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Water Stategies in the Southern Ghawrs and Northeast 'Araba

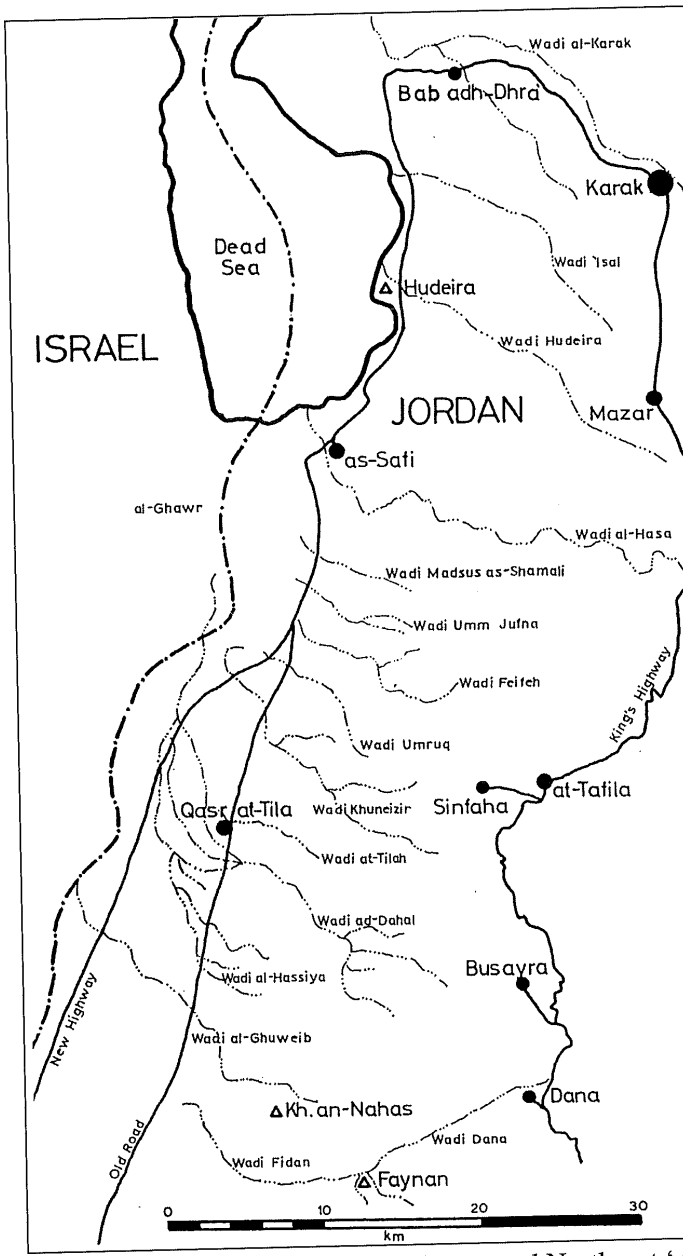
Introduction

The Southern Ghawrs and Northeast 'Araba are arid zones (FIG. 1). Their most critical resource is water. The water supply determines the abundance and distribution of other resources such as plants and animals available for hunting-gathering cultures, the crops that can be grown by farmers, and the animals that can be reared by both farmers and pastoralists.

The primary source of water is rainfall. Secondary sources are flowing streams, springs, wells, and moisture stored in the soil. All of the secondary sources are dependent ultimately on rainfall, which generally falls in the Highlands at the Eastern Rim of the Wādī 'Araba-Jordan Graben to the east of the Wādī 'Araba-Dead Sea-Jordan Depression (FIG. 2).

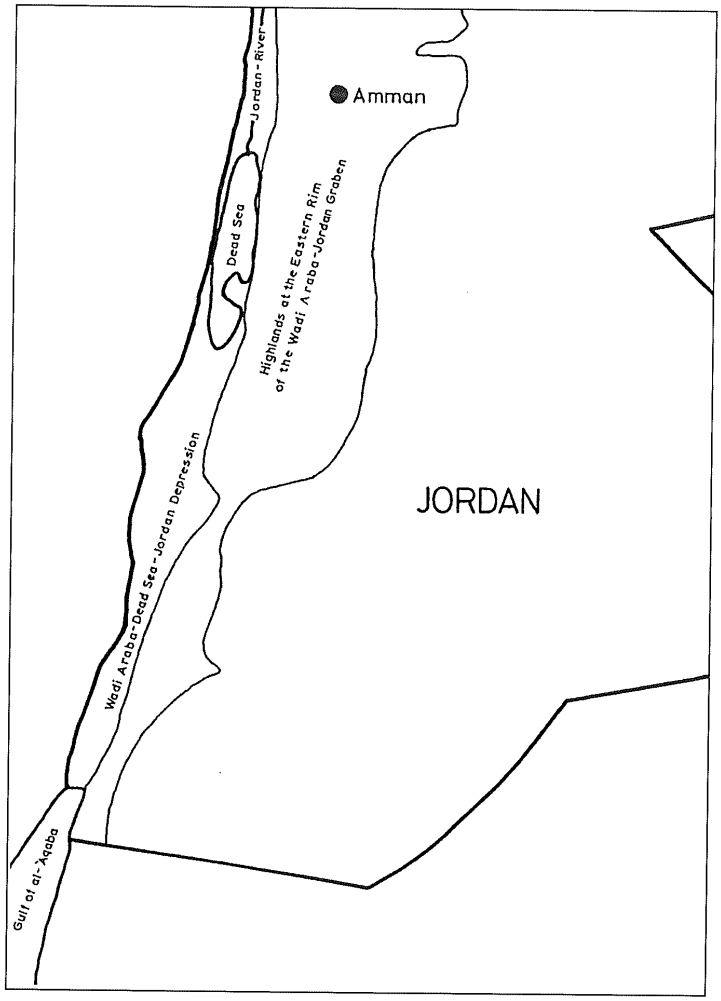
The distance between the two zones is not great and the ecological ties between them are intimate, fragile, and sensitive. For this reason, an understanding of the water resources of the Southern Ghawrs and Northeast 'Araba must depend to some extent on an understanding of the ecology of the Highlands. For example, water delivery in the two zones depends not only on rain in the Highlands but on water retention that is trapped and allowed to percolate slowly to the springs below or is released slowly from the upland soils to the perennial streams. In summary, the Southern Ghawrs and Northeast 'Araba ought not to be considered as isolated from the Highlands.

This paper will consider the main water sources between Wādī al-Karak in the north and Wādī Fīdān in the south, a distance of ca. 70 kilometres. These water sources include streams, some of which are perennial, and springs. Moreover, water is stored in the soil where it is available through the digging of wells. In addition, water from these



1. General Map of the Southern Ghawrs and Northeast 'A ba.

sources is stored in reservoirs, cisterns, and po And the water from these sources is used by p ple, animals, and plants. And it was the availabi



2. Map Showing Relationship between the Highlands and the Southern Ghawrs and Northeast 'Araba.

of water that made it possible for people to live in the areas.

Rainfall in the Southern Ghawrs and Adjacent Highlands

According to the rainfall data that Harlan used, a 37-year record at al-Karak, on the plateau east of Bāb adh-Dhrā', reports 360.7mm annual precipitation. A 36-year record at al-Mazār, on the plateau north of Wādī al-Ḥasā, and a 37-year record at aṭ-Ṭafīla, immediately south of the wadi, reports 339.8mm and 280.6mm annual precipitation respectively (Harlan 1981: Fig. 1, Table 1). In contrast, Ghawr al-Mazra'a, just north of Wādī al-Karak, and Ghawr aṣ-Ṣāfī, at the western extremity of Wādī al-Ḥasā, record only about 65mm annual precipitation over a 28- and 26-year time range respectively (TABLE 1).

From the data presented in TABLES 1 and 2 it is evident that the amount of rainfall in the Southern Ghawrs "is negligible from an agricultural point of view" (Harlan 1981: 155). The amount is so low that it can only replace one or two irrigations dur ing the winter-growing seasons (Harlan 1981: 155) Crops must, therefore, be raised under irrigation.

Farther to the south, rainfall in the Wādī 'Araba region is also less than 100mm annual precipitation Specifically, the mean annual rainfall in 1959/196(and 1966/1967 was less than 25mm (Anonymous 1984: 112-14).

From the above, it is evident that water sources in the Southern Ghawrs and Northeast 'Araba are dependent on rainfall in the Highlands.

The Wadi System in the Southern Ghawrs and Northeast 'Araba

Some of the rainfall that falls on the Highlands reaches the Southern Ghawrs and Northeast 'Araba by means of the west-flowing wadis that include, in a north-to-south order: Wādī al-Karak; Wādī I'sāl; Wādī Ḥudayra (= an-Numayra); Wādī al-Ḥasā; Wādī Madsūs ash-Shamālī; Wādī Umm Jufna; Wādī Fīfā; Wādī 'Umruq; Wādī Khunayzīr; Wādī aṭ-Ṭilāḥ; Wādī ad-Dahal; Wādī al-Ḥassiya; Wādī al-Ghuwayb; and Wādī Fīdān (see FIG. 1).

If the rainfall on the Highlands is heavy, the resulting precipitation very frequently reaches the Southern Ghawrs and Northeast 'Araba, via the above-listed wadis, in the form of destructive floods. And, as indicated in TABLE 3, these floods are frequent for the majority of the wadis in the Southern Ghawrs.

Since the water flowing in these wadis must be harnessed for use, those who wished to live in the Southern Ghawrs and Northeast 'Araba had to build dams and aqueducts in an attempt to harness the water. However, as will be indicated below, flash floods frequently destroyed these structures. As a result, the dams and their associated aqueducts and canals built to harness and to bring wadi water to people, animals, and crops were constantly in need of reconstruction and/or repair.

The greater the deforestation and general environmental degradation on the Highlands the greater the amount of rainfall that runs off into the wadis. As a result, the more destructive the floods can be (Harlan 1982: 73, 76; 2003).

Springs and Wells

Water delivery in the Ghawrs and Northeast 'Araba, as indicated previously, depends not only on rainfall in the Highlands but on water retention that is trapped and allowed to percolate slowly to the

TABLE 1. Rainfall at Three Highland and Two Ghawr Stations (from data sheets of the Natural Resources Authority. The Hashemite Kingdom of Jordan).

Location and Recording Period	*Average*	*Range (mm)*
Al-Karak 1937/1938-1973/1974	no missing data	
Ave. 37 seasons:	360.7	(101.9-661.0)
Ave. first 10 years:	414.7	(122.8-540.6)
Ave. last 10 years:	411.5	(187.1-661.0)
Al-Mazār 1937/1938-1973-1974	one season missing	
Ave. 36 seasons:	339.8	(119.8-610.0)
Ave. first 10 years:	414.6	(171.0-491.0)
Ave. last 10 years	315.7	(136.5-610.0)
Aṭ-Ṭafīla 1937/1938-1973-1974	no missing data	
Ave. 37 seasons:	280.6	(82.7-751.1)
Ave. first 10 years:	310.8	(131.0-463.5)
Ave. last 10 years:	315.2	(82.7-751.1)
Ghawr al-Mazra'a 1939/1940-1973/1974		
Ave. 28 seasons:	65.6	(6.5-149.0)
Ave. first 10 years:	63.5	(12.5-100.2)
Ave. last 10 years:	73.6	(22.0-149.0)
Ghawr aṣ-Ṣāfī 1939/1940-1973-1974		
Ave. 26 seasons:	65.2	(18.0-151.5)
Ave. first 10 years:	70.3	(35.0-109.6)
Ave. last 10 years:	57.2	(18.0-151.5)

More recent rainfall data (TABLE 2) than that which Harlan used supports the contrast between precipitation on the Highlands and in the Southern Ghawrs.

springs below or is released slowly from the upland soils to the perennial streams that are formed by the process whereby the rainfall on the Highlands infiltrates slowly through a chalky formation and is trapped by the hard limestone to emerge where erosion uncovers the impervious layers in the Wādī 'Araba-Dead Sea-Jordan Depression. The larger springs flow all year long and tend to be more stable with less fluctuation than the streams (Harlan 1981: 162-63; 2003: 60).

The process whereby the rainfall on the Highlands reaches the Southern Ghawrs and Northeast 'Araba can take months if not years. For example, the 1964/1965 season broke all records for rainfall on the Highlands at al-Karak, al-Mazār, and aṭ-Ṭafīla. However, the base flow at aṣ-Ṣāfī was less than the previous year and more than the next. The base flow at aṣ-Ṣāfī did not increase, in fact, until the 1966/1967 season (Harlan 1981: 157).

There are springs in most of the wadis flowing into the Southern Ghawrs and Northeast 'Araba. The water from these springs is also used for irriga-

TABLE 2. Rainfall at Three Highland and One Ghawr Station (from data sheets of The Hashemite Kingdom of Jordan, Meteorological Department).

Location and Recording Period	*Average*	*Range (mm)*
Ar-Rabbah/Al-Karak 1970-2003	no missing data	
Ave. 34 seasons	346.8	(123.5-638.8)
Ave. first 10 years	353.8	(184.2-582.0)
Ave. last 10 years	296.6	(123.5-518.2)
Mu'tah University 1986-1993		
Ave. 8 seasons:	389.4	(204.6-653.4)
Mu'tah University 1997-1999		
Ave. 3 seasons:	271.9	(183.0-385.1)
Mu'tah University 2001-2003		
Ave. 3 seasons	256.8	(147.7-349.1)
Al-Ḥasan/Aṭ-Ṭafīla 1971-2003	one season (1999) missing	
Ave. 32 seasons	235.0	(80.4-795.3)
Ave. first 10 years	300.5	(80.4-795.3)
Ave. last 4 years	158.0	(89.5-250.2)
Ghawr aṣ-Ṣāfī 1975-2003	no missing data	
Ave. 29 seasons	74.0	(25.1-130.4)
Ave. first 10 years	63.8	(25.1-111.7)
Ave. last 10 years	68.9	(33.9-130.4)

TABLE 3. Predicted Flood Frequencies per Century.

Wadi Name	Number
al-Ḥasā	2
I'sāl	262
Numayra/Ḥudayra	357
Fīfā	460
Khunayzīr	512
al-Karak	540

tion purposes. For example, water from springs in Wadis al-Karak, Ḥudayra, al-Ḥasā, Fīfā, 'Umruq, and aṭ-Ṭilāḥ irrigates fields nearby. Farther south, team members of the Southern Ghawrs and Northeast 'Araba Archaeological Survey (SGNAS) noted two springs near the western extremity of Wādī ad-Dahal (MacDonald *et al.* 1992: 269). And still farther to the south, 'Ayn Fīdān is located near the western extremity of Wādī Fīdān while farther to the east there are springs in both Wadi(s) al-Ghuwayr and Ḍānā (Barker *et al.* 1998: 23). These springs feed into Wādī Faynān and eventually into Wādī Fīdān.

Recent data compiled by the Geological Survey of Israel and the Natural Resources Authority of Jordan relative to the Dead Sea and northeast Wādī 'Araba indicates the present location of both springs and water wells (Sneh *et al.* 1998) (TABLE 4).

Where the impervious layers are not too deep, dug wells can tap sufficient amount of water for irrigation (TABLE 4). These sources are usually less

TABLE 4. Modern Springs and Wells between Wādī al-Karak and Wādī

Location (Ghawr - Wadi)	Spring(s)	Number of Wells
Ghawr adh-Dhrā' (W. Karak)	'Ayn Wada'a; 'Ayn Umm Sidra	1
Ghawr I'sāl (W. I'sāl)	In upper reaches of wadi	6 (4 are in the wadi)
Ghawr an-Numayra (W. Ḥudayra)	'Ayn Sadd Hābīl; more springs to the east	1
Ghawr aṣ-Ṣāfī (W. al-Ḥasā)	'Ayn 'Abāṭa; 'Ayn Khakhān	1 (wind pump)
Ghawr Feifeh (W. Fīfā);	Springs in W. Fīfā	1 in Ghawr and 12 in W. Fīfā;
W. 'Umruq Wādī Khunayzīr	Spring in W. 'Umruq Springs in wadi	2 in W. 'Umruq 5 between W. 'Umruq and W. Khunayzīr
Wādī aṭ-Ṭilāḥ	Springs in wadi	
Wādī ad-Dahal	Springs in wadi	
Wādī Fīdān	'Ayn Fīdān	1 to the southeast of 'Ayn Fīdān

reliable than springs and wells often go dry. Wells that are dug on low terraces near perennial streams in the wadi bottom are more reliable and these are exploited on a limited scale.

While springs depend upon rainfall on the plateau to the east, we must not think that the locations of present-day springs are also where ancient springs were located. Change in the location of springs is due to the fact that the down-cutting of the wadis of the Southern Ghawrs and Northeast 'Araba has gone on for millennia. This would have likely resulted in spring disruption (Donahue 1981: 153). Moreover, since the Dead Sea-Jordan River Rift is a tectonically active area, fault movements may have altered spring locations (Donahue 1981: 153). Relative to Wādī al-Karak, for example, Donahue points out that "it seems certain that the wadi floor had a higher elevation than at present" (1981: 151; see also 2003; Harlan 2003: 56). As a result, the present spring below Bāb adh-Dhrā' was not available to the Early Bronze residents of the site. The inhabitants, however, may have had access to the spring to the east in Wādī Dhrā' (Donahue 1981: 151).

Springs, being dependent on rainfall, do dry up. This is the case in periods of drought. As a result, ancient sites in the Rift Valley could have lost their source(s) of water. Thus, archaeological sites are not always located where there are present-day springs.

Wadi Sources of Irrigation Water for the Southern Ghawrs

Binnie and Jouzy Arup Bookers have studied the wadi sources of water for irrigation purposes in the Southern Ghawrs (TABLE 5). These water sources would come from the wadi flow and the springs, listed above in TABLE 4, associated with the wadis.

As indicated in TABLE 4, Wādī al-Ḥasā is, by

TABLE 5. Wadi sources of Irrigation Water for the Southern Ghawrs.

Location	Ave. Yearly base flow (l/s)	Hectares Irrigable
Wādī Dhrā'	40	68
Wādī I'sāl	30	51
Wādī Ḥudayra/an-Numayra	30	51
Wādī al-Ḥasā	810	1,377
Wādī Fīfā	110	187
Wādī Khunayzīr	40	68

far, the most important of these wadis for the purpose of irrigation. It is a perennial stream and, as TABLE 2 indicates, is considered more stable and reliable than other wadis flowing to the Dead Sea Rift and is less subject to disastrous floods than other wadis of the eastern rift escarpment (Harlan 1985). The base flow at aṣ-Ṣāfī, at the western end of Wādī al-Ḥasā, has been rated at 810 l/s based on a limited number of measurements (Harlan 1981).

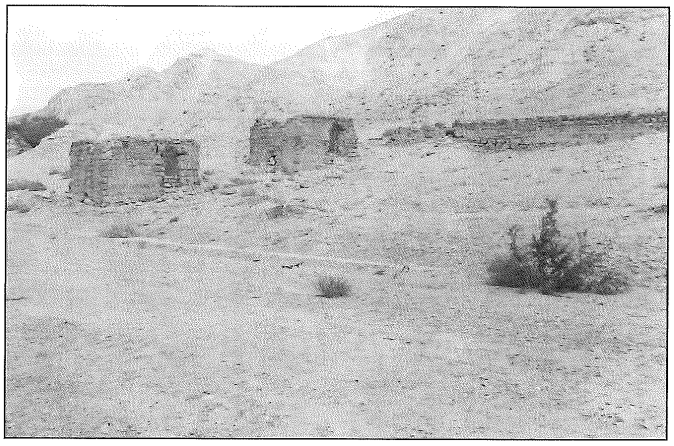
The overall pattern is one in which permanent agriculture can be developed near copious and reliable springs and at sites along the wadis that flow from the Highlands into the Southern Ghawrs and Northeast 'Araba.

Dams and Aqueducts

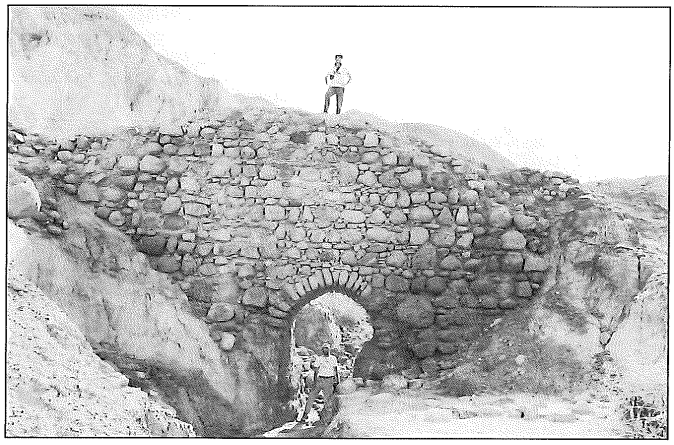
The problem is to harness the water from the wadis, springs, and wells to provide a permanent supply of water for settlers and animals and to irrigate the crops that farmers wish to grow and to provide water nourishment for the plants in the surrounding areas that the settlers harvest and animals eat. To this end, dams, aqueducts, water canals, reservoirs, cisterns, and pools needed to be constructed[1].

Harlan, in his investigations of the water resources of the Southern Ghawrs, states that he found evidence of broken and abandoned irrigation ditches along the sides of each of the wadis that he surveyed (1981: 156). Specifically, he noted the remnants of an aqueduct in Wādī al-Karak that was used to bring water to the edge of Bāb adh-Dhrā' itself (1981: 156-57). SGNAS team members found remnants of irrigation canals throughout their survey territory. For example, they found evidence of such structures in: Wādī al-Ḥasā (MacDonald *et al.* 1992: 249 [Site No. 1]; see also Waheeb 1995: 555); Wādī Fīfā (MacDonald *et al.* 1992: 167, 257 [Site Nos. 77, 84]) (FIG. 3); Wādī Khunayzīr (MacDonald *et al.* 1992: 178, 261 [Site No. 112]) (FIG. 4); Wādī aṭ-Ṭilāḥ (MacDonald *et al.* 1992: 89, 265 [Site No. 155]); and Wādī Fīdān (MacDonald *et al.* 1992: 156 [Site Nos. 16, 21]). From the above, it is evident that the struggle to maintain irrigation facilities has gone on as long as the Southern Ghawrs and Northeast 'Araba have been farmed.

Despite the rapid rate of development in the Southern Ghawrs and Northeast 'Araba, SGNAS team members found evidence of what would have been methods, probably not unlike ancient ones,



3. Aqueduct in Wādī Fīfā.



4. Aqueduct in Wādī Khunayzīr.

of irrigating the fields in the vicinity of both Fīfā (FIG. 5) and aṭ-Ṭilāḥ (FIG. 6).

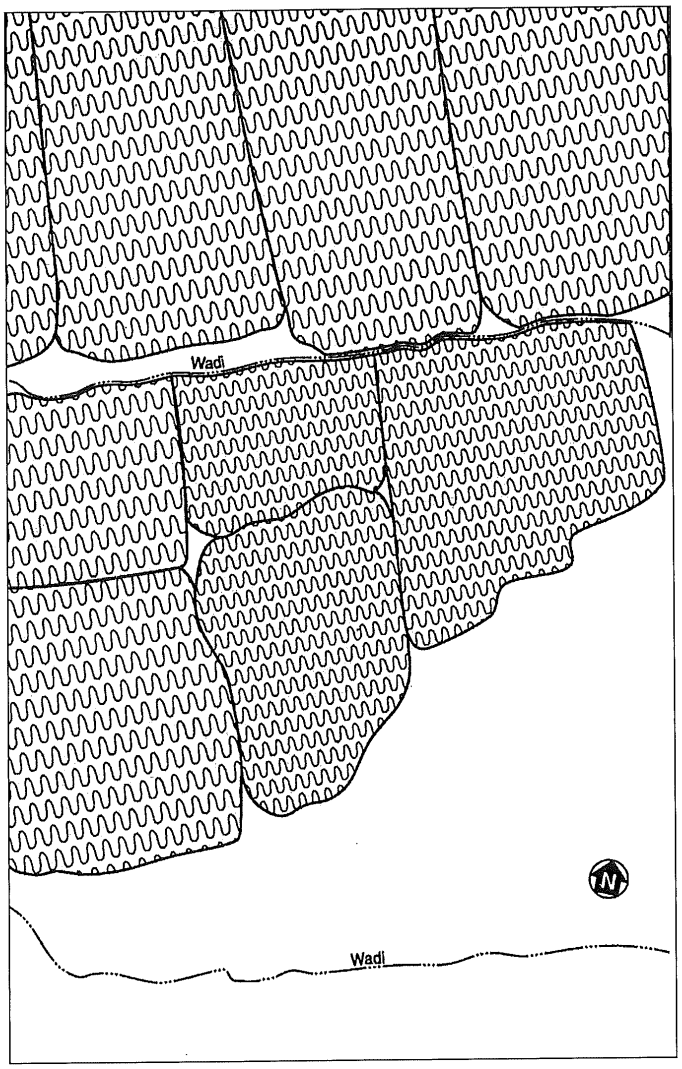
There are presently modern dams in Wādī al-Ḥasā – with plans for an additional one in the eastern segment of the wadi – Fīfā, and Khunayzīr. Moreover, the Jordan Valley Authority has plans to build a dam across Wādī Fīdān (Levy 2003: 4-5). The water from these dams is used for the purpose of irrigating the fields of the Southern Ghawrs (and eventually the Northeast 'Araba).

Reservoirs, Cisterns, and Pools

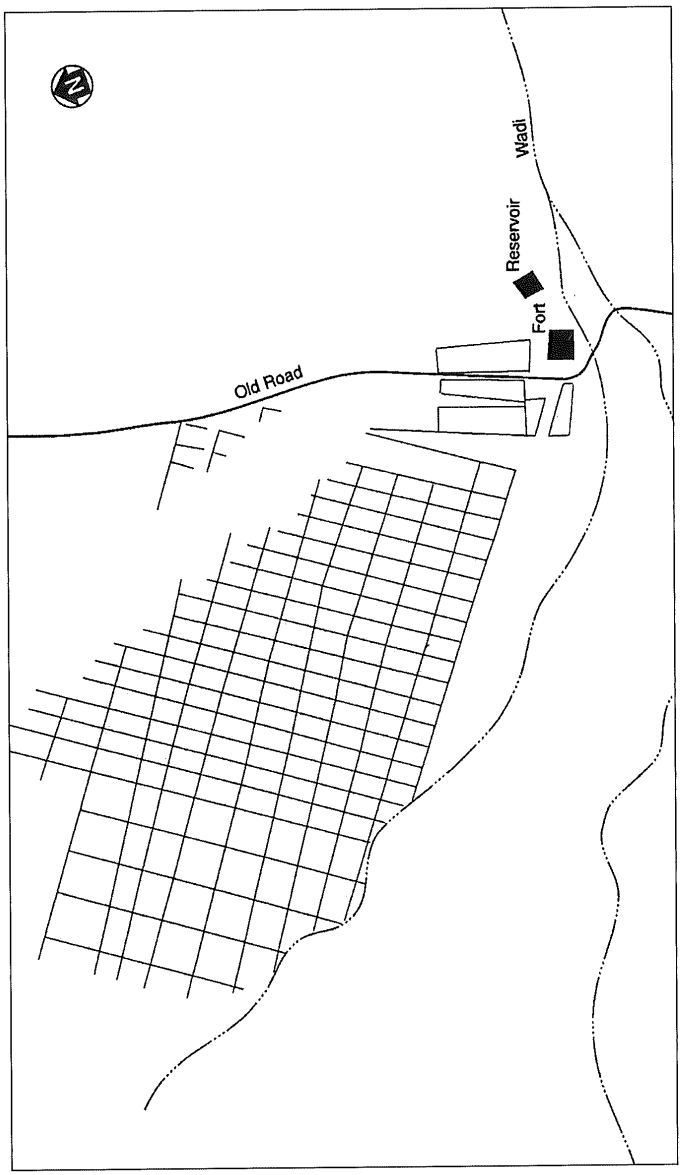
Water used for humans, animals, and plants can also be stored in reservoirs, cisterns, and pools. There is evidence of the first two of these devices in the archaeological record from the Southern Ghawrs and Northeast 'Araba.

Politis excavated a well-built cistern at Dayr 'Ayn 'Abāṭa/Lot's Cave (1998: 229-30, 232; see also MacDonald and Politis 1988 and MacDonald *et al.* 1992: 171, 254 [Site No. 46]) (FIG. 7).

[1] For the distinction among these terms see Oleson 2001.



5. Irrigated Fields to the North of Fifā.



6. Irrigated Fields to the West of Qaṣr aṭ-Ṭilāḥ.

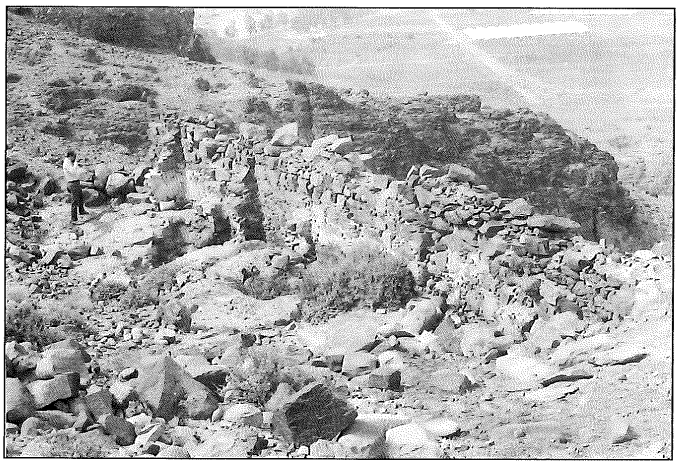
The structure measures 18 x 7m and is built into a steep cliff. The remnants of seven arches within the structure are what remain of the roof supports. Excavations of the structure uncovered an associated water catchment and distribution system (Politis 1989: 232).

SGNAS team members noted a rock-cut cistern in association with the hermitage at the mouth of Wādī al-Ḥasā, north bank (MacDonald *et al.* 1992: 104, 250 [Site No. 7). The structure measures ca. 2.2 x 3.5 metres. Plaster was visible on its interior walls at the time of the visit.

In the area of 'Unayz, between Wādī al-Ḥasā and the modern al-'Aqaba-Dead Sea Highway, SGNAS team members recorded a reservoir, al-Juwar (FIG. 8). It is presently located in an agricultural field. It probably dates to the Medieval Islamic period. The north and south walls of the structure are partially preserved (MacDonald *et al.* 1992: 252 [Site No. 27]; see also Politis 1998: 627). At the time of the survey team members' visit to the site, a modern (?) canal ran immediately to the east of the reservoir. SGNAS team members also surveyed a reservoir at Qaßr aṭ-Ṭilāḥ, a well-known fort and caravanserai (MacDonald *et al.* 1992: 89, 265 [Site No. 155]) that Glueck measured as 34.2 x 33.6m (1935: 12) (FIG. 9). The aqueduct that brought water from 'Ayn aṭ-Ṭilāḥ to the east could still be seen at places along the north side of the wadi at the time of our visit to the site (MacDonald *et al.* 1992: 89 and 92, Fig. 19)[2].

Although there are no reports of ancient pools, that is, depressions in the earth to store liquids,

[2] For additional information on Qaṣr aṭ-Ṭilāḥ, see T. M. Niemi's paper in this volume.



7. Cistern at Dayr 'Ayn 'Abāṭa/Lot's Cave at the time of its "discovery" in 1986.

8. Al-Juwar, reservoir.

9. Reservoir at Qaṣr aṭ-Ṭilāḥ.

there were undoubtedly some. These pools would have been used in times of flooding to preserve some of the water rather than having it all run off uncontrolled into the neighbouring fields. Such pools, especially where the soil is mostly clay, can hold water for an extended period of time.

Salinity

Hunting Technical Services conducted water analyses on six of the Southern Ghawrs water sources (1973). The result of this study is that the dissolved salts in the waters are fairly high. In Harlan's opinion, the waters carry more salt than is desirable (1981: 158). However, they are usable. Nevertheless, salt incrustation does occur on the irrigated fields.

The lighter the water application at each time of irrigation, the greater the problem with salt build-up. One solution to this problem is the application of heavier, less frequent irrigations.

Conclusions

Despite the fact that the Southern Ghawrs and Northeast 'Araba are arid zones, the archaeological record indicates that people have lived there for millennia. Such was possible because of rainfall on the Highlands to the east.

Some of this rainfall reaches the areas of concern almost immediately by means of west-flowing wadis. More of this rainfall percolates to the areas by means of the aquifers or water-bearing rocks, gravel, and sand that lie between the Highlands and the Wādī 'Araba-Dead Sea-Jordan Depression. This water then became available to humans, animals, and plants in the forms of springs and moisture stored in the soil.

One of the tasks of those who wished to live in the Southern Ghawrs and Northeast 'Araba was how to deal with the often destructive floods that frequently destroyed the devices that they erected to harness the water. The settlers built dams, aqueducts, and water canals for this purpose. Moreover, they dug wells and constructed reservoirs, cisterns, and probably pools to preserve the water so that it could be rationed out for the purposes of living and growing.

The amount of salt in the waters of the Southern Ghawrs does cause problems for the growing of crops. However, one solution to this is heavier and less frequent irrigations.

The above-described water-control strategies made, and continue to make, settlement in the Southern Ghawrs and Northeast 'Araba possible.

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