'Atiqot 68, 2011

The Umayyad Aqueduct to Ramla and Other Finds near Kibbutz Na'an

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Introduction

While laying the groundwork for the Cross-Israel Highway in 2001, ancient remains were uncovered in two areas, approximately 1.5 km east of Kibbutz Na'an (Figs. 1, 2).[1] In Area A (map ref. NIG 188755–880/643750–775, OIG 138755–880/143750–775), a 150 m long section of a built and plastered aqueduct was exposed; in Area B (map ref. NIG 189050–9150/644960–5060, OIG 139050–9150/144960–5060), agricultural installations and structures (tombs?) were uncovered (Gorzalczany 2005).

Ramla and the Aqueduct

The city of Ramla is located on the southern coastal plain, at the foot of the western Shephelah, an area that is also known as the Judean coastal plain or Philistia. It is built on alluvial soil of the Pleistocene period (*ḥamra*) and on clean sand dunes, some of which have been exposed in various excavations in the city. The city is situated on the local watershed, between the run-off basins of Naḥal Soreq and Naḥal Ayyalon, beyond the area of their flood plains (Nir 1970:83). Ramla, capital of Jund Filasṭīn, is 15 km from Jaffa and roughly 40 km from the central hill-country and Jerusalem, a strategic location that facilitated efficient administration and allowed for easy access to all areas within the district. Furthermore, it was far enough inland not to be susceptible to sudden attacks by the Byzantine navy (Luz 1996:28). The combination of these features, which were apparent to the Umayyad rulers, led to the rapid development of the city soon after it was founded (for a thorough discussion about the founding of Ramla, see Gat 2007:39–40, especially n. 1).

Historical Background

A policy of building monumental enterprises began in the Umayyad Dynasty, during the reign of 'Abd al-Malik ibn Marwān (685–705 CE) and continued throughout the reign of his son, al-Walīd (705–715 CE). The rapid founding and flourishing of the city of Ramla clearly reflects the importance the Umayyad rulers placed on Bilād al-Shām (Greater Syria). At this time, too, luxurious palaces, such as at Khirbat al-Mafjar (Hisham's Palace) and Khirbat al-Minya, were constructed in Israel. However, with the ascent of the Abbasid Dynasty to the throne in 750 CE, the situation changed completely. The transfer of the political base eastward brought the period of growth in Greater Syria to a close (Luz 1996:23; for a review of the history of the coastal region during the Early Islamic period, see El'ad 1982).

Sulaymān ibn 'Abd al-Malik, governor of Jund Filastīn and brother of Caliph al-Walīd ibn al-Malik, is considered by most scholars and historical sources to be the founder of Ramla (for a less accepted opinion, see Ish-Shalom 1973; Luz 1996:23–24, n. 7). In accordance with his brother's policy, he built a prosperous administrative and government center next to the established city of Lod (Diospolis). Ramla soon replaced Lod as the main crossroad and major commercial, agricultural and manufacturing center (Luz 1996:29–30). A description of the

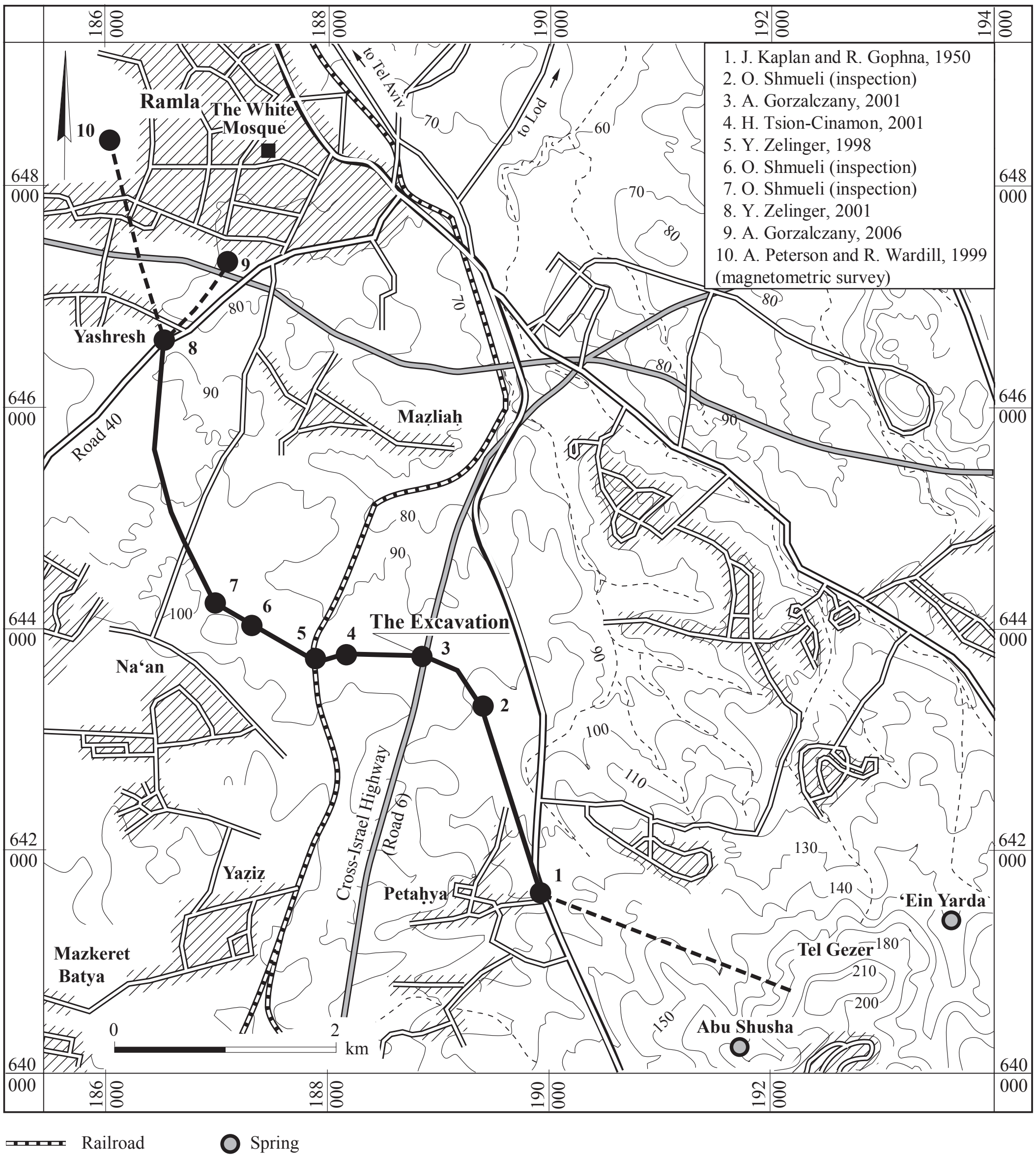


Fig. 1. Location map: the course of the aqueduct in light of recent surveys and excavations.

construction of Ramla as a planned city appears in *Ahsan al-Taqāsīm fī Maʻrifat al-Āqālīm*, the book written by the tenth-century historian al-Muqaddasī (1906:164, 176).2

Water Supply

The area over which the city extends today is somewhat hilly and the elevation of the surface level ranges, on average, from 90–95 m asl in the vicinity of the Jawarish Quarter to 70–75 m asl near Ramlod Junction. The White Mosque, one of the first spots that Sulaymān built in his city, extends across terrain with an average elevation of c. 80 m asl.

Today, the average annual precipitation in Ramla is 500–600 mm.[3] There is no readily available source of water in the city's vicinity,

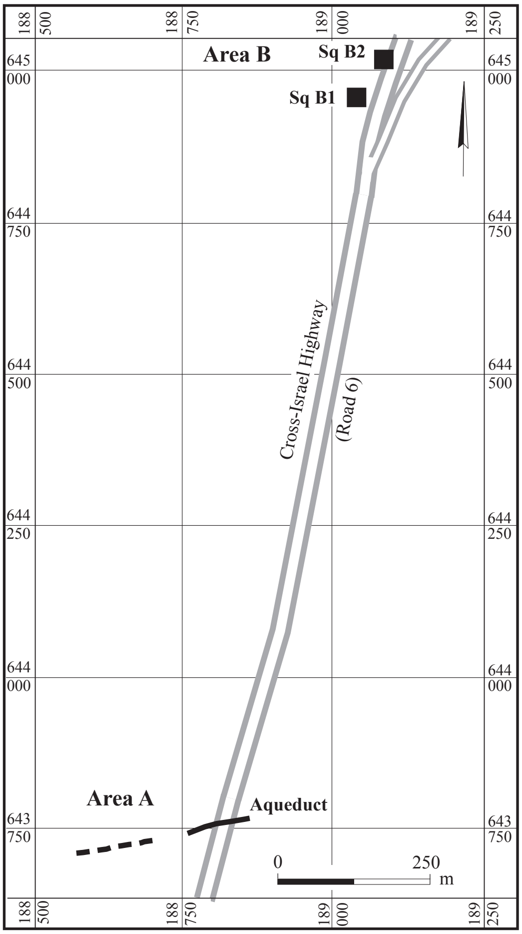


Fig. 2. Location map of excavation areas along the Cross-Israel Highway.

as its aquifer is at a great depth. Therefore, rainwater was collected in numerous plastered cisterns, some of which were exposed in archaeological excavations (e.g., Gutfeld 2010:43). In addition, both al-Ya‘qūbī and al-Muqaddasī mention wells in the city, albeit deep and brackish.[4] It is obvious that supplying potable water to the city was a fundamental urban-planning issue, and it is with this in mind that the aqueduct described below should be examined.

Several springs were previously postulated as being the water source for the aqueduct to Ramla. In the vicinity of Rosh Ha-‘Ayin, some 18 km north of Ramla, are the stable and prolific Yarqon springs, which have been suggested as the source of Ramla's water supply (Gil 1981:15; Sharon 1986). However, topographically, they are c. 60 m lower than the average elevation of Ramla. This would have presented almost insurmountable technological problems, therefore eliminating these springs as a potential water source.[5]

Another concentration of springs is located in the region of Tel Gezer (Fig. 1). In surveys conducted in the area (Luz 1996:28, n. 32), six springs were located, the current output of which is very meager. However, it is quite possible that the small quantity of water flowing from the springs today is the result of over-pumping of the aquifer since the founding of the State of Israel.

An intelligence report, filed with the *Hagana* Information Service in 1943, sheds light on yet another spring that could have been the water source for Ramla. It is located in the village of Abu Shusha, on the lower, western slope of Tel Gezer (Fig. 1; Kark and Shiloni 1984:339; see Gat 2003:107).[6]

A spring discussed at length (Gat 2003:106–108) as a potential water source for the city is ‘Ein Yarda (‘En Vered; Fig. 1), which flows forth from the lower, eastern slope of Tel Gezer. The spring appears in *The Survey of Western Palestine* as ‘Ayn Yarda (Conder and Kitchener 1882: map between pp. 428–429), and is described by the excavators of Tel Gezer (Macalister 1912:3). Its waters are both plentiful and steady-flowing and its name bears a close resemblance to that of the aqueduct (*Qanat al-Barda*, see below), leading some scholars to refer to the spring by the aqueduct's name. However, the location of the spring, on the eastern side of the mound and beyond the local watershed, would have required the quarrying of a tunnel through the tell in order to convey the water westward. We know of no such tunnel in the area and there is no written evidence that it ever existed (Luz 1996:35; 1998:122–124), thus ruling out any possibility that the aqueduct to Ramla began at this spring.

I suggest considering the possibility that the aqueduct was fed by not one, but a group of springs in the region of Tel Gezer. By creating a drainage basin, a large quantity of water could be collected, sufficient to meet the requirements of the city's residents and to justify the construction of such an enormous project. This point requires further clarification, which only additional excavations and surveys in the region of Tel Gezer are likely to provide.

The Aqueduct in Historical Sources

The aqueduct is mentioned in ancient historical sources, such as the *Futūh al-Buldān* of the ninth-century Persian historian, Ahmad ibn Yahyā al-Balādhurī. He relates that Sulaymān ibn ʿAbd al-Malik, founder of the city of Ramla, governor of Jund Filasṭīn and the future caliph, constructed, among other things, works for supplying water to the new city (al-Balādhurī 1866:170). An additional ninth-century source, *Kitāb al-Buldān* by al-Ya'qūbī states: "… the river of Ramla is *Nahar Abū Futrus* (the Yarqon River) and the residents of Ramla drink from a small river…" Some would interpret this as speaking of the aqueduct; however, other researchers conjecture that al-Ya'qūbī was referring to the Yarqon River itself, which, compared to the Tigris and Euphrates Rivers, is indeed a small river (Gat 2003:105–106). The aqueduct is also referred to by Ibn al-Faqīh in the tenth century and in works by Yāqūt in the thirteenth century, although it is quite likely that both merely quote al-Balādhurī, who preceded them.

In the sources, the aqueduct is referred to as *Qanat al-Barda*, i.e., 'the cold aqueduct', and there are two versions regarding the origin of the name. One holds that, in his desire to boast of a construction project of his very own, Sulaymān gave the aqueduct the same name as that of the river that flows through Damascus, the capital of the caliphate. The other version states that the origin lies in the name of the ʿEin Yarda spring, being that in Arabic script the difference in the dotting of the vowels between the two names is only a single diacritic point, so that the name could have been confused and changed to Barda. However, as noted above, ʿEin Yarda has been ruled out as a possible source for the aqueduct (Gat 2003:106–108).

On the map of the British survey from 1882, the aqueduct is referred to as *Kanāt Bint el-Kāfir* ('the heretic daughter's aqueduct'; Conder and Kitchener 1882:422, 444; IDAM archives file: Qanat bint el Qafr); the source of this name is not known. The prevailing notion among scholars is that this name derives from a similar name given to a pool located in the city and also fed by the aqueduct (see Zelinger and Shmueli 2002).

History of Research (see Fig. 1)

Remains of the aqueduct have been spotted by farmers from Kibbutz Naʿan and other agricultural settlements in the region, who have reported finding stones while cultivating their fields. Some of the stones are visible even today, including many stones exposed on the surface up to 170 m southwest of the limits of the present excavation.[7] On a number of occasions, these remains have been documented by the Israel Antiquities Authority.[8]

In October 1950, Ram Gophna and Jacob Kaplan documented a short segment of the aqueduct (Fig. 3), accidentally discovered

Fig. 3. Ram Gophna surveying the aqueduct at Moshav Petaḥya in October 1950 (photograph: J. Kaplan).

during the course of infrastructure work not far from the entrance to Moshav Petaḥya (Fig. 1:1; IDAM Archives File: Qanat bint el Qafr; see Zelinger and Shmueli 2002:279–282). In recent years, several salvage excavations have been conducted along the route of the aqueduct. Yehiel Zelinger excavated a short section of the aqueduct in October 1998, next to the Lod-Reḥovot railroad tracks (Fig. 1:5; Zelinger 2000a; Zelinger and Shmueli 2002:284–285). In June 2001, he uncovered another section close to Road 40, some 100 m south of the entrance to Moshav Yashresh (Fig. 1:8; Zelinger 2001; Zelinger and Shmueli 2002:285–286). In 2001, sections of the aqueduct were revealed both at the present site (Gorzalczany 2005) and in the vicinity of Zelinger's site near the railroad tracks (Fig. 1:4; Tsion-Cinamon 2005). It is apparent that the characteristics of the aqueduct there are similar to those uncovered in other areas (Zelinger and Shmueli 2002:283–284). After the preparation of this report, another segment of the aqueduct, close to Yashresh (Fig. 1:9) was identified in a survey (Haiman, Shmueli and Barda 2008) and investigated by Alexander Onn (pers. comm. 2005). This segment was subsequently excavated by the author in 2006 (Gorzalczany 2008a; forthcoming). In addition, over the years, a number of segments of the aqueduct have been identified and recorded during routine archaeological inspection (Fig. 1:2, 6, 7; Oren Shmueli, pers. comm. 2010).

In 1999, a magnetometric survey was conducted within the precincts of the city of Ramla and its environs (Petersen and Wardill 2001). The survey reconfirmed the existence of the aqueduct along its conjectured route and also revealed another section of the aqueduct just west of the city (Fig. 1:10).

AREA A: THE AQUEDUCT

The Excavation

During excavations in July 2001, the remains of the aqueduct were uncovered along a continuous line for some 150 m, running in a general east–west direction and gently bending to the south in its western section (Figs. 2, 4, 5; Plan 1).

Fig. 4. Ram Gophna visiting the aqueduct after 50 years, during the present excavations.

Fig. 5. Aerial view of the excavation, looking northeast; top left: the Nesher cement works at Ramla (photograph: Albatros Aerial Perspective Ltd.).

The aqueduct is presented below from east to west, according to the direction of the water flow. The description applies to three areas—eastern, middle and western—subdivided for the convenience of the publication into four segments (I–IV; Plan 1). The general features and construction technique of the aqueduct are described under the "Eastern Area". Variations in construction, most likely a consequence of local soil conditions and topography, are discussed under the "Middle and Western Areas".

Construction Technique

The Eastern Area (Segments I–II). The width of the aqueduct is fairly uniform, at c. 1.5 m. The foundation of the aqueduct is constructed from fieldstones bonded with cement (*debesh*). Above it are two parallel walls (0.4–0.5 m wide), built of dressed limestone masonry blocks and topped by a layer of fieldstones mixed with gray cement (Plan 1). The inner face of the walls was treated with plaster (see below). In the eastern area only, the outer faces of the walls were covered with a plastered revetment, descending from the top of the channel to its base (L177; see Plan 1; Fig. 6).

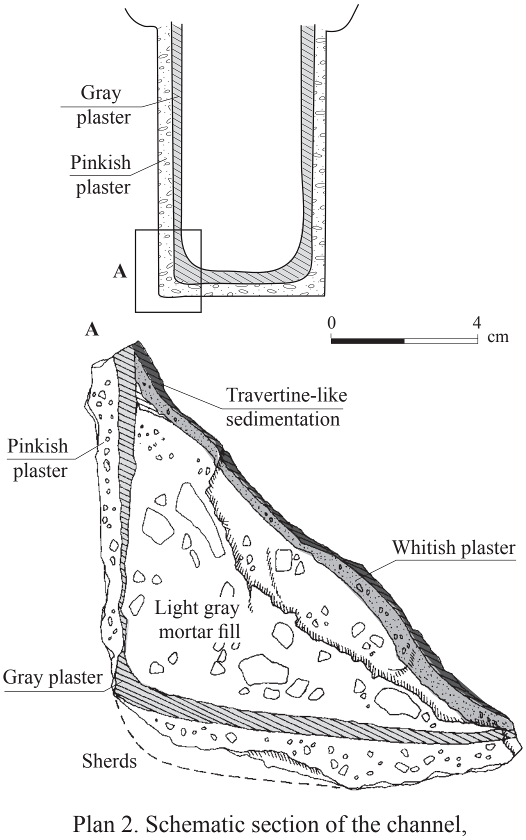
The aqueduct's channel was not well preserved in the eastern area due to its collapse in antiquity (see below). However, according to the findings in the middle and western areas (see below), the channel between the walls was originally rectangular. It was covered with flat limestone slabs (0.3 × 0.8 m on average, 0.12–0.15 m thick), which were laid crosswise (Plan 1: Sections 2–2, 6–6, 10–10; Fig. 6). The cover stones were preserved *in situ* at the eastern end of the segment, while they were missing—probably reused in antiquity—in its western end. The cover stones were all dressed in the same technique and are all of similar size. Evidently, they were centrally produced because their specifications required a high standard of craftsmanship and uniformity. This is in contrast to the ashlar stones making up the aqueduct walls, which differ in size and shape, suggesting they were removed from buildings

Fig. 6. The cover stones and revetment walls in the eastern area of the aqueduct.

and put into secondary use, such as the column of a chancel screen in W160 (see Fig. 18).

The plaster coating the inner surface of the channel (Plan 2; Fig. 7) was applied to a base of potsherds—apparently ceramic pieces that were intentionally prepared for this purpose, rather than fragments of vessels in secondary use. It is interesting that these sherds are not incorporated into the plaster, but form a kind of interface between it and the underlying earthen or stone surface. The reason for this is apparently structural, the intention perhaps being to create an insulating layer against ground movement and/or to allow for a slow curing of the plaster following its application. Had the plaster been directly applied to the walls, its moisture would likely have been absorbed immediately by the soil, thereby impairing the quality of the material, which required slow drying.

Three phases of plaster are evident within the channel (Plan 2; Fig. 7; see Tsatskin, this volume). The underlying pinkish layer (1–2 cm thick) follows the rectangular contour of the channel. The subsequent phase consists of a dark gray layer with a diagonal thickening, comprising a light gray mortar fill, at the



Plan 2. Schematic section of the channel, demonstrating the provenience of the plaster sample and its cross-section.

Fig. 7. Sample of plaster.

Fig. 8. The aqueduct with cover stones in the western area, looking east.

seam between the walls and floor, possibly to prevent leakage. This plaster was then coated with a one-centimeter thick whitish plaster. The plasters are lime-based and contain a variety of inert fillers, such as potsherds and shells. A small amount of charcoal was also added to prevent cracking and seeping, and to augment the plasticity of the plaster (Porath 2002a:25).

Two travertine-like layers of sedimentation (calcite precipitation? see Tsatskin, this volume), a few millimeters thick, are discernible—one coating each of the plaster phases (only the outer layer is depicted in Plan 2). The sediment was deposited in those places where water came in contact with the plaster (i.e., the wetted surface), covering the channel walls up to a height of c. 60 cm. This was probably the maximum height the water reached when flowing in the aqueduct. Both layers are thin in comparison with similar sedimentations measured in other water systems, such as the aqueduct of Köln (Grewe 1986), where travertine deposition is frequently dozens of centimeters thick, causing the systems to become defunct on more than one occasion.[9] The thin sedimentation layer in the Ramla aqueduct is probably more a function of the quality of the source of its water than of the duration of its use. Nevertheless, the difference in thickness between the sedimentation layers can still be used as an indication of the varying durations of these phases.

The Middle and Western Areas (Segments II–IV). In these areas, there appears to have been less damage to the aqueduct (see below). It was well preserved, attesting to the channel's original rectangular shape (0.50–0.55 m wide, c. 1.2 m high; Plan 1: Sections 6–6, 9–9, 10–10, 11–11). In this portion of the aqueduct, most of the cover stones were found *in situ* (Loci 105, 106, 121, 134, 135, and 140; Figs. 8, 9). The missing stones may have been removed in antiquity. Evidence of this is an exposed cover slab, which was found atop the fill that covered the channel.

Fig. 9. The middle area of the aqueduct with *in situ* cover stones;
Manhole 127 in the upper left.

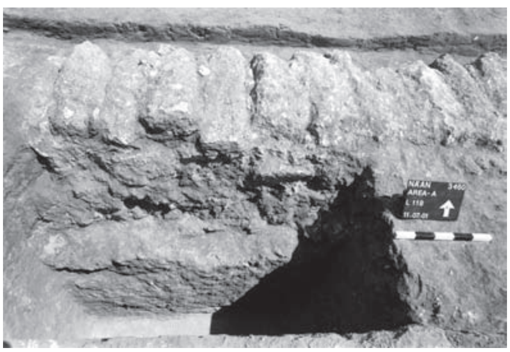


Fig. 10. Probe 118, facing north, showing the cover stones and protruding *debesh* foundation of the aqueduct.

Fig. 11. Probe 118, looking west, showing the foundation trench (see dotted line).

In a number of spots (Loci 118, 143, 148, 151 and 158), probes were cut, revealing the aqueduct’s foundation trench (Plan 1: Sections 7–7, 8–8, 10–10, 11–11; Figs. 10 and 11). The aqueduct’s foundation (1.5 m wide, 0.7 m high) was dug into *ḥamra* soil and established on a layer of sand. It is made of *debesh* and is slightly wider than the channel above it, protruding c. 0.2 m on each side. This building technique was employed to maintain the desired gradient required for the normal flow of water, in accordance with the topographical conditions (see below).

In this area, also, the travertine-like coating was observed to a height of c. 60 cm on the plaster lining the channel.

Manholes

Two manholes are incorporated in the aqueduct. The eastern manhole (L127) in Segment II (Plan 1: Section 9–9; Fig. 12) is cylindrical on the exterior (diam. 1.3 m) and preserved to a height of 0.5 m above the level of the cover stones. The inner hollow of the manhole's superstructure is roughly hexagonal in contour, its longest dimension being 0.7 m. It is built above a square-shaped opening set between the cover stones; the opening is large enough to allow a person to pass through it.

Another manhole (L199), with dimensions and features similar to those of Manhole 127, was exposed in the western area (Segment IV; Plan 1: Sections 14–14, 15–15 and 16–16; Fig. 13). Manhole 199 is poorly preserved, its cylindrical superstructure having collapsed (Fig. 14). Most of the structure is missing, but its western quarter (L198) was found lying on

Fig. 12. The eastern manhole (L127), looking east.

Fig. 13. The western manhole (L199), looking north; to the left is the collapsed superstructure.

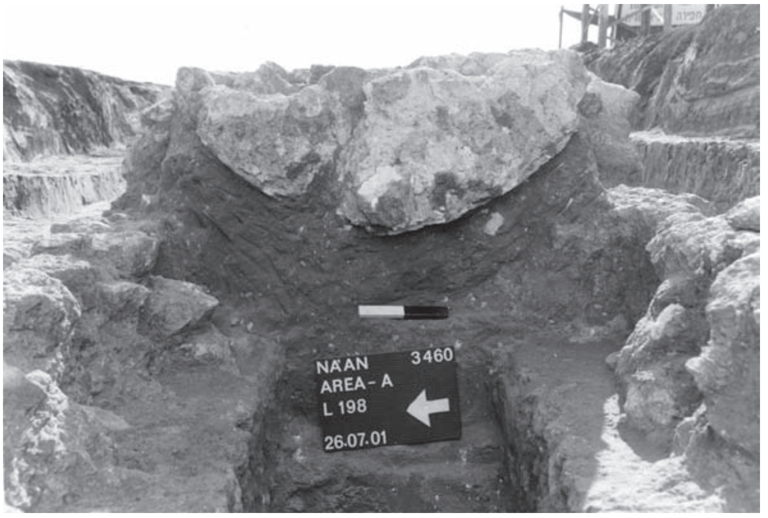


Fig. 14. The western manhole (L199), looking east; at top is the collapsed superstructure.

the fill that covered the aqueduct; the gray-white plaster covering the cylinder was still visible on its outer face. Like the other manhole, the opening descending down into the channel is large enough to allow a person to pass through it.

It is obvious that the construction of both manholes was coordinated as part of the same project. Perhaps coincidentally, they are 45 m apart, equivalent in Roman measurements to one *actus*, as recommended by Vitruvius (*On Architecture* VIII.6.3) for the spacing of shafts.[10] This distance is also similar to distances measured between some of the shafts in Roman-period aqueducts, such as the Upper Naḥal Tanninim water-supply system, conveying water to Caesarea (Siegelmann 1998; Siegelmann and Rawak 1996; 1997; Siegelmann and Ravaq 1999). However, it should be noted that in the area of Manhole 127, the aqueduct curves gently toward the south at a deviation of 8°. The placement of a manhole where an aqueduct changes direction probably facilitated cleaning and maintenance, as in the case of other vulnerable spots along an aqueduct's route, where alluvium was likely to accumulate. Unlike the construction method employed in tunnels, shafts did not have a role in the initial surveying of the water works; rather, their purpose was solely operational—for ongoing maintenance of the aqueduct in order to ensure a regular flow of water. As no other manholes were discovered during the excavation, it is not known whether in this particular aqueduct they were set at fixed intervals or at specific locations for some operational purpose.

The Destruction of the Aqueduct

The Eastern Area (Segments I–II). In this area, the channel was distorted, probably by movement that caused the inward collapse of its walls (Plan 1: Sections 3–3, 4–4; Fig. 15). This could have been caused by an earthquake; however, it might have been the result of the ground's absorption of moisture. An analysis of the ground conditions in the region makes it clear that the area is rich in heavy alluvial clay soil, characterized by movement and upheaval resulting from the absorption of moisture (Plan 1: Section 5–5). The plastered revetment abutting the outer face of the channel walls (see above) was probably built to protect the aqueduct from the pressure expected due to the absorption of moisture in a clayey environment

Fig. 15. The collapsed stones of the channel, looking east.

(Yaalon 1966; Vider and Yaalon 1983; Dan and Yaalon 1990:86–87, Fig. 5).

After the aqueduct became defunct, the extreme weight of the alluvial soil in the eastern part of the site probably caused the collapse of the inner channel walls over the years, especially if the channel stood exposed and empty. Furthermore, the removal of cover stones along the western part of this segment, which probably took place in antiquity, could have also contributed to the collapse. Where the cover slabs were left in place, i.e., in the eastern part of Segment I, the aqueduct withstood the pressure better. Thus, it seems that the type of soil and the loss of structural strength due to the absence of cover slabs brought about the collapse of the system in this segment. The phenomenon of aqueducts collapsing as a result of soil pressure is known from other places, such as the "unfinished aqueduct" north of Binyamina, although there the foundation collapsed, and not the walls ('Ad 1999:95*).

The Middle and Western Areas (Segments II–IV). Here, the aqueduct was built upon *ḥamra* soil. The ground stability of the *ḥamra* soil left the channel walls in a much better state of preservation than those uncovered in the eastern area. The state of the aqueduct here is the same for its entire length, except for a severely damaged one-meter long segment that was disturbed by mechanical equipment (Loci 195, 197). Although cover stones were missing in this segment as well, no movement of the walls was noted (Plan 1: Section 13–13; Fig. 16) because the *ḥamra* is less susceptibile to moisture damage.

The Aqueduct's Rate of Flow

The calculation of the maximum rate of flow in the aqueduct is only theoretical, and it is based on data acquired from the excavated sections only. It was performed using Manning's formula, which takes into account the roughness coefficient (friction) of the plaster

Fig. 16. The western area of the aqueduct, looking north; the cover stones are missing.

(Hodge 1992:354–355).11 As the water almost certainly did not flow at the maximum possible height within the channel for the entire year, the sedimentation on the walls of the channel should be considered a consequence of seasonal flow. Nevertheless, we shall try to ascertain the maximum flow rate for the aqueduct using the data presented above. This rate should not be considered as constant.

The overall gradient of the aqueduct was calculated by measuring the absolute elevations of the bottom of the channel at both of the exposed ends and at a number of points along the excavated line of the aqueduct. The difference in elevation measured over a distance of 100 m between the eastern and western ends was about 12 cm, i.e., a gradient of 0.12%. A moderate increase in the elevations was noted west of Manhole 127 (see W171, W172, L135), but this probably stems from ground upheaval having occurred over the years. For the most part, the aqueduct's gradient is quite uniform. Given that the data relate to measurements made within the excavation area only, it is not known how a change in parameters (width, gradient, etc.) from areas not excavated will affect the overall calculation. At another segment of the aqueduct, excavated near the entrance to Moshav Yashresh (Fig. 1:8; Zelinger 2001), 5 km west of the westernmost point of our excavation, an elevation of 81.44 m asl was measured. The difference in elevation between the two points is almost 13 m, so that the gradient between the two is 0.26%, which is greater than the gradient measured within the confines of our excavation. Nonetheless, for the purpose of calculating flow rate, we should refer to the smallest known gradient along the length of the aqueduct as the constant gradient (i.e., 0.12%). The aqueduct's data and the calculation of the flow rate are presented in Table 1.

It is apparent from the data gathered that if we consider a flow height of 0.6 m (based on the maximum height of the deposits on the plastered walls) and a 0.12% gradient (taking into account the most moderate gradient known along the route), then the maximum theoretical flow rate is c. 700 cu m per hour.[12] The water flow was probably drastically

Table 1. Calculation of the Water-Flow Rate in the Middle Section of the Gezer–Ramla Aqueduct[i]

Parameter	Definition	Calculation	Result
H	Height of flow	-	0.6 m
W	Width of flow	-	0.5 m
A	Cross-sectional area (H × W)	0.6 × 0.5	0.3 sq m
P	Wetted perimeter (2H + W)	2(0.6) + 0.5	1.7 m
R	Hydraulic radius (A/P)	0.3/0.7	0.1765 m
S	Slope	-	0.0012
K	Roughness coefficient	-	60
V	Velocity (K × R^(⅔) × S^(½))	60 × 0.1765^(⅔) × 0.112^(½)	0.6531 m^3/sec
Q	Discharge (V × A)	0.6531 × 0.3	0.1959 m^3/sec
Max. hourly rate of flow	Q × 3600	0.1959 × 3600	705 m^3/h

[i] Calculations were performed by Yehuda Peleg.

affected by different factors, such as the amount of precipitation in any given year. However, the number and capacity of cisterns and water reservoirs exposed in Ramla are absolutely in keeping with such considerable quantities of water.[13]

There is no doubt that these data place the Ramla aqueduct amongst the premier water systems of its type, such as the aqueducts of Caesarea (Peleg 2002; Porath 2002b); Jericho (Netzer and Garbrecht 2002); Bet Guvrin (Amit 2002; Sagiv, Zissu and Amit 2002); and Jerusalem (Billig 2002; Mazar 2002). The flow rate, quality of planning and construction of the Ramla aqueduct are suitable to a well-developed, prosperous capital city populated by thousands of people.

Reconstruction of the Course of the Aqueduct

Upon completing the excavation presented here and summarizing its findings, along with those of previous excavations over the years (see above), a reconstruction of the aqueduct's ten-kilometer course can be proposed (Gorzalczany 2008d). The reconstruction is wanting on a number of points, as we do not have accurate data regarding the source of water and the nature of the connection of the aqueduct to the Umayyad city. Topographical considerations may help overcome these difficulties.

As suggested above, the group of springs in the vicinity of Abu Shusha should be considered the water source of the aqueduct. The combined flow of a number of springs can explain the enormous potential flow of the aqueduct as calculated by means of a hydrological formula. Today's diminished flow rate is the result of over-pumping in recent years, which caused a sharp drop in the level of the aquifer.

The first point at which the aqueduct has been identified with certainty is on the Bet Shemesh–Ramla road, near the entrance to Moshav Petaḥya (Fig. 1:1). Northwest from there, the aqueduct is visible through agricultural fields, and it can be traced by plaster and masonry surface remains up to the landing strip at Kibbutz Na'an. At that point, the aqueduct veers sharply west, some 200 m south of Na'an's wastewater treatment reservoir, about 2 km south of Moshav Maẓliaḥ. In this area, along the route of the Cross-Israel Highway, our excavations (Fig. 1:3) exposed more than 150 m of the aqueduct. In addition, traces of the aqueduct are visible on the surface for about 170 m westward. Directly to the west, the aqueduct was uncovered and excavated at two locations near the railroad tracks (Fig. 1:4, 5).

Traces of its construction can be followed in the fields for approximately 1 km to the northwest (Fig. 1:6, 7; Oren Shmueli, pers. comm. 2010).

The next spot where the aqueduct was exposed is on Road 40, c. 100 m south of the entrance to Moshav Yashresh (Fig. 1:8; Gorzalczany 2008b), some 5 km northwest of the present excavation. The aqueduct's course between these two points is not known for certain, but it probably runs along the line of the local watershed and turns north toward Ramla in keeping with the topography.

The northernmost segment of the aqueduct revealed to date was excavated by the present author in 2006, northeast of Moshav Yashresh (Fig. 1:9). It is narrower (0.25–0.30 m) than the other segments thus far uncovered, possibly indicating the aqueduct split into several branches before it entered Ramla. A channel width of 0.5 m was measured near Moshav Yashresh (Zelinger 2001: Fig. 259); therefore, it seems safe to assume that the bifurcation point was positioned somewhere between Moshav Yashresh and Segment 9. Presumably, each branch conveyed water to a different part of the city.

The destination of Segment 9 of the aqueduct is unclear. It may have been the industrial neighborhood of the city of Ramla excavated between 2004 and 2008, south of the city and close to Moshav Maẓliaḥ (Gorzalczany 2008a; 2008c; 2009a; 2009b; Gorzalczany and Spivak 2008; Tal and Taxel 2008; Gorzalczany and ‘Ad 2010; Gorzalczany and Marcus 2010; Gorzalczany, Yehuda and Torge 2010). This conjecture is based upon the general direction of the channel and the topography, as well as the numerous water cisterns and water-related installations uncovered in this area, which could have hardly been filled by roof-drainage or local wells alone. On the other hand, the aqueduct's route may have entered the city from the south, reaching the Umayyad compound and the pools at the White Mosque (average elevation of the bottom of the pools—75 m; elevation at the top of the arches—82.20 m; elevation of present surface level—82.90–83.00 m). A third possibility is that this branch further subdivided and reached both areas.

It is worth noting an irrigation channel running almost parallel to Segment 9 of the aqueduct, which was unearthed in 2004, close to Road 40 (Shmueli 2011). Despite the fact that it is not connected to our aqueduct, the channel may be considered part of a local water system that appears to have been very well-developed.

A geophysical survey undertaken by Petersen and Wardill (2001:4, 6; Fig. 1:10) discovered the straight contour of an anomaly (max. 3 m wide) below the surface of an open field outside the modern city limits, approximately 1.5 km west of the White Mosque; it was identified as the remains of an aqueduct. It is unclear whether this segment constitutes part of the aqueduct under discussion or another conduit, the course of which is unknown. Its east–west direction and its narrowing toward the east were explained as either intentional or due to the fact that it is covered by a thicker layer of alluvium (Petersen and Wardill 2001:4). The narrowing may indicate a certain gradient in the direction of the pools at the White Mosque. This discovery constitutes another tier in the data that has amassed in recent years regarding the sophistication and complexity of the urban plan for supplying water to Ramla during the Early Islamic period (Gutfeld 1999c; 2010:43, Photographs 2.12–2.16, 4.1–4.7, 5.1, 7.1–7.5; Plan 3.9; Zelinger and Shmueli 2002).

The Finds

Pottery

A miniscule amount of pottery was found in the excavation. The finds include especially large fragments of ceramic pipes and large flat sherds incorporated into the bedding of the plaster. The latter cannot be identified or dated exactly. The diagnostic material was mainly recovered from the manholes and probably reflects the last stages of the aqueduct's maintenance.

The pottery (Fig. 17:1–6) includes glazed and unglazed bowls, fragments of bases and the fragment of a lamp bearing an inscription. This material is known from other excavations in the country and therefore, only a minimum number of references are provided. The principal source for comparison is the ceramic report of Yoqne'am (Avissar 1996).[14] We have also sought comparisons with material from recent excavations in Ramla and its surrounding area.

Unglazed Bowls (Fig. 17:1, 2).— Bowls with and without combed decoration were recovered. One (Fig. 17:1), without combed decoration, is made of reddish orange clay; its walls are curved and its rim is folded and rounded. It belongs to the type designated at Yoqne'am as Type PLDB 5 (Avissar 1996:119, Fig. XIII. 68:1), probably an imitation of Cypriot Red Slip Ware, particularly Hayes' Forms C-B 9 and 10, dating from 580–600 CE to the end of the seventh century CE and even later (Hayes 1972:379–783, 423–424). These bowls are quite common and are found in a large number of sites—including Jerusalem, Bet Yeraḥ, Niẓẓana, Shepherd's Field and Kursi—together with Umayyad pottery and genuine Cypriot vessels. Their form apparently continues into

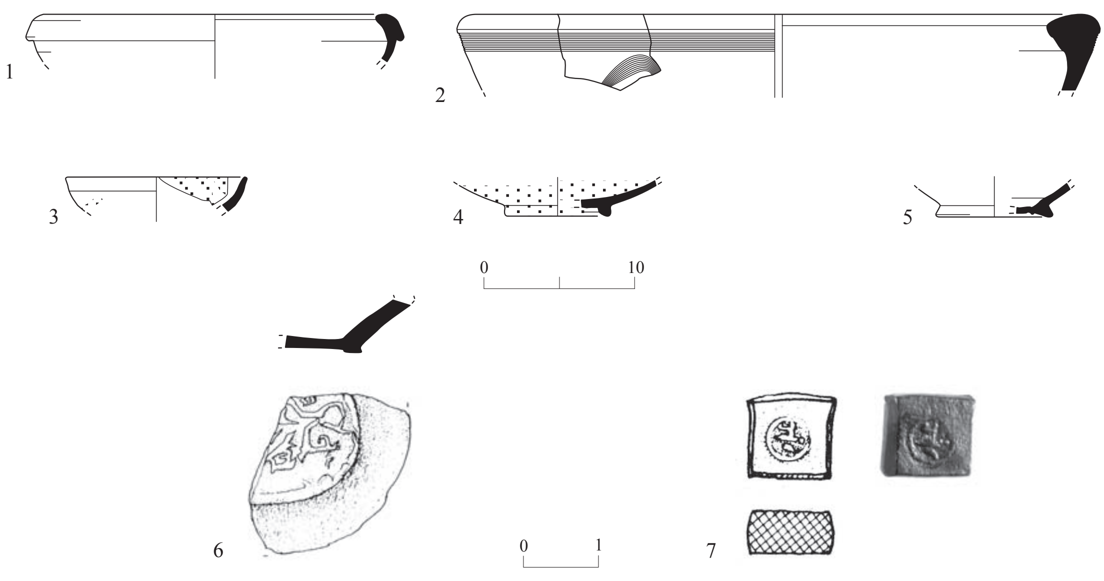


Fig. 17. Early Islamic pottery (1–6) and an Islamic weight (7) from the aqueduct.

No.	Vessel	Reg. No.	Locus	Description
1	Bowl	1044/1	138	Reddish orange, levigated clay, small dark inclusions
2	Bowl	1082	199	Reddish brown, levigated clay, small brown and gray inclusions, wavy combed decoration
3	Bowl	1070	199	Polychrome Splashed and Mottled Ware; reddish brown, well-levigated clay
4	Bowl	1082/2	199	Polychrome Splashed and Mottled Ware; yellowish, light brown levigated clay, very small white, gray and reddish inclusions
5	Jug base	1082/1	199	Well-levigated, yellowish white clay, grooved disk base
6	Lamp	1031	199	Light orange levigated clay, Arabic inscription on base
7	Weight	1019	132	Bronze, stamped

the Abbasid period, when the original vessels could no longer be obtained (for references, see Avissar 1996:119).

The combed bowl (Fig. 17:2) is made of coarse, reddish-brown clay with thick, incurved walls. Straight combing surrounds the rim, below which is a wavy band of combing around the wall. This type of bowl is well known and especially prevalent in the south of the country. Bowls, with and without handles, were also found at Jericho, Herodium, Niẓẓana and Ma‘on. At Shepherd's Field, this vessel is designated as Type 6 (Tzaferis 1975: Pl. 16). At Yoqne‘am, it is classified as Type PLDB 25, and is dated to the end of the Byzantine–Early Islamic periods (Avissar 1996:125–126, Fig. XXIII.79:2; see discussion and references therein). Similar vessels were previously uncovered at Ramla and in its surrounding area (Glick 1998: Fig. 134:9; Priel 1999: Fig. 157:6; Zelinger 2000a: Fig. 107.2; Kletter 2005b: Fig. 13:2–6). Due to the relatively long life span of this vessel, chronological conclusions cannot be based on it.

Glazed Bowls (Fig. 17:3, 4).— Two glazed bowls of Polychrome Splashed and Mottled Ware were found inside Manhole 199, in the western area of the excavation. These bowls are decorated with splashed yellow and green paint and are coated with a lead-based glaze. The painted patterns are probably inspired by prototypes of Chinese origins—vessels attributed to the Tang Dynasty and produced in China until the ninth and tenth centuries, and exported to a wide variety of countries (Avissar 1996:79).

Our bowls are of a type classified at the Yoqne‘am excavations as Type GLB 6 and dated to the ninth and tenth centuries CE (Avissar 1996: Fig. XIII:1–6). They are known throughout the Islamic world (see Avissar 1996:81 for parallels and discussion) and from various excavations in the country, such as Abu Ghosh, where they are dated to the same centuries (de Vaux and Stève 1950:122), Capernaum (Loffreda 1983: Fig. 4:1, 2, 5) and Ramla and its vicinity (Singer 2004: Fig. 2:6; Kletter 2005b: Fig. 11:15).

The presence of these vessels in the aqueduct's manhole suggests the latest possible date for the ongoing maintenance activity in the water works.

Jug Base (Fig. 17:5).— This is a grooved disk base encircled by shallow, concentric incisions. The clay is yellowish white in color and rather well levigated. Similar bases were uncovered at Capernaum (Loffreda 1974: Fig. 15.21) and Caesarea (Brosh 1986: Fig. 1.4), and belong to jugs made of the buff color clay very common in the Early Islamic period. They can also frequently occur in Coptic Glazed Ware. At Yoqne‘am this type of base is classified as Jug Type 11 (Avissar 1996:160–161, Fig. XIII. 137:1–2, and see discussion and references therein).

Oil Lamp (Fig. 17:6).— A fragment of an oil-lamp base made of light orange clay was found. The base of the lamp was probably piriform shaped. These lamps are known to have a tongue handle, as evidenced by examples unearthed at numerous excavations in Israel, such as in the Ma‘ale Adummim region (Cohen-Finkelstein 1997:32*, Fig. 8), at Yoqne‘am (Avissar 1996:192) and in the Ḥamat Gader baths (Uzzielli 1997:326–327, Fig. 14). To date, the overwhelming majority of lamps recovered in excavations at Ramla belongs to this type (Rosen-Ayalon and Eitan 1969).

These lamps date to the Abbasid period and are considered later than the Umayyad lamps with a circular base and a conical handle (Day 1942:71–72; Brosh 1986:71; Avissar 1996:191–194; Hadad 1997:174, Type 3). Stratigraphic evidence at Bet She'an has reconfirmed a post-750 CE date for the type (Hadad 1997:176–177).

On the base of our lamp, one can discern the Arabic inscription "…blessing…". Lamps of the Early Islamic period with inscriptions are known in Israel and Transjordan (‘Amr 1986a; Khairy and ‘Amr 1986; Hadad and Khamis 1998), including those bearing the word "blessing" (Rosenthal and Sivan 1978:133).

Glass

A total of fourteen fragments of glass vessels was found in the excavation.[15] Of the meager finds, all the rim fragments and bases are too small to be illustrated, and only a few are diagnostic for determining vessel type or date.

In general, it can be said that the earliest fragment is that of a flared-rim bowl with a double fold on the rim (L176), a type that is known from the Roman period. The other fragments represent vessels that began to appear in the Byzantine period and continued into the Early Islamic period. These include bottle or wineglass rims rounded by fire (Loci 176, 178) and a bottle or jar rim that is folded inward (L199).

The finds worthiest of mention are two lumps of glass-production waste, found in Manhole 199. One chunk must have originated on the floor of a furnace, its underside being of lime waste and the pale bluish-green glass above it containing a large amount of residue typical of the bottom of a furnace. The second chunk is of raw, purplish-colored glass, a hue typical of most of the Late Islamic material. The color and fabric are similar to glass finds from Baniyas dated from the eleventh to the fourteenth centuries CE (Gorin-Rosen 2001).

Metal Finds

The metal artifacts consist of a number of iron and bronze nails, including a nail that was found *in situ*, sunk into the plaster of the aqueduct's outer facade. The nail was probably hammered in place to reinforce a wooden frame on which bonding material was poured, either when the aqueduct was being built or during a repair of some sort.

A square bronze weight (1 × 1 cm; Fig. 17:7) was also uncovered.[16] The item is 50 mm thick and weighs 5.8 g. A stamped, off-center circular impression (diam. 50 mm) is discernible on one of its broad sides. Within the circle is the personal name, Imad. An exact parallel, weighing 5.6 g, was found at Ṣarafand el-Kharab, Nes Ẓiyyona (Gorzalczany 1998: Fig. 137:b; 2004: Fig. 4:3). A very similar weight was found at Ramla (Kletter 2005a: 117, Fig. 1:2; see also Holland 1986: Pls. 35; 36).

Fig. 18. Column of a chancel screen in secondary use in W160.

Chancel Screen Fragments

While cleaning Manhole 199, two connecting pieces of a white marble chancel screen (2 cm thick) were uncovered (not illustrated). Traces of an incised frame are visible on one side of the screen. The screen was probably in secondary use—on both sides are the remains of an Arabic inscription from the Early Islamic period. The inscription was painted in black. Two letters are discernible, but due to its fragmentary state, it is impossible to decipher or accurately date it based on paleographic considerations.[17]

In addition, part of a column from a chancel screen was incorporated into W160 in Segment II (Fig. 18).

Animal Bones

Very poorly preserved animal bones were found in Manhole 199; it was impossible to identify the species.

Discussion: Dating the Aqueduct

The ceramic assemblage recovered from the vicinity of the aqueduct was minimal, as would be expected in a scantily populated agricultural region. Some of the pottery types have long life spans, and thus cannot be used as the basis for an unequivocal chronological determination. Of the material found in Manhole 199, the glazed bowls are characteristic of the ninth and tenth centuries CE, and the lamp is post-Umayyad (see above).

It is obvious that the water system was constructed in a single concentrated effort, both well planned and managed by a central guiding hand. The vast quantity of historical sources mentioned above leaves no room for doubt regarding the date of its construction, and it suits well the works of Sulaymān ibn ‘Abd al-Malik, who devised and planned anew the city of Ramla, building markets, city walls, gates and administrative and religious centers (Kaplan 1959; Sharon 1986:112–115; Luz 1996; Gat 2003:66–175; 2007; Gorzalczany 2008a; Gutfeld 2010). However, it cannot be ascertained whether he finished the project before his death in 717 CE. Al-Balādhurī and al-Muqaddasī state that Sulaymān passed away before he managed to complete the construction of Ramla’s mosque; therefore, it is possible that he also did not complete the construction of the aqueduct.

The aqueduct probably fed the pools in the vicinity of the White Mosque, the political, social and religious center of Umayyad Ramla (Luz 1996:34). Given the importance of this region and the efforts expended in controlling production (as evidenced by the transferring of cloth manufacturing and dyeing industries to the city, along with coppersmiths, date and perfume merchants; see Luz 1996:40), it would not be far-reaching to assert that the mosque’s control of the water sources was part of an overall policy encouraging the population to align itself with the new administration and Islam. The phenomenon of building water cisterns and reservoirs within the precincts of religious buildings, such as synagogues and churches, is known already from the fourth and fifth centuries CE. In carrying out the project, the topography was not lost on the planners of the aqueduct—the average elevation of the region (80 m asl) in relation to the bottom of the pools in the White Mosque (74.98 m asl) made it possible to convey water to the city by gravity, perhaps one of the considerations in choosing the location of the city.

In light of the above, the question must be asked: why are pottery types that are specifically characteristic of the first phases of the Umayyad period missing, not only from the limited ceramic assemblage of the aqueduct, but from the numerous excavations in the city of Ramla? These early types of vessels have been found and defined in recent years in a large number of excavations in Israel and Transjordan. They are characterized, inter alia, by the continuation of common Byzantine forms, red slip, and the application of red or white paint to the vessels; lamps with round bases and conical handles are also typical (McNicoll, Smith and Hennessy 1982: Pls. 147, 148; ‘Amr 1986b; Northedge 1992: Pls. 131:1–9, 132:1–5, 133:1–7; Orssaud 1992; Sodini and Villeneuve 1992:208–209, Fig. 10:17–20; Watson 1992; Ben-Arieh 1997: Pls. VII:21–23, VIII:18, 24).

The absence of the earliest phase of Umayyad pottery should not be explained as a result of the seismic events in the first years of Ramla, as has been suggested by Luz (1996:28), for an earthquake should have provided clear and unequivocal archaeological evidence in its destruction stratum. Rather, the phenomenon can probably be explained by the relatively short period during which the Umayyad Dynasty ruled the city. One should bear in mind that ceramic assemblages do not always overlap the chronological-political or cultural definitions of a period; ceramic types continue to be manufactured by potters despite changes of ruling power. The traditional division of periods into political units instead of centuries or shorter time spans also contributes to the confusion (Falkner 1993–4:41).

Moreover, it is reasonable that the assemblage collected from the aqueduct reflects its later phases. The system apparently ceased to function during the ninth or tenth century CE, given that the latest potsherds, which were found in the manholes and represent the last phase in which the aqueduct was maintained, date to this period. The glass lumps recovered from Manhole 199, although not unequivocal, are somewhat later (see above).

In examining the plaster, well preserved over long sections of the aqueduct, I have concluded that only one major series of repairs was carried out over the course of its use (for a variant of this interpretation, see Tsatskin, this volume). This reflects the fine quality of workmanship employed during its construction, while also implying that the aqueduct had a relatively short life span. Reinforcing this latter supposition is the minute quantity of travertine-like deposit accumulated on the plaster, particularly over that of the repair phase, where it is only a few millimeters thick. (Alternatively, it remains possible that this later plaster could have had different characteristics than that of the first phase, which might have hampered the travertine's adhering to its surface.)

A description of Ramla recounted by al-Muqaddasī in his book, written between the years 985 and 988 CE, states that: "…her wells are deep and brackish. The rainwater in [the city] is collected and held in cisterns and therefore the poor go thirsty and the stranger searches [for water] to no avail" (al-Muqaddasī 1906:164–165). This situation is compatible with a period during which there was no regular water supply to the city, perhaps due to disruptions or malfunctions in the aqueduct. Evidently, there lacked either the interest or capability to carry out the repair and renovation of the aqueduct, resulting in a water shortage among the populace.

The possibility that the aqueduct ceased to function as a result of an earthquake should be considered. A number of very severe and extremely destructive seismic events have been documented in the region (among them the later earthquakes that occurred in 1033 and 1068 CE, known from the Cairo *geniza* and other contemporary sources). Such earthquakes measured as much as 6 on the Richter scale (Amiran 1996:128), and would ostensibly seem to be good candidates as events that put the aqueduct into disuse. However, there are no historical sources that mention damage caused by earthquakes to the city of Ramla in the eighth–tenth centuries, as we have regarding other cities in the southern Levant. The only possible mentions of such an event at Ramla are several allusions in contemporary poetry (for a detailed discussion, see Gat 2003:30–31 and references therein).

One finds it hard to believe that Ramla, located in a very tectonically sensitive area, remained untouched by the aforementioned earthquakes, while other cities, e.g., Bet She'an, became piles of rubble. However, it is important to note that in archaeological excavations within the precincts of Ramla, no unequivocal evidence has been found of an earthquake (Kaplan 1959; Rosen-Ayalon and Eitan 1969; Rosen-Ayalon 1976; Segal 1998; Glick 1999; Gutfeld 1999a; 1999b). Those who do use the above-mentioned earthquakes as explanations for the downfall of the city are aware of this fact (Vitto 2000; Kletter 2005b:95–96). In this regard, it is noteworthy that in excavations carried out by the author close to Moshav Maẓliaḥ, in what seems to have been an industrial area on the outskirts of ancient Ramla, indications of a strong earthquake were detected for the first time. The analysis of that excavation is still in progress, but for the time being it appears that the earthquake damage there can probably be attributed to the seismic event of 749 CE (Gorzalczany 2008a:34).[18]

It must be clearly stated that our excavation of the aqueduct yielded no signs of the kind of damage that could be caused by earthquakes. In fact, of the 19 criteria defined by researchers (Mazor and Korjenkow 1999; Fabian 1998) for determining the occurrence of an earthquake based on archaeological findings, not one was observed in the remains of the aqueduct. Geological evidence from the excavation area strengthens the same conclusion (Ariel Heimann, pers. comm.). Therefore, the obsolescence of the aqueduct should probably be attributed to other factors, e.g., the collapse of its walls as the result of the pressure of the alluvial soil and the lack of ongoing maintenance. Such neglect could have resulted from the absence of a central government that appreciated the importance of the aqueduct, perhaps even prior to the earthquakes of 1033 and 1068 CE.

In summary, excavations along the course of the aqueduct did not expose any visible evidence of a tectonic occurrence; therefore, the date that the aqueduct ceased to function cannot be established conclusively.

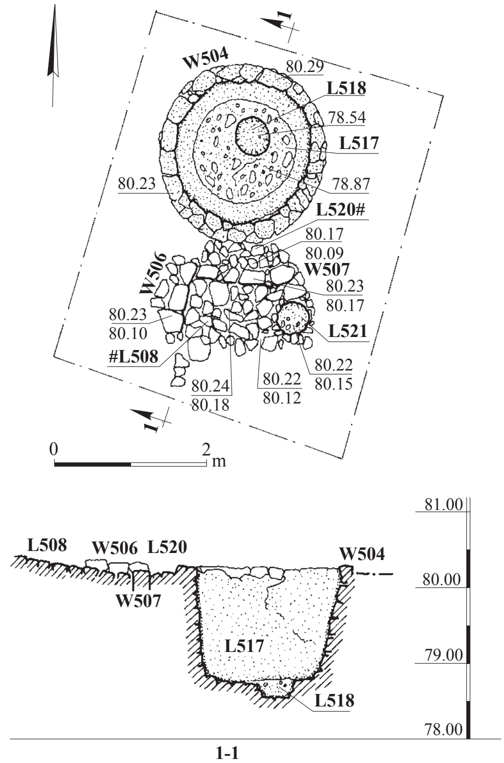
Area B: Installation and Tombs(?)

Area B is located approximately 1 km north of Area A (see Fig. 2). During the course of development work in the area, architectural finds were exposed in two squares (B1, B2), approximately 50 m apart (Gorzalczany 2005).

Square B1

An installation consisting of a number of components was exposed in this square (Plan 3). In the northern part of the square was a circular pit (L517; depth 1.5 m), its opening (diam. 1.9 m) wider than its base (diam. 1.6 m). The pit was dug into *ḥamra* soil and lined with a wall (W504; width c. 0.15 m) built of fieldstones bonded with gray mortar. The surface of W504 was coated with gray plaster mixed with scattered, very small stones. Although the plaster had been damaged over time, it was still possible to discern at least three layers. At the bottom of the pit is a depression (L518; diam. 0.55 m, 0.25 m deep). The base of the pit is also coated with at least three layers of gray plaster above a layer of pebbles. The pit was filled with large fieldstones and earth, in which were found a number of ribbed potsherds dating to the Byzantine period (fifth century CE) and several white tesserae (2.5 × 3.5 cm). The manner in which the pit was filled suggests it was intentionally blocked in antiquity.

A surface (L520) paved with medium-sized pebbles, was exposed adjacent to the southern side of the pit. This surface was mostly



Plan 3. Square B1, plan and section.

destroyed, but it appears to have adjoined the wall of the pit. Two walls (W506, W507), built of medium-sized fieldstones and preserved only to the height of one course, were discerned south of Surface 520. Wall 507 runs east–west; W506 is aligned north–south and forms a corner with W507. The southern end of W506 was destroyed.

To the south of W507 is another surface (L508), made of two layers of pebbles bonded with gray mortar. Apparently, only part of the surface survived (0.9 × 1.1 m); it was destroyed mainly toward the south and east. This surface probably served as a foundation for a mosaic, as evidenced by the coarse, white tesserae found in the square.

A small, concave installation (L521; diam. c. 0.4 m), which was plastered and partially paved with pebbles, was located at the eastern end of Surface 508. The installation appears to sever W507, therefore implying at least two

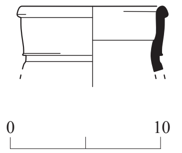
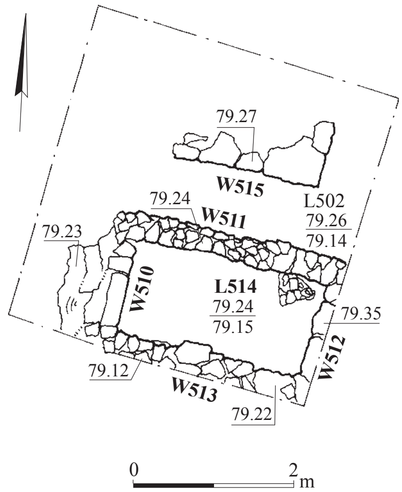


Fig. 19. Jar from Square B1.

phases of use for the entire complex. The two surfaces and the walls were built directly atop *ḥamra* soil.

The entire installation is poorly preserved. As the excavation was not extended beyond this square, neither the installation's function nor its original shape can be determined with certainty. We can reasonably assume that the plaster-lined round pit was used to store liquids, perhaps connected with the wine industry. The dating of the installation is also equivocal. The ceramic finds discovered in the stone debris that filled the pit include several jar fragments characteristic of the fifth century CE, suggesting that the pit went out of use during the Byzantine period or the beginning of the Early Islamic period. One example, presented here (Fig. 19), is made of well-levigated, reddish-orange clay with small gray and white inclusions. It has a high neck and a delicate, thickened rim that is folded outward. There is a thin protruding ridge where the neck joins the shoulder of the vessel. This type of jar is known from, among other excavations, Caesarea, where it is designated as Type 1A and is dated from the second through the fifth centuries CE (135–140 CE; Riley 1975:26–27, 29, Nos. 8, 9).

It is worth noting that Tel Ḥamid (Wolff 1999; Wolff and Shavit 1999) is located about 0.5 km northeast of Area B. The remains exposed here are probably within the agricultural hinterland of the settlement on the tell.



Plan. 4. Square B2.

Square B2

This square is some 50 m northeast of Sq B1. The outline of a rectangular enclosure was uncovered (L514; 1.9 × 2.5 m; Plan 4). The walls of the structure were built of unworked limestone blocks, save one large dressed stone on the interior face of the western wall (W510). This stone measures 0.20 × 0.65 m and was probably originally used as a threshold. The wall was preserved to the height of at least two courses. The fill in the enclosure included a number of Byzantine-period potsherds and one unidentifiable bone.

Approximately one meter north of Enclosure 514, another wall (W515) lies along a roughly east–west alignment. The dimensions of this wall cannot be ascertained, but it appears to be similar to those of the enclosure walls.

The excavation of Sq B2 was not completed, so it is impossible to fully establish the nature of the structural remains; however, they would appear to be tombs.

NOTES

[1] Iftach Gutman was the first person to spot this segment of the aqueduct during the leveling of the ground prior to the construction of the Cross-Israel Highway. He brought it to the attention of IAA inspector, Oren Shmueli. Following the exposure of the aqueduct, a salvage excavation was conducted on behalf of the Israel Antiquities Authority, under the direction of the author (Permit No. A-3460). Hanita Tsion-Cinamon and Varda Shlomi (area supervision) participated in the excavation. Additional assistance was provided by Ella Altmark (metallurgical laboratory), Ya'ir Rachamim (administration), Rami Hen (metal detection), Tsila Sagiv (photography), Avraham Hajian (surveying), Yehoshua Drey (reconstruction of ancient technology), Tsvika Tsuk and Yehuda Peleg (hydraulic calculations and aqueducts), Moshe Sharon (epigraphy), Yael Gorin-Rosen (glass), Miriam Avissar (ceramic consultation), Marina Shuiskaya (pottery drawing), Shimon Gat and Dov Nahlieli (historical sources), Elizabetta Boaretto (Carbon 14), Alexander Tsatskin (petrography and plaster analysis), Albatross (aerial photography), Ariel Heimann (geology), Eldad Barzilay (geomorphology) and the factory for irrigation planning at Kibbutz Na'an (office assistance). David Amit generously shared with the author his vast knowledge regarding aqueducts and water-supply systems. Eli Yannai, Yehiel Zelinger, Kamil Sari, Oren Shmueli, Dror Barshad, John Talab Haj Yichiya, Radwan Badhi and Iftach Gutman were also of assistance.

The IAA Conservation Department carried out conservation work and relocated part of the aqueduct. The Derekh Eretz Company, which was constructing the Cross-Israel Highway, financed the excavation, and the Ben-Ari Company provided considerable assistance during the course of the project.

[2] For a review of the locations of the Islamic capitals in Israel, the first days of Ramla as the capital and the building works of Sulaymān ibn 'Abd al-Malik, see Sharon 1986:112–115; Luz 1996 and references therein.

[3] According to data provided by the Meteorological Service, an average multi-year precipitation of 524 mm was measured for the years 1961–1990:

Month	Precipitation (mm)
August	-
September	0.1
October	23.0
November	68.0
December	130.0
January	134.0
February	89.0
March	61.0
April	17.0
May	2.7
June	-
July	-
Total	*524.8*

[4] The depth of the water-bearing strata in the city of Ramla was measured during the days of the British Mandate. The measurements range between 40 and 50 m: 48.40 m in a well near the military cemetery; 43.58 m in the Ramla municipal well (Muristan); 48.40 m in the Waqf Abu Ja'afer well (Blake and Goldschmidt 1947:252–253).

[5] The origin of their erroneous identification as the source of Ramla's water supply probably lies in an incorrect interpretation of a tenth-century historical source mentioning a Qarmatī military force stationed in Rosh Ha-'Ayin, which succeeded in cutting off the water supply to Fatimid Ramla. It is quite possible that a military force stationed in the vicinity of Rosh Ha-'Ayin would have been dispatched elsewhere to carry out the mission, as discussed by Luz (1996:35, n. 63). Other scholars, such as Shimon Gat, reject this interpretation, and attribute the mistake to an incorrect interpretation of al-Ya'qūbī's narrative by Muslim historians who were unfamiliar with the geography of Israel and misconstrued the Yarqon River as the source of Ramla's water. Furthermore, the historical truth of the Qarmatī attack is in doubt (Gat 2003:106).

[6] Reported by Moshe Ben Abraham of Kibbutz Na'an in 1943: "…flowing water, including a spring with potable water, very strong, located inside the village…" (Kark and Shiloni 1984:339). Tsvika Tsuk has suggested that the above-mentioned spring should be identified with a certain artesian well that was still operating in the 1980s (Gat 2003:7).

[7] I wish to thank Rami Hen and Iftach Gutman, members of Kibbutz Na'an, who accompanied me to places in which remains of the aqueduct were exposed over the course of years of cultivating the land.

[8] I would like to thank Yehiel Zelinger for his kind help.

[9] Travertine sedimentation is a function of the amount of dissolved lime produced in a spring and the speed of the flow of the water. In some instances

the accumulation of sediment is so great that it can be hewn and used as building material for architectural elements, such as column capitals and altars, a well-known phenomenon in Europe (Grewe 1986:269–287).

[10] The first-century BCE Roman architect and engineer, Vitruvius, in the eighth book of his corpus, *De Architectura* (Vitruvius, *On Architecture*), discusses a wide variety of subjects related to the technology of water conveyance across great distances. We can reasonably assume that the technology of building systems for water conveyance was still available with the collapse of the Byzantine Empire and the founding of the Umayyad Dynasty. It is not unlikely that experienced craftsmen, and perhaps even engineers would have been among the residents in the Lod–Ramla region, affording a skilled work force that could have been tapped for the benefit of the project.

[11] The calculation of the flow rate was performed by Yehuda Peleg, to whom I extend my deepest gratitude. The data was checked by Tsvika Tsuk, who suggested other values for the purpose of calculating the roughness coefficient (friction) of the plaster (see n. 12). There exist a number of other formulas used by hydrologists and engineers for determining the flow rate of channels and rivers. Further information on Manning's, Bazin's, and Chezy's formulas can be found in the following publications: Urquhart 1940:319, 321; Barna 1957:78; Francis 1958:223, 255; Fox and McDonald 1985:522–523.

[12] This figure is based on a roughness coefficient (friction) of 60 for rough plaster. With a roughness coefficient (friction) of 70 for smooth plaster, the rate of flow is calculated to be 822 m³/h. Tsvika Tsuk would use a roughness coefficient (friction) between 33.3 and 50.0, thus altering the calculation of the flow rate to c. 400 m³/h. For information regarding the roughness coefficient (friction) of materials, see Chow 1959:111–113; Farrington 1980:287–305.

[13] From the data gathered from measurements conducted during the days of the British Mandate between the years 1928 and 1947, it has been determined that the aquifer for the length of the Cenomanian and Turonian layers between Rosh Ha-ʻAyin and Ramla was (until 1947) as much as 200 m in width and rich in water (Blake and Goldschmidt 1947:267). The following data were obtained from a multi-year, ongoing follow-up of a number of selected bores that were conducted in the area of Gezer, Naʻan and Ramla: (1) Gezer bore (al-Barriya village): map ref. NIG 192500/642220, OIG 142500/142220, elevation 118 m asl, depth of aquifer 96–160 m, output 100 m³/h, measured 1947 (Blake and Goldschmidt 1947:260–261); (2) Niʻna bore (Hanotaia deep bore N. 1): map ref. NIG 193600/637600, OIG 143600/137600, elevation 90.4 m asl, depth of aquifer 175–219 m, out-put 150 m³/h, measured April 1934 (Blake and Goldschmidt 1947:257); (3) Niʻna bore (Hanotaia deep bore N. 2): map ref. NIG 192890/637610, OIG 142890/137610, elevation 83.8 m asl, output "abundant" (Blake and Goldschmidt 1947:258–259); (4) Faiyumi's well: map ref. NIG 191640/637200, OIG 141650/137200, elevation 71.24 m asl, depth of aquifer 175–219 m, output 70 m³/h, measured 1931.

[14] At the time this report was written, Avissar 1996 was the main reference regarding Early Islamic pottery. Only a few references to finds from other excavations in and around Ramla were added in the process of preparing the manuscript for publication.

[15] I would like to thank Yael Gorin-Rosen for her generous help in processing the glass finds from the excavation.

[16] The weight was examined by Ariel Berman, who is inclined to date it to the tenth century CE (pers. comm.).

[17] Although the inscription could not be deciphered, Prof. Moshe Sharon identified the presence of two letters, part of an Arabic inscription from the Early Islamic period.

[18] There remains the possibility that the lack of evidence of earthquakes in Ramla stems from the fact that the city was totally destroyed and therefore moved from its original location, its masonry having been put to secondary use.

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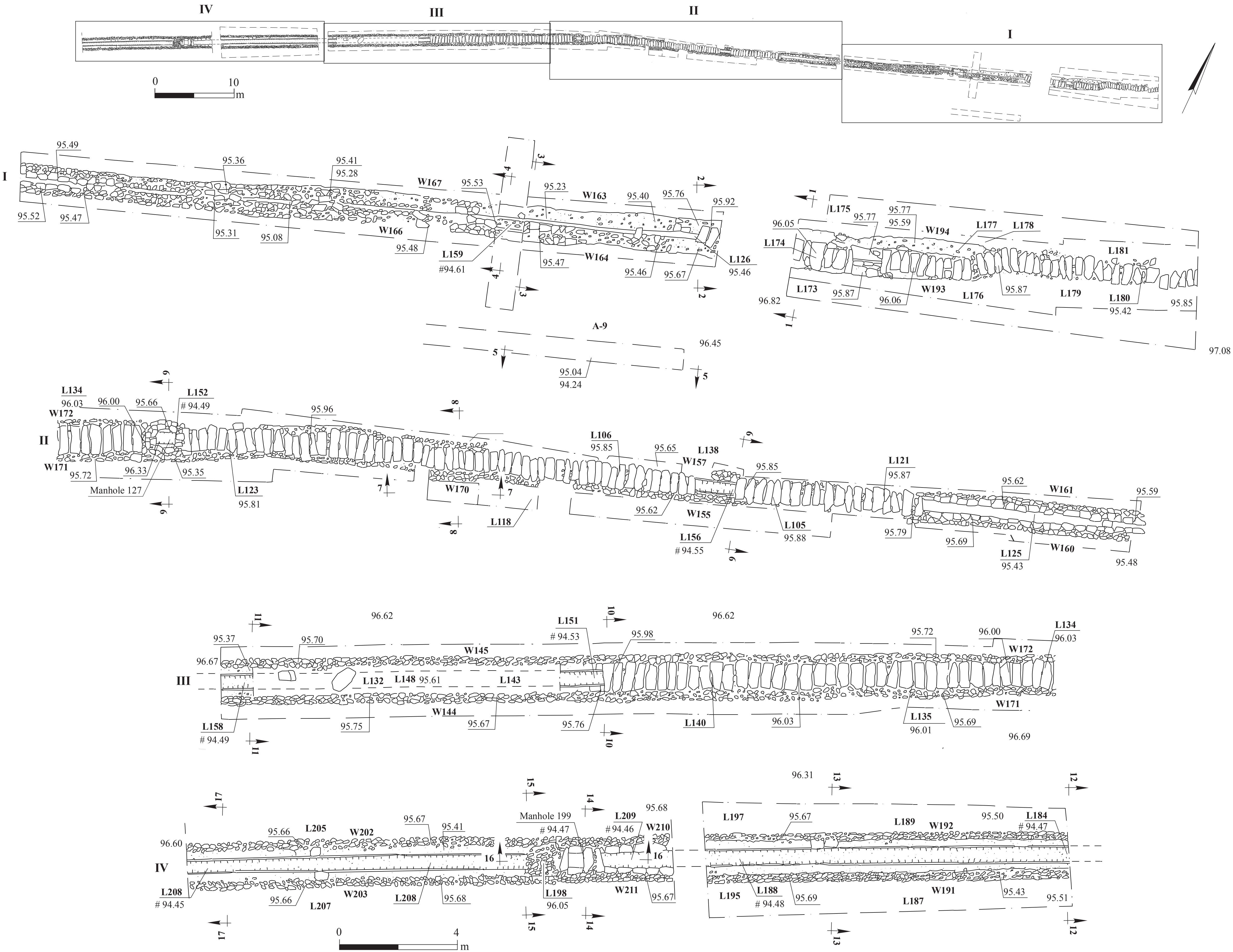
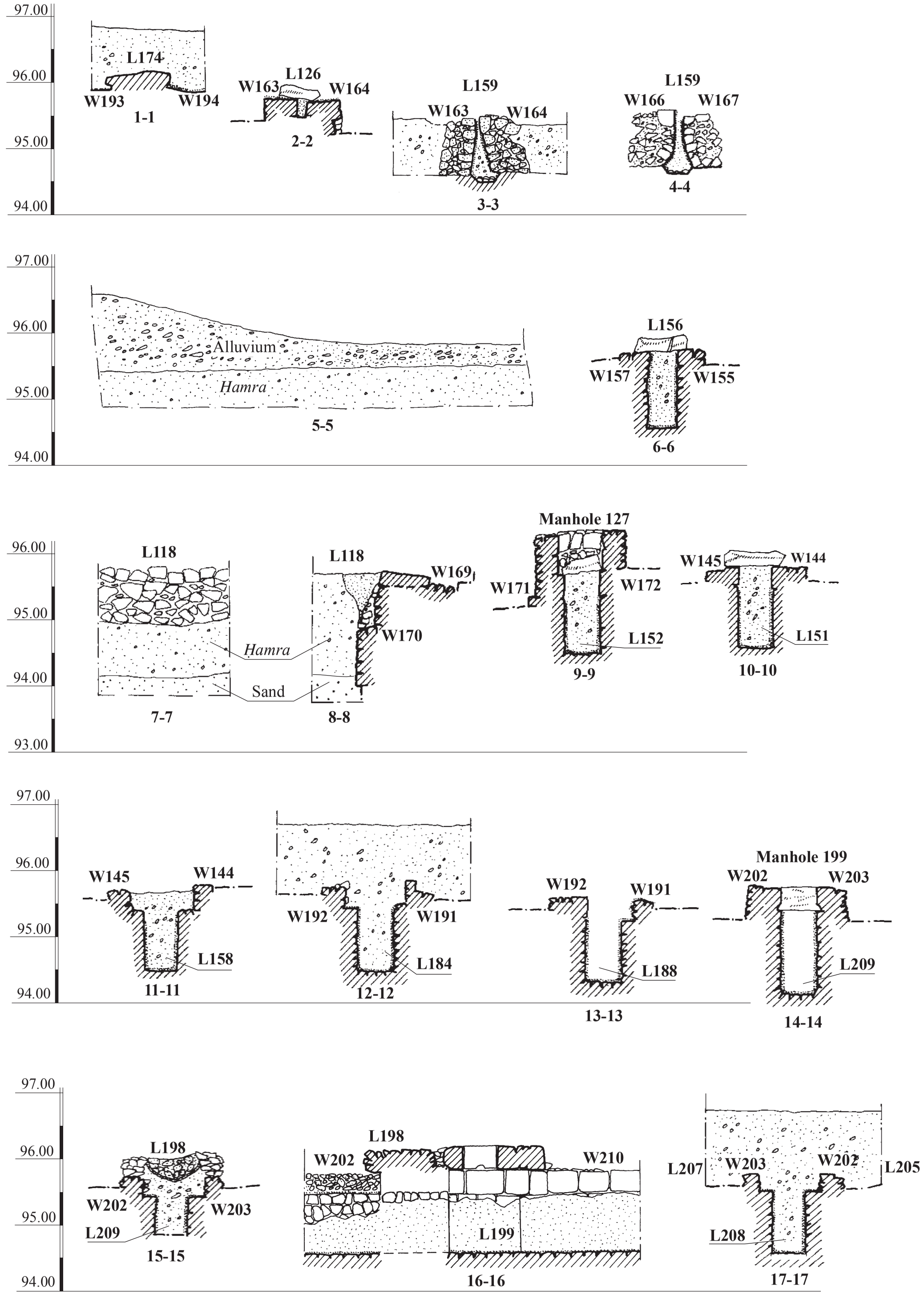


Plan 1. The aqueduct, plan and sections (on back of page).



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