THE ḤUMAYMA HYDRAULIC SURVEY: PRELIMINARY REPORT OF THE 1986 SEASON

by
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Introduction

The first season of the Ḥumayma Hydraulic Survey took place between 31 May and 26 June, 1986. This project, funded by a three-year grant from the Social Sciences and Humanities Research Council of Canada and by the Faculty of Arts and Sciences of the University of Victoria, has as its objective the analysis of the character and evolution of the system of water-supply of the ancient settlement of Avara during the Nabataean, Roman, Byzantine, and — it is hoped — the Umayyad periods. The project is licensed by the Department of Antiquities of the Hashemite Kingdom of Jordan.[1]

The site of Avara, now called Ḥumayma, was one of the major Nabataean centres in the Ḥisma, Jordan's southern desert.[2] It is located 15 km west of the modern Desert Highway, approximately equidistant between ʿAqaba on the south and Maʿan on the north. The relatively good preservation of the site, its well-marked urban or proto-urban focus,[3] and the clear definition of its catchment area and hydraulic resources make it an excellent candidate for a case study. Much has been written about Nabataean skills in intercepting and storing water in the arid region they inhabited, but no integrated analysis of their capabilities has yet appeared.[4] Furthermore, the precise character of the reworking of this technological inheritance by the Romans after their occupation of the kingdom in the early second century has never been properly documented. The goal of the Ḥumayma Hydraulic Survey is completion of research for a monograph provisionally entitled *The Water-Supply Systems of Nabataean and Roman Ḥumayma: Technology and Society in a Desert Environment.* This will be the first full evaluation of all the water systems at a well-preserved Nabataean site, taken in their historical and technological context.[5] It will concern itself as well with broader questions, such as the origins of the Nabataean skill in hydraulic technology, and the cultural reasons for differences between Nabataean, Roman, and possibly post-Roman use of the scarce desert water resources.

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1. The author was the Project Director; the Field Assistant was Mr. Andrew Sherwood, Princeton University; the Representative of the Department of Antiquities was Mr. Suleiman Farajat. Through the kind permission of the Ministry of Education the team was allowed to live in a school building at New Ḥumayma. I am very grateful to Dr. Hadidi, Director of the Department of Antiquities, for granting a permit for this season's work, for his advice on the project, and for helping with the practical arrangements. I would also like to thank Prof. John W. Eadie, University of Michigan, who holds the original permit for the site of Ḥumayma, for permission to initiate this related project. Dr. David McCreery and Mr. David Jacobsen of the American Center of Oriental Research, Amman, provided invaluable advice and logistical assistance during the 1986 season and the year of preparation that preceded it.

2. For the bibliography on Ḥumayma, see Eadie and Oleson 1986, p.73-6. Add now Eadie 1984; Gregory and Kennedy 1985, p.317-29, 433; Jobling 1984; Mayerson 1986, p.41-2; Oleson 1984.

3. I have tried to avoid as much as possible applying the term "city" to the site, since it still is not clear how appropriate that term is to Avara or any other Nabataean settlement. There is good discussion of the question of the nature of Nabataean "urbanism" in Negev 1976, p.132-3, 1977, p.586.

4. The most important studies are cited in Eadie and Oleson 1983.

5. A doctoral dissertation presented at the Sorbonne in 1983 by Zeidoun Al-Muheisen, *L'Alimentation en eau de Petra,* provides an admirable catalogue of the evidence for hydraulic technology in the ancient city, but the analysis is only rudimentary. There is a copy of this dissertation in the Department of Antiquities Library, Amman.

In 1983, in collaboration with Prof. John Eadie of the University of Michigan, who holds the permit for the city site, I carried out several soundings in reservoirs within the settlement and surveyed part of the aqueduct.[6] The comprehensive survey of hydraulic technology just begun will stretch over three seasons of field work. The first — completed in 1986 — involved the careful survey of the natural catchment area of Avara, outside the actual habitation centre, in an attempt to locate and catalogue all water resources and the structures associated with their exploitation. Included were springs, cisterns, wadi barriers, artificial terraces and cleared fields, an aqueduct, and a dam. The second season, scheduled for 1987, involves searching out and cataloguing all such facilities within the habitation area proper, particularly reservoirs and cisterns, and, where necessary, excavation to determine the nature of the distribution system and its chronology. During the third season, scheduled for 1988, the project director will examine structures associated with hydraulic technology at other Nabataean and Roman sites in Jordan and the surrounding regions as comparative material.

Execution of the 1986 Survey

The area selected for survey in 1986 was quite large for a team of three individuals to cover in four weeks: 240 square kilometres. The objective was feasible, however, because the goals were circumscribed and strictly defined, and the structures targeted were very characteristic in design and usually easy to spot in the barren landscape. The survey was judgemental and did not attempt to record all evidence for past human occupation of the region.

The survey area was essentially the drainage catchment between Ḥumayma and the al-Sharah escarpment, along with the Wadi Qalkha and its tributaries from Ḥumayma proper as far south as the modern Ma'an- 'Aqaba highway (Fig. 1). The northern boundary was the crest of the escarpment between 'Ain el-Qanah and the line of the new highway just below Ras en-Naqab. The line of the new road was taken to define the eastern and southern border. Although this last boundary is artificial in strictly archaeological terms, it does in fact include only slightly more than the rainfall catchment area along its northern portion. It terminates 10 km south of the site at the natural southern boundary of the territory presumably presided over by Avara: the gap between Jebel Thaur and Ḥudeibāt Um Dureira, through which passes the Wadi Qalkha. The western limit was taken to be the boundary between the Wadi el-Jamam and Wadi el-Beiḍa watersheds. The former feeds the Wadi Qalkha. The latter leads into the Wadi el-Ḥilwa, which dives steeply through the western mountains to the Wadi 'Araba. Exceptions were made, of course, for sites like 'Ain el-Qanāh, which is in the Ḥilwa watershed but is connected to the city by an aqueduct, and for several sites on the southeastern slopes of the hills along the highway which are outside the watershed but well within Avara's probable area of interest. The fringes of the Wadi el-Beiḍa watershed were, in fact, surveyed during some extra time available at the end of the season, but without result. South of the settlement centre, the western boundary of the survey area was formed by the crest of the Jebel Qalkha, which backs right up against the precipitous descent to the Wadi 'Araba, and by the lower slopes of the Jebel Thaur, which towers over the pass down the Wadi el-Yutum to 'Aqaba.

In simplified form this area can be visualized as two great amphitheater-shaped valleys just north and just south of Ḥumayma, separated from each other by a low ridge extending west from the Ḥudeibāt edh-Dhiru (adjacent to the new highway) almost as far as the site itself, cut off from it by the wide bed of the Wadi el-Amghar. The winding courses of the Wadi el-Jamam and Wadi el-Amghar in the north and the great Wadi Qalkha in the south form their respective foci. From the settlement site the crest of the escarpment can be reached

6. Reported in Oleson 1984; Eadie and Oleson 1986.

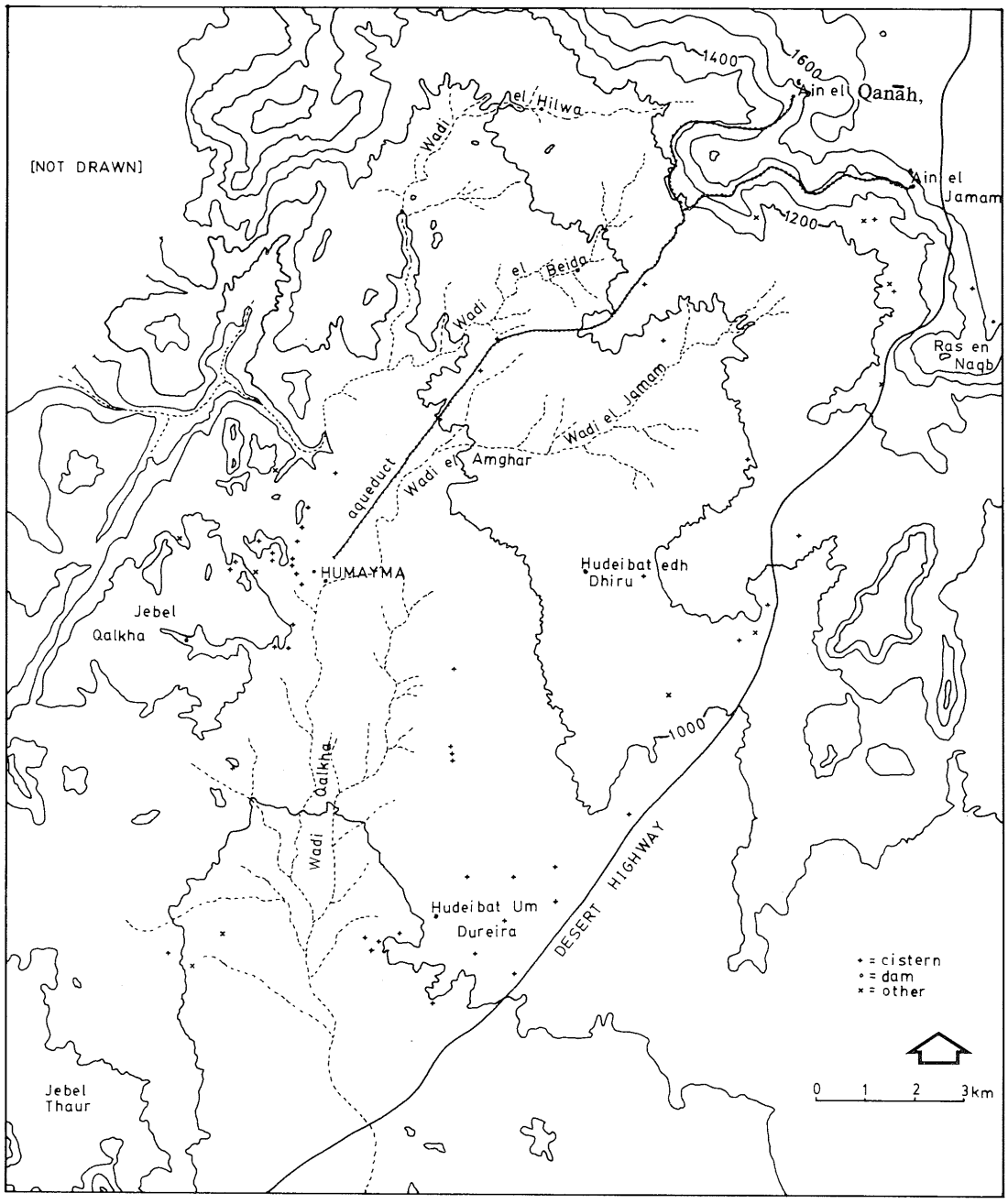

Fig. 1. Ḥumayma: map of survey area. (Map: Oleson).

in about five or six hours of walking (depending on the route), the eastern edge of the Ḥudeibāt edh-Dhiru in two hours, the intersection of the Wadi Qalkha and the new highway in about three hours, and the sheer cliffs overlooking the Wadi Aḥeimir, west of the city, in about one hour. The 1986 campaign began at the periphery of this survey area and worked toward the settlement site near its centre, treating the aqueduct as a single feature that was examined separately. The modern network of dirt roads and tracks provided relatively easy access to much of the area by four-wheel-drive vehicle, but the search for hydraulic installations was carried out for the most part on foot. As each new site was discovered, relevant data were entered on standard site record sheets, and each site was assigned a number for ease of reference. No excavation was carried out this season, but the nature of ceramics observed on the surface was recorded, and samples of building materials were collected.

Results

Sixty-one sites were recorded during the 1986 survey, some of which contained several different types of structure or several examples of a single type. The results can be tabulated as follows:

cisterns: 51
springs: 4
aqueduct: 1
dam: 1
wadi barriers: 2
terraces and stone piles: 6
"slides": 4

Cisterns. The predominant category clearly is that of cisterns, although reuse and the similarity of some ancient and modern building traditions occasionally made it difficult to determine whether a cistern was of ancient or recent origin. Nineteen of the cisterns (all but one of them cut in the bedrock) are only possibly ancient. The design or present condition of the remaining 32 examples mark them out clearly as ancient in origin, although the precise chronology cannot yet be determined. Only two of these ancient cisterns are built mostly of blocks rather than cut in the bed-rock. Of the remaining rock-cut cisterns, 16 were unroofed, roofed with stone slabs, or roofed with an undisturbed stratum of bedrock. The other 14 were roofed in typically Nabataean fashion by means of stone slabs carried on arches springing from the side walls of the cistern basin. One of these must be the best-preserved unrestored Nabataean cistern known: four of the five arches were intact, carrying nearly all their original roofing slabs (Pl. XLIII, 1).

Springs. The three springs that fed the aqueduct — 'Ain el-Qanāh, 'Ain el-Jamam, and 'Ain Sharah — must have been critical to the water-supply system of Ḥumayma, because their discharge was brought to the settlement at enormous effort through 27 km of conduit. At present the springs discharge an average total of 2.2 m^3/hour; the 'Ain el-Jamam and adjacent 'Ain Sharah are by far the most prolific.[7] The survey documented the connection of these three springs with the aqueduct leading to Ḥumayma. It is puzzling that a fourth spring, the 'Ain 'Abu 'Insor, approximately 2.25 km southeast of 'Ain el-Jamam, does not seem to have been connected to the aqueduct.[8] It may be that the flow of this spring was less in antiquity than now and was completely exhausted by the needs of a Nabataean and, later on, Roman military post the remains of which are still visible

7. The statistics on water flow were provided through the kindness of Mohammed Abu Taha of the Irrigation Authority, Amman. The present average flows are 'Ain el-Qanāh, 0.25 m^3/hour, 'Ain el-Jamam, 1.2 m^3/hour, 'Ain Sharah, 0.75 m^3/hour, 'Ain 'Abu 'Insor, 0.9 m^3/hour. The maximum possible flow through the aqueduct has been calculated at 6.2 m^3/hour (Eadie and Oleson 1986, p. 68).

8. Jobling 1983, p. 188 assumes that 'Ain 'Abu 'Insor was connected to the Ḥumayma aqueduct system, but a careful search for evidence of a branch channel between this spring and 'Ain el-Jamam produced nothing. Construction of the new highway has disturbed much of the intermediate area, but some traces of the channel's substructure or highly characteristic conduit blocks should have survived had they existed there.

100 m to the south.

Aqueduct. The aqueduct leading to Ḥumayma is the most remarkable surviving example of Nabataean hydraulic technology so far reported anywhere. Even in isolation it would make the site of Ḥumayma memorable. The main line extends from 'Ain el-Qanah, at an elevation of 1,425 m for 18.901 km to the Nabataean reservoir at the north end of the habitation centre, at 955 m. A branch line 7.625 km long connected 'Ain el-Jamam and 'Ain Sharah, also at an elevation of 1,425 m, to the main line, joining it 6.557 km downstream from 'Ain el-Qanah, The character and design of the aqueduct is described in some detail by Oleson in Eadie and Oleson (1986, p. 61-70). In summary, it consists of a heavy rubble foundation wall 0.80 m. across, carrying long stone conduit blocks framed by rubble packing set in mortar (Pl. XLIII,2). A water channel 0.12 m wide and 0.14 m deep has been carved lengthwise along each of the monolithic conduit blocks.

Along almost the entire course of the aqueduct the conduit blocks have been exposed by the decay of its superstructure, but this year for the first time intact sections were found that revealed the method of roofing the channel. Fist-sized pieces of rubble were set in a hard mortar on the upper edges of the conduit blocks alongside the trough and smoothed over with stucco on the interior. Untrimmed, but for the most part flat, slabs of limestone were laid over the top, covering the water course. This roofing was designed to protect the water from evaporation, contamination, obstruction by falling debris, and possibly from unauthorized diversion. A still unexplained feature is the use of inverted roof-tiles set inside the conduit blocks in the Jamam branch to carry the water (Pl. XLIV, 1).

The use of a hand-operated odometer wheel permitted accurate recording of the aqueduct, starting from the springs and ending at the city. In this way, precise measurement of the enormous structure was accomplished, slopes calculated, and the location recorded of features of special interest encountered along the way. The 1986 survey documented for the first time the presence of draw tanks along the course of the aqueduct and recorded stretches of the structure which preserved their covering slabs (Pl. XLIV,2). The remarkable variations in the slope of the aqueduct, only now accurately charted, continue to be astonishing. The average slope from the springs to the city is 2.45%. The actual slope varies constantly, however, from slightly less than 1% at either end to 10%, 20%, and even 45% for precipitous sections along the el-Sharah escarpment (Pl. XLV,1).

Dam. A large, beautifully constructed and splendidly preserved dam was found late in the season in a small canyon just south of Ḥumayma (Pl. XLV, 2). This structure (L 10.66 m, W 4.36 m, H 3.65 m) was built of blocks of limestone set in mortar in a head-and-stretcher arrangement, and the spillway, the most vulnerable part of any dam, was cut into the bed-rock at one end. Sand has completely filled the basin upstream, but it still retains a significant amount of water, which trickles out slowly between several of the blocks. The location, coursing of the blocks, and presence nearby of a Nabataean inscription cut in the canyon wall confirms its Nabataean character. Rock-cut stairs give access from below to the upper surface of the dam, where water could have been obtained by dipping. The canyon walls are too steep and high to allow any other approach.

Wadi Barriers. Although the Bedouin around Ḥumayma now commonly make use of earth and stone wadi barriers to slow the process of erosion and foster the infiltration of run-off water into their fields during the winter, only two possibly ancient structures of this type were catalogued. By their very nature, such barriers are vulnerable to complete destruction, and in the immediate vicinity of Ḥumayma the recent use of tractor-drawn plows in the ancient fields has obliterated any traces. One of the two sets of barriers tentatively accepted as ancient (Pl. XLVI, 1) differs from the modern examples in being constructed of large boulders rather than of earth or small

stones. The antiquity of the other is suggested by the presence nearby of ancient architectural remains.

Terraces and Stone Piles. The clearing and terracing of slopes was a method used by the Nabataeans, along with most other Near Eastern peoples, to improve and protect arable land on such terrain. In addition, the terraces help hold back water running off the slopes after a rain and thus increase absorption. Only six sites with this feature were identified, perhaps because the local geology makes most of the sloping ground around Humayma totally unsuited for agriculture. In one case, a field was simply cleared of surface stones by heaping them in orderly rows of piles (Pl. XLVI, 2). This procedure freed some ground for agricultural activity, but it may also have been intended, as at Nabataean sites in the Negev,[9] to increase run-off to a field lying below.

''Slides''. Two types of grooves cut in the slopes of sandstone hills were encountered in the course of the survey: the enigmatic features were termed ''slides'' for lack of any better definition. They seemed at first possibly relevant to water-supply, but in retrospect they can be seen to be unrelated. The features nevertheless are mentioned here to prevent confusion among other researchers in the field of ancient hydraulic technology and in the hope of eliciting suggestions of their function. The first class (Pl. XLVII, 1) consists of smooth, shallow grooves, 0.20-0.40 m wide, worn down short, steep sandstone slopes, usually in groups of 3 to 6. They are often associated with rows of circular depressions that seem to be eroded toe holds for ascending the slope to the crest. The grooves are capable of carrying water, but they were never associated with a cistern or natural catchment area. Examination of some freshly-worn examples revealed the presence nearby of abraded, flat-bottomed stones or flattened jerry-cans, suggesting that at least at present some of the grooves are used as slides by Bedouin children. The grooves are not necessarily ancient, and their relevance to hydraulic technology is highly doubtful.

The second type of ''slide'' remains enigmatic. These are wide, shallow slots, 0.30-0.40 m wide and 0.02-0.05 m deep, cut into bedrock slopes with picks or chisels (Pl. XLVII, 2). They nearly always have a slightly deeper, narrow, central groove and vary in length from 1.0 to 30 m. The cuttings are usually arranged in a disconnected series of 5 or 6 examples of different lengths up the side of a rolling sandstone hill. The upper end of the lowest cutting is always at precisely the same level as the lower end of the next cutting, but separated from it by a horizontal distance of 1 to 10 m, and the same arrangement continues up the hillside with the rest of the cuttings. Some of the channels are placed in such a position that they could have carried water, but most are not. In any case, no cistern was ever observed in association with any of the cuttings. Since the manner of stone-working seems to be ancient, and groups of these grooves can be found throughout the northeastern part of the survey area, they should have some relevance to Nabataean culture in the region.[10]

Preliminary Analysis

The water supply system of ancient Avara was regional in scope and varied in its strategy. Around the periphery of the catchment area, where the bed-rock is at the surface and the topography fosters rapid, directed run-off of rain water, there are rock-cut cisterns and wadi barriers. Few cisterns were built in the lowland area around the settlement centre, in the land most suited for agricultural use. Construction would have been more difficult here, since the bed-rock is inaccessible, and local run-off is more scanty in the absorbent sandy soil. Only in the habitation centre

9. See Evenari, Shanan, and Tadmor 1982, p. 127-47.

10. I have not seen parallels for the second type of groove at any Nabataean site. I would be grateful for any information concerning similar features elsewhere, or suggestions of their function.

itself, where the concentration of population required it, and where the aqueduct and roofs of houses supplied artificial catchments, where cisterns built entirely of blocks. The cisterns around the periphery of the Humayma catchment must have been intended primarily for livestock and the herdsmen and farmers spread thinly over the region. Rainfall is too meager and evaporation too extensive to allow dependence on irrigation for major crops.[11] The wadi barriers and terraces were designed to counter these factors and enhance the moisture content of the soil. The placement of most of these cisterns close to the border between bed-rock and arable land is consistent with this interpretation. Both farmers in the nearby fields and herdsmen leading their flocks from field stubble to wild brush land and back again could have made use of such a location.

All these structures must have been planned and built by individuals, and consequently privately owned. The aqueduct, by contrast, must have been a public structure. It is by far the longest known Nabataean aqueduct, and it is longer than any other pre-Roman aqueduct in the Near East, with the exception of that serving Herodian Jerusalem.[12] The concentration of resources needed for its construction shows that it was felt to be critical to the survival of the settlement. Only excavation can reveal whether it was built when Avara was founded, to ensure the viability of the settlement, or later on, when the population had out-grown the local water sources. What is significant is that Avara reached out farther into the countryside for its water than any other pre-Roman settlement in the Near East. The extent of this effort implies as well the existence of highly developed social mechanisms within the settlement for governing the distribution and use of the water. Excavations within the habitation centre in 1987 should shed light on this important question.

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11. See Eadie and Oleson 1986, p.72.

12. Parallels for the aqueduct are cited in Eadie and Oleson 1986, p.69-70.

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