THE ḤUMAYMA HYDRAULIC SURVEY PRELIMINARY REPORT OF THE 1987 SEASON

by
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Introduction

The second season of the Ḥumayma Hydraulic Survey took place between 4 June and 3 July, 1987. 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 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 and Roman centres in the Ḥisma, Jordan's southern desert (Fig. 1).[2] It is located 15 km west of the modern Desert Highway, approximately equidistant between ʿAqaba to the south and Maʿan to the north. The relatively good preservation of the site, with its well-marked urban or proto-urban focus, and the clear definition of its catchment area and hydraulic resources make it an excellent candidate for a case study of Nabataean skills in intercepting and storing water. No integrated analysis of these capabilities has yet appeared, and little attention has been paid to either the effect of outside influence on the genesis of this local technology or alterations to it imposed or fostered by the new needs and resources of the Roman conquerors.

During the 1986 season, the team surveyed the 240 km^2 region of the catchment around Ḥumayma, examining and cataloguing the aqueduct system, four springs, 51 cisterns, two sets of wadi barriers, one dam, and six sets of hillside terraces or stone piles. Plans for the 1987 season included the excavation of probes at selected points along the aqueduct and at several cisterns outside the settlement, but the major focus was the water-supply and distribution system within the settlement centre itself. Particular importance was placed on defining the structure, chronology, and function of the reservoirs inside the military camp and at the end of the aqueduct, and of the two large cisterns in the centre of the habitation area. These were the keys to the water-system of Avara. Careful examination of the site also led to the identification of a number of smaller cisterns and of several conduits and drains associated with water management inside the settlement. In all, sixteen new structures were catalogued in the course of the season: two reservoirs, eleven cisterns, two sets of conduits or drains, and one bath building. In addition, 43 probes were executed at ten distinct sites. Although some of the structures examined in 1986 impinged on the periphery of the ancient settlement centre, all those probed or catalogued in 1987 (with the exception of

1. The author was Project Director; Field Assistant was Mr. Andrew Sherwood, Princeton University; Representative of the Department of Antiquities was Mr. Suleiman Farajat. Mr. Erik De Bruijn of the University of British Columbia and Mr. Esam ed-Din ʿOthman el-Hadi of Yarmouk University served as trench supervisors. Through the kind permission of the Ministry of Education the team was allowed to live in a school building at Ras en-Naqab. I am very grateful to Dr. Hadidi, former Director General 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. Dr. David McCreery and Mr. Glen Peterman of the American Center of Oriental Research, Amman, provided invaluable advice and logistical assistance during the 1987 season.
2. For the bibliography on Ḥumayma, see Eadie and Oleson 1986: 73-6. Add now Eadie 1984; Gregory and Kennedy 1985: 317-29, 433; Jobling 1984; Mayerson 1986: 41-2; Oleson 1984, 1986, 1987a, 1987b.

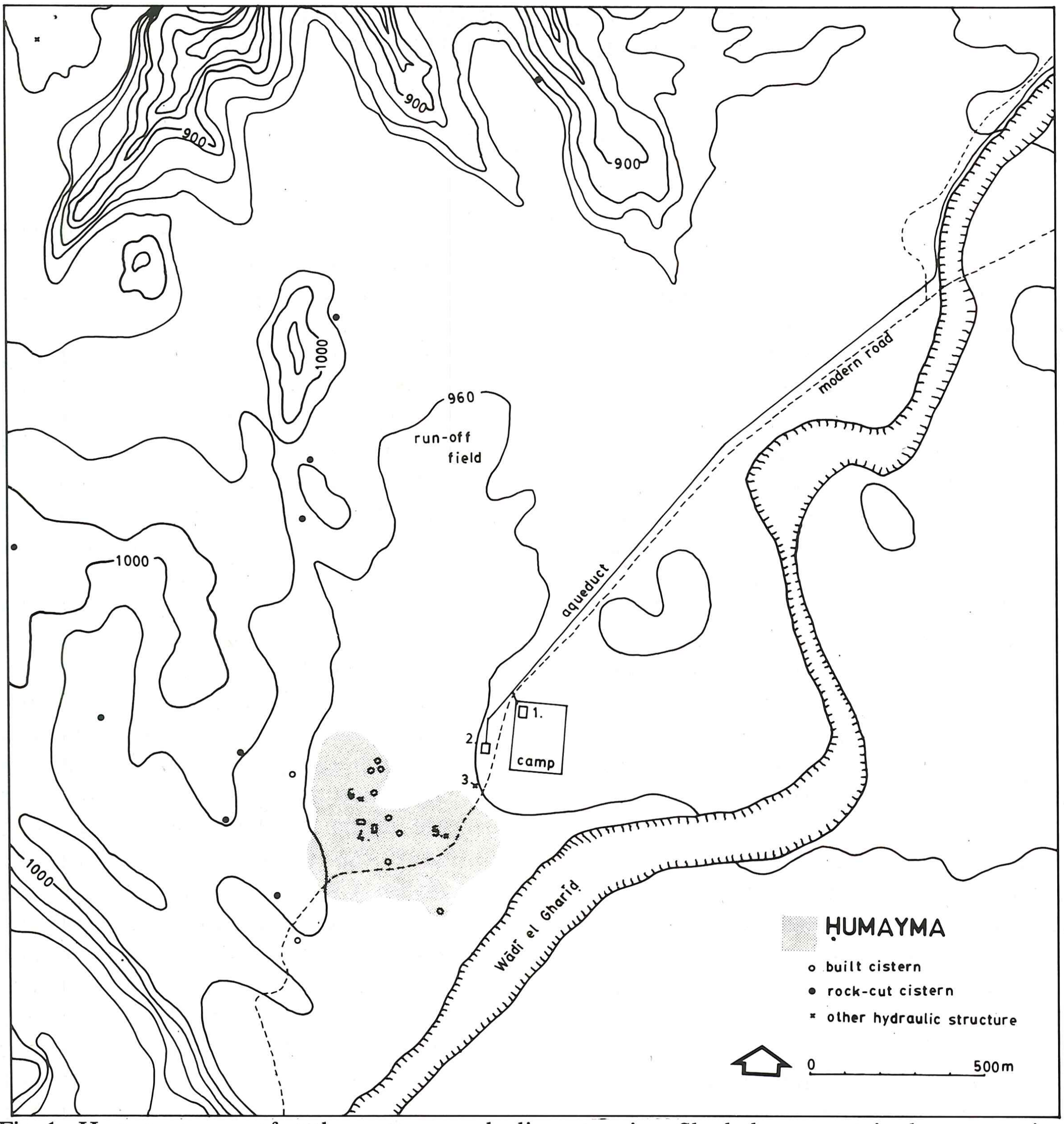

Fig. 1. Ḥumayma: map of settlement area and adjacent region. Shaded area contains house remains. No. 1: *castrum* reservoir. No. 2: Nabataean reservoir. No. 3: possible bath building. No. 4: large Nabataean cisterns.No. 5-6: drains.

the aqueduct) were well within the area occupied by the ruins of ancient Avara. Some of the cisterns around the periphery of the settlement indicated on Fig. 1 were recorded in the 1986 season.

Aqueduct

The aqueduct system serving Ḥumayma consists of a main line 18.901 km long from the Ghana spring (at an elevation of 1425 m) to the Nabataean reservoir in the settlement centre (at 955 m), and a branch line 7.625 km long leading from the Jamam and Sharah springs (at 1425 m) to km 6.557 of the Ghana line (at 1180 m elevation). This aqueduct, by far the longest and most elaborate in the Nabataean world, and remarkable even in comparison with the aqueducts built in the Near East by the Romans, was carefully surveyed during the 1986 season.[3] A number of anomalies or

3. See Oleson 1986, 1987a, 1987b. Parallels for the aqueduct are cited in Eadie and Oleson 1986: 69-70.

points of special interest were noted at that time, and probes were carried out at seven of these points in 1987: five probes near the beginning of the Jamam branch, and two on the main Ghana line just downstream from its junction with the Jamam branch.

An intact portion of the Jamam branch at km 1.770 was probed to clarify the design and construction of the aqueduct, and to provide ceramic evidence for its date (Pl. XXVI,1). As expected, the probe revealed that the aqueduct structure was composed of typical marl conduit blocks (L ±0.95 m; W 0.34 m; H 0.36 m) set in a packing of mortared rubble and framed on both sides by larger, partially trimmed blocks. A line of fist-sized stones packed in the same grey mortar ran along both top edges of each conduit block, framing an inverted terracotta roof tile set in mortar in the channel itself. A coating of hard white plaster lined the inside surface of the tiles, covered the rubble packing above them on either side, and was finished to a smooth upper surface. The capping slabs, for the most part virtually unworked stone blocks with at least one more or less flat face, were placed face down over the channel on the mortared surface and the edges sealed with a chalky but hard white plaster. The overall width of the finished structure was 0.90 m. The surface fill around the aqueduct at this point contained a rich collection of Nabataean, Roman, and Byzantine coarse wares, while the foundation loci, including sherds imbedded in the mortared rubble, contained only "Roman" coarse wares of the first centuries B.C. or A.D.[4] Even the broader chronology of the surface collection suggests a *terminus post quem* of the Nabataean period, since there is no other obvious stimulus for the concentration of sherds along the line of the aqueduct other than the presence of the aqueduct itself. Sherds are very rare on the surface beyond three to five metres of either side of the aqueduct. In combination with the ceramic evidence for the date of the Nabataean reservoir in the settlement centre that was fed by the aqueduct (see below), these data suggest that the Jamam branch, and thus the main Ghana branch as well, was built by Nabataeans in the early years of Avara's existence, during the first century B.C.

An intact section of the main line of the aqueduct was cleared at km 6.860, just downstream from its junction with the Jamam branch. The design and construction technique is the same as that of the Jamam branch, except that no tiles were set into the stone conduit channel (Pl. XXVI,2). Instead, a thin (Th 0.002 m) coating of hard, white plaster lined the channel and (increasing to Th 0.01 m) extended up over the packing stones above and on either side of the conduit blocks. No sherds were recovered in the fill around the foundation of the aqueduct at this probe, but a Nabataean or Early Roman jar fragment of the first century B.C. or A.D. was recovered from the mortar packing at km 4.482. A thin surface scatter of Nabataean, Roman, and Byzantine pottery occurs along almost the whole length of the Ghana line, reinforcing the data recovered from the Jamam branch.

Four small tanks built across the Jamam branch at km 1.182, 1.790, 1.925, and 2.495 were also probed. Two more tanks identified at km 1.373 and 2.260 were too damaged to justify excavation. Although these features all vary somewhat in design and dimensions, each incorporates a sturdy tank (L 0.50-0.76 m; W 0.33-0.70 m; depth 0.30-0.50 m) on or next to the line of the aqueduct, built of stone slabs and lined with waterproof plaster. A heavy circular curb was preserved around the tanks at km 1.182 (D 1.75 m) and 1.790 (D 2.15 m; Pl. XXVII,1). Although the relevant loci have not always been preserved, none of the basins is obviously a later addition to the aqueduct. At first glance they look like draw basins intended to provide water for the use of shepherds

4. These and the other chronological deductions in this report are based on our preliminary reading of the pottery: further study and refinement of the chronology will take place over the coming year. I would like to thank S. Thomas Parker, Burton MacDonald, Robin Brown, David McCreery, and Nancy Lapp for their advice concerning some of the ceramic material.

or settlers on the edge of the Ghana escarpment. The cover slab preserved at km 2.495, however, is too heavy to have allowed the frequent, convenient removal typical of draw basins, and the basin at km 1.182 is located on the edge of a cliff, at a point where access is very difficult (Pl. XXVII,2). In consequence, it is more likely that these features were designed as settling basins to remove some sort of sediment carried by the water from the Jamam and Sharah springs. This interpretation fits in as well with the location of the basins, since they occur only along the first 2.5 km of the Jamam branch.[5] The use of tiles inside the conduit blocks along most — but not all — of the Jamam branch may be related to the same problem, since neither tiles nor basins occur anywhere along the Ghana branch. Possibily the Jamam and Sharah springs threw a particularly heavy sediment or mineral deposit, and the hyperbolic curve of the cross-section of the tiles was designed to speed up the water during periods of low flow so that the sediment would be carried along to the tanks for removal. Beyond the tanks, where the slope increases, the tiles may have been intended to hurry the water along to the junction with the Ghana line, where dilution apparently solved the problem, whatever it was.

It is unlikely, in view of the unique character among Nabataean aqueducts of this use of tiles, that the Jamam branch was designed from the start to incorporate tile inserts. Nevertheless, the tiles must have been added at the initial stages of testing and use, since there is no water deposit on the stone conduit channels, below the tiles. The problem the tiles were meant to solve probably became apparent during preliminary testing of the channel, even before the cover slabs were put in place. Here and there along the Jamam aqueduct the tiles subsequently were torn out in antiquity for stretches of 10 to 20 m, damaging the plaster finish; just upstream from the tank at km 2.495, for example. It is possible that the insertion of tiles in the aqueduct subsequent to the survey, levelling, and construction raised its level to such an extent that some sections gradually became inoperable as a result of even slight settling. As the flow of water slowed and pooling occurred in some sections, removal of the tiles for a short distance downstream from the affected portion could have alleviated the problem. The deposition of calcium carbonate on the stone conduit channel is proof that the aqueduct continued to function afterward. It is hoped that further study will resolve these related questions concerning the tile inserts.

Reservoirs

The two reservoirs at the northeast edge of the habitation area are at present the most spectacular hydraulic structures at the site, and they have been noticed by nearly all the early archaeological surveys and travellers.[6] The larger of the two (L 29.40 m; W 14.20 m; depth 3.05 m) was built just inside the northwest corner of the military camp, or *castrum,* next to the modern dirt road (Fig. 1.1; Pl. XXVIII,1). Since the interior is filled with rubble and wind-deposited earth to within 1.25 m of the lip, a probe was laid out at the northwest corner to determine the depth. The horizontal, plastered stone floor was found 3.05 m below a flat slab with a curved inner edge that formed the transition between the curved mortar packing of the waterproof lining below and the square corner of the curb above. The dimensions of the reservoir, which are very close to 10 by 50 by 100 Roman feet, indicate a Roman or Byzantine date, as does the

5. Rock-cut settling basins very similar in internal dimensions occur along the early Roman aqueduct at Oinoanda, most of them close to the most productive feeder spring serving the system. See Stenton and Coulton 1986: 21-22.

6. See Brünnow and Domaszewski 1904-1909: 476-78; the best description is found in Sir Aurel Stein's 1940 report, now published in Kennedy 1982: 274-75; Gregory and Kennedy 1985: 317-29, 433.

typically Roman plan of the *castrum* around it.[7] A probe into the rubble packing behind the reservoir wall at the southwest corner yielded Nabataean, Roman, and early Byzantine sherds. The reservoir and camp should belong to the same construction period, since they are complementary in character and the long axes of each have the same bearing (10°). The walls of the reservoir, which has a capacity of 1252 m^3, were built of seven courses of massive, carefully trimmed sandstone blocks set in a hard white mortar and waterproofed with plaster.

At the beginning of the season, the method by which this enormous structure was filled with water remained a puzzle. Some early travellers had reported that the aqueduct which carried water from the Ghana, Sharah, and Jamam springs to Avara led to this reservoir,[8] and some of the local Bedouin asserted that the blocks of this channel survived until 30 years ago. There are, to be sure, remains of the aqueduct 80 m west of the northwest corner of the camp, but in 1983 I proved that it was designed to feed the Nabataean reservoir 200 m farther south and noted that there were no longer any traces of an aqueduct at the northwest corner of the reservoir or the adjacent corner of the *castrum.*[9] Although acceptance of early travellers' reports without archaeological confirmation seemed risky, some connection to a major source of water appeared necessary, since the reservoir is built at the highest point inside the camp and therefore could not easily have been filled by run-off from the roofs of buildings within the walls. Even the run-off from the large field just to the north of the camp probably would have been insufficient to fill it reliably.[10]

A trench was excavated across a depression in the rubble of the northwest corner of the *castrum* wall to search for traces of this branch conduit (see Pl. XXVIII,1, arrow in background). This probe uncovered a rough rubble pavement approximately 1.0 m below the present ground level, surrounding a conduit built of sandstone blocks similar to those used in the Ghana aqueduct (Pl. XXVIII,2). The sides of the conduit blocks were raised by a packing of small, flat stones set in mortar, and further wall and roof slabs were laid on top of the smooth mortar surface. This aqueduct entered the camp from a northwestern direction, zig-zagging through a confused heap of rubble that has tumbled from the walls at this point. The remains were very disturbed and contained sherds dating from the Nabataean through Umayyad periods. Unfortunately, this conduit survived only below the rubble spill: it had been robbed out elsewhere both inside and outside the *castrum* wall, probably to provide building material for the Bedouin village at Ḥumayma. The bearing (350°) of the final preserved stretch at the camp wall would have taken this branch line to an intersection with the Ghana aqueduct approximately 100 m to the north, but plowing has obliterated all traces of the aqueduct at this point. At its southern end, just inside the line of the inside face of the western wall of the camp, the conduit has a bearing of 179°, which could have taken it either along the inside face of the wall or diagonally across the space between the wall and reservoir to the reservoir's southwest corner. Probes failed to uncover any traces of the aqueduct in this intermediate area, but clearing of surface debris around the southwest corner of the reservoir revealed another sandstone conduit slab set

7. Although the tumbled character of the visible remains of the *castrum* makes precise measurement difficult, the dimensions from centre line to centre line of the walls are 150.2 m (E/W) and 205.8 m (N/S): the design dimensions may have been 500 by 700 Roman feet. Depressions for gates can be seen in the centre of the north and south walls, but the gates on the east and west have been shifted 19 m south of centre, perhaps to leave room for a central parade ground. The centre of each east and west gate opening is roughly 122 m south of the north wall, instead of the expected 102.9 m.

8. Stein in Kennedy 1982: 275; Gregory and Kennedy 1985: 323.

9. Eadie and Oleson 1986: 59-63.

10. *Pace* Eadie and Oleson 1986: 58.

into the top of the rubble packing behind the great blocks of its western wall (Pl. XXVIII,1; arrow in foreground). This conduit, identical in design to those at the corner of the camp, was oriented east/west in a position that would have served to carry water into the reservoir. Unfortunately, the surface context was disturbed, and this block may not be in its original position. Nevertheless, the total absence of any conduit or other arrangement for dumping water at the northwest corner makes restoration of the original conduit outlet at the southwest corner very likely. The conduit probably extended along the inside face of the west *castrum* wall, then turned due east when nearly level with the south end of the reservoir, dumping its water just north of the southwest corner. The location of the spout at this end of the structure, closer to the inhabited area of the camp, may have been intended to facilitate direct access to flowing water by the inhabitants. No overflow spout was identified. Clearing of surface rubble inside the reservoir showed that there were no stairs to give access to the interior, so pooled water probably was obtained by dipping.

Although proof is now impossible, it seems very likely that the *castrum* reservoir was designed from the start to be filled by a branch line added to the main Ghana aqueduct a significant length of time after its original construction. In fact, the camp may have been located here primarily because of the proximity of the aqueduct. The absence of any obvious arrangements for handling overflow from the reservoir suggests as well that the main aqueduct line did not terminate at this point after construction of the camp, but continued to flow south to the Nabataean reservoir.

This second reservoir is located 77 m west of the west wall of the *castrum,* its north wall even with a point 16 m north of the camp's southwest corner (Fig. 1.2; Pl. XXIX,1). Even before the probes of 1987, a Nabataean origin was assumed: the alternation of headers and stretchers in the masonry and the diagonal surface trimming of the blocks are both Nabataean characteristics in this region.[11] Furthermore, a probe in 1983 showed that it was designed from the start to be fed by the Ghana aqueduct, which is typically Nabataean in design.[12] Although nearly as large as the *castrum* reservoir in horizontal interior dimensions (L 27.60 m; W 17.00 m), it is only half as deep (depth 1.75 m below aqueduct spout), with a capacity of approximately 821.1 m^3. The Ghana aqueduct terminates in the exact centre of the north wall, its masonry carefully bonded with that of the reservoir (Pl. XXIX,1). The overflow conduit, which does not survive in its original form (see below), was located toward the west end of the south wall, positioned to allow water to remain inside to a depth of approximately 1.35 m (for an actual storage capacity of 633.4 m^3). The sandstone blocks of the wall are very carefully trimmed and were laid in a fairly regular pattern of alternating headers and stretchers, both on the interior and exterior faces. The floor, too, was paved with heavy blocks, and the interior was waterproofed with a layer of hard, sandy white plaster. The shallow depth of the reservoir observed in the probes that extended 3.0 m inward from the north and south walls aroused the suspicion that there was a central depression or tank surrounded by a broad but shallow ledge. A probe in the centre of the structure, however, proved that the floor was level across the entire area. The west and south walls are thicker (Th 1.52 m) than those on the north and east (Th 1.16 m), probably as a precaution against settling down of the slopes on these sides. The foundation of the west wall, revealed by excavation, extended 1.4 m below the level of the interior floor. Traces of a paved walkway above the cistern rim survive along the west wall, but this feature has been lost on the south and probably could not have been accommodated on the north and east.

11. See Eadie and Oleson 1986: 60, fn. 6.

12. Eadie and Oleson 1986: 69-70.

In the initial arrangement, the overflow from the reservoir passed over the south wall by means of a slot cut in one of the wall blocks. This block survives but has been pulled from its original position. The water was carried off by a conduit of marl blocks, identical in design and dimensions to the Ghana aqueduct, which could be traced for 85 m to the south at a bearing of 205°. Beyond this point it has been obliterated by plowing and pilfering of the blocks. Stein, however, reports that he could trace the channel for approximately 100 m beyond the Nabataean reservoir to another "poorly built reservoir," before losing its traces in a field.[13] There was a niche (H 1.16 m; W 0.53 m; depth 0.42 m) at the junction of this outflow aqueduct and the southern reservoir wall which must originally have held some sort of basin to receive the flow of water (Pl. XXIX,2). At a later date this basin was removed and the overflow conduit replaced by a bronze pipe installed in a hole cut through the wall at the level of the interior floor. The stubs of attachment lugs, probably for some sort of filtering screen, survive on the interior. On the exterior, within the niche, flow was regulated by a large bronze stopcock (L 0.296 m; 3.350 kg) (Pl. XXX,1). This remarkable artifact, recovered intact except for the perforated plug that turned within the housing, fed the water into a lead pipe that was laid in a hard white mortar in the conduit channel (Pl. XXX,2). All but the final section of pipe adjacent to the valve had been torn from position for salvage at some later stage in the development of the system, but the surviving section (outside D 0.044-0.055 m; inside D 0.038-0.049 m) reveals that the pipe was manufactured clumsily by rolling up sheets of lead (Th 0.003 m) and soldering the outside seam of the overlap. The entire circumference was encased in plaster wrapped while wet in heavy woolen cloth, which has left its impression on the exterior. The intent probably was to provide a pressurized water system, but the pipe nevertheless was laid (at least initially) along the gentle slope of the aqueduct. Four notches cut at the front corners of the valve niche suggest the presence of a door or grating that would have controlled access to the valve, and thus to the water.

Several other probes also traced the course of a terracotta pipeline running around the reservoir from north to south approximately 1.1 m outside its west wall. The pipeline, made up of wheel-turned sections (L 0.30 m, max. D 0.082m) flanged to fit into one another and sealed with white plaster, tapped a small, rough rubble basin built across the Ghana aqueduct 3.0 m north of its intersection with the reservoir. The pipeline continued south of the reservoir at a bearing (180°) that should have brought it across the course of the outflow conduit mentioned above, 15 m south of the overflow spout. The pipeline, however, was laid at a higher level than the conduit and has been lost at this point.

Unfortunately, the cultural material and stratigraphy were not of much help in providing absolute dates for all these changes in the arrangement of the water-distribution system at the Nabataean reservoir. The foundations of the west wall were uncovered in one probe, but the foundation deposit contained only a single Early Roman sherd, which may in fact have fallen from the baulk, and the upper layers of fill all yielded a rich variety of pottery dating from the Nabataean to Byzantine and Umayyad periods. The latest pottery in the hard-packed surface into which the terracotta pipeline was laid, however, was Byzantine. The loci around the bronze stopcock in the recess had been badly disturbed by the obstruction of the valve and removal of the pipe, and the sherds ranged from Nabataean to Umayyad in date. Most seem to have washed in over time. The soil packed around the valve housing itself, however, contained only Roman and Byzantine pottery, and that beneath the valve only a few Nabataean and Early Roman wares.

The quantity and wide chronological spread of the pottery found in the upper

13. Kennedy 1982: 275; Gregory and Kennedy 1985: 323.

levels of fill around the cistern reveal that the structure was a hub of activity during the entire history of the settlement. In contrast, the near absence of sherds from the foundation levels indicates that the reservoir was constructed in Avara's early years, perhaps as an essential concomitant to occupation of the site. It was an integral part of the Ghana aqueduct, designed to hold a quantity of water for use in this part of the settlement, and to provide a conduit to carry any surplus farther along the ridge or into the settlement centre. Sometime later, probably in the Late Roman period to judge from the design and dimensions of the stopcock (which is exactly one Roman foot in length), this gravity-flow discharge was replaced by a pressurized pipe system which could tap the whole reservoir.[14] Later still, possibly in the Byzantine period, the flow into the cistern was intercepted completely or in part by the terracotta pipeline, which carried water to some unknown destination farther along the ridge. Probably at this moment the relatively accessible stopcock plug, grating, and lead pipeline were salvaged, while the bronze pipe mortared into the wall and the valve housing soldered firmly to it were packed with mortar and stones. Either one of these pipelines may have carried water to a possible bath building identified this season 100 m south of the reservoir (Fig. 1.3). The presence of Umayyad sherds suggests that there may have been some sort of water supply in the cistern or its associated pipes through the early Arab period.

Cisterns

Although smaller in size, the two cisterns (our catalogue nos. 67 and 68) in the centre of the habitation area (Fig. 1.4; Pl. XXXI,1) are almost large enough to be called reservoirs: they have capacities of 445 and 487 m^3, respectively. They were, however, narrow enough to be roofed with flat stone slabs carried by sixteen transverse arches. The two structures are virtually identical in size and design and form part of a unified water-supply system, suggesting that they were built simultaneously, or no. 67 only a short time before no. 68, which is designed to take its overflow. They are 20 m apart, in the very centre of the ruins of Avara, 50 m west of a funnel-shaped depression that allowed them to harvest the run-off of the large, gently-sloping field that covers approximately 100 ha north of the settlement. They are oriented at right angles to one another: no. 67 almost due N/S (344°), no. 68 almost due E/W (70°). Cistern no. 67 (L 19.74 m; W 7.04 m; depth below intake, 3.20 m) was filled by a 25 m long intake channel, which was completely rebuilt in the 1960's when the whole cistern complex was cleared out and refurbished for use. From the intake, the water passed through a settling tank and into the main cistern. It is still used as the major public water source for the region. In antiquity, when this cistern became full, the excess water was diverted by the rise in level in the intake channel into a conduit angling out northwest toward the intake for no. 68. Although this second cistern was partly cleared in the 1950's by local Bedouin, it was not put into use, and consequently more details of its construction are preserved (L 20.05 m; W 7.0 m; depth below intake, 3.48 m). The intake channel (W 0.64 m; depth 0.35 m) was carefully built of large, heavy slabs of stone, and the deep settling tank (L 3.18 m; W 2.58 m; depth 1.6 m below floor of intake) was roofed with slabs carried by two transverse arches. Fourteen of the sixteen original arches of the main cistern tank have survived and still support significant portions of the roof. Part of the draw hole survives as well, cut into a slab close to the southwest corner. The masonry was very carefully cut

14. As far as I am aware, this is the first large Roman stopcock to have been found in Jordan. There is a significant bibliography on spigots found in the Roman West: Saglio 1892; Kretschmer 1960; Balty 1962; Lebel 1965; and Fassitelli 1972. The Latin term for such a device is *epitonium*.

and laid and was waterproofed with a hard white sandy plaster containing pebbles.

The size and finish of these two cisterns, their location in the very centre of the settlement area, and their close interrelationship suggest that they were built by some municipal authority, or possibly even under the patronage of Avara's founder, Aretas III (87-62 B.C.). This impression is reinforced by comparison with the other nine cisterns found in the settlement centre. Like no. 67 and 68, these are built of blocks rather than cut into the bedrock. Virtually all the cisterns in the hills around Ḥumayma were cut into the bedrock, which is at or close to the surface there (Fig. 1: solid circles). The settlement, however, was located on the edge of the fertile loessal plains, where the bedrock is out of reach, so cisterns within the settlement had to be built of blocks. For the same reason, most of them had to be furnished with settling tanks to keep silt out of the main cistern. In contrast to nos. 67 and 68, all but one of the other nine cisterns identified within the centre are circular in plan, and all have capacities of less than 200 m^3 (Fig. 1: circles; Pl. XXXI,2). A circular cistern is more economical of material and easier to build and waterproof than a rectangular one, but since roofing becomes difficult with diametres of more than 5.0 m, the two large cisterns nos. 67 and 68 had to be rectangular. The lower capacities of these round cisterns, and the fact that they usually are partly buried in structural remains, suggest that they were built beneath private homes by individual families for their exclusive use.

Conduits

Drains or water conduits were observed and excavated at two points within the habitation area in 1987. The first consists of a series of marl and sandstone conduit blocks of the type used in the Ghana aqueduct, but lined up carelessly down a gentle slope near the periphery of the habitation area for 10 m without any rubble packing or framing blocks (Fig. 1.5). Before excavation, the top edges were flush with present ground level. The stratigraphy is disturbed, and the sherds include material from the Nabataean through Byzantine periods — more or less identical to sherds found at present on the surface nearby. In view of the absence of foundation or framing blocks, and the overall slipshod design, the feature probably represents a drain or water channel built for domestic use with material salvaged from a disused section of aqueduct in the last period of Avara's existence, or in recent years.

A second group of drains, connected to a settling tank, was found 80 m north of cistern 67, still within the settlement centre (Fig. 1.6). A channel built of marl conduit blocks roofed with stone slabs followed an irregular, southward course from a courtyard in front of a small domestic structure. The conduit blocks are identical to those used in the Ghana aqueduct, and may in fact have been salvaged from it, since two more blocks were re-used as doorjambs in the house itself. The lowest level of fill around the blocks included Nabataean, Roman, and Byzantine pottery, but the upper limits of the chronology are still undetermined. This drain emptied into a settling tank (L 0.86-0.98 m; W 0.61-0.66 m; depth 0.94 m) built of carefully trimmed sandstone blocks and lined with a pebbly white plaster. The transition to the tank was reinforced by an hourglass-shaped "Pompeian" type millstone tipped on its side, the central hole allowing the water to flow through. There is a second opening without reinforcement on the opposite (south) wall of the tank, and a sill for a third, now walled up, on the east wall. Although the connection could not be documented this season, this last sill may be connected with a larger, slab-built drain (H 0.40 m; W 0.31 m) that can be traced for 17 m to the east. The fill around the lower part of this drain contained pottery of the Nabataean, Roman, and Byzantine periods. All three of the conduit channels probed in the centre of Avara have slopes close to three percent. Although the sample is small, the similarity in slope may reflect some consistent rule of thumb used by Nabataean or later engineers in laying out such drains.

The presence of a settling tank indicates that this complex of channels was not designed to remove waste water from the settlement area, but to collect potable or at least usable water from some source within it and conduct it to a cistern. As at Subeiṭa, the source of the run-off may have been the streets themselves, whether paved or unpaved, or the streets and house roofs or courtyards together.[15] The fact that the drains were sturdily built and roofed, suggests as well that they were built at or close to the ancient ground level, possibly beneath or next to a street. The eastern conduit heads in the general direction of several surviving cisterns, but the fact that it seems to have collected water from a variety of sources suggests that it may have led to the two large public(?) cisterns nos. 67 and 68 rather than to any of the adjacent circular cisterns.

Preliminary Analysis

It is now clear that the problem of a reliable water supply was carefully considered from the very foundation of Avara, and that the major structures built to deal with it may therefore have been funded or somehow sponsored by the royal patron Aretas III. The Nabataean reservoir and attached aqueduct were built on sterile ground, before habitation began to litter the area with sherds. The great roofed cisterns nos. 67 and 68 must also be early. They are typically Nabataean in design and were laid out according to the cardinal directions, in close relationship to each other, in the very heart of the settlement. These two cisterns were designed to be filled with the run-off from a large field to the north, one that was protected from habitation throughout Avara's history (Fig. 1; Pl. XXXII). Even today, the fields above the site in this direction are nearly devoid of structural remains or sherds. The scattered dwellings that gradually sprang up around the two cisterns are all located on the slightly higher ground that spreads out in an arc on either side of the flow channel for this run-off field, the two ends oriented to the north (see Fig. 1: shaded area). In general, these structures do not climb the adjacent slopes, but are restricted to the approximate 6.0 m rise that marks the difference in elevation between the upper Nabataean reservoir and the lower cisterns no. 67 and 68. They kept to the low ground so that their own private cisterns, usually circular in shape, with adjacent settling tanks, could be filled by run-off from the same field. It is likely that more of these domestic cisterns lie still concealed in the ruins of Avara.

It may be that the location of Avara was influenced as much by the presence of this perfectly positioned and adequately proportioned run-off field as by the availability of excellent grain-growing land to the east, and the proximity of the route down into the Wadi 'Arabah through the wadis behind Jabal Ḥumayma. The area of the field was not so great or its slope so steep that the run-off would pose a threat to the settlement it sustained. The isolated, rock-cut cisterns on the hillsides around Avara were not as susceptable to damage from excess water as the vulnerable homes and block-built cisterns on more level ground.

But the generosity or foresight of Aretas III or the early city fathers did not stop with the provision of the run-off water systems so typical of Nabataean sites. Some individual or group in charge of considerable resources — both economic and social — also constructed 19 km of aqueduct to bring to a reservoir above the new settlement the flowing water of the mountain spring 'Ain Ghana. It is not yet clear whether the 7.6 km branch line connecting the reservoir with the 'Ain Sharah and 'Ain Jamam was part of this original scheme, or a slightly later addition. This special water was pooled in the great reservoir on the low ridge above Avara, and the excess allowed to flow farther on along the ridge in another

15. Negev 1978:1119.

conduit. The excess flow, which may not have been very significant, may have been directed either to the private or public cisterns in the settlement centre, or to the possible bath, the remains of which can be seen 100 m south of the reservoir. Only excavation can determine the chronology of the bath building, but the ceramics visible on the surface are Roman. Alternatively, this source of constantly flowing water may have been used to irrigate small vegetable and fruit gardens at the south end of the settlement.

It is difficult at this point to be certain why the Nabataean reservoir was located 6 m above and 150 m north of the structural remains of Avara, rather than down in the apparent habitation centre itself. It may be that Aretas' engineers feared damage to the vulnerable aqueduct channel by run-off from the field north of the settlement, and occasional degradation of the spring water through mixing with the lower quality run-off water. In addition, the present focus of structural remains may not in fact represent the ancient centre of population. The character of Nabataean urbanism is still poorly defined, but it is at least clear that many Nabataean "cities" had only a few permanent inhabitants. The population of settlements such as Mampsis, Subeiṭa, and Avara seem to have fluctuated markedly from one season to another, as groups set up tents on the outskirts to take part in caravan trade, livestock markets, or agricultural work.[16] It is difficult to document the location of these seasonal encampments archaeologically, but the open ground north and east of the Nabataean reservoir would have served such a purpose very well, particularly after the provision of a flowing supply of spring water. Permanent housing was located in the gentle valley below, where it could capture run-off water for private, domestic cisterns. Later, the Roman *castrum* spread out over the same campground, both because of its physical suitability and because of the proximity of the water supply and the *Via Nova Traiana*. Since the chastened Nabataeans undoubtedly continued to camp in their habitual spot, now in the shadow of the camp's walls, the Roman garrison could conveniently have kept watch over their new subjects.

The provision of both fresh and cistern water must have been a source of great satisfaction to the inhabitants of Avara and the neighbouring desert. They undoubtedly preferred to drink fresh spring water rather than cistern water whenever possible, but the procedures for arranging access and sharing of this portion of the water supply can not be documented directly. There must also have been some method of ensuring the equitable division of the run-off water in the public cisterns. The water in private cisterns then, as today, must have been private property. The supplies in the settlement centre would have sustained the populace and the animals kept in the town, and would have also been used for washing, and for craft processes such as pottery production or fulling. Any excess, particularly overflow from the reservoir, may have been directed to the irrigation of small plots of vegetables or fruit trees in the immediate downhill vicinity of the settlement.[17]

The fields of wheat and barley, however, which probably spread out over thousands of hectares around Avara as they do today, were irrigated naturally by direct rainfall and, to a much greater extent, by run-off from adjacent slopes or the great wadis themselves, which brought down the water of the Sharah escarpment. As today, farmers probably owned specific fields that they would plant in the winter after observing which had received sufficient moisture.

On the whole, this arrangement must have lasted basically unchanged for as long as Avara did. Sometime during the Roman period, probably in the second or third centuries A.D., a new reservoir was provided on the ridge, inside the protective walls of a new military camp. It is not clear yet whether this reservoir diverted all or only part of the water brought by the

16. See Oleson 1986:259.

17. See Eadie and Oleson 1986:71-72.

aqueduct, but it may represent an attempt to gain partial control over the highest quality source of water for the settlement. Such reliance on aqueduct rather than run-off water is typically Roman, expressive of a confidence in complex, highly artifical systems of water management and in long-term political stability. This same self-confidence may be represented by the possible provision of a bath building for Avara sometime during the Roman period, probably — to judge from the surface remains — with the typical radiant heating in the floors and walls. The stopcock installed in the Nabataean reservoir to replace the previously uncontrolled outflow, and the pipeline laid in the outflow conduit, are also typically Roman. Together with the enclosed *castrum* reservoir, they probably represent both new applications of the water and new restrictions on its consumption.

We do not as yet know precisely when the aqueduct stopped bringing water to Avara, because the settlement probably could have survived on run-off sources alone. Umayyad potsherds do, however, appear in significant numbers around the Nabataean reservoir, and in the fill of the *castrum* reservoir, so one or both of these structures probably held water into the Arab period; the aqueduct is the only method of filling them. In addition, a round cistern with domed roof in the settlement area may be an Umayyad construction.

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