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The Yarmouk Tributary to the Jordan River I: Agreements Impeding Equitable Transboundary Water Arrangements

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ABSTRACT: This article explores the ways in which two international water agreements on the Yarmouk tributary to the Jordan River induce or impede transformation to equitable transboundary water arrangements. The agreements in question were reached between Jordan and Syria in 1987, and between Jordan and Israel in 1994. Following a brief review of theory and a summary of the body of knowledge on 'model' agreements, the article combines official river-gauging data with interviews and textual analysis to query the text and role of the agreements, particularly in relation to key dams and other infrastructure. Both agreements are found to i) lack important clauses that could govern groundwater abstraction, environmental concerns, water quality, and the ability to adapt to changing water quality, availability and need; and ii) include both ambiguous and rigid clauses that result in generally inequitable allocation of water and thus of the benefits derived from its use. Due to their omissions and to their reflection of the asymmetries in power between the states, both agreements are found to be 'blind' to existing use, to be incapable of dealing with urgent governance needs, and to impede more equitable arrangements.

KEYWORDS: Jordan River, Yarmouk, transboundary water politics, water treaties, water agreements, hydro-hegemony, Jordan, Syria, Israel

INTRODUCTION

Do international agreements promote or impede fair transboundary water arrangements? And, if they do, how do they do so? The people who live the effects of inequitable arrangements would benefit from clear answers, as would the many activists, researchers and diplomats who are trying to improve the collaboration between states and their citizens on the sharing of water.

Formal agreements have been hailed in established hydropolitical research and policy reports as proof of 'cooperative' arrangements, meaning that the treaties themselves are sometimes presented as the end goal (Wolf, 2007; FOEME, 2008; Brochmann, 2012; EcoPeace-INSS, 2018; Wang and Li, 2018). Investigators into the design and function of water agreements are beginning to question the degree to which the received wisdom holds (Zawahri and Gerlak, 2009; Gerlak et al., 2011; Zentner, 2012; Giordano et al., 2013; Lankford, 2013; Aggestam and Sundell, 2015; Dinar et al., 2015; Gerlak and Mukhtarov, 2015; Giordano et al., 2016; Krampe, 2016; GWH-SFG, 2017; Zawahri and Michel, 2018; Dinar et al., 2019). In fact, the exact opposite argument has also been advanced: that transboundary water agreements can be used to coercively achieve the outcome sought by the more powerful actor, just as readily as they can be used to encourage joint action or other more and less friendly forms of cooperation (Zeitoun et al., 2011; Zeitoun et al., 2016).

This article answers the research questions by examining the two agreements reached over the Yarmouk tributary of the Jordan River, while a companion article (The Yarmouk tributary to the Jordan River II: Infrastructure impeding the transformation of equitable transboundary water arrangements (Zeitoun et al., 2019b)) explores these questions in relation to the suite of infrastructure that the agreements have enabled. The agreements in question are the "Agreement concerning the utilization of the Yarmuk [sic] waters (with annex). Signed at Amman on 3 September 1987" (hereinafter referred to as the 1987 Syria-Jordan agreement or 1987 agreement), and the Yarmouk-relevant aspects of Annex II of the "Treaty of Peace Between the State of Israel and the Hashemite Kingdom of Jordan" (hereinafter referred to as the 1994 Israel-Jordan Water Annex, or simply 'Annex II'). The Syria-Jordan agreement has received relatively little scrutiny (though see the very thorough Haddadin, 2002, and Wolf and Newton, 2007), while quite contradictory evaluations have been produced by the many investigations of the Israel-Jordan Water Annex, as will be discussed. Both agreements continue to shape transboundary water arrangements more than a quarter of a century after their negotiation, even as their static text stands in direct contrast to the ever-changing natural and political environment.

This article is the first to evaluate the two agreements alongside each other, and to evaluate them – to the extent that it is feasible within data limitations – in relation to the hydropolitics of the wider Jordan River Basin. The article also departs from others in examining the extent of the influence of the agreements specifically in relation to 'equitable transboundary water arrangements'. Here, a transboundary water arrangement is understood to refer to the infrastructure, protocols, river basin commissions, and other formal and informal institutional structures that shape policy and the use of transboundary waters (primarily) between states (Zeitoun et al., 2019b); 'inequitable' arrangements are understood to mean those that lack measures that might ensure fairness (with 'fairness' being interpreted loosely as 'equitable and reasonable use' as it is put forward in International Water Law).

The first level of analysis compares the text of the agreements against the growing body of peer reviewed research on model water agreements. The analysis is then deepened through a study of the perceived and actual violations of the agreements and the equitability of their allocation mechanisms. The data for this second cut of analysis comes from the published literature, from archives (French, British, Zionist), from interviews with key Jordanian and Israeli water resource managers, and from field observation, satellite imagery and all public hydrologic or hydraulic data available from Syria, as well as from Israeli pumping records and Jordanian river and canal-gauging records.

While pumping and gauging records are presented with some degree of accuracy, the quality of this data limits the article’s findings to being only indicative. There is a particular lack of confidence in the quality of the gauging records, as noted in greater detail in the relevant sections. A further challenge to the analysis is its focus on a tributary of a wider basin. Isolating the Yarmouk tributary from the rest of the Jordan River Basin would be feasible if only flows and water use were being considered, but this is not possible when international institutions and politics are also being investigated. The Yarmouk is not considered independently of the Jordan River by water resource managers (whether Syrian, Jordanian or Israeli), by International Water Law (which uses the wider basin as a unit of measurement), or by Annex II of the 1994 Israel-Jordan peace treaty.

The clauses of the agreements are found to fall well short of those of a model agreement. This is due in part to the fact that the authors of the agreements could not benefit from the many advances in treaty analysis that have been made in the last few decades. Still, the omission of very basic clauses, considered alongside the presence of rigid, ambiguous and inequitable clauses, suggests that the agreements were designed in part to lock in the arrangement that had been established at the time of signing. The agreements are in effect 'blind' to much water use that would otherwise be considered violations of an equitable arrangement, and constrain transboundary management efforts.

WHAT WE KNOW ABOUT TRANSBOUNDARY WATER AGREEMENTS

The transformation of an inequitable transboundary water arrangement to a more equitable and sustainable arrangement is understood in the manner of Lederach (2003, 2005), with an appreciation that conflicts are never truly resolved. The transformation from one form of arrangement into another is the result of processes of continuous interaction between the parties. As such, the conflict and cooperation that exist alongside each other (Mirumachi, 2015) can be transformed through alteration of the institutional and physical structures that sustain the arrangement, and this conflict/cooperation itself can initiate structural change (within, for example, the political economy, geopolitical or ecological systems). The resultant arrangement may be more equitable and sustainable according to the above definition, but it is not likely to be seen as such by all concerned – and some tensions are bound to remain.

Disagreements over agreements

Moving beyond the assumption that international water treaties or agreements are evidence of transboundary water 'cooperation' (see discussion in Zeitoun and Mirumachi, 2008), investigation into the design and function of water and environmental agreements reveals that there is a lot more to the picture. Large-N analysis of associations between treaties and politics suggests, for instance, that reaching a cooperative agreement "facilitates reconciliation in international rivalries", at least when there is great environmental attention, internal political stability, traditions of environmental cooperation, and existing processes of reconciliation (Ide, 2018). As such conditions are not present in the case at hand, insight may be shed by other studies that concentrate on the extent to which agreements reduce tensions. These find, for example, that the associated institutions can evolve with crises (Fischhendler, 2004), and can produce a certain ability to generate "stress-management capabilities" (Zentner, 2012).

Case studies of individual treaties offer yet further insight and nuance. One example is the influence of non-state actors on the negotiation of agreements between Canada and the United States (Norman, 2012); another is the limited extent of the guiding role of the International Water Law on Nile water agreements (Abseno, 2013; Salman, 2014); yet another example warranting study is that of the problems arising from the inflexibility of negotiators on Indus water agreements (Zawahri and Michel, 2018). A more critical vein of hydropolitics explores how agreements are used to maintain transboundary water arrangements that favour the more powerful actors, as in the case of the 1959 Nile Waters Agreement (Cascão and Nicol, 2016), the 1995 Mekong Agreement (Bearden, 2012), the 1995 Oslo II Accord between Israel and the Palestine Liberation Organization (Selby, 2013), the Ganges Treaty between India and Bangladesh to share the waters of the Farakka Barrage (Thomas, 2017), and other treaties to share the water of the Zambezi Basin and the Mekong (Fox and Sneddon, 2007). Taken together, and as considered in greater detail in Zeitoun et al. (2019), these cases show how the (usually technocratic) structures and processes of international negotiations serve to set the parameters of the water deals that are reached.

Model water treaties and agreements

The fact that the 1987 Syria-Jordan water agreement was the result of a renegotiation of the immediately postcolonial 1953 agreement confirms a well-known fact: that treaties are modified, ripped-up, or renegotiated whenever the political will to do so arises. An agreement can otherwise endure for decades, no matter how skewed or faulty. Fortunately, in these latter cases, legal and social science research into the effectiveness of transboundary water agreements provides guidance that may help the drafters to 'get it right' from the outset. The guidance comes in the form of the recommended inclusion in sustainable agreements of a number of features or mechanisms, as presented in Table 1. The discussion following is limited to mechanisms that deal with allocation, accounting and uncertainty.

Table 1. Some of the indicative features of a model transboundary water agreement.

Features of a model transboundary water treaty
Allocative mechanisms
Based on 'equitable and reasonable use'
Specific, rather than ambiguous
Flexible, rather than rigid
Technical mechanisms (related to, for example, conjunctive groundwater and surface water)
Acknowledgement of surface water and groundwater as part of the same transboundary watercourse
Adequate accounting for use, amount and quality of groundwater in reserve, and rate of replenishment
Common identification, delineation and characterisation of transboundary groundwater
Appropriate measures to prevent, control and reduce the pollution of transboundary groundwater
Comprehensive water accounting (including use, amount and quality of soil water, and gains made through improvements in irrigation efficiency/in the 'paracommons')
Uncertainty mechanisms (related to changes in needs, climate, etc)
Revisiting clauses
Escape clauses
Institutional mechanisms
'prior notification'
'no significant harm'
Enforcement clauses
Monitoring provisions
Dispute-resolution mechanisms
Self-enforcement mechanisms
Creation of multilateral bodies for information exchange or joint management
Environmental and health concerns
Water quality provisions
Biodiversity, river base flows, etc.

Source: Based on Hayton and Utton, 1989; UNECE, 1992; Rieu-Clarke et al., 2012; Zentner, 2012; Giordano et al., 2013; Tanzi, 2013; UNECE, 2013, Dinar et al., 2015; Simons et al., 2015; Jafroudi, 2018).

The body of knowledge on water agreements finds, for example, that allocative mechanisms are more effective when based on a combination of water quality, use, need, and availability, rather than on availability alone as they have tended to do in the past. The UN Watercourses Convention and the UNECE Water Convention are the gold-standard guides in this regard, notably for their substantive principle of equitable and reasonable use (McCaffrey, 2008; Rieu-Clarke et al., 2012; Vink, 2014). In places where availability cannot satisfy demand, the conventions advise that prioritisation be negotiated on the basis of use, with domestic and drinking water, for example, being prioritised over industry use.

Allocative mechanisms, furthermore, are found to be more effective if they avoid ambiguity in defining flows and uses. As Fischhendler (2008b) notes, ambiguity in the clauses allows negotiators to interpret them differently, meaning each can present the agreement in a favourable light to their head of state and compatriots. On the other hand, intentional ambiguity can lead to lowest-common-denominator outputs (thus potentially compromising a better agreement), or it can simply displace the more contentious issues. As Jägerskog (2003: 118) points out, "ambiguity is only useful when reaching agreement, and is problematic in the implementation process". The point is particularly apposite in relation to the 1994 Israel-Jordan water agreement, as discussed below.

The literature further advises that allocative mechanisms should be flexible rather than rigid, in order particularly to reflect the variability in rainfall and water availability within or across the years (see, for example, Zentner, 2012, and Dinar et al., 2015). An agreement that specifies percentages of river flow makes for much easier compliance by all sides than one that allocates, for example, specific volumes, particularly in semi-arid basins with significant wet and dry seasons.

To be effective, transboundary water arrangements should also incorporate all available sources of water, not least of all the groundwater which is often hydraulically linked with mainstream river flows.[1] While irrigation water that seeps into the soil or aquifers may be considered an indicator of inefficiency, these water flows often become available for use elsewhere (Perry et al., 2009; Gleick et al., 2011; Lankford, 2012). Water gains that are made as irrigation systems become more efficient are part of what Lankford (2013) calls the 'paracommons'. Reconceptualising the way that water is accounted for or moves around its cycle may further add transparency to the negotiations and therefore to the agreements (see, for example, Bastiaanssen et al., 2014; Bromwich et al., 2018; Abbott et al., 2019).

Another identified component of effective transboundary water agreements is the ability to deal with and adapt to changes and uncertainty. In and around the Yarmouk, conditions are constantly changing. River modelling under different climate scenarios projects drops in precipitation in the basin (Al Raggad et al., 2018) and in the mainstream Yarmouk flow (Rajsekhar and Gorelick, 2017). The demand for water has increased with the dramatic rise in population, particularly in Jordan because of its hosting of millions of displaced Palestinian, Iraqi, and Syrian people (Hussein and Grandi, 2015). Examples of textual mechanisms that have been developed to allow treaties to accommodate such change include the revisiting clauses that schedule renegotiations after the passage of time, as found in the Columbia River Treaty between Canada and the US (Cosens and Williams, 2012); the amendable portions of an agreement, as exemplified by the minutes of the US – Mexico water arrangements (Milman and Schott, 2010); and the escape clauses inserted to cover exceptional circumstances such as floods or acts of revolution (De Stefano et al., 2012; Dinar et al., 2015).

The features of a model agreement can be discussed at length; it should be noted, however, that although these features are necessary they are not at all sufficient conditions for an equitable and sustainable transboundary water arrangement. All transboundary water arrangements are much more than their agreements, and the transformation of these arrangements requires deeper study at the

[1] Soil water can be considered a further resource because of the substantial amount of food that is produced from it, especially in humid or tropical climates. Transpirated back to the atmosphere primarily through leaves, the main qualitative difference between soil water and groundwater or surface water is the fact that it is not shareable. It cannot be abstracted, treated, distributed or denied to anyone.

outset (see Zeitoun et al., 2019a). Still, the theory reviewed here suggests that the excluding or ignoring of most of the features of a model agreement is a symptom of inequitable transboundary water arrangements, ones which merit further investigation.

DEVELOPMENT AND SHARING OF THE YARMOUK, WITHIN THE WIDER JORDAN RIVER BASIN

This section reviews how Syria, Jordan and Israel developed, use and share the water resources of the Yarmouk tributary. The Yarmouk River (Figure 1) is the longest tributary of the Jordan River, running for over 140 kilometres. It flows from Jabal al Arab/Jabal al Druze, at an elevation of about 1700 metres above sea level (masl), to Baqura/Naharayim, at 200 metres below sea level, where it joins the lower main Jordan River (Al-Rubeai, 2004; UN-ESCWA/BGR, 2013). Approximately 80% of its 7000 square kilometre river basin (Al-Ghraibeh, 2008; Al Manaseer, 2012) lies inside Syria, including the Golan, which has been occupied by Israel since 1967, 19.7% of the river basin lies inside Jordan; and 0.3% is in Israel, not including the Occupied Syrian Golan (UEA, 2019a). In 2010, an estimated 1.6 million people lived in the basin (UN-ESCWA/BGR, 2013; Al Qusaym, 2016; CBS, 2016), though there are no reliable census figures and many thousands have been displaced since the start of the war in Syria in 2011. The basin also overlies a series of aquifers that span an area that extends beyond the hydrological border, notably the 'shallow basalt' and 'deeper limestone' aquifers in Syria, with the latter also referred to as the A7/B2 Aquifer (Cr2cn cp/Cr2m-d) (Burdon et al., 1954; Ponikarov and Mikhailov, 1964; Hobler et al., 2001; Orient, 2011; UN-ESCWA/BGR, 2013; Margane, 2015; Al Raggad et al., 2018). Rainfall patterns are typically Eastern Mediterranean, with no rainfall at all during the summer months and roughly 200 and 400 millimetres falling primarily in the winter months (Burdon, 1954; Mourad and Berndtsson, 2011); reliable meteorological data does not exist, however, due to the lack of operational weather gauging stations. (For modelling, see Shentsis et al., 2018b).

Development and use of surface water and groundwater flows

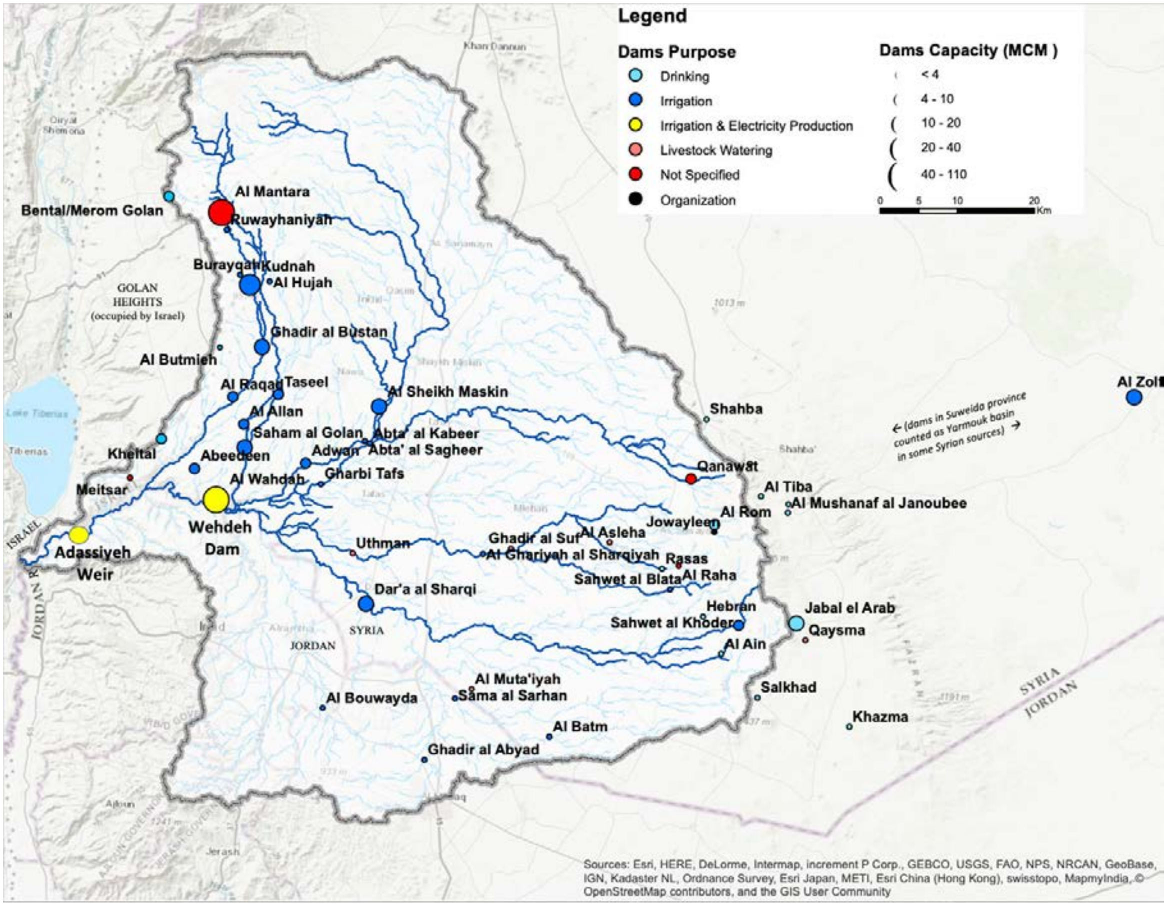
There is considerable disagreement over what is taken to be the normal flow rate of the river, as it is clearly affected by constantly changing surface and groundwater use.[2] Between 1979 and 1988, the average flow of the Yarmouk, as gauged near its confluence with the Jordan River at Baqura/Naharayim, was 229 million cubic metres per year (Mm^3/y) (JVA, 2016). Roughly 40 to 50% of this flow is estimated to have originated as groundwater (see, for example, Ionides, 1939; Shentsis et al., 2018a; also a discussion in UEA, 2019b). The average flow has dropped steadily since the late 1980s; between 2008 and 2015 it was approximately 40 Mm^3/y (HSI, 2016b), this low rate probably being due mainly to changes in water availability, surface water offtakes and groundwater abstraction in Syria and, to a lesser degree, in Jordan (Muller et al., 2016). While water managers in Jordan and Syria tend to agree that the amount of groundwater and surface water pumped out of the basin is greater than the amount that flows or rains back into it, the paucity of reliable gauging data means that it is not possible to estimate actual rates of over-abstraction.

The bulk of the water abstracted is used for agriculture in the Hauran Plain (which is mainly in southern Syria, though extends into northern Jordan); to a lesser extent, the abstracted water is used in what is known as the Yarmouk Triangle, the land between the confluence of the Jordan and the Yarmouk, the Lake of Tiberias, and al Himmeh/Hamet Gader which is mainly in Israel. The abstraction comes through a suite of uncoordinated infrastructure elaborated upon in Zeitoun et al. (2019) and as shown in Figure 2. This includes thousands of wells in Syria and Jordan (Al-Husein, 2007; UN-ESCWA/BGR, 2013; Margane, 2015), the Wehdeh Dam between Syria and Jordan, dozens of dams in Syria (discussed below), three

[2] Early studies converged on an average flow (gauged at Adassiyeh) of approximately 450 to 480 Mm^3 per year (Ionides, 1939; Burdon, 1954; Burdon et al., 1954; Baker and Harza, 1955; Energoprojekt, 1964), while flood flow alone was estimated at 226 Mm^3 per year (Ionides, 1939).

dams in Jordan, four Israeli dams in the Occupied Golan Heights, the King Abdullah Canal in Jordan (see Mustafa and Talozi, 2018), and the 'water exchange' infrastructure (which includes the Adassiyeh diversion weir) built between the Lake of Tiberias and the Yarmouk tributary by Jordan and Israel.

Figure 1. Topographic map of the Yarmouk tributary basin, showing location of the Adassiyeh Weir and the Wehdeh Dam (in yellow), and 31 smaller dams within the hydrological limits of the basin.



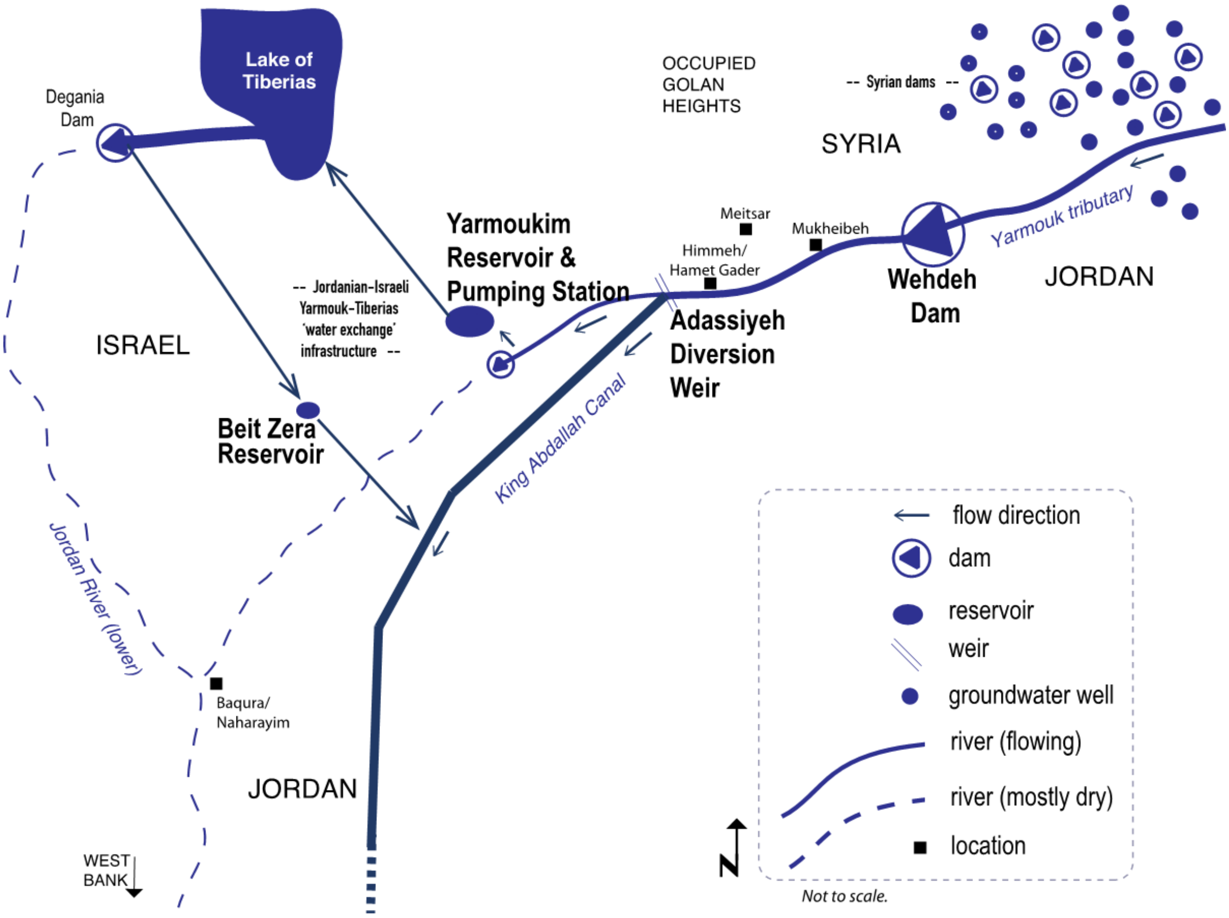
Note: Dams that are outside of the hydrological limit of the basin are also shown, as these are counted as inside the basin by some Syrian sources.

Narratives and inequitable distribution

The development of the Yarmouk is most accurately viewed from the political context of the wider Jordan River Basin, a context which has often been violent. Particularly from the 1950s onwards, there have been repeated military attacks, kidnappings, and several attempts to divert the river (Sosland, 2007; Wolf and Newton, 2007; Gasteyer et al., 2012). Since the signing of the water agreements, the conflict has been expressed primarily through a number of narratives that are tied to perceptions of the agreements.

One of the main narratives heard in ministry and other governmental offices in Jordan is that "Syria violates the water agreement". This is accompanied by claims that Syria has built over 50 dams and drilled thousands of wells; it is often also accompanied by a sub-narrative that "Syria is using more than its fair share" (Hussein, 2017). A Syrian narrative that is less well investigated takes a different tack: "Jordan needs water because it committed to supplying too much to Israel through the 1994 Peace Treaty"; alongside this is a conviction that any additional flows provided to Jordan by Syria would in fact be used by Israel (Dana, 2016; Galili, 2016; Tawil, 2017; Serneel, 2018).

Figure 2. Sketch of the infrastructure in the Yarmouk tributary basin that is investigated in this article. Of direct relevance are the Syrian dams and the infrastructure that accomplishes the 'water exchange' between Jordan and Israel.



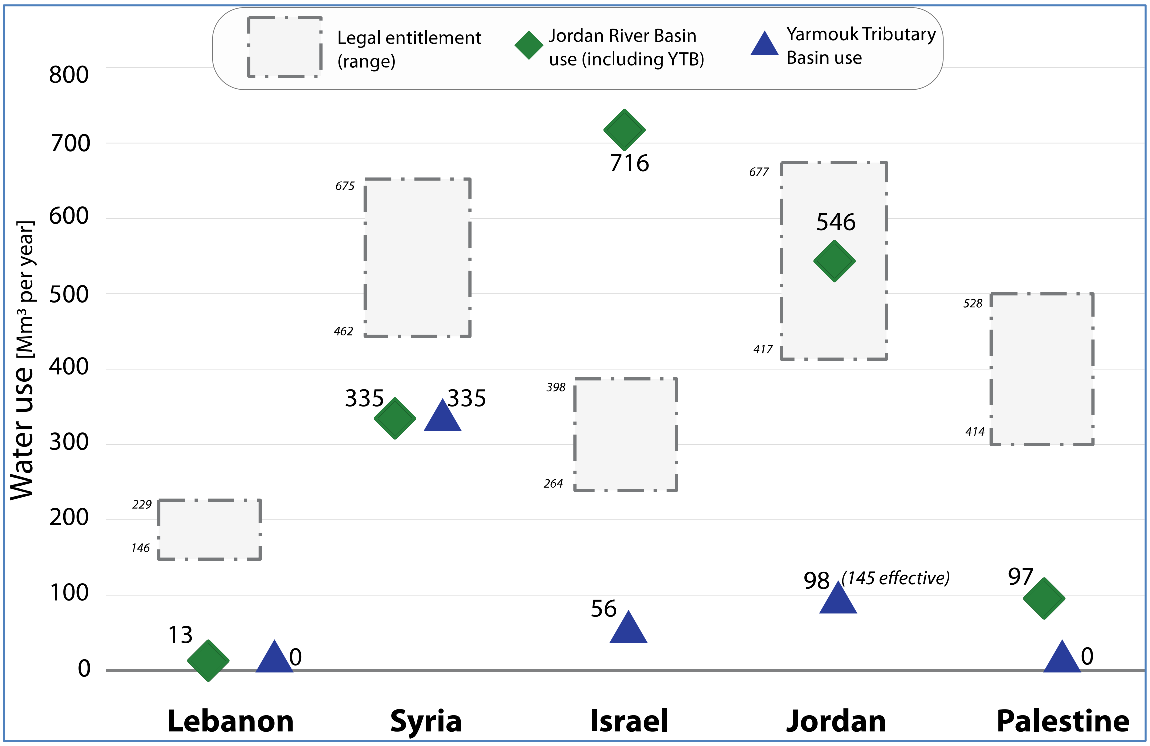
One way to begin an evaluation of the extent to which the narratives hold is by considering how each state's use of the waters of the Yarmouk and the Jordan compares to that of the others. This is shown in Figure 3, and references an estimate of the legal entitlement of each of the Jordan River's riparian states. The estimate comes from Quba'a's (2017) and Quba'a et al'.s (2017a) variation (+/-30%) on the weighting of each of the factors that the International Water Law suggests make up 'equitable and reasonable' shared, as guided by Rieu-Clarke et al. (2012). The same source provides a rough estimate of each state's use of the Jordan River Basin, incorporating the use of groundwater.[3]

Figure 3 seeks to address the previously noted challenge of analysing a tributary of a wider basin without isolating it from its legal, institutional and biophysical context. Taken from a UEA (2019b) analysis, Syria is estimated to use approximately 335 Mm^3/y from the Yarmouk tributary basin,[4] of which

[3] The article did not investigate the number of wells or the estimates of groundwater use in the wider Jordan River Basin.

[4] A review of the literature provides other estimates of Syrian water use in the Yarmouk Basin. UN-ESCWA/BGR (2013: 197) cites the MWI (2014) figure of 453 Mm^3/y, but this figure applies to the administrative (rather than hydrological) boundary of the Yarmouk, which includes all of Al Suwayda Governorate, some of which is outside of the hydrological basin. Of this total Syrian water use, 327 Mm^3/y (of which 60% is groundwater) is used for agriculture, 92 Mm^3/y is for domestic use (assumed to be all sourced from groundwater), and 34 Mm^3/y is for industry (assumed to be all sourced from surface water). The figure of 165 Mm^3/y is derived from these figures and is accurate within the margins of error deriving from the above assumptions. The figure also closely matches the 180 Mm^3/y given in Al Qusaym (2016) and Hoff (n.d.).

Figure 3. Indicative estimates of the use of Yarmouk tributary basin and Jordan River Basin flows, in relation to the range of legal entitlements for each Jordan River state in about 2012.



Source: The estimates of legal entitlements of Jordan River Basin use are based on several secondary sources compiled in Quba'a et al. (2017b: Table 2). (See also Quba'a, 2017: Table 2.6). Estimates of Yarmouk tributary basin use are from numerous secondary sources processed in UEA (2019a) and as explained in the text. Notes: The range for legal entitlement reflects 30% +/- variation in weightings given to ten factors that comprise the calculation of 'equitable and reasonable use'; the Occupied Golan Heights is counted towards the legal entitlement for Syria and towards use for Israel; the numbers are indicative only, due to the limited reliability and compatibility of the data, as explained further in the text; YTB = Yarmouk tributary basin.

approximately 170 Mm^3/y is groundwater pumped from thousands of wells, and roughly 165 Mm^3/y is surface water stored behind 32 dams. Jordan is found to use approximately 98 Mm^3/y directly from the Yarmouk, roughly 32 Mm^3/y of which is groundwater pumped from over 200 wells, and approximately 66 Mm^3/y is surface water diverted by the Adassiyeh Weir into the King Abdullah Canal (as will be discussed below). Since 1995, Jordan has also benefitted from an average of 47 Mm^3/y of non-Yarmouk flows supplied by Israel from the Lake of Tiberias, according to the terms of the 1994 Israel-Jordan peace treaty; Jordan's effective use of the Yarmouk, then, is roughly 145 Mm^3/y. Israel is found to use approximately 56 Mm^3/y of Yarmouk water, which includes the 35 Mm^3/y used directly from the Yarmouk tributary via the Yarmoukim Reservoir (as discussed below), roughly 4 or 5 Mm^3/y from the four dams in the Occupied Syrian Golan Heights (which have a retention capacity of approximately 10 Mm^3/y), roughly 2 Mm^3/y from the wells on the Golan at Meitsar (HSI, 2016a: 352), and 14 Mm^3/y of spring discharge at al Himmeh/Hamat Gader (HSI, 2016a: 353).

Bearing in mind the difficulties of conducting a separate analysis of connected flows, Figure 3 reflects geographical features which are relevant to an analysis of the hydropolitical situation in the area. First, the Yarmouk flows are 'available' to different states in different capacities, with Lebanon and Palestine[5] having no access to the water of the Yarmouk tributary. Second, Syria's use of the Jordan River Basin

[5] 'Palestine', here, refers here to the territories also known as the West Bank and Gaza.

(with water use in the Golan Heights counted as Israel's use) is solely within the Yarmouk tributary basin. There is a generally unequal distribution of Yarmouk water (with Syria using more than double the rest) and of water use across the Jordan Basin as a whole (with Israel using more than triple the rest). Moreover, Israel is using Jordan River flows at a level well beyond the most favourable interpretation of its legal entitlement, while Jordan is abstracting within its range of legal entitlement, and Syria, Lebanon and Palestine are using less than what might be considered their fair shares. The following sections address the extent to which this inequity is challenged or reinforced by the water agreements in question.

THE 1987 SYRIA-JORDAN WATER AGREEMENT

Like its predecessor in 1953,[6] the main purpose of the 1987 Syria-Jordan water agreement was to establish the basis for the construction of a dam at Maqarin that would produce electricity and regulate river flows for irrigation and for "other Jordanian schemes" (Article II). As discussed in greater detail in Zeitoun et al. (2019), construction of the dam at Maqarin has been subject to the considerable ebb and flow of Jordanian – Syrian relations, as well as to Israeli efforts to prevent its materialisation (Sosland, 2007). The dam – without its power-generating component – was completed only in 2006, and was renamed the Wehdeh (or Unity) Dam.

To the extent that the 1987 agreement facilitated the construction of the dam, it can be considered both to have been successful and to be out-dated. But the agreement also suffers from a number of omissions and other weaknesses that suggest that it continues to impede the emergence of an equitable and sustainable transboundary water arrangement.

Rigidity, omissions and allocation

Apart from the 1987 agreement's clause specifying potential heightening of the Maqarin Dam "where such measures are technically and economically justified and agreed on by the two States" (Article VI), the agreement provides little scope for dealing with changed circumstances, including rapid or slower-onset changes in water use and availability driven by war, weather or climate.

The agreement calls for a joint Syria – Jordan Commission to implement its provisions, and advocates that disputes be resolved by finding "an objective solution" (Article IX); however, neither the commission nor the agreement itself can accommodate shifts in water use, whatever their cause. Such shifts may result from significant loss of territory, as followed from the Israeli occupation of the Golan in 1967; reduced water availability because of increased abstraction; heightened demand for water resulting from in-migration, notably to Jordan; the increased availability of alternative sources, such as the gains from increased water use efficiency; or wastewater reuse and desalination, both of which remain minor in Syria and Jordan but are significant in Israel (Feitelson and Rosenthal, 2012; Aviram et al., 2014).

The 1987 agreement makes no mention of, or accounts in any way for, its impact on downstream users – a weakness commonly found in bilateral agreements on multilateral watercourses (not least on the Nile, as discussed by Cascão and Nicol, 2016). The agreement also has no monitoring clauses, no self-enforcement mechanisms that might regulate unfulfilled clauses, and (remarkably) makes no mention of water quality or pollution. In fact, it expresses no concern for the environment in any way and appears to be very much a product of the mindsets that dominated at the time it was originated in the 1950s (see discussion in Giordano et al., 2013).

The sole mention of groundwater is found in Article VII, which specifies that Syria "retains the right to use of the water of all springs welling up within its territory in the basin of the Yarmuk [sic] and its tributaries, with the exception of the waters welling up above the dam below the 250-metre level". The

[6] Of interest is the American draft Jordan–Syrian water agreement of 1952, which appears to be the basis of the 1953 treaty originally signed (see FO, 1952: 42). The 1952 draft is much more specific than the 1953 agreement that was signed – for example, it quantifies flows – and avoids the 250 masl benchmark altogether.

agreement's elevation-based allocation mechanism and neglectful treatment of groundwater is problematic for three reasons. First, considering that all of the springs that are captured in Syria lie above 250 masl (UEA, 2019), the article appears designed to ensure the continuation of the Syria-favouring regime of water use that had been established before the agreement was signed. Second, the lack of limits placed on groundwater abstraction is also a hindrance because of the direct hydraulic connection between the shallow basalt aquifer and the surface water flow or spring discharge. This hydraulic connection means that pumping from wells can diminish surface water flows, at least in the Hauran Plain if not in the deeper gorge where a fault creates a largely impermeable barrier at the border. The third problem with the agreement's poor treatment of groundwater is political. A strict interpretation of the text could be used to argue that Syria would have to limit the depth of the withdrawal levels of its wells to above 250 masl. A related argument could insist that the letter (if not the spirit) of the agreement obliges Jordanian wells to extend below 250 masl, meaning some of the existing Jordanian production wells are not covered.

Apart from the elevation-based mechanism to allocate flows, Article VII of the agreement lumps together the distribution of benefits and of water. This specifies that the electricity the dam was meant to produce would be split between Syria (75%) and Jordan (25%), but that Jordan would bear all the costs of construction and maintenance. Article VII further states that Jordan be given "the right to use the overflow from the Wehdeh Dam reservoir".[7] Because the dam was originally intended to generate electricity, the overflow referred to was in the form of expected releases after the production of electricity and following the abstraction of an unspecified volume of water by Syria for irrigation or domestic consumption. By way of the 1987 agreement, then, Jordan's entitlement is ambiguously limited to the flows in the Yarmouk mainstream that are released from the Wehdeh Dam, which are themselves defined by a very specific clause about dams and surface water use.

In response to claims of inequity and to requests from the Jordanian government, the Government of Syria agreed to a series of additional releases of water for Jordan between 1999 and 2002. The relatively small volume freed up over this period (about 8 Mm^3 in total) contrasted starkly with the great amount of publicity generated (KUNA, 1999; al Farawati, 2001; UEA, 2019a). The Syrian releases, furthermore, were based on a request, not founded in an international agreement; they have also not been repeated since.

No violations but no governance: Omissions and rigidity impeding an equitable arrangement

The filling of the Wehdeh Dam is restricted by Article VI:

> Jordan shall undertake to *design* and build the Wahdah [sic] dam to a total height of 100 metres including floodgates, in order to store the waters flowing into the Yarmouk river *after the filling of the reservoirs of the Syrian dams which are specified with their storage capacity in the annexed table* (emphasis added).

The dams referred to are the very subject of the Jordanian violation narrative previously discussed. The table in question lists the names and storage capacities of 26 dams (which have a total storage capacity of 134 Mm^3).[8] Extensive satellite imagery analysis conducted by the Water Security Research Centre of the University of East Anglia (UEA, 2019: Annex B) identifies 32 dams built in Syria (outside of the

[7] As an interesting historic footnote, the arrangement is similar in this sense to the 1922 Franco-British agreement that specified, among other things, that the "runoff not used by Syria" would flow to Palestine (FNA, 1921, 1940).

[8] This does not include two dams (al Rumi and al Butm) which are mentioned in the table but are not counted as contributing to the filling of the Wehdeh Dam as they are located on the Raqqad tributary, which enters the Yarmouk downstream of the Wehdeh Dam).

Occupied Golan),[9] as shown in Figure 1, with an estimated total storage capacity of 197 Mm^3. This suggests that Syria has thus built six more dams with 63 Mm^3 more storage capacity than each state had agreed to, and that the Jordanian narrative of Syrian violations of the agreement reflects reality to a certain extent.

Because of siltation, pollution, redundancies and rainfall variability, however, the actual retention of water by the dams is considerably less than their design capacity (Avisse et al., 2017; UEA, 2019). It is therefore not likely that the 26 Syrian dams specified in Annex B have ever been consistently filled to their capacity, with some estimates of their actual stored volumes being as low as 20 to 40% of their official capacity (SANA, 2015, 2016). Furthermore, because Article VI stipulates that the filling of these dams is a precondition for the operation of the Wehdeh Dam, it could be argued that the capacity – if not strictly the number – of dams is in compliance with the terms of the agreement.

The findings thus challenge the allegations of violations expressed in the Jordanian narrative of 'syria violates the agreement', but there is a further message to consider. As is the case with lack of regulation of groundwater abstraction, water quality or environmental flows, the text of the agreement offers no incentive or mechanism to either side to even coordinate the construction of the additional dams (not to mention boreholes). While there may be no violations of the agreement, it also provides little governance and locks in the distribution of use that is so apparent in Figure 3.

It is not insignificant, furthermore, that the omissions, inflexibility and inequity all work in favour of the more powerful actor. Refraining from a hydro-hegemonic reading of the situation – which would investigate *why* Jordan agreed to the terms of a clearly skewed agreement – a relevant conclusion is that the obstacle to a more equitable arrangement is not the alleged Syrian violations of the agreement, as the narrative contends, but is the agreement itself.

THE 1994 ISRAEL-JORDAN WATER ANNEX

The water clauses that prescribe the water sharing arrangement between Jordan and Israel are found in Annex II of the 1994 Israel-Jordan peace treaty. Because Annex II does not separate the Yarmouk flows from the broader Jordan River Basin flows, this article's investigation into its influence over the wider Israel-Jordan transboundary water arrangement treads a fine line: it must neither over-attribute the importance of Yarmouk-related findings nor interpret them as divorced from the wider basin and political context.

Contradicting evaluations

With almost no fully endogenous water resources and having consented to a constraining agreement with Syria six years earlier, the peace treaty provided the Government of Jordan with a doubly important opportunity to secure greater use of water resources. Annex II has been heralded for how it secured Israeli recognition of Jordanian "rightful allocations"[10] following decades of contestation and violence (see, for example, Al-Kloub and Abu-Taleb, 1998; Shamir, 1998; Haddadin, 2002; Shamir, 2003; Wiczyk, 2004; Meisen and Tatum, 2011; Choudhury, 2017; Yasuda et al., 2017). A further virtue of the Water Annex is its consideration of water quality, which is intended to protect the resource against pollution. It proposed, for example, treatment of the saline spring flows diverted from the Lake of Tiberias (Article III). Annex II also has relatively strong institutional mechanisms that i) specify a six-month warning period on any projects that might affect the other signatories, ii) establish a Joint Water Committee, and iii) propose that committee as the forum for discussion of prevention of harm and mitigation of adverse

[9] The analysis of satellite imagery also identifies four dams built by Israel within the Yarmouk tributary basin on the Golan, with an estimated storage capacity of 10 Mm^3. Israel has built considerably more water infrastructure on the Golan, which is inside the Jordan River Basin but outside the Yarmouk tributary basin (Dajani, 2018).

[10] As stated in the main text of the treaty, though not in the Water Annex.

effects of any project. It is also forward looking, in the sense that it holds a promise that both sides develop an additional 50 Mm^3/y for Jordan (Art. I.3).

Critics of the Israel-Jordan water agreement argue that its lack of consideration for downstream Palestinian water use means Jordan effectively consents to, and legitimises, the pre-emption of any form of Palestinian self-determination (Baim, 1997; Kubursi et al., 2011; Talozi et al., 2019). The large number of 'creative compromises' made by Jordan have furthermore been considered to be well short of the (1950s US-led diplomatic) 'Johnston allocation' that the state had long been lobbying for (Sosland, 2007: 175), and may be related to what Wine (2019b) sees as being a disproportionate gain by the Israeli agricultural sector. Noting that the compromises have served to achieve gains in other spheres – not least of all political peace with and security from a former enemy – other analysis questions whether a better deal could not have been reached (Beaumont, 1997) or implemented during times of drought (Feitelson, 2000; Jägerskog, 2003). Indeed, and as discussed below, Annex II also suffers from omissions, rigidity and ambiguous distribution mechanisms that call into question the equitability of the Israel-Jordan transboundary water arrangement, particularly with regard to the Yarmouk tributary.

Omissions and ambiguous allocation

Apart from the lack of consideration of Palestinian water use, the Water Annex also lacks adequate consideration of groundwater. Article IV mentions groundwater in relation to Israel maintaining (and increasing) its pumping from inside Jordanian territory at Wadi Araba (well outside the Jordan River Basin). However, the Water Annex conspicuously ignores the hydraulic connections and ongoing conjunctive management of groundwater with surface water within the Jordan River (Zeitoun et al., 2009), not to mention the Yarmouk tributary basin. Annex II also provides little scope for dealing with changed circumstances, be these border adjustments due to conflict (e.g. Israeli occupation of the West Bank, Gaza, and southern Lebanon),[11] reduced water availability, increased demand because of population fluxes, or increased availability of alternative sources such as wastewater reuse and desalination (as previously discussed). The Water Annex, furthermore, makes no mention at all of biodiversity and does not include a self-enforcement mechanism that might regulate clauses that are not fulfilled.

The omissions are straightforward to interpret, compared with the extensive ambiguity of many of the other clauses of Annex II. Fischhendler (2008a) details the way in which this ambiguity allowed the negotiators of each side to present the treaty favourably. From the wider Jordan River Basin the most extreme Israeli accounting would see Israel conceding (only) 35 Mm^3/y to Jordan, while the most extreme Jordanian accounting would see a concession of 245 Mm^3/y (ibid). Al-Kloub and Abu-Taleb (1998: 165) claim, for instance, that the treaty "guarantees to Jordan about 215 Mm^3/y", a figure repeated in Al Majdoub (1998).

An initial assessment of the several clauses allocating the Yarmouk flows, as shown in Table 2, suggests that the Yarmouk portions of the agreement are also highly ambiguous and very specific.

From the Yarmouk flows alone, then, Annex II stipulates 25 Mm^3/y for Israel (Art. I.1a,b), 20 Mm^3/y for Jordan (Art. I.2b), and excess flood water to be available to both parties.[12] But Annex II does not so much allocate the Yarmouk flows as detail the terms of the 'water exchange' between Israel and Jordan.

[11] Though Annex I of the 1994 peace treaty states, in relation to borders, that

[t]he boundary line shall follow natural changes (accretion or erosion) in the course of the rivers unless otherwise agreed. Artificial changes in or of the course of the rivers shall not affect the location of the boundary unless otherwise agreed. No artificial changes may be made except by agreement between both Parties.

[12] The temptation to compare directly with the figures of Yarmouk use from Figure 3 should be resisted, as the Water Annex is not limited to the Yarmouk tributary.

Table 2. Summary of clauses from Annex II of the 1994 Israel-Jordan peace treaty that are relevant to Jordanian and Israeli use of the Yarmouk tributary of the Jordan River.

Yarmouk-related clauses	
Israel is:	*Jordan is:*
To pump 25 Mm^3/y from the Yarmouk (12 Mm^3 from 15 May to 15 October, and 13 Mm^3 from 16 Oct to 14 May) (Art. I.1.a,b)	Entitled to store and use a minimum average of 20 Mm^3 (from 16 October to 14 May) of "the floods" in the Jordan River "south of its confluence with the Yarmouk" (Art. I.2b)
To pump an "*additional 20* Mm^3/y" from the Yarmouk (Art. I.1b), and to transfer this back to Jordan per Art. 1.2a (see next column)	To receive 20 Mm^3 (from 15 May to 15 October) from Israel (from "directly upstream from the Deganya gates", meaning the Lake of Tiberias), and assume all related operations and maintenance costs (Art. I.2a)
Entitled to maintain its current uses of the Jordan River waters from the confluence of the Yarmouk and the Jordan, to the northern border of the West Bank (Art. I.2c)	Entitled to a quantity equivalent to Israeli use of the Jordan River downstream from the confluence of the Yarmouk and the Jordan to the edge of the West Bank (Art. 1.2c)
Jordan and Israel further agree:	
To build the Adassiyeh Weir (on the Yarmouk) in order "to improve the diversion efficiency into the King Abdullah Canal of the water allocation of the Hashemite Kingdom of Jordan, and possibly for the diversion of Israel's allocation of the river water" (Art. II.1).	
That both sides can use the "*excess floods*" that are not used by Jordan during the winter period (i.e. 20 Mm^3, referring to Art. I.2b).*	
That both sides can use the "*excess flood water*" downstream of the Adassiyeh Weir, after Israel takes the above-mentioned 25 Mm^3/y (Art. I.1c).*	

* In relation to the flood flows, Israel agreed in a separate addendum of 10 March 1998 to allow Jordan an additional 40 Mm^3 of storage, so, 60 Mm^3 total (see Haddadin, 2002: 438).

Non-Yarmouk-related clauses discussed briefly in this paper	
Israel is:	*Jordan is:*
To retain (and increase pumping from) its wells inside Jordan in the Wadi Araba (Art. IV.1,3)	Entitled to 10 Mm^3/y of desalinated salt springs diverted by Israel away from Tiberias (Art. I.2d)
Jordan and Israel agree:	
To "cooperate in finding sources for the supply to Jordan of an additional quantity of 50 Mm^3/year of water of drinkable standards" (Art. I.3).	

Originally conceived in the 1940s (see Hays, 1948), the rationale was to store winter flood flows from the Yarmouk tributary in the Lake of Tiberias, where they could be used instead of flowing unused into the Jordan River and from there to the Dead Sea; in return, water would flow from the Lake of Tiberias to Jordan for use in the Jordan River Valley during the dry summer months. The influx of fresh river water further dilutes the salinity of the lake, which remains until this day an important source of drinking water for Israel. A more complete evaluation of the extent of influence of the Water Annex thus requires scrutiny of this 'water exchange' and of who uses how much of the excess flood water.

The Yarmouk – Tiberias 'water exchange'

This section, in order to query the flows that make up the 'water exchange', interprets the relevant data available from the (Jordanian) Jordan Valley Authority (JVA), the (Israeli) Jordan Valley Water Authority (JVWA), and the Hydrological Service of Israel (HSI). The datasets are presented in Table A.1, summarised in Table 3, and shown figuratively in Figure 4.

Table 3. Summary of the distribution of Yarmouk tributary flows after Adassiyeh, showing the balance of the Yarmouk – Tiberias 'water swap' (in Mm3/y) within data limitations.

a	b	c	d	h	i
Year	^Total flows diverted into the KAC, via sandbar/rock weir/ AW (including Mukheibeh Wells discharge and Wehdeh releases) ('alpha' flows) (JVA, 2016, 2019)*	Flows bypassing the AW by passing through gates (JVA, 2016, 2019)*	Flows not diverted into the KAC, because they i) (before 1999) overspill the sandbar or rock weir; or ii) (after 1999) overspill or bypass the AW, ('beta' flows) (JVA, 2016, 2019)*	Total JVWA pumping from YR (JVWA, 2016)	Flows received into KAC downstream of AW via Beit Zera Reservoir (JVA, 2016, 2019)*
Avg. for series	105	37	94 / 65 (if 1992+2003 removed)	34	47
Avg. from:	1999-2018 72 / 71.5 (if 2003 removed)	2003-2018 37	1999-2018 69 / 48 (if 2003 removed)	1995-2016 35	1995-2018 47

Sources: Jordan Valley Authority and Jordan Valley Water Authority, and as noted (see Table A.1 in Annex).

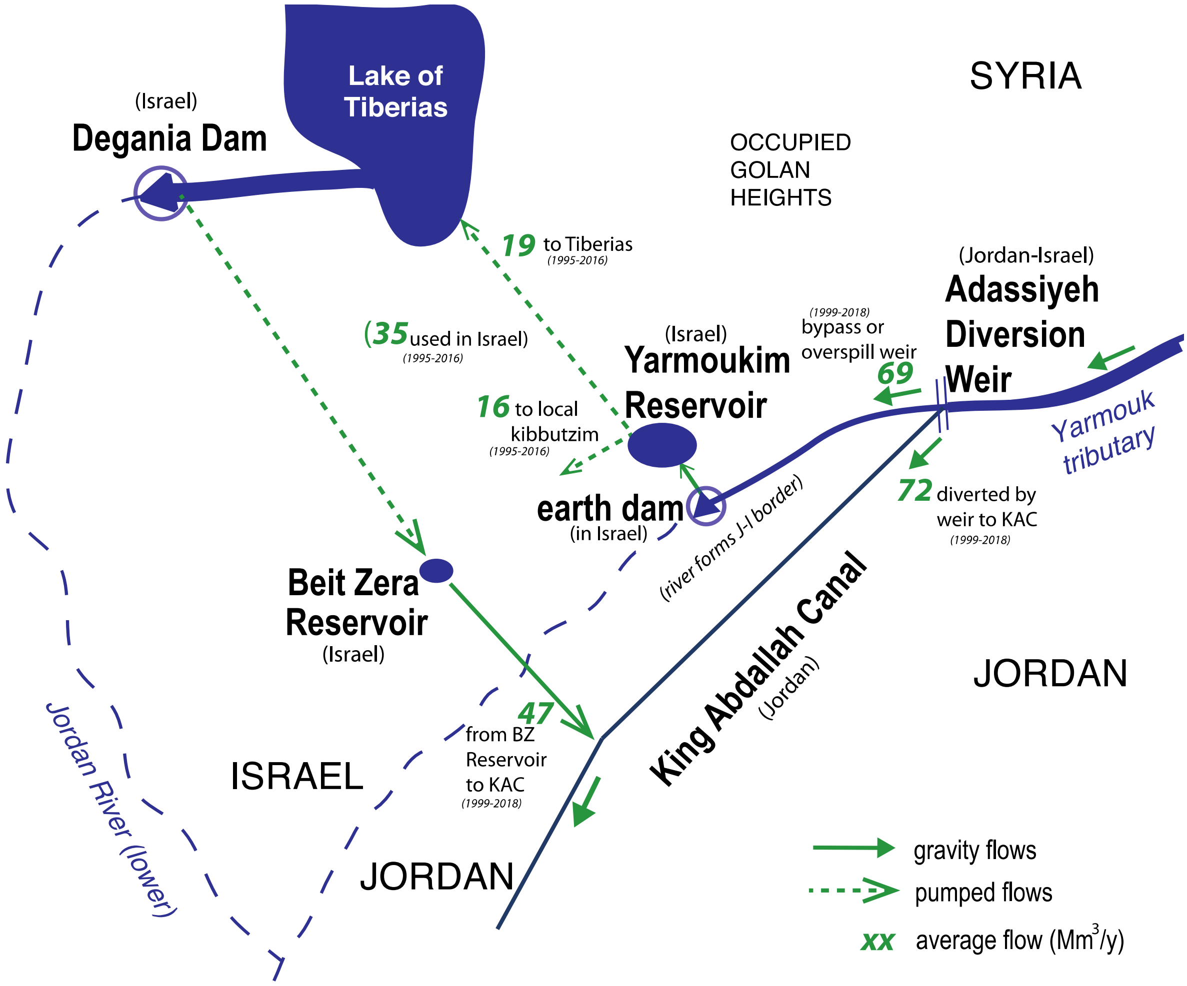
Notes: Discrepancies are due to measurement error, poor reliability of the reported data, and non-calibration of different datasets, as discussed further in the text; AW = Adassiyeh Weir; YR = Yarmoukim Reservoir; KAC = King Abdullah Canal.

*checked against JVA (2006) and a third JVA source.

^Because of minor changes in the JVWA pumping and data-recording regime, the total pumping from the Yarmoukim Reservoir is not identical to the sum of pumping to Tiberias plus the pumping for local kibbutzim.

For a number of reasons, the data presented is reliable only to an indicative degree. First, there are discrepancies that may be attributed to the fact that the Israeli and Jordanian datasets have not been calibrated or normalised in any way, which is an issue typical of international hydropolitics (see, for example, Milman and Schott, 2010; Jepson, 2014). A second weakness is the unreliability stemming from measurement error, particularly for the flood flows that overspill the Adassiyeh Weir and are gauged telemetrically by the JVA. Third, there are potential biases or inaccuracies in reporting. Though the research conducted for this article has not traced a cause for concern of bias, it remains a possibility that merits deeper investigation (Wine, 2019a). Moreover, reporting of both the long-term JVWA and JVA datasets has changed, for example, from seasonal years to annual, and from different gauging equipment. JVA data keepers also report that the JVA data is prone to duplication errors – with the same or similar data found on different datasets – and apparently contradictory labelling (Ghureir, 2018; Shattat, 2018). A fourth and final reason to consider the data in this section to be indicative only has to do with potential interpretation errors; whether in Arabic, Hebrew, or inconsistently translated English – and even though they have been checked several times by the authors – the datasets may have been misinterpreted.

Figure 4. The 'Yarmouk-Tiberias Water Exchange' of Yarmouk tributary flows between Jordan and Israel (in Mm^3/y).



Sources: As per Table A.1, (Jordanian) Jordan Valley Authority (JVA) and (Israeli) Jordanian Valley Water Authority (JVWA); data was cross-checked with datasets from the Jordanian Ministry of Water and Irrigation (MWI) and the Hydrological Service of Israel (HSI).

Notes: Includes heavy flood year of 2003; as noted in the text, the difference between the flows bypassing the Adassiyeh Weir and the flows pumped from the Yarmoukim Reservoir reflects data limitations and differences in the datasets.

The division of the flows at the Adassiyeh Weir is attributed to its operation and design, as discussed in Zeitoun et al. (2019b). One of several relevant points of that article is the annual average of approximately 72 Mm^3/y of Yarmouk flows that have been diverted into the King Abdullah Canal between 1999 and 2018 (Table A.1, Column b). This can be compared to the 69 Mm^3/y that the JVA data gauges as the volume of water that it sent to Israel during the same time period through gates designed to bypass the weir (according to the terms of Annex II), *plus* the flood waters that overspill the weir (Table A.1, Column d) – see also Zeitoun et al. (2019b).

In other words, the JVA gauges show that when flood flows are counted, the magnitude of water that enters into the King Abdullah Canal is roughly the same as the amount that bypasses it. As with the agreement itself, however, the design and operation of the weir is more complicated than that. JVA employees and operators of the weir testify that they seek to operate the gates to allow 1 m^3/s to Israel (Ghureir, 2018; Ghantous, 2018); this is roughly 32 Mm^3/y, or the equivalent of the 25 Mm^3/y agreed to in Annex II (Art. I.1a,b) plus an additional approximately 22% to make up for potential losses from seepage or evaporation (Ghureir, 2018). JVA records show that between 2003 and 2018 it has sent an average of 37 Mm^3/y to Israel through the gates at the Adassiyeh Weir (Table A.1, Column c), an amount which is approximately 50% more than it has committed to.

The 'excess flood water' that overspills the crest of the weir is gauged at 69 Mm^3/y on average (from 1999 to 2018), and is referred to as 'uncontrolled water' (JVA, 2016, 2019; see also Zeitoun et al. (2019)). The flows are not uncontrolled for long, however; like the flows that bypass the weir, the water that overspills it returns to the Yarmouk riverbed, which at this point still forms the border between Jordan and Israel. The flow of the river is then interrupted across its breadth by an earth dam that allows pumping into the Yarmoukim Reservoir in Israel (see Figure 5). This reservoir has a storage capacity of 750,000 m^3, and has four pumps each with a capacity of 6500 m^3/h (or a combined total maximum pumping capacity of 16,000 m^3/h, as the design of the installation restricts pumps from operating in parallel) (Nathan, 2017a). Equivalent to 140 Mm^3/y, this design pumping capacity means that all the flows that bypass or overspill the Adassiyeh Weir can be diverted into and pumped out of the reservoir, except in unusually wet years such (as 2003). As confirmed by an employee of the Jordan Valley Water Authority (the Israeli institution responsible for supplying water in the Yarmouk triangle): "Today, the Yarmouk has been diverted into that big pond. For all intents and purposes, that is the end of the Yarmouk" (Nathan, 2017b).

Data from the (Israeli) Jordan Valley Water Authority (Table A.1, Column h) shows that it pumps an average of 35 Mm^3/y from the reservoir.[13] The dataset shows that roughly 19 Mm^3/y (Table A.1, Column f) of this is diverted to the Lake of Tiberias, while 16 Mm^3/y is used for drinking water and irrigation at local kibbutzim in the Yarmouk triangle (Table A.1, Column g).

JVWA pumping records thus confirm that the Israeli pumping of (on average) 19 Mm^3/y to the Lake of Tiberias is in accordance with Article 1.1b of Annex II, which stipulates 20 Mm^3/y. The records also confirm that its local use of (on average) 16 Mm^3/y of Yarmouk flows is lower than the 25 Mm^3/y stipulated in Article I.1a,b. On the other hand, Israel is the only side making use of the excess flood flows, in apparent contravention of Articles I.1c and I.2b.

A second point to note is the average of roughly 47 Mm^3/y that (Jordanian) JVA records show is pumped by Israel[14] from the Lake of Tiberias to the King Abdullah Canal in Jordan (Table A.1 Column h); this is more than twice the 20 Mm^3/y that Israel committed to in Article I.2b.[15] Data from the Jordanian Jordan Valley Authority and interviews with staff indicate that these flows are accounted for from four different sources: i) the 25 Mm^3/y promised by the then Israeli Defence Minister Ariel Sharon to King Hussein in 1997 (labelled by the JVA as 'Additional')[16]; ii) a steady 10 Mm^3/y labelled by the JVA as 'Desalination' (in relation to Art. I.2d – see Table 2), though it is otherwise openly acknowledged to be fresh water from Tiberias; iii) additional flows (labelled 'concession') which are over and above the 1 m^3/s (35 Mm^3/y) that Jordan allows to bypass the Adassiyeh Weir through the gates, and which vary between 2 and 20 Mm^3/y); and iv) the water Jordan purchases from Israel which is labelled by the JVA as 'sold water', an amount that, theoretically, is as much as 20 Mm^3/y but which in practice varies from 0 to 16 Mm^3/y) (JVA, 2006; Abed, 2017; JVA, 2017; Shattat, 2018).

[13] There are several reasons for the difference of 39 Mm^3/y between the flow gauged by the JVA as bypassing or overspilling the Adassiyeh Weir (75 Mm^3/y) and the flows gauged by the JVWA as pumped from the Yarmoukim Reservoir (36 Mm^3/y): the difficulty of accurately measuring the flood flows that overspill the weir, inconsistent and uncalibrated gauging records between Jordan and Israel, and seepage and evaporation. However, the difference is judged as being significant enough to warrant further investigation.

[14] These flows are pumped by the national water company (Mekoroth), not by the JVWA.

[15] The 47 Mm^3/y may also be considered to be part of the additional 40 Mm^3/y that Israel agreed to provide in the March 1998 addendum (see footer of Table 1 and Haddadin, 2002: 438), though is counted by the JVA otherwise (see text), and has not been investigated further.

[16] Sharon's promise of 25 Mm^3/y may be in partial fulfilment of the "additional 50" Mm^3/y of Article II, Para 3 (see Shamir, 2003: 12).

Figure 5. The 'end of the Yarmouk'. Top: the Yarmoukim Reservoir showing the diversion and termination of the Yarmouk. Bottom: the reservoir and the motors of the four pumps.

Source: Top: adapted from Google Earth; bottom: authors, 2018.

Omissions, rigidity and ambiguity impeding an equitable arrangement

The details of the Yarmouk – Tiberias water exchange and the method of accounting of flows reveals a number of features that cast doubt on the equitability of the Yarmouk features of Annex II of the 1994 Israel-Jordan peace treaty. The first feature to note is the apparent Israeli contravention of Articles I.1c and I.2b in relation to excess flood flows, and other non-Yarmouk clauses.[17] There are also several other notable features that relate to the flows pumped by Israel to the King Abdallah Canal. First, the 10 Mm^3/y of 'desalinated' water (Art. 2.2d) is actually freshwater from the Lake of Tiberias; second, the 0-16 Mm^3/y of water purchased by Jordan is an economic arrangement not covered by Annex II; and third, the 25 Mm^3/y water promised by the former Defence Minister is not as resilient to political changes as are the clauses of an international treaty (in the same way that the previously discussed Syrian releases of water to Jordan were not impervious to political changes). Furthermore, the method of accounting casts doubt on the fulfilment of the only clause that specifies water pumped to Jordan (that is, the 20 Mm^3/y of Art. I.2a), not to mention the additional 40 Mm^3/y agreed to in the 1998 addendum (see Table 2), as this is not accounted for by the JVA.

For the rest of Annex II, the omissions and ambiguity favour the more powerful actor, just as the omissions and rigidity do in the 1987 Syria-Jordan water agreement. As previously discussed, the ambiguous clauses allowed both sides to present the Water Annex as an achievement, with one interpretation seeing Israel 'concede' (only) 35 Mm^3/y to Jordan (Fischhendler, 2008a). Considering Israeli use of the Yarmouk in the Occupied Syrian Golan (not covered by Annex II), and its control and sole use of 'excess' flows from the river, Israeli use of the Yarmouk has actually increased since the agreement was signed. By contrast, Jordan's effective use of the Yarmouk is 145 Mm^3/y, which is roughly half of the maximum 'concession' from Israel that has been claimed (given that the Water Annex secures no other volumes for Jordan outside of the Yarmouk), and much of this is not enshrined in the text. Nestling the analysis into the wider Jordan River Basin, it is noteworthy that Annex II also omits Palestinian rights of use and has been perceived to legitimise the heavy skew in use towards Israel (Figure 3) as well as Israeli water use in the Occupied Golan. Considered alongside its almost complete neglect of groundwater and biodiversity and its inability to accommodate changes in water availability and needs, the conclusion is that Annex II impedes the transformation of the Jordanian – Israeli transboundary water arrangement.

THE AGREEMENTS ARE OBSTRUCTIVE

The Yarmouk agreements are far from being models

As the evaluation of the Yarmouk agreements against the model in Table 4 shows, each lacks many of the desired features in each category. A number of omissions stand out for the negative impact they have had on encouraging an equitable arrangement. First, the lack of any provisions on groundwater has ensured that roughly half of the groundwater within the Yarmouk tributary basin remains wholly ungoverned, and also that the thousands of wells that have been drilled are not violations of the agreements. The minimal concern for water pollution and biodiversity also likely blocks progressive measures that societies in each of the states might push for. The impact is compounded by the absence of mechanisms for adapting to change. By specifying the number of dams that can be built, or the purpose of a weir, or the precise months by which flows can be exchanged, the agreements were clearly focussed on the most immediate challenges facing the negotiators when they were signed in 1987 and 1994. But

[17] As was the case with the 1987 Jordan–Syria agreement, violations of Annex II are debatable. The fact that only Israel can actually make use of the "excess flood water" of Article I.1c, for example, does not mean that Jordan cannot do so eventually, at least in theory. Similarly, the "additional 50 Mm^3/y" of Article I.3 may be argued to be more of an (as yet) unfulfilled clause than a violation, due to the lack of enforcement mechanisms in the treaty.

the rigidity of the agreements has locked in water resource managers in the subsequent decades, which has been a period of constant change in the dependency on, and use of, freshwater resources.

Table 4. The two bilateral treaties related to Yarmouk flows, compared with the indicative features of a model agreement shown in Table 1.

Features of a model transboundary water agreement	1987 Jordan – Syria	1994 Jordan – Israel
Allocative mechanisms		
Based on 'equitable and reasonable use'	No	No
Specific, rather than ambiguous	Yes	No
Flexible, rather than rigid	No	No
Technical mechanisms (related to, for example, conjunctive groundwater and surface water)		
Acknowledgement of surface water and groundwater as part of the same transboundary watercourse	No	No
Adequate accounting for use, amount and quality of groundwater in reserve, and its rate of replenishment	No	No
Common identification, delineation and characterisation of transboundary groundwater	No	No
Appropriate measures to prevent, control and reduce the pollution of transboundary groundwater	No	No
Comprehensive water accounting, including use, amount and quality of soil water, and gains made through improvements in irrigation efficiency (the 'paracommons')	No	No
Uncertainty mechanisms (related to changes in needs, climate, etc)		
Revisiting clauses	No	No
Escape clauses	No	No
Institutional mechanisms		
'Prior notification'	No	Yes
'No significant harm'	No	No
Enforcement clauses	No	No
Monitoring provisions	No	No
Dispute-resolution mechanisms	Yes	Yes
Self-enforcement mechanisms	No	No
Creation of multilateral bodies for information exchange or joint management	Yes	Yes
Environmental and health concerns		
Water quality provisions	No	Yes
Biodiversity, river base flows, etc.	No	No

Source: Based on Hayton and Utton, 1989; UNECE, 1992; Rieu-Clarke et al., 2012; Zentner, 2012; Giordano et al., 2013; Tanzi, 2013; UNECE, 2013, Dinar et al., 2015; Simons et al., 2015; Jafroudi, 2018.

Furthermore, both agreements fall down when tested for equitability of allocation. Here, the case analysis reveals several features, quite apart from the fact that neither agreement considers the rights of use of downstream Palestinians. The 1987 agreement has Jordan paying for the Wehdeh Dam, but Syria receiving three-quarters of the electricity that would have been produced if the hydroelectric component of the project had been completed; according to this agreement, Syria also reserves the right to build and fill 26 dams upstream from the dam. Israel has used more water from the Yarmouk tributary basin since the 1994 Water Annex was signed, despite its access to vastly greater amounts of freshwater from other sources in and outside of the Jordan River Basin, the Jordanian – Israeli informal economic and political arrangements notwithstanding. Indeed, the allocation mechanisms of neither text consider the legal entitlement, or even relative water 'needs' of the states. And in both cases, Jordan's share of the transboundary resources is relegated to overflows – or whatever the more powerful side does not use.

One potential explanation for the poor score of both the agreements is lack of knowledge. They were negotiated and signed well before the deposition of the Watercourses Convention at the UN General Assembly in 1997, and the authors could not have benefitted from the subsequent decades of research on water agreements. Nonetheless, related discussions on water sharing were happening around the world at the time of the negotiations, and particularly in relation to the Yarmouk. The Yarmouk tributary, for example, was in full focus during the Johnston Mission of the 1950s which debated and advanced principles of fair water sharing all the way through to the 1970s.[18] Furthermore, there is a centuries-old practice of including 'revisiting' and other types of clauses in an arrangement in order to build in flexibility by allowing renegotiation after a certain amount of time or under changed circumstances. The region's interannual variability in rainfall and river flow were also well known; this variability could have been dealt with in the cases at hand by basing the allocation on percentages of available flows rather than on fixed volumes. The latter is a particularly salient point, not only because of the highly volatile interannual flow of the mainstream, but also because the only country that has signed both agreements is now 'stuck' by the rigidity, in the sense that it is wholly unsure of the amount of the flows that will come into the Wehdeh Dam, yet is committed to providing a secure supply downstream (see Zeitoun et al. (2019b)).

Other weaknesses that cannot be attributed to a lack of knowledge are better understood through politics. Though no data on motives for signing the agreements was collected for this research, water resource managers in Jordan have cited their very weak political position vis-à-vis Syria in 1987 as the main reason for their government's consent. Former Jordanian water minister Haddadin attributes the official Jordanian consent to 'higher politics', as well as to the government following the idea of Arab brotherhood (Haddadin, 2002; Haddadin, 2017). The previously discussed ambiguity in the Water Annex helps explain why Jordanian negotiators would support the water clauses, as noted by Jägerskog (2003: 118). In any case, reaching agreement on water issues was deemed to be not worth threatening the chance to end the official state of war between Jordan and Israel that the peace treaty anchored (Haddadin, 2017).

Seen from a more critical transboundary water analysis, it is worth noting that all aspects of the weaknesses of the agreements favour the more powerful state – be they built-in inequality, omissions, rigidity or ambiguity. The findings challenge the less critical evaluations of the Israel-Jordan water agreement but are in keeping with other analyses on the Jordan River, be it Israeli-Palestinian (Selby, 2003) or Israeli-Lebanese (Zeitoun et al., 2013; AFIAL, 2014). A more realistic interpretation of the agreements would suggest that the more powerful player has a greater ability to set the parameters and structures of the negotiations, and hence has the ability to define the terms of the agreement thereby benefitting most from the ambiguity, rigidity and omissions. In other words, if there is to be skew in any

[18] Debates about the very principle of 'equitable and reasonable use' took place; notably, the 'Baxter Report' was commissioned by USAID in 1977 to give a legal opinion on the legitimacy of the Wehdeh Dam. This report concluded that violations of the principle of equitable use/apportionment were unlikely because "construction of the dam does not necessarily involve any change in present allocations of the basin waters" (Baxter, 1977: 131).

agreement, it would be expected to be in favour of the more powerful actor. With an appreciation that power asymmetry does not necessarily determine outcomes, Jordan's signing of both agreements could be read as tactical or strategic moves, if not outright contestation of them.

The agreements are the problem

Both agreements are judged to discourage fair transboundary water arrangements, whether through omissions or because of rigid or ambiguous clauses. To return to the assertions of the bulk of hydropolitical research and policy reports, the Yarmouk agreements are thus not only *not* evidence of a cooperative arrangement, they are in and of themselves part of the problem. However, they are not equally problematic to all sides.

The short end of the agreements may be felt first and foremost by water resource managers in midstream Jordan. Regardless of the benefits of any tactical concessions on water by the Jordanian government, Jordanian water managers are tasked today with managing a resource that is "impossible to manage", as one employee of the Jordan Valley Authority put it (Ghantous, 2018). The difficulties arise from the fact that the institution has no physical control over the sources of the Jordan or Yarmouk flows, while its legal control is circumscribed by the terms of the international agreements as well as by their jurisdiction and design.

The problems with the jurisdictions of the two agreements goes beyond the issues arising from the absence of any regulation of groundwater use. The 1987 agreement, for example, is limited to the Yarmouk tributary itself, and so does not include the Golan Heights. The 1994 Water Annex also makes no mention of the Golan Heights, though the Yarmouk-related clauses legitimise Israeli water use at their foot. The jurisdiction of Annex II also stops at the junction of the West Bank and the Jordan River. Jordanian water resource managers are thus impeded by agreements that ignore both the sources *and* the end point of the Yarmouk tributary that flows across its north-western border. Pollution entering from the Golan or detected in the Jordan River south of the West Bank affects Jordanian water supplies and farmers directly, but neither the international agreements nor the infrastructure or the joint committees that they spawned have a mandate to address it. The agreements are thus 'blind' in their lack of acknowledgement of actual water use and are of no use in attempting to point out, raise or discuss even the most pressing of related issues. The issues that do arise are always dealt with in an ad hoc manner, often through promises that remain much less secure and more prone to power asymmetries than do the agreements.

A related part of the impediment that the agreements pose to equitable transboundary water arrangements is their original purposes, even their very nature. The goals of the water agreements were to build a dam (the 1987 agreement) or to manage a relatively minor component of a much broader political treaty (the 1994 Water Annex); their aim was *not* to ensure 'equitable arrangements', nor even to alter the terms of water use that had been established at the time of ratification. At some point before or after the agreements enabled the construction of the Wehdeh Dam and the Adassiyeh Weir, they became instruments that locked in the arrangements. As explored at greater length in the Zeitoun et al. (2019), the agreements also influence the design and operation of the infrastructure. In this way, for over a quarter of a century, the written word and concrete have worked hand-in-glove to impede the development of an equitable transboundary water arrangement.

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ANNEX A. TABLE OF YARMOUK – TIBERIAS WATER EXCHANGE DATA

Table A.1. Distribution of Yarmouk flows after Adassiyeh, showing the balance of the Yarmouk – Tiberias 'water swap' (in Mm^3/y) within data limitations.

a	b	c	d	e	f	g	h	i
Year	^Total flows diverted into the KAC, via sandbar/rock weir/AW (including Mukheibeh wells and Wehdeh releases) ('alpha' flows) (JVA, 2016, 2019)*	Flows bypassing the AW by passing through the gates (JVA, 2016, 2019)*	Flows not diverted into the KAC, because they i) (before 1999) overspill the sandbar or rock weir; or ii) (after 1999) overspill or bypass the AW, ('beta' flows) (JVA, 2016, 2019)*	Flows pumped from the Yarmouk to Tiberias (HSI, 2016b)	JVWA pumping from YR to Tiberias ^ (JVWA, 2016)	JVWA pumping from YR to nearby kibbutzim (JVWA 2016)	Total JVWA pumping from YR (JVWA 2016)	Flows received into KAC down-stream of AW via Beit Zera Reservoir (JVA 2016, 2019)*
1962	nd	nd	nd	nd	nd	nd	nd	nd
1963	93.44	nd	nd	nd	nd	nd	nd	nd
1964	109.08	nd	nd	nd	nd	nd	nd	nd
1965	138.94	nd	nd	nd	nd	nd	nd	nd
1966	133.93	nd	nd	nd	nd	nd	nd	nd
1967	136.15	nd	nd	nd	nd	nd	nd	nd
1968	150.54	nd	nd	nd	nd	nd	nd	nd
1969	97.73	nd	nd	nd	nd	nd	nd	nd
1970	63.22	nd	nd	nd	nd	nd	nd	nd
1971	115.86	nd	nd	nd	nd	nd	nd	nd
1972	149.64	nd	nd	nd	nd	nd	nd	nd
1973	112.01	nd	nd	nd	nd	nd	nd	nd
1974	124.57	nd	nd	nd	nd	nd	nd	nd
1975	125.60	nd	nd	nd	nd	nd	nd	nd
1976	126.10	nd	nd	4.3	nd	nd	nd	nd
1977	126.78	nd	nd	6.8	nd	nd	nd	nd
1978	128.64	nd	nd	13.1	nd	nd	nd	nd
1979	113.75	nd	nd	29.8	nd	nd	nd	nd
1980	124.23	nd	nd	4.5	nd	nd	nd	nd
1981	128.26	nd	nd	4.7	nd	nd	nd	nd
1982	144.02	nd	nd	17	nd	nd	nd	nd
1983	128.56	nd	nd	31.1	nd	nd	nd	nd
1984	145.12	nd	nd	30	nd	nd	nd	nd
1985	126.39	nd	nd	25.8	25.4	21.1	nd	nd
1986	125.92	nd	109.42	54.4	24.4	16.4	nd	nd

1987	167.90	nd	179.92	18.2	13.4	19.1	nd	nd
1988	144.35	nd	184.67	20.2	3.2	18.5	nd	nd
1989	108.12	nd	50.84	28.3	18.3	22.6	nd	nd
1990	98.4	nd	58.18	32.5	26.0	22.0	nd	nd
1991	95.5	nd	66.42	33.7	32.2	13.9	nd	nd
1992	164.9	nd	613.34	6.8	11.1	11.3	nd	nd
1993	118.5	nd	146.95	17.8	4.3	16.3	6.9	nd
1994	99.2	nd	67.73	8.9	18.9	12.0	30.8	nd
1995	124.6	nd	68.70	21.8	9.5	15.6	25.0	21.8
1996	121.4	nd	55.58	26.9	26.5	14.3	40.8	30.8
1997	114.7	nd	57.02	26.2	28.3	19.1	47.3	47.4
1998	102.3	nd	62.98	10.6	20.5	17.8	38.3	55.9
1999	79.2	nd	28.11	20.8	10.4	12.6	22.9	41.9
2000	72.5	nd	51.27	20.7	24.9	16.0	40.9	54.5
2001	50.3	nd	38.36	34.3	23.3	13.1	36.5	45.4
2002	53.1	nd	58.65	43.8	35.4	12.9	48.3	51.1
2003	79.1	46.9	465.42	22.0	48.0	11.4	59.4	53.4
2004	97.4	36.6	172.84	31.1	18.9	14.5	33.4	50.2
2005	74.7	41.0	59.06	25.0	26.9	15.1	42.0	47.0
2006	49.1	42.8	45.05	17.1	24.2	15.4	39.6	53.1
2007	47.8	33.5	35.13	8.7	14.7	15.6	30.3	43.4
2008	52.0	28.3	30.78	15.3	10.2	15.6	25.9	42.1
2009	55.0	34.0	40.58	14.2	16.5	13.1	29.6	42.2
2010	51.9	32.8	33.00	10.9	10.5	16.7	27.2	45.5
2011	49.6	32.1	32.7	16.1	11.6	15.2	26.8	43.6
2012	63.2	41.4	51.6	20.2	17.8	16.3	34.1	48.4
2013	88.5	45.2	76.9	4.5	17.2	19.9	37.1	52.9
2014	78.5	33.9	33.9	nd	8.8	18.4	27.2	55.1
2015	91.2	32.4	32.5	nd	9.0	18.7	27.8	48.3
2016	115.3	34.2	34.4	nd	nd	nd	nd	51.9
2017	120.8	28.8	28.8	nd	nd	nd	nd	48.1
2018	109.3	29.9	29.9	nd	nd	nd	nd	49.5
Avg. series	105	37	94/65 (if 1992+2003 removed)	21	19	16	34	47
Avg. from:	1999-2018: **72 / 71.5** (if 2003 removed)	2003-2018: 37	1999-2018: **69** / **48** (if 2003 removed)	1995-2016: 21	1995-2016: 19	1995-2016: 16	1995-2016: 35	1995-2018: 47

Sources: JVA and JVWA, and as noted.

Notes: Discrepancies are due to measurement error, poor reliability of the reported data, and non-calibration of different datasets, as discussed further in the text; nd = no data; AW = Adassiyeh Weir; YR = Yarmoukim Reservoir; KAC = King Abdullah Canal.

* Main databases used are listed; all are checked against JVA (2006), JVA (2016), JVA (2018), and JVA (2019), with minor irregularities due to different labels and periods.

^ JVWA figures differ from HSI figures (Column d), though not significantly over the long run; JVWA figures are retained in the article.

REFERENCES

Abbott, B.W.; Bishop, K.; Zarnetske, J.P.; Minaudo, C.; Chapin, F.S.; Krause, S.; Hannah, D.M.; Conner, L.; Ellison, D.; Godsey, S.E.; Plont, S.; Marçais, J.; Kolbe, T.; Huebner, A.; Frei, R.J.; Hampton, T.; Gu, S.; Buhman, M.; Sara Sayedi, S.; Ursache, O.; Chapin, M.; Henderson, K.D. and Pinay, G. 2019. Human domination of the global water cycle absent from depictions and perceptions. *Nature Geoscience* 12(7): 533-540.

Abed, M. 2017. Personal communication, Amman, 6 April 2017. Anonymised.

Abseno, M.M. 2013. The influence of the UN Watercourses Convention on the development of a treaty regime in the Nile River basin. *Water International* 38(2): 192-203.

AFIAL. 2014. *Legal analysis of transboundary waters in the Upper Jordan River Basin*. Beirut: Association of the Friends of Ibrahim Abd el Al.

Aggestam, K. and Sundell, A. 2015. Depoliticising water conflict: Functional peacebuilding in the Red Sea-Dead Sea water conveyance project. *Hydrological Sciences Journal* 61(7): 1302-1312.

al Farawati, O. 2001. Wihdeh Dam construction to start next March. *Jordan Times*. 21 July 2001.

Al Majdoub, T. 1998. *La Ahada Yashrab: Mashare' Al Miya fi Istratijiyat Israel [Not a Drop to Drink: Israeli water strategy*. Beirut: Riad El-Rayyas Books.

Al Manaseer, A.F.A.R. 2012. *Jordan’s water security: Challenges and risks*. Middle East University, Political Sciences.

Al Qusaym, M. 2016. الجنوبية المنطقة في المياه واقع عن أولي تقرير (اليرموك حوض).

Al Raggad, M.; Salameh, E.; Alqadi, M.; Magri, F. and Ciogna, G. 2018. Implication of projected climate change for groundwater recharge in North Jordan. *Geophysical Research Abstracts, EGU General Assembly 2018* 20(EGU2018-12359).

Al-Ghraibeh, R.A. 2008. Yarmouk river basin management, an attempt to an integrated approach. Jordan university of science and technology, Faculty of Graduate Studies.

Al-Husein, A.B. 2007. اليرموك حوض في التلوث. *Syrian Cosmological Society*.

Al-Kloub, B. and Abu-Taleb, M.F. 1998. Application of multicriteria decision aid to rand the Jordan-Yamrouk basin co-riparians according to the Helsinki and ILC rules. *Water International* 23(3): 164-173.

Al-Rubeai, S. 2004. *The Syrian water conflict in Al-Yermouk and Orontes (Al-Asi) Basins*. Al-diwan Printing Press – Bagdad-Batawen.

Aviram, R.; Katz, D. and Shmueli, D. 2014. Desalination as a game-changer in transboundary hydro-politics. *Water Policy* 16: 609-624.

Avisse, N.; Tilmant, A.; Müller, M.F. and Zhang, H. 2017. Monitoring small reservoirs storage from satellite remote sensing in inaccessible areas. *Hydrology and Earth System Sciences Discussions* 21(12): 6445-6459.

Baim, K.A. 1997. Come hell or high water: A water regime for the Jordan River Basin. *Washington University Law Review* 75(2): 919-952.

Baker, M. and Harza. 1955. The Hashemite Kingdom of Jordan – Yarmouk-Jordan Valley Project – Master Plan Report. 1955.

Bastiaanssen, W.G.M.; Karimi, P.; Rebelo, L.M.; Duan, Z.; Senay, G.; Muttuwatte, L. and Smakhtin, V. 2014. Earth observation based assessment of the water production and water consumption of Nile Basin agro-ecosystems. *Remote Sensing* 6: 10306-10334.

Baxter, R.R. 1977. Legal questions arising out of the construction of a Dam at Maqarin on the Yarmuk River. Washington, DC: Report of a Working Group Established by the American Society of International Law under Contract AID/NE-C-1256 with the Agency for International Development. AKA 'the Baxter Report'.

Bearden, B.L. 2012. Following the proper channels: Tributaries in the Mekong legal regime. *Water Policy* 14: 991-1014.

Beaumont, P. 1997. Dividing the waters of the River Jordan: An analysis of the 1994 Israel-Jordan Peace Treaty. *Water Resources Development* 13(3): 415-424.

Brochmann, M. 2012. Signing river treaties – Does it improve river cooperation? *International Interactions* 38(2): 141-163.

Bromwich, B.; Allan, T.; Colman, T. and Keulertz, M. 2018. Food, water and society: An analytical framework. In Allan, T.; Bromwich, B.; Colman, T. and Keulertz, M. (Eds), *The Oxford handbook of food, water and society,* pp. Oxford: Oxford University Press.

Burdon, D. 1954. Infiltration rates in the Yarmouk Basin of Syria-Jordan.

Burdon, D.J.; Mazloum, S. and Safadi, C. 1954. Ground water in Syria. *Assemblé générale Ass. Int. d'Hydrologie*.

Cascão, A.E. and Nicol, A. 2016. GERD: New norms of cooperation in the Nile Basin? *Water International* 41(4): 550-573.

CBS. 2016. Central Bureau of Statistics data, Government of Syria. Damscus, Syria.

Choudhury, E. 2017. The nature of enabling conditions of transboundary water management: Learning from the negotiation of the Indus and Jordan Basin treaties. In Islam, S. and Madani, K. (Eds), *Water diplomacy in action: Contingent approaches to managing complex water problems,* pp. 177-199. London: Anthem.

Cosens, B.A. and Williams, M.K. 2012. Resilience and water governance: Adaptive governance in the Columbia River Basin. *Ecology and Society* 17(4).

Dajani, M. 2018. Water Struggles as struggles for recognition: The lived geographices of farming communities in Sahl al-Battuf and the occupied Golan Heights. PhD thesis from the Department of Geography and Environmnent. London School of Economics and Political Science, London.

Dana, O. 2016. Personal communication with Syrian academic, via Skype 25 November 2016. Anonymised.

De Stefano, L.; Duncan, J.; Dinar, S.; Stahl, K.; Strzepek, K.M. and Wolf, A.T. 2012. Climate change and the institutional resilience of international river basins. *Journal of Peace Research* 49(1): 193-209.

Dinar, S.; Katz, D.; De Stefano, L. and Blankespoor, B. 2015. Climate change, conflict, and cooperation: Global analysis of the effectiveness of international river treaties in addressing water variability. *Political Geography* 45: 55-66.

Dinar, S.; Katz, D.; De Stefano, L. and Blankespoor, B. 2019. Do treaties matter? Climate change, water variability, and cooperation along transboundary river basins. *Political Geography* 69: 162-172.

EcoPeace-INSS. 2018. *Israeli water diplomacy and national security concerns*. EcoPeace Middle East, and The Institute for National Security Studies.

Energoprojekt. 1964. The Yarmouk Project – Preliminary Study. 1964.

Feitelson, E. 2000. The Ebb and Flow of Arab-Israeli water conflicts: Are past confrontations likely to resurface? *Water Policy* 2000(2): 343-363.

Feitelson, E. and Rosenthal, G. 2012. Desalination, space and power: the ramifications of Israel's changing water geography. *Geoforum* 43: 272-284.

Fischhendler, I. 2004. Legal and Institutional adaptation to climate uncertainty: A study of international rivers. *Water Policy* 6(4): 281-302.

Fischhendler, I. 2008a. Ambiguity in transboundary environmental dispute resolution: The Israel-Jordanian water agreement. *Journal of Peace Research* 45(1): 91-110.

Fischhendler, I. 2008b. Institutional conditions for IWRM: The Israeli Case. *Ground Water* 46(1): 91-102.

FNA. 1921. Communication issued by Etat-Commissariat de la Republique Francaise en Syrie et au Liban, 19 Novembre 1921. Signed by "British Experts" General Grant and Rotenberg, and by "French Experts" E. Achaud and A. Younes. French National Archives in Nantes: Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 450; Fonds – "Beyrouth"/2e versement; Serie – Service Techniques "Hydraulique"; Sujet – Utilisation de la rivière Yarmouk et du bassin supérieur du Jourdain Station de jaugeage de Wadi-Khaled, 1921-1942.

FNA. 1940. Lettre de le Capitaine PERREUX, Officier des services speciaux à Merdjayou, à Monsieur le Haut-Commisaire (Cabinet Politique) à Beyrouth, concernant la Rectification de la Frontière libano-palestinienne. With accompanying map 'Carte Indiquant la Frontière entre la Syrie et la Palestine – Sheet 1'. French National Archives in Nantes: Archives des postes diplomatiques, consulaires, culturels et de cooperation: Caisse 656; Fonds – Syrie-Liban/1er versement; Serie – Cabinet Politique, Dossiers de principe (1926-1941) / Inventaire no 5: répertoire numérique; Sujet – Palestine: Frontière Syro-Palestinienne.

FO. 1952. American Draft Agreement. UK Foreign Office record FO 371-9882.

FOEME. 2008. *Environmental peacebuilding: Theory and practice*. Eco Peace / Friends of the Earth Middle East (Amman, Bethlehem and Tel Aviv).

Fox, C.; A. and Sneddon, C. 2007. Transboundary river basin agreements in the Mekong and Zambezi basins: enhancing environmental security or securitizing the environment? *International Environmental Agreements: Politics, Law and Economics* 7(3): 237-261.

Galili, A. 2016. Personal communication via Skype, 5 December 2016. Anonymised.

Gasteyer, S.; Isaac, J.; Hilal, J. and Walsh, S. 2012. Water grabbing in colonial perspective: Land and water in Israel/Palestine. *Water Alternatives* 5(2): 450-468.

Gerlak, A.K.; Lautze, J. and Giordano, M. 2011. Water resources data and information exchange in transboundary water treaties. *International Environmental Agreements* 11: 179-199.

Gerlak, A.K. and Mukhtarov, F. 2015. 'Ways of knowing' water: integrated water resources management and water security as complementary discourses. *International Environmental Agreements* 15: 257-272.

Ghantous, R. 2018. Personal communication, Beirut, 17 July 2018. Anonymised.

Ghureir, M. 2018. Personal communication at Adassiyeh, Sept 2018. Anonymised.

Giordano, M.; Drieschova, A.; Duncan, J.A.; Sayama, Y.; De Stefano, L. and Wolf, A.T. 2013. A review of the evolution and state of transboundary freshwater treaties. *International Environmental Agreements: Politics, Law and Economics* 14(3): 245-264.

Giordano, M.; Suhardiman, D. and Peterson-Perlman, J. 2016. Do hydrologic rigor and technological advance tell us more or less about transboundary water management? *International Environmental Agreements* 16(6): 815-831.

Gleick, P.; Christian-Smith, J. and Cooley, H. 2011. Water-use efficiency and productivity: Rethinking the basin approach. *Water International* 36(7): 784-798.

GWH-SFG. 2017. A matter of survival: Report of the Global High-Level Panel on Water and Peace. Geneva: Geneva Water Hub, and Strategic Foresight Group.

Haddadin, M. 2017. Personal communication, Amman, 9 June 2017.

Haddadin, M. 2002. *Diplomacy on the Jordan: International Conflict and Negotiated Resolution*. New York: Springer Science and Business Media, LLC.

Hays, J.B. 1948. T.V.A. on the Jordan – Proposals for Irrigation and Hydro-Electric Development in Palestine. Washington, DC, USA: A Report Prepared Under the Auspices of the Commission on Palestine Surveys, Public Affairs Press, assisted by A.E. Barrekette, with an introduction by Walter C. Lowdermilk.

Hayton, R.D. and Utton, A.E. 1989. Transboundary Groundwaters: The Bellagio Draft Treaty. *Natural Resources Journal* 29: 663-722.

Hobler, M.; Margane, A.; Almomany, M.; Subah, A.; Rayyan, M.; Khalifeh, N.; Al Mahamid, J.; Hijazi, H.; Zuhdy, Z.; Ouran, S. and Hammoudeh, A. 2001. Volume 4 – Contributions to the Hydrogeology of Northern Jordan. Amman, Jordan: Federal Institute for Geosciences and Natural Resources and Water Authority of Jordan. 2001.

Hoff, H. n.d. Climate change, impacts and adaptation in the MENA region, with focus on Syria.

HSI. 2016a. Development and utilization of water resources in Israel until Autumn 2014 [in Hebrew]. Jerusalem: Hydrological Service of Israel.

HSI. 2016b. State of water sources in Israel 2016 (Hebrew). Jerusalem: Hydrological Service of Israel. http://water.gov.il/Hebrew/ProfessionalInfoAndData/Data-Hidrologeime/Pages/water-resources-2014.aspx

Hussein, H. 2017. Whose 'reality'? Discourses and hydropolitics along the Yarmouk River. *Contemporary Levant* 2(2): 103-115.

Hussein, H. and Grandi, M. 2015. Contexts matter: A hydropolitical analysis of Blue Nile and Yarmouk River basins. In Fayyad, M.; Sandri, S.; Weiter, M. and Zikos, D. (Eds), *Social water studies in the Arab region: State of the Art and Perspectives,* pp. 159-178. Berlin: Humboldt University Seminar für Ländliche Entwicklung (SLE).

Ide, T. 2018. Does environmental peacemaking between states work? Insights on cooperative environmental agreements and reconciliation in international rivalries. *Journal of Peace Research* 55(3): 351-365.

Ionides, M.G. 1939. Report on the the Water Resources of Transjordan and their Development. 1939.

Jafroudi, M. 2018. Climate change and accommodation of water availability in transboundary rivers: Lessons learned from the Guadiana basin. *Water Policy* 20: 203-217.

Jägerskog, A. 2003. *Why states cooperate over shared water: The water negotiations in the Jordan River Basin*. Linköping, Sweden: Linköping University.

Jepson, W. 2014. Measuring 'no-win' waterscapes: Experience-based scales and classification approaches to assess household water security in colonias on the US-Mexico border. *Geoforum* 51: 107-120.

JVA. 2006. Index for surface water, dams, and King Abdallah Canal, 1990-2006. Amman: Spreadsheet of the Jordan Valley Authority (Jordan).

JVA. 2016. JVA Historical Data 1962-2016. Amman: Spreadsheet of the Jordan Valley Authority (Jordan), provided Nov 2017. Shows Yarmouk River Discharge from 1962 to 2016, monthly totals.

JVA. 2017. Yarmouk Dams in Jordan. Spreadsheet of the Jordan Valley Authority (Jordan), provided Sept 2018. 2017.

JVA. 2018. Inflows to KACn & Con & Alloc & JR 2008-2017. Amman: Spreadsheet of the Jordan Valley Authority (Jordan), provided September 2017. Shows sources of flows to northern parts of King Abdallah Canal, plus Concessions to Israel.

JVA. 2019. اليرموك وطبريا والوحدة Yarmouk Tiberias and Unity Dam 2016-2019 Amman: Spreadsheet of the Jordan Valley Authority (Jordan), provided December July 2019. Shows monthly gauging records for Wehdeh Dam (in and out), KAC (alpha and beta flows) and returns from Tiberias (via Beit Zera), 2016 to half of 2019.

JVWA. 2016. Yarmouk River pumping from April 1982 until May 2015. Tel Aviv: Spreadsheet of the Jordan Valley Water Authority (Israel).

Krampe, F. 2016. Water for peace? Post-conflict water resource management in Kosovo. *Cooperation and Conflict*: 1-19.

Kubursi, A.; Grover, V.; Darwish, A.R. and Deutsch, E. 2011. Water scarcity in Jordan: Economic instruments, issues and options. Giza: The Economic Research Forum.

KUNA. 1999. Syria pumps the first amount of water to Jordan. 14 May 1999, Kuwait News Agency. www.kuna.net.kw/ArticlePrintPage.aspx?id=999853&language=ar

Lankford, B. 2012. Fictions, fractions, factorials and fractures; on the framing of irrigation efficiency. *Agricultural Water Management* 108: 27-38.

Lankford, B. 2013. Does Article 6 (Factors Relevant to Equitable and Reasonable Utilization) in the UN Watercourses Convention misdirect riparian countries? *Water International* 38(2): 130-145.

Lederach, J.P. 2003. *The little book of conflict transformation*. Intercourse, PA: Good Books.

Lederach, J.P. 2005. *The moral imagination: The art and soul of building peace*. Oxford: Oxford University Press.

Margane, A. 2015. Updating the A7/B2 Groundwater Contour Map in North Jordan, 2015.

McCaffrey, S. 2008. The 1997 UN Watercourses Convention: Retrospect and Prospect. *21 Pac. McGeorge Global Global Business & Development Law Journal* 21(2): 165-173.

Meisen, P. and Tatum, J. 2011. *The water-energy nexus in the Jordan River Basin: The potential for building peace through sustainability*. Global Energy Network Insitute.

Milman, A. and Schott, C. 2010. Beneath the surface: intranational institutions and management of the United States-Mexico transboundary Santa Cruz aquifer. *Environment and Planning C: Government and Policy* 28: 528-551.

Mirumachi, N. 2015. *Transboundary water politics in the developing world*. London: Routledge.

Mourad, K.A. and Berndtsson, R. 2011. Syrian water resources between the present and the Future. *Air, Soil and Water Research* (4): 93-100.

Muller, M.F.; Yoon, J.; Gorelick, S.M.; Avisse, N. and Tilmant, A. 2016. Impact of the Syrian refugee crisis on land use and transboundary freshwater resources. *Proceedings of the National Academy of Sciences* 113(52): 14932-14937.

Mustafa, D. and Talozi, S. 2018. Tankers, wells, pipes and pumps: Agents and mediators of water geographies in Amman, Jordan. *Water Alternatives* 11(3): 916-932.

MWI. 2014. Ministry of Water and Irrigation Annual Report 2014. Amman, Jordan. 2014.

Nathan, J. 2017a. Personal communication by Skype with JVWA employee, 26 April 2017. Anonymised.

Nathan, J. 2017b. Personal communication with JVWA employee, Yarmoukim Reservoir, 28 Sept 2017. Anonymised.

Norman, E.S. 2012. Cultural politics and transboundary resource governance in the Salish Sea. *Water Alternatives* 5(1): 138-160.

Orient. 2011. Yarmouk River Basin Water Resources Assessment and Use – Final report. The Hashemite Kingdom of Jordan, Ministry of water and irrigation, Jordan Valley Authority. 2011.

Perry, C.; Steduto, P.; Allen, R.G. and Burt, C.M. 2009. Increasing productivity in irrigated agriculture: Agronomic constraints and hydrological realities. *Agricultural Water Management* 96(11): 1517-1524.

Ponikarov, V. and Mikhailov, I. 1964. Geological Map of Syria.

Quba'a, R. 2017. A positive apportionment framework for water allocation in contested transboundary river basins: Energy as a welfare catalyst. PhD thesis submitted to the Department of Civil and Environmental Engineering. American University of Beirut, Beirut.

Quba'a, R.; El-Fadel, M.; Alameddine, I. and Abou Najm, M. 2017a. A positive apportionment framework towards enhancing cooperation in the Jordan River Basin. Paper read at 9th International Conference on River Basin Management, 19-21 July 2017, at Prague.

Quba'a, R.; El-Fadel, M.; Alameddine, I. and Abou Najm, M. 2017b. The undisclosed role of groundwater in water allocation along the Jordan River Basin. *Draft prepared for the 9th International Conference on River Basin Management, 19-21 July 2017*.

Rajsekhar, D. and Gorelick, S.M. 2017. Increasing drought in Jordan: Climate change and cascading Syrian land-use impacts on reducing transboundary flow. *Science Advances* 3(e1700581 30 August 2017).

Rieu-Clarke, A.; Moynihan, R. and Magsig, B.-O. 2012. UN Watercourses Convention: User's Guide. IHP-HELP Centre for Water Law, University of Dundee.

Salman, S.M.A. 2014. Entry into force of the UN Watercourses Convention – Where are the Nile Basin Countries?. In *International Water Law Project Blog*.

SANA. 2015. "The total storage is around 1 MCM in Deraa dams" Syrian Arab News Agency 02 December 2015. Deraa. Accessed online http://sana.sy/?p=306513

SANA. 2016. "more than 6 MCM is the total storage in Deraa dams" Syrian Arab News Agency 11 February 2016. Deraa. Accessed online http://sana.sy/?p=335240

Selby, J. 2003. *Water, power and politics in the Middle East – The Other Israeli-Palestinian Conflict*. London, UK: I.B. Tauris.

Selby, J. 2013. Cooperation, domination and colonisation: The Israeli-Palestinian Joint Water Committee. *Water Alternatives* 6(1): 1-24.

Serneel, A. 2018. Personal communication Dec 2018. Anonymised.

Shamir, U. 1998. Water agreements between israel and its neighbours. In Bernhardson, A.M. and Keena, R. (Eds), *Transformations of middle eastern natural environments: Legacies and lessons,* pp. 274-296. Yale.

Shamir, U. 2003. The Jordan River Basin, Part II: The Negotiations and the Water Agreement Between the Hashemite Kingdom of Jordan and the State of Israel. Paris: UNESCO /IHP / WWAP.

Shattat, O. 2018. Personal communication in Amman, December 2018 and May 2019. Anonymised.

Shentsis, I.; Inbar, N.; Magri, F. and Rosenthal, E. 2018a. Assessing water consumption and aquifer discharge by springs based on the joint use of rain and flow data in the Yarmouk River Basin. *Geophysical Research Abstracts, EGU General Assembly 2018* 20(EGU2018-13072).

Shentsis, I.; Inbar, N.; Rosenthal, E. and Magri, F. 2018b. Numerical representation of rainfall field in basins of the Upper Jordan River and of the Yarmouk River. *Environmental Earth Sciences* 77(24).

Simons, G.W.H.; Bastiaanssen, W.G.M. and Immerzeel, W.W. 2015. Water reuse in river basins with multiple users: A literature review. *Journal of Hydrology* 522: 558-571.

Sosland, J.K. 2007. *Cooperating rivals: The riparian politics of the Jordan River Basin*. New York, USA: State University of New York Press.

Talozi, S.; Altz-Stamm, A.; Hussein, H. and Reich, P. 2019. What constitutes an equitable water share? A reassessment of equitable apportionment in the Jordan-Israel water agreement 25 years later. *Water Policy*.

Tanzi, A. 2013. Regional contributions to international water cooperation: The UNECE contribution. In Boisson de Chazournes, L.; Leb, C. and Tignino, M. (Eds), *International law and freshwater: The multiple challenges,* pp. 155-178. Cheltenham: Edward Elgar.

Tawil, M. 2017. Personal communication with Syrian water expert, April 2017. Anonymised.

Thomas, K.A. 2017. The Ganges water treaty: 20 years of cooperation, on India's terms. *Water Policy* 19: 724-740.

UEA. 2019a. *Hydro-political baseline of the Yarmouk Tributary of the Jordan River*. Norwich: Water Security Research Centre of the University of East Anglia.

UN-ESCWA/BGR. 2013. *Inventory of shared water resources in Western Asia*. Beirut: UN Economic and Social Commission for Western Asia (ESCWA), and the German Federal Institute for Geosciences and Natural Resources (BGR).

UNECE. 1992. Convention on the Protection and Use of Transboundary Watercourses and International Lakes. Helsinki, 17 March 1992: UN Economic Commission for Europe.

UNECE. 2013. Guide to implementing the Water Convention. United Nations Economic Commission for Europe – Convention on the Protection and Use of Transboundary Watercourses and International Lakes.

Vink, K. 2014. Transboundary water law and vulnerable people: Legal interpretations of the 'equitable use' principle. *Water International* 39(5): 743-754.

Wang, W. and Li, X. 2018. The Heilongjiang (Amur) River in Sino-Russian relations: From conflict towards cooperation. *Water International* 43(5): 665-695.

Wiczyk, O. 2004. An analysis of the treaty of peace between Israel and Jordan in the context of international water law. *Yearbook of International Environmental Law* 14(1): 139-160.

Wine, M.L. 2019a. Response to comment on "agriculture, diversions, and drought shrinking Galilee Sea". *Science of the Total Environment* 663: 436-437.

Wine, M.L. 2019b. Under non-stationarity securitization contributes to uncertainty and Tragedy of the Commons. *Journal of Hydrology* 568: 716-721.

Wolf, A.T. 2007. Shared waters: Conflict and cooperation. *Annual Review of Environmental Resources* (32): 241-269.

Wolf, A.T. and Newton, J.T. 2007. *The Jordan River – Johnston Negotiations 1953-1955; Yarmuk Mediations 1980s*. Program in Water Conflict Management and Transformation, Oregon State University.

Yasuda, Y.; Schillinger, J.; Huntjens, P.; Alofs, C. and De Man, R. 2017. *Transboundary water cooperation over the lower part of the Jordan River Basin: Legal political economy analysis of current and future potential cooperation*. The Hague: The Hague Institute for Global Justice.

Zawahri, N. and Michel, D. 2018. Assessing the Indus Waters Treaty from a comparative perspective. *Water International* 43(5): 696-712.

Zawahri, N.A. and Gerlak, A.K. 2009. Navigating international river disputes to avert conflict. *International Negotiation* 14: 211-227.

Zeitoun, M.; Cascão, A.; Warner, J.; Mirumachi, N.; Matthews, N.; Farnum, R. and Menga, F. 2016. Transboundary water interaction III: Contesting hegemonic arrangements. *International Environmental Agreements*: 271-294.

Zeitoun, M.; Eid-Sabbagh, K.; Talhami, M. and Dajani, M. 2013. Hydro-hegemony in the Upper Jordan waterscape: Control and use of the flows. *Water Alternatives* 6(1): 86-106.

Zeitoun, M.; Messerschmid, C. and Attili, S. 2009. Asymmetric abstraction and allocation: The Israeli-Palestinian water pumping record. *Ground Water* 47(1): 146-160.

Zeitoun, M. and Mirumachi, N. 2008. Transboundary water interaction I: Reconsidering conflict and cooperation. *International Environmental Agreements* 8(4): 297-316.

Zeitoun, M.; Mirumachi, N. and Warner, J. 2011. Transboundary water interaction II: Soft power underlying conflict and cooperation. *International Environmental Agreements* 11(2): 159-178.

Zeitoun, M.; Mirumachi, N. and Warner, J. forthcoming 2019a. *Understanding water conflicts: Analysis for transformation*. New York: Oxford University Press.

Zeitoun, M.; Abdallah, C.; Dajani, M.; Khresat, S. and Elaydi, H. 2019a. The Yarmouk tributary to the Jordan River II: Infrastructure impeding the transformation of equitable transboundary water arrangements. *Water Alternatives* 13(3):

Zeitoun, M.; Mirumachi, N.; Warner, J.; Kirkegaard, M. and Cascão, A. 2019b. Analysis for water conflict transformation. *Water International*.

Zentner, M. 2012. *Design and impact of water treaties: Managing climate change*. Berlin: Springer-Verlag.