* and *lower* "*red lines*" (−208.9 and −213.0 m, respectively)

depends on winter rainfall. The lake is maintained within legislated limits ("red lines"), determined in order to prevent flood damage, on one hand, and negative ecological processes due to low water level, on the other hand. The maximum level was set at an elevation of –208.8 m above sea level (ASL) and the minimum at –213.0 m (ASL, Fig. 11.2). In recent years, the actual lake level dropped below the lower red line due to an extended period of drought conditions and excessive withdrawal. These changes along with the dramatic decrease in lake level in 2001 led to the definition of the black line (−214.87) which means the minimum water level allowed in any scenario.

1.2. *Fishery Regulation* – It is used as a tool for managing and balancing the ecological system of the lake mainly by population regulation of predominantly algae feeding *Sarotherodon galilaeus* and zooplankton feeding *Acanthobrama terraesanctae*. The effectiveness of this management tool for controlling water quality is questioned (Markel 2008).

1.3. *Lake Salinity Control* – The salinity problem was partially solved by diverting of several major saline inputs along the northwest shore of the lake into a "salt water canal" bypassing the lake and leading to the southern Jordan River. Currently, the lake water salinity varies between 220 and 280 mg Cl L^{-1} and is inversely correlated with the lake water level because when less water enters the lake, the salt inventory of the lake is diluted by less water.

2. Watershed Management

2.1. *Preventing of Point Source Pollution* – The Water Authority together with the non-statutory body of the Lake Kinneret Authority acts intensively to eliminate point source pollution in the Israeli part of the watershed. Almost 100% of the sewage is treated and reserved in reservoirs for summer irrigation. All dairy cowsheds were renovated in the last decade, and their sewage is treated in treatment plants as well. Fishpond water is recycled or filtered at their outlet.

2.2. *Reduction of Diffuse Source Pollution* – Through regulations the Water Authority is trying to reduce nutrient leakage from irrigated crops and from pasture areas. The Water Authority, together with the Ministry of Environmental Protection, acts to control amount and types of pesticides and herbicides that are used in Lake Kinneret watershed.
2.3. *Water Resources Management at the Watershed* – Different measures are taken in the watershed to allocate water from different sources (freshwater, drainage water, treated sewage) to different consumers (domestic, farmers, ecotourism sites). A large-scale rehabilitation project (the Hula Project) was initiated in 1994, creating ca. 90 km of regulatory channels and a small, shallow lake (Lake Agmon) which now serves as the focus for developing ecotourism, as well as for storage and reuse of peat drainage water in order to prevent it from being drained to Lake Kinneret (Hambright and Zohary 1999; Markel et al. 1998).

The complexity of the Lake Kinneret and its watershed system requires scientifically based water resources management accounting for the above-mentioned objectives. The methodological framework suggested by us (Parparov and Gal 2012) is a step toward a holistic approach to solution of a multidisciplinary task of the Lake Kinneret water resources management bridging a gap between limnologists, economists, and water resources managers.

11.3 The Structure of the Methodological Framework

The suggested methodological framework includes ecological monitoring, a quantified system of WQ indices, and an ecosystem model. Extensive hydroecological monitoring of the Lake Kinneret, initiated in 1969, includes systematic determinations of more than 100 variables in the lake and its watershed (Markel 2008) organized within a computerized database, which makes Lake Kinneret one of the most investigated lakes of the world. Analysis of this unique multiannual database was used at different stages of WQ quantification (Parparov and Hambright 2007) and for calibration of the ecological model (Gal et al. 2009). Implementation of the quantified system of WQ indices offers a means by which to focus on only a subset of the monitored variables, 10 in total, in order to provide “water quality monitoring.” Combining of the quantified WQ system and the lake ecosystem model provided a means for establishing and verifying the quantitative relationships between WQ and major economic activities (EA) and thus to outline a “sustainable management policy” for Lake Kinneret water resources.

Establishment of water quality standards and indices is the most difficult stage of management, with conflicts of interest arising within and between the various groups of users and experts. Quality is not absolute; the terms “good” or “poor” water quality have meaning only in relation to the use of water and are based on assessment by the user. Our approach to WQ assessment, which included the

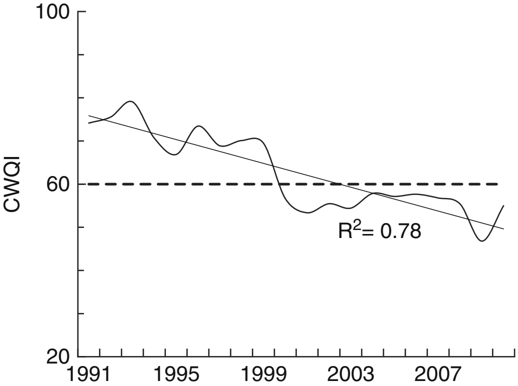


Fig. 11.3 The aggregated water quality (as CWQI) dynamics in Lake Kinneret during 1991–2010. The *solid straight line* represents a linear trend of the CWQI dynamics, and *horizontal dashed line* indicates lower boundary of acceptable water quality (CWQI = 60)

establishment of a system of WQ indices and their permissible ranges, was based on quantitative modifications of the expert panel method (Brown et al. 1970). Methodology and the steps of WQ quantification in Lake Kinneret were described in detail in Parparov and Hambright (1996) and Hambright et al. (2000). We assumed that water resources of Lake Kinneret and its watershed would be managed in order to maintain water quality within the range of steady state, which we defined based on variability recorded during the period 1969–1992 ("reference state"). Adoption of this management scenario requires realization of long-term policies to conserve the present lake ecosystem and to prevent deterioration of the lake's water quality ("no deterioration rule" of the WFD (2000)).

The WQ system established for Lake Kinneret provides a means for identifying major environmental threats associated with water resource uses:

- *Eutrophication*: given by indices such as the total phosphorus and total nitrogen, primary production, chlorophyll, and percentage of cyanobacteria of total algal biomass.
- *Organic pollution*: represented by an index of number of coliform bacteria.
- *Food supply for fishes*: the zooplankton biomass index.
- *Increase in salinity*: above accepted drinking and irrigating water supply standards: chloride concentration index.

The aggregated WQ (composite water quality index (CWQI)) was calculated as a weighted sum of rating values for the entire set of the WQ indices. The weighting procedure used variable weights that are inversely proportional to the separate rating values thus providing extra weight to indices with lower rating values. "Acceptable" WQ corresponds to $60 < \text{CWQI} < 100$. Aggregated WQ calculated as CWQI corresponds to the viewpoint of pragmatic limnologists and water resource managers (Parparov and Hambright 2007).

During the period 1991–2010, monthly average CWQI values varied from 27.4 ("bad" WQ) to 87.3 ("excellent" WQ). Usually, WQ was lower in the summer, due to increased percentages of cyanobacteria and chloride concentrations. The overall annual average CWQI showed a clear trend of deterioration in lake WQ (Fig. 11.3).

The correspondence between permissible ranges for WQ indices (established by the expert panel) and permissible ranges for Major EA (nutrient loads, lake water level) served as a conceptual background of the sustainable WRM. Loading beyond the critical value and/or excessive water level lowering will lead to significant deterioration of WQ. Search for such a “critical threshold” value is a key point of modern limnology (WFD 2000). Statistical analysis of the existing databases and ecological modeling were used for establishment of the relationships between WQ and EA. In the current analysis, we focus on the multiannual dynamics of WQ in Lake Kinneret during the period 1991–2010.

11.3.1 Brief Description of the Ecosystem Model, DYCD

The impact of a number of management scenarios on the Lake Kinneret ecosystem was evaluated based on 20-year simulations using the ecosystem model DYRESM-CAEDYM (DYCD, Gal et al. 2009). It is a process-based model that incorporates the important physical processes taking place in a lake leading to changes in temperature and salinity with time and depth; it has been applied to Lake Kinneret for a number of years (Bruce et al. 2006; Gal et al. 2003). The ecosystem model consists of the Computational Aquatic Ecosystem Dynamics Model (CAEDYM) coupled to the one-dimensional physical model: Dynamic Reservoir Model (DYRESM). CAEDYM uses a series of ordinary differential equations to describe changes in concentrations of nutrients, detritus, dissolved oxygen, bacteria, phytoplankton, and zooplankton as a function of environmental forcing and ecological interactions for each Lagrangian layer represented by DYRESM. Due to the fast run-time of the model and its accuracy over time, DYCD is well suited for long-term simulations and for examining multiannual variability. Input required for model simulations includes forcing data (inflows in terms of both quantity and quality, withdrawals and meteorological conditions), initial physical, chemical and biological conditions, and a series of user-defined parameters.

11.3.2 Simulation Runs

In order to assess the relationships between the selected EA (nutrient loads and water level) and lake WQ, we conducted a series of simulations and examined the output in the form of the individual WQI or the CWQI:

– Nutrient loading into the lake was varied over a wide range (from ×0.01 to ×10 the baseline loads) by multiplying the concentrations of N, P or N and P (in tandem) in the inflows. During the loading simulations, lake level was held constant between years; thus, there was seasonal variation but no interannual variability. Initial and final lake level for these simulations was –210 m.

– Lake level was varied between –208.0 and –216.0 m (WL scenario, hereafter). Under the WL scenario, the nutrient loads were unaltered within the baseline values (with a multiplication factor value ≈x1).

The 20-year simulation input data were constructed based on real data collected during the year 2000.[2] The mean annual values of the last 3 years of the simulations were used to establish the relationships between CWQI and major MA. This was done in order to ensure use of results from quasi-steady state conditions.

11.4 Relationships Between the Economic Activities and Water Quality

11.4.1 Relationships Obtained from the Monitoring Data

In most publications concerning WQ assessment, the main function of WQ monitoring is indicating changes in water quality (Cude 2001; Burns et al. 2005). However, the quantified WQ is an argument of the objective function of management (Eq. 11.1), and therefore, the aggregated WQ (e.g., CWQI) should be a target of management, rather than only an indicator of change (Parparov and Hambright 2007). Moreover, determining the correspondence between permissible ranges for water quality indices and permissible ranges for economic activities makes quantified water quality an important management tool.

Traditionally, the relationships between ecosystem variables and different environmental effects are revealed from statistical analysis of the monitoring data. For Lake Kinneret, among considered economic activities, water level appeared to be the best variable correlated with several WQI (Table 11.2).

Table 11.2 Square correlation coefficients of the relationships between water quality (as ratings of chloride and %Cyano, and aggregated water quality, CWQI) and major management activities (MA): nutrient loads and water level

Economic activities	Rating (Cl)	Rating (%Cyano)	CWQI
Nitrogen load	0.22*	0.26*	0.08
Phosphorus load	0.18	0.19	0.04
Water level	0.88**	0.33**	0.38**

Annual average values for the period 1991–2010
*$P < 0.05$; **$P < 0.01$

[2] Note that the absolute results may be sensitive to the year chosen.

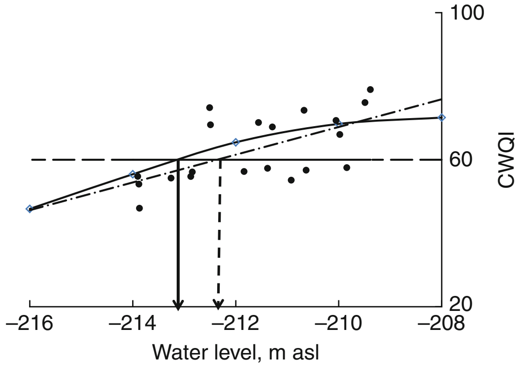


Fig. 11.4 The relationship between annual average aggregated water quality (as CWQI) and lake water level. The results are based on simulation results (*solid line*) and lake-based data for 1991–2010 (black dots). The *dashed line* represents linear regression obtained from lake-based data. The *arrows* indicate the threshold water level value (CWQI $\leq$ 60), based on model output (-213.5 m, *solid arrow*) and lake-based data (-212.5 m, *dashed arrow*)

The relationship between the lake water level and CWQI establishes a direct relationship between WQ and EA, which allowed estimation of a permissible range for the lake water level (Fig. 11.4).

The data shown in Table 11.2 represent the combined effect of the separate economic activities: loads and water level, acting together with each other. The net effects of the individual EA could be revealed only under assumptions about constancy of other EA, due to modeling simulations.

11.4.2 Relationships Obtained from Simulation Run

Results of all water level scenarios were combined in order to determine a quantitative relationship between lake level and aggregated WQ (CWQI); thus, they provide a means for estimating the critical value for water level lowering (CWQI $=$ 60; Fig. 11.4). The modeling results are in a good correspondence with those obtained from the lake-based data, thus providing similar estimates of the permissible range for lake level: WL > -213.5 m and WL > -212.5 m, respectively.

Therefore, the observed statistically significant relationship between the water level and WQI (especially, CWQI), obtained despite "noisy masking" by the loads, could be interpreted as indirect evidence of relatively higher Lake Kinneret ecosystem sensitivity to its water level changes. It should be emphasized that implementation of the methodological framework to estimating the critical lake water level is based on a single hydroecological criteria (water quality).

Simulation results allowed us to assess the direct relationships between nutrient loads and the aggregated WQ in the form of a "polygon" of permissible ranges of

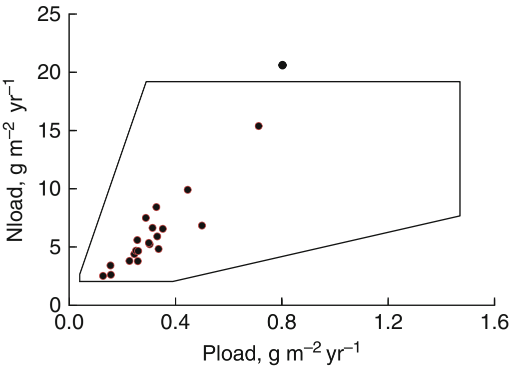
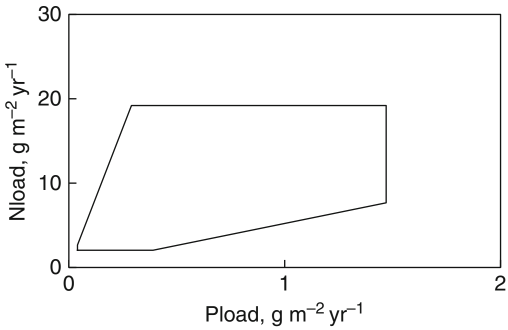


Fig. 11.5 Polygon of permissible values of Nload and Pload, obtained from the results of simulation runs under assumption of stability of lake water level (WL − 210 m). The load values within the polygon should allow maintaining of lake water quality within its permissible range (60 < CWQI < 100), while the loads outside of the polygon can lead to a deterioration in water quality. *Black circles* within the polygon represent nutrient loads obtained from lake-based data (1991–2010)

Table 11.3 The set of the permissible ranges for major management activities (nutrient loads and water level) allowing conservation of lake water quality

Economic activity	Permissible range
Nload (g m^{-2} year^{-1}) Pload (g m^{-2} year^{-1})	(see figure below)
Water level (m asl)	WL > −213.5



the nutrient loads (Fig. 11.5) allowing conservation of the lake WQ (Parparov and Gal 2012). The polygon of the permissible ranges establishes the correspondence between the combined effect of the nutrient loads and the aggregated water quality: the N and P load values inside of the polygon correspond to the loads which should allow sustaining of acceptable WQ conditions (CWQI ≥ 60). The load values outside of the polygon are potentially dangerous for the lake water quality. Combining these results with the estimate of the permissible range for the lake water level (WL > −213.5 m) allowed us to outline the sustainable water resources management policy (Table 11.3), based on single ecological criterion: conservation of water quality.

It should be emphasized that Fig. 11.5 shares the results obtained with various independent methods: a Delphi expert panel, ecological monitoring of the lake and its watershed, and ecological modeling. It is important to note that the nutrient loads obtained from the monitoring database for the period from 1991 to 2010 are well within the N and P polygon obtained from the simulation runs (besides one extreme point, Fig. 11.5). Good correspondence between lake-based data and the output of the combined independent methods indicates a successful implementation of the ecological model DYCD for solving the tasks of sustainable water resources management and should be considered as important, though indirect, model validation.

11.5 The Results and the Challenges

Optimization of the objective function, Q (Eq. 11.1), is the basic concept of scientifically grounded water resources management (Straskraba and Gnauck 1985; Naveh and Shamir 2004), which requires quantification of its components and constraints.

For a long time, the task of maximization of water supply from Lake Kinneret had a single, hydrological, constraint. Accounting for potential deterioration in lake water quality, this led to the establishing of the water level "red lines" ($-213.0 <$ water level < -208.9 m). The methodological framework developed for Lake Kinneret (Parparov and Gal 2012) suggests a management policy based on a single, ecological constraint ($60 <$ CWQI < 100, Table 11.3). Understanding of the necessity to transfer to "sustainable water resources management," accounting for the needs of both water supply and conservation of the aquatic ecosystem (i.e., water quality), contributes to a management policy based more upon combined hydrological and ecological criteria (Markel 2008; MAP 2011).

Once established, will this combined hydrological–ecological criterion be sufficient for the effective water resources management? Not once, during the drought years, was the water level "red line" deepened, due to the Water Authority's decision (after consultation with experts). The damages associated with these decisions are multiple: loss of the lake water potential and deterioration of the lake water quality for drinking water supply and recreation. However, the benefits are also obvious – uninterrupted domestic water supply and water for irrigation: without water supply these uses of the social-ecological system of Lake Kinneret would be significantly damaged.

Cost and benefit analysis is apparently obvious and a natural way to compare the management options of the Lake Kinneret water resources. The problem is in the determination of economic (i.e., money) values of those costs and benefits. Understanding the vital importance of water for human well-being is accompanied with existence of water prices which not necessarily reflect its real social value. For instance, the price of water withdrawn from Lake Kinneret comprises only few percent of Israel financial budget (Kislev 2010). Obviously, existing economic valuation of water resources of Lake Kinneret is not complete: it represents an indeterminate part of its market value, while nonmarket value, associated with the environmental ecosystem services, remains unknown.

The importance of economic valuation in management of the natural water resources was mentioned in the European Union Framework directive (WFD 2000). Recently, the state of the art in this intensely developing field of science was described in the WFD technical guidelines (Brouwer et al. 2009). Having said that, we repeat and emphasize the difficulty in assessing those indirect economic values of the lake.

The economic valuation of water resources should allow supplementation of the objective function of management with a conceptually important variable, accounting for which should lead to essential transformation of the management criteria (O'Riordan 1999).

Implementation of water resources management based on combined hydrological, ecological, and economic criteria is a challenging scientific problem which will contribute significant modification of the developed methodological framework:

A quantified system of WQ indices should be revised in view of suitability for carrying out economic valuation surveys based on preference and contingent valuation methods (Brouwer et al. 2009).

The DYCD ecological model should be transformed to an ecological-economic model ("ECO-DYCD").

The total economic value of the social-ecological system of Lake Kinneret should be assessed, and its relationships with major management activities should be estimated in interaction with the Monitoring and Ecological-Economic Model despite the challenges involved.

Finding solutions to these tasks should allow establishment of new, advanced, methodological framework (Fig. 11.6). We understand how challenging this task is: to our knowledge such a task has not been solved for any natural water body to date. However, the solution to this task is a very important step in the development of a Decision Support System for sustainable management of the Lake Kinneret water resources. Accounting for the unique importance of Lake Kinneret in the Israel economy and national heritage and for sake of international limnology, this task should be solved.

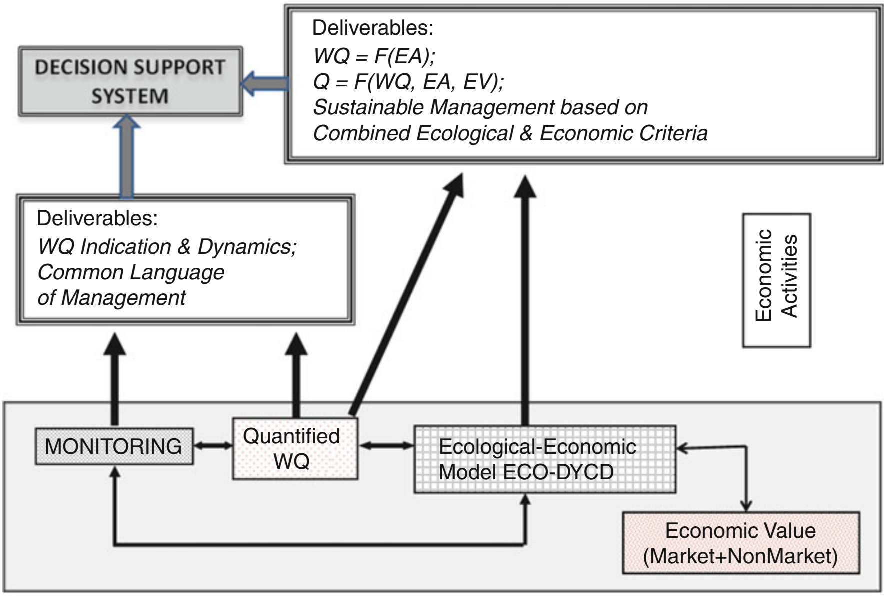


Fig. 11.6 Structural scheme of advanced methodological framework accounting for economic valuation of the Lake Kinneret water resources

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Chapter 12
The Red Sea–Dead Sea Conveyance Feasibility Study, 2008–2012

Doron Markel, Jitzchak Alster, and Michael Beyth

12.1 Background

The Dead Sea is a hypersaline terminal lake formed about 14,000 years ago along the central part of the Dead Sea Rift after the desiccation of its precursor Lake Lisan (Neev and Emery 1967; Garfunkel and Ben-Avraham 1996; Stein 2001). The Dead Sea drains an area of approximately 40,000 km^2 with the Jordan River as its main source of inflow (Fig. 12.1). While in the past the Dead Sea level changes were caused by climate changes, in recent years its level is controlled primarily by anthropogenic activity. At present the Dead Sea level is approximately 425 m below sea level (BSL) (Givati and Tal 2012) while the lake's deepest point at 730 m BSL is the deepest terrestrial spot on Earth.

The level of the Dead Sea declines at a rate of more than 1 m per year (Fig. 12.2). The decline stems from the increasing, and inevitable, use of all available fresh water resources that flow into the Dead Sea, thereby upsetting the equilibrium between inflows and evaporation. In addition, the chemical industries, the Israel-based Dead Sea Works and the Jordan-based Arab Potash Company, that extract potash and other chemicals from the Dead Sea by way of evaporation ponds

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Disclaimer: This chapter summarizes the principal technical and environmental findings of the feasibility study for the Red Sea–Dead Sea Conveyance Project and does not replace in any form or manner the professional studies and sub-studies referred to herein. The views expressed herein are those of the authors' and do not necessarily represent those of the Water Authority and/or of the Government of Israel.

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Fig. 12.1 Map showing study area and Dead Sea catchment area (Coyne et Bellier 2010)

pump approximately 600 million cubic meters per year (MCM/year) from the northern part of the Dead Sea into the evaporation ponds with an evaporation loss of approximately 330 MCM/year, accounting for approximately 40% of the total annual deficit of the lake of 700 MCM/year (TAHAL and GSI 2011).

Fig. 12.2 Water level of the Dead Sea from 1977 to 2010 as measured by the Israel Hydrological Survey (Givati and Tal 2012)

The decline of the Dead Sea water level is accompanied by severe environmental and ecological impacts including the development of hundreds of sinkholes along the shore of the Dead Sea (Abelson et al. 2003) causing damage to the surrounding infrastructure, like roads and bridges (TAHAL and GSI 2011).

Water availability per capita in most of the Middle East is among the lowest in the world and has been even further exacerbated by the onset of the effects of climate change and the reduced rainfall in the region. Even with the full utilization of all existing fresh water resources, the water availability is far below the World Bank minimum per capita standards, and there is an urgent need to develop additional water resources by way of water reuse (recycling) and desalination. Jordan is most affected by the shortage of water supply and in the capital Amman water is supplied once a week only. Israel has been able to cope with the growing demand for water by turning to large scale desalination, which at present reaches 300 MCM/year and is projected to reach 600 MCM/year by 2014 (IWA 2012).

12.2 The Concept of a Water Transfer

The declining level of the Dead Sea coupled with the acute water shortage conditions led to an opportunity to find a single, integrative, and comprehensive solution for both problems. The idea which was devised in many versions over the years (Vardi 1990; Beyth 2007) calls for the desalination of sea water and for the discharge of the reject brine (55% of the seawater amount pumped for desalination) into the Dead Sea. Three environmental benefits are achieved at the same time: the Dead Sea level is stabilized by the discharge of the reject brine into the Dead Sea, the desalination is partially powered by clean energy utilizing the elevation differences between the sea level and the Dead Sea level, and the brine is disposed in the Dead Sea rather than back into the marine environment. The project, if materialized, will be a symbol of cooperation between the peoples of the region.

12.3 From Concept to a Feasibility Study

The idea to investigate the feasibility of a transfer of sea water from the Red Sea to the Dead Sea (the Red Sea-Dead Sea Conveyance Project “RSDSCP”) was jointly devised by Jordan and Israel and announced by them at the 2002 World Summit on Sustainable Development, in Johannesburg. The RSDSCP was (and still is) viewed as a comprehensive solution for stabilizing the Dead Sea level, for the production of desalinated water and as a symbol of peace and cooperation between the peoples of the region. The proposal calls for a transfer of up to 2,000 MCM/year of sea water from the Red Sea (at the head of the Gulf of Aqaba/Eilat) through a conveyance passing through the Araba/Arava Valley to the Dead Sea (Figs. 12.1 and 12.5). The project would incorporate a hydroelectric power plant utilizing the elevation differences of 425 m between the Red and Dead Seas and a desalination plant with an output capacity of up to 800 MCM/year of desalinated water.

It was later agreed that as the plan would benefit Jordan, Israel, and the Palestinian Authority, all three beneficiaries (the “Beneficiary Parties”) would jointly commission the performance of a feasibility study and environmental and social assessment of the RSDSP to be managed by the World Bank (Fig. 12.3). The beneficiary parties drafted therefore, together with the World Bank, terms of reference for a feasibility study and an environmental and social assessment to assess whether the RSDSCP was environmentally as well as economically and technically feasible, while assessing its environmental and social impacts.

The TOR was finalized in 2005, the donor financing agreements and the procurement process were completed in 2008 and in May 2008 the study program commenced.

12.4 The Study Process

12.4.1 The Study Structure

The beneficiary parties, together with the World Bank, and in compliance with the latter’s safeguard policies commissioned the performance of two separate

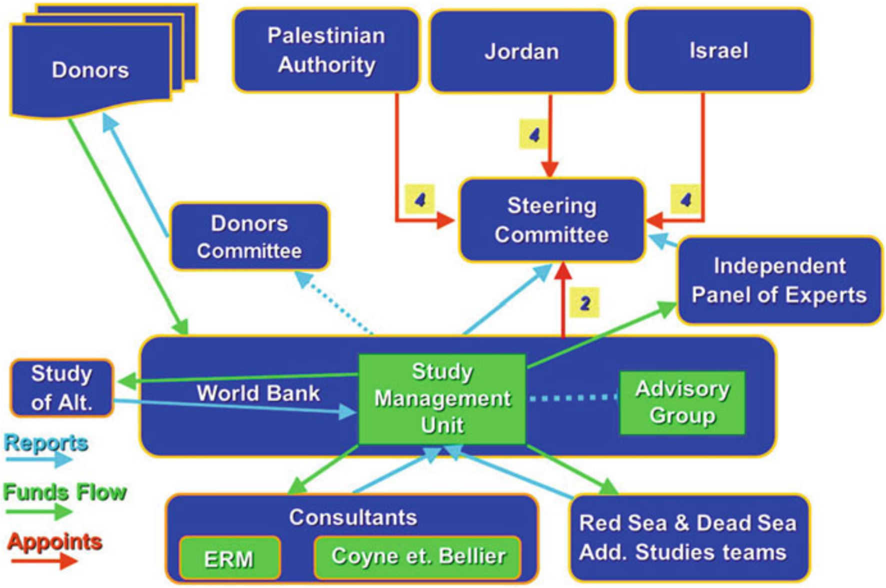

Fig. 12.3 The RSDSCP feasibility study structure as agreed in the TOR

studies: a feasibility study (environmental, economic, and technical) ("FS") and an environmental and social assessment ("ESA"), each carried out by a separate consulting firm. The studies were to receive inputs from four sub-studies, one for each of components of the project: sub-study A on the Red Sea, sub-study B on the water conveyance, sub-study C on the Dead Sea, and sub-study D on the hydropower facilities and desalination plants (Fig. 12.4).

The study was carried out in three phases. In order to avoid duplications of previous studies, the consultants were instructed to establish in the first phase a knowledge baseline comprised of the available data and information from previous studies, and to identify the knowledge gap to be investigated by the feasibility study and the environmental and social assessment. In the second phase the consultants carried out, primarily as part of the sub-studies, investigations for the closing of the knowledge gap identified in the first phase. In the third phase, the consultants with synthesized the findings from the sub-studies and complemented these with economic, legal, organizational, and crosscutting studies to arrive at a feasibility report and an environmental and social assessment. The consultants were commissioned to produce two separate reports, a feasibility study report and an environmental and social assessment report (see Fig. 12.4).

Following a tendering process undertaken by the World Bank, the French firm of Coyne et Bellier (COB) was selected to carry out the feasibility study and Environmental Research Management Ltd. (ERM) of the UK was commissioned to carry out the environmental and social assessment.

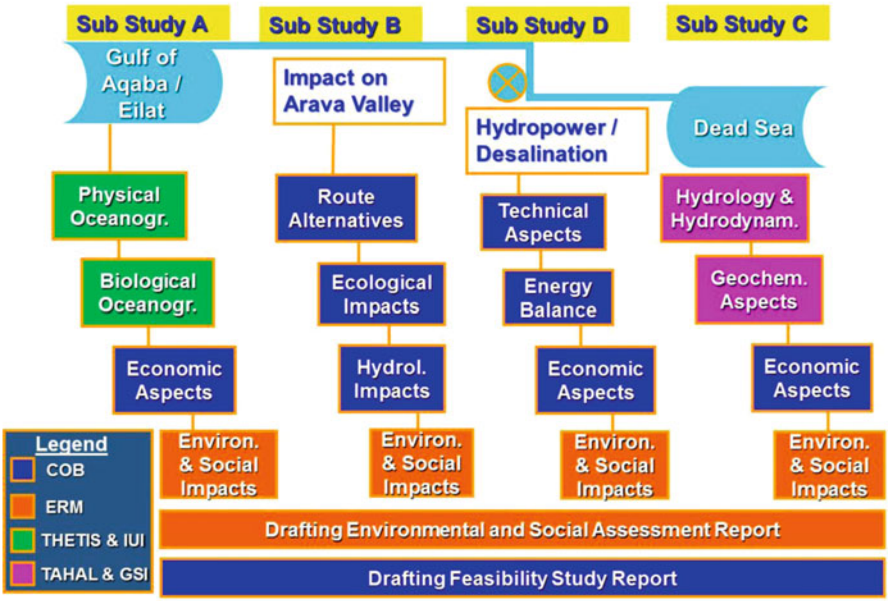

Fig. 12.4 Division of the study to four sub-studies according to the TOR and actual execution by the different consultants

In order to allow a more in-depth study of certain critical aspects of the proposed project, it was decided in 2009–2010 to augment the study program and engage consultants for modeling certain core aspects of sub-studies "A" (Red Sea) and "C" (Dead Sea) (Markel 2010). The THETIS Group from Italy, together with the Interuniversity Institute for Marine Sciences in Eilat, was selected to carry out a detailed modeling study of the impact of pumping up to 2,000 MCM/year of sea water from the Red Sea—on the sensitive ecology of the Gulf of Aqaba/Eilat, including the coral reefs. The TAHAL Group from Israel together with the Geological Survey of Israel (GSI) was selected to carry out a study on the impact of mixing Red Sea water or reject brine with the Dead Sea waters.

In parallel to the performance of the feasibility study, a study of alternatives was carried out to analyze alternatives to the RSDSCP which would arrest the decline of the Dead Sea level and augment available water for use in the region.

12.4.2 Organizational Structure of the Study

In order to oversee this rather complex set of studies, a dedicated organizational structure, as shown in Fig. 12.3, was formed.

In accordance with the TOR, the overall study program is overseen by a Study Technical Steering Committee (the "STSC") composed of senior representatives of the beneficiary parties and chaired by the World Bank. Subject and reporting to the STSC, a Study Management Unit (SMU) composed of a single representative of each of the beneficiary parties and of the World Bank was formed and entrusted with the task of conducting the day-to-day contacts between the beneficiary parties and the consultants (Markel 2010). It was expected by the beneficiary parties that through the ongoing contacts between the SMU and the consultants, a professional dialogue between experts from the region and those of the consultants would enrich the experts' understanding of the processes involved in the RSDSCP. The TOR stipulates that the draft reports of the consultants are to be reviewed by the SMU and the STSC.

In addition to the above structure, the TOR called for the formation of an independent panel of experts (IPE) to independently review the reports and present their findings to the STSC. The World Bank together with the STSC and the SMU also reported periodically to a Donors Committee.

Under the auspices of the ESA consultant, multiple public hearings took place in each of the beneficiary parties during all phases of the study. These open public hearings were augmented by target group meetings in the project area. The comments were synthesized and reproduced by the ESA consultant in the ESA reports.

12.5 Preliminary Results[1]

In devising the TOR, the beneficiary parties followed a recommendation of the prefeasibility study carried out by Harza (1996) to investigate the feasibility of the Red Sea–Dead Sea conveyance as a solution for the decline of the Dead Sea and the production of water and as a symbol of peace. Accordingly the consultants studied the various ways by which water could be conveyed between the seas taking into account that while the Dead Sea is 425 m below sea level (BSL), the elevation of Wadi Araba/Arava Valley reaches 205 m above sea level (ASL). Accordingly any pipeline conveyance has to first raise the water to at least 205 m ASL before dropping to the Dead Sea. The project configurations that were considered by the consultants included various intake locations along the Gulf of Aqaba; options for tunnels, pipelines, open channels, and combinations thereof for the conveyance along the Arava Valley/Wadi Araba; discharge locations into the Dead Sea; and a discussion on the optimal site for the hydropower station and the desalination plant (see Fig. 12.4).

[1] As of the writing of this chapter, the final reports of the FS and ESA consultants have not yet been completed and reviewed by the STSC. We are therefore basing this chapter on the preliminary findings and recommendations as well on the final reports on sub-studies A (Red Sea) and C (Dead Sea).

In order to arrive at an optimal design configuration the consultants employed a weighted multi-criteria assessment process which took into account environmental, technical, and economic factors. Based thereon the consultants recommended (1) an eastern intake in the Gulf of Aqaba; (2) a conveyance pipeline (of six parallel pipes and three after the pick elevation) along the Wadi Araba/Arava Valley; (3) a high-level desalination plant; (4) two, high and low level, hydropower plants; and (5) a brine/sea water discharge into the Dead Sea in the area of the small gulf east of the Lisan Peninsula (Coyne et Bellier 2010). The total construction cost of the project at the above configuration is estimated at US$ 10–11 billion with an annual O&M cost of approximately US$ 400 million. The pipeline option of the RSDSCP was preferred over a low-level tunnel (see Fig. 12.5) as it reduces the potential of negative environmental impact of tunnel leakage into the aquifers and as it allows a modular construction of the conveyance rather than a one-time investment necessary if a tunnel were to be selected (Coyne et Bellier 2010).

Additional findings of the studies can be summarized as follows:

1. *The Gulf of Aqaba/Eilat.* The pumping of 2,000 MCM/year of water from the Gulf of Aqaba will only have a minor ecological impact provided that a suitable intake with a bell mouth at a depth of 140–160 m BSL is employed (THETIS et al. 2011).
2. *Leakage into the Arava aquifer.* The danger of leakage from the pipelines along the conduit can be minimized by lining the pipes and embedding them in a cement trench with a granular fill, and by providing for proper drainage and constructing in-line isolation valves at regular intervals (Coyne et Bellier 2010).
3. *Arava ecology.* The environmental impact of the pipelines on the ecology of Wadi Araba/Arava Valley during operation is expected to be limited and can be mitigated. However, the impact on certain habitat and key species like the acacia trees during construction phase may be serious and hence needs to be mitigated by suitable measures (ERM 2010).
4. *Dead Sea stratification.* Discharge of brine reject from the desalination plant into the Dead Sea in quantities of up to 400 MCM/year will most likely not create stratification (creation of upper and lower water layers) in the Dead Sea (TAHAL and GSI 2011).
5. *Algal blooms in the Dead Sea.* Even with a discharge of up to 600 MCM/year of reject brine into the Dead Sea, the overall density of the upper layer of the sea will remain above the threshold of 1.21 kg/m3 below which algal blooms can occur (TAHAL and GSI 2011).
6. *Gypsum precipitation in the Dead Sea.* Gypsum precipitation will, at most, be at an order of magnitude less than the present halite precipitation of 10 cm annually. Although a whitening effect due to rapid precipitation of gypsum may occur, it can be mitigated by spreading gypsum powder which will scavenge the gypsum crystals to the bottom of the Dead Sea (TAHAL and GSI 2011). Coprecipitation of limiting nutrients with gypsum might reduce biological blooming in the diluted upper water mass (TAHAL and GSI 2011).

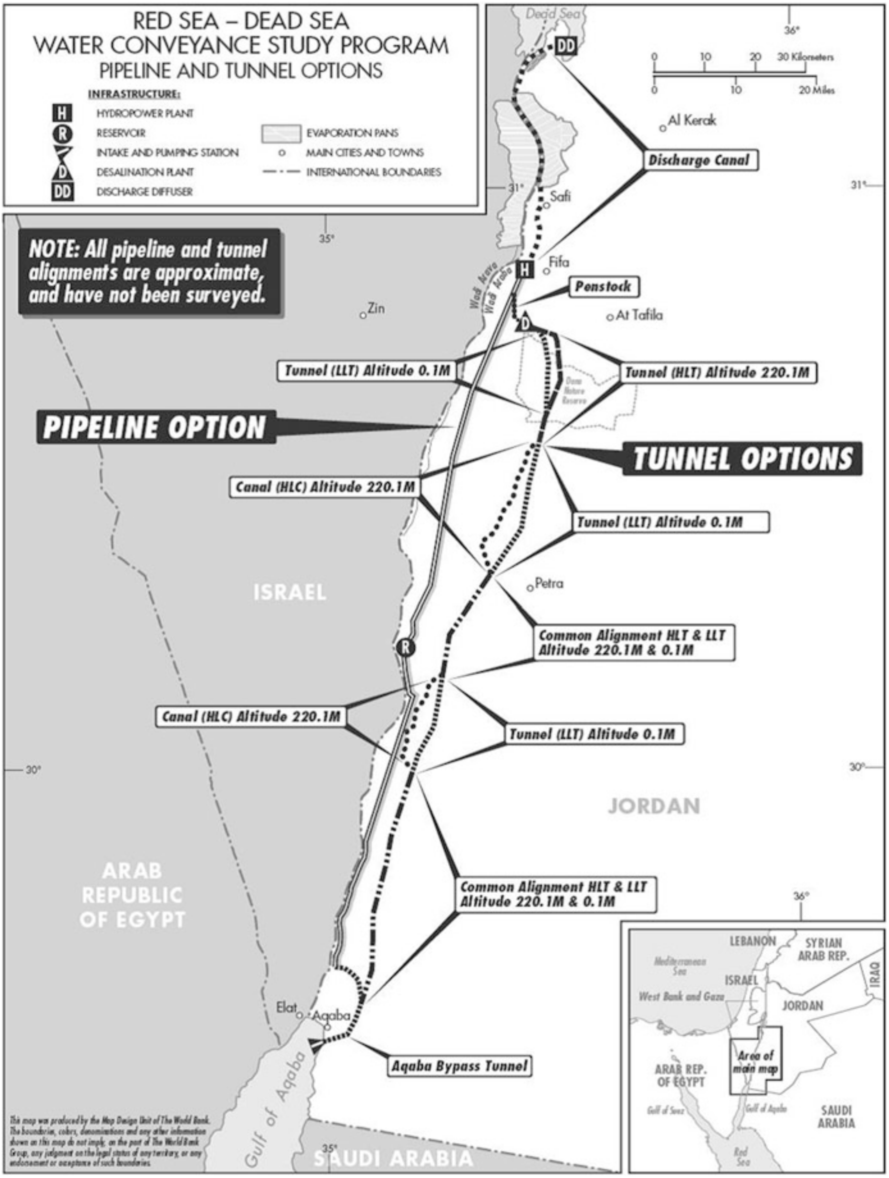

Fig. 12.5 A schematic map of the proposed pipeline and tunnel options for the RSDSCP, as was defined by COB and placed in the WB web page: http://siteresources.worldbank.org/INTREDSEADEADSEA/Resources/RDSQ&A13Dec2011_final.pdf

One of the outcomes of the above is the notion that a phased implementation of the RSDSCP could overcome most of uncertainties still remaining especially those that impact the Dead Sea.

12.6 Summary and Recommendations

Although the RSDSCP feasibility study has not been completed and final reports not yet been submitted, it appears from the information that has been released that any decision on the project can be made on a sound scientific basis.

From the already published results of the different studies, especially those of the Red Sea (THETIS et al. 2011) and the Dead Sea (TAHAL and GSI 2011), it appears that the environmental impacts of the RSDSCP on the Red Sea and the Dead Sea that were of primary concern can be mitigated if the project is properly planned and managed.

One important conclusion of the study is that a phased implementation approach is preferable and the pipeline recommendation lends itself thereto. The phased implementation would track the increasing regional water needs will allow the studying of the environmental impacts of the RSDSCP on a small-scale project first.

While the study results appear to be promising, it is essential that the detailed planning, construction, and O&M of the RSDSCP will be conducted at the highest professional standards to avoid any negative impact on the fragile environment. Also monitoring of the Gulf of Aqaba/Eilat and the Dead Sea should continue during all project implementation phases.

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Chapter 13
Impacts of Changes in Regional Rainfall-Distribution Patterns on Winter Agriculture in Israel

Iddo Kan and Naomi Zeitouni

13.1 Introduction

According to climate models, the steady accumulation of greenhouse gases in the atmosphere is expected to cause global warming and variations in precipitation distribution over the globe. Since 1750 the concentration of CO_2 has increased by 31%, currently rising at a rate of about 0.4% per year. The Intergovernmental Panel on Climate Change (IPCC 2001) estimates a consequential increase of 1.4–5.8°C in the global average surface temperature during the period between 1990 and 2100. During the twenty-first century, the average precipitation is expected to increase in most of the world. However, simulation models seem to concur that in the Mediterranean basin, rainfall is about to decline. Israel is located in the eastern part of the basin – an area with extraordinary sensitivity to climate changes due to the confluence of several different climates, particularly the cold, rainy European climate in the north and the subtropic African conditions in the south. Recent studies focusing on Israeli climate have identified an increase in the frequency of extreme temperatures (Ben-Gai et al. 1999b), as well as in extreme weather events (Alpert et al. 2002). Ben-Gai et al. (1999a) found considerable spatial variations in the annual precipitation distribution.

Such climate variation trends are expected to have significant socioeconomic implications through their impact on various factors, e.g., agronomic conditions, natural ecosystems, recreation patterns, seawater floods, and intrusion into aquifers.

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Most studies that have assessed the economic results of such climate variations have been carried out on a large scale. Estimates frequently suffer from uncertainty and imprecision, which results from combining regions with different climate patterns together (Tol et al. 2003). This chapter intends to provide a regional scale analysis of climate-change impacts. Furthermore, climate changes are often incorporated into economic analyses by considering changes in average climate factors. This study, however, applies changes in the probability distribution of climate conditions and thereby provides a unique opportunity to evaluate the economic aspects of climate changes in terms of expected net benefits from agricultural production and risks.

This work concentrates on changes in net benefits from agricultural production in Israel due to changes in rainfall patterns. It does not cover all types of climate-related effects or the entire range of agricultural activities. The focus is on the impact of projected variations in annual rainfall distributions on the profitability of winter crops, which encompass about 2 million dunams (200,000 ha) – nearly half of the state's cultivated lands.

As for the most celebrated effect of climate change, the rise in temperature, scholars are indecisive. Ben-Gai et al. (1999b) report changes in temperature patterns, particularly an increase in the frequency of warmer summers and colder winters. There are forecasts in the literature for higher temperatures in the Mediterranean region; among them is the study of Dayan and Koch (1999). However, given the aforementioned trend, the impact on winter temperatures is unclear. Moreover, field experiments indicate that the impact of temperature on yields is uncertain. For example, Lawlor and Mitchell (2000), using output from numerous experiments, show that the response of wheat yield to temperature increase and water shortages is inconsistent. On the other hand, the impact of water on yields has been extensively investigated and documented in the literature. There are models ready to use for producing data that can be used for estimating response functions. We therefore concentrate on changes in rainfall-distribution patterns rather than changes in temperatures.

The focus on winter crops is related to the fact that these crops are the most sensitive to changes in rainfall distributions. It is well recognized now in the climate-change-impact literature that a distinction should be made between the irrigated agricultural lands and the nonirrigated lands. According to Schlenker et al. (2006) "...in dryland farming areas such as Iowa, water is a (naturally occurring) fixed input available at a price of zero; in irrigated areas such as California, water is a variable but costly input with a supply curve that varies with the supply source" (p. 396). "The evidence suggests that the economic effects of climate change on agriculture need to be assessed differently in dryland and irrigated areas" (p. 406). In Israel, where there is a rainy season and a dry season, this means treating separately winter crops' production, which generally can be considered as dryland agriculture, and summer crops, which critically depend on irrigation. While summer crops are grown in the higher quality lands, where it is worthwhile to invest in irrigation systems, greenhouses, etc., winter crops are grown in relatively lower quality lands (e.g., lands with lower accessibility, larger slopes, and thin root zones). Feasibility of land reallocation between summer and winter crops is therefore quite limited.

Also, this implies that production during winter relies heavily on precipitation, and therefore, profitability is highly sensitive to variations in annual rainfall levels. Contrary, profitability of summer crops depends on irrigation water prices and quotas. In Israel these are determined by the government in light of water availability in the economy as a whole, which in turn depends on precipitations during multi-annual periods. This is because almost all the regions in Israel are interconnected by the national water-delivery system, and hence, the storage capacity in the aquifers balances the impact of annual rainfalls fluctuations on irrigation water availability throughout the whole country. Consequently, considering long-run changes in the average annual rainfall may be sufficient for the case of summer crops, while for winter crops, the probability distribution of annual rainfall is much more relevant.

We consider supplemental irrigation as the most significant adaptation tool for the case of winter crops growing. To some extent, this decision emphasizes the shorter-term adoption to new precipitation patterns, since long-term adaptation instruments such as land reallocation and changes in surface-water constraints are exogenous. It should be acknowledged, however, that the impact of these factors on the production of winter crops is relatively low. First, the principal purpose of surface-water infrastructures is to support summer crops' irrigation, which consumes much water in an order of magnitude. Second, the nature of the decision-making process is recursive (McGuirk and Mundluck 1992): land preparation for winter crop growing takes place during the fall, implying that decisions about land allocation among crops occur when farmers have no prior information about the rain available for the plants during the winter (except for their knowledge about the rainfall distribution). The picture of total annual surface-water availability becomes clear only at the end of the winter, when decisions about land allocation among crops were already made and at a stage where a considerable portion of the cultivation expenditures were realized. Therefore, in most cases supplemental irrigation (for germination and early plant growing) is expected to be applied regardless of surface-water availability, and responses in terms of land reallocation can be considered an insignificant adaptation mean. That is, it is rather safe to refer to supplemental irrigation as an (unconstrained) adaptation strategy for intra-season changes in precipitation, whereas land allocation is not.

The aforementioned timing feature sheds light on another character of winter crop production relative to summer crops – the risk. The uncertainty associated with water availability at the planting stage increases the risk in the production decision because expenditures on land preparation and planting may not be returned in drought years, even when supplemental irrigation is applied. Embedding rainfall probability distributions in the analysis enables us to quantify such variations in winter agricultural production risks.

Our spatial economic analysis utilizes a study by Ben-Gai et al. (1999a), who have estimated the probability distribution functions for annual rainfall using data collected from 60 rainfall-monitoring stations spread throughout Israel. Although rather small, Israel is characterized by a sharp climate gradient, varying from arid conditions in the south to semiarid in the north. Hence, this detailed spatial rainfall data set enables us to pursue a high-resolution analysis, which accounts for the considerable spatial variability in production management and profitability throughout the country.

The economic evaluation is based on the production-function approach: yield-response functions are used for simulating net profits under projected scenarios of rainfall conditions. Examples of studies implementing this approach include Adams et al. (1990, 1999) and Rosenzweig and Parry (1994). Another analytical strategy is the Ricardian approach (Mendelsohn et al. 1994; Deschênes and Greenstone 2007); it relies on the assumption that the market price of land is a reliable proxy to the land's present discounted value of future profits, which in turn are affected by climate features. The preference for the production-function approach is attributed to the absence of a free market for agricultural lands in Israel. Since most lands are owned by the state, prices are significantly affected by administrative regulations and national policies.

The next section of this chapter presents the formal economic evaluation model. Section 13.3 describes the procedures for estimating rainfall-distribution functions and yield-response functions, as well as economic data used in the simulations. Section 13.4 shows the simulation results for optimal surface-water applications at various levels of annual rainfall, net-profit expectations under rainfall-distribution patterns in the past and according to a projected future scenario, aspects of profits' variation and risks, and sensitivity to surface-water prices and salinity level. Section 13.5 provides a summary and conclusions.

13.2 General Model

Consider a geographic area with semiarid climate conditions. The area is divided into N regions. I types of winter crops are grown in each region. Rain and supplemental surface-water irrigation constitute the potential water sources available for plant growth. Farmers observe rainfall, r, and select for each crop i, $i = 1, \ldots, I$, the optimal per-area-unit annual surface-water application, $s^{*i}(r)$, by solving:

$$\begin{aligned} & s^{*i}(r) = \arg\max \pi^i \left(s^i, r\right) = p^{yi} y^i \left(s^i, r\right) - p^s s^i - \phi^i \\ & s.t. \qquad \sum_i s^i \leq \bar{S}; \end{aligned} \tag{13.1}$$

π^i, $y^i\left(s^i, r\right)$, and ϕ^i are the crop i's annual per-area-unit profit, yield, and non-water costs, respectively; p^{yi} denotes crop i's output price; p^s is the price of surface water, and $\bar{S}$ is the total quota of surface water available for the farmer.

Spread out over each region, n, are J^n rainfall-monitoring stations; each of these stations represents a subregion covering its surrounding area. In each subregion j, the annual rainfall, r, is a random variable distributed according to a gamma-distribution function:

$$f\left(r;\alpha_{nt}^{j},\beta_{nt}^{j}\right)=\left(\beta_{nt}^{j}\right)^{\alpha_{nt}^{j}}(r)^{\alpha_{nt}^{j}-1}e^{-\beta_{nt}^{j}r}\left[\Gamma\left(\alpha_{nt}^{j}\right)\right]^{-1};$$
$$r\geq 0,\quad \alpha_{nt}^{j},\beta_{nt}^{j}>0\ \forall\ j=1,\ldots,J^{n}, \tag{13.2}$$

where α_{nt}^{j} and β_{nt}^{j} are the shape and scale parameters of the specific subregion's gamma-distribution function, respectively. The t index indicates that these parameters are related to a particular time period and may change due to global warming. $\bar{r}_{nt}^{j}=\alpha_{nt}^{j}\beta_{nt}^{j}$ and $v_{nt}^{j}=\alpha_{nt}^{j}\left(\beta_{nt}^{j}\right)^{2}$ are subregion j's rainfall expectation and rainfall variance, respectively. Let $G_{nt}^{j}\equiv\left\{\alpha_{nt}^{j},\beta_{nt}^{j}\right\}$ denote the pair of gamma-distribution parameters during time period t in subregion j of region n; in time period t, the average annual net-profit expectation for region n with respect to crop i is:

$$\Pi_{nt}^{i}\left(G_{nt}\right)=\frac{x_{n}^{i}}{J^{n}}\sum_{j=1}^{J^{n}}\int_{0}^{\infty}\pi^{i}\left(s^{*i}(r),r\right)f\left(r;G_{nt}^{j}\right)\mathrm{d}r, \tag{13.3}$$

where x_{n}^{i} denotes the area allocated to crop i in region n and $G_{nt}\equiv\left\{G_{nt}^{j},\ldots,G_{nt}^{J^{n}}\right\}$. Summation of (13.3) over regions and crops yields the annual net-profit expectation of the winter-crop production throughout the discussed area during period t:

$$\Pi_{t}\left(G_{t}\right)=\sum_{i=1}^{I}\sum_{n=1}^{N}\Pi_{nt}^{i}\left(G_{nt}\right), \tag{13.4}$$

where $G_{t}\equiv\{G_{nt},\ldots,G_{Nt}\}$. Using these settings, we analyze the impact of changes over time and space in the rainfall gamma-distribution parameters, G_{t}, on the net-profit expectation associated with winter crops growing, $\Pi_{t}\left(G_{t}\right)$, along with other related issues, such as risks, prices, and water quality.

13.3 Data

13.3.1 Past and Projected Annual Rainfall-Distribution Functions

As mentioned in the introduction, the climate basis of the analysis is the spatial rainfall-distribution functions estimated by Ben-Gai et al. (1999a) for 60 rainfall stations spread throughout Israel. The data set from each station, consisting of 60 years' worth of records, was divided into two periods: Period I covers the winters from 1931/1932 to 1960/1961 with a median at 1945, and Period II, the winters from 1961/1962 to 1990/1991, a median at 1975. For each meteorological station, two gamma-distribution functions were estimated to represent the distribution pattern in each period. Ben-Gai et al. (1999a) found that there are three distinct weather regions, which we will refer to as the north, center, and south of Israel. These regions are characterized by differences in annual precipitation distribution (thus, in terms of our economic model, this implies that $N = 3$). Ben-Gai et al. also detected different changes over time in the rainfall distribution functions. In the north, the shape parameter decreases in Period II relative to Period I, while concomitantly the scale parameter increases (see Fig. 13.1). This increase in the distribution asymmetry implies an increase in the frequency of high rainfall events together with an increase in the average annual rainfall. In the south, however, the average shape parameter increases and the scale parameter declines. These trends reveal a reduction in the aridity of the southern region of the country and indicate a transition toward a normal distribution. Alpert (2001) attributes this variation in the south of Israel to local factors, particularly to the widespread and intensive agricultural activity that creates an increase in local evaporation. This activity has begun with the opening of the National Water Carrier in 1964, which enabled a sharp increase in the agricultural production in the south. The increase in evaporation created a change in the microclimate toward greater amount of clouds and consequently higher precipitation. Changes in the center are similar to those found in the south, however, on a more moderate scale.

Substituting the estimated distribution functions in Eq. 13.4 enables calculation of the profit expectations associated with rainfall patterns typical for the two aforementioned periods. Our interest, however, is in analyzing projected rainfall patterns and their impact on the profitability of winter-crop production throughout Israel. One may view the changes identified in the estimated rainfall-distribution functions as an evidence for the existence of a continuous variation in the distribution. Under such a supposition, the analysis of Ben-Gai et al. can be considered as an estimation of two points (for 1945 and 1975) on a curve that describes the trend of this variation. By extrapolation we calculate points on this curve that are related to three future periods. The extrapolations were conducted so as to adjust the average annual rainfall expectation over the whole area to the forecasts provided by Dayan and Koch (1999), who estimate (based on a GCM developed by Palutikof et al. (1996)) rainfall reductions of 1–2%, 2–4%, and 4–8% in the years 2020, 2050, and 2100, respectively. Figure 13.1 illustrates the resultant changes in the gamma-distribution functions calculated for three periods (Period III represents an annual rainfall reduction of 10%) at two stations typical of their regions: Kfar Blum in the north and Dorot in the south.

The change in the distribution at Kfar Blum is characterized by a slight rise in rainfall variation from Period I to Period II and an increase in the average annual precipitation from 524 to 536 mm/year. Assuming the continuation of this direction of change in the parameters from Period II to Period III yields an expansion of the left tail of the distribution and a reduction of 30 mm/year in the average annual rainfall in the north. In Dorot, the variance reduces, while the expected rainfall increases, first from 345 mm/year in Period I to 367 mm/year in Period II, and then sharply declines in Period III to 233 mm/year.

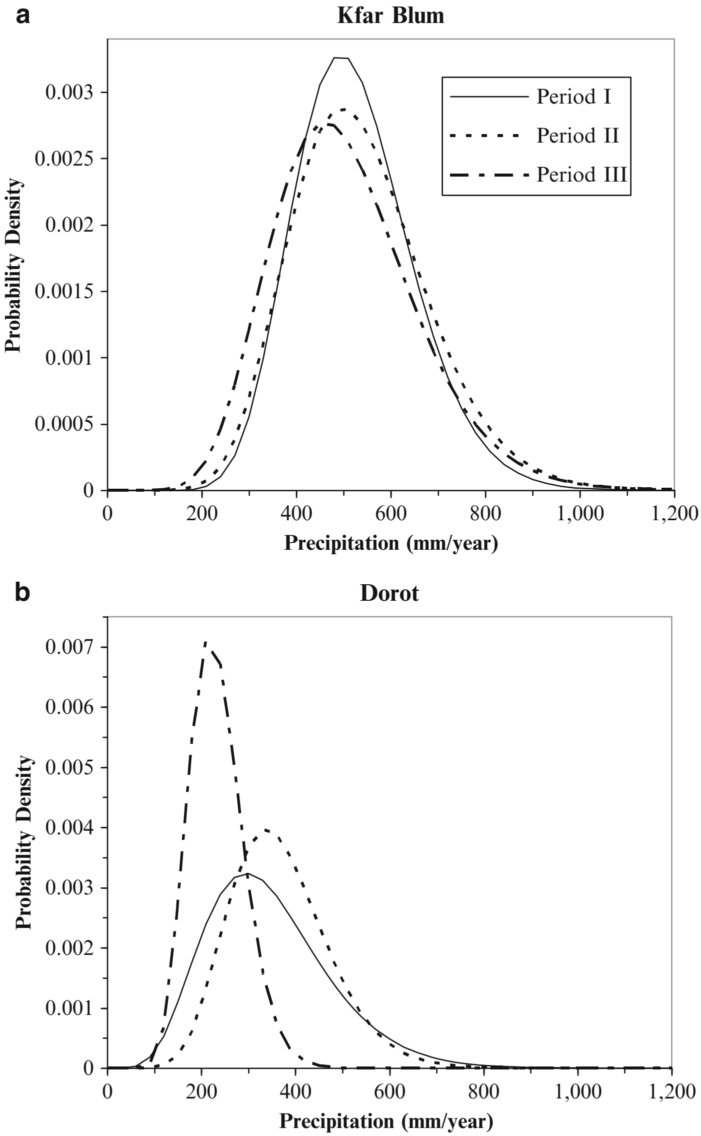

Fig. 13.1 Annual rainfall distribution functions for (**a**) Kfar Blum station in the north and (**b**) Dorot station in the south

13.3.2 Production Functions

Three seasonal crops were selected that represent the major winter-crop groups: wheat for field crops, processing tomatoes for vegetables, and vetch for fodder. Production functions were generated for each crop through a two-stage meta-modeling procedure. This procedure is detailed in Kan et al. (2002). Briefly, first, the evapotranspiration (ET), e (mm/year), is described as a function of the applied water, w (mm/year), and the applied water's salt concentration, c (dS/m). Let s (mm/year) be the applied irrigation water such that $w = s + r$ (mm/year) and $c = \frac{sc^s}{w}$, where c^s (dS/m) is the salinity level of the surface water and the rain r (mm/year) has zero salinity. The ET function is:

$$e(w, c) = \frac{e_{\max}}{1 + \gamma_1(c + \gamma_2 w^{\gamma_3})^{\gamma_4}}, \qquad (13.5)$$

where γ_1–γ_4 are crop and irrigation-system specific coefficients to be estimated using data produced by a plant-soil-water equilibrium model (Letey et al. 1985). Note that (13.5) enables us to calculate the volume of deep percolations, d (mm/year), according to the identity $d = w - e$. Second, a function describing the relationship between the annual yield, y (t/dun-year), and e is estimated:

$$y(e) = \delta_1 e^{\delta_2}, \qquad (13.6)$$

where δ_1 and δ_2 are coefficients. Table 13.1 presents the parameters estimated for the three crops.

13.3.3 Economic Data

The analysis is based on 2003 economic parameters that were reported for the Israeli agricultural sector. Output prices, as well as production costs, were collected from various reports. In addition, we used growing-cost studies published by the Israeli Ministry of Agriculture and by an agro-economic consulting company (Tzmudot 2002). Data and sources are presented in Table 13.1. Also reported are 2002 crop production areas in the three regions under consideration, as detailed by the Israeli Central Bureau of Statistics. Monetary values are in 2003 US dollars. Surface-water salinity (c^s) equals 0.75 dS/m, according to records supplied by Mekorot, the Israeli national water company. The average price of surface water for agricultural use (p^s) is subsidized and stands on about \$0.24/m^3. The impact of changes in policies affecting the levels of c^s and p^s are analyzed below.

13.4 Results

13.4.1 Optimal Surface-Water Applications

As stipulated above, we assume an internal solution to Eq. 13.1, so that the farmers act as if they choose annual irrigation $s^{*i}(r)$. Based on the corresponding functions and economic parameters, Fig. 13.2a1, a2 presents the variation in the

Table 13.1 Model's parameters, production-function coefficients, and economic data

Description	Wheat (field crops)	Tomato (vegetables)	Vetch (fodders)
Plant-level coefficients[a]			
y_{max} (t/dun-year)[a]	0.75	12	11
w_{min} (mm/year)	469	420	260
e_{max} (mm/year)	261	820	800
C (dS/m)	6.0	2.5	3.0
B (t-m/dun-year-dS)	7.1	9.9	11.0
Field-level coefficients			
γ_1	1.343×10^{-2}	1.742×10^{-2}	5.836×10^{-4}
γ_2	6.666×10^{13}	2.690×10^{10}	21,931
γ_3	−4.910	−3.420	−1.181
γ_4	1.130	1.453	2.556
δ_1	2.488×10^{-6}	1.696×10^{-6}	7.237×10^{-6}
δ_2	2.055	2.360	1.796
Prices and costs[b]			
p^y (\$/t)	157.8	48.9	170.7
$\boldsymbol{\phi}$ (\$/dun)	69.8	316.0	43.1
p^s (\$/m^3)	0.24	0.24	0.24
Production areas (dun)[c]			
North	346,791	96,433	290,377
Center	95,723	55,173	63,758
South	130,316	128,163	744,054

[a]Data are from Letey and Dinar (1986), Mass (1990), and Asher Izenkot from the Israeli Ministry of Agriculture and Rural Development (personal communication)
[b]From sample cost studies of the Israeli Ministry of Agriculture and Rural Development (2002), and Tzmudot Information and Management LTD (2002). Output price is net of yield-related costs, such as harvesting
[c]Source is the Israeli Central Bureau of Statistics for 2002; the areas are for total winter field crops, vegetables, and fodder crops, represented for the economic analyses by wheat, tomato, and vetch, respectively

optimal surface-water application levels, s^*, for wheat and tomatoes with the annual precipitations, r. Also presented are the associated changes in applied water, w, changes in ET, e, and in deep percolations, d. Figure 13.2b1, b2 shows the corresponding variations in the per-unit-area net profits, π, and yields, y.

When there is no rainfall, $r = 0$, surface water constitutes the single plant intake water source. As precipitation increases, there are two phases of change. First, there is a linear reduction in the optimal surface-water application, s^*, which reflects the substitution between the two water sources. Note that the substitution is imperfect due to the difference in the sources' salinity levels. This variance is exhibited by the slight decrease in the total applied water, w, as rain increases – the increase in rainfall reduces the salinity of the annual applied water and thereby reduces the optimal water application, i.e., less water intake is required to compensate for the negative effect of salinity on yields. The combination of the two water sources maintains ET at an almost constant level, which implies that the yield does not

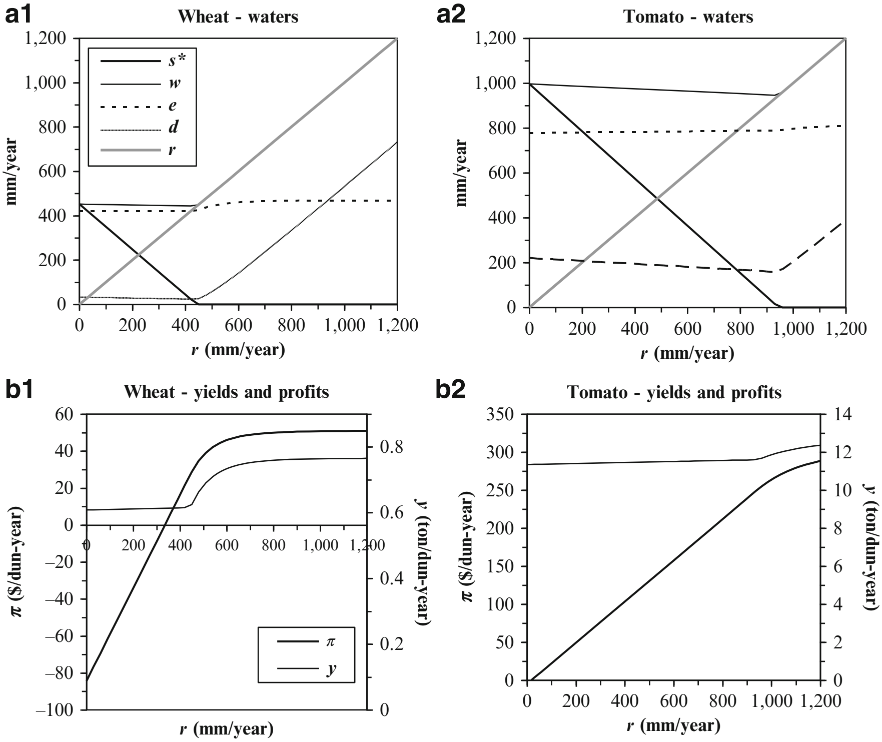

Fig. 13.2 Plotted versus annual rainfall, r, the optimal annual surface-water applications, s^*, the associated applied water w, evapotranspiration e, and deep percolations d, for (**a1**) wheat and (**b1**) tomato, and the yields y, and net profits π, for (**a2**) wheat and (**b2**) tomato

change significantly. This management regime maintains the equality between the price of surface water and its value of marginal production (VMP). Profits directly increase linearly with rainfall due to the reduction in surface-water purchasing costs and indirectly increase nonlinearly because of the decline in salinity, which also positively affects the yield.

The second phase of variation starts at the rainfall level at which s^* reaches zero – from this point on surface water's VMP is lower than its price. Thus, precipitation constitutes the single water source, and w increases along a line angled at 45°. At the same time, ET also rises. However, as seen in the variation of d, as rain continues to increase, the portion of rain that penetrates down as deep percolations grows almost in a 1:1 ratio – approximately parallel to the 45° line. Profits in this phase increase according to the response of yields to the additional rainwater. Note that in wheat (and vetch, not shown) production continues even when there are negative profits, because, as we mentioned before, land preparation and planting are completed before the rainfall level is known. Hence, the non-water cost, ϕ^i, can be viewed as a lost expenditure.

13.4.2 Economic Impacts of Rainfall-Distribution Changes

The optimal surface-water applications for various rainfall levels (Fig. 13.2) are utilized in Eq. 13.3 to calculate the average annual net-profit expectation for each region and crop group. This expectation is associated with a specific annual rainfall-distribution pattern, determined by to the gamma distribution. Apparently, the total annual net profit increases from \$93.0 million at Period I (1945) to \$101.7 million at Period II (1975). Subsequently, however, this positive trend is reversed, and profitability is expected to decline. Considering the aforementioned forecasts provided by Dayan and Koch, the overall annual net-profit expectations in 2020, 2050, and 2100 are estimated to be \$98.5–100 million, \$94.8–98.5 million, and \$86.1–94.8 million, respectively. Relative to Period II, these are reductions of 1.6–3.2%, 3.2–6.9%, and 6.9–15.4%, respectively.

Winter agriculture in the south is found to be the most sensitive to rainfall-distribution changes; the net profit of all crops increases from \$16.6 million in Period I to \$24.8 million in Period II, but then falls. This outcome is attributed mainly to the effect of the necessary changes in irrigation on the expected profit from field crops. In the north, rainfall patterns affect the profitability of field crops and fodder, while vegetables show almost no response to the changes in precipitation distribution. Changes in the center are minor for all types of crops.

13.4.3 Sensitivity to Water Price and Salinity

The net-profit expectation estimations based on 2003 observations of prices, technologies, quality of inputs, etc., are expected to vary over time, and several of these changes may be stimulated by the variations in rainfall patterns. The increasing demand for domestic water use due to population growth and the continuing rise in per capita water consumption, together with the increase in surface-water scarcity in Israel, are already affecting water prices and water allocation to the agricultural sector. Currently, fresh water allocations that have been protected historically by grandfathered seniority rights are being sharply cut and replaced with allotments of treated wastewater. This policy is expected to increase soil salinity, leading to reduced yields. In the long run, the use of treated wastewater will depreciate groundwater sources, thereby escalating water scarcity. Furthermore, the construction of seawater desalination plants for providing water to urban users puts the current subsidies of agricultural water under intensifying criticism, and calls for a dramatic price increase are often debated in the political arena. However, the availability of almost unlimited amount of desalinated water transfers the discussion from a discussion about water shortage into a discussion about profitability reduction. In this subsection, we analyze the impact of such trends by reevaluating the economic effect of changes in rainfall-distribution patterns under various surface-water prices and qualities. For each exogenous change in these

Table 13.2 Sensitivity of net-profit expectations under rainfall patterns in 1975 (Period II), 2020, 2050, and 2100 (Dayan and Koch) to an increase in surface-water price up to the level of seawater desalination cost, 0.56 \$/m^3, and to a rise in surface-water salinity toward the level of treated waste water, 2.00 dS/m

	Net-profit expectations (million \$/year)			Change relative to "reference" (%)	
	Reference	Higher price	Higher salinity	Higher price	Higher salinity
p^s (\$/m^3)	0.24	0.56	0.24	0.56	0.24
c^s (dS/m)	0.75	0.75	2.00	0.75	2.00
1975 (Period II)					
Entire area	101.8	59.5	93.8	−41.5	−7.8
North	47.4	33.9	44.7	−28.5	−5.6
Center	17.1	10.8	15.9	−36.7	−7.1
South	24.8	−3.0	20.0	−112.0	−19.2
2020					
Entire area	99.3	56.0	91.2	−43.7	−8.2
North	46.5	32.7	43.8	−29.8	−5.9
Center	16.9	10.5	15.7	−37.8	−7.3
South	23.0	−5.6	18.1	−124.4	−21.2
2050					
Entire area	96.5	51.8	88.2	−46.4	−8.6
North	45.6	31.3	42.8	−31.4	−6.2
Center	16.7	10.2	15.4	−39.0	−7.5
South	20.8	−8.9	15.8	−142.6	−24.2
2100					
Entire area	90.7	43.1	81.9	−52.5	−9.7
North	43.6	28.4	40.6	−34.8	−6.8
Center	16.2	9.5	14.9	−41.5	−8.0
South	16.2	−15.8	10.9	−197.6	−33.0

parameters, the area's average net profit under various rainfall-distribution patterns is calculated by solving Eq. 13.1 to find the appropriate $s^*(r)$ and substituting the results in Eq. 13.3.

Table 13.2 summarizes the results of the sensitivity analyses, based on the scenario provided by Dayan and Koch for average rainfall reductions relative to Period II (with the median year 1975) of 1.5, 3.0, and 6.0%, for 2020, 2050, and 2100, respectively. The second column in the table presents net-profit expectations according to the reference scenario, where surface-water price and salinity are those observed in 2003 – \$0.24/m^3 and 0.75 dS/m, respectively. Columns three and four present the effects of higher surface-water price and higher salinity on the profit expectations. The higher price represents the marginal cost of seawater desalination (\$0.56/m^3), and the higher salinity is that of treated wastewater – about 2.0 dS/m. Columns five and six express these effects as percentage rates relative to the reference case.

The simulated increase in surface-water price creates a considerable reduction in profitability – for Period II rainfall distributions, there is a decline of 41.5% for the entire area. Moreover, the prospective changes in further rainfall increase this loss up to 52% in 2100. As expected, this effect increases along Israel's climate gradient from the north to the south; in fact, without any supplementary policy, such as provision of a non-water-related subsidy, production of field crops and vegetables in the south becomes unprofitable at all periods. As the highest water consumption crops (Fig. 13.2a2), vegetables are the crop group most sensitive to water prices, with a profit reduction of 82.2 and 95.1% in 1975 and 2100, respectively (not shown). Field crops are ranked second in sensitivity to water price, despite the fact that fodder consumes more water. This seeming contradiction is attributed to the steeper response of profits to water applications (not shown).

The "higher salinity" scenario shows similar patterns in its impact on profitability, but of a lower magnitude. Nationwide profits are reduced by 7.8 and 9.7% in 1975 and 2100, respectively. The impact is strongest in the south. Represented by the tomato, a relatively salt-sensitive crop, vegetables are the most sensitive group with a reduction of about 15% throughout the entire country. Fodder is second with nearly 6%, and wheat, representing field crops, exhibits a reduction of about 3%. Rainfall distribution changes throughout the periods enlarge salinity's negative impact by approximately 2%.

13.5 Concluding Remarks

The novelty of this work is attributed to the use of rainfall probability distribution functions for generating regional scale estimations of climate-change impacts on agricultural profitability. The methodology is mostly applicable to agriculture in semiarid regions with significant reliance on rain-fed crops. The findings indicate that projected variations in rainfall-distribution patterns inflict significant damage on winter-crop production in Israel. On average, net profits are expected to decline by about 11% by the year 2100, relative to the latter part of the twentieth century, although the effects vary considerably depending on location. The semiarid southern region is the most sensitive to the projected climate change, with a 35% decline in profit, whereas in the center and the north of the country, reductions in profitability amount to 5 and 8%, respectively. Also, risks are in general lower in these two latter regions because a more dramatic rainfall reduction is projected in the south.

The above findings point on a growing threat to the agricultural sector in the southern part of Israel. Farmers' incentives to leave the agricultural sector in favor of more secure income sources are expected to rise dramatically. Simultaneously, growing pressures to utilize agricultural lands for alternative purposes, particularly urban ones, will entail changes in the landscape and a reduction in the availability of open spaces. Nevertheless, to some extent some exogenous factors, such as increases in food demands and supportive governmental intervention (driven by national objectives), may balance these negative effects of climate change. Being limited by estimation and forecasting errors, our analysis can serve as an estimation of the damage expected under a scenario of no change, toward more sophisticated agricultural methods. However, it is our belief that preparation to the future is required, and indeed nowadays there is a growing attention in Israel to climate-change impacts.

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Chapter 14
A State of Uncertainty Regarding the Impact of Future Global Climate Calls for Creating Groundwater Storage in Order to Ensure a Safe Supply of Water for Israel

Arie S. Issar and Yakov Livshitz

14.1 Introduction

Various studies have shown that warm climatic spans in the history and prehistory of the Middle East have often engendered periods of drought and famine. These studies were based on profiles of proxy data such as changes of sea and lake levels, tree and stalagmite rings, and pollen ratios in lake and sea bottom sediments. Assuming that the past is a reliable key to the future, it may be predicted that ongoing global warming will cause a reduction in precipitation throughout the Mediterranean Region. In Israel the supply of future demand for water is based largely upon desalination of seawater and reuse of wastewater.

Recently, however, significant doubt has arisen concerning the aforesaid prediction: an entirely new factor may counteract the effects of global warming. According to scientists at the National Solar Observatory (NSO) and the US Air Force Research Laboratory, the number of sunspots is forecast to decline to a minimum and thereby cause the cooling of our planet. The previous long-term cooling phase due to a dramatic reduction of sun spots – the Maunder Minimum distinguished by a virtual absence of sunspots – occurred between 1645 and 1715 AC precipitating the so-called Little Ice Age. Proxy data such as the stalagmites of Israel's Soreq Cave reveal this period to have been unusually humid.

Which of these two countervailing projections will determine the climate of the Middle East in the coming decades, global warming resulting in dryness or the

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diminution of sunspots triggering colder and humid winters? Or will there be a new sort of climate, one, as suggested by records of the past, of periods of plentiful rainfall alternating with years of droughts?

As the trend toward global warming accelerates due to the increase in greenhouse gases, countries relying on burning oil for their electricity supply will be required to take dramatic measures to reduce consumption. These will very likely involve a rise in the cost of energy based on gas and oil combustion. Today as well as in the foreseeable future, desalination plants in Israel derive their energy from power stations that burn fossil fuels, thus producing greenhouse gases. Thus, albeit that at present the consumption of energy for desalination represents only about 2% of the annual total electricity consumption of the country, the question still remains: what will be the impact of a future rise in electricity costs taken together with an increase of demand for desalination of seawater to produce freshwater for a growing population?

Moreover, the possibility of unexpected destructive incidents, for example, an earthquake and/or tsunami impacting upon power stations along Israel's coastline, although of low probability, cannot be dismissed out of hand.

In the face of these and other uncertainties, such as, for example, the recurrence of 5 or more consecutive years of drought, Israel's focus should be upon creating groundwater storage capacity. What must also be assessed is the effect of an anticipated reduction of 25% in water availability between 2070 and 2099 in comparison to 1961–1990 due a loss of water pumped from the coastal plain aquifer as a result of the potential rise in sea level (IPCC 2007; Axelrod 2010).

Due to hydrogeological conditions, this storage of groundwater will have to occur mainly in the eastern part of the coastal plain.

14.2 Present Regime of Precipitation

Israel is divided into two climate regimes: its northern half is influenced by the Mediterranean, while its southern half, the Negev, belongs to the Saharo-Arabian desert belt. As a result, the northern region is humid during the winter – from November to March – as it lies in the path of the rainstorms which arrive as cold cyclonic lows that originate in the North Sea and Atlantic Ocean and move over the Mediterranean Sea. These storms seldom reach the southern part of Israel, the Negev, which is south of the track of the storms, as can be seen on the precipitation map (Fig. 14.1). As a result the Negev gets less than 200 mm/year. This amount precipitates mainly in cold years during which the cyclonic lows manage to reach the northern part, but seldom the central portion of the Negev.

From April to October, the whole country gets no rain as it is dominated by the high-pressure system of the Saharo-Arabian desert belt, which moves northward. Nevertheless, from the middle of March to the middle of November, the weather is

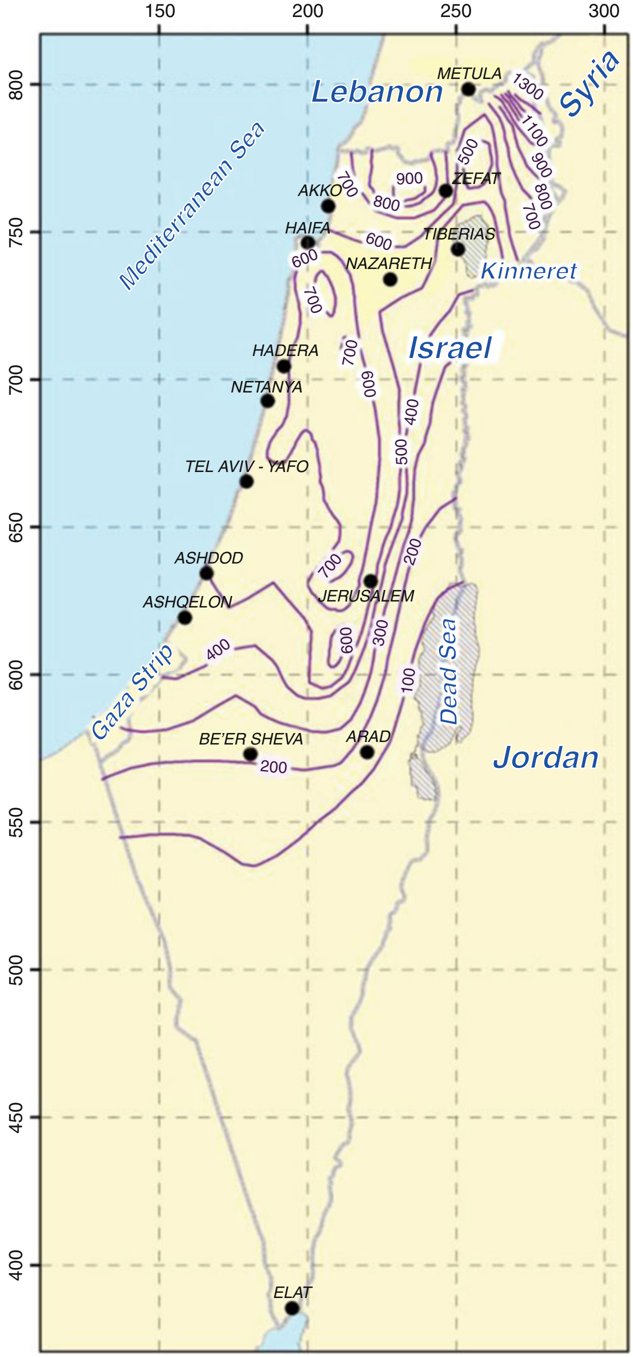


Fig. 14.1 Average precipitation map of Israel, 1961–1990

rather unstable. Dry, warm eastern storms (locally known as *khamsin*), frequently dust laden, occur from time to time. These easterly storms are often followed by westerly winds which deposit quantities of fine dust.

In addition to the outline of the coastline of the Mediterranean Sea, the geography and topography of the interior also exercises control over the distribution of rainfall. Thus, the rift valley that stretches from the Arava Valley in the south to the Hula Valley in the north is relatively arid as it is located in the shadow of the rain coming from the sea. On the other hand, the mountains, mainly their western face, receive relatively large amounts rain and snow in winter. In general, as one proceeds from the northern part of the country southward and from the west to east at the same topographic height, both the scarcity of rainfall and its high variance increase markedly from year to year.

14.3 The Past Is the Key to the Future

Investigations based on the interpretation of data for climate changes during the past and their impact on the history of the Middle East (Issar 2003, 2007b; Issar and Zohar 2007) show that during cold periods the region that includes Israel was humid and flourishing, whereas during warm periods it became drier, enduring frequent droughts that caused famine and, especially along the desert margins, the abandonment of settlements. Yet not all places shared this calamity equally, for settlements which obtained their water supply from rivers or springs fed by regional aquifers, like the valleys of Tiberias and Jericho, suffered less from the droughts. On the other hand, communities that got their water from non-perennial streams or local groundwater reservoirs, like Arad and most other Negev cities and villages, were periodically deserted.

Based upon these observations, it can be reasonably forecast that the ongoing warming of the globe will result in a drier period in the Middle East. Frequent spells of drought and lower amounts of annual rainfall will lead to a lowering of the groundwater table which in turn will reduce the flow of the major springs that feed the main rivers of this region, not to speak of the decline and even drying up of small springs, especially in the areas of relatively low rainfall average.

While the climate changes during the Pleistocene era, namely, the last million years, which involved glaciation and deglaciation phenomena, are satisfactorily explained by the Milankovitch theory of orbital forcing (Milankovitch 1998), climate changes during the Holocene era are still under debate. Although it is beyond the scope of the present chapter to discuss the various theories regarding these variations, more than a few senior scientists refer to intensity of solar radiation as the main factor. The main argument rests upon evidence that no sunspots were observed during the Maunder Minimum, also known as the Little Ice Age which lasted from 1640 to 1710 AC.

Among the scientists who refer to changes in the solar radiation as responsible for Holocene climates are Dansgaard et al. (1984). They base their conclusion on oscillations of oxygen-18 deep within Greenland ice cores and the beryllium-10 concentration, which is a cosmogenic isotope (Dansgaard et al. 1984). Oeschger et al. (1984) note that solar-induced variations of the beryllium isotope by a factor of 1.5 have been found for the Little Ice Age. Van Geel and Renssen (1998) suggest that the cold period, which occurred around 2,650 BP in Northwest Europe, was caused by reduced solar activity. Schove (1984) maintains that the sun's activity had an influence on the climate of the globe during the last millennia. This conclusion is strengthened by average winter temperatures from 1659 in central England, calculated by Lockwood et al. (2010) as compared with records of highs and lows in solar activity. Their conclusion is that during years of low solar activity, winters in the Britain are far more likely to be colder than average.

14.4 The Greenhouse Effect and Present Global Warming

Most scientists agree that the primary cause of present global warming is an excessive amount of carbon dioxide in the atmosphere, functioning, as it were, like the glass roof of a greenhouse. The source of the high quantities of CO_2 emissions is the burning of fossil fuels by cars and power plants. Assuming that the warming and cooling events during protohistory and history of the planet were due to solar activity, the question is how would forecasted reduction in the number of sunspots, as envisaged by astronomers, interact with continuing warming occasioned by a steady increase in the emission of greenhouse gases? Devolving from this, how will these contrary trends affect the water resources of the Middle East in general and of Israel in particular?

Three potential scenarios generated by global warming and a dearth of sunspots follow:

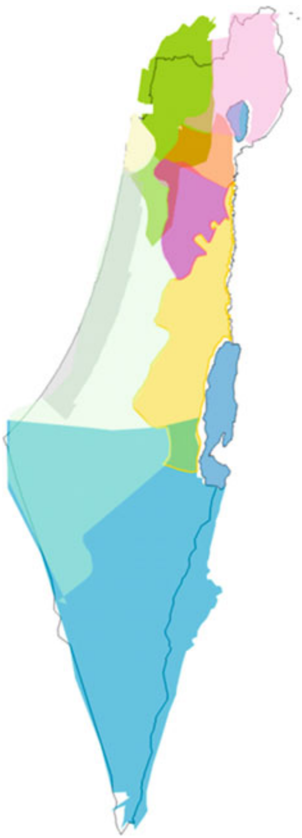
- Ascending global warming will dominate and therefore the continuation of the regional aridization that might result in a series of droughts.
- A decrease in the number of the sunspots until their total disappearance followed by the cooling of the globe, causing abundance of rains and floods in the Middle East.
- "The scenario of waves" as a result of a combination of the above. The waves will bring a number of warm years of severe drought alternating with a period of cool, wet years and flooding.

In order to cope with each of these scenarios and to ensure the country's water supply, the principle solution hereby offered lays emphasis upon ensuring reserves of groundwater. These reserves would be created by recharging the various aquifers during times of abundance and their exploitation during periods of shortage.

14.5 Potential Aquifers Suitable for Long-Term Groundwater Recharge and Storage

The natural water supply of Israel is based on nine water basins (Fig. 14.2) and two main aquifers:

1. The limestone-dolomite aquifer of the mountainous part of Israel – the Judea Group of Cenomanian Turonian Age.
2. The calcareous sandstone coastal plain aquifer of Quaternary Age.



Basin	Recharge (mcm)
Kineret	579
Coastal	243
Western Mountain	352
Eastern Mountain	192
North Eastern Mountain	142
Lower Galilee	28
Western Galilee	136
Carmel	41
Negev	32
Total	1745

Fig. 14.2 Main water basins and the average annual recharge from the rain in million cubic meters (MCM) during the period of 1973–2009 (After Weinberger et al. 2012)

14.5.1 *The Limestone-Dolomite Aquifer: The Judea Group of the Cenomanian Turonian Era (Mountain and Western Galilee and the Carmel Basins)*

This important aquifer of permeable limestone and dolomite comprises the mountainous backbone of the northern and central parts of Israel and extends to below the west-southern part. Its permeability is a function of the fracturing and dissolution processes it has undergone. The rainwater, which falls on the region underlain by these rocks and which has neither evaporated directly from the surface nor been transpired by vegetation, infiltrates through the soil or solution channels and fractures in the exposed rocks. This water flows vertically until it reaches the saturated part of the aquifer from where it flows in a subhorizontal direction toward either the natural outlets of the aquifers, that is, regional springs, or into artificial outlets, that is, wells. In many places the water is discharged through small springs due to the formation of local water tables perched on marl layers. In some areas these layers become thick and extend over wide areas. In these cases the springs become perennial.

In general the Judea Group is divided lithologically and thus hydrologically into three parts:

- The uppermost portion is built of highly permeable limestones and dolomites (of the Turonian to Upper Cenomanian Age); its average thickness is about 150 m.
- The middle part is built of semipermeable marly limestone, chalks, and marls (mid-Cenomanian Age). Its thickness is about 150 m.
- The lower part is composed mainly of permeable dolomites (Lower Cenomanian to Albian Age). Its thickness is about 400 m.

In the Galilee where a thick sequence of impermeable chalks and clays of the mid-Cenomanian period is found, the aquifer is divided into upper and lower parts. In most areas in Israel, the lower part subsists under subartesian conditions. In the mountainous part of the country, the groundwater divide is located along a line running north to south, more or less along the topographical backbone of the region. This directs the groundwater to flow into two main directions, one to the west and southwest and the other to the east. The annual flow to the west is discharged mainly by wells and to a lesser extent by springs. The discharge to the east is to the Sea of Galilee mainly by springs. Part of the groundwater flow emerges as saline springs, a portion from the bottom of the lake (Issar 1993). Part of the saline springs along the shoreline has been diverted to flow directly into the Jordan River.

In the central part of the country, the subdivision between the upper and lower part of the Judea Group is local, and thus, this aquifer can be regarded as a single hydrological system. All the western flank of the mountainous backbone forms the western mountain aquifer. In the region of foothills, there is practically no recharge as the limestone is covered by impermeable layers chalks and marls (Hashefela Group of Senonian to Eocene Age). Here the water table is subartesian and, when the borehole strikes the top of the aquifer, it rises to a certain level. In the past, the outflow of the groundwater to the west and northwest was discharged through the freshwater springs of Rosh Ha'ayin to the Yarkon River and the brackish Taninim springs on the western foot of the Carmel. At present this aquifer is discharged by wells.

Due to the high permeability and low storativity of this aquifer, its storage capacity is rather low; this can be ascertained from the sharp rise of the level of water table during wet years and its decline during dry years. Thus, it is preferable to carry out the recharge and storage of groundwater in either the mountainous part of the aquifer or in the western portion of the foothills. Because of the distance from the outcrops' areas, where the recharge takes place, to the outlets and pumping fields and natural discharge (Yarkon and Taninim springs), the storage of the recharged water is for a number of years in this aquifer.

The portion of the Judean Group aquifer east of the groundwater divide flows toward the rift valley. Part of it is fresh, part is brackish flowing into the Dead Sea, and the rest flows northeast to the Beit Shean Valley. The salinity of the springs derives from its interface with deep saline water. Thus, freshwater may be tapped more to the east, nearer to the groundwater divide. This requires deep wells and pumping from great depth, both of which require nonconventional methods of operation. The annual quantity that flows to the northeast and east is about 225 MCM (Weinberger et al. 2012).

14.5.2 The Sandstone Coastal Plain Aquifer of Quaternary Age

The aquifer underlying the coastal plain is built of permeable sandstone layers which are divided into sub-aquifers by layers of semipermeable loam and impermeable clay. These subdivisions are mainly found in the western part of the coastal plain where one borehole may go through several separate sub-aquifers, each having a different groundwater level and different quality. Due to this separation, infiltration from rain falling on the sandstone layers in the western part penetrates only the uppermost sub-aquifer. All along the coast in this part of the coastal plain, there are areas in which, due to overpumping and a decline of the groundwater table, there is penetration by the sea. This, however, is differentiated according to the position of the hydraulic head in each sub-aquifer. The separate layers disappear a few kilometers from the shoreline toward the east where the sub-aquifers merge to form a single system. This enables direct infiltration into the saturated part of the aquifer and an opportunity to enhance recharge by damming streambeds and terracing hillside slopes.

14.5.3 The Limestone and Chalk Aquifer of the Eocene Age

Compared with the Judean limestone and coastal plain aquifers, this aquifer is of minor importance from the quantitative point of view. In the Galilee as well as in Mount Gilboa, it is found in a reef facies (Bar Kochba Limestone). The total annual recharge of this aquifer is on the order 80 MCM.

In the western foothill region of the Hebron Mountains, the aquifer is semipermeable as it's built of layers of chalk. The flow is mainly deposited into solution channels along major streambeds. Salinity varies from about 300 mg/Cl/L under and near the streambed to 2,000 mg/Cl/L further away. The main source of this salinity is ancient residual water trapped in pores of the chalk (Livshitz et al. 2011).

14.5.4 Alluvial Layers in the Intermountain Valleys

14.5.4.1 The Yezreel Valley

The Yezreel (or Jezreel or Esdraelon) is a northwest by southeast rift valley. It is bordered to the north mainly by faults, to the northeast by the Lower Galilee highlands, to the southwest by the Menashe Hills, and to the south by the Samarian highlands. The sediments filling the valley are mainly clays and marls. An artesian aquifer exists at the depth of about 10 m in the subsurface of the valley composed of alluvial material of sand and fine gravel of about 2-m thickness. The alluvial layers extend along ancient, buried riverbeds. Water from this aquifer leaks upward to emerge at the surface and causes soil to become saline. The leakage is accelerated by an increase in the pressure produced by the artificial, surface water reservoirs. Some of these even block the flow through the subsurface alluvial channels (Adar et al. 1991).

The draining of the alluvial layers caused by pumping shallow wells proved to be an optimal solution for reducing the pressure and thus the leakage and soil salination.

14.5.4.2 The Arava Rift Valley

Bordered on the east by Transjordan and on the west by the Negev Highlands, this valley, part of the Syrian-African Rift Valley, extends from south to north. The aquifer in most parts of the valley is composed of alluvial fill of Quaternary Age, mainly gravel and sands. In the northern Arava, there exists an additional artesian aquifer built mainly of sand, namely, the Hazeva Formation of Neogene Age.

The salinity of the groundwater in the Arava differs from subbasin to subbasin depending upon the source of recharge and local salination processes. The range extends from 1,000 to 10,000 mg/L total dissolved solids (TDS). The two main sources of recharge are the floods infiltrating into the alluvial fans and the inflow from the Nubian sandstone aquifer. Annual quantity of recharge from floods is about 16 MCM (Weinberger et al. 2012). Outflow is to the Dead Sea in the north and the Red Sea in the south. The north-south groundwater divide line occurs at Qa e Saidin or Gav Haarava. Where the groundwater table approaches, the surface *sabkha* conditions are created. This brings about an accumulation due to capillary action of salts at the surface and thus to the very saline groundwater in the uppermost layers. At greater depths and in confined conditions subsists water of better quality, albeit still brackish. Israel and Jordan share this alluvial aquifer.

14.5.4.3 The Nubian Sandstone Aquifer

Under the Negev is located the Nubian sandstone aquifer, an extension of the aquifer of central and northern Sinai. It is composed mainly of sandstone of Lower Cretaceous and Jurassic Age (the Kurnub formation). The water it contains is brackish to saline (200–1,000 mg/L TDS, with up to 500 mg/L SO_4) (Issar 2007a). The water is some tens of thousands of years of age. The general gradient is from south to northeast, that is, from the paleo-recharge zone, which were the outcrops of the Nubian sandstone in Sinai – to the Dead Sea, its main outlet. At some secondary outlets along the Arava Valley, the direction of flow shifts to west to east. It is fossil water, like what is found under the Sahara Desert and parts of Jordan and the Arabian Peninsula; consequently, pumping of water from this aquifer actually mines a nonrenewable resource.

14.6 Long-Term Groundwater Recharge and Storage

The water supply of Israel is based on three main sources: the Sea of Galilee Basin, the western mountain aquifer, and the coastal plain aquifer. Both red lines and green lines have been defined for the Sea of Galilee and for the mountain and the coastal aquifers. The red lines identify minimally permitted water levels. Dropping below them may cause damage to water quality (chemical or/and biological). The green lines indicate optimal operational levels. The total water storage between red and green lines for all three resources is estimated as 1,440 MCM (Hydrological Service of Israel 2007, 2008 in Hebrew).

According to the plans of the Israel Water Authority, by the year 2013 the annual quantity of desalinized seawater will reach about 550 MCM and by the year 2020 Israel will be desalinating about 750 MCM/year. Taking into account that already in 2007 urban consumption reached about 760 MCM/Y, further population growth, more years of drought, and the occurrence of extremely rainy years (like 1968/1969 and 1991/1902), storage of drinking quality groundwater (even after being mixed with desalinized seawater) has to be constructed. Owing to hydraulic properties (relatively high storativity reaching 15–35% and relatively low hydraulic conductivity, which is 5–20 m/day) and geographic location (along the seacoast, close to main consumption area), the coastal plain aquifer would provide the most suitable location for storage.

Unfortunately, as a result of overexploitation, the current water storage capacity in the coastal aquifer is about 2,000 MCM less than in the mid-1930s (Livshitz and Zentner 2011). It is important to point out that the mid-1930s experienced one of the worst droughts in the last 150 years and that water levels were particularly low. This huge area could be adapted for much increased storage capacity.

The problem with reinjecting water into the coastal plain aquifer at high levels is the increased gradient seaward (westward), that is, the loss of fresh groundwater. In the mid-1930s about 120 MCM/Y flowed to the sea. Currently this discharge is estimated as 6 MCM/Y. We suggest that this problem could be solved by the artificial management of the seawater intrusion. This management will include two sets of pumping wells. Pumping wells in the freshwater body would preserve groundwater heads, while pumping wells in the saline water body would control the advance of its interface. Pumped freshwater would then be integrated into the water supply system, whereas the saline water could be desalinated or redirected for other needs (swimming pools, air conditioners, etc.) instead of freshwater. The desalinization of seawater pumped from an interface is significantly cheaper than from the sea (there is no need for pretreatment).

14.7 Securing Reserves of Groundwater During Periods of Abundance

14.7.1 Rehabilitation of the Natural Reserve of the Coastal Plain Aquifer

Overexploitation of the coastal plain aquifer brought a general decline of the groundwater table, causing in some regions not only the penetration of the sea interface but also intrusion of brackish water from adjoining Eocene chalk aquitard (Livshitz 1999). Intensive land use reduced the natural recharge on the one hand and on the other increased its vulnerability to water salinization and contamination. As a result, about half of natural recharge (100 MCM) occurs in areas containing non-drinkable water (Weinberger et al. 2012). The rehabilitation of this aquifer demands a reduction of its incessant exploitation and thereafter an intensification of its recharge in order to arrive at some kind of a balance. Only this sort of program will ensure both the restoration of the aquifer and simultaneously maintaining control of the flow of groundwater to the sea. Overexploitation can be reduced even in the event of a possible decline of precipitation tanks to an increased supply of household water derived from the desalination plants together with greater quantities of water of low salinity originating from reclaimed sewage destined for agricultural purposes. Yet rehabilitation by natural recharge has been inhibited because such an extensive part of coastal region has been developed both for residential dwellings and commerce and much rainwater that falls over the coastal plain aquifer does not infiltrate to the subsurface. Thus, recharge has to be carried out either through wells by water from the desalination plants during hours, days, and seasons of reduced demand or by flooding of those areas not covered by buildings. Such areas extend mainly along the eastern margins of this region, a zone where the layer above the groundwater table is not impermeable. Additionally, along the eastern border of these areas extend alluvial fans of streams that flow from the mountain and foothill region rendering these areas suitable for recharge projects. However this process has to take place outside of streambeds, as in most cases these are underlain by heavy, impermeable clay layers. The solution is to divert floodwater to recharge basins constructed some distance from the main, usually ancient riverbed, underlain by clay.

14.7.2 Storage of Floodwater from Small Drainage Basins

From hydrological investigations carried out in various parts of Israel, it has been learned that there is a difference of an order of magnitude of ten between percentages of runoff in a drainage basin whose area comprises tens of square kilometers and that of an area of just a few square kilometers. Investigations carried out at Sede Boqer by hydrologists from the Institute for Desert Research of Ben-Gurion University of the Negev have demonstrated that for a small catchment of a stony hill slope, one barren of vegetation, the reduction of runoff efficiency is a function of its size (Karnieli et al. 1988).

Once the bedrock is permeable, whether composed of limestone, dolomite, gravel, or sandstone, then the water stored behind these small dams infiltrates through the fractures and solution channels to the subsurface where it is protected from evaporation. Thereafter, below the root zone of the local vegetation (if any), it can reach local groundwater reservoirs. On the other hand, floods from large areas are usually laden with silt which gets deposited behind the dam to form a semi-impermeable layer, thus preventing downward infiltration of water and causing losses through evaporation. Thus, dams built to capture floods from large basins are impeded by severe obstacles: exceptionally major floods which cause damage to the dams or massive loads of silt which fill the reservoir behind the dam. The damming of small drainage basins, however, circumvents these disadvantages. The Nabateans, the early inhabitants of the Negev, understood the effectiveness of small dams from small catchments for the collection of runoff for their plantation, while in the more humid regions of the country, mountain and hillside slopes have been terraced by their inhabitants since ancient times (Evenari et al. 1971).

The average annual quantity of floodwaters in Israel is 235 MCM of which 210 MCM occurs in the western drainage regions and 25 MCM in the eastern flow system (Weinberger et al. 2012). Unfortunately, only a quarter of this quantity, around 50 MCM, is now being caught and utilized. In the national master plan, delineated in May 2007 as the National Master Plan 38 b/4, the impounding of surface water and recharge to groundwater are mainly executed by relatively large dams. No doubt there are positive aspects to these projects, but the bottom line is that they can catch only a relatively small percentage of floodwaters. Moreover, if the forecast of very large future floods in time materializes, those dams built for catching the average-sized floods will be swept away.

Thus, we suggest the adoption of a long-term national policy which promotes small projects for catching and storing water from floods in relatively small catchment areas. This will involve a new policy in some places of building new, small dams and in other places of restoring ancient small terraces and dams. To cope with this undertaking will require a major reorganization of government departments and agencies active in the field of water. The gain in precious water, however, through the recharge of the country's groundwater reservoirs, would make it all worth the while.

14.7.3 Storage of Floodwater from Large Basins

During typical rainstorms over the Negev, when the catchment area is smaller than 250–300 km^2, the volume of water is generally proportional to the area of the basin. For larger catchments, the discharge-area relationship may yield an inverse relationship, the volume ceasing to increase relative to increases in the area (Meirovich et al. 1998).

In any case, because of the barren landscape, major floods can and do occur in the anomalous event of a torrential rainfall. On such occasions, the amount of water which may be intercepted in the small and intermediate basins and of recharged groundwater is small relative to the amount of rain that falls during the storm. Trapping water from such floods is not an efficient procedure when undertaken by conventionally built dams, for investment in a dam capable of withstanding a major flood is far too great to justify for the results. After all, major flooding is an uncommon event and peak floods may destroy dams planned to control typical flooding. In order not to harvest all the water from peak flooding, we should exploit to our advantage the natural, topographical bottlenecks found in a few of the wadis of the Negev. These slow down the water, causing it to deposit its load of gravel, sand, and mud. We could assist natural processes by detonating parts of the walls already liable to fall of their own accord, thereby obstructing the flow of water with big chunks of rock blasted down into the riverbed from the walls of the bottleneck. The slowed flow of floodwater will then recharge the alluvial aquifer which usually may be found upstream from the bottleneck.

An alluvial aquifer containing a local groundwater storage is located behind the bottleneck of the Paran Stream (Wadi el-Jeraffi), notable for having the largest drainage basin in Israel. Stretching over an area of 3,700 km^2, it extends from the mountains of Sinai and the southern Negev to the Arava Valley. Upstream from the bottleneck there abides a graben structure (by the name of Karkom); it is filled with deposits of the Neogene Age as well as alluvial deposits of the Quaternary Age (Golts and Rosenthal 1998).

The annual average recharge of this alluvial basin is estimated to be about 7.0 MCM (including the inflow from adjoining regional aquifers). The natural outflow is about 3 million m^3, half through the riverbed and half along the regional fault line bordering the graben from the south. The water pumped from the graben is utilized mainly by the farms of the Arava (Zurieli 2008).

In the case of Wadi Hiyyon, south of the Paran with a drainage area of about 1,000 km^2, one does not encounter such a natural obstacle. Therefore, floods from this basin flow to the Arava Valley and, on their way northward to the Dead Sea, recharge the alluvial aquifer under the Arava Valley. Relatively small dams have periodically created temporary ponds which help in recharging the local aquifer.

North of the Paran and Hiyyon, the biggest drainage basin to the Arava is Nahal Zin whose drainage basin extends over 1,350 km^2, second in size to Paran's. It starts from the peak of the Ramon anticline and after 120 km, reaches the Arava Valley. Floods at Nahal Zin recharge the alluvial aquifer of the northern Arava. The other extensive drainage basin north of Para and Hiyyon is Nahal Nekarot, which drains the southern part of the Ramon anticline and extends over an area of 980 km^2. Its floods also reach the Arava Valley, enriching its groundwater resources. From year to year fluctuations in the flow of these floods are extreme, and long-term storage of floodwater in these reservoirs is ineffective due to extremely high evaporation rates; thus, the efficiency of small dams for the storage of floodwater remains under debate. In the opinion of the authors, a more efficient use of this water would be to divert it and recharge the alluvial aquifers or for direct use for irrigation employing terraces in small catchment basins.

The northwestern sector of the Ramon and northern Negev anticlines, the catchment area of which extends over 800 km^2, is drained by Nahal Nizanna. Until it crosses the border with Sinai, where its riverbed is covered by sand dunes, there are a few bottlenecks along its flow beyond which exist a local alluvial basin and a local, shallow groundwater table. In its more northern zone (near the ruins of the Nabatean-Byzantine city of Nizanna), the flow is in the solution channels carved out of the chalks of Lower Eocene Age. The people of that time excavated a deep well on top of the hill on which they built their fortified city.

In this connection it is important to note that during the Nabatean and later the Roman-Byzantine rule of the Negev, that is, during the first half of the first millennium A.D., the climate was more humid than at present and most probably with greater frequency of rain, hence more flooding (Issar and Zohar 2007).

Yet rather than large dams, the main efforts of the inhabitants were directed toward the construction of small dams on little catchment basins. Dams built in the riverbed above the city of Mampsis (Mamshit) in the northeastern part of the Negev were most probably for the purpose of supplying drinking water, as due to the city's proximity to the steep eastern slope of the anticlines' range of Makhtesh-Gadol Efee, a shallow groundwater table did not develop. That the dams, which could contain about 10.000 m^3, were built below the level of the agricultural fields proves that the water was not intended for irrigation. It has been surmised that after a flood the water was carried by donkeys and camels to the city and stored in the many public and private cisterns which served for domestic supply (Negev 1966, 1997).

A similar system existed in the Nabatean to early Moslem city of Shivta where the water from the hillside was channeled to flow into two cisterns located in the center of the town.

14.7.4 Utilization of Runoff from Built-Up Areas

By the early 2020s, the built-up area of Israel is expected to reach more than half a million square meters (information from the Center for Environmental Policy of the Jerusalem Institute for Research of Israel and the Ministry of Environment). As most of these areas are located in zones in which the yearly average amount of precipitations is about 0.5 m, approximately a quarter of a million cubic meters of water may be expected to fall on them. Depending upon the density of construction and gardening activity in municipalities, from 26 to 32% of this water will run off, reaching as high as 70% in industrial districts (Goldshleger et al. 2009).

Municipal area runoff is characterized by low salinity and a concentration of heavy metals rendering it below acceptable standards for drinking (Asaf et al. 2004). Recent legislation (TAMA 34) requires recharge of urban runoff as a precondition for obtaining a permit for new building. According to this regulation, in coastal areas at least 15% of the parcel should be reserved for use as a recharge area. Nevertheless, a large part of urban runoff still flows to the sea. In general terms it can be stated that the annual quantity of the urban water runoff may reach a few tens of MCM.

At present the only successful project of recharge into coastal aquifer operates in the Rishon LeZion area; it recharges about 2 MCM/year of urban water. Inasmuch as runoff after heavy rainstorms may cause significant damage, the government recommends augmenting present open space and the gardening areas in order to permit greater quantities of water to penetrate the surface into the aquifer. In addition, although no one doubts that the separation of rainwater runoff from untreated sewage is vital to public health and should receive highest priority – it has, in fact, been mandated by law – nevertheless, there remain cities and towns where drainage and sewage systems are still interconnected. So even at the basic level much remains to be done.

When it comes to the utilization of the runoff water, once the built-up area is situated on permeable rock, schemes for the recharge of the runoff to groundwater should be considered. The rapid infiltration of the water to the subsurface can be effected either directly from the rooftops by channeling the runoff into gravel-filled shafts, or into boreholes, or by flowing through streets whose sides are lined with deep conduits which are covered by a grille of concrete slabs. Another recommended strategy for collecting runoff is a system of trenches – each covered by a concrete grille – that crisscross streets in such fashion that drainage of runoff water to the subsurface is facilitated. Needless to say, in the field of capture and recharge of runoff from built-up areas to groundwater, there is ample space for innovation. In order to stimulate such activity, we propose that the government create a special budget line for the active participation of the state's water authorities in research and development projects. Financing requests for innovative patents should be included (ideas mentioned in this chapter have copyrights).

From the historical point of view, it is worthwhile adding that in the Nabatean-Roman-Byzantine cities of the Negev mentioned above, water from the rooftops and streets was channeled and collected in cisterns, both private and public.

14.7.5 Securing Recharge to Groundwater by Reforestation

Investigations into the infiltration rate of rainwater to subsurface terrains underlain by limestone and dolomite bedrock (especially of the Judean Group of Cenomanian Turonian Age) disclose significant differences between forested and barren areas. Research completed in the 1970s by the late Ami Shchory together with Dan Rosenzwieg, Abraham Michaeli, and others revealed that in barren areas the percentage of infiltration may reach up to 60%. In sharp contrast, in forested areas the percentage of infiltration is negligible as the water that does not evaporate transpires after being absorbed first by roots and then by trees. Our assessment is that forested areas underlain by dolomite and limestone rocks of the Judea Group occupy about 200 km^2. Taking into consideration that limestone and dolomite rocks constitute the mountainous part of central Israel and the Galilee in which average annual precipitation is about 500 mm (which guarantees the development of a forest), it can be estimated that the minimum amount of precipitation runs in the neighborhood of 100 million m^3/year. Whenever these areas have been kept exposed, however, the penetration might reach about 60 million m^3/year. But in those areas the dense planting of pine forests considerably decreases the infiltration to groundwater. If one of the worst case scenarios of the global warming materializes resulting, and, in due course, to a severe shortfall of Israel's water resources, the question would be whether the typical landscape of densely forested areas, mainly by pine trees, should persist. In the opinion of the present authors, the answer is negative. Accordingly, if the decision of thinning the forested landscapes is ultimately taken, the densely planted areas of pine trees should be replaced by an assemblage of deciduous trees and shrubs with a shallow root system. These would significantly decrease transpiration and thus enlarge the replenishment of the aquifers in the subsurface of these regions.

After a thinning of forested landscapes is accomplished, or even simultaneously with it, areas that in ancient times were terraced and at present are covered by a "natural thicket" should be reclaimed and replanted with deciduous trees and shrubs endowed with a shallow root system. This project also aims both to reduce transpiration and thus to enlarge recharge to groundwater and to restore the ancient agricultural plantations. To those ends, the non-terraced mountain slopes should be managed with an eye to realizing their potential as zones of wildlife grazing. The ultimate purpose of these new zones is the rejuvenation of the world of wildlife which has been badly decimated ever since firearms came into general use by the fraternity of hunters.

14.8 Conclusions and Recommendations

Studies of the past have shown that the history of the Middle East in general and of Israel in particular was influenced by past global climatic changes. Warm periods caused desertification, while cold periods were humid and caused regression of the desert. Thus, it is expected that global warming will cause dryness and desertification of Israel and the neighboring countries. On the other hand, scientists forecast a decline in the number of sunspots, which may cause the cooling of planet Earth. This happened during the Maunder Minimum of sunspots between 1645 and 1715. Proxy data show that this period was humid.

In order to be prepared to mitigate the negative impact of these possible future climates, either warm and dry or cold and humid, or even that of periods of alternations between periods of humidity followed by that of droughts and *vice versa*, Israel should create reserves of groundwater. These will be carried out during periods of abundance. Empty underground space for the storage of groundwater is available in the eastern part of the coastal plain. This will require projects aimed to increase recharge of surface runoff to form reserves of groundwater and drilling pumping and recharge wells as well.

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Chapter 15
Basin Management in the Context of Israel and the Palestine Authority

Richard Laster and Dan Livney

> *In theory there is no difference between theory and practice.*
> *In practice, there is.*
>
> *(Yogi Berra)*

Preparation of a master plan for a transboundary watercourse serves as a touchstone for cooperation between two conflicting entities. It enables decision making under any scenario: coexistence, cooperation, or partnership. It weighs the value of each scenario and allows policy makers to make decisions based on value judgments. It improves tools for grassroots democracy, stakeholder involvement, and collaborative decision making (heterarchy). In the worse case, it serves as a platform for discussion instead of acrimony; in the best case, a platform for cooperative river restoration, improved planning, and increased biological diversity.

15.1 The Makings of a Platform

Rivers and streams serve as a natural conduit of all things occurring in a basin. They also act as a natural habitat for plants, animals, and human culture. They carry the DNA of the basin, so that traces of every natural occurrence in the basin can be

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found in the river, its lowest point. Rivers contain food for survival and liquid for drinking, agriculture, and industry. They provide places for humans to picnic, swim, and boat and function as "blue and green" arteries within urban areas.

The various functions of a river make its "management" difficult, if not impossible. So from the outset, although the term river or basin management is used throughout this article, we are referring to some control of man's actions in a basin. Rivers cannot be managed; they can be channeled or exploited, but for an ecosystem that has developed over millions of years, man is unequipped to manage them.

15.2 Diversity in Essence and Approach

Due to the convoluted nature of streams, the biological diversity that thrives in and around them, and the multiple uses made by humans, all work on rivers and streams is interdisciplinary. In order to understand a basin, one needs to study its hydrology, ecology, geography, demography, anthropology, archeology, etc. and the stakeholders who form its political and economic base. For years, primitive water laws prevented an overall view of the basin, which led to overexploitation and degradation. These early "primitive" laws made sense in the context of their promulgation, and they were not unlike other laws "protecting" the natural environment, the air, the ocean, and the ocean bed (Tarlock 2004; Wiel 1909). Together they formed the basis for protection of the "common" areas of the biosphere not protected by property rights. Since no one could own the ocean, the air, or running water, these common areas were not protected as one would protect private property.

The early water laws developed as communities developed. Logic dictated that one living near a water source had the right to exploit that source. Thus, early water laws, based on this system of riparian rights, set up mechanisms for regulating withdrawal of water from a stream and the return of wastewater to that stream (Teclaff 1985). Where people created water transport systems, another regulating system that gave rights to prior appropriators also came into being (Tarlock 2004). Yet, these laws were not developed to protect the diversity of a basin, but to manage man's use of the water for life and profit. Inevitably, usage pushed the stream's ability to maintain its health to the maximum and beyond. It is the purpose of this article to drive this point home. Practically all water laws protect man's use of surface water and do not strive to increase biological diversity of a basin. Most water laws serve as platforms for conflict resolution, while they preserve the conflict in order to resolve it. Fifty years into the environmental revolution, most countries' water laws simply manage a conflict, not the basin.

There is a better way to manage man's activities in a basin than by umpiring strikes and balls: by promoting the idea that the river is a bridge to cooperation and partnership and not a border over which bickering requires conflict resolution. This requires rewriting the script and treating management of a basin not as a round table for bounded conflict (Lee 1993), but as a platform for networking.

15.3 In Dubio Pro Natura

As the environmental revolution gradually penetrated the minds and souls of millions of people worldwide, other governance tools for managing water courses developed. The major tool is regulation by an administrative body, where man's actions are checked in advance before he dries up or pollutes a stream or river. One of the earliest, the Clean Water Act, was promulgated to address water pollution problems that existed for centuries in the United States. It was followed by similar laws in other countries to try and restore rivers to a more natural state.

Over time, most forward thinking countries developed a more comprehensive approach to surface water management known as integrated water resources management in a catchment basin (IWRM). The idea behind this approach was to try and develop the river's full potential. IWRM begins with a premise that in order to manage man's activities in a basin, one must understand and "control" those activities in favor of a better basin environment. What exactly is a better basin environment is a subject for debate, but in a broad sense, its goal is to improve the basin from a combined economic, environmental, historical, cultural, social, and legal perspective.

Achieving a balance of all these interests brings all stakeholders to the table, each with its own "dietary" requirements, to hear and be heard. This is a never-ending process and, depending on the size of the basin, an overwhelming one. Everyone and everything is a stakeholder. But that, of course, is what is ingenious about the process; it is grassroots democracy in a world based on far removed democracy. It also requires recognition by scientists and policy makers that those living in the basin also understand its workings and have their own vision of its future for themselves and their children.

In order to find the stakeholders and discover the hidden resources of the basin, one must begin with a "map." And the best way to develop the map is by embarking on a master plan process. A master plan presents a number of possible scenarios on how best to utilize the water, land, and other resources of the valley while preserving its value, based on current and expected land and water use. In addition, master plan meetings bring local and regional stakeholders together with planners and local authorities to discuss their visions of the valley.

Once a master plan is completed, an action plan takes the master plan to the implementation phase. This also requires adopting a governance scheme developed by the master plan. Who makes decisions? Who pays for implementation? Who enforces decisions? Over time there has developed a consensus that there are five minimal governance requirements in the implementation of a basin action plan. The basin authority must have access to knowledge of the basin; it must be representative of the stakeholders in the basin; it must have an independent financial base; it must be able to control water use and misuse in the basin; it must have enforcement powers. Even with these powers in place, the basin authority will be making decisions under the principles of adaptive management, or decision making by trial and error, with an important caveat: in dubio pro natura.

15.4 The Israeli Experience

The above progression, from water supply and usage regulation to water and environmental protection and then to integrated basin management, did not bypass Israel. In the 1950s Israeli lawmakers passed a series of four water laws that set the framework for water policy and development. These laws, when read together, created an administrative framework for governmental control of all water resources. They abrogated all rights in water, including riparian and prior appropriation rights, and created a water commissioner empowered with the authority "to manage the water affairs of Israel." The water commissioner determined the fate of every drop of water – its direction, its use, and its destiny.

In spite of his vast powers, the water commissioner failed to use his vast powers to administer Israel's water sources to protect and enhance stream quality and quantity (Laster 1976). Due to intense pressure from water users, he saw his role chiefly as a water supplier and spent his resources on distributing existing sources of water and finding new ones. By the 1960s Israel's streams were tapped at their sources and used as receptacles for sewage and other waste. They became the backyard blight of the growing cities and towns along the Mediterranean coast.

The benign neglect of stream quality encouraged other governmental agencies to try their hand at improving the quality of Israel's streams and rivers. These attempts were carried out under powers delegated to them by the water commissioner, while he stood by, refusing to soil his hands by cleaning up rivers.

15.5 The Association of Towns Model

The Hadera Association of Towns for Environmental Protection (ATEP) was one such agency. Under Israeli law, several cities, towns, and regional councils can form an association of towns to manage a joint public project. There are several ATEPs in Israel, mostly created between 1973, the creation of the Environmental Protection Service, and 1989, when the Service became a full-fledged Ministry for Environmental Protection. The water commissioner granted each ATEP the power to reduce water pollution.

The Hadera Association ordered the polluting firms along the Hadera River to prepare a sewage treatment plan. But the major polluter of the stream, the Hadera Paper Mill, refused to prepare a plan and appealed to the Water Tribunal instead of obeying its terms. In 1989 the Water Tribunal rejected the paper mill's appeal and it was forced to abide by the cleanup order. This was the first case in Israel requiring a polluting company to clean up its sewage. Yet this only highlighted the other major polluters left in the river: the towns that made up the Hadera ATEP. No legal action was taken against them. An association of towns finds it politically impossible to act against its members. The association then tried another tactic. Banking on government loan support, the ATEP spearheaded an effort by several of its members to plan and build a sewage treatment plant for municipal effluent.

Eventually this effort was successful, but solving one problem highlighted another: what about those sources of pollution in the basin that did not come under the aegis of the ATEP? Since these sources were not located within the statutory parameters of the ATEP and without more authority than a mandate to order the preparation of a sewage treatment plan, the ATEP failed to revive the Hadera River and its environs. Lesson one: if one wants to restore a river's vitality, an ATEP is a partial solution.

15.6 The Drainage Authority Model

Another attempt at stream rehabilitation was spearheaded by a drainage authority in the Western Galilee's Naaman stream. At that time the drainage authorities of Israel had a narrow mandate for river protection, limited to flood mitigation and soil conservation. Like the ATEPs, drainage authorities are composed only of local authorities and therefore lack a broad base of stakeholder interests.

At the time the Naaman stream was chock-full of industrial sewage near its estuary. Like the Hadera ATEP, it also sent out stop orders to polluters and brought some of them to court, but the authority itself was too weak to fully implement a program of river restoration. Just as in the case of the Hadera ATEP, it also failed to prevent pollution, not for lack of trying, but for lack of a comprehensive strategy, a full panoply of powers, and the will to fight pollution. With all its good intentions, the drainage authority failed to rein in the polluters, and for an additional 15 years, the Naaman stream and others like it remained polluted.

15.7 The River Authority Model

Unlike the previous attempts at river restoration, Israel's two river authorities, the Kishon River Authority and the Yarqon River Authority (YRA), had both the statutory powers and the appropriate constituency to implement regeneration of a river. They were created under a statute designed for river rehabilitation: the Law for Rivers and Springs Authorities, 1965. When the law was passed, the Yarqon had an average annual flow of 250 million m^3, second only in size to the Jordan. But the law was not implemented until 1990, while the river flow was progressively reduced in order to supply water to the greater Tel Aviv area. At the same time, sewage outlets dotted the banks and gave the Yarqon the appearance of a drug addict, getting a noxious fix every few hundred meters.

Unlike the drainage law, the Rivers and Springs Authorities Law actually mandated river restoration. This law endowed both river authorities with the five minimal governance requirements: sufficient stakeholder representation, an independent financial base, enforcement powers, a capacity for information gathering, and control of its uses. The law even required them to operate under a master plan, so in 1996 the YRA's first major step was to prepare a master plan for the river and its surrounding biosphere – the first basin master plan in Israel.

The Yarqon River master plan multidisciplinary team developed a slogan, which was adopted by later plans to rehabilitate urban rivers: “Convert the Yarqon River from the backyard of Tel Aviv to its showcase.” The master plan allowed the river room to breathe and expand in case of flooding. The plan envisioned the river as a hub for leisure activity, one of the few open spaces left in a congested urban area. It developed a concept of “green fingers” reaching out from Tel Aviv to the surrounding suburbs. And the plan developed methods of reducing water pollution while keeping a minimal flow, even in times of drought, based mainly on purified effluent.

With the completion of the master plan, an action plan was prepared to implement the master plan. Two statutory outline plans were prepared and approved by the National Planning Council. They mapped out space for flood plains and designed walking and bicycle paths along the length of the river and into the suburbs. In addition, the planners drafted a government decision to allocate money for the Yarqon and its environs. The government and the members of the YRA approved over 100 million shekels to improve the quality of the river flow. Implementation took 10 years, coming to full fruition in February 2011, with the inauguration of an artificial wetland to further purify the treated effluent which maintains the river.

15.8 Hybrid Model: Drainage Authorities with the Powers of River Authorities

The Yarqon River became the envy of other cities and towns and its success served as a model of river restoration. It had wider implications, however; it led to a reformation of the drainage authorities in 1996. In that year, during the tenure of a Minister of Agriculture who also held the post of Minister of Environment, there began a process of transforming the drainage authorities into river authorities. The YRA’s success coupled with the epistemic community’s articles and lectures on the importance of basin management had turned the tide.

The reform reduced the number of drainage authorities from 26 to 11, and their borders realigned along catchment basin lines rather than political boundaries. With the new borders came a new appetite, and soon the plucky drainage authorities began gathering the reins of power vacated by the Water Commission and left unattended by the Ministry of Environment. Their goal was to continue in their traditional role in drainage management and flood protection but in addition move into the field of river restoration and environmental enhancement. And this reformation was done, just as the previous one, without drafting national legislation.

The reform began when two drainage authorities filed applications with the Ministry of the Environment under the Rivers and Springs Authorities Law to receive river authority powers, and after some infighting in the Ministry, the powers were granted.

Thus, the process of converting the drainage authorities to river and drainage authorities with sufficient powers to revitalize rivers and streams and their environs began. Today, all 11 drainage authorities have been granted river authority powers. Two have also been granted the legal powers to act as a soil conservation authority. Thus began a process, proceeding apace today, to use the drainage authority platform for the improvement of environmental quality in Israel.

With their new power package, the drainage authorities copied the YRA and began developing master plans for their basins. This new development caught the planning commissions off balance, who in response initiated a national outline plan for rivers, streams, reservoirs, and drainage. The National Outline Plan for Rivers, however, instead of reducing the powers of the drainage authorities, actually handed them a veto power over new development plans that would have a significant impact on the drainage basin. In addition, the outline plan included flood plains near major rivers to prevent new developments from encroaching on rivers and their flood plains.

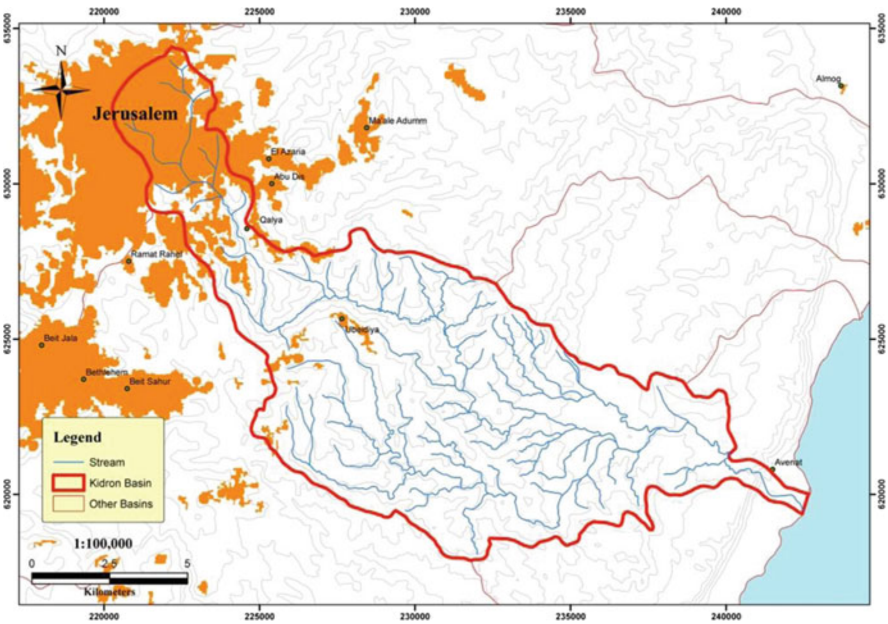
Thus endowed, the drainage authorities began the process of rehabilitating the rivers of Israel, with stops and starts, criticism from the green sector, and errors galore. But the vision and the will were there, and through trial and error, change began taking place. Several examples will suffice. The Shikma-Besor Drainage/River Authority embarked on a plan to convert the sewage water flowing in the Beer Sheva river as the corner stone for a new city park. The government of Israel has allocated 150 million shekels for this enterprise. The Kishon Drainage and River Authority, in a brilliantly executed plan, has received 200 million shekels to regenerate the Kishon River. The Carmel Drainage and River Authority teamed up with the Antiquities Authority to restore antiquities in its basin and revive the original Roman pumping stations for the Taninim River. The Kinneret Drainage and River Authority went so far as to promote legislation creating an association of towns for the protection of the Kinneret. As part of the law, the Kinneret Drainage and River Authority functions as the operating arm of a new authority created to protect the Sea of Galilee, Israel's only large fresh water lake.

15.9 Cross Boundary Basin Management

As work progressed on basin management plans and stream rehabilitation, the drainage authorities realized that the "basin" or "catchment area" actually incorporated areas not included in their statutory jurisdiction, i.e., areas beyond the borders of Israel. Officially this meant the two entities with signed treaties with provisions for water management: the Kingdom of Jordan and the Palestine Authority (PA). Seen in this new light, how should these basins be "managed"? The inspiration came from a study comparing the Elbe River with the Kidron Valley. Researchers from Germany, Israel, and the PA compared the management schemes in the Elbe River prior to German reunification and the Kidron/Wadi Nar, which crosses four statutory jurisdictions. Actually working together with Palestinians on basin management emboldened the authors of this article, who participated in the joint study, to propose to the Dead Sea Drainage Authority to draft the first international basin plan in the Middle East. With much enthusiasm and a little trepidation, the wheels were put in place.

15.10 The Kidron Valley/Wadi Nar Basin Master Plan

In 2009 a coalition composed of representatives from the Dead Sea Drainage and River Authority and the city of Jerusalem met to set out the parameters of the first international basin plan for the Kidron Valley, aka Wadi Nar in Arabic. The Yarqon River master plan served as their model, and they chose the same architect to spearhead the planning team, Arie Rahamimov. They also established a steering committee that was a balance of governmental and NGO representatives, so as not to give too much weight to the government. They chose representatives from three statutory bodies: the Dead Sea Drainage and River Authority, the city of Jerusalem, and the Ministry of the Environment. They added to these authorities three NGO’s: the Jerusalem Center for Israel Studies, the Milken Institute, and the Peres Center for Peace. One of the authors of this article, Richard Laster, was chosen as chair of the committee.



Map of the Kidron basin (Courtesy of Dr. Ram Almog)

The chair of the steering committee had a series of preliminary meetings with Palestinian government authorities and NGO's to discuss their joining the team. These were difficult meetings. There was mutual respect on both sides, but the Palestinians were adamant: without the approval of the director of the Palestine Water Authority, Dr. Shaddad Attili, no one would join the project. The chair of the steering committee met with Dr. Attili, who was pleasant, jovial, and frank: "Richard, any other river flowing between Israel and Palestine, except the Kidron/Wadi Nar. Ninety five percent of this river's channel is located in Palestine." Pressing his disadvantage, the chair of the steering committee asked Dr. Attili if he had his permission to develop joint cross boundary master plans for all the transboundary streams except the Kidron, and Attili agreed. Then the chair told Attili that he would like to continue in any case with the Kidron master plan without active Palestinian participation but would like to present the plan to the PWA as it developed and receive comments. To this Dr. Attili also agreed.

The master plan process began by developing a guiding principle and project goals:

Guiding Principle: The Kidron basin – a quality area between the Old City [of Jerusalem], Central Jerusalem, and the Dead Sea

Goals:

1. The Kidron basin plan in scenarios: coexistence, cooperation, and partnership
2. Solving the Kidron sewage problem
3. Involving the community and empowering the population
4. Creating a "biosphere" – an area that balances between development and preservation
5. "The stream as a bridge":

   Between political entities and cultures
   Between societies, populations (about 250,000 today), communities, and neighborhoods

6. Creating a tourist area and preserving historical sites – "the valley of the holy city"
7. Strengthening the connection between the ridges and the stream bed, between built-up areas and open spaces – "the Kidron matrix"
8. Developing leisure activities, including sports and recreation
9. Creating tools for long-term management and development of the basin
10. The plan as a catalyst for fund raising
11. Implementation in stages while developing the plan steering committee, drainage authority, city of Jerusalem
12. The master plan as a basis for an action plan and statutory plans

For someone unfamiliar with life in Israel or the PA, these goals seem fairly banal. Yet for someone living here, with years of acrimony built up to the point of expertise in conflict propagation, the goals are truly revolutionary. Not one mayor of

Jerusalem since the unification of Jerusalem has treated East Jerusalem, where the Kidron begins its descent to the Dead Sea, as West Jerusalem. Yet the master plan clearly sets out as one of its main goals to change this mind set. In addition, no one setting policy in Israel ever considered a vision of Jerusalem as a city facing east to the desert. Jerusalem has no connection with its neighbors to the East; there is no vision of Jerusalem as a continuation of the Judean desert. And, finally, no one ever even gave a thought to rehabilitation of the Kidron Valley or understood its potential as a link to the past and an axis on which to build a new future. The best indicator of this is the 25,000 m^3 of untreated sewage which flows daily in the Kidron Valley.

The steering committee gave the planning team one year to develop the master plan. The timetable was set at breakneck speed to get a group of experts molded into a single-minded team working in a dedicated gestalt to develop a new vision for an ancient valley. Rahamimov had the team hiking all over the Kidron, from top to bottom, by foot, car, and jeep. Each expert was invited to explain every polygon of territory from his/her own perspective. He had the community liaison specialist find perspective partners to a vision of cooperation and partnership, both in East Jerusalem and beyond. In this fashion, the team met and visited the homes of citizens of East Jerusalem to hear their perspectives. As the team moved down the Kidron toward the Dead Sea, partnerships developed with West Bank towns within the PA. The mayor of Ubadia stood out as a partner for change. With his involvement, the scenario also changed, and there began a series of meetings to develop a plan for sewage removal amenable to both Israelis and Palestinians, something that had never been achieved.

15.11 Ubadia and Beyond

Ubadia is a small community of 10,000 residents located 10 km east of Jerusalem. It is a nondescript town but close to two historical/religious treasures: Theodopolis, a large monastery in the center of town, and Mar Saba, a beautiful monastery carved in the cliffs of the Judean desert just outside the town's borders.

Alongside these treasures flows the Kidron/Nar stream, composed mostly of untreated sewage. Ubadia has no sewage treatment plant, and none of the homes have sewerage connections. The sewage is collected in septic tanks and finds its way into the Kidron, which flows past the city carrying the sewage of Jerusalem, Bethlehem, and other Palestinian towns. This same flow skirts Mar Saba and makes the view of the monastery more breathtaking than it already is.

For the mayor of Ubadia, there was no more important task than removing this blight from his town. He decided, in spite of the lack of cooperation from the Palestinian authorities, to partner with the planning team for the good of his town. The mayor wants the sewage treated, and he does not care if it is Israeli or Palestinian "liquid organic waste." He is the type of politician that most small communities can only dream about.

The Mar Saba monastery built into the cliffs of the Kidron Valley. Founded in the year 483, it is one of the world's oldest inhabited monasteries

15.12 Planning a Sewage Treatment Plant

> Life is like a sewer: what you get out of it depends on what you put into it.
>
> Tom Lehrer

The saga of Jerusalem's sewage is indeed grist for a historical novel of several hundred pages. It took years to build a modern wastewater treatment plant (WWTP) for sewage flowing west to the Mediterranean Sea. Sewage originating in the eastern catchment, which flows in the Kidron, is still awaiting treatment after 150 years of heavy urban settlement. For years, authorities have discussed and even planned the site of a joint WWTP. In fact, in 1991 the mayors of Jerusalem, Bethlehem, and Beit Jala worked out an agreement for treating sewage from the western side of the watershed at the Soreq treatment plant, which continues to this day. They attempted to do the same for the Kidron sewage in 1994–1995 by building a joint WWTP in the upper Kidron, near Ubadia. The German government, at that time heavily involved in developing cooperation between Israel and the Palestinian Authority, had approved funding for the plant's construction. The mayors of Jerusalem and Bethlehem had given their approval. But in the end the Palestinian Authority refused to sign the contract, arguing that this would be tantamount to acknowledging Israel's sovereignty over East Jerusalem.

Since the failed German-sponsored WWTP, the need for action has been raised from time to time, with no results. When the Israel Environment Ministry threatened the city of Jerusalem with legal action if nothing was done, the Jerusalem water company quickly put together several alternative plans for sewage treatment. These plans included building a WWTP within the city limits, pumping the sewage over the watershed divide westward to the Soreq WWTP, or pumping the sewage northward to a plant at Nebi Musa, in the Og catchment. A fourth plan, which is a combination of the other proposals, would pipe the sewage along the Kidron and then north to Nebi Musa along the Horkania plateau. These plans were designed not to remove the sewage from the Kidron, but to reduce pressure from the Minister of the Environment.

The plans described above were based on the premise that there was no Palestinian partner. The master plan process proved otherwise. Once the master plan process began in earnest, the music changed and work began in earnest for a joint solution to the problem. It all came about as a natural result of following the theoretical model for integrated water management in a basin. A council was created with stakeholders from the basin: the cities of Ubadia and Jerusalem, the Palestine Water Authority and the Israel Water Authority, Engineers Without Borders Israel and Engineers Without Borders Palestine, the Jerusalem company for sewerage and water (Gihon/Mafti), members of the master plan steering committee, and representatives of the US State Department and the Israel Ministry of Foreign Affairs. As in all basin committees, this one is representative of the key players in the basin, and although it has no statutory power, it is connected to those players who do.

The Kidron/Wadi Nar council has met on several occasions and is now implementing the master plan. Its first order on the agenda is the removal of sewage from the basin. In its latest meeting there was agreement to lay a sewage pipe from Jerusalem to Ubadia as the first step in getting the sewage out of the Kidron channel. A group of engineers and planners from Israel and the PA are developing a joint plan for this effort.

15.13 Project Initiatives

As the master plan took shape, it became clear that in order for the plan to become more than just another report gathering dust on a shelf, implementation needed to begin during the planning process. The team put together a list of initiatives to be implemented in the short term. The idea was that changes on the ground would jumpstart implementation and prove to the local stakeholders that implementation was not just possible but already happening. It would empower local residents to initiate their own projects. The first and most urgent initiative is the above-mentioned sewage collection and treatment system. But other initiatives are also having a positive impact on life in the Kidron Valley.

15.14 The Football (Soccer) Field

There is a dirt playing field in Jabel Mukaber, where the local football team plays and hosts its games. Even though the Jabel Mukaber football team was the champion of the West Bank Premier League for the 2009/2010 season, their field is without grass or markings, let alone dressing rooms or stands for the spectators. It is an embarrassment and a stark example of the discrimination between East and West Jerusalem.

Construction of the new football grounds in Jabel Mukaber

The Kidron planning team met with a local activist who dreamt of building a real football field. With support from the Kidron steering committee, the city engineer approved construction of a new football field. Several months later, a similar request to build a dressing room and a warm up facility was also approved. For 50 years no one had taken the initiative to approach the city of Jerusalem to improve the football grounds, and here, overnight, as a result of the new atmosphere resulting from the master plan process, the field is being built.

15.15 The American Road (Derech Sheikh Sa'ad)

One of the major roads in East Jerusalem is called the American Road, so named as the United States funded its construction during the reign of King Hussein of Jordan. It has no shoulders, sidewalks, drainage infrastructure, guardrails, or lighting. It offers an unrestricted view of the mounds of building waste strewn along its sides. Instead of serving the community, it serves as a reminder of their second class status.

For years the city of Jerusalem had plans to upgrade the road and the national government allocated a large amount of money to fund the effort. Originally this money was just to widen and repave the road, ignoring its importance as a major community thoroughfare. The landscape architect on the master plan team designed a different role for the road, one that could serve as a hub for local commerce and community interaction and also provide a beautiful overlook of the Old City of Jerusalem on the one hand and the desert landscape on the other.

After a series of meetings and with the blessing of the deputy mayor of Jerusalem, the proposed concept was presented to those residents owning property along the road, who would have to waive a portion of their building rights in order to make room for the proposed changes. A meeting was arranged with 25 landowners together with the city engineer of Jerusalem. Although tense at first, the two sides began a dialogue to properly plan the road for the benefit of all concerned.

15.16 Environmental Education

One planning team discussion led to the development and implementation of an environmental educational program for the residents of East Jerusalem, based in the Sur Baher neighborhood.

The program was an immediate success. In fact, in less than one year, there were six schools in the program giving instruction to 2,000 pupils. Since 2009, sustainable water and energy demonstration projects have been built; an environmental education program for teachers and local activists was started; a women's empowerment group began meeting; and paper and plastic recycling containers were installed.

Residents of other neighborhoods heard about the success of the Sur Baher program and asked to get involved. It is too early to know how the program will develop, but the enthusiasm, the drive, and the willingness to try a new educational program in an area that for years had shunned environmental quality show the importance of the master plan process and its ripple effect. The expansion of people's vision, empowerment of local leaders, and a feeling of hope for the future all flowed from the energy created by the master plan process. More important, looking beyond borders enables creative ventures theretofore unheard of.

15.17 Basin Management, the Next Direction

The Kidron basin committee is only one example of the general acceptance of integrated water management in a basin. Both in the upper and lower Jordan as well as the Eilat-Aqaba interface, drainage authorities are making serious efforts

Meeting of local landowners with the city engineer of Jerusalem to discuss the road. The American Road (Derech Sheikh Sa'ad) today

for cooperation. The Yarqon and Kishon basins are next in line for cross boundary master plan schemes and others will follow suit. Even the civil administration, the semi-military body managing the area of the West Bank outside Palestinian Authority control, has recognized the importance of basin management and has embarked on a learning process. Finally, the director of the Palestine Water Authority, Dr. Shaddad Attili, has expressed his interest in this approach, and this may lead to mirror authorities on both sides of the green line as well as joint authorities.

The speed in which Israel's drainage authorities adapted to basin management can serve as a model to other countries. But it must be noted that Israel does have one of the most comprehensive water laws in the world, making the state a trustee for its water resources. Israel has also developed desalinated seawater as a major source of water. At the same time, policy makers and planners recognize the importance of riverbeds as the last open space in urban Israel due to heavy land use demands. In this situation, if building is not allowed in riverbeds, they make a convenient site for infrastructure. Therefore, the pressure on rivers and streams increases as the population increases, making it all the more imperative for integrated water management. We are proud to be forerunners in this project and fortunate to be part of a process which encourages cooperation and rejects conflict resolution as a process. Throughout the master plan process, no one discussed resolving a conflict, but rehabilitating a basin.

> The Voyage of discovery is not in seeking new landscapes but in having new eyes.
>
> Marcel Proust

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Chapter 16
The International Hydro-Political Policies of Israel

Deborah F. Shmueli and Ram Aviram

16.1 Introduction

Israel's major natural water sources are hydrologically shared with several of its neighbours: the Jordan Basin with Lebanon, Syria, Jordan and the Palestinians and the mountain and the coastal aquifers with the Palestinians. Understanding the water sector management system requires a thorough analysis of Israel's international hydro-political interactions.

The new (2011) master plan for Israel's water sector states that the responsibilities of Israel's Water Authority are to ensure water supply, sewerage services, the quality and discharge area of effluents and runoff and drainage management. The goals are to ensure quality, quantity and reliability of the water supply, economic efficiency and the health of consumers. The master plan states unambiguously that the quantity of water which will be supplied to the Palestinian Authority (PA) is subject to future political agreement and is unknown at the moment (Israel Water Sector Master Plan 2011, 20). It follows then that achieving the national water goals of the master plan involves a great deal of uncertainty.

Kissinger's (almost cliché) statement that Israel has no foreign policy but only internal policy (Mizrahi et al. 2001) was reflected in Israel's water policy arena. It was symbolized by the fact that the Political Division for Water Issues was established within the Peace Process Department in the Israeli Ministry for Foreign Affairs only in 1996. It was then that Israel chose to join many other foreign

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ministries which had already recognized the importance of ‘water diplomacy’ as a key component of their foreign missions (Kjellen 2007).

The variables which determine the international dimensions of Israel’s policies are heavily influenced by changes in domestic demand and supply which, as explained in other chapters of this book, depend on many factors – from population increase and the expansion of Israel’s economy and concomitant consumer demands to climate change and technological developments and potential changes concerning water allocations to agriculture. As this list of variables continues to grow, Israel’s efforts to ensure its portion of its internationally shared water resources need to be adjusted within the context of its geostrategic interests and positions, its international commitments and the growing global concern with water issues.

This chapter highlights the main characteristics of Israel’s foreign policies in the water sector, how they have evolved, and present conclusions which point to possible future trends.

16.2 Setting the Scene

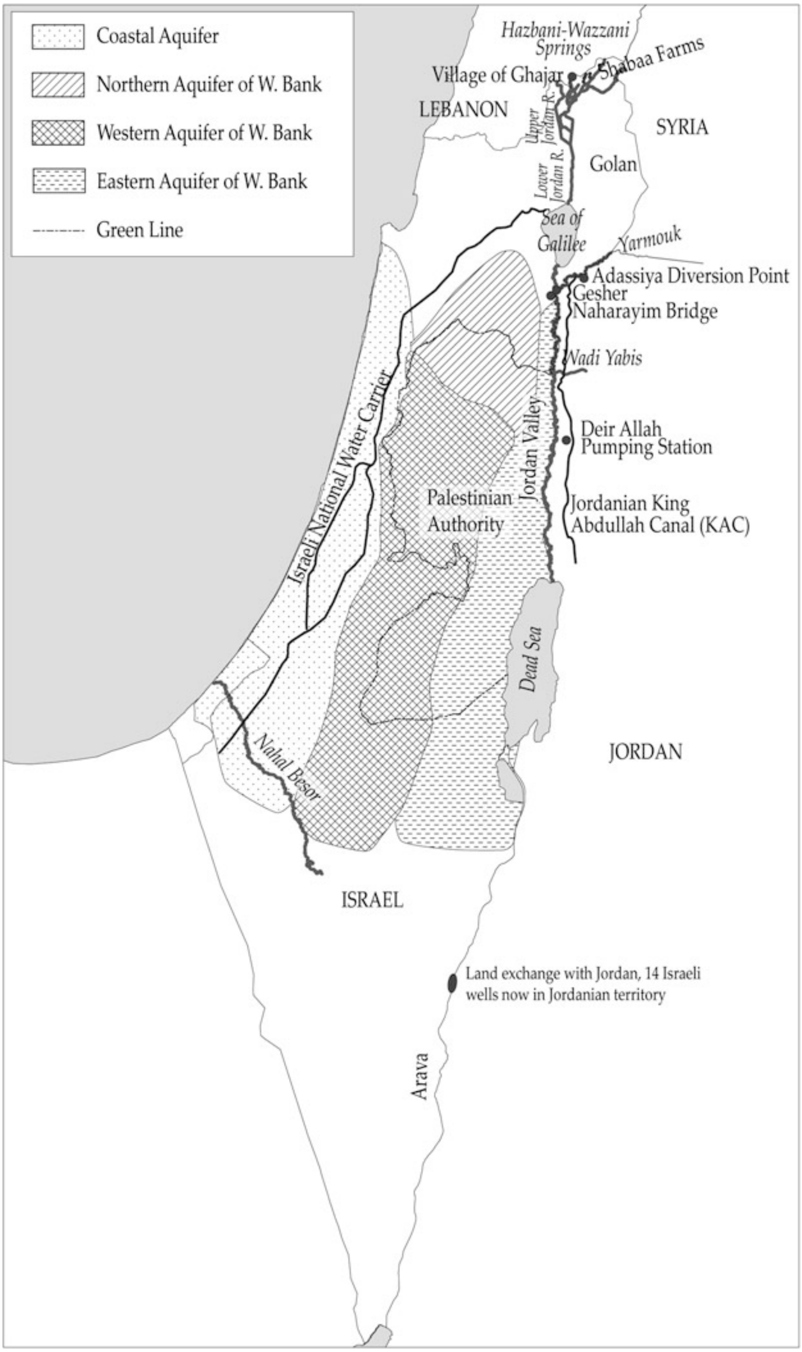
Four factors affect the overall shaping of the international hydro-political policies of Israel: dependence on trans-boundary sources, institutional changes, new and additional sources and a changing international agenda.

16.2.1 Dependence on International Sources

The dependence of Israel on shared resources both in terms of quantity and quality is a major element in determining its policies (Map 1 refers to all sources mentioned in this chapter). The Upper Jordan River and its tributaries, which flow from the North to the Sea of Galilee, supplied the Israeli water system between 1973 and 2009 an average of 626 MCM/year, representing between 25 and 33% of the total average consumption of fresh water in Israel (Israel Water Authority 2012). Since 2004, this quantity has been reduced owing to a long cycle of drought. In 2008–2009 the overall contribution of this source was down to 312 MCM (Hydrology Service Report 2011). It is understood that in supplying such a large percentage of the country’s water, the Upper Jordan River system is an essential source of significant quantities of fresh water (Map 16.1).

The Sea of Galilee is important in its role as one of the strategic water storage sources which allow management of a unified national system to overcome seasonal and yearly precipitation variables.

Israel currently controls some 80% of the sources of the Upper Jordan River following its conquest of the Golan Heights in 1967. Lebanon is an upstream riparian for the rest of the Jordan’s water. The Yarmouk River is the main year round tributary that feeds the Lower Jordan River. Since the 1994 agreement with Jordan,



Map 16.1 Hydro-political setting

Israel receives around 25 MCM/year and occasional flood waters. The Lower Jordan River flows out of the southern tip of the Sea of Galilee, just north of the Yarmouk River, on its route to the Dead Sea. Israel uses the western tributaries to the river, while Jordan uses almost all eastern streams flowing into this part of the Jordan River. The reduction in the water flows in the lower Jordan is a result of a gradually increasing extraction of water from the river's various sources over the past 50 years by the riparians. The Lower Jordan is left with less than 100 MCM/year, more than a billion cubic meters less than its historical average natural flow (Tal and Abed-Rabo 2010, 318). The significance of these sources is in the quantities they contribute to the supply side. Israel shares it with Syria and Jordan which are upstream and uses the River extensively. There is an ongoing dispute with the Palestinians over their right to the Lower Jordan River.

The Mountain Aquifer is a very significant water supply source of Israel and the only one for the Palestinian Authority (PA) in the West Bank. It is divided into three sub-aquifers, each with its own hydro-political characteristic: the Western (Yarkon-Taninim) Aquifer – the PA contends that the recharge area within its border is the major source of the aquifer and consequently determines their water rights for most of the aquifer, while Israel, being downstream, emphasizes the natural historical outlets and the storage capacity of the aquifer as the decisive element, historic prior use going back some one hundred years. In the Eastern and Northeastern (Nablus-Gilboa) sub-aquifers, Israel is again located downstream.

In the Coastal Aquifer, the water flows mainly from east to west in a way which weakens the connections between Israel and Gaza. Israel is considered upstream for the groundwater and floods in Nahal Besor.

As a consequence of this sharing of its fresh water resources and its upstream riparian's (Syria and Lebanon) refusal to recognize its existence as a State, Israel is forced to pursue an international agenda aiming at protecting its fresh water resources, with certain flexibility, in terms of both quantity and quality – thus its very basic interest of water security. The environmental security approach to resources expands the perception of 'security' beyond simple military power to economic and social strength and, finally, to the environment and water resources (Frerks 2007; Feitelson 2002).

16.2.2 Institutional Changes

The Madrid Framework for a peace process, which started in 1991 (Eran 2002), marked a beginning of an overall strategic change in the relations between Israel and the other co-riparians including issues related to water sources. Within this framework two parallel negotiation processes were conducted, both involving water issues: a bilateral process between Israel and each of its neighbours and a multilateral one in which the main players were Israel, Jordan and the Palestinians.

The bilateral talks led to two agreements, one between Israel and Jordan and the other between Israel and the Palestinian Liberation Organization (PLO).

The negotiations with Syria have not culminated in an agreement, but water issues played a significant role in the agenda of these talks (Sagie 2011). These negotiations have brought about a shift from indirect interactions such as the Johnston process (Lowi 1993) or other, limited in scope, business contacts such as the ‘picnic table talks’ with Jordan, mentioned later in this chapter (Wolf 2001a, b), to direct negotiations and full-scope agreements. It also altered Israel’s hydro-political arena, moving away from formal ‘isolation’ to active ‘interaction’, and most importantly Israel has made official international commitments and forged institutions to deal with some of its co-riparians.

Bilateral agreements on water are much more common and easier to reach than multilateral (Wolf 1998). This is particularly the case in the Middle East where Israel’s relations with Syria, Lebanon and the Palestinians are not on the same level that it now enjoys with Jordan. Israel prefers that each water agreement stands on its own, be as comprehensive as possible and, where feasible, not be connected to agreements with other co-riparians.

16.2.3 New and Additional Resources

In the last three decades, Israel has developed two major strategic resources which are independent of its neighbours – reuse of reclaimed effluence for agriculture and desalination. Those resources are significant contributors to the overall water balance of Israel. Israel now uses about 75% of its sewage effluent potential (around 355 MCM/year) for irrigation, which represent around 30% of the country’s irrigation supply (Friedler 2001; Israel Water Authority 2012). In 2002, Israel embarked on a strategic plan of sea water desalination for domestic use. Desalinated water has become the second most important source of water and in 2010 supplied around 300 MCM which represent 25% of Israel’s domestic needs (Israel Water Authority 2012). The plan aims at supplying up to 700 MCM by 2020, which would consist of about 70% of the projected domestic needs (Dreizin et al. 2007). For Israel’s central water management, which was based almost exclusively on the storage capacity of one surface lake and two aquifers and nearly total dependency on fresh water resources, this is a revolutionary development, as discussed in other chapters. From the international hydro-political point of view, its significance is threefold:

- Large-scale desalination has given Israel an independent source, which is not shared with any of its neighbours.
- Israel is moving away from patterns of supply and demand which characterize those of its co-riparian neighbours; this may change the nature of the interactions, negotiations and agreements over water.
- The cost of water has fiscal dimensions which previously were not part of the international water equation.

16.2.4 Changing International Agendas

The international water world touches Israel's water foreign relations in a number of ways. The most important is the development of international water law. The official position of the Israeli Ministry of Foreign Affairs to international law development is 'Israel is obliged to conform to the Helsinki Rules issued by the International Law Association in 1966 which reflects the International Customary Law . . . ' (Ministry of Foreign Affairs 2009). However, officials in the Water Authority have stated publically that they do not feel that Israel will ever give up any of the shared waters it presently uses. Israel did not sign the 1997 UN Convention for Non-Navigable Uses of International Watercourses, in contrast to Jordan, Syria and Lebanon which are signatories. In any event, the convention is not yet officially in force or binding since it has not received the required number of signatories. In practice Israel does not find it useful to use this convention in its international interactions (Shamir 2004). Israel's position is that 'water rights' is an issue which can only be achieved through practical understandings. As stipulated in the Treaty of Peace with Jordan: 'The Parties, recognizing the necessity to find a practical, just and agreed solution to their water problems . . . ' (Treaty of Peace 6, 2). Moreover, the Israeli negotiation team were working under the understanding that the various international documents suggest a set of criteria for allocation of water between international riparians but leave it to the parties to prioritize them and provide no specific algorithm for their quantification.

Other environmental issues are much higher on the diplomatic world's agenda, for example, the world is paying more attention to neglected resources such as ground water (i.e. the Law of Transboundary Aquifers (United Nations 2009)) and there is a growing role for NGOs in addressing global water issues. All these developments have changed the international hydro-political scene by expanding regional dimensions into more global ones.

A number of important efforts have been made by Israeli–Palestinian NGOs such as the Geneva Initiative and Friends of the Earth Middle East to formulate comprehensive final drafts of Israel-Palestine Water Agreements to be included, hopefully, in a final peace agreement. Both of which have been based on the concept of 'equitable sharing of common water resources' in the spirit of international customary law.

16.3 From Unilateralism to Engagement

'Contention over water has proved to be subordinate to symbolic and territorial issues such as peace, Jerusalem, borders, settlements, and the return of refugees . . . ' (Allan 2002, 260). Indeed water policies are subordinate to overall political relations and only very rarely determine them.

Thus, Israel's international hydro-political policies reflect its international relations. Different policy approaches are exercised in the Jordan basin – with Jordan, a full peace including a water treaty; with the Palestinians, an Interim Agreement and an anticipated permanent agreement within the context of the ongoing occupation; with Syria, which remains in a formal state of war, no agreement but with a few rounds of direct negotiations which include a significant element of water arrangements; and with Lebanon no agreement and hostile relations.

This approach is demonstrated, for instance, by Israel's rejection of the policy which calls for 'management by basin' – claiming it is impossible to look at the Jordan River basin as a management unit while two major players do not recognize Israel's very existence. Syria continues to act unilaterally with respect to the tributaries of the Yarmouk River, while absence of a permanent agreement with the Palestinians also precludes a unified policy towards the basin. Therefore, while Israel's basic policies which treat water resources as a key element in building the State in a sustainable manner remain intact, the international hydro-politics of Israel can be understood by looking at the evolution from unilateralism and limited 'tacit understandings' to an era of engagement.

16.3.1 The Era of Unilateralism

Since the beginning of the twentieth century during the early period of Zionism until October 1991 and the outset of the Madrid process with direct face-to-face negotiations for comprehensive peace agreements, the leading tone of the Israel's policy was unilateralism.

Unilateral designs for the utilization of the waters were common during the first six decades of the twentieth century – during the rule of the Ottoman Empire and the British and French mandates.[1] The plans differed and conflicted with each other; details of these various plans can be found in studies by Kliot (1994), Kliot (2000), Haddadin (2002) and Soffer (1999).

International initiatives to conduct indirect coordination within this period did not lead to agreement. The Johnston missions during the 1950s, which were the first and, to date, only integrative effort to include all five riparians, were conducted under heavy clouds of mistrust. They ended without an agreement mainly due to lack of Arab incentive to conclude, as they feared conclusion would imply indirect recognition of Israel.

During this period Israel conducted its policy within a narrow environmental security framework while managing its water resources without or with very limited

[1]Examples are Franjieh (1913), Mavromatis (1922), Henrich (1928), Ruthenberg (1926), Ionides (1939), Lowdermilk (1944) and T.V.A. on the Jordan (1948). After Israel's independence in 1948, plans included the Israeli Total Plan (1951), MacDonald (1951), Bunger Plan (1952), Main-Clapp Plan (1953), The Arab Plan (1954), The Israeli Plan (1954), Baker-Harza Plan (1955), The Johnston Plan (1953) and The Second Johnston Plan (1956) (Hays 1948; Kliot 1994, 189–197).

coordination with any of its co-riparians. The overriding perception of various Israeli Governments was that any water project by a neighbouring entity that affected Israel negatively was casus belli.

The actions which characterized this period are Israel's skirmishes with the Syrians over the Arab League plan to divert the sources of the Jordan River. The actions by Israel should be seen in the context of the water-security discourse which prevailed in Israel (see, e.g. Zeitoun et al. 2012.) but also against the background of lack of trust, absence of lines of communication and the overall perception of the aim of the Arab countries to eliminate Israel – this time by 'taking away' its water resources.

Involvement of the United States was primarily limited to the support of two unilateral projects: the building of Israel's National Water Carrier and of Jordan's King Abdullah Canal (KAC).

Through Israel's victory in the 1967 War, it gained physical control over most of its current water resources. These included the sources of the Jordan River on the Golan, the lengthy occupation of south Lebanon which provided control over the Hazbani-Wazzani Springs and the full control over the Mountain Aquifer. All those, coupled with military superiority and lack of serious diplomatic efforts to improve general relations with its neighbours, made Israeli's unilateral era nearly monolithic.

The connections with Jordan were somewhat more complicated and an exception. During the period before 1967 when Jordan controlled the West Bank, no particular incidents were registered over the Mountain Aquifer. This can be attributed to lack of attention to groundwater in general, poor supply systems and the relations within Jordan between the two banks of the River Jordan. After the Johnston rounds of mediation, Israel and Jordan complied, without formal agreement, with its conclusions.

The most significant ad hoc and tacit coordination occurred from the mid-1980s until the signing of the Treaty of Peace between the State of Israel and the Hashemite Kingdom of Jordan in 1994 (referred to also as the Israel-Jordan Treaty of 1994 (or IJ 1994)). The two sides met discreetly to coordinate allocation of water of the Yarmouk River. To affect this, a temporary 'dam' made of sandbags was constructed just downstream of the diversion point to KAC in order to regulate the quantities diverted. These actions were approved by the governments of both sides and kept secret. A sense of mutual trust and personal relations developed among the participants during the talks. At the same time, each side stood firmly by its interests. Two of the negotiating principals were later designated after the Madrid Conference to lead the formal negotiations on water between the two countries: Munther Haddadin on the Jordanian side and Noah Kinarti on the Israeli side (Haddadin 2002; Wolf 2001a, b; Shamir and Haddadin 2003).

16.3.2 The Era of Engagement

The agreement with Jordan (1994) and the manner of its implementation, the agreements with the Palestinians (1993, 1995) and their implementation and the activities of the Multilateral Middle East Working Group on Water Resources have one common denominator – an institutional framework within which most of the issues were addressed. This is qualified by the limited role and capabilities of the institutions and their positions in the overall relations (both will be dealt with hereafter) – but their establishment signalled a turning point.

When acting within this new framework, Israel developed a more sophisticated approach which views cooperation and coordination over water security as meeting much broader interests such as international legitimacy, strengthening strategic relations with Jordan, maintaining relative quiet on the Lebanese border and, in general, avoiding steps that would disrupt stability within its neighbours' political systems.

The negotiations with Syria challenged Israel's policy makers in a different way by demanding that they prioritize their interests. Israel has two vital interests: the first is to strengthen its water security by maintaining full control over the water sources of the Golan and the second is to eliminate the water-security threat posed by Syria to Israel's most cherished strategic source – the Sea of Galilee. On the other hand, these interests had to be weighed within the context of the benefits of a full peace agreement with Syria. Although nothing has come of these negotiations and the outcome of the current revolt against Assad in Syria puts all negotiations between the two countries on hold, during those early negotiations, the voices which preferred institutional arrangements which would enable the realization of both interests were not marginal (Sagie 2011).

With respect to Lebanon, Israel's approach was to maintain stability. This was put to the test when Lebanon took unilateral action in building a relatively small pumping station on the Hazbani-Wazzani Springs in 2002. Constructed on tributaries of the Jordan River, it was perceived in Israel as a strategic water-security threat, if only as a precedent, as the rhetoric of its leaders expressed (Zeitoun et al. 2012). In the era of unilateralism, this probably would have provoked Israeli military retaliation. With Israel's policy of engagement, the station was allowed to remain.

The evolution of the policies in this era is also the result of the development of other water sources in Israel such as desalination and reused water for irrigation, which reduce weather and political uncertainties and, to a certain extent, allow more flexibility in the management of water resources. Water has become a tool to achieve its broader interests (Feitelson and Rosenthal 2012).

16.4 Hydro-Political Policies in Practice

The following section will highlight some of the most significant hydro-political interactions with each co-riparian. For each the hydro-interaction framework is set forth, followed by institutional agreements and the main hydro-political interests for Jordan and the Palestinians, and, in lieu of institutional agreements, the patterns of interactions and the hydro-political interests for Syria and Lebanon.

16.4.1 Jordan: A Full Agreement

The relations in the water sphere between Israel and Jordan, organized within the Israel-Jordan Treaty of 1994, were the outcome of negotiations between two sovereign states.

The Israeli supremacy in military and economic powers was balanced with its strong desire to engage Jordan in a peace treaty (recognition, strategic relations with an Arab state) and created a relatively equal geopolitical leverage. Relatively symmetrical negotiations led to a more balanced agreement that would be of mutual benefit to both sides. Since the signing of the treaty, there has been continuous cooperation between the two parties and no substantive problems have arisen that have not been addressed amicably (Shamir 2004). It is a comprehensive bilateral agreement as stated in Article 6: 'With the view to achieving a comprehensive and lasting settlement of all the water problems between them . . . ' (IJ, Article 6).

16.4.1.1 The Institutional Agreement

Two geographical areas are embraced within the Israel-Jordan water agreement. The Northern area consists of two sections – southeast of the Sea of Galilee where the Yarmouk River forms the common border between the two countries until it enters the Jordan River at Naharayim and the Jordan River from Naharayim south to the point at which Wadi Yabis enters the Jordan River opposite the Israeli settlement of Tirat Zvi. The part of the treaty dealing with the Southern area focuses on the groundwater of the Araba/Arava Valley (all names appear in the treaty in their Arabic and Hebrew forms).

Article 6 of the treaty signed on October 26, 1994, deals with shared water resources, including 'rightful allocation' of the waters of the Lower Jordan-Yarmouk Rivers and the ground waters of Wadi Araba-Arava. In recognition of the water insufficiency, Israel and Jordan agree to work cooperatively so as not to harm each other's water resources and to develop mechanisms that facilitate cooperation including trans-boundary water transfers. Provisions include minimizing waste, preventing contamination, and mutual assistance in alleviating water shortages, transfer of information and joint research (IJ 1994).

According to the treaty, Jordan is entitled to water from the Jordan River, including an extra up to 20 MCM from Israel in the summer period in return for the additional water that Jordan concedes to Israel in winter (paragraph I.1.b of the Annex II, Water-Related Matters of the Israel-Jordan (IJ) Treaty).[2] The summer

[2]Notation: The citations from the Israeli-Jordanian Treaty are mostly from Annex II Water-Related matters, detailing implementation under Article 6. Annex II, Article (roman numerals I–VII), Number (1,2, . . .), Subcategories (a–i). Annex II will not be noted; IJ I.4.b is Annex II, Article I, no. 4, subcategory a. When citations are taken from Article 6, they will read IJ 6.number, subcategory, e.g. IJ 6.4.d (Article 6, number 4, subcategory d).

transfer to Jordan is from the Jordan River directly upstream of the Deganya gates on the river (IJ I.2.a). The agreement included a unique arrangement in which Jordan owns the pipeline which was constructed in Israel to carry the water from the Jordan River to the King Abdullah Canal (KAC), and Israel owns the wells in the Arava Valley located under the Treaty in Jordan.

Jordan takes its share of Yarmouk water from Adassiya/Point 121. A dam across the Yarmouk is designed to ensure the allocation between the countries according to the agreement – Israel's share of 13 and 12 MCM from the Yarmouk in summer and winter (the seasons are defined by specific dates), while Jordan is entitled to all the rest (IJ I.1).

The treaty stipulates that all wastewater released into the waterways must be treated to a quality suitable for unrestricted agricultural use. This proviso, together with one for the removal of the saline waters from the Jordan River, is designed to restore the river's environmental quality.

As part of the peace treaty, the border in the Arava Valley was moved westward, giving Jordan additional land and marked in a way which leaves the above-mentioned 14 wells that Israel had drilled in this area are now in Jordanian territory. Under the treaty, Israel continues to operate these wells, drawing water at the same rates as before. Israel is also entitled to explore for additional groundwater, up to 10 MCM/year, provided that this is hydro-geologically feasible and does no harm to existing Jordanian uses (IJ IV.3).

A Joint Water Committee (JWC) comprised of three members from each country was set up as the implementation mechanism. It sets up schedules and procedures, has established subcommittees for the North (the Jordan River) and the South (the Arava) and may invite experts or advisors.

16.4.1.2 Hydro-Political Interests

Within this framework Israel satisfies a number of its interests:

Supremacy of Geopolitics: '. . . the peace with Jordan is of critical importance for us . . . the late King Hussein and King Abdullah were true partners for peace. This peace serves the strategic interests of both countries and encourages stability in our region . . . ' (Prime Minister Netanyahu 7 February 2011).

This policy has been pursued by consecutive Israeli governments for decades. The relatively narrow interest of how much water Israel would obtain was subordinate to the overriding interest of preserving the peace.

This prime interest is demonstrated by the terms of the agreement and by its implementation. The treaty has certain built-in ambiguities which have allowed Jordan to present the allocation as a dramatic increase in quantities (225–295 MCM/year, (Fishhendler 2008)) of water it will receive from the rivers. In the same spirit most of the financial issues are either not mentioned (financial sources for additional water) or are ambiguous (financing the desalinated water). But what is more important in this context is implementation. During years of drought, in the framework of the articles dealing with mutual concessions, Israel continued supplying Jordan during summer time with higher quantities than it actually abstracted during the winter. Perhaps the most significant act which demonstrates Israel's use of the water to enhance its relations with Jordan is the May 1997 decision of then Minister of Infrastructure Ariel Sharon to supply Jordan with 25 MCM/year. This was justified as part of the implementation of the treaty in which the sides agreed to look together for additional 50 MCM/year and Sharon's decision refers to Israel's commitment. The decision was taken against the background of a long cycle of drought to ameliorate Jordan's urgent need for drinking water.

Overcoming Downstream Position: As a downstream riparian on the Yarmouk, Israel strives to overcome uncertainties resulting from upstream uses and development projects by Syria, Jordan or both. This interest is secured by a commitment in the agreement with Jordan for a fixed quantity of water to Israel (12 MCM/year in summers and 13 MCM/year in winters).

Recognizing the Overall Regional Water Scarcity: As Israel wishes to refrain from the image of the 'rich water nation', it is important that the agreement recognizes the overall water scarcity and the need for both sides to look for additional resources.

Preventing Inclusion of a Foreign Partner from Having a Direct Interest in the Sea of Galilee and Separating the Upper and the Lower Jordan River: Israel wished to address Jordan's need for storage capacity. The agreement says, 'Jordan concedes to Israel pumping an additional (20) MCM from the Yarmouk in winter in return for Israel conceding to transferring to Jordan during the summer period the quantity specified in paragraphs (2.a) below from the Jordan River . . . ' (Annex II, I, 2). Paragraph 2.a stipulates the same 20 MCM/year. The way it is phrased does not allow Jordan any interest in the Sea of Galilee. The Sea of Galilee is not mentioned by name in the entire treaty.

New and Additional Sources and Hydro-economic Aspects: Since it embarked on its own large-scale sea water desalination, Israel wishes to share the fiscal burden with its co-riparian. Israel and Jordan are involved in at least one large-scale project – the Dead Sea Water Conveyance Project. Israel participated in the pre-feasibility study which was done by the World Bank between 2007 and 2011 even though it was fully aware that the desalinated water would mainly serve Jordan. Water price is an issue which is constantly on the agenda between the two countries. While Israel generally tries to avoid water trade with its neighbours, the ability to value the desalinated water in a more price-effective way softens its position. In this context it reached an understanding with Jordan in 2011 to supply additional small quantities of water for a higher price than the water, which is supplied according to their original agreement, but cheaper than the price of desalinated seawater. This understanding was not made public except as it appeared in some press reports (see, e.g. Piskin 2011).

16.4.2 Palestinians: An Interim Agreement

The relations between Israel and the Palestinian Authority are unstable and since 1993 have experienced many crises, the worst of which was the Second Intifada between 2000 and 2005. Change in international borders and consequently change in sovereignty is one of the most common causes for conflict over shared water resources. In 1967 Israel seized control of the water resources of the West Bank and Gaza. With the 1994 signing of the Gaza-Jericho Agreement between the PLO and Israel and Israel's 2005 'disengagement' from Gaza, all of Gaza's water resources (including the distribution systems) were transferred to the Palestinian Authority (PA). When the Interim Agreement was signed in 1995, the PA gained partial control over the water supply systems to the Palestinian population (further details below). The PA and Israel are territorially intertwined on the West Bank. The boundaries between them are yet to be determined. The PA has some jurisdiction over the resources within Area A and Area B. Area C, including water resources, remained under Israeli administration. Thus, Israel and the PA both depend on groundwater from the Mountain Aquifer.

16.4.2.1 The Institutional Agreements

The Declaration of Principles (Oslo1993): Annex 3 stated that there will be cooperation on water-related research and programmes which would discuss the 'water rights' of both sides. Annex 4 refers to more practical aspects such as open water infrastructure, desalination projects and overall regional initiatives.

Gaza-Jericho (1994): The agreement included transfer of the water supply system in Gaza to the Palestinians, who were to become responsible for the management, development and maintenance of water and sewage systems (except for Israeli settlements). In 2005, as part of the 'disengagement', the water systems which served the Israeli settlements which had been disbanded were transferred to the Palestinians. At the end of the disengagement, all water and sewage systems in the Gaza Strip were placed under exclusive Palestinian control.

Interim Agreement (1995): This agreement states that Israel recognizes the Palestinians' water rights in the West Bank and that these are to be finalized in the permanent settlement. It also states that the Palestinians would receive a set amount of water while protecting existing uses. The future needs of Palestinians were defined as an addition of 70–80 MCM per year on top of the existing uses when the agreement was signed (118 MCM per year). Of this supplement, 28.6 MCM will be provided to the West Bank during the interim period (Israeli–Palestinian Interim Agreement 1995 Annex III article 40, 6, 7).

It was emphasized that these additions will be supplied from the hitherto underutilized eastern sub-aquifer. Finally, it was agreed to create a joint committee to implement the management of the aquifer.

The last signed declaration on the issue of water was a joint statement by the heads of the Joint Committee (Kinarati and Sharif) on 31 January 2001, calling for both sides not to damage the infrastructure of water during the violence of the Second Intifada (International Water Law Project 2001).

As the overall relations are unbalanced in terms of sovereignty, military power, economy, etc., the water sphere is unbalanced as well. A significant example of this imbalance is the Joint Water Committee (JWC) which was established to conduct 'coordinated management'. The committee deals almost entirely with Palestinian issues inasmuch as major Israeli water development projects are connected to the Israeli settlements which the PA oppose and perceive as illegal. Selby (2003) has argued that the Interim Agreement water accord has dressed up domination as cooperation. Throughout the years of its work, the JWC has continued meeting and the water supply systems in the West Bank have been improved significantly, yet in some areas they do not meet the needs of basic services and in other cases of economic development.

The Western or Yarkon-Taninim aquifer is a major source of Israel's high-quality drinking water. Its recharge area and surface flows are on the West Bank, while the augmentation portion is largely to the west of the 1967 border (Green Line). As a consequence, the Agreement on Water and Sewage (Article 40 of Annex III in Oslo II) is highly detailed in its emphasis on quality issues.

In the Gaza Strip the situation is more geographically clear-cut. Gaza is perched over the southern part of the Coastal Aquifer, to the south of the Israeli portion. Both surface and underground waters flow perpendicular to the coastline so that there is little mixing of the Israeli and Palestinian portions of the aquifer. However, some of the aquifer also extends eastward and inland into southern Israel. In this area, therefore, the Gaza portion of the aquifer is affected by the quantity of water drawn by the Israel side and by the pollutants that affect its quality.

The geopolitical imbalance between the two parties made the water negotiations and the implementation inevitably asymmetrical. In the Interim Agreement negotiations, water policy, including steps towards implementation, was considered by Israel to be a central part of the overall peace process and not subordinate to other negotiating tracks. Nonetheless, once the permanent borders were to be agreed upon there would have to be a more focused negotiation process on water issues. For example, the issue of the Palestinians as riparian to the Jordan River would have to be faced.

The political environment following the Second Intifada and the subsequent breakdown of trust brought a halt to the Oslo process. Since then, conflicting views have emerged within Israeli decision-making circles as to the types of water management structures which should be sought and secured. The rounds of talks within the last decades between Israel and the PA did not change the daily water relations but did expand the hydro-political discourse.

16.4.2.2 Hydro-Political Interests

In 2012 Israel and the PA continue to act in accordance with the same hydro-political conceptual frameworks: (a) they both wish to maintain a supply system under the partial agreement which, by its nature, entails many difficulties (the division of the land into various jurisdictions is one example); (b) the fact that the agreement was signed for a period of 5 years and almost 13 years have passed since this expiration date, but absent a new agreement, the old one remains the law (thus, there has been no adjustment for population growth and the need for change in allocation); and (c) the two sides are constantly anticipating permanent status negotiations and a formal agreement; their main aim is to avoid creating a precedent which may be used by the other side for 'gains' in the water sphere but as or more importantly reflect on other issues such as borders or settlements. At the same time they are constantly engaged in a political public relations battle in the international arena: for example, the constant claim by Israel over the non-treated sewage by the PA as a mark of 'irresponsibility' and the claims by the PA over the unequal allocation of water as the characteristic approach of a hegemonic power. In response, the Palestinians point out the extensive flow of sewage from Israeli cities and settlements into Palestinian areas such as the massive flow of raw sewage from the eastern areas of Jerusalem to the West Bank and Jordon Valley and from Kiryat Arbah. It is the hydro-political climate that leads the two sides to 'play' the game in arenas other than the purely bilateral one and to emphasize the need for international legitimacy to support their positions.

The Point of Departure: The Interim Agreement states: 'Israel recognizes the Palestinian water rights in the West Bank. These will be negotiated in the permanent status negotiations and settled in the Permanent Status Agreement relating to the various water resources' (Israeli–Palestinian Interim Agreement 1995 Annex III article 40, 1). Israel's position is that 'water rights' are the outcome of a practical understanding (as was the case with Jordan) while the Palestinians insist on looking for some 'objective' source for determining their 'rights' such as customary international law.

With regard to the Jordan River basin, Israel's position is to leave this discussion to the time when the borders are marked and agreed upon. During the interim period Israel has done its utmost to avoid any precedent in which the Palestinians would even implicitly be accepted as a riparian to the basin. For example, in the context of the World Bank feasibility study on the Red Sea-Dead Sea Water Conveyance Project (2005), the trilateral agreement (including Jordan) gives the Palestinians the standing of 'beneficiary party'.

Quantity: While Israel understands the need to establish a reallocation procedure within an agreement, it wishes to do so within the parameter mentioned in the Interim Agreement concerning the future needs of the Palestinians, namely, 70–80 MCM/year. The data gathered within the interim period concerning the Eastern Aquifer may change the estimated capacity of the water resources. The Palestinian position is based on the argument that current uses were achieved as part of an illegal occupation and as such cannot be recognized. Their demands are as follows:

a redistribution of the water resources of the whole of the Eastern, Western and Northeastern aquifer systems, on the basis of equitable and reasonable distribution principles (Barghouthi 2004).

Israel prefers, within a permanent agreement, to agree to a fixed quantity for the Palestinians in order not to be responsible for future shortages that may result from economic development activities or from the uncertainties concerning the size of the Palestinian population in the future. It has been pointed out that the fixed allocation formulation presents certain problems in an area of highly variable rainfall. The Geneva Initiative draft water agreement solves this problem by enabling a degree of variation in water allocations to the partners based on changes in the hydrological conditions. The return of Palestinian refugees anywhere between the Mediterranean and the Jordan River would change current predictions of water needs.

Quality: As noted previously, Israel is a downstream riparian in the Mountain Aquifer. Feeling vulnerable, Israel will first and foremost focus on quality issues which are connected both to amount pumped out of the aquifer and the treatment of all sewage effluent. Feitelson (2002) has pointed out that the internal Israeli discourse is beginning to shift to concerns over water quality and therefore recognition of the need for joint management of shared aquifers (Feitelson and Haddad 2000; Feitelson 2000; Mizyed 2000).

New and Additional Sources: While all sides recognize that the available quantities will not be sufficient and that there is a need for new and additional water resources, the argument will focus on the point at which Palestinians should opt for desalination and who shall bear the costs. Israel has suggested to the Palestinians a possibility of building desalination plants for the West Bank on the Mediterranean coast, promising an exterritorial passage to the future border. There is a question of the economic viability of such a scheme, bearing in mind the differences in altitude between sea level and major Palestinian urban areas. The Palestinians also claim that once they are allocated their ‘water rights’, they will need to desalinate for the West Bank. The need in Gaza is acknowledged, and the PA is promoting a desalination plant of about 55 MCM/year in Gaza – Israel supports this initiative (Union for the Mediterranean 2012).

16.4.3 Syria Nonactive War and Negotiations

Israel and Syria have been in a formal state of war since the establishment of the State of Israel. The most significant event in terms of control over territory was Israel’s conquest of the Golan Heights in 1967. Since the 1973 war and the subsequent disengagement agreement, the overall relations between Israel with Syria have stagnated. From 1991 onwards, a few rounds of negotiations have taken place; however, none have culminated in a peace agreement. Meanwhile, Syria has strengthened its alliance with the radical anti-Israeli axis of Iran and Hezbollah. How the success or failure of the current revolt against Assad may affect Syria’s relations with Israel remains to be seen.

16.4.3.1 Patterns of Hydro-Political Interactions

Perception of Existential Threat: Mutual suspicion and lack of trust characterize the interactions between the countries. The water-security interest of Israel in the headwaters of the Upper Jordan River has been the dominant motive for its policies. Israel perceives the threat to the water resources as part of the overall war aimed at its elimination, as Syria continues to reject the very existence of Israel and Israel reacts accordingly. It is against this background that the borders and water nexus played a major role in the discourse between the countries.

Diplomacy and Military Power: During Israel's first two decades of existence, disputes over trans-boundary water issues between Israel and Syria escalated into violent incidents. In the 1950s and 1960s, both sides tried to block the other's unilateral water projects (Wolf 1995). Although conquest of the Golan (in 1967) was not driven by water issues, but it resulted in Israel's acquiring physical control over the watershed of the Sea of Galilee.

Unilateral Actions: The absence of joint institutions or any other method of direct, or even indirect, communication on trans-boundary water management has added to the mistrust between the countries with respect to water issues. The hydro-political arena became subordinate to the overall geopolitical relationships – and both sides opted for unilateral actions.

Israel uses its physical control over the Golan Heights in order to maintain its almost full usage of the Upper Jordan River and to build projects such as storage dams on the Heights. Syria uses its control over the tributaries of the Yarmouk River (which is the part of the Jordan Basin to which Israel is a riparian) to exploit it for the most part unilaterally with only partial coordination with Jordan.

Direct Negotiations: During several rounds of negotiations from 1991 to the present, no agreement has been reached. How much of this can be attributed to Israel's water interest can be gleaned from examining how negotiators treated the water issue in the event that the Golan were to be returned to Syrian sovereignty. The chief Israeli negotiator, Uri Sagie (Sagie 2011, 154), reported that a detailed plan was prepared by the Israeli negotiation team based on a specific interpretation of the 'June 1967 lines' and a set of understandings that Israel sought. For example, the water quantity interest focused on Syria's agreeing to allocate the bulk of the water to Israel's needs while using the rest for future civilian Syrian settlement on the Golan. The quality of water streaming to the Sea of Galilee would be addressed through the limitation over future Syrian agricultural activities west of the watershed line on the Golan. Even the question of the Sea of Galilee, of importance for Israel, was addressed by a set of possible solutions which included the option of Syria's 'touching the waters but not using them'. At the end of the day, the negotiations in 1999 failed in a meeting between Assad and US President Clinton over Assad's understanding that his demand for full Israeli withdrawal 'from all the territories it conquered in 1967 including the North-Eastern part of the Sea of Galilee would not be fulfilled' (Sagie 2011, 167–168). Since the water issue has been perceived as a security issue, we can expect that as long as the political differences and the climate of mistrust between the parties continue, the water issues will be treated accordingly.

16.4.4 Lebanon: A Hostile Environment

The relations between Israel and Lebanon have been marked by continuing violent hostilities over the last 40 years. In the years 1976, 1982 and 2000, Israel occupied parts of southern Lebanon for long periods of time. In 2000, it withdrew to the internationally recognized borders as marked and recognized by the UN. A relatively small area (Shabaa farms and the village of Ghajar) remained in Israeli hands due to the uncertainty of the border in those places between Syria and Lebanon. Those areas bear some significance as to the sources of the Jordan River.

Lebanon's position towards Israel is subordinate to the Syrian position either at times due to a strong military presence of Syria in Lebanon or through the strong Syrian support of Hezbollah, a dominant political and military group within Lebanon which calls for the destruction of Israel. The Iranian involvement through the Hezbollah is another issue at hand. While Israel is considered the hegemonic power in an unbalanced overall power struggle, the Hezbollah claims to possess deterrence capabilities against Israel.

16.4.4.1 Patterns of Hydro-interactions

As opposed to the other co-riparians, Israel has no institutional or ongoing interactions with Lebanon over water resources – the last indirect communications were in 2002 in the context of Lebanon's construction of its pumping station.

Perception and Images: The Lebanese believe that Israel seeks to take the water sources by force. For example, Lebanese newspapers claim that Israel is diverting the water from the Litany in some 'magical' way and that the use of the Hazbani is unfair due to Israel's powerful methods of protecting its use of this source (Zeitoun et al. 2012).

On the other hand, given Lebanon's interest in Israel's destruction or causing it heavy damage, Israel perceives hydro-politics from a security perspective. Dependence on the tributaries of the Jordan River requires the maintenance of the quantities and quality of this source.

Unilateral Acts: While both sides have refrained from taking unilateral actions related to small water projects, thereby avoiding rounds of conflict, mutual distrust continues to block any form of cooperation.

16.5 A Regional Approach

There are multiple common issues in the water sphere shared by Israel and the co-riparians and also with the wider circle of countries in the Middle East and North Africa (MENA). By jointly tackling common issues, there are gains for all participants. The Middle East Multilateral Water Working Group was established within the framework of the Madrid Conference. It continues to function, albeit to a lesser degree than when it operated in the 1990s. The group includes Jordanians, Palestinians, Israelis and members from the MENA region such as Morocco and Oman. Syria and Lebanon refused to take part in the working group – once again a missed opportunity to work closer in the wider basin forum. A number of international donors are involved as project leaders. In a wider circle, the groups have worked on some common issues, such as sharing know-how in the context of water resources management.

For the smaller group (the Core Parties) consisting of representatives from Jordan, the PA and Israel, in which all three parties were equal by the power of veto, the multilateral track has offered an opportunity to (1) reduce the intensity of conflict over water by advancing win-win solutions in the water sector and (2) make use of the process of reducing conflict over water as confidence building measures between the parties, which were intended to have an impact on the wider political conflict. The action strategy was based on creating a large number of projects, varying in scale and areas of concern. Projects included a comparison of legal systems within the Jordan River basin, data banks and capacity building projects and the establishment of the Middle East Desalination Research Center (MEDRC). Israel, Jordan and the Palestinian Authority are members of the governing body of MEDRC, which decided on a few special programmes aimed at capacity building in the desalination sector for the Palestinians.

Within the multilateral framework, attention has also been given to development of new and additional water resources. A joint declaration for the development of new and additional water resources (Declaration of Principles 1996) was signed among the parties. In several projects sea water desalination was the ultimate proposed solution for the long run – for example, the ‘Survey on Demand and Supply in the Core Parties’ (1998) (Middle East Regional Study 2001). However, the activities within this multilateral framework, as pioneering as they were at the time, did not dramatically alter the overall hydro-political relations. Moreover, the anticipated trust-building spillover effects on the relations among the parties in other realms of conflict did not occur. This highlights our conclusion that it is the overall international relations which determine the hydro-political agenda and not vice versa.

16.6 Conclusions

Israel water management is characterized by a long struggle with scarcity. It has demonstrated its willingness to do the utmost in efficient water management steps from pricing policies to the use of reused water for irrigation to a large-scale, relatively expensive sea water desalination scheme. Since it shares most of its resources with its neighbours, a primary concern of its management is 'water security'.

As long as there was no recognition of its right to exist as a State by all of its co-riparians, Israel perceived the water issues as part of the overall attempt to eliminate it. While no lines of communication existed, Israel's approach to water conflicts was unilateral, applying hegemonic, military power to the conflict. This was an era marked by unilateralism. Once the way was open for institutional arrangements through agreements with Jordan and the Palestinian Authority, water issues policies were addressed within the broader geopolitical security framework that took into account military strategic, economic and international political considerations.

Combined with other strategic interests Israel is opting towards establishing institutions and agreements, replacing power methods with trust and cooperation. As can be seen in the chart using the Sadoff and Grey scale, water cooperation goes hand in hand with the overall improvement of the relations (Sadoff and Grey 2005; Fig. 16.1).

The current water relations with the Palestinians is dominated by the nature of occupation and the asymmetric balance between occupiers and occupied. When Israelis and Palestinians sit down at the peace table, the pressures on both peoples will frame the discussion. In such circumstances, Israel's environmental security concern will become subordinate to the broader geopolitical issues, and the negotiations on water are likely to be more balanced.

An Israeli–Palestinian peace agreement would require modification of the Israel-Jordan Water Treaty should the western bank of the Jordan in the lower part of the River, now held by Israel, become part of the Palestinian State or be put

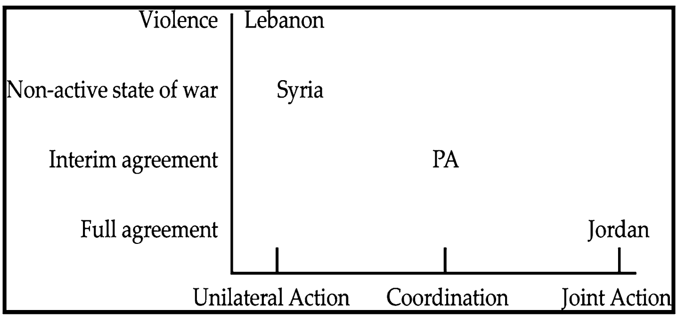


Fig. 16.1 The relationship between institutional arrangements and types of engagement

under long-term international supervision. Under such circumstances, a bilateral agreement between a Palestinian State and Jordan would complicate the situation.

Should Israel and Syria arrive at a peace agreement, a new Quadrilateral Accord would have to be developed, inasmuch as Syria will control the Jordan River headwaters. This will demand very detailed understandings and verification methodologies. This suggests that the complex water resource system in this part of the Levant will require an accord which makes provision for the interests of all the concerned parties.

All parties will have to make long-term capital commitments to developing new sources and abating pollution. Sea water desalination is emerging as the only viable large-scale source of supply. As part of a broader solution to the water problem, there are three desalination programmes: the Israeli scheme, which has already been implemented in part; the Jordanian plan to either desalinate water of the Gulf of Aqaba as a stand-alone or as part of the Red Sea-Dead Sea Canal regional project; and the Palestinian plan to build a large-scale desalination plant in Gaza, which would also serve the West Bank and depend on an agreement with Israel. Introduction of desalination to the region will have much wider ramifications including (a) the exploitation of cheaper resources such as reused water, (b) significant economic reforms which will reduce agricultural sector uses and (c) wider forms of 'water trade' based on the ability to desalinate on the seashore the high economic cost of transferring water for long distances and the ability to produce water as an industrial product with a price tag.

Water has historically been a source of both conflict and peaceful relations among states. It is to be hoped that a strategy of accommodation and sharing will lead the way, not only in the Israeli–Palestinian peace process, but as a guide to the peaceful resolution of other conflicts between Israel and its neighbours.

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Chapter 17
The Water Authority: The Impetus for Its Establishment, Its Objectives, Accomplishments, and the Challenges Facing It

Eli Feinerman, Hanna Frenkel, and Uri Shani

Water scarcity is a "fact of life" in Israel, where demand for water routinely exceeds its supply. The commonly agreed-upon policy to bring demand and supply into balance failed mainly due to population increase. In addition, the years 2001–2005 saw the most severe drought to hit Israel in a century.

The long-term annual average availability of natural water for the period 1932–2008, 1.35 billion cubic meters (bcm), masks a downward trend: in the last 18 years, the average has been only 1.175 bcm. The above-mentioned droughts made the situation progressively worse, turning it into an acute water shortage. At the end of winter 2003/2004, the water stocks in the operable reservoirs stood at only 1.3 bcm above what is defined as "red lines."[1] Precipitation in the following 3 years was poor and forced intensified harvesting of existing water stocks. Consequently, all the winter water accumulated in the reservoirs was consumed in the next summer.

Winter 2007/2008 was especially dry (precipitation averaged only 62% of the long-term average). As a result, water in the reservoirs dropped by another 0.5 bcm. Winters 2008/2009 and 2009/2010 saw only a slight rehabilitation of the reservoirs, caused mainly by reduced water consumption and additional seawater desalination. Precipitation in winter 2010/2011 was also short of the long-run average.

[1] Red lines signify the level of water in the reservoir below which the reservoir may sustain damage.

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A review of the updated quantities and quality of water in major water resources can be found in Rejwan (2011).[2] Additional factors contributing to the accumulating overdrafts are population growth and economic development, resulting in increased domestic and industrial consumption of freshwater, and, until a few years ago, inefficient institutional and administrative mechanisms for water allocation and control, including both hydro-politics and effective pressure by the "agricultural lobby." An excellent recent review of the water economy of Israel can be found in Kislev (2011).[3]

The long history of inefficient management of Israel's water economy constituted the main reason for establishing the Governmental Authority for Water and Sewage (AWS). The decision to establish it was, "luckily," taken before the latest water crisis, and the regulatory powers with which AWS was endowed were crucial in its successful coping with this crisis. AWS was instituted on January 1, 2007, and replaced the Office of Water Commission that had existed before, which constituted the organizational basis on which AWS was founded. The former had been a government department in the Ministry of National Infrastructure (today's Ministry of Energy and Water). The immediate challenge was to struggle with the severe water crisis. This task was multifaceted because of primary missions of reforming the water economy economically and institutionally. Such reforms were intellectually challenging and politically loaded.

The remaining of the chapter is organized as follows. Section 17.1 reviews the background and circumstances for the establishment of the AWS. Section 17.2 describes the structure and the main functions and tasks of the AWS. The coping of the AWS with the current water crisis is detailed in Sect. 17.3, and the reforms of the water and sewage corporations and of the water and sewage tariffs in the urban sector are discussed in Sects. 17.4 and 17.5, respectively. Finally, Sect. 17.6 discusses the vision, targets, and challenges concerning the future of the Israeli water economy.

17.1 The Background and Circumstances of the Creation of the AWS

The implications of the changes in the water economy are detailed in the June 2002 report of the Parliamentary Commission on the Water Economy, headed by M.K. David Magen.[4] The commission was appointed in the wake of the dire water situation during the decade preceding its work. The upshot of the report was the realization that repeated water crises are not a force majeure but are a consequence of the absence of a central, professional management of the water system. The main

[2] Rejwan (2011).

[3] Kislev (2011).

[4] http://www.knesset.gov.il/committees/heb/docs/vaadat_chakira_mayim.html

failure consisted of overutilization of water reservoirs and scant development of alternative sources. This led to a continuous depletion of supply sources and a severe imbalance between the availability of water from natural resources and the demand for water usage. The solution lay in a concept of management that would allow for long-run considerations and sustainable planning, protected from political constraints.

As mentioned above, the AWS was founded on January 1, 2007. The forming of the AWS involved organizational changes to the old Water Commission, a governmental department in the Ministry of National Infrastructure (today's Ministry of Energy and Water), comprising considerable expansion to its functions and responsibilities. The main idea driving the establishment of the AWS was the concentration of all authority concerning water and sewage in one governmental-professional agency. This would engender an all-encompassing and coherent approach to the needs of the water economy and possess the proficiency needed to oversee and regulate it, including the setting of tariffs for water and sewage.

The law which facilitated the formation of the AWS also promulgated the formation of the Governmental Authority Council for Water and Sewage (henceforth Council). It comprises eight members: the chief executive of the AWS who also serves as the Council's chair, five representatives of government ministries (Finance, Energy and Water, Agriculture and Rural Development, Environmental Protection and Interior), and two representatives of the public, appointed by the government.

Prior to the formation of the AWS, the water economy had been overseen by a clutch of government units, belonging to six different ministries. The Knesset had also been involved. In addition to the Water Commission's responsibility for development and husbandry of the water resources, and the allocation of water based on licenses for the production and provision of water, the Ministry for Environmental Protection was charged with the responsibility of water treatment and contamination prevention; the Ministry of Health was responsible for the quality of potable water, the Ministry of Agriculture and Rural Development had been in charge of water allocation in the farm sector, the Ministry of the Interior had been responsible for water and sewer services in the municipalities, and the Ministry for National Infrastructure had been responsible for developing sewer infrastructure. To this, one has to add the role of various ministers, who together with the Minister of Finance and the Knesset's Finance Committee, had been granted the authority to set tariffs: the minister of the interior fixed those paid by consumers to the municipal authorities, the Minister of National Infrastructure set those paid to Mekorot Corporation (the Israeli water company which is the main producer and supplier of water in Israel) by its customers, and the Minister of Agriculture and Rural Development set rates in the agricultural sector.

The main problem with the setup of multiple regulators was the existence of parallel authorities, sometimes overlapping, where each agency is responsible for a different aspect of the water economy. This generated conflicts between different interests, caused preferences for sectorial over national considerations, and obviated long-run decision-making.

A good example of what was happening concerns water treatment and prevention of contamination. Responsibility for these tasks was given to both the Ministry of Environmental Protection and to the Water Commission. This generated constant friction and turf wars. The ministry was intent on prioritizing the environmental aspect of water contamination, while the commission was interested in contamination as part of its management of the water resources component of the provision of water. An additional, and particularly egregious, example of the clash between different interests concerned the economic aspect of the water system. Since the authority for setting tariffs was held by ministers and the Knesset, the set tariffs did not reflect adequate cost considerations and were set mostly on the basis of political and social considerations. Consequently, the water and sewer system did not constitute a financially self-sustaining economy, requiring support from government budgets. The Water Commission, nominally authorized to plan and execute the development and allocation of water resources, did indeed formulate plans, but did not possess the means to see them through. Consequently, the Water Commission traded its demand for expanding seawater desalination for additional financial assistance from the government budget. Likewise, during the last years preceding the establishment of the AWS, it had been impossible to get the consent of the minister of agriculture and the Knesset's Finance Committee for increases in water tariffs. This led the Finance Ministry to insert circumventing clauses in omnibus bills dealing with Israel's economy.

Given this litany, it became clear that a radical change was called for and see to it that all aspects of the water economy management be concentrated in a single agency.

17.1.1 Agreement with the Farm Organizations

One big obstacle to the formation of the AWS had been the problem of water tariffs for agriculture. This had been a particularly hard nut to crack, both because the agricultural sector still possessed considerable political clout and because it had been feared that the farm sector would not be able to survive water rates that are based on realistic, marginal costing. It was thus clear that considerations of the quality of the environment and the well-being of inhabitants of peripheral zones, in addition to security and social concerns, would have to be taken into account when formulating the new water regime for agriculture. And this needed doing before the creation of the AWS.

On November 16, 2006, a historic agreement (henceforth Agreement) between the government and the agricultural organizations was concluded. The Agreement postulated that the target price of freshwater for agriculture would be based on the farm sector's share of the average cost of freshwater production and supply, including desalinated water. One of the principles of the Agreement stipulated that cost calculations will be carried out as far as possible for each of the pumping units of Mekorot and for each of the water types (freshwater, saline water, recycled wastewater), separately.

The Agreement also stipulated that whenever the cost of provision of water for farm uses fell short of the cost of provision of water for urban usage, the farmers will pay the full actual cost of the water provided to them, and whenever the cost of providing water to agriculture exceeds the cost of urban provision, the farmers will pay the overall average cost of water. This implies that whenever the second of these contingencies applies, the urban sector will shoulder part of the cost of providing water for agriculture (known as “inter-sectorial cross-subsidization”). For the purpose of calculating the cost of water provided to farmers and urbanites, a normative model is utilized. It takes into considerations the capital requirements for conveying the water to each type of user; it then assumes that all water users are alike and apportions to each sector the actual capital costs of each sub-plant, based on the relative amounts used by the two sectors.

The Agreement also fixed the tariff for brackish water supplied to farmers, as a derivative of the freshwater tariff (60% before the inclusion of desalination costs, i.e., cross-subsidization between the prices of freshwater and brackish water provided to farming). The Agreement also set the price for recycled effluent from the Dan Region (the plant known as the Shafdan, which recycles the effluent from the Greater Tel-Aviv megalopolis and supplies the recycled effluent to farmers in the Negev) at NIS 1/cm (November 2006 prices).

In order to alleviate the burden on farmers, the process of attaining the target tariff was spread in the Agreement over a period of 7 years. During this process, the farmers were to receive financial support from the government budget, equal to the total increase in tariffs, for the purpose of increasing the efficiency of irrigation systems. The Agreement also provided for special treatment of areas that are not hooked up to the country’s water network (e.g., the Arava – the Jordan Valley south of the Dead Sea).

The Agreement was clearing the way for the creation of the AWS. Concurrent with this, the Agreement was also ratified by the newly established Council and became an obligatory principle foe setting tariffs by the Council. We shall return later to the implications of the Agreement for water tariffs in general.

17.2 The Water Authority: Structure, Status, and Functions

When the Minister of National Infrastructures, Dr. Uzi Landau, charged by law with the responsibility for the water economy, was asked during his testimony before the Commission of Inquiry on the Water Economy of Israel[5] (The Bein Commission)

[5]Bein Committee (2010).

what his role and what his authority are vis-a-vis the AWS, he replied that aside from having tea with the AWS's chief executive, he does not have much of an influence. His colorful answer reflects the unique nature of the AWS within the government system. One would be hard-pressed to find another government agency that, at least as far as the law is concerned, resembles the AWS in the scope of its authority and the degree of its independence of ministers and the legislature.

The AWS constitutes an amalgam of three separate agencies: the first is the Water Commission on whose foundation the AWS was created, the second is the unit in the Ministry of National Infrastructure that used to be responsible for developing the sewer system, and the third is the unit in the Interior Ministry that used to oversee the urban water and sewer systems as well as the water corporations that had already existed in some cities. Thus, the AWS has become the chief overseer and regulator of all involved in the water and sewer economy: producers, suppliers, and consumers, in the urban, rural, agricultural, and industrial sectors. As a consequence, the roles played by the various bodies that had previously been involved in the water and sewer economy have shrunk very considerably.

- The Knesset's sole remaining function is to ratify, or reject, the surcharge on water extraction, as the proceeds from this surcharge constitute fiscal revenue (the purpose of these surcharges is to equalize the cost of extraction in private wells with the cost incurred by Mekorot).
- The Ministry of Agriculture, which in the more distant past ran Israel's water economy (the Water Commission has been under its jurisdiction into the 1990s), is left with the sole task of allocating the amount of water allotted to the farm sector by the Council, among the various farms. In order to facilitate a smooth transition on the basis of the Agreement, the minister of agriculture was granted the power to ratify water tariffs for farm usage for a period of 5 years following the creation of the AWS (those 5 years ended at the end of 2011).

The AWS is a professional government agency, subject to governmental rules and procedures. Its employees are government employees. It has allocated its own budget from the government budget. Even though the representative of the Finance Ministry is only one of eight Council members, his clout in the council exceeds that of the other members because of the dependence of the AWS on the government budget. The lack of independent financial resources for the operation of the AWS hurts its ability to function independently and manage the water economy consistently. This is why the executives of the AWS have endeavored, ever since its establishment, to base its operation on a self-sustained financial foundation, by turning the extraction surcharges from a revenue item in the government budget into a source of revenue for the AWS.

At the same time, criticism of the exaggerated independence of the AWS, and the lack of its subjection to governmental and parliamentarian oversight mechanisms, has been voiced. The criticism became especially vociferous following the drastic steps that the AWS took to deal with the water crisis and the reforms that it initiated.

The sharp rise of water tariffs begat continuous efforts by members of the Knesset to return the supervision of tariffs to the Knesset, under the pretext that water constituted an essential good that everyone has the right to receive equitably. As a consequence, and based on the recommendations of the Bein Committee, the government instituted some changes in the AWS. These included the addition of a representative of the minister of health to the Council, splitting the positions of the AWS's chief executive and the chair of the Council and turning the former into a regular member of the Council. The chair would be a public representative. The master plans for the water economy, put together by the AWS, were to be henceforth subject to ratification by the water and energy minister and by the government.

17.3 The Coping of the AWS with the Water Crisis

As mentioned earlier, in recent years, Israel has experienced the most severe water crisis in its history. This, because of the unlikely event of seven consecutive years of severe droughts (2005–2011), of which 1 year, 2008, saw an extreme drought. For example, the rate of flow in the Dan springs, which constitute the largest single water source in the Middle East, stood at the beginning of January 2009 at the lowest rate since measurements had begun in 1949. Likewise, the total volume of water availability in the Kinneret (Sea of Galilee) stood in January 2009 at 935 million cm (mcm). This was a far cry from the 1.9 bcm that had been expected to be added to the Kinneret during the said period, implying a deficit of about 1 bcm.

The AWS was formed during the height of the crisis and had virtually no time to get organized in order to face the situation. It had been clear that in the absence of a drastic reduction in the demand for, and increased supply of, water, usage would reduce reservoirs to below the "black lines,"[6] having already been reduced to under the "red lines." As detailed in the sequel, the AWS undertook rigorous steps designed to facilitate continued orderly and steady water provision while attempting to minimize the risk of irreversible damage to water reservoirs. Some of the steps sought to increase water supply, and some to curtail water demand, both in the short and long run. The AWS puts together two emergency programs and asked the government to adopt them. The government did and allocated the funds required for their implementations. The 2009 and 2010 budgets allocated NIS three billion to the water economy.

[6] Black lines are below the red lines, such that damage sustained by the reservoir may be irreversible.

17.3.1 Supply-Side Management

The steps taken to increase water supply were as follows:

- Full utilization of the existing potential (and not fully utilized) in the short run, without crossing red or black lines, including:
  – Accelerated drilling in order to maximize extraction from natural sources
  – Reduction of extraction surcharges, so as to render pumping more profitable in areas with the potential to add to water availability
  – Reclamation of water contaminated by salination or by percolation of contaminants into ground water
- For the long run, two significant steps were taken concerning desalination and effluent recycling:
  – *Desalination*: On May 2008, the Council resolved to increase the annual scope of sea water desalination to 750 mcm not later than 2020.[7] The resolution was adopted by the government on the following June. It also concluded to have a desalination capacity of 600 mcm operative by 2013. This massive desalination plan puts an end to past practices and opens a new era of reliable water provision, which is capable of coping with the shock of droughts. It also means less emphasis on conducting water from north to south and more on shipping it from the Mediterranean Sea in the west to the east.
  – *Effluent recycling*: In many countries, effluent is considered a nuisance to be disposed of. In contrast, in Israel, due to the severe scarcity of water, effluent is recycled and reused. The AWS adopted various resolutions designed to further recycling, so that more freshwater formerly allocated to irrigation may be replaced by recycled stuff. Recycling is carried out in special plants, normally adjacent to a city or a cluster of cities, using advanced technologies. The rate of effluent recycling stands at 75%,[8] and most of it is used for irrigation. There are 140 recycling plants, supplying close to 400 mcm annually. This amount constitutes 30% of all the water supplied to agriculture and 20% of the total water supply. Recycled effluent destined for farm irrigation incorporates all the required quality standards. The same goes for the part used for watering gardens and for industrial use. The AWS helps private entrepreneurs to construct recycling plants by granting them significant investment subsidies. It intends to expand the construction of such plants so that by 2020, their capacity will have reached about 600 mcm (comprising 95% of all effluent). The supply of reclaimed water is expected to grow, as the supply of water to the expanding domestic and industrial sectors will grow, while irrigation will use the increasing amounts of recycled effluent.

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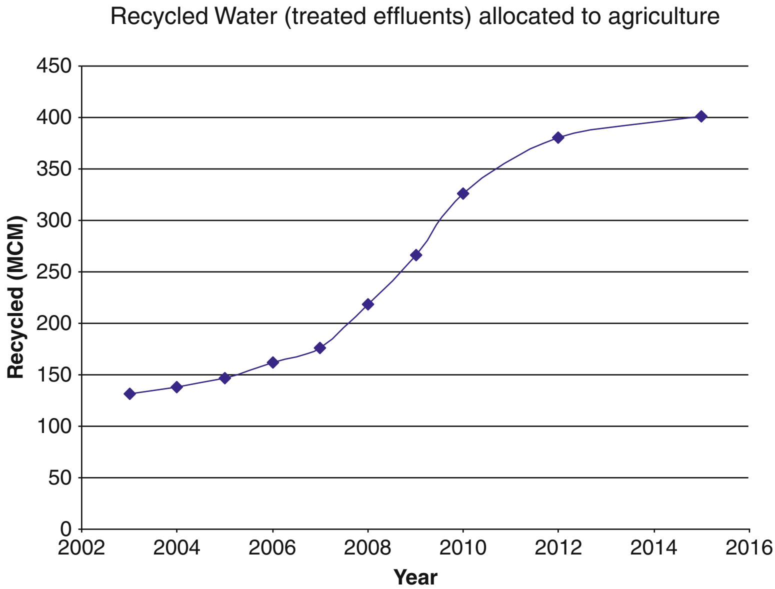
[7]Up to 2005, only the desalination plant in the city of Eilat supplied consumers regularly. In 2005, the government began constructing new plants, using B.O.T. tenders. As a result, at this point, desalination capacity stands at 330 mcm.

[8]This constitutes the highest rate in the world.

The dramatic historic increase and the planned further increase of recycling can be surmised from the following diagram.



17.3.2 Demand-Side Management

Despite all the efforts made to increase water supply, it was still expected that water levels will fall below the "black lines," so that it became paramount to reduce water usage by all users. Freshwater consumption in 2007, the year the AWS was founded, totaled 1,408 mcm (not counting water supplied to Jordan and to the Palestinian Authority). This consisted of 551 mcm destined for agriculture, 90 mcm allocated to industry, and 767 mcm provided to households.

Following is a description of the main steps taken by the AWS in its effort to reduce water demand:

A drastic administrative reduction of the water quota allotted to agriculture: The allocation of freshwater to agriculture has been declining over the years. A decade ago, the farm sector was allocated 920 mcm. From this point on, it had been gradually reduced in accordance with water availability. Reduction had been facilitated both by increased irrigation efficiency and the move to increased use of recycled effluent. The amount of freshwater allotted to agriculture in 2008 was 530 mcm. In 2009, the Council resolved that annual water allocation to farming will be reduced by 100 mcm compared to the 2008 allocation. This is the lowest allocation to agriculture ever (it should be noted that because of these reductions, the government resolved on February 2009 to provide farmers with financial support.

Freshwater in agriculture is used nowadays mainly for orchards and greenhouses, and the tightening water supplies in these uses exert a considerable impact on farmers' incomes).

A reduction of (administrative) water allocation to industry: Water consumption by the industrial sector constitutes about 6% of total water consumption. Freshwater consumption by industry stood in 2008 at 88 mcm. The reduction is implemented at the industrial plant's level. The plant does not get the quota it asks for: prior to the allotment of water to the plant, a detailed inspection of its production processes takes place, from which a water usage model emerges, and the plant is required to adhere to the more efficient water utilization implied by the model. In addition, freshwater use by industry is reduced by using water of inferior quality in power plants and saline water in quarries.

Reduction of household consumption: Freshwater consumption by households exceeds that of any other sector. Over the years, per-capita consumption has been growing, reaching a peak of 106 cm per person per year in 2007. Israel's population at that point numbered 7.2 million persons. It should be noted that the term "household consumption" consists of actual household consumption of about 60 cm annually per person and of water loss and public water consumption.

The main AWS decisions that led to a significant decline of per-person consumption were as follows:

- The setting of higher tariffs charged by the municipal water corporations,[9] which meant *a very considerable increase of tariffs for urban water consumers.* The new tariffs were to be implemented gradually: 40% of the increase on January 1, 2010, a further 25% on the following July 1, and the rest in 2011. In addition, a special "social rate" was conceived – a lower rate for the basic water needs of poorer families. The demand for urban water is not totally inelastic (Bar-Shira et al. 2007[10]). Thus, increased tariffs were bound to cause reduced water consumption.
- *The surcharge on excessive water consumption*: In the wake of winter 2008/2009, it seemed that steps taken up to that point would not be adequate and an additional reduction of water consumption, of at least 50 mcm, is called for. The assessment was that such a goal could not be attained without the immediate implementation of serious measures. One alternative considered by the AWS was a total cessation of lawn watering throughout the country. This was criticized by some as too harsh and impossible to enforce (it is worth noting that during a water crisis in Spain and in France, a total ban on irrigating gardens had been imposed,

[9]These were established on the basis of a law, adopted in 2001, according to which the urban provision of water services was transferred from municipal governments to these corporations, each of which is a viable financial entity, regulated by the AWS.

[10]Bar-Shira et al. (2007).

and in other countries, notably the US and Australia, limitations on garden watering had, as well, been instituted). In view of the criticism, economic rather than administrative measures were considered. Based on an initiative of the AWS, the Knesset adopted a law authorizing a special levy on excessive water consumption, with the objective of curtailing household usage. The levy was set at NIS20/cm for monthly amounts exceeding 4 cm/person. The law came into effect on July 15, 2009. Because of harsh public criticism, and in view of the tariffs' reform (see next paragraph), which was to hike tariffs on January 1, 2010, the surcharge was abolished on December 31, 2009.

- *A media campaign and measures to bring about water conservation*: This included various forms of propaganda using the media, educational means, and the provision of incentives for water conservation.
- *Abolishment of reduced tariffs for gardening*: A significant part of household consumption, estimated at 140–180 mcm annually, is used for gardening. Already at the beginning of the efforts to deal with the water crisis, it was thought that water for gardening constituted the largest potential source for saving water. This is because irrigation for gardening was relatively inefficient and also because use for gardening was less essential than other components of household consumption. In order to reduce the use of gardening water, the AWS abolished the discount that had existed for both private and public gardens. In addition, the AWS instituted, for the first time ever, water quotas for public gardening.

Analysis of water use data for the period under consideration reveals that the steps taken by the AWS, and particularly the aggressive media campaign and the surcharge on excessive use (even though the latter was rescinded after a short while), caused a significant drop in consumption. In fact, the mere introduction of the water problem into the public square caused a decline in usage (in August 2009, water usage already declined by 15% compared to a year earlier). The analysis further indicates a lasting effect of all the measures taken by the AWS on the per-capita consumption of water during 2010. First indications are that this persisted in 2011.

It is very doubtful that the measures used in order to cope with the water crisis could have been implemented under the system governing the water economy prior to the establishment of the AWS. One can therefore conclude that the advent of the AWS was a timely reform that yielded considerable benefits.

It also behooves one to note, in the present context, the long-term master program for the water economy (covering the period to 2050)[11] that the AWS advanced and which deals with objectives, priorities, and budgeting for the amount of billions of shekels.

[11]The Water Authority (2010).

17.4 The Reform of the Water and Sewer Corporations

Water provision and sewer disposal in the urban sector used to be under the auspices of local governments (city councils). Consequently, there had been many actors involved in this area (many of them quite small): there are 263 municipalities in Israel, of which 64 are cities, 146 local councils, and 53 regional councils. Local governments supplied about 70% of the water in the urban sector. Maintenance of the water and sewer piping network and its operation had been concentrated in the water and sewer department of the local government, which also extracted the water in those cases where the locality possessed its own water sources. Other units of the municipality provided billing and management services. Tariffs reflected in no way the costs. Rather, they reflected bureaucratic jumble and conflicting economic and social objectives. In view of this blatant inefficiency, the government resolved to transfer the water and sewer infrastructures to the oversight of professional and regulated bodies. The Law of Water and Sewer Corporations, adopted by the Knesset in July 2001, was designed to achieve this purpose. A central objective of the law was the running of these new bodies along business lines, so as to instill efficiency and proficiency in the management of urban water and sewer systems. Revenues accruing to these bodies were to be earmarked for investment in the infrastructure. They were also empowered to raise funds for investment, so as to render them independent of the national or local governments. The new corporations were to be owned by the respective local governments, but their sole function would be to run the water and sewer system. The law also stipulated that water and sewer tariffs in each locality reflect that locality's costs, so that revenues would cover costs, including a reasonable rate of return on capital.

The reform did not really take off at first. The formation of corporations, which had at first been voluntary, but later made obligatory, faced stiff resistance by most local governments. The objection was driven by the desire to avoid the forfeiting of revenues generated by water and sewer to the corporations and also the fear of losing control over an area that they viewed as part of the services that they were to provide their citizens. The revenues that resulted from the sale of water and from levies on infrastructure development had been used by local governments to finance spending that had nothing to do with the water economy. Moreover, the Authority for Public Services Water and Sewer in the Interior Ministry, which had been charged with setting cost-based tariffs, and criteria for the proper running of local corporations, had been politically hamstrung.

In view of this state of affairs, when the government decided to establish the AWS in 2007, it also resolved to move the aforementioned unit from the Interior Ministry to the newly created AWS. The Ministry of Finance then stepped in and provided local governments with financial incentives in order to hasten the process of forming corporation. It is estimated that to date, NIS1.7 billion was devoted to that end.

Due to political constraints, it proved impossible to goad local governments into forming associations that would jointly form corporations, which would thus serve larger constituencies. The rationale for such a move is economic: it would make the provision of water and sewer services more efficient because of economies of scale. It would also economize on the AWS oversight functions. The number of water and sewer corporations formed to date is 52, some of them quite small. Out of these, 24 operate in jurisdictions of more than one municipality, while 28 are single-municipality entities.

It has been more than 10 years since the Water and Sewer Corporations Law passed, and most of the municipal water and sewer economies are indeed operated by such corporations. Out of a total of 184 municipalities that had been obliged to form corporations (excluding rural municipalities, who did not have to form corporations), 136 municipalities, serving 5.6 million inhabitants, formed corporations, and 48 municipalities, serving 908 thousand inhabitants, have not yet done so. The data indicate that the advent of corporations, and their subjection to the AWS's oversight, has led to increased investment in the municipal water systems, enhanced water conservation, and reduced water loss and bill-paying delinquency.

Still, the reform has not been completed. The AWS is striving to bring about the formation of as yet unformed corporations. It is also trying to bring about mergers between existing corporations.

17.5 The Reform in Water and Sewage Tariffs

As already mentioned, the reform that bases water tariffs on costs came into effect on January 1, 2010. At that date, new tariffs were imposed on Mekorot, on the local water and sewage corporations, and partially also on municipalities that had not formed such corporations at that time.

Prior to the reform's implementation, tariffs had not reflected costs. The tariffs in municipalities had a two-tier structure: a one-time charge was levied when a new structure was hooked to the water and sewer system, and there was a current charge for consumption. The latter consisted of two components: one was a charge for water determined by decries under the Water Law, and one was a charge for sewer based on municipal bylaws. This structure lacked a clear connection to the costs of providing water and sewer services, resulting in an inefficient allocation of funds to the water system. The most obvious symptom of this has been the continuous lack of funds for essential investment.

As has already been pointed out, implementation of the reform required a steep increase of water and sewer tariffs. To the reasons already mentioned, one needs to add the following:

1. The newly coming desalination plants and the expansion of existing plants in Ashkelon and in Palmachim, as well as of investment, required to adapt the water transportation system to the uptake of desalinated water. The production and provision of desalinated water costs considerably more than the cost associated with natural freshwater.

2. The sharp decline in water consumption, brought about by the emergency measures taken by the AWS, itself caused a rise in per-unit tariffs. This is because the supplier's fixed costs are of course unaffected by output, and so when output declines, the fixed costs have to be borne by a smaller amount of water, implying a higher price per unit.

The average cost per cm climbed by about 40%. This translated to an increase of NIS50 per month (excluding VAT) for an average family of four, consuming 4 cm per person. Declined consumption, however, reduced outlays for water, so that the above figure is a gross one. It is worthwhile to note that water cost for the average family constitutes only 1–1.4% of the consumer cost of living.

Prior to describing the details of the water-tariffs reform, we shall illuminate the objective difficulty with which an administrative setting of tariffs has to contend and the tortuous process of AWS resolutions in this context, brought about by political pressure exerted by members of the Finance and Economics Committees of the Knesset and by a hostile press egged on by some members of the Knesset as well as by some mayors.

17.5.1 Efficiency Prices and Administrative Prices

Economists define "efficiency prices" as those prices which will bring about an efficient allocation of the limited water resources among the various users, implying maximization of the water economy's contribution to the national welfare.

- Efficiency prices must reflect water quality, the geographic distribution of water sources as well as water users (plains vs. valleys and mountains), the time of extraction and usage (summer vs. winter), and the availability of water from a specific source. They must also reflect differences between water from sources that are part of the national grid and those that are not connected to this grid and between water whose provision is reliable and water whose provision is not. When water prices are determined administratively rather than by the free market, those who set the prices must be aware of the advantages engendered by efficiency prices (even if it is impossible to figure out what these actually are).
- Administratively set prices have to satisfy certain conditions. They have to balance demand and the supply that can be generated without causing long-run damage. They have to generate enough revenue to cover all costs, fixed, variable, and the shadow price, reflecting scarcity. They have to minimize cross-subsidization among water users. And they have to strive to fulfill the signaling function that free-market prices fulfill. Namely, signal to consumers the marginal cost of a cm supplied and signal to producers how much consumers are willing to pay for the marginal cm extracted.
- Administrative prices also have to take into account fairness in the allocation of burdens among social classes, even if that obviates coming closer to efficiency prices.

In Israel, the two principles that are applied in practice, and which affect tariff the most, are:

(a) *The principle of fairness or uniformity*: As a rule, all users of water in a given sector pay the same price, or the same tiered prices[12] countrywide, regardless of their location of abode.
(b) *The principle of covering all costs*: The Water and Sewer Corporations Law stipulated that tariffs paid by corporations will be set so as to cover all costs. This is as distinct from the less stringent system set by the Water Law (which applied to Mekorot). The present principle applies to Mekorot as well, based on the cost structure model of this government company.

The Water and Sewer Corporations Law set forth methods for calculating the costs of the services provided by the corporation and instructed that tariffs be set on the basis of costs: "the price of each service will reflect, as far as possible, the cost of that service." This implies that tariffs need not be uniform. The tariffs for each corporation will fit that corporation's costs and will be set separately for water and for sewer services. The implication of this system of particular tariffs for each corporation is that every corporation will have to balance its books, so that there will be no cross-subsidization between corporations. But the reality is that water tariffs for households served by the corporations have been set uniformly everywhere. They are staggered, consisting of two tranches: the first is set as an "official basic quantity," at 2.5 cm per person per month (upgraded on July 1, 2011, to 3.5 cm), and a second tranche, more expensive for any amount used beyond the first tranche. This replaced the uniform price that each local government had paid to Mekorot prior to the reform.

17.5.2 The Decision-Making Process at the AWS

In the first stage of the deliberations concerning the new tariffs, the AWS assigned too much importance to costs and too little to fairness. *The first proposal* of the AWS, published in October 2008, proposed unequal tariffs for the various water and sewer corporations. These reflected cost differentials, with the higher tariffs applying to the weaker, higher-cost corporations and the lower tariffs to the stronger, more efficient ones. *The proposal invited public hearings* and elicited responses from the media as well as from members of the Knesset's Finance and Economics Committees. Although the law allowed for differential tariffs, even members of the Council felt that the proposal could not be implemented, as it hurts especially weaker parts of the population, living mainly in the periphery. Therefore, in May 2009, the AWS floated a *second proposal*, according to which

[12]Tiered prices are structured as follows: one pays a certain price per cm for the first tranche of waterused; for the next tranche, a higher price is paid and so on.

rates were to be somewhat lower relative to the first proposal where costs were high and as a counterbalance will be raised a bit where costs are low. However, due to public pressure, this proposal, too, was rejected, and the AWS came up with a *third proposal*, this time setting uniform tariffs throughout. That is, fairness considerations trumped economic ones.

The proposal was adopted by the Council and made official. Although consumers pay a uniform price, the corporations do not. The more efficient ones pay Mekorot a higher price than do the less efficient ones. Consequently, a cross-subsidization among corporations has come into existence. This weakens the incentive to increase efficiency. It has resulted in a somewhat comic situation. An inefficient corporation will receive a letter from the overseer of corporations: in the first paragraph, it will be chided for the inefficiency; the second will award it a prize: a reduction in tariffs paid by the corporation to Mekorot. Since the costs of Mekorot have to be covered, this implies that the more efficient corporations will be charged higher tariffs than they otherwise would have been. Question is can this system be upheld in the long run?

17.5.3 The Calculation of Tariffs

The purpose of setting tariffs based on costs, including fair return on capital, was to ensure the corporations and Mekorot that their revenues will cover their costs, thus rendering them financially independent of either the state or the municipalities. This approach was also called for in view of the drawn out water crisis, partially caused by the inefficient allocation of water brought about, among other factors, by the artificially low tariffs paid by users. The setting of cost-based tariffs enhances the users' awareness of the real cost of providing water and disposing of sewer. As mentioned, increased water desalination also played an important role in raising tariffs.

The calculations were based on the two enunciated principles, setting a uniform tariff for all urban users, while at the same time covering all costs.

The conceptual framework for the calculations was as follows:

The uniform rate for consumers was calculated based on the average approved costs of the local corporations and Mekorot. That is, costs per cm are calculated as the average cost for providing water. Concerning corporations, for each of them, an approved total cost was set, based on the costs of the various operational inputs, capital, and maintenance. This includes the price paid by the corporation to Mekorot.

To demonstrate, assume two corporations, each providing half of the total services. One is efficient, having an approved cost of NIS4/cm, and the other inefficient, at NIS6/cm. Neither cost includes the payment per cm to Mekorot. Assuming that the average cost of Mekorot is NIS3/cm, it follows that total cost for the efficient corporation is NIS7/cm, while for the inefficient one, it is NIS9/cm. Averaging yields NIS8/cm. Therefore, the efficient corporation will purchase

Mekorot water at NIS4/cm, while the inefficient one will do it for NIS2/cm. That way, both corporations will bear the overall average cost of water. Mekorot, at the same time, receives a total of NIS6 for the two cubic meters, that is, NIS3/cm, corresponding to its average costs. The cross-subsidization consists of transferring NIS1/cm from the efficient to the inefficient corporation.

The reform was implemented in stages, as the following description explains.

1. *A two-rung tariff system for households*: For a basic amount of 2.5 cm per person per month, and not less than 5 cm per household, a lower tariff was set (these amounts were updated in July 2011 to 3.5 cm and 7 cm, respectively). Any consumption above that is charged a higher tariff. This was implemented in two stages: an average increase of 25% on January 1, 2010, and an additional average of 8% 6 months later. On January 1, 2012, the tariffs for water and sewer to households were NIS8.63/cm for the lower rung and NIS13.889 for the higher one.

   It behooves one to ask whether the distinction between a basic amount of water and quantities above it is worth the considerable expense involved in implementing such a system. It is reasonable to answer the question in the affirmative. The institution of the lower rung expedited the shepherding of the reform through the political establishment, because it puts a social face on a reform that made water and sewer more expensive.
2. *Industry*, *agriculture*, *and hospitals* were also allowed a period of adjustment to the new tariffs. For hospitals, the final new tariff will take effect by the end of 2013 (the tariff on January 1, 2012, was NIS6.993/cm); for industry, it will take until the end of 2014 to face the final tariff (on January 1, 2012, it paid the same as hospitals); agriculture will have until 2016 to adjust, at which time, it will pay the average cost of water (tariffs for freshwater for farming are set along a 3-rung system: on January 1, 2012, they were NIS2.079, 2.375, and 2.972/cm).

Even before the reform came into effect, it had faced heavy public criticism. The thrust of the criticism were the high tariffs and the cross-subsidization embedded in them, particularly the subsidization of the industrial and agricultural sectors. The cross-subsidization generated by the uniformity of tariffs for households also came under fire. Local governments, water corporations, and consumers submitted petitions to the High Court of Justice against the reform. Recently, the Court handed down a decision affirming the legality and reasonableness of the norms and the tariffs based on them. The Court has still to decide whether or not cross-subsidization constitutes a fiscal act requiring Knesset ratification. The state's position is that even though cross-subsidization does exist, there is no taxation involved, and the government enjoys no revenue. The state also emphasizes that the system is based on the principle of costs covering.

A further argument voiced against the reform was that a cost-based system of tariffs ignores the less fortunate, by depriving them of reduced tariffs. This objection originated mainly in the Knesset and served as a pretext for the demand to reinstate the Knesset as the arbiter of water tariffs. The AWS contends that the provision of a basic amount of 3.5 cm per person per month at a charge considerably below the average cost constitutes a reasonable alleviation of the burden on the weaker consumers. Further reductions of tariffs for poorer households will intensify the distortion of the tariff structure and will impose further burdens on other segments of the population.

It seems that the Finance Ministry and the Knesset have come around to accept this stance, and so recently, the Finance Ministry and the Knesset's Finance Committee have concluded an agreement according to which the ministry will earmark some NIS40 million for subsidizing water for the disabled. The arrangement is going to take effect in the second half of 2012.

17.6 Vision, Targets, and Challenges Concerning the Water Economy

The long-run master plan for the water economy, which awaits government approval, facilitates the delineation of long-run targets, but the constantly changing technological, environmental, and geopolitical conditions requires constant reevaluation of these targets. It is to be assumed that the degree of success of the AWS in creating and operating the regulatory mechanisms will affect the future structure and stability of the water economy.

The vision for the water economy has been defined in the master plan thusly: "Water is an existential necessity for humans and for the environment. The water economy constitutes a strategic infrastructure for the State of Israel and an essential factor in its development and realization of its national objectives. The management and sustainable development of the water economy will be carried out professionally, efficiently, fairly and transparently on the basis of modern criteria, so as to maximize the public's welfare and to maintain its health. The natural water sources will be rehabilitated and conserved."

The practical upshot of this vision is the paramount objective of "securing in an efficient manner adequate, high quality and reliable water and sewer services provision to the various consumers, and to treat sewage and use recycled effluent so as to increase the sustainable welfare of all water users."

Following are some of the various challenges facing the water economy:

- *Stabilizing the various water sources*, rehabilitating the natural reservoirs, realizing the planned desalination and brackish and recycled effluent quantities, and guaranteeing reliable provision both on the national and local levels. This, by managing demand and supply, while taking into account stretched out extreme conditions, such as consecutive droughts, spurts of demand and curtailed supply.
- *Improving the regulatory rules* and the economic/administrative mechanisms of their implementation, in a manner that will enhance economic efficiency, fairness, transparency, and supply reliability: Tariff setting, looking after the financial stability of suppliers on the one hand, and monitoring criteria for

acceptable service to customers on the other. The water economy will be run so as to include the bulk of costs in water tariffs, while financing special national projects from the state budget.
- Detailed planning and execution of *development projects* throughout the water system based on the master plan recommendations: The water economy requires vast investment, but this is hampered due to structural, organizational, lack of professional labor, differences of opinion concerning sources of finance (government budget or increased tariffs), etc.
- *Concerning the water and sewage corporations*: It is necessary to render the oversight mechanisms more efficient and improve service to the customers. It is also desirable to strive for the merging of currently separate water and sewer corporations, based on engineering, geographic, economic, and social considerations. In addition, steps should be taken to enhance the creation of water and sewer corporations in rural regions.
- *In agriculture*: The sophistication of the administrative allocation methods should be enhanced so as to render water usage more flexible and to increase supply reliability in the long run. This, by using financial incentives (such as allowing regional trade in water quotas, without forfeiting the right to these quotas) and on the basis of the Agreement. In the future, farming will use mainly marginal water, restricting itself to relatively small amounts of freshwater. The geographic incidence of farming, land conservation, improved soil fertility, flexibility in crop selection, food security, and support for peripheral communities are to be achieved by providing farms with appropriate quantities and quality of water.
- *Effluent recycling*: A concerted endeavor must be made to hook up all the generators of sewer to central systems. Similarly, it is important to strive to increase immediately the quality of recycled effluent to the tertiary level and in the more distant future to higher levels. This will enhance public health and minimize damage to the environment and to natural water sources.
- *Water provision for environmental and landscape purposes*: Nature is an equal-rights consumer of water with all other users. The ecological systems whose viability depends on water will be rehabilitated and conserved. Water allocation to nature will increase mainly by rehabilitating natural water sources.
- *Governance*: it is necessary to organize the bodies that are active in the water economy so as to enable them to work in maximum harmony while shrinking the areas where delineation of domains of authority and responsibility are blurred. The various bodies should be allowed to carry out their responsibilities by providing them with the appropriate financial and organizational means.

In addition to the above (partial) list, it should be borne in mind that the water economy is a central participant in the development of the State of Israel and has to serve as a means to the realization of national targets such as peace agreements with neighboring countries, development of agriculture and the periphery and enhancing the settlement of the country, conservation of the environment and the landscape, enhancing water-related industries in Israel, and helping other countries to develop their own water economies.

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Chapter 18
Summary and Concluding Words

Nir Becker

As I am writing these lines, I read in the weekend's newspaper about water shortage possibilities and water cutoffs in the coming summer months. A solid and good water policy is meant to eliminate any reasonable chance that such a scenario will occur. This, if happens, is a bad outcome. But is that a direct consequence of bad policy? The question that this book has tried to raise is if Israel has a solid and rational water policy in the face of the country's unique and specific water issues/concerns.

A rational water policy should be derived from well-defined goals. The policy should guide us toward the goals, and it should do so with the lowest cost possible. It is not an easy task because not only is there a dispute about the goals, but there is a dispute about the best road toward the goals. The reason is that each mixture of goals and means affect different groups in different ways. It is not a win-win situation but rather a win-lose, and as such, it brings about political forces that enter the arena. The art of good policy planning is to minimize the objection for its different components. Hence, an excellent policy can fail because it raises too much opposition despite maximizing the net benefit for the entire society involved.

The book provides a window to the interested reader who wants to know more about those forces that shape the past, current, and probably the future of Israel's water policy. The various chapters tried to concentrate the unique forces that the Israeli water sector has to deal with. After reading the book, the reader is probably more familiar with the history that brought Israel to where it is today (Chaps. 2 and 3). By understanding the important elements that caused those changes from one era to another, one can learn more about how to manipulate the different players in order to get them under one common policy umbrella.

The book emphasized two interesting sectors in Israel's water policy. The first is the most significant water user, namely, the agricultural sector. After reading

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Chap. 4, the reader can better grasp the importance of water to that sector and how exogenous and endogenous forces have led the sector to where it is today. Its transition from a sector that employed about 25% of the working force in Israel about 50 years ago until current days where it employs less than 3% is a significant change. The farming sectors can and probably should rely more on its secondary benefits which contain landscape and heritage values (the original value which was the basis for agricultural development in Israel, even before the creation of the state in 1948). That can be achieved only with a solid water policy. On the other hand, agriculture also produces negative externalities which probably realize the most by negatively affecting Israel's water sources. These affects are described in Chaps. 8 and 11. The interested reader can learn more about the implication of water use by farmers, on the two main groundwater aquifers (Chap. 8), and knows much more about the implication of water diversion and water use in the upper Jordan basin on the Sea of Galilee (Chap. 11).

The increasing use of water for domestic purposes without a proper decrease in the other sectors caused another problem which became more and more evident and worrisome to many Israelis, namely, the Lower Jordan River and specifically the Dead Sea. This has led to one of the most ambitious and controversial plans – the Red-Dead Canal. Chapter 12 describes the situation that brought the Dead Sea to its current situation and takes an in-depth look into the proposed solution to replenish the lake from the Red Sea.

Increasing water scarcity, as well as water pollution caused by excessive agricultural water use, brought about an interesting and rather unique solution: to rely on reuse of treated domestic wastewater. Chapter 6 explains the reasons that have led policy makers to consider this option and analyze its costs and benefits. The agriculture sector in Israel today uses less than 50% freshwater of what it used to consume in its peak times. A major reason that this sector did not collapse was the introduction of treated reused wastewater. This policy allowed another sector to emerge, namely, water for nature. Chapter 5 describes how treated wastewater to a definite degree is being released to revive the once dry rivers that were treated more as sewage canals rather than as ecological assets. This could not have been done without a proper water policy that reacted to changing conditions.

Treated wastewater released, of course, more water to the urban sector – but apparently, this was not enough. Another major water source that emerged in the last decade and a half is the desalinated seawater. Chapter 7 analyzes the consequences of such a significant increase in the water supply sources of Israel. It describes the pros and cons of such a policy which certainly had an effect on Israel's water sector in terms of both tariffs as well as the environment.

Water policy is not always about increased supply but also about decrease in demand. Although less attractive for policy makers, these tools are still used in Israel and were analyzed in Chaps. 9 and 10. Chapter 9 emphasized the pricing and market tools while Chap. 10 emphasized relevant the non-price tools. The reader could learn how difficult it is from a political point of view to implement such tools and especially market ones. Therefore, innovative alternatives such as block price rates or other non-price measures were also considered and even dominated the more orthodox pricing mechanism. This is not unique to Israel, but it does add another dimension to better understand the ways that created Israel's current situation.

Water policy is shaped by exogenous forces as well and Chaps. 13, 14, 15, and 16 deal with two kinds of such forces. While Chaps. 13 and 14 deal specifically with natural forces, Chaps. 15 and 16 deal with some regional perspectives of the water conflict between Israel and its neighbors. The reader could learn from Chap. 13 that variability in rainfall is a major cause for profit reduction in the agricultural sector. This can be addressed in several ways; one of them was suggested in Chap. 14, which calls for better ways to stabilize the water system that can better address these kinds of issues. Chapters 15 and 16 deal with the water conflict on a micro-basin scale (Chap. 15) as well as on the larger one (Chap. 16). The reader could learn from those chapters that there is a real problem in finding a mutual solution when basins are positioned in a way that one entity is upstream, while the other is downstream. The authors of these chapters are optimistic in their own ways. Creating a master plan has a significant potential in the case study provided within Chap. 15. Chapter 16 went into details of Israel's negotiations on water issues with its neighbors. There is no easy solution, but there is no better place than here to repeat the known phrase that water knows no boundaries. Not only should water not be an obstacle to peace, but it may, in fact, be the bridge to better cooperation and understanding between the relevant entities.

Finally, Chap. 17 deals with the other flip of the coin. It puts the water authority as the center and asks how it reacted to the changing conditions over time. The most significant step was in its creation in 2007. The authors explain why there was a need to create this authority and its accomplishments ever since.

The page limit was a constraint to the addition of more topics that likely should also be covered if one seeks a fuller understanding of ongoing changes from a policy perspective. One such fascinating topic is the major change that occurred in the urban water sector. This was explained in Chap. 17 but warrants a chapter dedicated solely to the topic. The past policy was to let the local municipalities take care of their own distribution facilities and infrastructure. However, since the money collected was not earmarked toward proper maintenance of the system, local municipalities found it more desirable to use revenues to more short-sighted purposes. One of the major changes in the last few years was to create closed circle regional water corporation. All of a sudden, urban water consumers faced the real cost of providing them the water which actually was reflected in the higher prices – in turn, raising a significant amount of resistance. The burden shifted from the anonymous tax payer to the specific water consumer.

Another issue that did not get a proper treatment in the book is the use of water tariffs to create cross subsidization. This was once true among sectors and among regions. These days, it is not true that one sector subsidizes the other, but it is true that water rates are equal in any location in Israel. This is true despite the different costs associated with supplying water to any given point. It is based on a policy that values equality more highly than it does efficiency. What are the benefits and costs of such a policy and are there any alternatives that can save the same equality level while still create less inefficiency?

Despite those two examples (and maybe more) of such topics that were not treated properly in the book, reading the book can help in understanding better how complex it is to form water policy in a country such as Israel. Wrong or right, the Israeli water sector would continue to be a lively arena for a dialog, criticism, and an unconditional estimate that challenges the policy makers toward continuous improvement. It is my hope that readers can learn from mistakes and achievements that were made along the way and be better able to create solid rational water policies.

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