Ocean & Coastal Management 64 (2012) 27–36

Contents lists available at SciVerse ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Desalinate or divert? Coastal non-market values as a decision tool for an integrated water management policy: The case of the Jordan River basin

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ARTICLE INFO

Article history:
Available online 20 April 2012

JEL classification:
Q25
Q28
Q51

ABSTRACT

This paper deals with a cost effective analysis of two options to increase the water supply in Israel. The first policy is to divert 300 Million Cubic Meters (MCM) of water from the Sea of Galilee (SOG) to the central part of Israel. This policy is the existing one. The second policy is to replace this diversion with desalinated water plants that will be built on the Mediterranean Coast (MC). These two options carry both market and non-market consequences. The first policy has a negative effect on the SOG itself due to the lower lake level. It also carries some negative consequences on the Jordan River (JR) and the Dead Sea (DS) which are located downstream. The second policy involves water production at a higher cost and has negative external effects of scarce coastal land usage and high energy consumption. A Payment Card (PC) Contingent Valuation (CV) survey was performed at the four sites (the SOG, the DS, the JR and the MS). We show that when one takes these non-use values into account, the preferred solution will shift from the usage of the SOG to the desalination policy.

1. Introduction

Water resources are essential for household, farming and industrial uses. Projected demand, especially in the household sector, will worsen the existing water problems worldwide (Afgan et al., 1998). Therefore, water use should be planned in a rational way in order to account for all uses and allocate water where the marginal contribution is the highest. This should be done by taking into account both market as well as non-market values of the water resources (Mitchell and Carson, 1989; Loomis, 2005).

After counting out approximately 99% of the available water on earth (too saline or stored in icebergs), even the remaining 1% is not equally distributed. Therefore, while observing high rainfall areas, we also observe semi-arid as well as arid regions. Desalination is one of the proposed solutions to alleviate the increasing demand vs. supply gap in such semi-arid and arid regions.

The Water sector in Israel is no exception and suffers from an increasing gap of fresh water. The climate in Israel varies according to location but it is generally defined as a semi-arid region. Approximately 70% of the rainfall evaporates, another 25% will infiltrate into the aquifers and the remaining 5% will flow into the rivers.

Israel's water resources have been relying on the two major underground aquifers as well as the transfer of water from the SOG. This is accomplished through the Water Carrier which transfers an average of 300 MCM annually. Since the SOG is the only fresh water lake in Israel, it has several values ranging from recreational to cultural and sentimental values. Decreased water table due to water transfer to the central part of Israel has long been claimed a major concern from a touristic and heritage point of view. In addition, water transfer is actually achieved by damming the water outflow from the SOG through the JR into the DS. It has been claimed that the major reason for the reduction of size of the DS is due to the damming of the JR (Becker and Katz, 2006).

In contrast to using the water of the SOG, we can desalinate 300 MCM from the Mediterranean Sea. Desalination has two drawbacks. The first is that, it is more expensive than using fresh water (either from underground aquifers or from the SOG) by approximately 100%. The second drawback is that it carries along with it negative external effects, one of which is capturing limited coastal areas as well as the usage of energy.

In order to decide on the better alternative we are going to use an integrated approach which measures the cost of one unit of water saved or produced (including both market and non-market values). We can summarize the pros and cons of both alternatives in Table 1 below.

As can be seen in Table 1, the first parameter is a market value parameter, while the other parameters are non-market values.

Analyzing the two alternatives will capture the economic values of the Mediterranean Coast, the SOG and the JR combined together.

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doi:10.1016/j.ocecoaman.2012.04.008

Table 1
Qualitative cons of the two options to produce 300 MCM.

Diverting water from the SOG	Desalinating water on the Mediterranean Coast
Reduced water table at the SOG	Cost is higher than using fresh water
Reduced water flow into the Jordan	External effects of desalination on Coastal areas along the Mediterranean Coast

This paper continues as follows. Section 2 describes desalination within the general water policy expansion plans. Section 3 describes the methodology used to estimate the non-market values. Section 4 describes the data and especially the survey used, while Section 5 will contain the results and discussion. Section 6 concludes and reflects on the policy issues.

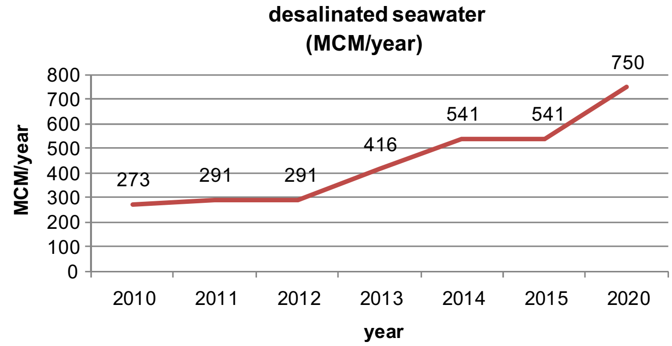

Fig. 1. Desalination plans by 2020.

2. Desalination and existing water sources within Israel's general water plans

Over the past decade, Israel has suffered from periods of multi-year droughts. In parallel, a steady increase in domestic water consumption was caused by increased municipal water demand; increased allocations of water shared with neighboring Arab countries – as dictated by the peace agreements; increased demand for the allocation of water for environment purposes; and significant population growth (both natural and due to immigration) combined with rising standards of living (Becker et al., 2010).

While water demand was rising throughout the 1990s and 2000s, the water supply was becoming less reliable. The demand for water on one hand, and water supply shortage on the other, led to the development of desalination technology and optimal timing for their implementation (Tsur and Zemel, 2000). Given frequent water shortage, water managers (e.g., the water authority) and policy makers (e.g., legislators) considered a range of management options. In the supply management framework, decision-makers decided to focus primarily on developing desalination on a large-scale. A series of government decisions have determined the need for desalinated seawater as part of the national water balance. Consequently, desalination plants in Israel will be required to produce desalinated water to the amount of 505 MCM/year by 2013, and 750 MCM/year by 2020. Fig. 1 demonstrates the gradual increase in addition of desalinated seawater expected by the year 2020.

The above figure demonstrates the most significant change in Israel's water supply system. The fresh water supply averages at approximately 1300 MCM, but the increased water share from planned desalination plants will reach more than 50% by the year 2010 (Tal, 2006).

Since water desalination will capture an increasing part of the total water supply in Israel over the foreseen future (Dreizin et al., 2008), it is important to compare this alternative to the current situation of diverting water from the SOG. This does not mean that desalination will stop, but it only deals with the issue of 1–2 plants and their desirability vs. the existing situation.

The costs and benefits arising from desalinating seawater and introducing it into the Israeli national water system are varied; they include market as well as non-market values. We will try to point out the major issues which are crucial for conducting a true and full assessment. The main objective of seawater desalination is to meet the demands of current and future water shortages in Israel's entire freshwater balance. The newly introduced water from desalination plants is reliable in both quantity and quality, and includes various environmental, health, social and economic benefits:

- It provides a solution to natural and strategic issues of supply reliability and water quality.
- It will allow rehabilitation of the natural resources, being the SOG in particular, as well as the DS and the JR.
- It will improve the quality of the water, both in terms of salination and water softening, within the national water system. While the level of salinity in freshwater is roughly 250 mg Cl/L, the level of salinity in desalinated water is roughly 100 mg Cl/L. The decline in the salinity level contributes in three aspects: preventing crop yield reduction, improving aquifer water quality as well as extending the life of household, industrial electrical equipment and salinity systems (Lavee, 2011).
- Desalinated water production near the areas of consumption will reduce the need for multiple investments in energy and infrastructure for the supply of water from remote sources (Tal, 2006).
- Desalination reduces most of the chemical treatment costs which are usually needed to secure water sanitation.
- An additional non-market value is the ability to ensure a permanent water quota for environmental water flows.

In addition to the direct production costs, the external costs must be considered in order to estimate the full social costs of desalination. Seawater desalination is associated with three major negative environmental impacts:

- **Air pollution and greenhouse gas emissions** – A concern was raised regarding the pollution originated from the development and production of desalination plants, since they consume significant amounts of energy resources. However, as long as the assumption is that the SOG and seawater desalination are definite alternative options, the additional energy consumption might turn out to be insignificant. The current energy consumption of the 3 existing desalination plants, which produce approximately 300 MCM annually (equivalent to the SOG's annual volume), is less than 1% of the total country's energy consumption (Lavee et al., 2010). Moreover, if desalinated water will fully substitute the SOG's flow through the Water Carrier from the northern part of Israel to its center and southern areas, it might turn out to be an energy saving decision due to the added amount of water that is produced in the center of the country, rather than diverting the water from the north.
- **Expropriation and use of land along coastal areas** – Israel's National Statutory Plan for the location of desalination plants accompanied with a background check for the future water demand is up to the year 2050, as well as the potential expansion of present and approved desalination plants, in water capacity terms. One of the most disturbing findings is the demand of coastal areas. As the margin between supply and demand will grow, additional desalination plants will be