

## Chapter 6

# Jordan River Basin



INVENTORY OF  
**SHARED WATER RESOURCES**  
IN WESTERN ASIA (ONLINE VERSION)



**BGR** Bundesanstalt für  
Geowissenschaften  
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# Jordan River Basin



The Jordan River at one of its narrowest points, Jordan, 1992. Source: Ed Kashi/VII.

## EXECUTIVE SUMMARY

Originating from the Anti-Lebanon and Mount Hermon mountain ranges, the Jordan River covers a distance of 223 km from north to south and discharges into the Dead Sea. The river has five riparians: Israel, Jordan, Lebanon, Palestine and Syria.

The Jordan River headwaters (Hasbani, Banias and Dan) are fed by groundwater and seasonal surface runoff. The Lower Jordan River originally received its main inflow from the outlet of Lake Tiberias and the Yarmouk River, the largest tributary, as well as from several wadis and aquifers. The flow of the Upper Jordan River into

Lake Tiberias remains nearly natural, but flow rates in the downstream part of the river have decreased sharply in the last 50 years due to the construction of a series of infrastructure and diversion schemes established in the basin. For instance, the mean annual historic flow of the Yarmouk that was estimated at 450-500 MCM in the 1950s has today decreased to 83-99 MCM. The current annual discharge of the Lower Jordan River into the Dead Sea is estimated at 20-200 MCM compared to the historic 1,300 MCM. Moreover, water quality in the Lower Jordan River is very low.

Water use in the Jordan River basin is unevenly developed. Palestine and Syria have no access to the Jordan River; hence their use of water resources from the river itself is nil. However, Syria has built several dams in the Yarmouk River sub-basin, which is part of the Jordan River basin. The country uses about 450 MCM/yr of surface and groundwater resources in the basin, mainly for agricultural purposes. Annual abstractions in the Hasbani sub-basin in Lebanon are estimated at 9-10 MCM, which are mainly used for domestic water supply. Israel is the largest user of water from the Jordan River basin, with an annual withdrawal of between 580 and 640 MCM. It is also the only user of water from Lake Tiberias. Jordan uses about 290 MCM/yr of water from the Jordan River basin. Water diverted from the Yarmouk River to the King Abdullah Canal is used for irrigation of crops in the Jordan Valley and for domestic use in Amman. Overall, the Jordan River basin has an estimated total irrigated area of 100,000-150,000 ha of which around 30% is located in Israel, Jordan and Syria, 5% in Palestine and 2% in Lebanon.

The quality of water in the Jordan River has severely deteriorated in recent decades. While the headwaters are relatively unaffected, the Lower Jordan River consists primarily of untreated sewage and agricultural return flows, groundwater seepage, as well as brackish water from springs diverted into the river away from the Lake Tiberias area. The Lower Jordan River in particular is extremely polluted. Other environmental concerns include water-level fluctuations in Lake Tiberias and the associated risk of saline water intrusion from below, and, more importantly, the decline of the Dead Sea, which all threaten the stability of the basin ecosystem.

Since the early 20th century, numerous attempts to foster cooperation between basin riparians have been hampered by the regional political conflict which continues to stand in the way of any basin-wide agreement on water. A number of bilateral agreements encourage cooperation over water between Israel and Jordan, and Israel and Palestine.



The Dead Sea, Jordan, 2010. Source: Martin Schäfer.

## BASIN FACTS

RIPARIAN COUNTRIES	Israel, Jordan, Lebanon, Palestine, Syria
BASIN AREAS SHARES	Israel 10%, Jordan 40%, Lebanon 4%, Palestine 9%, Syria 37%
BASIN AREA	18,285 km <sup>2</sup>
RIVER LENGTH	223 km
MEAN ANNUAL FLOW VOLUME	<p><b>Natural conditions (1950s)</b>  Upper Jordan River: 605 MCM  Yarmouk River: 450-500 MCM  Lower Jordan River: 1,300 MCM</p> <p><b>Current conditions</b>  Upper Jordan River: 616 MCM  Yarmouk River: 83-99 MCM  Lower Jordan River: 20-200 MCM</p>
MAIN DAMS	45 (max. storage capacity ~390 MCM)
PROJECTED IRRIGATED AREA	100,000-150,000 ha
BASIN POPULATION	7.18 million

## MAIN AGREEMENTS

JORDAN - SYRIA	1953 and 1987 – On the use of the Yarmouk River, including the construction of the Wahdah Dam and 25 dams in Syria. The agreement also establishes a joint commission for the implementation of the provisions on the Wahdah Dam.
ISRAEL - JORDAN	1994 – Annex II of the Treaty of Peace concerns water allocation and storage of the Jordan and Yarmouk Rivers, and calls for efforts to prevent water pollution as well as the establishment of a Joint Water Committee.
ISRAEL - PALESTINE (PLO)	1995 – Article 40 of the Oslo II political agreement states that Israel recognizes Palestinian water rights in the West Bank only and establishes the Joint Water Committee to manage West Bank waters and develop new supplies. Palestinians are denied access to the Jordan River under this agreement.

## KEY CONCERNS

WATER QUANTITY
Ensuring adequate quantities of water for all riparians is a key challenge in the basin given the relatively small volume of water available and the large population. River flow has been greatly reduced over the years as a result of increased exploitation of water resources in the basin. The rapid decline of the Dead Sea is an indicator that the region's ecosystem is at risk.
WATER QUALITY
Water quality rapidly deteriorates along the course of the Jordan River and its lower portion displays extremely high salinity and pollution rates.
GEOPOLITICAL
The question of water sharing in the Jordan River basin is inextricably linked to the ongoing conflicts between Israel and Syria, Israel and Lebanon, and Israel and Palestine, and while a wide range of issues are at stake, control over water in the basin has added to existing regional tensions.



## OVERVIEW MAP



## Jordan River Basin

- |                                      |                                |                      |
|--------------------------------------|--------------------------------|----------------------|
| ----- International boundary         | ~~~~~ River                    | Dam                  |
| - - - Armistice Demarcation Line     | ~~~~~ Intermittent river, wadi | ▲ Monitoring station |
| ● Capital                            | --- Canal, irrigation tunnel   |                      |
| ● Selected city, town                | ■ Freshwater lake              |                      |
| ■ Basin boundary                     | ★ Spring                       |                      |
| ■ Main shared sub-basin boundary     | × Mountain                     |                      |
| /// Zone of agricultural development |                                |                      |



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### Inventory of Shared Water Resources in Western Asia

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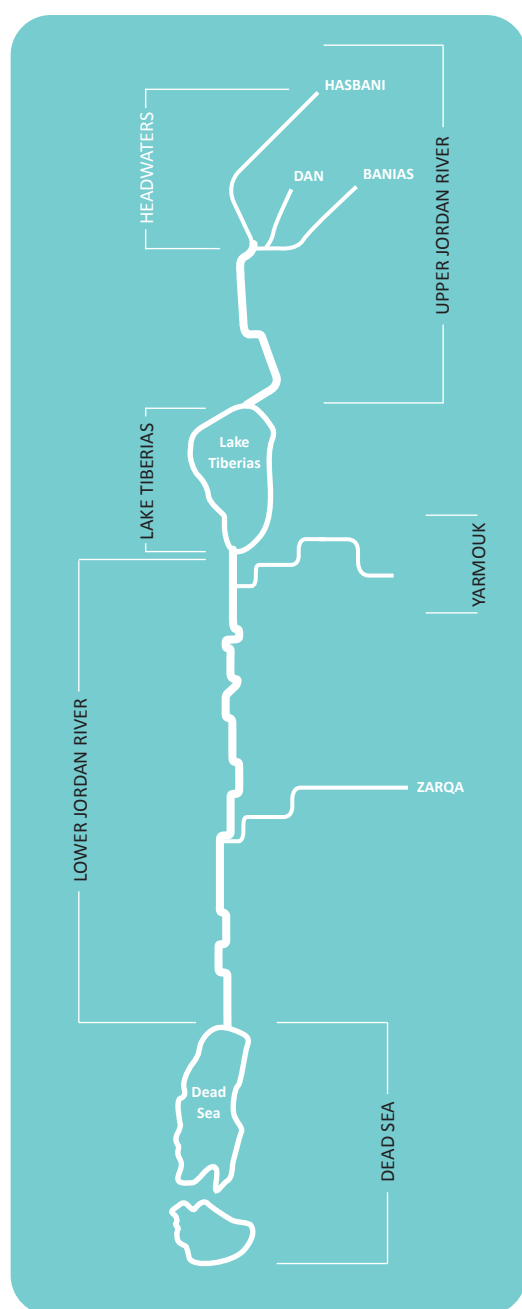




# Geography

This chapter on the Jordan River basin covers the headwaters of the Upper Jordan River, the Upper Jordan River, Lake Tiberias, the Yarmouk River and the Lower Jordan River (Figure 1). This Inventory focuses on shared freshwater bodies and perennial rivers. The Dead Sea Basin,<sup>1</sup> which covers a total area of 43,280 km<sup>2</sup>, is therefore not considered in this chapter.

Figure 1. **Sketch of the Jordan-Yarmouk River System**



Source: Compiled by ESCWA-BGR.

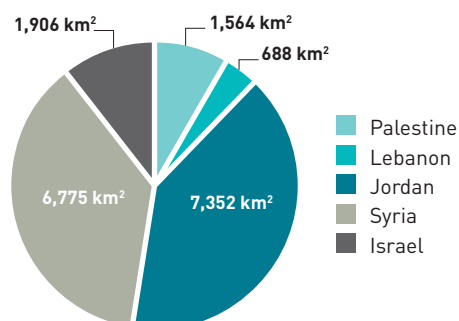
The Jordan River forms the axis of a basin system, flowing from the slopes of Mount Hermon in the north at the junctures of the borders of Israel, Lebanon and Syria to the Dead Sea in the south (see Overview Map). The basin is shared by five riparian countries: Israel, Jordan, Lebanon, Palestine and Syria.<sup>2</sup>

The area of the Jordan River basin is estimated at 18,285 km<sup>2</sup> including the Baniyas, Dan (Liddan)<sup>3</sup> and Hasbani headwater sub-basins and the basin of the largest tributary, the Yarmouk River.<sup>4</sup> The largest part of the basin is located in Jordan (40%) and Syria (37%), with the remainder situated in Israel (10%), Lebanon (4%) and Palestine (9%) (Figure 2). The river has a total length of 223 km measured from the confluence of the headwaters to the Dead Sea. North of Lake Tiberias, the river is generally designated as the Upper Jordan River, while the part that flows south from Lake Tiberias to the Dead Sea is referred to as the Lower Jordan River.

## RIVER COURSE

The Upper Jordan River is principally formed by the flow of three spring-fed rivers: the Hasbani, Baniyas and Dan. The Hasbani River originates in Lebanon, while the Baniyas River rises in the occupied Syrian Golan and the Dan Spring lies in Israel.<sup>5</sup> The Dan and the Baniyas Rivers meet north of the Hula Valley and upstream of the confluence with the Hasbani, where the three main headwaters form the Upper Jordan River. There is an ongoing discussion about the principal source of the Jordan River, revolving around the hydrological definition of various parameters such as water yield and river length.<sup>6</sup>

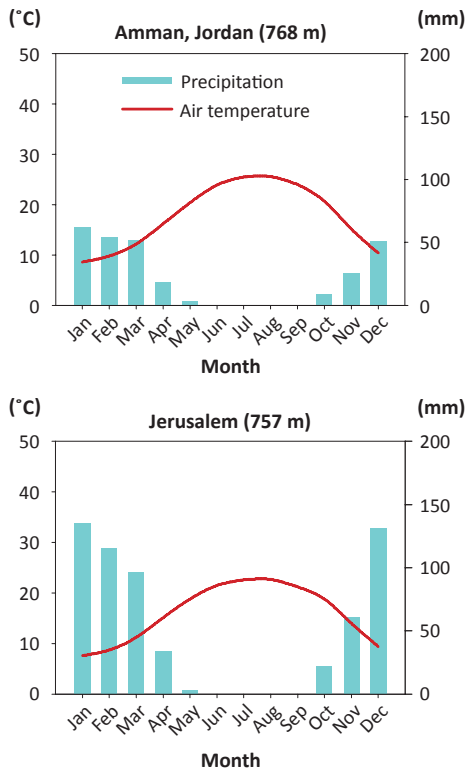
Figure 2. **Distribution of the Jordan River basin area**



Source: Compiled by ESCWA-BGR.



Figure 3. Mean monthly climate diagrams for Amman, Jordan, and Jerusalem



Source: Compiled by ESCWA-BGR based on data provided by WorldClim, 2011; Climate Diagrams, 2009; Phytosociological Research Center, 2009.

The Lower Jordan River flows from the outlet of Lake Tiberias and is joined about 5 km downstream by the Yarmouk, a river with a total length of 143 km. The Yarmouk River originates from sources in Jordan and in the eastern Golan in Syria. It forms the Jordanian-Syrian border for about 49 km and then flows through the Addasiya Triangle where it runs along the Israeli-Jordanian border for a few kilometres before joining the Lower Jordan River.

The Lower Jordan River covers a distance of 115 km from the outlet of Lake Tiberias to the Dead Sea, with several wadis joining the river from both sides and the Zarqa River discharging into it from the east.

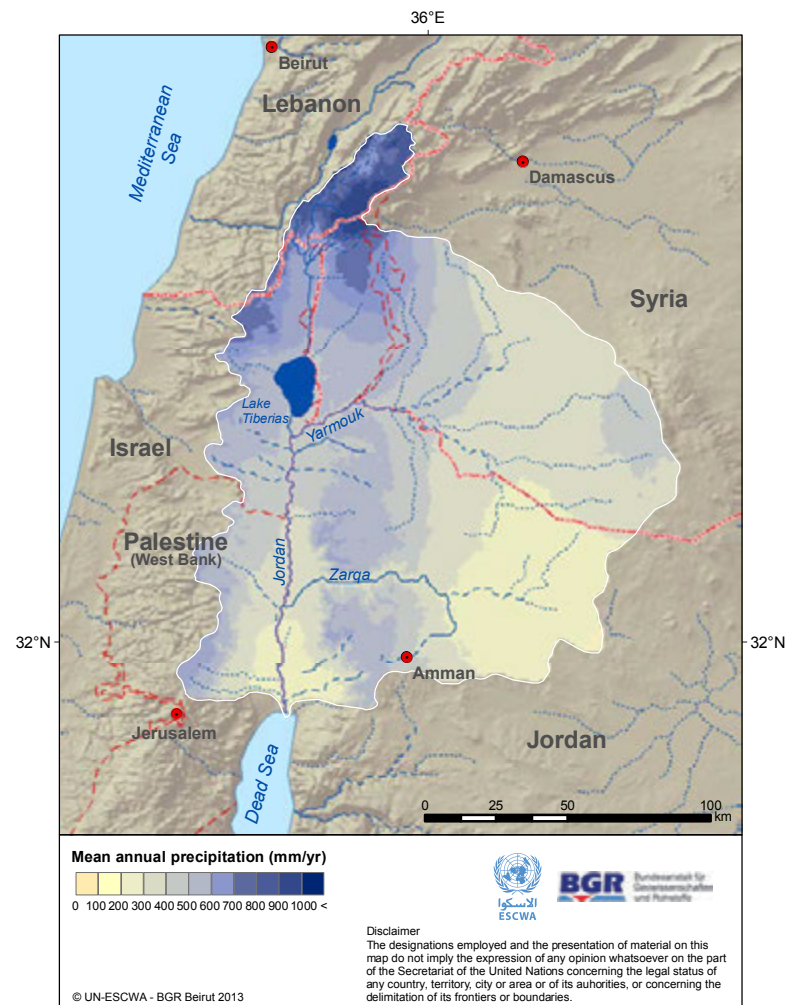
## CLIMATE

The Jordan River basin displays broad climatic variations within a relatively small area, which is typical of climatic conditions in the region. The rapidly changing topography with influences of Mediterranean and continental climates creates different microclimates in the basin. The steep west-east climate gradient gives rise to a sequence of Mediterranean, semi-arid and arid climates over a distance of just 10 to 20 km in places. The mountains in Lebanon and Syria, which extend over a small area in the northern part of the basin, are hardly influenced by the Mediterranean climate due to their altitude,

while the slopes of the north-eastern mountain ridges and parts of the east bank of the Jordan River are characterized by a dry, temperate Mediterranean climate. The highest mean temperature lies around 22°C, with at least four months per year averaging above 10°C (Figure 3). The hillslopes of the West Bank and the Jordan Valley have a steppe climate with low precipitation and mean annual temperatures above 18°C. Parts of the Syrian plateaus and most of the Jordanian highlands have an arid climate.<sup>7</sup> High summer temperatures in parts of the basin account for the relatively high evaporation rates, which are estimated at 65% in winter and 45% in summer.<sup>8</sup>

Precipitation rates in the Jordan River basin vary from over 1,000 mm/yr on the eastern slopes of Mount Hermon in the north to less than 200 mm/yr in the lower West Bank and less than 100 mm/yr on the Dead Sea coast (Figure 4).<sup>9</sup> Rainfall declines from north to south and from west to east, which explains why the limited surplus water is confined to the northern and coastal uplands in Israel, Lebanon and Syria.<sup>10</sup> Precipitation is concentrated in the

Figure 4. Mean annual precipitation in the Jordan River basin



Source: Compiled by ESCWA-BGR based on data provided by WorldClim, 2011.



winter months between November and March. The basin has a pronounced seasonal climate variability, with strong fluctuations in rainfall from year to year.<sup>11</sup>

## POPULATION

The Jordan River basin has a total population of more than seven million. The majority of the basin population lives in Jordan (71%), while 18% lives in the Syrian part of the basin, which includes parts of the Yarmouk sub-basin and the Golan Heights in Syria. The populations living in the three remaining riparian countries make up 11% of the basin population (Table 1).



Mount Hermon, Lebanon, 2009. Source: Eileen Maternowski.

### Syrians Living in the Occupied Golan

Before the Israeli occupation of the Golan in 1967, the area was home to over 140,000 Syrians, most of who were displaced by the occupation. Today an estimated 20,000 Syrians live in small villages in the Israeli-occupied Syrian Golan.<sup>a</sup>

(a) Permanent Mission of the Syrian Arab Republic to the United Nations, 2010.

(b) Central Bureau of Statistics in Israel, 2010.

### Israelis Living in the West Bank

Between 1996 and 2009, the number of Israelis living in settlements in the West Bank more than doubled from 140,000 in 1996 to 300,000 in 2009 (450,000 including East Jerusalem).<sup>b</sup>

Table 1. **Estimated basin population**

RIPARIAN COUNTRY	COUNTRY POPULATION (MILLIONS)	ESTIMATED POPULATION IN THE BASIN		SOURCE
		MILLIONS	AS PERCENTAGE OF TOTAL BASIN POPULATION	
Lebanon	4.5	0.105	1	Ministry of Energy and Water in Lebanon, 2011.
Syria	23.7	1.3	18	Central Bureau of Statistics in the Syrian Arab Republic, 2005; Central Bureau of Statistics in the Syrian Arab Republic, 2011. <sup>a</sup>
Israel	7.7	0.294	4	Central Bureau of Statistics in Israel, 2009. <sup>b</sup>
Jordan	6.1	5.05	71	Department of Statistics in Jordan, 2012. <sup>c</sup>
Palestine (West Bank)	4.1	0.431 (+30,000 Israeli settlers)	6	PCBS, 2012. <sup>d</sup>
<b>Total</b>		<b>7.18</b>		

Source: Compiled by ESCWA-BGR.

(a) The population estimation for the basin area situated in Syria is based on a 2004 population census and 2010 estimates and includes populations living in the Syrian governorates of Dar'a, Quneitra, Reef Dimashq and As Suwayda.

(b) The population estimate for the area of the basin situated in Israel is based on a 2008 population census and includes populations living in the Israeli districts/sub-districts of Golan, Kinneret, Yizre'el and Zefat.

(c) The population estimate for the basin area situated in Jordan is based on 2011 estimates by the Department of Statistics and includes populations in the governorates of Ajlun, Amman, Balqa, Irbid, Jarash, Mafraq and Zarqa.

(d) The population estimate for the basin area situated in Palestine (West Bank) is based on a 2007 population census by the Central Bureau of Statistics and includes populations in the West Bank governorates of Aghwar Jenin, Jericho, Jerusalem, Nablus, Ramallah & Al-Bireh and Tubas. In addition, about 30,000 Israeli settlers in the West Bank live within the boundaries of the Jordan River basin (PCBS, 2011).





# Hydrological Characteristics

For the purpose of this Inventory, the hydrological characterization of the Jordan River basin is divided into four parts: Headwaters of the Upper Jordan River, Upper Jordan River, Yarmouk River and Lower Jordan River. This division allows for the presentation and discussion of available discharge data for each of the four basin parts and for the analysis of measured differences between gauging stations along the course of the river. Wherever possible, riparian contributions are presented before annual flow variability and flow regime data. Depending on data availability, the connection between surface and groundwater resources is also addressed.

Finally, findings from the hydrological characterization will enrich the subsequent comparison between the presumed near-natural flow regime of the Jordan River basin and its current state.

Available discharge data presented in this section covers the period from the hydrological year 1944 until 2008 for the three headwaters of the Upper Jordan River, and from 1948 until 2008 for other stations on the Upper Jordan River. For the Yarmouk, available discharge data covers the period 1963-2006, while data for the Lower Jordan River is only available for 20 years from 1979 to 1999.



Lake Tiberias from Umm Qais, Jordan, 2007. Source: Eileen Maternowski.





## HEADWATERS OF THE UPPER JORDAN RIVER

### DISCHARGE AND FLOW REGIME

The Hasbani,<sup>12</sup> Banias,<sup>13</sup> and Dan Rivers are the main contributors to the flow of the Upper Jordan River with respective surface catchment areas of 698 km<sup>2</sup>, 189 km<sup>2</sup> and 17.6 km<sup>2</sup>.<sup>14</sup> Although it has the smallest surface basin area, the Dan River contributes the largest flow volume to the Upper Jordan River (Table 2), most likely due to the presence of an important transboundary aquifer system that extends northward beyond the limits of the Dan surface water sub-basin into the Hasbani sub-basin and the Mount Hermon area.<sup>15</sup>

### ANNUAL DISCHARGE VARIABILITY

The mean annual flow of the Dan (228 MCM) is about double that of the Hasbani and Banias Rivers (122 MCM and 113 MCM respectively). The mean annual flow of these headwater rivers has a measured total of 463 MCM for the entire period of record between 1944 and 2008 (Table 2). Maximum flows of the Hasbani and Banias sub-basins were observed in 1968/69 (232 MCM for the Banias), while minimum flows were recorded in 1989/90 (30 MCM for the Hasbani) and 2000/01 (47 MCM for the Banias). The Dan River displays a much lower annual variability, with the lowest annual

Table 2. Summary of annual flow volume statistics for the Hasbani, Banias and Dan Rivers (1944-2008)

SUB-BASIN (SURFACE DRAINAGE AREA, km <sup>2</sup> )	MEAN (MCM)	MINIMUM (MCM)	MAXIMUM (MCM)	CV <sup>a</sup> (-)
Hasbani (698)	122	30	304	0.53
Banias (189)	113	47	232	0.35
Dan (17.6)	228	89	312	0.22
Measured total	463	-	-	-

Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.

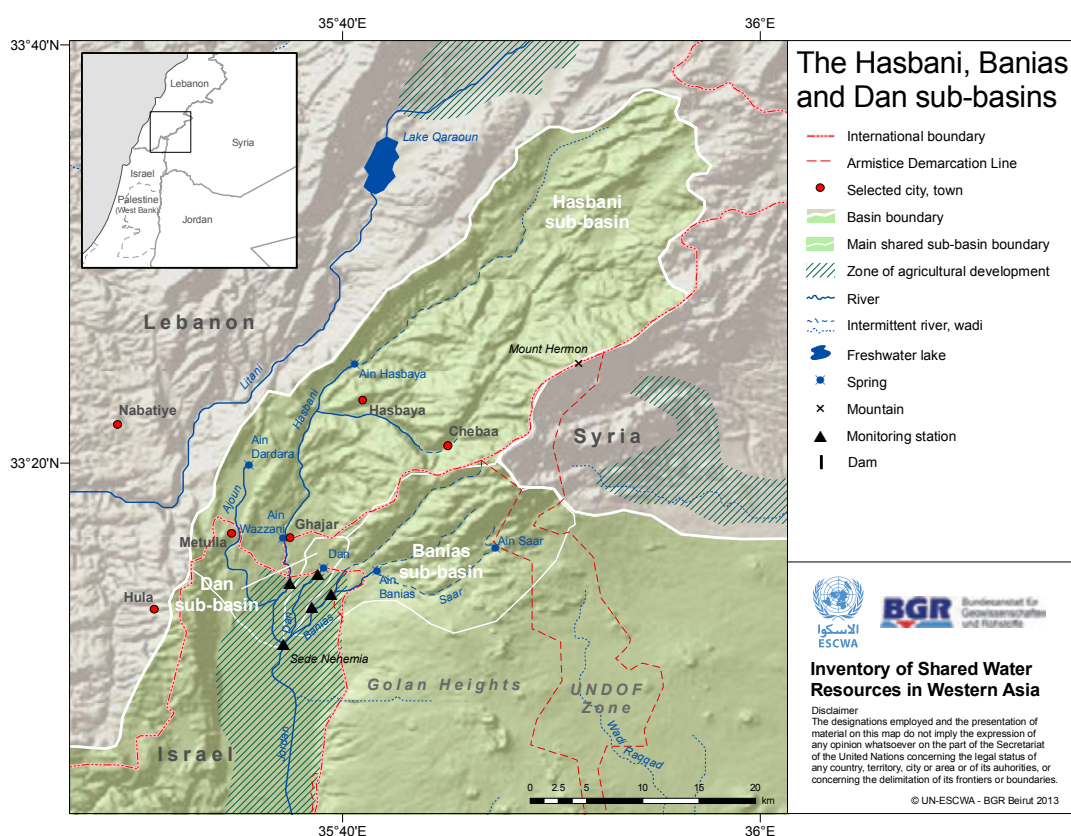
Note: The period of record shows a consistent gap from 1946 until 1949.

(a) Coefficient of Variation. For information on the definition and calculation of the CV see 'Overview & Methodology: Surface Water' chapter.



The Dan River, Israel, 2008. Source: Nethanel H.

Figure 5. The Hasbani, Banias and Dan sub-basins





flow volume recorded in 2008 (89 MCM) and the highest in 1996 (312 MCM). Figure 6a shows the long-term observed discharge of the three Jordan headwater rivers. Figure 6b presents a theoretical specific discharge per km<sup>2</sup> of the surface water catchment for these headwater rivers. The mean annual specific discharge anomaly time series shows a frequent oscillation between wet and dry years (Figure 7), which repeats every three to four years on average on the Hasbani and Baniyas Rivers. Only the period between 1995 and 2002 shows a prolonged drought of more than five years. The Hasbani and Baniyas Rivers exhibit similar annual dynamics. The annual stream-flow dynamics of the Dan River follows a different pattern, with longer wet and dry cycles (e.g. the wet period from 1974 to 1984) than the adjacent rivers. Since 1998 the Dan has experienced a sustained decrease in discharge, also in comparison to the Hasbani and Baniyas Rivers (Figure 7c). It is unclear whether the decrease is related to changes in the monitoring set-up (location of station, methodology), growing abstraction/water diversion upstream of the monitoring site or whether it reflects changing precipitation patterns (drought) and/or recharge dynamics in the catchment areas of the Dan Spring and River. However, no significant trend could be observed at the Dan monitoring station for the whole period of record.

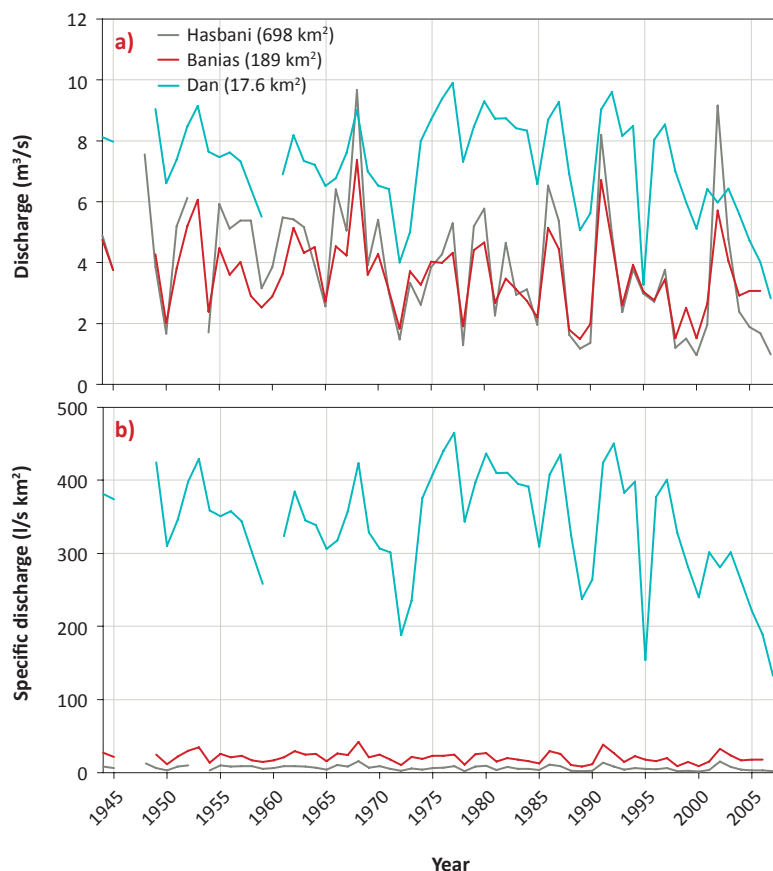
## FLOW REGIMES

The mean monthly flow regime of the Baniyas and Hasbani Rivers is characterized by high winter precipitation and snow-melt-dominated peak flows in February and March, while minimum flows usually occur in September and October (Figure 8). The Hasbani exhibits higher mean monthly peak flows and lower flows in the dry months compared to the Baniyas. The flow regime of the Dan is much more balanced than that of the Baniyas and Hasbani, with only a slight increase in flows in March and April. This can be explained by the larger groundwater catchment that influences the flow of the Dan Spring. Generally, for the period of monitoring between 1944 and 2008, the three Jordan headwater rivers do not appear to be influenced by stream regulation, and flow regimes may be considered near-natural.

## GROUNDWATER

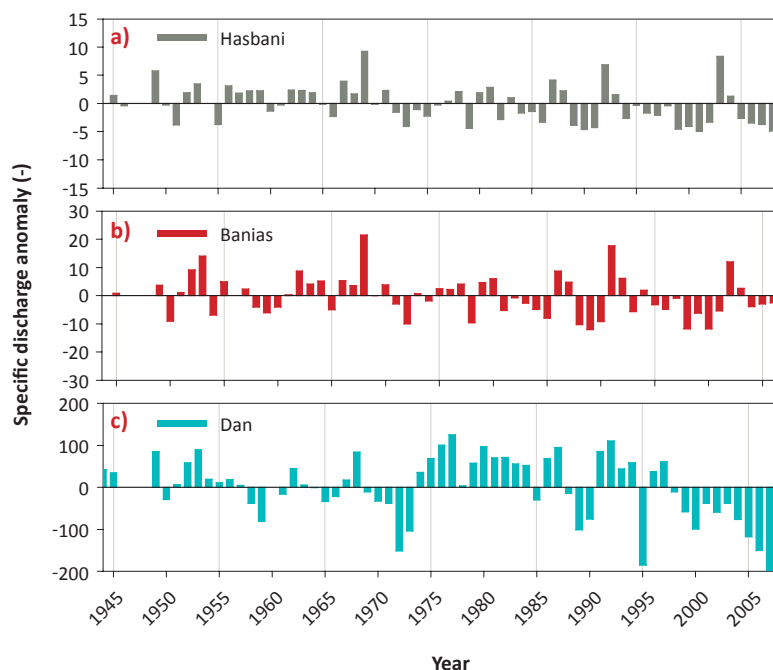
The discharge of all three headwaters originates primarily from strong karstic groundwater springs which appear to be partially fed by the same aquifer or aquifer system on the eastern slopes of Mount Hermon. For the Hasbani River, the groundwater catchments of both springs, the Hasbani and Wazzani, are likely to extend

Figure 6. a) Mean annual discharge and b) specific mean annual discharge of the Hasbani, Baniyas and Dan Rivers (1944-2008)



Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.

Figure 7. Specific discharge anomaly time series of the Hasbani, Baniyas and Dan Rivers (1944-2008)



Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.

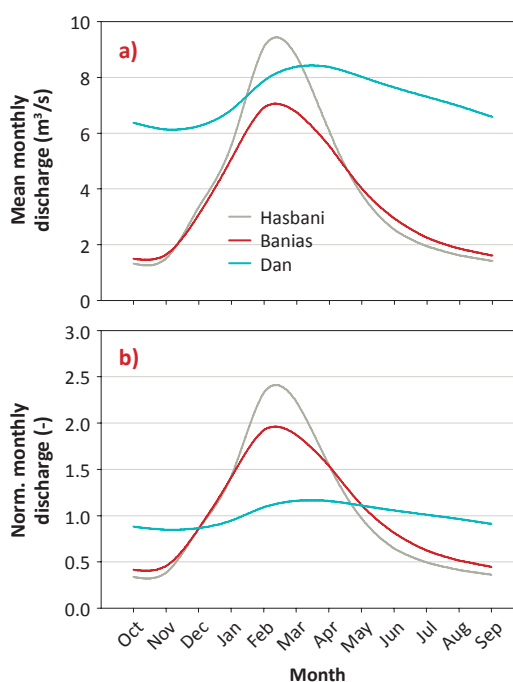




mostly in Lebanon, upstream of the respective springs. The discharge of the Dan Spring and probably of the Banias Spring originates from a transboundary aquifer or aquifer system, whose recharge area lies primarily in Lebanon and possibly also in Syria.

Furthermore, the Dan sub-basin, which covers a relatively small surface area (17.6 km<sup>2</sup>), has a high mean discharge (228 MCM/yr) compared to the adjacent sub-basins such as the Hasbani, which extends over an area of 698 km<sup>2</sup> with an annual mean discharge of only 122 MCM. Recent hydrogeological studies suggest that the Dan may have a much larger actual subsurface recharge basin area of more than 1,320 km<sup>2</sup> (compared to an estimated 520 km<sup>2</sup> for the Banias) as the Dan Springs emerge from a deep and productive Jurassic limestone aquifer with outcrops in Lebanon and Syria.<sup>16</sup> This transboundary aquifer is recharged by rain and snow-melt, especially along the slopes of Mount Hermon.<sup>17</sup> A geological fault may divide the southern Mount Hermon recharge area into an eastern and western part which feed the Banias on one side and the Hasbani and Dan on the other.<sup>18</sup> Nevertheless, the flow regimes of the Hasbani and Banias headwaters appear to be very similar.

**Figure 8. Mean monthly flow regime of the Hasbani, Banias and Dan Rivers (1944-2008)**



Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.



The Banias River, Golan Heights, 2008. Source: Nethanel H.

A simple estimate of required effective rainfall recharge for the Dan Spring (13,000 mm/yr over 17.6 km<sup>2</sup>) reveals that the small surface water catchment cannot be sufficient to sustain flows. A combination of the surface water catchments of the Hasbani and Dan or even of all three headwaters results in more realistic estimates with a required effective rainfall of 489 or 512 mm/yr over the respective catchments. While this is clear evidence that the Dan and most likely also the Baniyas Spring groundwater catchments extend into Lebanon, further research is required to delineate the actual extent of the catchments.<sup>19</sup>

## UPPER JORDAN RIVER

### DISCHARGE AND FLOW REGIME

The Upper Jordan River formed at the confluence of the headwater streams in Sede Nehemia, Israel (Figure 5) flows into Lake Tiberias. Discharge data is available for two gauging stations along the course of the Upper Jordan River (Figure 9): Sede Nehemia for the period 1948-2008 and Obstacle Bridge for the period 1960-2008. The overlapping period of record covers 45 years.

### ANNUAL DISCHARGE VARIABILITY

Discharge records from the Sede Nehemia and Obstacle Bridge gauging stations on the Upper Jordan River exhibit dry and wet periods. Maximum flows were observed at both stations in 1968/69 (1,096 MCM at Obstacle Bridge, Table 3) and minimum flows were recorded in 1972/73 (155 MCM at Sede Nehemia) and 1998/99 (215 MCM at Obstacle Bridge).<sup>20</sup>

The mean annual flow for the entire period of record at Sede Nehemia is 382 MCM, 81 MCM (approx. 17%) less than the measured total mean annual flow of the three headwater rivers (463 MCM) for the period 1944-2008 (Table 2). This discrepancy can most likely be explained by water diversions for irrigation and domestic use in the Dan sub-basin.<sup>21</sup> The mean annual flow of the Upper Jordan River increases from 382 MCM to 475 MCM between the stations Sede Nehemia and Obstacle Bridge. The increase may be the result of runoff from the northern Golan Heights and spring water feeding the Jordan River, but could also be due to the inflow of irrigation return water from the extensive agriculture developments in the Hula Valley (Box 9).<sup>22</sup>

The mean annual specific discharge time series measured at the two gauging stations show frequently but almost identically oscillating wet and dry years (every two to three years) (Figure 9). Only the period from 1949 to 1961 shows a

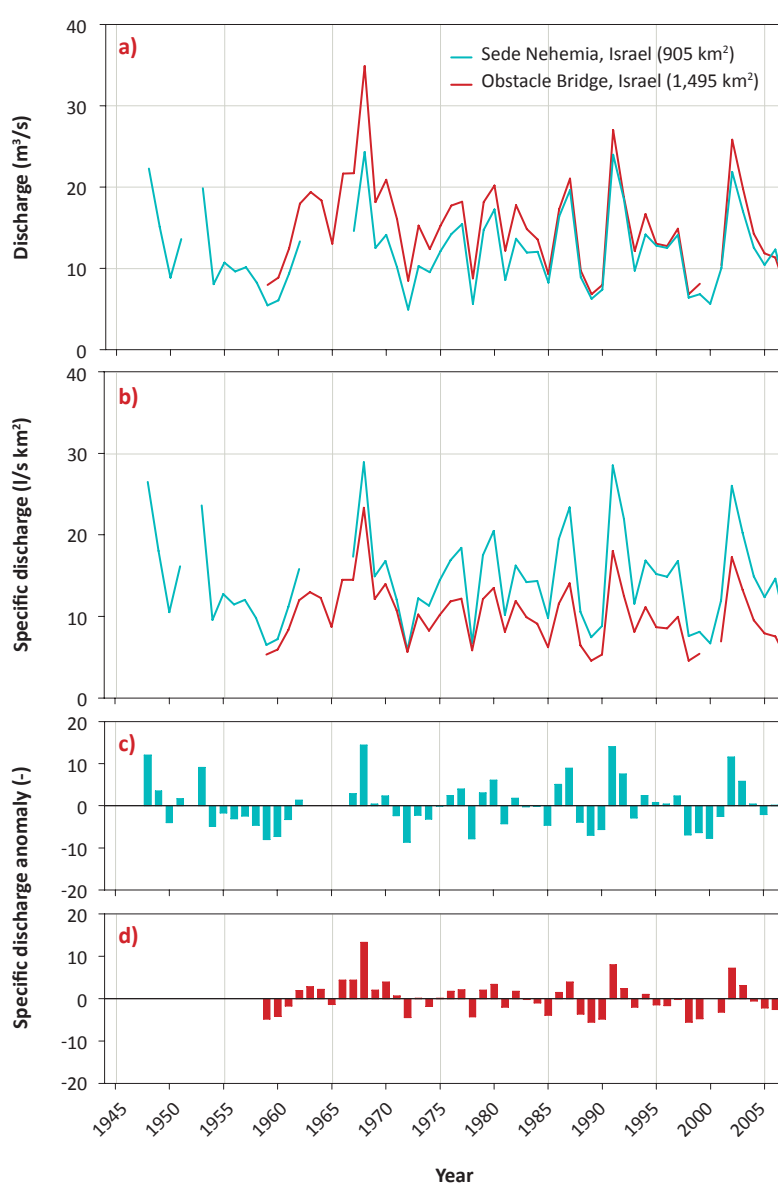
**Table 3. Summary of annual flow volume statistics for the Upper Jordan River (1960-2008)**

STATION [DRAINAGE AREA, km <sup>2</sup> ]	MEAN [MCM]	MINIMUM [MCM]	MAXIMUM [MCM]	CV <sup>a</sup> [-]
Sede Nehemia (905)	382	155	763	0.4
Obstacle Bridge (1,495)	475	215	1,096	0.38

Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.

(a) Coefficient of Variation. For information on the definition and calculation of the CV see 'Overview & Methodology: Surface Water' chapter.

**Figure 9. a) Mean annual discharge, b) specific mean annual discharge, c) and d) discharge anomaly time series of the Upper Jordan River (1948-2008)**



Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.

prolonged drought of more than five years at Sede Nehemia. Wet periods can be identified during most of the 1960s and the early 1990s (Figure 9c and d). The discharge data shows no significant trend.

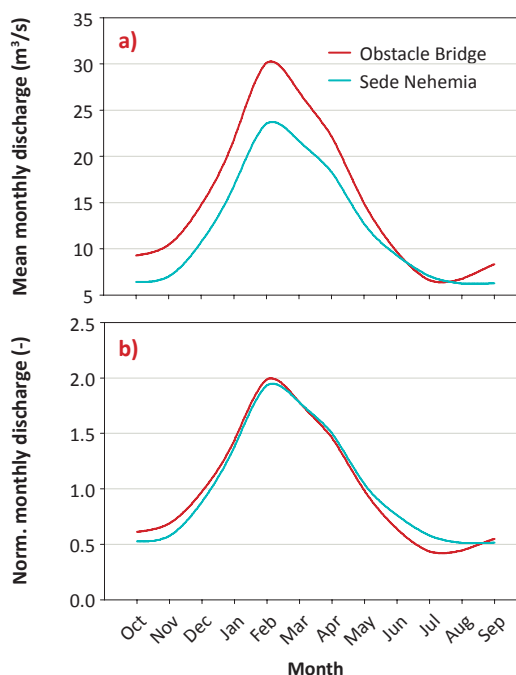




## FLOW REGIME

The stream-flow regime of the Upper Jordan River at the Obstacle Bridge and Sede Nehemia gauging stations indicates a distinct dry and wet season, with low and high flows similar to the Hasbani River flow regime. Peak flow usually occurs between February and March depending on the volume of rainfall and snow-melt originating from the mountainous regions in southern Lebanon and Syria. The low-flow season extends from June to November with minimum flows occurring in July at Obstacle Bridge, and in August/September at Sede Nehemia. However, it is likely that the stream-flow regime presented in Figure 10, which covers the period from 1960 to 2008, already reflects stream regulations such as water abstractions and diversions, particularly the changes made as part of the Hula Valley Drainage Project (Box 9).

Figure 10. Mean monthly flow regime of the Upper Jordan River at different gauging stations (1960-2008)



Source: Compiled by ESCWA-BGR based on data published by HSI, 1944-2008.

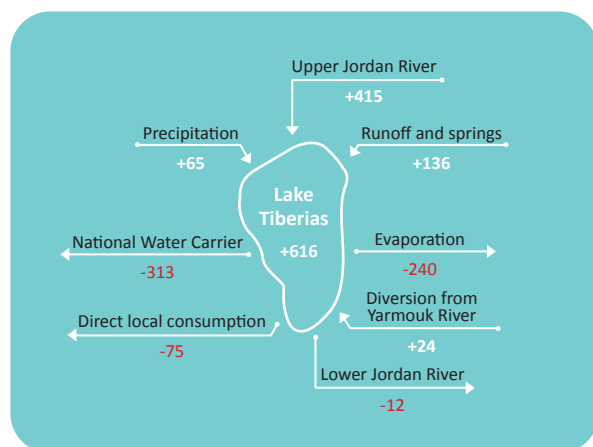


View over Lake Tiberias and Golan Heights, Jordan, 2011. Source: Tamra Hays.

**BOX 1 Lake Tiberias**

Lake Tiberias, originally a natural brackish water lake, extends over an area of around 170 km<sup>2</sup>. The diversion of saline water from surrounding springs to the Lower Jordan River since the mid-1960s has led to a gradual reduction in salinity over the years.<sup>a</sup> Today, the lake is Israel's largest freshwater reservoir, supplying approximately one third of the country's annual water requirements.<sup>b</sup> It is also an important touristic and religious site. In addition to supplying water for domestic and agricultural purposes, the lake was until recently intensively used for commercial fishery, with yields of 1,000-2,500 tons a year,<sup>c</sup> a figure which has been considerably reduced in recent years.<sup>d</sup>

Figure 11. Mean annual water balance of Lake Tiberias in MCM (1985-2008)



Source: Compiled by ESCWA-BGR based on HSI, 2008; IWA, 2010.

The average annual water inflow into Lake Tiberias for the period 1985-2008 (Figure 11) was 616 MCM, including supply from the Jordan River (415 MCM), precipitation (65 MCM) and side streams and springs (136 MCM). Water leaves the lake primarily through surface evaporation (240 MCM) and through Israel's National Water Carrier (313 MCM).<sup>e</sup>

Until 1986, Israel set the operational level of Lake Tiberias at -212 m asl, but after successive years of drought, it was lowered to -213.18 m asl. Rising demand and more frequent droughts caused the lake to drop to around -215 m asl in 2001, its lowest recorded level.<sup>f</sup> The 2002-2003 rainy period allowed for a small rise after 2003, but water levels dropped again to -214 m asl in 2008 (Figure 12).<sup>g</sup> Recent monitoring has shown that the lake's level has risen to -211.5 m asl in March 2012, its highest in nine years.<sup>h</sup> The constant fluctuation in water level negatively impacts ecosystem stability and water quality, and damages the local tourist industry.<sup>i</sup>

(a) FAO, 2009; Farber et al., 2004; FoEME, 2010. For further information, see section on Water quality & environmental issues below.

(b) Siebert et al., 2009.

(c) Representing around 5% of total fish production in Israel (Markel and Shamir, 2002).

(d) Blanchfield et al., 2012. A two-year fishing ban was announced in 2010 in order to restore the lake's ecological balance (The Telegraph, 2010).

(e) HSI, 2008. Israel's National Water Carrier is a 200 km conduit that conveys water from Lake Tiberias in the Jordan River basin to urban centres along the Israeli coast and further south to the Negev (Al Naqab). See section 'Water Development & Use: Israel' below and Box 7 for more information.

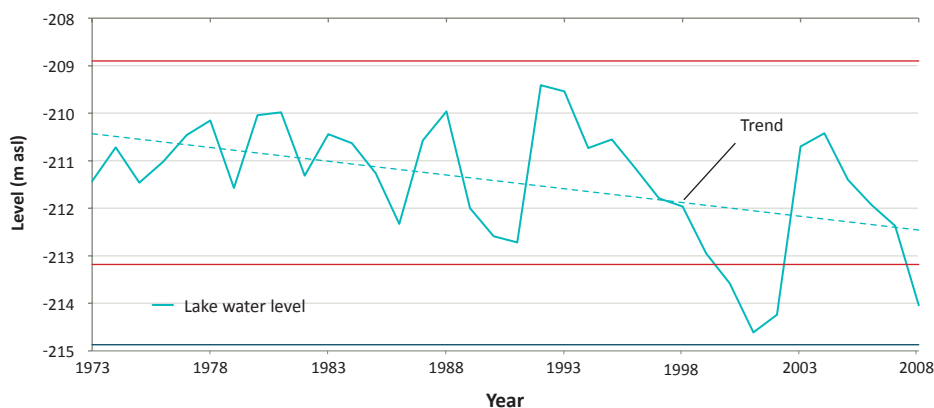
(f) Markel, 2005.

(g) It is important to stabilize the lake's level at around -213 m asl in order to prevent the highly saline water at the bottom of the lake from flowing up and mixing with the overlying freshwater. This would disrupt the ecological stability of the lake and compromise its use as a freshwater reservoir (Siebert et al., 2009; Markel, 2005; Israel Weather, 2012).

(h) Globes, 2012.

(i) Hambright et al., 2000; Markel, 2005; FAO, 2009.

Figure 12. Water-level fluctuations in Lake Tiberias (1973-2008)



Source: Compiled by ESCWA-BGR based on IWA, 2010.

Note: The red lines represent the minimum and maximum levels at which the National Water Carrier can operate.

The dark blue line represents the level below which water cannot be pumped without causing severe damage to Israel's long-term water supply.



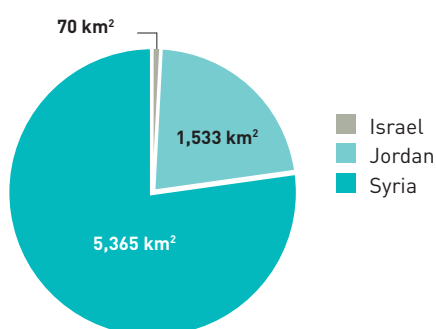
## THE YARMOUK RIVER

### DISCHARGE AND FLOW REGIME

The basin of the largest Jordan River tributary, the Yarmouk, covers a total estimated area of 6,968 km<sup>2</sup> and is shared between three riparian countries: Syria (77%), Jordan (22%) and Israel (1%) (Figure 13).

The Yarmouk Basin is mainly of volcanic origin and features mountainous regions and plains that have been affected by erosion. The catchment boundary is defined by the Jabal al Arab Mountains in the east and the Golan Heights in the west. In the western part of the basin, the middle and lower plateaus rise to altitudes of 1,500 m and are composed of basaltic rocks. This is also the origin of seasonal streams such as Wadi Raqqad and Wadi Allan.<sup>23</sup> The Yarmouk River gauging stations located farthest downstream are Maqarin (downstream of the Wahdah Dam) and Addasiya (close to the confluence with the Jordan River). Available monthly discharge data from the two stations covers the period 1963-2006 with interruptions.<sup>24</sup>

Figure 13. Distribution of the Yarmouk Basin area



Source: Compiled by ESCWA-BGR.

### ANNUAL DISCHARGE VARIABILITY

Discharge records from the Maqarin and Addasiya gauging stations on the Yarmouk River are located below a number of major stream regulation features, including the recently completed Wahdah Dam and many smaller dams on upstream tributaries in Syria. Therefore available discharge records do not necessarily reflect earlier, natural flow conditions. In addition, the construction of the first dams and the increase in water use from the river predates available discharge records. Estimates for the annual historic flow of the Yarmouk range between 450 and 500 MCM,<sup>25</sup> though the river has a highly variable flow regime and is prone to severe flooding.

Maximum annual flows were observed in 1963 at Addasiya<sup>26</sup> and in 1966 at Maqarin (272 MCM at Addasiya, 253 MCM at Maqarin, Table 4), while minimum flows were recorded in 2000 at

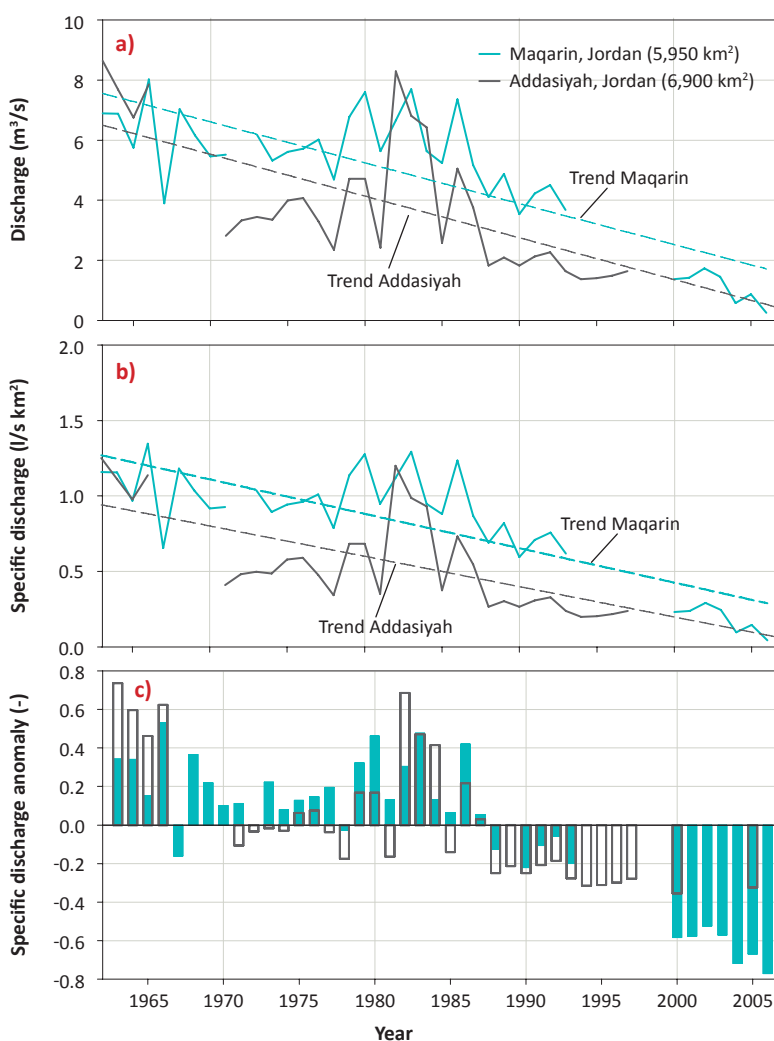
Table 4. Summary of annual flow volume statistics for the Yarmouk River (1963-2006)

STATION (DRAINAGE AREA, km <sup>2</sup> )	PERIOD	MEAN (MCM)	MINIMUM (MCM)	MAXIMUM (MCM)	CV <sup>a</sup> (-)
Maqarin (5,950)	1963-2006	152	7.6	253	0.44
	1963-1984	193	123.0	253	0.17
	1985-2006	99	7.6	232	0.66
Addasiya (6,900)	1963-2006	120	35.0	272	0.61
	1963-1984	156	74.0	272	0.44
	1985-2006	83	35.0	225	0.69

Source: Compiled by ESCWA-BGR based on data provided by GRDC, 2011; Ministry of Water and Irrigation in Jordan, 2002a.

(a) Coefficient of Variation. For information on the definition and calculation of the CV see 'Overview & Methodology: Surface Water' chapter.

Figure 14. a) Mean annual discharge, b) specific mean annual discharge and c) discharge anomaly time series of the Yarmouk River (1963-2006)



Source: Compiled by ESCWA-BGR based on data provided by GRDC, 2011; Ministry of Water and Irrigation in Jordan, 2002a.

Addasiya (35 MCM) and in 2006 at Maqarin (7.6 MCM). The mean annual flow was 152 MCM at Maqarin and 120 MCM downstream at Addasiya (Figure 14).



Yarmouk River, Jordan, 2004. Source: Benjamin.

## Negative trend

The annual dynamics of the mean annual specific discharge time series of the Yarmouk River in Figure 14b is quite different from that of the Upper Jordan headwaters. Early records from both Yarmouk gauging stations for the period 1963-1984 show a certain degree of variation with high- and low-flow periods. From 1987, this dynamic is considerably muted and a significant negative trend can be observed in Figure 14a and 14b. The discharge anomaly plots in Figure 14c clearly show a below-average annual discharge since 1987.

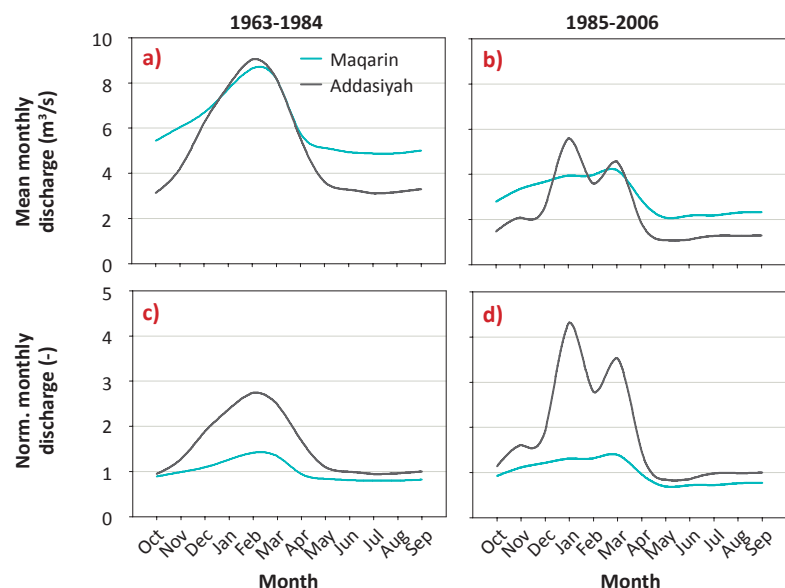
## Comparison

Table 4 groups available discharge records in two 20-year observatory periods in order to allow a comparison of mean annual flow volumes in the periods before and after dams were built in the basin.<sup>27</sup> It is important to note that the period 1963-1984 does not represent the near-natural flow of the river as dam construction in the basin started in the 1970s. The near-natural flow is assumed to be much higher than the mean annual flow of 193 MCM at Maqarin.<sup>28</sup>

Differences in flow volumes are apparent, with the mean annual flow volume at both gauging stations decreasing by about 50% from one observatory period to the next (Table 4).

For instance, the mean annual flow dropped from 156 MCM for the period 1963-1984 to 83 MCM for the period 1985-2006. This is most likely due to droughts, large-scale water diversion from the Yarmouk River and upstream groundwater abstractions in the area feeding the river, mainly for agricultural purposes.<sup>29</sup>

**Figure 15. Mean monthly flow regime of the Yarmouk River at different gauging stations in Jordan (1963-2006)**



Source: Compiled by ESCWA-BGR based on data provided by GRDC, 2011; Ministry of Water and Irrigation in Jordan, 2002a.





## FLOW REGIME

The flow regime of the Yarmouk River at the Maqarin and Addasiya gauging stations further highlights the impact of stream regulations. There is still a distinction between high- and low-flow periods, but the regimes differ significantly, with Addasiya exhibiting a double peak during winter high flows, while upstream Maqarin registers a damped winter high-flow period (Figure 15).

## LOWER JORDAN RIVER

### DISCHARGE AND FLOW REGIME

The Lower Jordan River has a length of around 105 km between Lake Tiberias and the Dead Sea and forms the border between Jordan to the east and Israel and Palestine to the west. In addition to contributions from the Yarmouk, the Lower Jordan River has two other main tributaries: Wadi Harod (Wadi Jallud in arabic, north of the West Bank foothills) and the Zarqa River in Jordan. Today only small quantities of water are recorded at the Degania Dam at the outflow of Lake Tiberias.<sup>30</sup>

### ANNUAL DISCHARGE VARIABILITY

Discharge data for the Lower Jordan River is only available from the Naarayim gauging station downstream of the Yarmouk confluence for the period 1977-1999. The discharge record for the Lower Jordan River at Naarayim is impacted by stream regulations. Maximum annual flows were observed in 1992 (647 MCM) and minimum flows in 1991 (25.4 MCM, Table 5). The mean annual flow was 175 MCM.<sup>31</sup>

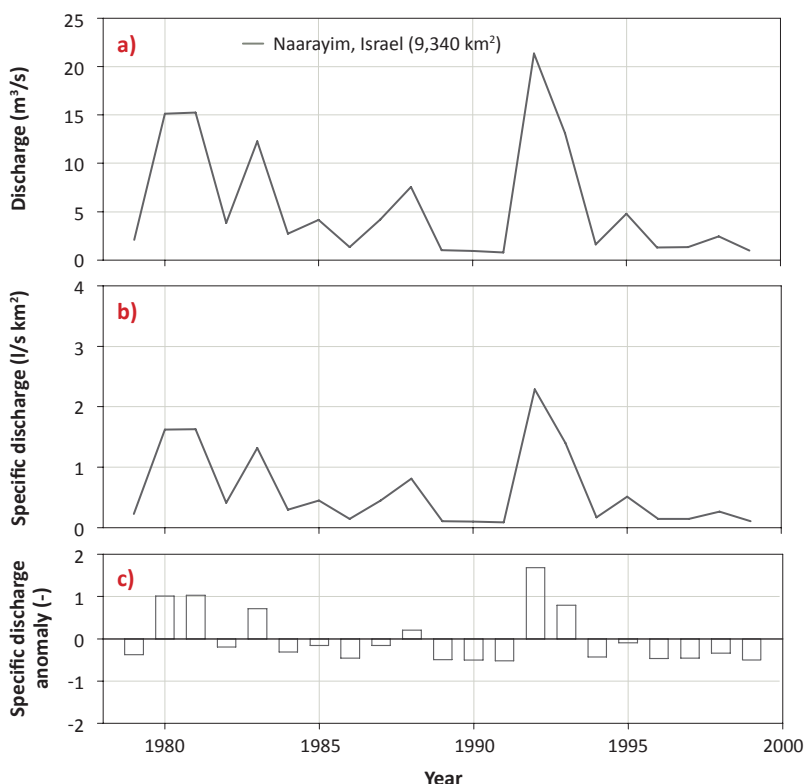
The mean annual specific discharge time series presented in Figure 16 shows an annual dynamic of wet and dry years with peak flows in 1992/93. This was followed by a prolonged dry period from 1993 until the end of the period of record in 1999. During most of the 1980s, discharge was below the mean annual flow of 175 MCM.

## FLOW REGIME

The Lower Jordan River stream-flow regime at the Naarayim gauging station exhibits a pronounced but brief winter high-flow period in February and an extended stable low-flow period from June to October (Figure 17). The Naarayim flow regime differs significantly from the near-natural flow regimes of the Upper Jordan River, as recorded at the Obstacle Bridge gauging station for instance, underscoring the impact of heavy stream regulation, particularly in the upper part of the basin.

There is no hydrological station farther downstream. However, flow contributions downstream of Naarayim are minor and include outflow from fish ponds, agricultural runoff, groundwater seepage, and, more rarely,

Figure 16. a) Mean annual discharge, b) specific mean annual discharge and c) discharge anomaly time series of the Lower Jordan River (1979-1999)



Source: Compiled by ESCWA-BGR based on data published by HSI, 1979-1999.

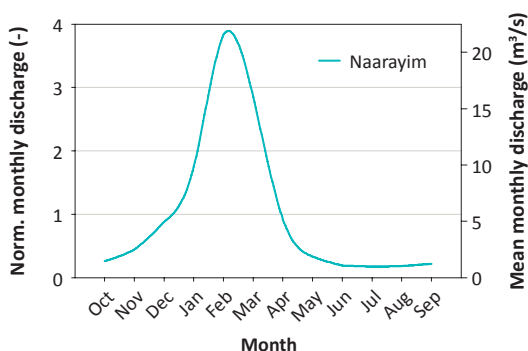
Table 5. Summary of annual flow volume statistics for the Lower Jordan River (1979-1999)

STATION [DRAINAGE AREA, km <sup>2</sup> ]	MEAN [MCM]	MINIMUM [MCM]	MAXIMUM [MCM]	CV <sup>a</sup> [-]
Naarayim (9,340)	175	25.4	647	1.07

Source: Compiled by ESCWA-BGR based on data published by HSI, 1979-1999.

(a) Coefficient of Variation. For information on the definition and calculation of the CV see 'Overview & Methodology: Surface Water' chapter.

Figure 17. Mean monthly flow regime of the Lower Jordan River at Naarayim in Israel (1979-1999)



Source: Compiled by ESCWA-BGR based on data published by HSI, 1979-1999.



## BOX 2 The Decline of the Dead Sea

As the lowest point on Earth (-422 m asl), the Dead Sea is an inland lake (endorheic) with no natural outflow. Historically, the Jordan River contributed an estimated 1,300 MCM/yr to the Dead Sea, equivalent to two thirds of the inflow.<sup>a</sup> Other contributions included primarily groundwater and water from Wadi Mujib, Wadi Hasa and limited amounts from Wadi Araba south of the Dead Sea. Inflow used to make up for the high evaporation rates in the Dead Sea.

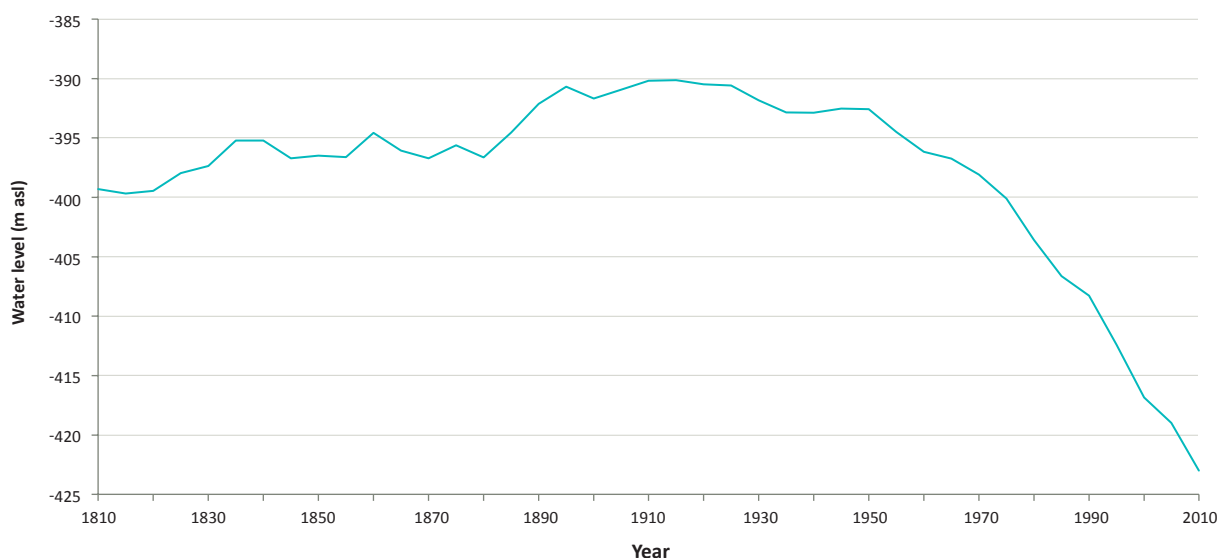
(a) Libiszewski, 1995.

(b) Klein and Flohn, 1987.

(c) Oren, 2010; Khlaifat et al., 2010.

The construction of large water diversion schemes in the Jordan River Basin since the 1960s has caused a sharp decrease in inflow into the sea, which has in turn led to a lowering of the sea level from -395 m asl in the 1970s<sup>b</sup> to -419 m asl in 2006 and -423 m asl in 2009, with an average decline of one metre per year. The drop in sea level has led to dewatering and sediment shrinkage, which has in turn resulted in the formation of sinkholes along the shores of the sea.<sup>c</sup>

Figure 18. Decline in Dead Sea water levels (1810-2010)



Source: Compiled by ESCWA-BGR based on HSI, 2008; IWA, 2010.



The Dead Sea, Jordan, 2009. Source: Marc Haering.



floodwaters that are not captured by the numerous dams in the Jordan Valley. The Lower Jordan River's second largest tributary, the Zarqa River, is dammed and its water is mainly used for irrigation. The same goes for all major side wadis on the east bank of the Lower Jordan River. Coupled with the high levels of abstraction in the upper part of the basin, these factors have resulted in a dramatic drop in discharge from the Jordan River into the Dead Sea, which was measured at 20-30 MCM in 2009.<sup>32</sup>

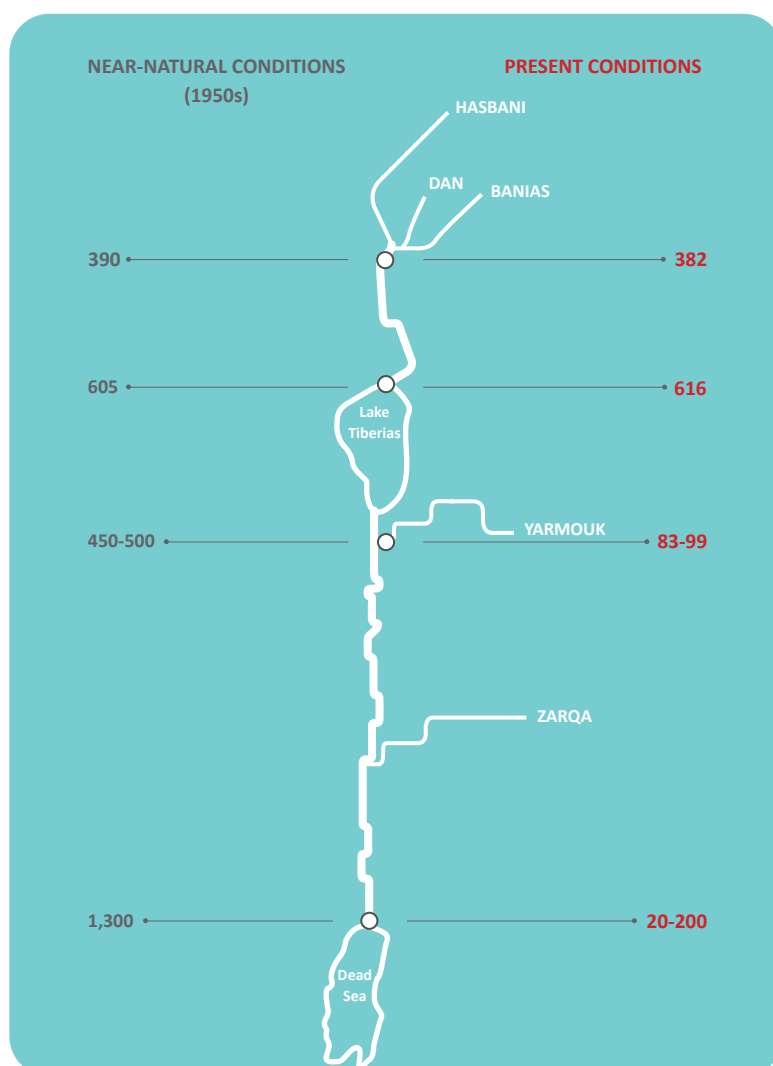
## FLOW REGIME REGULATION IN THE JORDAN RIVER BASIN

Under natural conditions, the mean annual discharge of the Upper Jordan River system into Lake Tiberias amounted to 890 MCM, of which 285 MCM were lost to lake evaporation.<sup>33</sup> The Yarmouk catchment drained an area of almost 7,000 km<sup>2</sup>, with an estimated mean annual discharge of 450-500 MCM<sup>34</sup> flowing into the Lower Jordan River. Water from several wadis and rivers originating in the mountain ranges to the east and west of the river and from aquifers also contributed perennial and seasonal flows to the Jordan River, resulting in a natural annual discharge of around 1,300 MCM (Figure 19).<sup>35</sup>

However, the natural state described above has been drastically altered as a result of human interference. While flow rates of the Upper Jordan River system are similar to the natural state and the inflow to Lake Tiberias remains fairly constant at 616 MCM (Box 1), the flow of the Lower Jordan River is affected by river diversions at several points along the course of the Jordan River. Israel diverts approximately 400 MCM from Lake Tiberias including limited amounts for irrigation purposes on the shores of the lake. Most of the abstracted water (329 MCM on average between 1969 and 2008) is transferred outside the basin through Israel's National Water Carrier for use in the agricultural, domestic and industrial sectors in the Mediterranean coastal plain (Table 8 and Box 7).

Moreover, the construction of a large number of storage and retention dams, excessive pumping and diversions from the Yarmouk River in Syria have diminished the river's annual flow from 450-500 MCM to less than 40 MCM downstream of Addasiya. Groundwater abstraction and an altered topography (infrastructure and civil structures) have reduced the share of the Yarmouk River in the Jordanian part of the catchment area. Jordan uses about 100 MCM/yr from the Yarmouk River and the Mukheibeh Wells to supply the King Abdullah Canal,<sup>36</sup> though recent data shows that it only diverted an average annual 30 MCM to the canal between 2002 and 2011.<sup>37</sup>

Figure 19. Annual water flow of the Jordan River in near-natural conditions and in present conditions (MCM)

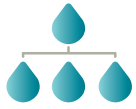


Source: Compiled by ESCWA-BGR based on Courcier et al., 2005; GRDC, 2011; HSI 1944-2008.

All three riparians, Israel, Jordan and Syria, abstract large amounts of groundwater in the upper parts of the basin which further reduces the natural inflow into the river.

Farther downstream along the course of the Jordan River, reservoirs have been built in the major side wadis along the east bank and their water is mainly used for irrigation purposes. The result is a drastic reduction in runoff in the Lower Jordan River. The flow of the Lower Jordan River is today mainly made up of drainage water from fishponds, wastewater, fresh and saline spring water and irrigation return flows.

Present-day discharge into the Dead Sea is estimated between 20 MCM and 200 MCM<sup>38</sup> compared to the historic flow of approximately 1,300 MCM (Figure 19).



# Water Resources Management

The Jordan River basin is one of the most contested river basins in the world, attracting considerable attention in political circles, the water community and the media. The basin has been the subject of numerous water development plans and studies (Table 6). The following two elements are frequently identified as root causes of the conflict over water resources in the region: water scarcity and the establishment of a Jewish State in British Mandate Palestine.<sup>39</sup>

Plans for the establishment of a Jewish State in Palestine in the early 20th century heralded a series of radical changes in the domain of water resources management in the basin.<sup>40</sup> From the 1950s onward, Israel, Jordan and Syria established and implemented national water schemes to develop their economy,<sup>41</sup> which created competition over the scarce resources in the basin. Technological innovations, specifically the introduction of pumping technology, demographic developments in riparian countries

and intensive agricultural development have also drastically altered the natural flow regime in the basin.

Due to political instability in the region, the sharing of water resources among riparian countries never materialized and thus none of the proposed plans were jointly implemented (Box 3). Instead, unilateral hydraulic development started in the 1950s and accelerated in the 1960s. In addition, political changes and the creation of the state of Israel in 1948 had far-reaching implications for water use in the basin. The 1967 Six-Day War fundamentally altered the power balance between riparians and greatly enhanced Israel's hydrostrategic position in the Jordan River basin.<sup>42</sup>

Changes in land and water use are also closely related to the demographic boom in the Jordan River basin. The 1948 Arab-Israeli war and the 1967 Six-Day War resulted in large-scale



Irrigation in the Jordan Valley, 2008. Source: Eileen Maternowski.





Table 6. Proposed riparian water allocations in selected Jordan River basin development plans

YEAR	NAME	COMMISSION	WATER ALLOCATION (MCM)				TOTAL (MCM)	BACKGROUND INFORMATION
			LEBANON	SYRIA	ISRAEL	JORDAN		
1913	Frangia Plan	Ottoman				-	-	Diversion channel from the Yarmouk to Lake Tiberias. Irrigation on both sides of the Jordan Valley; 21 hydropower plants.
1943/44	Lowdermilk proposals	USA				-	-	Development of the Jordan-Yarmouk Basin and the Litani River in Lebanon. A Mediterranean-Dead Sea canal; hydropower development.
1948	Hays Plan	Israel		-	50% of Yarmouk River water, 100% from Jordan River	50% of Yarmouk River	-	Diversion channel from the Yarmouk to Lake Tiberias to replace water diversions from the Upper Jordan River. Supply of 2 BCM of water to Israel for the irrigation of 240,000 ha; hydropower development.
1952	Bunger Plan	UNRWA <sup>a</sup> / Jordan/Syria					-	Construction of the Maqarin Dam on the Yarmouk River; irrigation of 43,500 ha in Jordan and 6,000 ha in Syria; diversion dam at Addasiya; hydropower development.
1953	Main Plan (Unified Plan)	USA	-	45	394	774	1,213	Integrated basin approach with regard to irrigation. Irrigation of 41,000 ha in Israel, 49,000 ha in Jordan and 3,000 ha in Syria. <sup>b</sup>
1954	Arab Plan	Arab League	35	132	289	975	1,431	Water storage on the Yarmouk at Maqarin and Addasiya; water diversions for irrigation of 23,400 ha in Israel, 49,000 ha in Jordan, 3,500 ha in Lebanon and 11,900 ha in Syria; hydropower development for Arab countries only.
1954	Cotton Plan	Israel	451	30	1,290	575	2,346	Use of the Litani River; hydropower development; diversions for irrigation of 179,400 ha in Israel, 41,600 ha in Jordan, 36,400 ha in Lebanon and 2,600 ha in Syria.
1955	Johnston Plan	USA	35	132	616 <sup>c</sup>	720 <sup>d</sup>	1,503	A dam on the Yarmouk; Lake Tiberias as storage for the Jordan and Yarmouk Rivers; diversion dam at Addasiya; feeder canal from Lake Tiberias to the East Ghor Canal; a siphon across the Jordan to convey water from the East Ghor Canal to the west.

Source: Compiled by ESCWA BGR based on Phillips et al., 2007; Kliot, 1994.

Note: For a comprehensive list of historical development plans of the Jordan River basin see: PLO, 2012.

(a) The United Nations Relief and Works Agency for Palestine Refugees in the Near East.

(b) The Main Plan also proposed (i) a dam on the Hasbani to provide power and water, (ii) dams on the Dan and Banias Rivers, (iii) drainage of the Hula Marshes, (iv) a dam at Maqarin, (v) a dam at Addasiya to divert water to Lake Tiberias and the East Ghor Canal, (vi) a small dam at the outlet of Lake Tiberias to increase its storage capacity.

(c) Phillips et al., 2007 found that Johnston calculated a residual flow of 466 MCM/yr for Israel and another 150 MCM/yr of local water.

(d) Some sources note that the Johnston Plan did not explicitly define the water rights of Palestinians in the West Bank as the West Bank was under Jordanian administration during that period. Nevertheless, the West Ghor Canal was planned (as part of the Yarmouk-Jordan Valley Project) to supply 240 MCM of water for irrigation in the Jordan Valley (Naff and Matson, 1984). Although the canal was never built, there are estimates that assess the Palestinian share under the Johnston Plan between 240 and 257 MCM/yr (PWA, 2012; Sherman, 1999).

population displacements and the resettlement of refugees from outside the basin. Around 1950, an estimated 450,000 people lived in the region. Agriculture was essentially limited to subsistence farming on both banks of the Jordan River, covering an area of about 10,000 ha and consuming less than 9% of the river's annual

flow. Since that time there have been several waves of immigration and birth rates have remained high. Thus, the population in the basin has increased more than tenfold, resulting in the rapid growth of cities such as Amman, Irbid and Zarqa in Jordan, and the large-scale development of irrigated agriculture.<sup>43</sup>



### BOX 3 A Short History of Water-Related Conflicts in the Jordan River Basin

Following the 1948 Arab-Israeli War and the signing of the General Armistice Agreements in 1949, Jordan and Israel launched several initiatives to develop water resources in their areas of control. In 1951, Jordan announced a plan to irrigate the Jordan Valley's East Ghor region by diverting water from the Yarmouk River through the East Ghor Canal. In response, Israel launched in the same year the first part of the All Israel Plan to drain the Hula Marshes, a wetland area that was partly located in the demilitarized zone created after the 1949 armistice agreement between Israel and Syria. Israel's initiative led to the first of many military clashes between Israel and Syria in 1951. Two years later, Israel embarked on the construction of the National Water Carrier, a project to divert water from Lake Tiberias to urban centres and agricultural areas farther south in Israel. In the early stages of the project, Israel planned the outlet in the demilitarized zone between Israel and Syria. However, Syria thwarted the plans by attacking the construction and lodging a formal complaint at the United Nations against Israel's unilateral move to transfer water out of the Jordan River basin. As a result, Israel was forced to relocate the works to the north-western shore of Lake Tiberias.

The regional tensions prompted the United States Government to appoint Eric Johnston as a special ambassador to the region, with the task of devising a unified water allocation plan for the Jordan Valley. The outcome, known as the Johnston Plan, was issued in 1955 and proposed annual allocations of 616 MCM to Israel, 720 MCM to Jordan, 35 MCM to Lebanon and 132 MCM to Syria.<sup>a</sup> While the plan was never ratified, it remains a point of reference

for water management in the basin and riparian countries often use it as a basis for negotiations.

Some scholars claim that water-related conflict in the basin was a major cause of the Six-Day War in June 1967. Following the inauguration of the National Water Carrier and the first water diversions from the Jordan River in 1964, the Arab states decided to launch the Headwater Diversion Project to transfer water from the Hasbani and Banias Rivers to the Yarmouk. Israel bombed the site of this diversion project in 1965 soon after the works started and further military attacks followed. These events are seen by some as one of the triggers of the 1967 Six-Day War, through which Israel gained effective control of the Golan Heights, the West Bank and the Gaza Strip, as well as the headwaters of the Jordan River and significant groundwater resources.

In the following decade, Israel confronted both Jordan and Lebanon in armed conflicts over the control of Jordan River water. In 1969, Israel launched raids in the area of the East Ghor Canal (currently known as the King Abdullah Canal) in Jordan after it suspected Jordan of diverting excess amounts of water.

Nine years later, Israel invaded Lebanon, gaining and maintaining control over the Wazzani Springs in the Jordan River headwaters region until it withdrew its troops in 2000. Tensions persisted in this area though, especially when Lebanon announced plans to build a pumping station at the Wazzani Springs in 2002 (Box 5).

Source: Compiled by ESCWA-BGR based on Murakami, 1995; Amery and Wolf, 2000; FAO, 2009; Zeitoun et al., 2012; Phillips et al., 2007.

(a) Phillips et al., 2007.

The shift from traditional land uses to entrepreneurial, market-oriented agricultural practices and generally improved living standards have led to an exponential increase in water demand, placing severe stress on the basin's limited water resources and fragile ecosystem.

At present, an estimated 100,000-150,000 ha are equipped for irrigation in the Jordan River basin. About 30% of this irrigable surface area is located in each of the Israeli, Jordanian and Syrian parts of the basin, while Lebanon and Palestine use respectively 2% and 5% of the irrigable area in the basin.<sup>44</sup> That translates into a basin-wide agricultural water withdrawal of around 1,200 MCM. A 2010 environmental flow study<sup>45</sup> found that Israel, Jordan and Syria divert over 98% (1,248 MCM) of the historic flow of the Lower Jordan River, mainly for agricultural use.<sup>46</sup>

## DEVELOPMENT & USE: LEBANON

To date, Lebanon has made limited use of the Hasbani River, one of the main Jordan River headwaters. Before the 1978 Israeli occupation, the Lebanese Government did not prioritize the development of the South.<sup>47</sup> South Lebanon was further isolated during the Lebanese civil war and the 22 years of Israeli occupation, which led to the deterioration of infrastructure and the disruption of water supplies. After the end of the civil war in 1990, Israel maintained its military presence in southern Lebanon for



The Hasbani River, Lebanon, 2003. Source: Ralf Klingbeil.

a further 10 years, in part to safeguard the security zone established after the 1978 Litani Invasion.<sup>48</sup> The Israeli troop withdrawal in May 2000 heralded a new era of reconstruction and development in the south,<sup>49</sup> but the Hasbani region remains one of the poorest in Lebanon.<sup>50</sup>

Israel's control of the Hasbani River and Wazzani Springs until 2000 precluded Lebanese use and development of those water resources. Following the Israeli withdrawal from the area, the Lebanese Government planned a series of projects including the Wazzani Water Supply Project, the Hasbaya-Habbarieh Water Project



and the Ibl al Saqi Dam Project (Box 4).<sup>51</sup> While the dam project has not been implemented to date, the first phase of the Wazzani pumping station was completed in 2002, sparking tensions between Israel and Lebanon (Box 5). According to the Lebanese Ministry of Energy and Water, the country annually abstracts almost 7 MCM from the Hasbani sub-basin of which 2.7 MCM are used for domestic purposes and 4.2 MCM for irrigation.<sup>52</sup> This figure includes

abstractions from the river and groundwater abstraction in the basin. Public and private wells in the basin abstract an estimated 5.1 MCM/yr of groundwater.<sup>53</sup> Most of the water is used for domestic purposes, with only limited amounts allocated to the agricultural sector. Since 2002, Lebanon has abstracted a maximum of 2.45 MCM/yr via the Wazzani pumping station (Box 5).

#### BOX 4 The Ibl al Saqi Dam Project

The village of Ibl al Saqi in southern Lebanon is surrounded by agricultural plains. About 500 ha of land is currently irrigated by the Hasbani River.<sup>a</sup> In a bid to expand irrigation networks in the region, the Lebanese Government has over the years commissioned several studies to assess the viability of a water storage dam on the Hasbani River. The capacity of various versions of the proposed Ibl al Saqi Dam varies between 30 and 80 MCM/yr. A feasibility study completed in 2010 outlines the design of a 50 MCM/yr capacity dam with an irrigation potential of about 2,600 ha in the Hasbani Plain and in the area of El Meri and Khiam.<sup>b</sup>

(a) Comair, 2009, p. 258-259.

(b) Ministry of Energy and Water in Lebanon, 2011.

#### BOX 5 The Wazzani Dispute

After the Israeli withdrawal from Lebanon in May 2000, Lebanon launched a reconstruction and development programme for southern Lebanon. In a bid to develop water resources in the region, the Council of the South installed two small pumps at the Wazzani Springs in March 2001. This immediately sparked protests from Israel, which threatened to intervene militarily if any water was withdrawn from the Hasbani River.<sup>a</sup> Tensions subsided until the Council of the South announced the construction of a pumping station at the Wazzani Springs in August 2002. The project was part of the Lebanese Government's plan to rebuild the South and ensure the reintegration of the local population by meeting domestic water needs in 13 villages in the region and creating jobs in the agricultural sector.<sup>b</sup> The Wazzani Water Supply Project featured two components: the construction of two pumping stations at the Wazzani Springs and Maysat Junction (part I) and the construction of a pipe network from the Maysat pumping station to the Ibl al Saqi Reservoir and other village reservoirs in the area (part II).<sup>c</sup> The Wazzani pumping station was designed to operate at a capacity of 12,000 m<sup>3</sup>/d, which results in a total capacity of 4.4 MCM/yr.<sup>d</sup>

Already before its inauguration, the Wazzani Project caused tensions to rise as Israel declared that any water abstractions from the Hasbani were a *casus belli*.<sup>e</sup> Analysts explained Israel's statement in the broader context of the Jordan River basin and said Lebanon's move to abstract water from the river could set a precedent for future water infrastructure projects in the Hasbani region, which would affect water flow to Lake Tiberias.<sup>f</sup> Lebanon retorted that the planned abstraction was only a fraction of the share of Jordan River basin water allocated to Lebanon in the Johnston Plan (35 MCM/yr).<sup>g</sup> The dispute attracted extensive media coverage.

Mediation efforts by the United States, the United Nations and the European Union failed to resolve the dispute or address future abstraction quotas and water rights.<sup>h</sup> Though Lebanon was able to complete the pumping station and officially inaugurate it in 2002, the incident demarcated clear de facto limits to the country's plans for further water development schemes on the Hasbani River and at the Wazzani Springs.<sup>i</sup> Since then, to avoid confrontation with Israel, Lebanon has not further developed the Wazzani pumping project or any other project in the Hasbani/Wazzani region.

Donor countries providing support to the Lebanese water sector have remained similarly reserved on the issue.<sup>j</sup>

The Wazzani pumping station has probably never reached its design capacity of 4.4 MCM/yr. Constant power shortages and a lack of maintenance mean that annual abstractions from the Wazzani pumping station are 2.45 MCM at most, assuming that the two generator-operated pumps run 24 hours per day.<sup>k</sup>

(a) Morrow, 2002.

(b) Republic of Lebanon, 2002, p. 14.

(c) Ibid., p. 16.

(d) Ibid. Given a 24-hr pumping cycle.

(e) BBC News, 2002.

(f) ICG, 2002, p. 10 and Blanford in MERIP, 2002 states: "Numerous Israeli officials claimed that Lebanon cannot be allowed to change the status quo governing the flow of the Hasbani."

(g) The Johnston Plan has never been implemented. See Box 9.

(h) Zeitoun et al., 2012.

(i) Maternowski, 2006. For information and an analysis of the Wazzani dispute see Zeitoun, 2004 and Zeitoun et al., 2012.

(j) Such as the Italian Development Cooperation.

(k) Ministry of Energy and Water in Lebanon, 2011.



The Wazzani pumping station, Lebanon, 2006. Source: Eileen Maternowski.



Total annual abstractions from the Hasbani Basin (representing Lebanon's current use from the Jordan River basin) can therefore be estimated between 9 and 10 MCM.

With its fertile soils and high-quality water, southern Lebanon has a huge agricultural potential, which has remained largely untapped to date. According to a 1999 agricultural census, potential agricultural land surface in the basin amounted to around 30,000 ha. However, only an estimated 15,000 ha was cultivated and 1,124 ha irrigated.<sup>54</sup> Another study based on a remote sensing exercise from 2002 states that an area of 17,600 ha was used for agriculture, of which about 9,150 ha received full or supplementary<sup>55</sup> irrigation.<sup>56</sup>

## DEVELOPMENT & USE: SYRIA

Water resources development in the Syrian part of the Jordan River basin is restricted to the Yarmouk River and its many tributaries. Since the Israeli occupation of the Golan in 1967, the country has not been able to access water resources in the Baniyas Basin, Lake Tiberias or other wadis on the east bank of the Jordan River. Therefore Syria does not use any of the Upper Jordan River flow.<sup>57</sup>

In the late 1960s and early 1970s, Syria built numerous small dams on Yarmouk tributaries, using 50–60 MCM/yr in the upper part of the basin.<sup>58</sup> By the mid-1970s, Syria used an estimated 90 MCM/yr from the Yarmouk River, mainly in the agricultural sector.<sup>59</sup>

### BOX 6

#### The Wahdah Dam

The Wahdah Dam was designed to generate hydropower and provide irrigation water for agricultural activities in Jordan and Syria. The generated electricity from the dam was to be divided between the two riparians, with Jordan receiving 25% and Syria 75%.<sup>a</sup> The 225 MCM/yr capacity dam, which was planned for completion in the early 1990s,<sup>b</sup> encountered long delays and was only completed in 2009 at less than half the design capacity.<sup>c</sup> The project was jointly funded by Jordan and Syria. With a storage capacity of 110 MCM/yr,<sup>d</sup> the Wahdah Dam has never reached full design capacity since it became operational in 2006. The maximum stored volume was measured at 20 MCM/yr in 2009/2010.<sup>e</sup> Possible reasons for the low intake include prolonged droughts since 2000, a high number of upstream dams retaining water from the Yarmouk wadis (Table 7),<sup>f</sup> as well as widespread groundwater abstraction.<sup>g</sup>

[a] The Syrian Arab Republic and Jordan, 1987, Article 7.

[b] Murakami, 1995.

[c] Al-Taani, 2011.

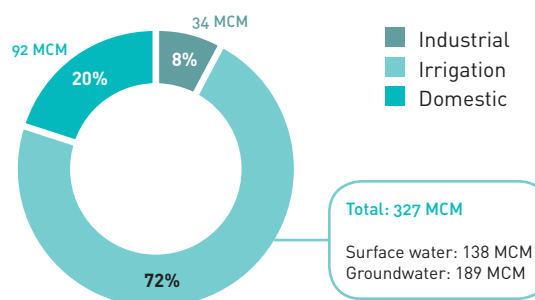
[d] Ministry of Water and Irrigation in Jordan, 2002a.

[e] Ibid., 2011.

[f] However all these dams were built before the Wahdah Dam.

[g] JVA, 2004.

Figure 20. Mean annual water use across sectors in the Yarmouk Basin in Syria (1999–2009)



Source: Compiled by ESCWA-BGR based on data provided by Ministry of Irrigation in the Syrian Arab Republic, 2012.

Table 7. Main constructed dams in the Yarmouk Basin in Syria

COUNTRY	NAME (RIVER)	COMPLETION YEAR	CAPACITY (MCM)	PURPOSE <sup>a</sup>	BACKGROUND INFORMATION
Syria	Dar'a East (Wadi Zaydi)	1970	15	I	Projected irrigated area: 1,100 ha
	Room Jawlayeen <sup>b</sup> (Wadi Dhahab)	1977	6.4	D, F	-
	Ghariyah al Sharqiyah (Wadi Dhahab)	1982	5	I	Projected irrigated area: 250 ha
	Sheikh Miskin (Wadi Arram)	1982	15	I	Projected irrigated area: 1,100 ha
	Tasil (Wadi Allan)	1982	6.65	I	Projected irrigated area: 700 ha
	Adwan (Wadi Arram)	1986	5.85	I	Projected irrigated area: 700 ha
	Sahwat al Khidr (Wadi Zaydi)	1986	8.75	LW	-
	Ghadi al Bustan (Wadi Raqqad)	1987	12	I	Projected irrigated area: 700 ha
	Abidin (Wadi Raqqad)	1989	5.5	I, LW	-
	Al Qanawat <sup>b</sup> [...]	1989	6.1	D	-
	Al Allan <sup>b</sup> (Wadi Allan)	1990	5.0	I	Projected irrigated area: 530 ha
	Jisr al Raqqad (Wadi Raqqad)	1994	9.2	I	Projected irrigated area: 1,800 ha
	Saham al Golan (Wadi Allan)	1995	20	I	-
	Kudnah (Wadi Raqqad)	1995	30	I, LW	-
Jordan / Syria	Wahdah (Yarmouk)	2009	110	D, I, HP	-

Source: Compiled by ESCWA-BGR based on The Syrian Arab Republic and Jordan, 1987; Ministry of Irrigation in the Syrian Arab Republic, 2006.

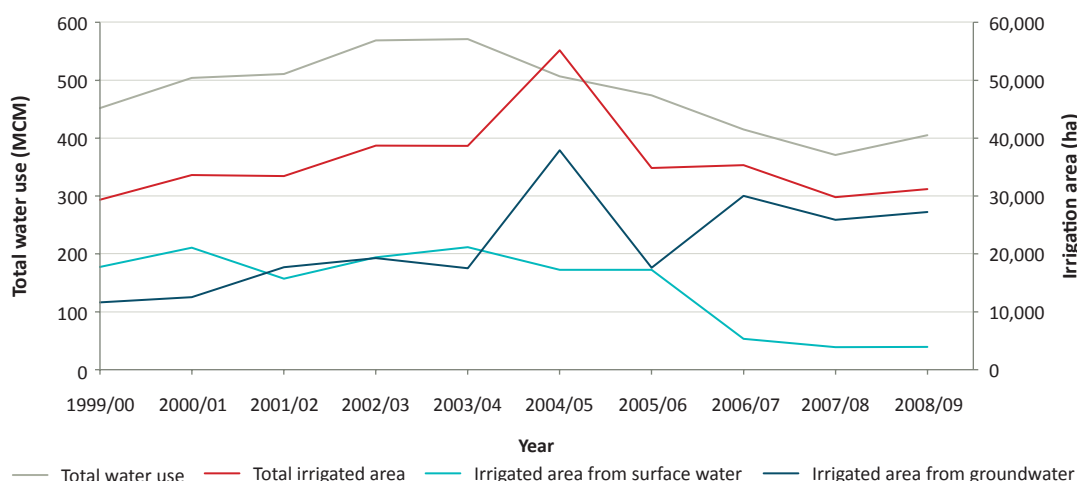
[a] Irrigation (I), Livestock Watering (LW), Domestic (D), Fisheries (F), Hydropower (HP).

[b] These dams are not listed in the 1987 agreement.





Figure 21. Evolution of total water use and irrigated areas in the Yarmouk Basin in Syria (1999-2009)



Source: Compiled by ESCWA-BGR based on data provided by Ministry of Irrigation in the Syrian Arab Republic, 2012.

The dam projects were designed to boost agricultural production in the parts of the Golan and its vicinity which remained under Syrian jurisdiction after the 1967 Six-Day War.

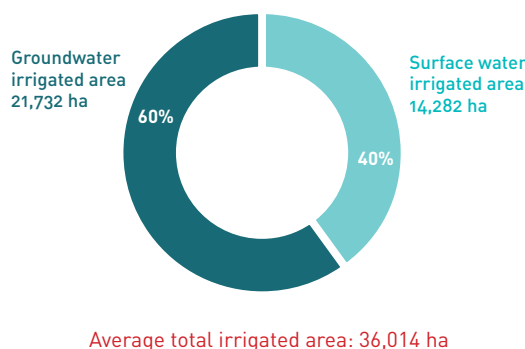
From the mid-1970s until the 2000s, annual use of Yarmouk water in Syria rose to 200 MCM.<sup>60</sup> In 1987, Jordan and Syria renewed the 1953 Agreement for the Utilization of the Yarmouk River,<sup>61</sup> in which they agreed to jointly build the Unity Dam, today known as the Wahdah Dam.<sup>62</sup> An annex to the 1987 agreement provides a list of 25 constructed and planned dams in Syria. With storage capacities ranging from 0.035 to 30 MCM, these dams are distributed across five wadis in the Upper Yarmouk Basin.<sup>63</sup> Together, the listed dams have a potential maximum storage capacity of 155 MCM.

Most of the dams mentioned in the agreement have been completed and additional structures have been built on northern tributaries of the Yarmouk River, amounting to a total of 38 dams.<sup>64</sup> This brings the current total dam capacity in the Syrian part of the Jordan River basin to an estimated 117 MCM, excluding the Wahdah Dam.<sup>65</sup> Fifteen of the 38 dams have a capacity of 5 MCM or above (Table 7).

The absence of official data from Syria on the amount of water diverted from the Yarmouk has left much room for speculation over the years. A review of sources from the 1990s estimated a total withdrawal of 90-250 MCM/yr.<sup>66</sup> The 1987 agreement between Jordan and Syria on the construction of a high dam on the Yarmouk River (Wahdah Dam)<sup>67</sup> does not give a specific water allocation to Syria, but the amount that Syria was diverting at the time was estimated at 170 MCM/yr.<sup>68</sup>

For the period 1999-2009, total annual water use in the Syrian part of the Yarmouk Basin (including surface and groundwater) was estimated at an average of 453 MCM,<sup>69</sup> of which

Figure 22. Irrigated area in the Yarmouk Basin in Syria (1999-2009), by source



Source: Compiled by ESCWA-BGR based on data provided by Ministry of Irrigation in the Syrian Arab Republic, 2012.

327 MCM was used for irrigated agriculture, 92 MCM for domestic purposes and 34 MCM for industry (Figure 20). During this period, irrigation water use in the basin fluctuated, with an increase in 2002/2003 and a subsequent drop back to 1999 levels in 2009 (Figure 21).

Figure 22 shows that the total irrigated area for the period 1999-2009 adds up to 36,000 ha, of which 60% is irrigated by groundwater and 40% by surface water.<sup>70</sup> Those values correspond with FAO data, which estimates a total irrigated area of 30,000-45,000 ha in the Syrian part of the basin.<sup>71</sup>

## DEVELOPMENT & USE: ISRAEL

Israel's use of the Jordan River is concentrated in the Upper Jordan River area and Lake Tiberias, the only major freshwater reservoir in the Jordan River basin. Long before the state of Israel was established, Zionist leaders in Europe made the quest for water in Palestine a priority, with plans to transfer water from the Jordan River to the Mediterranean coastal plain for irrigation and drinking purposes. The water company Mekorot was founded in 1937 to realize



this vision. In the following decades, Israel invested millions of dollars in the construction of the National Water Carrier (NWC), an ambitious scheme to divert an annual 120-520 MCM – about 60% of the Jordan River's total flow – from Lake Tiberias and transfer it outside the basin (Box 7, Table 8).<sup>72</sup> Besides the water it diverts through NWC, Israel also uses water from Lake Tiberias locally and abstracts water from the Jordan River headwaters and the Upper Jordan River.

Water infrastructure in the Israeli part of the basin includes the Degania and Alumot Dams. In the late 1950s, Israel raised the level of the Degania Dam in order to increase the capacity of Lake Tiberias and ensure the operation of NWC.

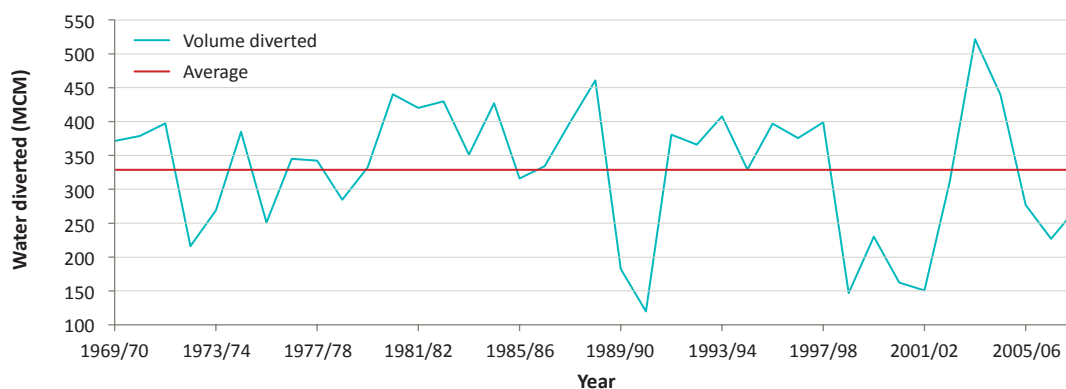
Table 8 lists statistical data and literature estimates on water abstractions in different parts of the basin. The table shows that total annual water use in the Israeli part of the basin ranges between 583 and 640 MCM, most of which is diverted by NWC. In addition, Israel abstracts 70-206 MCM annually from the Upper Jordan River (mainly for irrigation), 39-90 MCM for local consumption in the Lake Tiberias basin area as well as limited abstractions from the

Lower Jordan River. Israel is the only user of Lake Tiberias.<sup>73</sup>

Official Israeli data for the period 1969-2007 states that average annual water transfers from Lake Tiberias through NWC amounted to about 329 MCM, with minimum abstractions of 151 MCM and maximum abstractions of 521 MCM (Figure 23). Abstraction rates depend on water levels in the lake, and abstraction is restricted when levels drop to -212 m asl or lower, as was the case in the late 1980s.

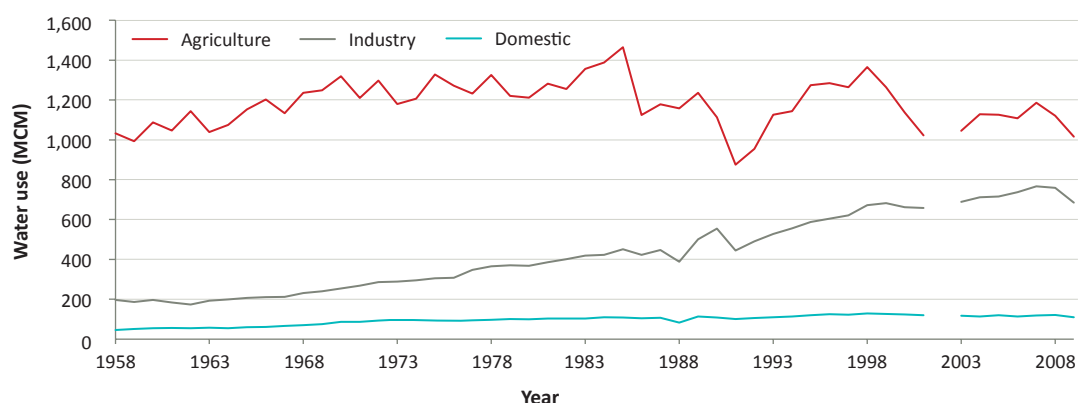
No information is available on the sectoral allocation of the water which Israel abstracts from the basin. According to Israeli data on national water use across sectors for the period 1958-2009, 69% of available water resources (1,180 MCM/yr) are used in agriculture, 25% (428 MCM/yr) for domestic purposes and 6% (96 MCM/yr) for industrial purposes. While water use for agriculture shows no clear trend over the last 50 years, domestic use has increased sharply, especially since the 1980s (Figure 24). Obviously, those figures cannot be used to precisely indicate water use in the Israeli part of the Jordan River basin; however, they may suggest use patterns.

**Figure 23. Volume of water diverted from Lake Tiberias to the National Water Carrier in Israel (1969-2007)**



Source: Compiled by ESCWA-BGR based on ACSAD and UNEP-ROWA, 2001; Ministry of Water Resources in Iraq, 2012.

**Figure 24. Total national water use across sectors in Israel (1958-2009)**



Source: Compiled by ESCWA-BGR based on Ministry of National Infrastructures in Israel et al., 2002; Central Bureau of Statistics in Israel, 2003-2009; HSI, 2008.



Irrigated agriculture in the Jordan Valley, Israel, 2010. Source: Cara Flowers.

Table 8. Annual water use in the Jordan River basin in Israel (MCM)

SOURCE	DIRECT USE FROM UPPER JORDAN RIVER BASIN	NATIONAL WATER CARRIER	DIRECT LOCAL USE FROM LAKE TIBERIAS	DIRECT USE FROM LOWER JORDAN RIVER BASIN	TOTAL
HSI, 1985–2009.	..	313	75	..	..
PASSIA, 2002.	130	420	90	..	640
UNEP, 2003.	..	500	..	..	..
Central Bureau of Statistics in Israel, 2003–2009.	206 <sup>a</sup>	314	..	..	520 (in the Upper Jordan Basin)
Courcier et al., 2005.	100	440	..	..	540 (in the Upper Jordan basin)
FoEME, 2011.	70–150	290	39 <sup>b</sup>	196	595
Zeitoun et al., 2012.	175	345	57–69 <sup>c</sup>	..	~583

Source: Compiled by ESCWA-BGR.

(a) This is referred to as “upper water” and in some years as “additional surface water”.

(b) A total of 89 MCM/yr are used in the vicinity of Lake Tiberias of which 50 MCM/yr are transferred to Jordan as part of the peace treaty between Israel and Jordan.

(c) This number refers to groundwater abstractions within the Lake Tiberias Basin (including the Golan) between 1999 and 2001, as estimated by the Israeli Government.

While Israel uses increasing amounts of treated wastewater and desalinated water for irrigation, freshwater still constitutes by far the largest share of the country’s total annual agricultural water quota.<sup>74</sup> As indicated above, no detailed information is available regarding the land surface area irrigated directly by Lake Tiberias or the volume of water transferred through NWC. However, the irrigated area in the northern part of the basin in Israel<sup>75</sup> is estimated at around 56,000 ha.<sup>76</sup> Therefore water

requirement estimates for irrigated agriculture in the north range from 100<sup>77</sup> to 560 MCM/yr.<sup>78</sup>

While it is difficult to trace how much water from Lake Tiberias is used for irrigation activities in southern Israel, water transfer through NWC has undoubtedly allowed for the large-scale expansion of irrigated areas in the arid south.<sup>79</sup> In total, an estimated 60,000 ha/yr are irrigated in the arid southern districts.<sup>80</sup> Israel’s total irrigated area is estimated at 183,000 ha.



## BOX 7 Israel's National Water Carrier

Israel's National Water Carrier (NWC) was designed to divert runoff from the upper catchment of the Jordan River to highly populated areas and agriculturally productive regions in other parts of the country. This complex water conveyance system pumps water from the north-western shore of Lake Tiberias to the southern part of the country, through more than 120 km of tunnels and open canals and across an elevation of 370 m (see Overview Map). The system, which supplies cities along the Mediterranean coast and irrigated land in the coastal plain and the Negev (Al Naqab) Desert, has an annual capacity of 450 MCM.<sup>a</sup>

Originally Israel had planned to divert water from an intake near the Jordan River headwaters, but Syria's vehement opposition to the plan forced it to relocate the diversion site to the Upper Jordan River at Jisr Banat Yaqub in 1949. However, Syria once again voiced objections and Israel established the NWC intake site on the north-western shore of Lake Tiberias.<sup>b</sup> In 1964, NWC was officially inaugurated and started to abstract water from the lake.

The project is Israel's largest water management scheme and today forms the backbone of the country's water distribution system as various other, smaller water supply and distribution schemes are linked to the NWC network. The volume of water conveyed through the system has gradually increased from

172 MCM in 1964/65 to 379 MCM in 1970/71 with an average of 329 MCM/yr between 1969 and 2007.<sup>c</sup>

Water abstracted from Lake Tiberias enters NWC through an underground pipeline. It is then split into two parts: one conveyor transfers water to the Negev, while the other directs water to Jerusalem and the Dan region. On its way to the country's south, NWC also transfers water from other sources, including admixed groundwater and treated wastewater. In the future, Israel plans to transfer desalinated water from the Mediterranean Sea to the east and south of the country.<sup>d</sup>

Israel's current water development strategy prioritizes the expansion of the country's desalination capacity, which is currently estimated at 315 MCM/yr and expected to increase to 650 MCM/yr by 2020.<sup>e</sup> While desalination activities are mostly located outside the Jordan River basin, the increase in desalinated water availability is likely to impact the basin's water balance. In the long term, desalination may replace water transfer from Lake Tiberias as the main source of water in Israel.

(a) Mekorot, 2012.

(b) Kliot, 1994.

(c) HSI, 2008.

(d) Mekorot, 2012.

(e) Dreizin et al., 2008.



The National Water Carrier in the Galilee, Israel, 1992. Source: Ed Kashi/VII.





## DEVELOPMENT & USE: JORDAN

Jordan's urban, industrial and agricultural activities are predominately concentrated within the Jordan River basin.<sup>81</sup> Consequently, Jordan has relied almost exclusively on the basin's water resources for its socio-economic development. In the mid-1950s, a US-led initiative to support Jordan's socio-economic development commissioned the Yarmouk-Jordan Valley Project,<sup>82</sup> which included the creation of canals on two sides of the Jordan Valley, two dams at Maqarin and Mukheibeh on the Yarmouk and several smaller dams to capture runoff from side valleys.<sup>83</sup>

Known today as the King Abdullah Canal (KAC),<sup>84</sup> the canal on the east side of the valley was built in three phases between 1957 and 1966 and initially covered 70 km from the Yarmouk to the Zarqa River.<sup>85</sup> Following the completion of the King Talal Dam on the Zarqa River in 1977 (see below), KAC was extended to a total length of 110 km to provide irrigation water to the southern parts of the Jordan Valley in Jordan.<sup>85</sup> The canal captures runoff from the Yarmouk River, the Mukheibeh Wells<sup>86</sup> and several wadis. In addition, it receives discharge from the King Talal Dam, which is a mix of freshwater from the Zarqa River and effluent from the Samra wastewater treatment plant which processes over 75% of Jordan's domestic wastewater.<sup>87</sup> The capacity of KAC ranges between 20 m<sup>3</sup>/s at the intake (630 MCM/yr) and 2.3 m<sup>3</sup>/s at its southern end.

The canal plays a central role in Jordan's agricultural development as it supplies irrigation water via pumping stations to farmers in an area of 400-500 ha.<sup>88</sup> However, as domestic demand continues to rise, water from KAC is increasingly pumped to the Greater Amman area over an elevation of 1,300 m. Between 2002 and 2011, Amman received an average annual amount of 47 MCM from KAC.<sup>89</sup> This transfer constitutes around one-third of water supplied to Amman and also corresponds to one third of the water diverted to KAC.<sup>90</sup>

The King Talal Dam was designed to store runoff from the Zarqa River, the Lower Jordan River's second largest tributary after the Yarmouk. The dam was raised in 1987 to increase the annual storage capacity from 56 to 75 MCM and capture an estimated 50 MCM/yr from the Samra wastewater treatment plant.<sup>91</sup>

Figure 25 presents total water use in Jordan and shows that Jordan's agricultural sector consumed 64% of the country's total water resources in 2007.<sup>92</sup> Agricultural activities in Jordan are concentrated in the Jordan Valley and the highlands.<sup>93</sup> Besides some rain-fed agriculture in the highlands, commercial agriculture is irrigated, both in the highlands

Table 9. Main constructed and planned dams in the Jordan River basin

COUNTRY	NAME (RIVER)	COMPLETION YEAR	CAPACITY (MCM)	PURPOSE <sup>a</sup>
Israel	Degania (Jordan River) <sup>b</sup>	1932	..	Regulation of Lake Tiberias
Jordan	Kafrein (Wadi Kafrein)	1967	8.5	I
	King Talal (Zarqa)	1977	75	I, HP
	Wadi Arab (Wadi Arab)	1986	16.8	I, D, HP
	Karameh (Wadi Mallaha)	1997	53	I
	Addasiya (Yarmouk)	1998	10	D, I
Jordan & Syria	Wahdah (Yarmouk)	2006	110	D, I, HP
Jordan	Kufrinjah (Wadi Kufrinjah)	planned	6	D, I

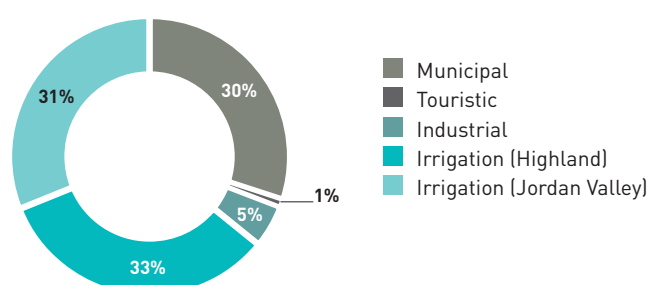
Source: Compiled by ESCWA-BGR based on Ministry of Water and Irrigation in Jordan, 2002a; Courcier et al., 2005; Amman Net, 2012; Jordan Times, 2011.

Note: For dams constructed in the Yarmouk Basin in Syria, see Table 7.

(a) Irrigation (I), Hydropower (HP), Domestic (D).

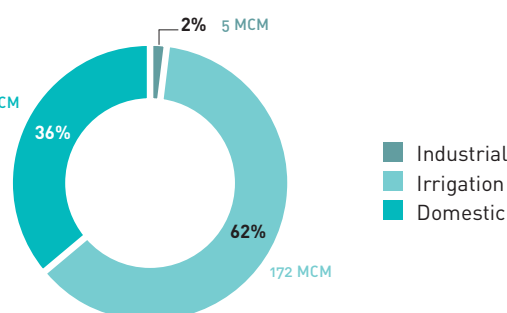
(b) Situated at the outflow of Lake Tiberias.

Figure 25. Water allocations across sectors in Jordan (2007)



Source: Compiled by ESCWA-BGR based on Ministry of Water and Irrigation in Jordan, 2009.

Figure 26. Water use across sectors in the Jordan Valley in Jordan (2010)



Source: Compiled by ESCWA-BGR based on JVA Annual Report, 2010.

and in the Jordan Valley. Over the last 60 years, irrigated areas in the Jordan Valley have steadily expanded from 9,300 ha in 1950 to over 23,000 ha in 2006 as part of public irrigation schemes.<sup>94</sup> In 2009, the Ministry of Water and Irrigation in Jordan stated that there was 33,000 ha of irrigated land in the Jordan Valley.<sup>95</sup> Cultivated crops in the Jordan Valley include vegetables, citrus fruits, bananas, field crops

and trees among others.<sup>96</sup> Irrigated areas in the highlands add up to about 44,100 ha<sup>97</sup> of which about half are situated in the Jordanian part of the Jordan River basin. Other sources state that groundwater irrigation has been developed on about 14,000 ha over the last 30 years, mainly via private wells.<sup>98</sup>

Data from 2010 on water use in the Jordan Valley shows that agriculture is the main user with 172 MCM/yr (Figure 26). Water for domestic use (99 MCM/yr) probably includes water pumped from the Jordan Valley to Amman.<sup>99</sup>

While the total water use for irrigation in Jordan has remained constant over the last two decades, the use of ground- and surface water for irrigation has decreased as irrigated agriculture in the Jordan Valley increasingly uses treated wastewater.<sup>100</sup>

To sum up, available surface water resources in the Jordanian part of the basin are used for agriculture in the Jordan Valley, and, since 1986, for domestic purposes in the Greater Amman area. Groundwater in the highlands is used mainly for agricultural purposes but also for municipal and industrial purposes. Total annual water use in the Jordanian part of the Jordan River basin is estimated at around 290 MCM.<sup>101</sup>

## DEVELOPMENT & USE: PALESTINE

Before the 1967 Six-Day War, the Jordan River was an important source of water for Palestinians in the West Bank, who used it for domestic and agricultural purposes. Palestinians used Jordan River water to irrigate about 10,000 ha in the Jordan Valley.<sup>102</sup> The Yarmouk-Jordan Valley Project that was outlined in the late 1950s included not only an East Ghor Canal (known today as King Abdullah Canal), but also a West Ghor Canal, which was to cover 47 km and be equipped with a siphon across the Jordan River to supply irrigation water to fields in the West Bank.<sup>103</sup> The West Ghor Canal was initiated in 1967 but construction was halted after the Israeli occupation of the West Bank.<sup>104</sup>

Since then, Israel has introduced and maintained a system of direct control over the development and use of water resources, which has resulted in the creation of a restrictive permit regime for the development of water-related infrastructure. Palestinian water rights on the Jordan River have been progressively curtailed since 1967 and today the Palestinian part of the Jordan River basin (1,564 km<sup>2</sup>) is either a “closed military area”<sup>105</sup> or part of the areas in the West Bank that are controlled and administered by Israel (Area C). Thus most of the fertile Jordan Valley is

off limits to Palestinians as it falls under Area C. In areas controlled and/or administered by the Palestinian Authority (Area A and B), all water-related projects still require permission from Israel.<sup>106</sup> As a result, Palestinians cannot access or use any water from the Jordan River itself<sup>107</sup> and are severely restricted in the implementation of water-related projects in the basin.

For the coming two decades, Palestine has planned around 30 projects in its share of the Jordan River basin, mostly focusing on the rehabilitation of springs, wells and canals. The Red Sea-Dead Sea project (Box 8) as well as the rehabilitation of the West Ghor Canal to transfer water from the Jordan River to the agricultural lands are planned for completion in 2030 pending available funds and appropriate political conditions.<sup>108</sup>



King Talal Dam which supplies water to Jordan Valley farms, Jordan, 1992. Source: Ed Kashi/VII.



## BOX 8 Planned Infrastructure Projects to Save the Dead Sea

The Dead Sea is severely affected by large-scale mismanagement and over-exploitation of the scarce water resources in the Jordan River basin (Box 2). In addition to the alarming drop in water levels in the Dead Sea, surface and groundwater bodies in the basin have been severely affected in terms of quantity and quality. The public debate on the shrinking of the Dead Sea tends to bypass the root causes of the crisis, and governments are keen to focus on large-scale infrastructural solutions without examining the legacy of past and current water management strategies in the region. For instance, Israel's use of the National Water Carrier (Box 7), which transfers significant amounts of water out of the Jordan River basin, is largely overlooked in the current debate. By contrast, technical solutions to the decline of the Dead Sea and water shortage in the basin at large are capturing media attention and generating a lively debate in the region. One of these projects is the Jordan Red Dead Sea Project (JRDP).

The idea of connecting the Dead Sea to the Red Sea or the Mediterranean goes back to the mid-19th century. In Jordan it has been under discussion since the 1980s in response to Israel's Mediterranean-Dead Sea projects. Concrete discussions about the construction of a conduit connecting the Red Sea to the Dead Sea started only after Israel and Jordan signed a peace treaty in 1994. The ambitious Red Sea-Dead Sea Conduit Project has since then received extensive international attention as a solution to the decline of the Dead Sea and a regional cooperation project.

Covering a distance of approximately 200 km, the proposed conduit would pump seawater from Aqaba on the Red Sea coast through the Arava Valley in Jordan where it would then be carried down to the Dead Sea through gravity. The project includes water desalination plants and a hydropower plant. Part of the Red Sea water would be desalinated and transported to Amman. The remaining brine, the by-product of desalination, would be released into the Dead Sea, with the aim of replenishing the rapidly shrinking sea.

In 2005 Israel, Jordan and the Palestinian Authority signed an agreement to proceed with a project feasibility study, which was administered by the World Bank and financed by various donors. The USD 15.5 million study comprises a technical, environmental and social assessment,<sup>a</sup> and was expanded in

December 2007 to include a study of alternatives.<sup>b</sup> The study programme was scheduled for completion in 2012.<sup>c</sup>

With an estimated cost of USD 4.2 billion,<sup>d</sup> excluding the costs of transferring the desalinated water to urban centres, the project is extremely expensive in comparison to other, less drastic proposals to reverse the decline of the Dead Sea.

Besides issues of cost, the project has also raised serious environmental and technical concerns over potential damage to the marine environment in the Gulf of Aqaba<sup>e</sup> and the risk of damage to the 200 km conduit in this area of high tectonic activity.<sup>f</sup> The mixing of waters with two different chemical compositions and salinities can negatively influence the sea's biological environment. The change in the sea's chemical composition could also damage the potash industry on the southern shores as well as the tourism industry in Israel and Jordan.<sup>g</sup> Furthermore, raising the water level of the Dead Sea might reverse hydrostatic gradients and contaminate surrounding groundwater tables.

Following Jordan's announcement of the Jordan Red Sea Project (JRSP) in 2009,<sup>h</sup> the three-way cooperation between Israel, Jordan and Palestine has taken a back seat. According to the Jordanian Government, JRSP can be regarded as the first phase of the Red Sea-Dead Sea Conduit Project. The project is designed to abstract about 400 MCM/yr of seawater from the Red Sea, and desalinate about 200 MCM/yr. The additional seawater and brine from desalination will be discharged into the Dead Sea. The project also includes the development of a series of residential and commercial areas, industrial centres, tourist resorts and other business support functions between the Red Sea and the Dead Sea in Jordan.<sup>i</sup> Israel is said to be participating in the coordination and planning of JRSP, and will become more closely involved at a later stage.

(a) World Bank, 2005.

(b) FoEME, 2007.

(c) World Bank, 2011.

(d) Israel Ministry of Foreign Affairs, 1995.

(e) RSS, 2007.

(f) Geological Survey of Israel, 2006.

(g) Gavrieli et al., 2005; Asmar and Ergenzinger, 1999; FoEME, 2007.

(h) JRSP Company, 2010.

(i) Ministry of Water and Irrigation in Jordan, 2012.



The Dead Sea, 2009. Source: Marc Haering.





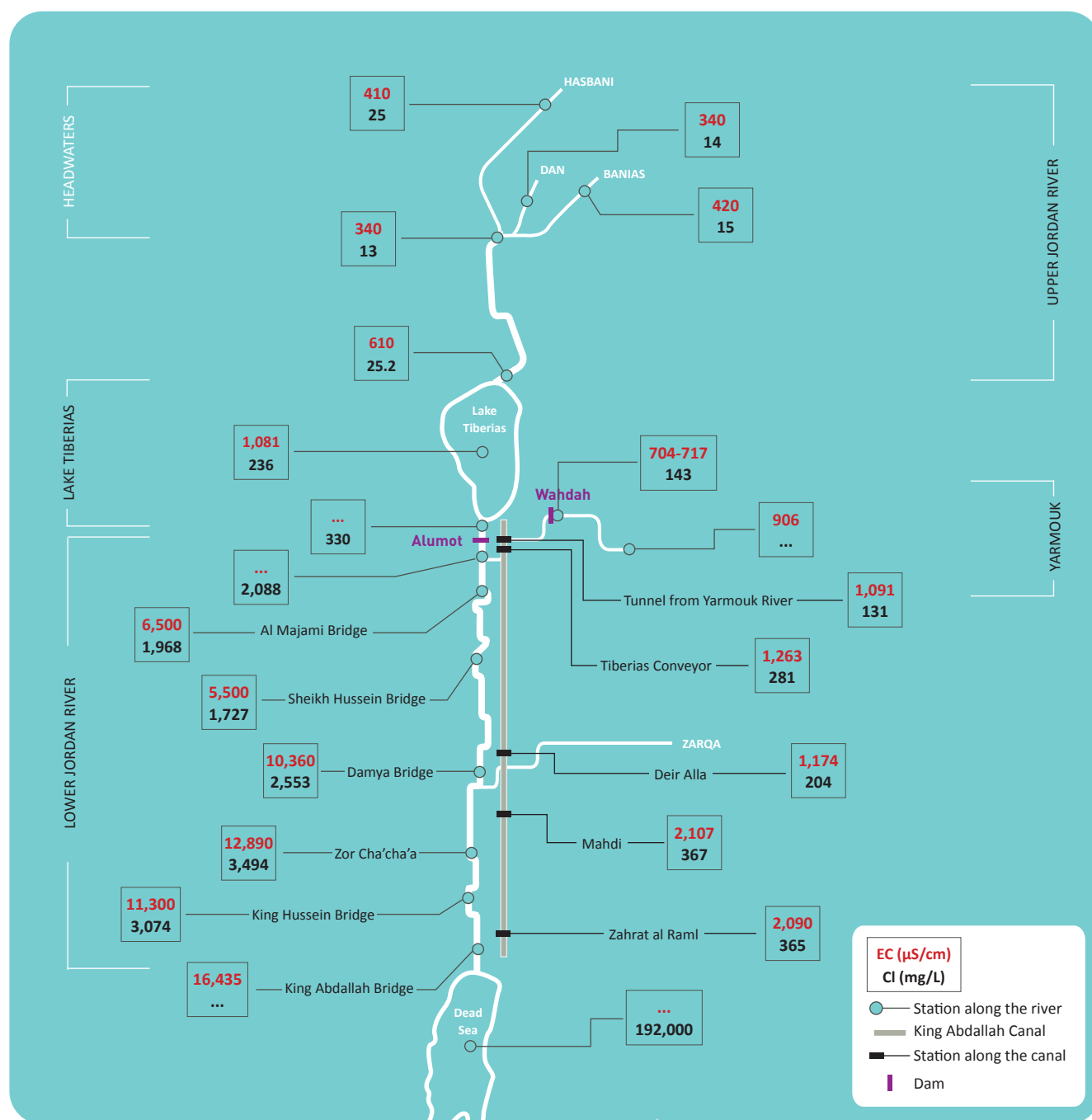
## WATER QUALITY & ENVIRONMENTAL ISSUES

While the Jordan River headwaters are a source of good-quality, low-salinity water, most of the rest of the river is heavily polluted by sewage, agricultural return flows, groundwater seepage and brackish/saline water diverted from springs around Lake Tiberias. Moreover, the Lower Jordan River has suffered a 50% loss in biodiversity due to the disappearance of

fast-flow habitats and dramatically heightened salinity levels.<sup>109</sup>

Figure 27 shows recent salinity data for the Jordan River and King Abdullah Canal (KAC). Table 10 summarizes available salinity data for the Upper Jordan River including the headwaters and for the Yarmouk River, while Table 11 presents the same information for the Lower Jordan River.

Figure 27. Sketch of salinity levels along the Jordan River and the King Abdullah Canal



Source: Compiled by ESCWA-BGR based on the references listed in Table 10 and Table 11.

Note: Due to minor gaps in the available salinity information, the values displayed in this figure are all based on data from 2009, except for the stations at Lake Tiberias (2006), the Wadiah Dam (2010) and KAC (2010). Data for the Yarmouk River is based on Ministry of Water and Irrigation in Jordan, 2002b but the exact sampling period is unknown.





## Headwaters of the Upper Jordan River

The Jordan River headwaters contain high-quality water along their entire course.<sup>110</sup> Sampling of water from the Dan and Banias Springs between 2002 and 2004 showed a mean salinity of 343  $\mu\text{S}/\text{cm}$  and 397  $\mu\text{S}/\text{cm}$  as Electrical Conductivity (EC) respectively.<sup>111</sup> The three upper tributaries (Hasbani, Banias and Dan Rivers) also have low salinity values ranging from 310 to 420  $\mu\text{S}/\text{cm}$  as shown in Table 10. While low salinity values are maintained until the confluence of the headwaters, agricultural activities in the Dan and Hasbani sub-basins are likely to expose the rivers to contamination from agricultural runoff. In particular, the Hasbani sub-basin is threatened by several types of pollution, including domestic wastewater and olive oil production residues.<sup>112</sup>

As it flows south, the Upper Jordan River passes through the Hula Valley (Box 8) and discharges into Lake Tiberias. The intensive agricultural activities in this region clearly impact water quality, with a noticeable increase in salinity values to 610  $\mu\text{S}/\text{cm}$  at the inlet to Lake Tiberias (Table 10).<sup>113</sup>

## Lake Tiberias

The water of Lake Tiberias has significantly higher salinity values than the Upper Jordan River (Table 10). In addition to an increase in salinity due to high evaporation rates,<sup>114</sup> higher salinity values are mainly a result of the presence of chloride-rich saline springs close to the lake shore and on the lake floor, which discharge an estimated 40 MCM/yr into the lake.<sup>115</sup> Prior to 1964, the chloride ( $\text{Cl}^-$ ) content of Lake Tiberias reached 400 mg/L, and the high salinity of lake water damaged crops.<sup>116</sup> However, the construction of the Salinity Diversion Channel (SDC) in 1967 as part of Israel's National Water Carrier project allowed for the diversion of saline water from springs on the western and north-western side of the lake<sup>117</sup> to the Lower Jordan River. That has led to the removal of about 70,000 tons/yr of salt from Lake Tiberias and the transferral of 15-20 MCM/yr of water to the Lower Jordan River at the Alumot Dam location.<sup>118</sup> As a result of the diversion, the chloride content of the lake was reduced to 236 mg/L in 2006,<sup>119</sup> making it suitable for use as drinking water.<sup>120</sup>

Apart from natural factors, anthropogenic activities in the basin have direct impacts on the lake's water quality. The Tiberias watershed area is mainly used for agriculture, including aquaculture, but tourism and recreation have also grown over recent decades, leading to an increase in pollution from agricultural, industrial and domestic sources.<sup>121</sup> In addition, the drainage of the Hula Valley marshlands

in the 1950s (Box 8) caused a rise in nutrient content in the lake and a bloom of potentially toxic cyanobacteria. It is estimated that more than 50% of the nutrient inputs into Lake Tiberias originate from the Hula Valley and surroundings.<sup>122</sup> Water-level fluctuations in the lake are also an issue of concern, threatening the stability of the basin's ecosystem.

## Yarmouk

In terms of salinity, the Yarmouk River is characterized by good-quality water in comparison to the Lower Jordan River, with an average chloride and TDS content of 134 mg/L and 749 mg/L respectively (2001-2002).<sup>123</sup> Recent salinity values at the Wahdah Dam show the same range of values. The intensive agricultural activities in the dam's catchment area have, however, resulted in high levels of Total Phosphorus (TP) and Total Nitrogen (TN) at the dam site, as well as frequent algal blooms caused by agricultural runoff and wastewater flowing into the reservoir.<sup>124</sup>

Heavy metals have been detected in the water of springs in the Yarmouk Basin.<sup>125</sup> Sediment samples taken along the river also displayed high heavy metal content, which can be attributed to agricultural activities as well as the presence of a treatment plant, a landfill site and small industries in the basin area.<sup>126</sup>

## King Abdullah Canal

The canal is mainly fed by water from the Yarmouk River and various sources along the Jordan River, including the water conveyed from Lake Tiberias, the Mukheibeh Wells and water from wadis and dams along the canal in Jordan (Wadi Arab, Wadi Ziqleb and the King Talal Dam).<sup>127</sup>



Polluted water in the Jordan Valley, Jordan, 2008. Source: Eileen Maternowski.



## BOX 9 The Hula Valley Drainage Project

Located to the north of Lake Tiberias in current-day Israel, the Hula Valley used to be a 6,000 ha wetland area that included Lake Hula (1,200–1,400 ha) and featured unique fauna and flora.<sup>a</sup> In a bid to expand the agricultural lands in the area, eradicate malaria and reduce evaporative water losses, Israel drained the lake and surrounding marshes in the 1950s.<sup>b</sup> However, in the following decades it became clear that the drainage project had a severe ecological impact, causing wind and water erosion, underground peat fires, loss of endemic species and the release of increased nutrient loads into Lake Tiberias.<sup>c</sup> Israel attempted to restore the heavily damaged ecosystem in 1994 with the Hula Restoration Project, which re-flooded part of the former wetland and created the shallow Lake Agmon.<sup>d</sup> This lake is currently an eco-tourism area and serves as a zone for storage and reuse of agricultural drainage waters.<sup>e</sup> Analysis of water samples in the first three years after the new system was put in place indicated high nutrient levels with a gradual increase in eutrophication over the years.<sup>f</sup> Most of the water that flows into Lake Tiberias passes through the Hula Valley, and its low quality obviously harms water quality in the lake.<sup>g</sup>

(a) Hambright and Zohary, 1998.

(b) Ibid. A small portion of the original swamps (350 ha) was left inundated and became an Israeli nature reserve in 1964.

(c) Ibid. Large amounts of nitrates and sulphates were washed into Lake Tiberias during the rainy season as a result of decomposing peats.

(d) Tsipris and Meron, 1998; Hambright and Zohary, 1998.

(e) Hambright et al., 2000.

(f) Hambright et al., 1998.

(g) Gophen, 2000.

Figure 28. Lake Hula before drainage in the late 1950s



Source: Compiled by ESCWA-BGR based on Hambright and Zohary, 1998.



Lake Hula, Israel, 2008. Source: Itamar Grinberg.



In terms of salinity, EC values along the canal lie between 894 and 2,601  $\mu\text{S}/\text{cm}$ , with values increasing from north to south.<sup>128</sup> The gradual increase can be attributed to the inflow of saline water along the course of the canal, specifically from the tunnel which conveys saline water from Lake Tiberias and the inflow of the Zarqa River (see Figure 27).<sup>129</sup>

Apart from its effects on water salinity, the high nutrient load of the water flowing into KAC from various sources causes serious problems of eutrophication. The most upstream discharge point of these compounds is the Yarmouk River (see Figure 27, Tunnel from Yarmouk sampling location), with mean nitrate ( $\text{NO}_3\text{-N}$ ) and TP concentrations of 1.6 mg/L and

0.21 mg/L respectively. In addition, water from the King Talal Dam on the Zarqa River contains high nutrient loads as measured at the Mahdi sampling station, where the mean nitrate level is 9.5 mg/L. Similarly, the mean TP level at this site is 1.73 mg/L, an eight-fold increase compared to the first sampling site.<sup>130</sup> The planned rehabilitation of the Khirbet As-Samra Wastewater Treatment Plant located upstream of the King Talal Reservoir is expected to improve the water quality of the Zarqa River and, as a result, water quality in KAC.<sup>131</sup>

The eutrophication of KAC water first became a problem in 1998, when the unpleasant odour of the drinking water in the Greater Amman area gave rise to public concern.

Table 10. Mean salinity values of the Upper Jordan River and Yarmouk River

STATION	TDS (mg/L)	EC ( $\mu\text{S}/\text{cm}$ )	Cl (mg/L)	YEAR	SOURCE
Hasbani River	..	391	..	2006 (March)	Barinova and Nevo, 2010.
	287	410	25	2009 (Jan-Apr)	
Dan Spring	230-320	..	..	1996-2000	Gur et al., 2003.
	..	343	..	2002-2004	Brielmann, 2008.
Dan River	..	336	..	2006 (March)	Barinova and Nevo, 2010.
	244	340	14	2009 (Jan-Apr)	
Banias Spring	247-408	..	..	1996-2000	Gur et al., 2003.
	..	397	..	2002-2004	Brielmann, 2008.
Banias River	..	389	..	2006 (March)	Barinova and Nevo, 2010.
	297	420	15	2009 (Jan-Apr)	
Confluence of upper tributaries	..	371	..	2006 (March)	Barinova and Nevo, 2010.
	240	340	13	2009 (Jan-Apr)	
Jordan River at the inlet to Lake Tiberias	..	406	..	2006 (March)	Barinova and Nevo, 2010.
	431	610	25.2	2009 (Jan-Apr)	
Lake Tiberias	..	..	$\leq 400$	Pre-1964	Hambricht et al., 2000.
	..	..	204-221	1980-1985	Hambricht et al., 2000.
	..	..	300	Mid-1990s-2002	Siebert et al., 2009.
	..	..	250	2003-2004	
	..	..	236	2006	Kiperwas, 2011.
	..	1,081	..	2006	Ministry of Water and Irrigation in Jordan, 2002b.
Yarmouk River	571-901	..	..	1996	Howari and Banat, 2002.
	749	..	134	2001-2002	Farber et al., 2004.
	580	906	..	..	Ministry of Water and Irrigation in Jordan, 2002b <sup>a</sup> .
Yarmouk Springs <sup>b</sup>	347-1,234	..	..	2006	Batayneh, 2011.
Wahdah Dam	541	845	..	1997-2002	Ministry of Water and Irrigation in Jordan, 2002b.
	..	704-717	143	2010	Al-Taani, 2011.

Source: Compiled by ESCWA-BGR.

Notes:

- The international TDS and EC guideline for irrigation of salt-sensitive crops is limited at  $<450$  mg/L and  $<700$   $\mu\text{S}/\text{cm}$  respectively (FAO, 1994). This differs from the Jordanian guideline, which is set at  $<1,700$   $\mu\text{S}/\text{cm}$  (JVA and GTZ, 2006).

- The Cl guideline for irrigation varies according to crop tolerance and ranges from 106 to 960 mg/L (FAO, 1994).

- For drinking water, the Cl standard ( $<250$  mg/L) is only taste-based and no health-based guideline is proposed (WHO, 2003).

For further information on the different water quality parameters and their respective guidelines, see 'Overview & Methodology: Surface Water' chapter.

(a) No specific date is mentioned for these salinity figures. In the document they appear as "According to the long-term monitoring data from the Jordan Valley Authority".

(b) Sampling of 36 major springs in the Yarmouk Basin.



Investigations revealed that dense algal growth in KAC, together with insufficiently treated water at the Zai Treatment Plant were the cause of the foul smell.<sup>132</sup> While treatment efficiency and KAC water quality monitoring programmes were subsequently improved,<sup>133</sup> algal blooms are still reported along the canal, which means there is a continued risk to public health.<sup>134</sup>

## Lower Jordan

There is a significant deterioration in water quality from the Upper to the Lower Jordan River. High salinity levels and pollution indicate that the ecosystem in the Lower Jordan Basin

is under threat and that the river's water is unsuitable for use in any sector.<sup>135</sup>

Water quality along the stretch of the river is particularly threatened by rising salinity levels caused by the dramatic reduction of freshwater inputs and the transferral of saline spring water from Lake Tiberias to the Lower Jordan River.<sup>136</sup> Water quality in the northernmost part of the Lower Jordan River is significantly modified downstream of the Alumot Dam (at around 1.5 km from Lake Tiberias) as effluent from SDC and agricultural and municipal sewage from Israel<sup>137</sup> is channelled into the river at this point.<sup>138</sup> This results in a sharp increase in chloride (Figure 27), TP and Biochemical Oxygen

Table 11. Mean salinity values of the Lower Jordan River at different stations

STATION	TDS (mg/L)	EC (µS/cm)	Cl (mg/L)	YEAR	SOURCE
Al Majami Bridge	3,823 [3,132-4,386]	5,986 [4,900-6,900]	..	2001-2008	Ministry of Water and Irrigation in Jordan, 2010.
	4,149	6,500	..	2009	
	..	..	1,968	2009	FoEME, 2010.
Sheikh Hussein Bridge	3,429 [3,093-3,706]	5,371 [4,800-5,800]	..	2001-2008	Ministry of Water and Irrigation in Jordan, 2010.
	3,494	5,500	..	2009	
	..	..	1,727	2009	FoEME, 2010.
	..	6,254 [5,800-6,754]	1,668 [1,482-1,846]	2010	RSS, 2010.
Damya Bridge	3,048 [1,717-3,813]	5,806 [5,649-5,960]	..	2001-2004	Ministry of Water and Irrigation in Jordan, 2010.
	..	10,360	2,553	2009	FoEME, 2010.
Zor Cha'cha'a	5,228 [5,074-5,382]	8,170 [7,930-8,410]	..	2001-2002	Ministry of Water and Irrigation in Jordan, 2010.
	6,582 [5,523-8,495]	10,283 [8,630-13,270]	..	2006-2008	Ministry of Water and Irrigation in Jordan, 2010.
	8,252	12,890	3,494 [1,698-5,138]	2009	
	..	9,930 [8,170-11,800]	2,703 [2,148-3,335]	2010	RSS, 2010.
King Hussein (Allenby) Bridge	5,907 [4,290-7,932]	9,230 [6,700-12,400]	..	2001-2008	Ministry of Water and Irrigation in Jordan, 2010.
	7,222	11,300	..	2009	
	..	..	3,074	2009	FoEME, 2010.
	..	10,105 [8,145-11,880]	2,762 [2,149-3,278]	2010	RSS, 2010.
King Abdullah Bridge	..	..	400	1925	Farber et al., 2005.
	..	..	Up to 5,400	2005 <sup>a</sup>	
	..	16,435	..	2009	FoEME, 2010.

Source: Compiled by ESCWA-BGR.

Notes:

- Sampling stations are displayed from north to south.

- Data from Ministry of Water and Irrigation in Jordan, 2010 does not include mean salinity values for 2003.

- The international TDS and EC guideline for irrigation of salt-sensitive crops is limited at <450 mg/L and <700 µS/cm respectively (FAO, 1994). This differs from the Jordanian guideline, which is set at <1,700 µS/cm (JVA and GTZ, 2006).

- The Cl guideline for irrigation varies according to crop tolerance and ranges from 106 to 960 mg/L (FAO, 1994).

- For drinking water, the Cl standard (<250 mg/L) is only taste-based and no health-based guideline is proposed (WHO, 2003).

For further information on the different water quality parameters and their respective guidelines, see 'Overview & Methodology: Surface Water' chapter.

(a) No precise date is provided. The author refers only to "nowadays".





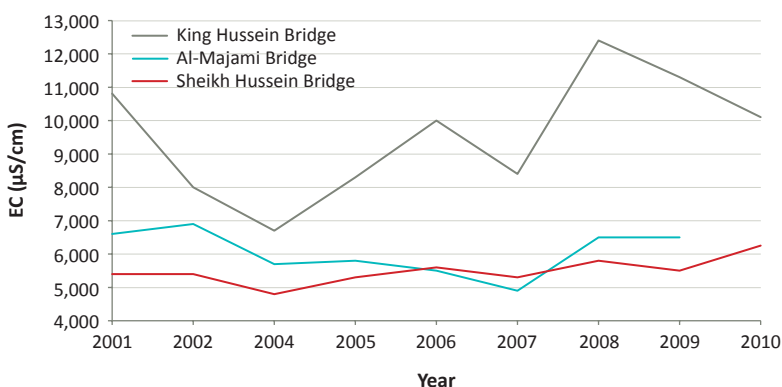
The King Abdullah Canal, Jordan, 2007. Source: Mark Haering.

Demand (BOD) levels. BOD values registered in 2009 showed a sharp increase from 1 mg/L upstream of the dam to 12 mg/L after the dam site. A similar exponential rise in TP was observed, with an increase from 0.3 mg/L before the dam to six times that amount downstream of the dam.<sup>139</sup>

Salinity levels increase progressively along the course of the Lower Jordan River,<sup>140</sup> with EC values of 6,500  $\mu\text{S}/\text{cm}$  registered in 2009 at the Majami Bridge station and 16,435  $\mu\text{S}/\text{cm}$  at the King Abdullah Bridge, the southernmost sampling station along the river (Table 11).<sup>141</sup> Available data on salinity variations in the last decade shows that no significant change has taken place during this period (Figure 29). However, sources suggest that there was a clear increase in salinity over the 20th century. For instance, historical data from 1925 indicates that the chloride concentration at the King Abdullah Bridge station was around 400 mg/L, while today it can reach up to 5,400 mg/L.<sup>142</sup>

The Lower Jordan River is also affected by extremely high levels of organic pollution, posing a risk to public health. This is of particular concern at the baptism sites on both banks of the river in Israel and Jordan, where observant

**Figure 29. Mean annual Electrical Conductivity (EC) values of the Lower Jordan River (2001-2010)**



Source: Compiled by ESCWA-BGR based on Ministry of Water and Irrigation in Jordan, 2010; RSS, 2010.

Christians immerse themselves in the water as part of religious rituals.<sup>143</sup> Moreover, the Lower Jordan River has suffered a 50% loss in biodiversity<sup>144</sup> as the inflow of saline water from side wadis, drainage water from fishponds, untreated sewage water, saline springs and agricultural return flows has increased over the years.<sup>145</sup> The deterioration of water quality in the Lower Jordan Basin severely restricts water use,<sup>146</sup> with serious long-term implications for the ecosystem.



# Agreements, Cooperation & Outlook

Riparian cooperation on water resources management in the Jordan River basin is tragically entwined with the regional conflict. Despite a range of multilateral initiatives to reach a basin-wide agreement on water resources allocation,<sup>147</sup> riparian countries have still not reached a consensus. The 1991 Madrid Conference sought to initiate a regional peace process and find a comprehensive solution to the Arab-Israeli conflict. The meeting paved the way for a series of bilateral and multilateral negotiations on various issues, including shared water resources in the region. Lebanon and Syria refused to take part in the multilateral meetings before tangible progress was made on the Israeli-Lebanese and Israeli-Syrian bilateral level.

Today, there are a number of bilateral agreements between riparian countries in the basin (Table 12), which can be divided into two categories: agreements between Jordan and Syria on the Yarmouk River without any third-party involvement, and agreements negotiated in the aftermath of the Madrid Conference (peace treaty between Israel and Jordan and the Oslo Accords).

## AGREEMENTS: JORDAN & SYRIA

From the late 1940s, the three Yarmouk riparians, Israel, Jordan and Syria, have held strong and often conflicting positions on water allocation in the basin. In 1953, Jordan and Syria signed an agreement on the use of the Yarmouk River, which outlined the construction of a dam near Maqarin in Syria to provide irrigation water to Jordan and electrical power to both countries.<sup>148</sup>

The agreement does not specify volumetric water allocations to the two countries, but instead states that Syria has the right to use all the water of the river and its tributaries entering the river upstream of the dam site, excluding the water necessary to supply the future dam.<sup>149</sup> Jordan is accorded the right to use the overflow from the reservoir and a quarter of the output from the joint generating station at Maqarin. According to the agreement, the electricity generated at Addasiya is to be divided on a 75%-25% basis between Syria and Jordan.<sup>150</sup> It also establishes a Joint Syrian-Jordanian Commission to oversee the implementation of

Table 12. Water agreements in the Jordan River basin

YEAR	NAME	SIGNIFICANCE	SIGNATORIES
1920	Franco-British Convention	Article 8 states that the signatories will undertake joint examination of the Upper Jordan and Yarmouk for the production of hydroelectric power.	Great Britain (Israel, Jordan, Palestine), France (Lebanon, Syria)
1923	Exchange of notes constituting an agreement between the British and French Governments	The agreement focuses on water rights.	Great Britain (Israel, Jordan, Palestine), France (Lebanon, Syria)
1926	Agreement I of Good Neighbourly Relations Concluded Between the British and French Governments	Article III focuses on water rights.	Great Britain (Israel, Jordan, Palestine), France (Lebanon, Syria)
1953	Agreement between the Republic of Syria and the Hashemite Kingdom of Jordan Concerning the Utilization of the Yarmouk Waters	Cooperative use and management of the Yarmouk River, including construction of the Wahdah Dam.	Jordan, Syria
1987	Agreement Concerning the Utilization of the Yarmouk Waters	Cooperative use and management of the Yarmouk River, including construction of the Wahdah Dam.	Jordan, Syria
1994	Treaty of Peace between the State of Israel and the Hashemite Kingdom of Jordan	Annex II outlines the principles of cooperative use and management on the Yarmouk River and the Jordan River.	Israel, Jordan
1995	Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip	Annex III, Article 40 comprises the interim arrangement for water management in the West Bank and Gaza Strip.	Israel, Palestine (PLO)

Source: Compiled by ESCWA-BGR based on Oregon State University, 2010.





works, which comprises three members from each country.<sup>151</sup>

While the agreement remained in place for 34 years, neither the dam nor the hydropower facility was constructed during this period due to the unstable political relationship between Jordan and Syria and conflicts with Israel.<sup>152</sup> The two countries returned to the negotiation table in 1987, when they narrowed down the scope of the agreement with regards to the dam (now called the Unity or Wahdah Dam) and the reservoir at Maqarin. The new agreement differs in that it (1) outlines the construction of a smaller dam, reflecting the gradual depletion of available water resources in the Yarmouk Basin, (2) alters the approach to dispute resolution from an arbitration mechanism to a mechanism of intergovernmental mediation and (3) authorizes Syria to implement and use 25 dams on the Yarmouk and its tributary rivers and wadis.<sup>153</sup> The Wahdah Dam began to receive water in 2006 and was completed in early 2009.<sup>154</sup>

## AGREEMENTS: ISRAEL & PALESTINE

Officially referred to as the Declaration of Principles on Interim Self-Government Arrangements (DOP), the 1993 Oslo Accords between Israel and the Palestine Liberation

### BOX 10

#### The Johnston Plan

The equitable sharing of water resources in the increasingly densely populated and water-scarce Jordan River basin has been problematic for more than a century. In the first half of the 20th century, the United States, Israel, Arab countries and the international community put forward a number of basin development plans (Table 6), which outlined different approaches to water allocation and management in the Jordan River basin.

Following the 1948 war between Arab states and Israel, the United States attempted to develop a scheme to guarantee the availability of irrigation water for all populations sharing the Jordan River, including Palestinian refugees.<sup>a</sup>

US Ambassador Eric Johnston subsequently developed such a scheme following a series of visits to the region between 1953 and 1955. While it was never implemented, the Johnston Plan<sup>b</sup> continues to be the most authoritative scheme and still forms the basis for discussions over water allocation in the basin. It is also often referred to as a base for a "tacit" understanding among riparian countries.<sup>c</sup>

The plan assumes a total annual water availability of 1,503 MCM in the basin and allocates 616 MCM to Israel, 720 MCM to Jordan, 35 MCM to Lebanon and 132 MCM to Syria<sup>d</sup> (Table 6). While all riparians accepted the plan on a technical level,<sup>e</sup> it failed politically after the Council of the League Arab States voted against its ratification in October 1955, arguing that it constituted a formal recognition of the state of Israel. Israel also had its reservations towards the plan as politicians feared it would set a precedent and encourage Arab states to make claims to water resources from the Upper Jordan River.<sup>f</sup>

(a) Phillips et al., 2007.

(b) The Johnston Plan dated September 1955 is the only full version of the Jordan Valley Plan.

(c) See Jägerskog, 2003; Kliot, 1994.

(d) Several authors state that Israel's allocation is 394 MCM/yr or 400 MCM/yr. However, Phillips et al., 2007 underline that this figure does not include the local flows that Johnston included in the allocation. They argue that "The confusion of previous authors in relation to this figure was generated by the omission of a specific flow for Israel within the Johnston Plan itself." (p. 34).

(e) Phillips et al., 2007.

(f) Lowi, 1993, p. 193.



Wadi Shihab, a tributary of the Yarmouk River in Dera'a Governorate, Syria, 2009. Source: Adel Samara.



Organization (PLO) were the result of extensive negotiations in the aftermath of the Madrid Conference. They were followed in 1995 by the Israeli-Palestinian Interim Agreement on the West Bank and the Gaza Strip or Oslo II, which addresses the topic of water in Article 40 of the Protocol on Civil Affairs (annex 3). In Israel, this agreement is widely seen as a turning point that shifted responsibility for the Palestinian water sector to the Palestinian Authority. Yet in practice the interim agreement did not change the scope of Israeli control.<sup>155</sup>

The Interim Agreement includes provisions for both parties to establish a permanent Joint Water Committee for the interim period. This body is charged with regulating water resources use in the West Bank.

## AGREEMENTS: ISRAEL & JORDAN

In the framework of the Madrid Conference, Israel and Jordan concluded the Treaty of Peace between the State of Israel and the Hashemite Kingdom of Jordan in October 1994. Annex II of the treaty deals with shared water resources, detailing water allocation, storage, water quality and protection, groundwater in Wadi Araba and the establishment of a Joint Water Committee.<sup>156</sup>

The agreement specifies that Israel is to receive an annual 25 MCM (12 MCM in summer, 13 MCM in winter)<sup>157</sup> from the Yarmouk River, while Jordan is to receive the rest of the flow.<sup>158</sup> The two countries also agreed that Israel can abstract an additional 20 MCM/yr from the Yarmouk River in winter, and in exchange transfers 20 MCM/yr of Jordan River water to Jordan in summertime.<sup>159</sup> In addition, Jordan is entitled to an annual 10 MCM of desalinated water from saline springs diverted to the Lower Jordan River. However, the treaty does not specify the exact amount of water to be supplied to Jordan.<sup>160</sup>

Besides ambiguities in the text,<sup>161</sup> several provisions have not been implemented as outlined in the agreement,<sup>162</sup> placing pressure on Israeli-Jordanian cooperation in the domain of water.

## COOPERATION: JORDAN & SYRIA

In accordance with the 1987 bilateral agreement, Jordan and Syria established the Jordanian-Syrian Yarmouk River Basin Higher Committee. Representatives from the Jordan Valley Authority and the Syrian Ministry of Irrigation meet regularly to discuss issues of common interest, such as flood water storage in Syrian dams and the Wahdah Dam, the prevention of illegal agricultural activities and the control of unregulated groundwater pumping.

### BOX 11

#### Division of the West Bank into Three Administrative Sectors

Following the Oslo Accords, the West Bank was divided into three administrative sectors, and most of the Jordan Valley – the area with the most fertile lands in the Palestinian part of the basin – was placed under Israeli control and administration (Area C, which covers about 60% of the West Bank). The land along the western banks of the Jordan River was declared “closed military areas”. The only water resources in the Jordan River basin that Palestinians can use are inflows to the Jordan River and precipitation falling in the part of the basin that is controlled and administered by the Palestinian Authority (Area A). Even in this area, however, Israel can exercise its veto power over any water-related project. As a result, Palestinian project proposals for water development and maintenance regularly encounter years of delay or are rejected entirely.<sup>a</sup>

(a) UN-OCHA, 2012b.

In 2009, the two countries commissioned a joint study to evaluate the quantity and quality of water resources in the Yarmouk Basin, identify the causes of their depletion, and propose ways of protecting the basin from pollution and arbitrary pumping.<sup>163</sup> Furthermore, the parties agreed to establish six water monitoring stations on the Yarmouk to measure water inflows upstream of the Wahdah Dam, with three stations in Jordan (Wadi Glaed, Wadi Shallala, Wadi Zizoun) and three in Syria (Wadi Raqqad, Wadi Allan, Wadi Harir).

## COOPERATION: ISRAEL & PALESTINE

In accordance with the Interim Agreement, the parties established in 1994 the Joint Water Committee (JWC), which comprises an equal number of representatives from Israel and the Palestinian Authority. It is charged with overseeing water resources management in the West Bank, excluding Gaza and the Jordan River.<sup>164</sup> Hailed as a success story for Israeli-Palestinian cooperation, the committee’s work had limited impact.<sup>165</sup> Thus while it was set up to make all decisions in consensus, it lacks a mechanism to settle disputes. This has allowed Israel to veto Palestinian requests to drill new wells and obtain the additional water resources stipulated in the agreement.<sup>166</sup> As a result, JWC has been criticized as a means of “dressing up domination as cooperation”.<sup>167</sup>

The Israeli minister of environment and the Palestinian minister of water conceded in December 2011<sup>168</sup> that JWC is ineffective. While they disagreed on how this could be remedied, they both called for the re-examination of the committee’s structure and operational mechanism.<sup>169</sup>

## COOPERATION: ISRAEL & JORDAN

The Israeli-Jordanian Joint Water Committee (JWC) was established to implement the treaty





between Israel and Jordan and facilitate joint development cooperation in the basin. The committee is made up of three high-ranking government officials from each state<sup>170</sup> and members communicate directly in regular meetings. Committee meetings are reportedly professional, but not always free of disputes. Decisions are made unanimously and at the end of each meeting minutes are compiled and submitted to the respective governments. Members are said to focus on technical issues in order to avoid discussion of sensitive political issues.<sup>171</sup>

The agreement mandates the committee to undertake monitoring inspections, but in practice it depends largely on the permission of member states to visit specific locations. In addition to the weak monitoring powers, JWC lacks a proper conflict-resolution mechanism. In case a dispute erupts but fails to be resolved in the committee, it can therefore negatively impact interstate relations.<sup>172</sup>

## OUTLOOK

The Jordan River basin is comparatively small in an international context, yet it has a unique cultural and historical significance. The basin has been extensively studied and discussed, attracting scholars from various disciplines, diplomats, politicians, development workers and the media to analyse the dispute over water allocation in the basin and, more recently, the worsening environmental degradation. However, numerous failed attempts to reach a basin-wide agreement over water-sharing indicate that a resolution of the over-arching political conflict is prerequisite.

Shared water management in the Jordan River basin forms the subject of numerous regional and international studies and projects, including several initiatives to promote cooperation between all or some of the basin riparians.<sup>173</sup> While some projects include all riparians, other projects neglect upstream basin riparians and focus on infrastructure projects in order to address the severe water shortage in the region. The political conflict in the region and the ongoing Israeli occupation continues to stand in the way of a basin-wide agreement on water but also hampers many attempts to encourage cooperation over and a common understanding of the sustainable development and management of shared resources in the basin, including the preservation of the basin's natural wealth.



Lake Hula, Israel, 2008. Source: Itamar Grinberg.

A number of other points are important when considering the future of the Jordan River basin:

The data available for this study does not allow for a clear statement on changing precipitation patterns in the basin area. The perceived increase in low rainfall years over recent decades may impact surface runoff, the level of dam reservoirs and the recharge of aquifer systems. However, the role of intensive water use in the basin may outweigh any effect caused by climatic changes.

Demographic development in the Jordan River Basin has resulted in an intensification of land (development of housing, roads and other topographic changes) and water resources use (construction of dams and rainwater harvesting systems, excessive well drilling) in Israel, Jordan and Syria and has dramatically reduced transboundary flow. This situation is unlikely to change in the near future. On the contrary, Lebanon will eventually develop its southern districts, while Palestine plans to implement projects such as the West Ghor Canal. The current strife in Syria and refugee spillover to Jordan and Lebanon are putting further pressure on water resources in the Jordan River Basin.

Finally, as the pressure on water resources in the basin continues to increase and its ecosystem is threatened, it is clear that the strengthening of monitoring programmes and the exchange of data would allow for more sustainable region-wide water resources management.



# Notes

1. The Dead Sea basin includes the Jordan River basin and catchments of wadis that discharge directly into Dead Sea from the east and west in addition to Wadi Araba to the south. The Dead Sea Basin is shared between six countries: Israel, Jordan, Lebanon, Palestine and Syria, with a minor part of the basin in Egypt.
2. Rouyer, 2000.
3. The Arabic name of the Dan is Liddan.
4. Basin area was estimated from a digital elevation model (HydroSHEDS) similar to Lehner et al., 2008.
5. Zeitoun et al., 2012.
6. Ibid. For the purpose of this Inventory the length of the Upper Jordan River has been calculated at 38 km from the confluence of the headwaters to the outlet at Lake Tiberias.
7. Institute for Veterinary Public Health, 2011; WorldClim, 2011.
8. Jordan Meteorological Department, 1999.
9. Precipitation data collected at high elevations in the basin show impressive records of 1,600-2,400 mm (Briemann, 2008).
10. Beaumont in Kliot, 1994.
11. Zeitoun et al., 2012.
12. Known as Snir in Israel.
13. Known as Hermon in Israel.
14. The Hasbani River has another perennial tributary, the Ajoun (also known as Bright), which also originates in Lebanon and has a basin area of 51 km<sup>2</sup>. The area for all three sub-basins was estimated from a digital elevation model (HydroSHEDS) similar to Lehner et al., 2008 and may therefore contradict national basin estimates as in the case of the Hasbani Basin which is stated at 600 km<sup>2</sup> [Ministry of Energy and Water in Lebanon, 2011].
15. Zeitoun et al., 2012; Briemann, 2008.
16. Briemann, 2008.
17. Rimmer and Salingar, 2006.
18. Briemann, 2008.
19. Klingbeil, 2012.
20. Both discharge records exhibit almost identical dynamics expressed by a CV of around 0.4.
21. These differences can also be a result of errors in discharge measurements. According to Sauer and Meyer, 1992, standard errors for discharge measurements can range from 2% under ideal conditions to about 20% when conditions are poor and shortcut methods are used.
22. Menzel et al., 2011.
23. See Chap. 21 for more information on the groundwater basin.
24. Errors in discharge measurements for these two stations are expected to be significant.
25. Courcier et al., 2005; FoEME, 2011 calculates the historic flow of the Yarmouk at 470 MCM. Kliot, 1994 estimates Yarmouk flow at 450-475 MCM, while Libiszewski, 1995, and Burdon, 1954 state that the Yarmouk contributes 450-500 MCM to the basin.
26. Extreme floods in 2003 disabled measurement facilities at Addasiya. Discharge in this year was estimated to be much higher than that of 1963 (Regner, 2012).
27. See Table 7 for an overview of dams in the basin.
28. Estimates range between 450 and 500 MCM (see Courcier et al., 2005; FoEME, 2011; Kliot, 1994).
29. See section on Water Resources Management and Chap. 21 for more information.
30. FoEME, 2011 reports that the level of Lake Tiberias has dropped below -211 m asl since 2006, which is the artificial level of the riverbed. This means that even when the dam was open, no water could flow out of the lake. Instead it had to be pumped from the lake to pass the Degania Dam.
31. During the monitoring period 1979-1999, a CV record of 1.07 was observed, indicating strong flow variability.
32. FoEME, 2010.
33. Courcier et al., 2005.
34. Courcier et al., 2005; FoEME, 2011 calculates the historic flow of the Yarmouk at 470 MCM. Kliot, 1994 estimates Yarmouk flow at 450-475 MCM, while Libiszewski, 1995, and Burdon, 1954 state that the Yarmouk contributes 450-500 MCM to the basin.
35. Anisfeld and Shub, 2009; Courcier et al., 2005; Al-Weshah, 2000 (1,400 MCM); Hof, 1998; Klein, 1998.
36. Courcier et al., 2005.
37. Ministry of Water and Irrigation in Jordan, 2011.
38. FoEME, 2011 states 20-30 MCM in 2009, Al-Weshah, 2000 states 175 MCM, Courcier et al., 2005 states about 275 MCM for 2000, while Klein, 1998 estimated 220-250 MCM during the 1980s.
39. Lowi, 1993.
40. Courcier et al., 2005.
41. In the case of Israel and Jordan in the early 1950s mainly for the absorption of immigrants and refugees (Lowi, 1993).
42. For more information on the region's hydropolitical history and the impact of the Six-Day War on water resources management see Feitelson, 2000; Lowi, 1993; Zeitoun and Warner, 2006.
43. Venot et al., 2006.
44. FAO, 2009, p. 85.
45. FoEME, 2010.
46. From 1996 onwards, water shortages have shifted the balance in favour of municipal use (e.g. in the eastern Jordan Valley, the agricultural sector uses treated wastewater).
47. Sofer, 1999, p. 217. "It must be noted that the region was much less developed than the rest of Lebanon before the occupation in 1978, particularly in terms of public infrastructure such as drinking water networks, sewerage collection and disposal networks and irrigation systems" (Comair, 2005, p. 14).
48. Israel's 1978 invasion of Lebanon is known as the 'Operation Litani'. It triggered the South Lebanon Conflict (Zeitoun et al., 2012).
49. Maternowski, 2006, p. 50.
50. Zeitoun et al., 2012, p. 51.
51. Republic of Lebanon, 2002.
52. The exact number quoted is 6.88 MCM/yr although no specific year is mentioned (Comair, 2005, p. 18; Comair, 2009, p. 255).
53. Rough estimate. Zeitoun et al., 2012.
54. The numbers include data from the 1999 agricultural census for three districts that lie in the Hasbani Basin: Hasbaya, Marjeoun and Rachaya (Ministry of Agriculture in Lebanon and FAO, 2005).



55. Supplementary irrigation can be defined as the addition of small amounts of water to essentially rain-fed crops in order to improve and stabilize yields when rainfall fails to provide sufficient moisture for normal plant growth.
56. Merheb, 2010.
57. Zeitoun et al., 2012, p. 55.
58. Kliot, 1994, p. 209.
59. Hof, 1998.
60. El-Nasser in Courcier et al., 2005.
61. See section on Agreements, Cooperation & Outlook below for more information.
62. Also known as the Maqarin Dam.
63. See table annexed to the agreement (The Syrian Arab Republic and Jordan, 1987). Of the 25 dams listed in the agreement, 22 have been constructed to date, with a total capacity of 145.7 MCM.
64. Ministry of Irrigation in the Syrian Arab Republic, 2006.
65. Syria considers two additional dams to be part of the Yarmouk Basin: Al Zalf and Jabal al Arab, which have a storage capacity of 9.6 MCM and 19.5 MCM respectively. As they are located outside the Yarmouk Basin as delineated in this Inventory, these two dams are not included in the total capacity.
66. Kolars, 1992, p. 110.
67. See section on Agreements, Cooperation & Outlook below for more information on the Syrian-Jordanian agreement.
68. Kliot, 1994, p. 212.
69. Ministry of Irrigation in the Syrian Arab Republic, 2012.
70. Ministry of Irrigation in the Syrian Arab Republic, 2012. Varelo-Ortega and Sagardoy, 2003 states similar values for 1999/2000 for the irrigated area in the Yarmouk Basin.
71. FAO, 2009, p. 85.
72. According to PASSIA, 2002, Israel diverts 75% of the Jordan River before it reaches the West Bank.
73. Courcier et al., 2005, p. 2.
74. OECD, 2010.
75. Including the sub-districts Golan, Lake Tiberias and Zefat.
76. FAO, 2012.
77. Courcier et al., 2005 suggest that 100 MCM were used annually (in 2000) for irrigated agriculture in the north/Lake Tiberias region.
78. According to an assumed water application rate of approximately 10,000 m<sup>3</sup>/ha/yr.
79. OECD, 2010. However, more recently this water has been supplemented by application of treated wastewater.
80. FAO, 2012.
81. The Jordan River basin is the most water-rich area in Jordan, supplying 80% of the country's water resources (see Courcier et al., 2005).
82. Also known as the Greater Yarmouk Project.
83. Murakami, 1995, p. 297.
84. Originally East Ghor Canal.
85. Murakami, 1995.
86. The Mukheibeh Wells are an important groundwater resource situated to the north of the Jordan Valley, representing an annual flow of 25 MCM (Grawitz, 1998).
87. Ammary, 2007.
88. Venot et al., 2005.
89. Ministry of Water and Irrigation in Jordan, 2011.
90. Courcier et al., 2005.
91. Ibid.
92. Ministry of Water and Irrigation in Jordan, 2009 (figures for 2007). Other sources state that the agricultural sector in Jordan consumes 70% of water resources (Venot, 2004.)
93. Venot, 2004. The Jordanian highlands extend from the north of the country to the south and separate the Jordan Valley from the eastern desert plains.
94. Molle et al., 2008.
95. Ministry of Water and Irrigation in Jordan, 2009.
96. Venot, 2004.
97. Ministry of Water and Irrigation in Jordan, 2009.
98. Molle et al., 2008.
99. JVA, 2011, p. 43-44. These sources include the Yarmouk River, Mukheibeh Wells, Zarqa River, and the following wadis: Hisban, Jurum, Kafrin, Kufrinjah, Rajib, Ziqlab and other small wadis in the northern part of the Jordan Valley.
100. See also Ministry of Water and Irrigation in Jordan, 2002a and JVA, 2011.
101. Zeitoun et al., 2012, p. 30.
102. PWA, 2012.
103. Kliot, 1994, p. 217.
104. PWA, 2012.
105. Ibid.
106. UN-OCHA, 2012a.
107. Ibid; Amnesty International, 2009; Shuval and Dweik, 2007, p. 22.
108. PWA, 2012.
109. FoEME, 2010.
110. Murakami, 1995.
111. Briemann, 2008.
112. Zeitoun et al., 2012.
113. Barinova and Nevo, 2010.
114. Shafir and Alpert, 2011 reported that evaporation from Lake Tiberias, measured by pan-evaporation, has increased by 20%-25% over the past four decades.
115. Siebert et al., 2009; FoEME, 2011.
116. Hambright et al., 2000.
117. Markel, 2005; Farber et al., 2005. Primarily the Tabgha Springs and Tiberias Hot Springs.
118. Farber et al., 2005.
119. Kiperwas, 2011. The highest chlorinity level after the construction of SDC was 300 mg/L during the drought period from the mid-1990s to 2002 (Siebert et al., 2009).
120. FAO, 2009; Farber et al., 2004; FoEME, 2010.
121. Hambright et al., 2000; Markel, 2005.
122. Rom, 1999 in Gophen et al., 2003.
123. Farber et al., 2004.
124. Al-Taani, 2011; Ministry of Water and Irrigation in Jordan, 2002b.
125. Batayneh, 2011.
126. Batayneh, 2010; Abu-Rukah and Ghrefat, 2001.
127. Alkhoury et al., 2010.
128. RSS, 2010.
129. Ibid; Farber et al., 2004.
130. RSS, 2010.
131. Al-Wer, 2009; Al-Momani, 2011.



132. Melkawi and Shiyab, 2003.
133. Ministry of Water and Irrigation in Jordan, 2002b.
134. Alkhoury et al., 2010.
135. John Hopkins University Global Water Program Magazine, 2010.
136. FoEME, 2010.
137. Referred to as "Bitaniya sewage" from the Bitaniya wastewater treatment plant.
138. Barinova et al., 2010; Farber et al., 2005.
139. FoEME, 2010.
140. Ibid.
141. Ministry of Water and Irrigation in Jordan, 2010. It is suggested that shallow groundwater discharge buffers river quality and reduces salinity in the northern part of the Lower Jordan River (Farber et al., 2005).
142. Farber et al., 2005.
143. FoEME, 2010; The Huffington Post, 2010.
144. FoEME, 2010. Mainly resulting from the loss of fast-flow habitats and floods as well as high water salinity.
145. Farber et al., 2004, Barel-Cohen et al., 2006.
146. RSS, 2010.
147. See section on Water Resources Management above for detailed information on the plans.
148. Jordan was the driving force behind the agreement and was motivated by its ambition to build a dam on the Yarmouk – a structure discussed in the various development plans that preceded the Johnston Plan. See Hof, 1998.
149. See The Syrian Arab Republic and Jordan, 1953, Article 8a.
150. Ibid., Article 8b and 8c.
151. Ibid., Article 10.
152. Hof, 1998.
153. The Syrian Arab Republic and Jordan, 1987; Hof, 1998.
154. Al-Taani, 2011.
155. Zeitoun, 2008.
156. The State of Israel and the Hashemite Kingdom of Jordan, 1994, Article 6 and Annex 2.
157. The summer is from 15 May to 15 October, and the winter is from 16 October to 14 May.
158. The State of Israel and the Hashemite Kingdom of Jordan, 1994, Annex 2, Article 1, Item 1.
159. Ibid., items 1 and 2.
160. Dombrowsky, 2003.
161. Fischhendler, 2008.
162. Haddadin, 2006.
163. Jordan Times, 2009.
164. Israel and the PLO, 1995.
165. Rouyer, 2000.
166. Zeitoun, 2008; UN-OCHA, 2012b.
167. Selby, 2003. Similarly Amnesty International, 2009 refers to JWC as a pretence of cooperation.
168. The discussion took place as part of the panel "Cross-Border Waters and Regional Sustainability" moderated by Gidon Bromberg, Israeli Director of Friends of the Earth Middle East. The Palestinians have suspended their side of JWC since September 2011, arguing that the committee is unable to address any water-related issue. A number of sub-committees are still active but the main decision-making body is not working.
169. According to Bromberg's conclusion of the meeting. See EMWIS, 2012.
170. The secretary-general of the Jordanian Ministry of Water and Irrigation and Jordan Valley Authority and the Israeli director of the Water Demand Management Division are responsible for the daily work of JWC. The Jordanian minister of Water and Irrigation and Israeli water commissioner periodically attend JWC meetings and oversee the institution. See Zawahri, 2010.
171. Zawahri, 2010.
172. For instance, the 1997 desalination dispute and the 1999 drought required emergency meetings between the state leaders of Jordan and Israel. See Zawahri, 2010 for more detailed information on these cases.
173. Kramer, 2008 reports on water cooperation initiatives in the basin. In addition, there is the Arab Jordan River Basin Initiative, which was promoted through the American University of Beirut in 2009, and the Red Sea-Dead Sea Conduit Project.





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