The Ottoman Water Distribution System in Acre

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International Conservation Center
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

The aqueduct leading from the springs of Kabri to Old Akko is a monumental structure of Ottoman design, which has been the subject of much research. The water with which it provided the city allowed the economy and culture of Akko to flourish, while the structure itself, as well as the numerous fountains it supplied within the city, made a bold statement about the dominance of the Turkish Pasha who built and maintained it.

Until now, however, very little attention has been paid to the structures that connected the aqueduct with Akko and facilitated the distribution of water within the city. Many of these structures are already in an advanced state of decay due to neglect. Additionally, they occupy a location within the city that is rapidly being developed. If not treated soon, Akko risks permanently losing this part of its architectural heritage. The following work attempts to supplement the understanding of the water conveyance system in Akko through the investigation of these structures.

The work is divided into two parts. The first begins by tracing a historical overview of water distribution in Old Akko and placing the Ottoman hydraulic system within the scheme of the city's cultural and infrastructural development. The second part deals with the physical documentation of the individual structural elements. Each one is examined both in isolation and within the context of the water distribution system as a whole.

It is hoped that this work will be seen as a starting point for a more in-depth treatment of the Ottoman waterworks in Akko with the final aim of implementing a conservation effort to preserve these structures.

HISTORICAL OVERVIEW OF WATER DISTRIBUTION IN AKKO

As early as the Hellenistic period there is evidence that an aqueduct served the population of Akko. Experts debate whether the source of the water was the springs of ‘En Shayyara, or those of Ein Majnunch.

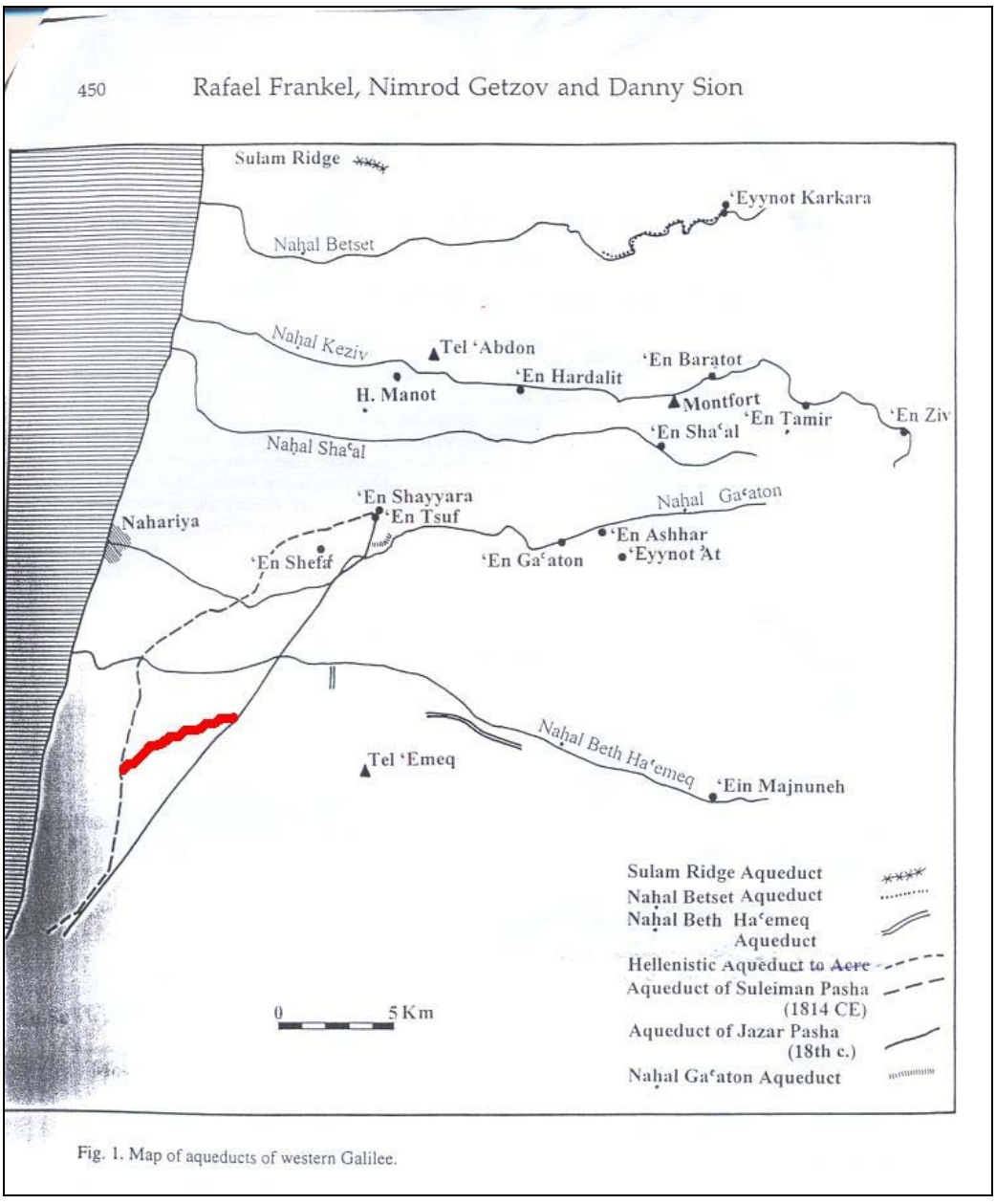

Fig. 1. Map of aqueducts of western Galilee.

Fig. 1. Route of Hellenistic aqueduct. Amit, D., Patrich, J., Hirschfield, Y., “The Aqueducts of Israel.” Journal of Roman Archaeology Supplementary Series No. 46 (2002) 450.

In crusader times, the town relied primarily on internal sources of water. Wells were used to tap the subterranean water table, while cisterns (see figs. 2 and 3) were constructed under buildings and courtyards and funneled rain water from the roofs. Of the two, cisterns were most likely the preferred source of water, due to the vulnerability of well water to contamination;[1] however, given the infrequency of precipitation in northern Israel, wells were a more reliable source of water.

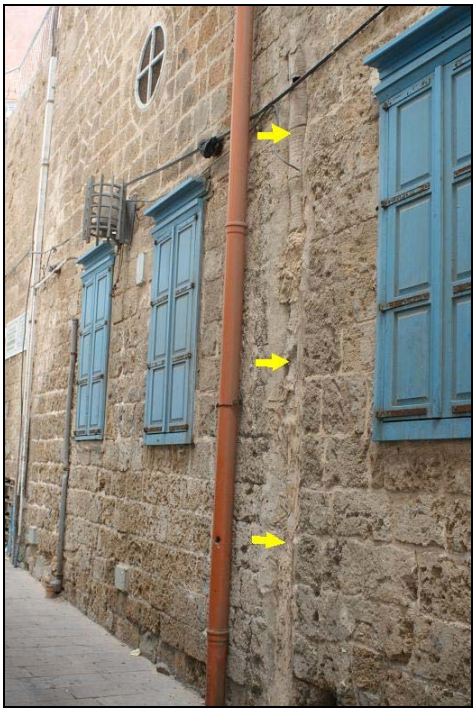

Fig. 2 & 3 (detail). Ottoman cistern pipes embedded in wall.

In addition to internal sources of water, historical accounts of Akko make reference to two springs: Ain al-Bakr, located to the East of town, and al-Sitt.

> "In 1783, Pococke mentioned al-Sitt, noting the canals that transported its water to Akko.[2] Seetzen, who visited Akko in 1806-7, confirmed that Ain al-Sitt provided Akko with water."[3]

Some sources even suggest that a canal facilitated the conveyance of water from the springs to town.

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[1] Syon, D., Stern, E., and Mitchell, P.D., "Water Installation in Crusader Akko," (yet to be published) 2.
[2] Pococke, R., Beschreibung des Morgenlands (Erlangen: 1754) 80. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 252.
[3] Seetzen, U. J., Reisen…. (Berlin: 1854) 78. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 252.

> "Al-Jazzar's waqfiyya holds monthly payment orders for workers employed to clean and care for the water pipe leading from Ain al-Sitt to the Great Mosque. Both Ain al-Sitt and Ain al-Bakr were part of al-Bakr's waqfiyya; their total area was 18 dunams."[4]

Though the use of the springs since crusader times is undisputed, there is no definitive archaeological evidence that supports the existence of a canal to the city.

With the Mameluk invasion in the 13th century the city was demolished and remained virtually uninhabited for the next 500 years. In 1652 when the pilgrim Doubdan visited Akko, he refers to the existence of only one mosque in the town, hinting at the modest size of the population at the time.[5] It was not until Akko was claimed by Daher el-Omar as the capital of his new fiefdom that the city's infrastructure began to be rebuilt. Under the rule of Daher, the population of the city increased exponentially. By the time of al-Jazzar's rule, the city's population had reached 40,000.[6]

In response to the population explosion Al-Jazzar implemented a major building campaign which included the construction of institutions to match not only domestic need, but also the agricultural, economic, religious, and cultural requirements of the new, bigger city. Until this time the city had relied primarily on cisterns converted from underground crusader vaults, thus an aqueduct was planned that would bring water from the springs of Kabri to the town in order to supply the addition of numerous mosques and fountains, public baths and the Khan el-Umdan.

> "As early as 1785 al-Jazzar requested, through Renaudot, the French consul in Akko, that France send expert hydro engineers to plan the aqueduct from the Kabri springs."[7]

During Napoleon's siege in 1799, he cut off the supply of water to Akko from the aqueduct, diverting it for the use of his army. The remains of the original aqueduct built by al-Jazzar are insufficient to garner a meaningful understanding of the water distribution system in Akko at that time; however, we do know that the aqueduct consisted of a subterranean pipe which ran in an open conduit to the place now occupied by the Yad Nathan School, and from there to the city in earthenware pipes covered with gravel. From maps published in l'Expedition d'Egypte, we also know that the original aqueduct entered the town by way of the palace after having run along the counterscarp of the moat.[8]

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[4] Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 252.
[5] Doubdan, J., Le Voyage de La Terre-Sainte. Paris: 1657. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 252.
[6] Rubin, M., The walls of Acre : intergroup relations and urban development in Israel (New York: Holt, Rinehart and Winston, 1974) 10.
[7] Paris Archives, AH E.T.B. 1 9727, pp. 122-123. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 230.
[8] Jonquière, C. de la, L'epedition d'Egypte 1798-1801. Paris: 1904. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 147.

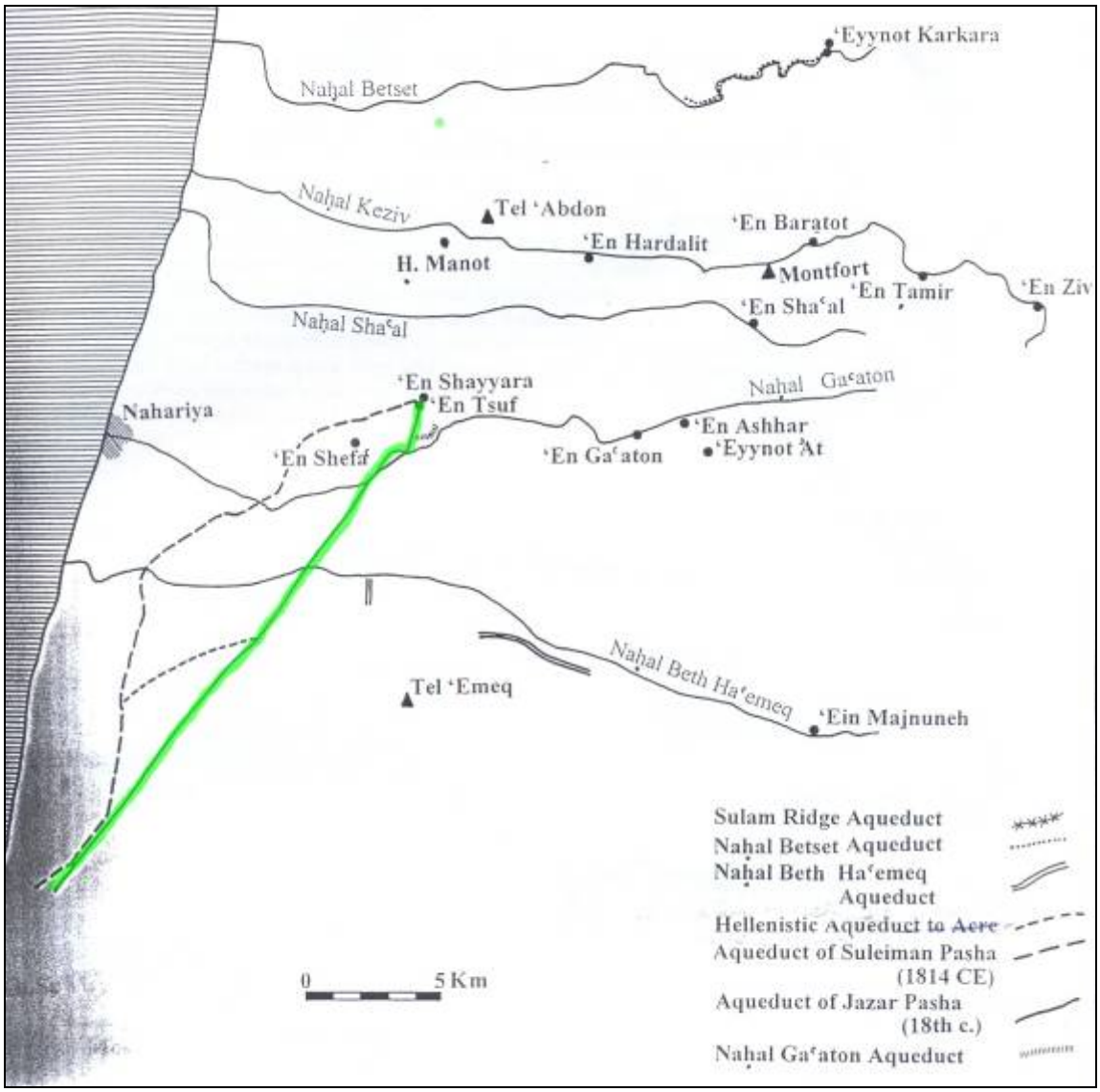


Fig. 4. Route of Al-Jazzar's aqueduct. Amit, D., Patrich, J., Hirschfield, Y., "The Aqueducts of Israel." Journal of Roman Archaeology Supplementary Series No. 46 (2002) 450.

In 1812 Suleiman Pasha initiated a reconstruction of the aqueduct on an even grander scale at the sum of 3600 ottoman kis.[9] British geographer J.D. Buckingham was so impressed with the project when he visited in 1816 that he compared it to the aqueduct supplying Cairo's citadel.[10] What remains of the water system in Akko today dates from this period.

[9] al-Aura, Ibrahim, The History o the Reign of Sulayman Pasha the Rightful. Sidon: 1936. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 258-9.

[10] Buckingham, J.S., Travels in Palestine. London: 1821. Referenced in Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000).

The aqueduct took a new course, west of where it had been previously, in order to facilitate the irrigation of the Pasha's fields between Umm el Faraj and El Bahja to the north.[11]

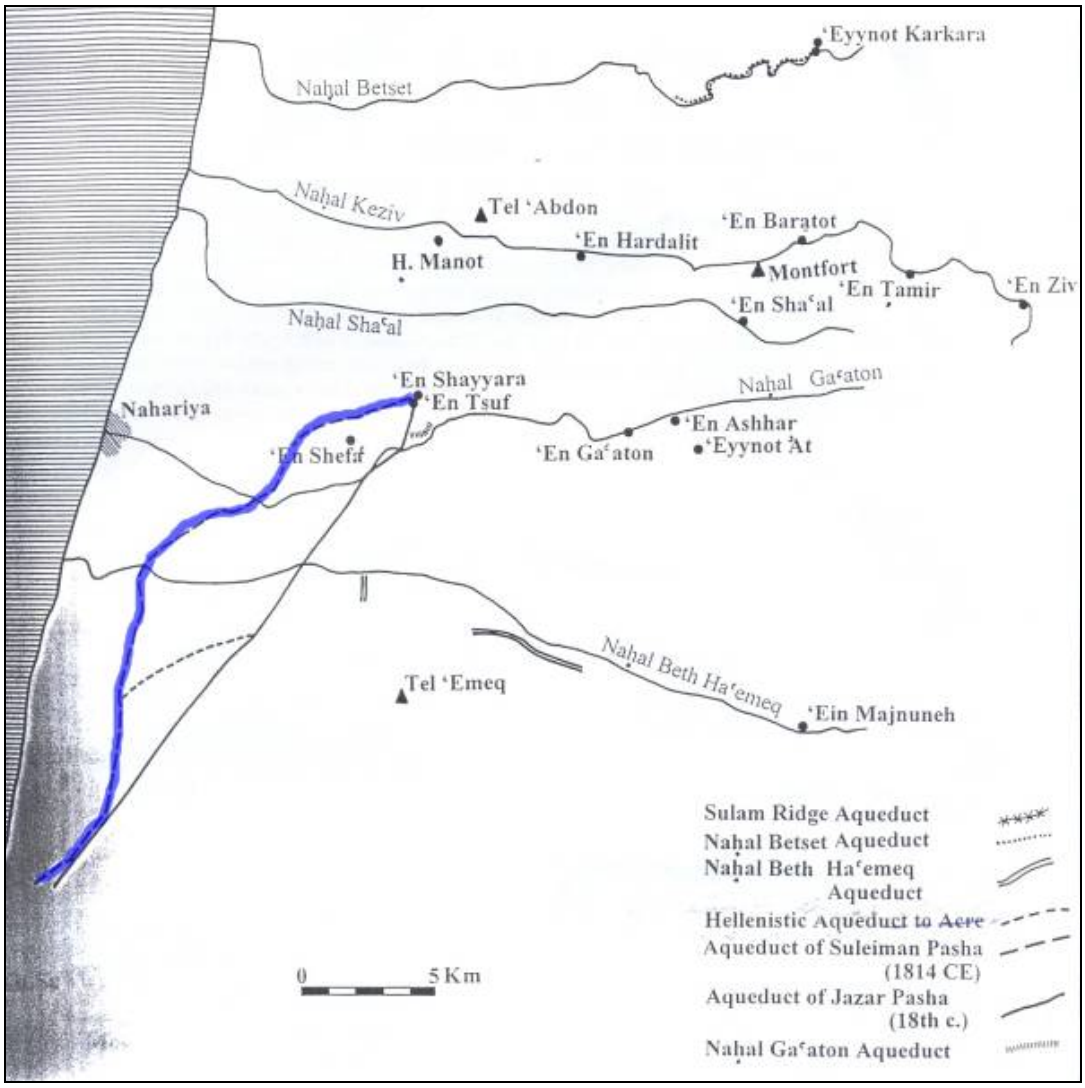


Fig. 5 Route of Suleiman Pasha's aqueduct. Amit, D., Patrich, J., Hirschfield, Y., "The Aqueducts of Israel." Journal of Roman Archaeology Supplementary Series No. 46 (2002) 450.

Tall arches were constructed to support the conduit where the valley bisected the aqueducts route. Harnessing the law of hydraulic levels, a series of four high water towers functioned as inverted siphons to usher the water through underground pipes to the entrance of the town. Jazzar's route was used only for this last section of the new aqueduct.[12]

[11] Makhouly, N., Acre – The Aqueduct: verbal report. 1940.
[12] Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 230.

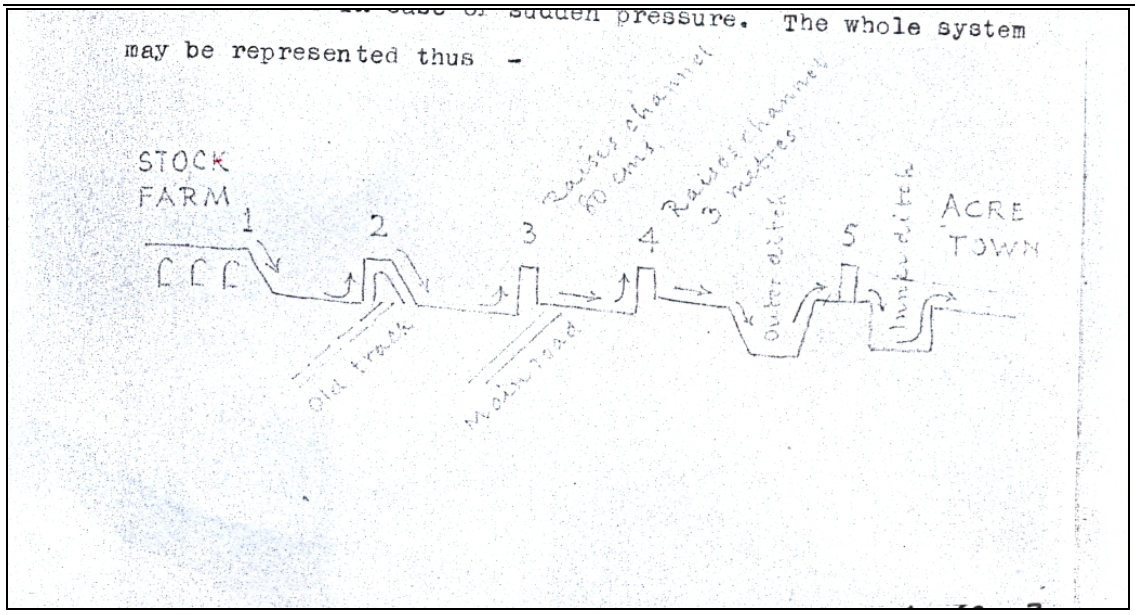


Fig. 6. Water towers . Photo source: Makhouly, "Aqueduct", Akko 1949.

The aqueduct entered the city through a water tower[13] ('Water Tower 1' [see fig. 9]) built into the new outer wall of the city. From there it traveled via a subterranean stone pipe to the final tower ('Water Tower 2'), integrated into the Daher el-Omar wall. The water then traveled over an open aqueduct to the distribution basin ('Basin 2') located near the entrance of the White Market. In addition to supplying the pipes that distributed the water to the various fountains, baths, mosques, etc. throughout the city, water was accessible to the public on tap from a *sibil*[14] located on the other side of the basin.

Today the water system includes a second basin ('Basin 1') located in the area that was previously the location of the royal orchards and stables. The absence of the basin in historical maps dating from the 1840's (see figs. 7 and 8), as well as the fact that it was supplied by subterranean pipes (as opposed to being served by the aqueduct, as with Basin 1), suggest that Basin 2 was a later addition to the water distribution system.

The earliest record of Basin 2 is a map dating from 1923. Given that the British Mandate took effect in 1919 it is possible that the basin was constructed during the first four years of British rule; however, it is more likely that it was constructed by a Pasha in the final years of the Ottoman Empire for irrigation purposes. If this is the case, then it needs to be reconsidered how the Mosque of al-Jazzar and his personal hammam were supplied with water prior to the construction of Basin 1, which until now was assumed to be an intermediary collection point and distribution chamber for water before it reached the two structures.

[13] The terms 'water tower' and 'water balance' are sometimes used interchangeably in literature on the subject to mean a tall structure functioning as an inverted siphon. To avoid confusion all such structures will be referred to as 'towers' in this report.
[14] For an explanation of italicized vocabulary, see the glossary in Appendix A.

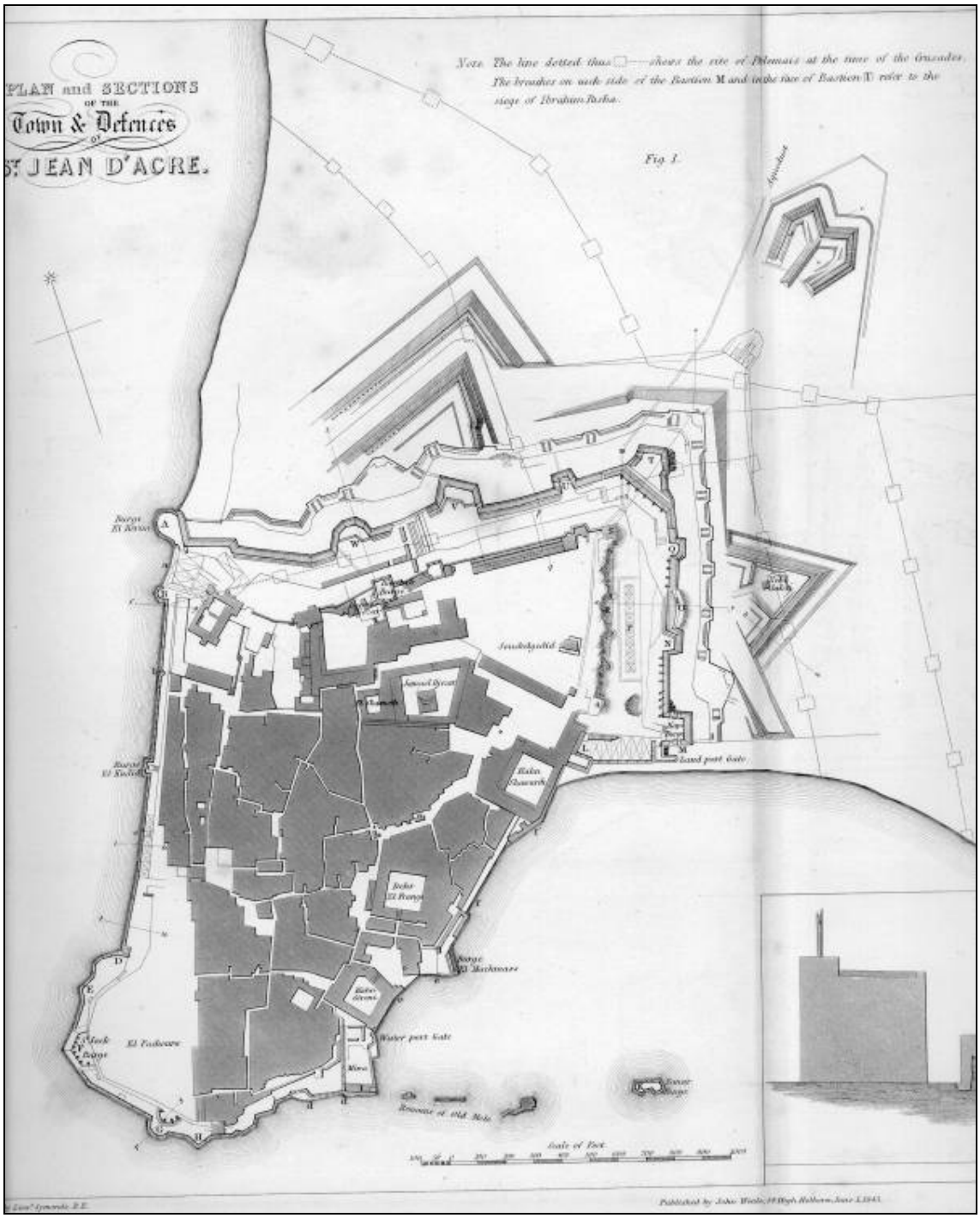


Fig. 7. Map of Akko showing water infrastructure. Note the absence of Basin 1. Alderson, Lieut. Col. R. C., <u>Notes on Acre and some of the Coastal Defense of Syria</u>. 1841.

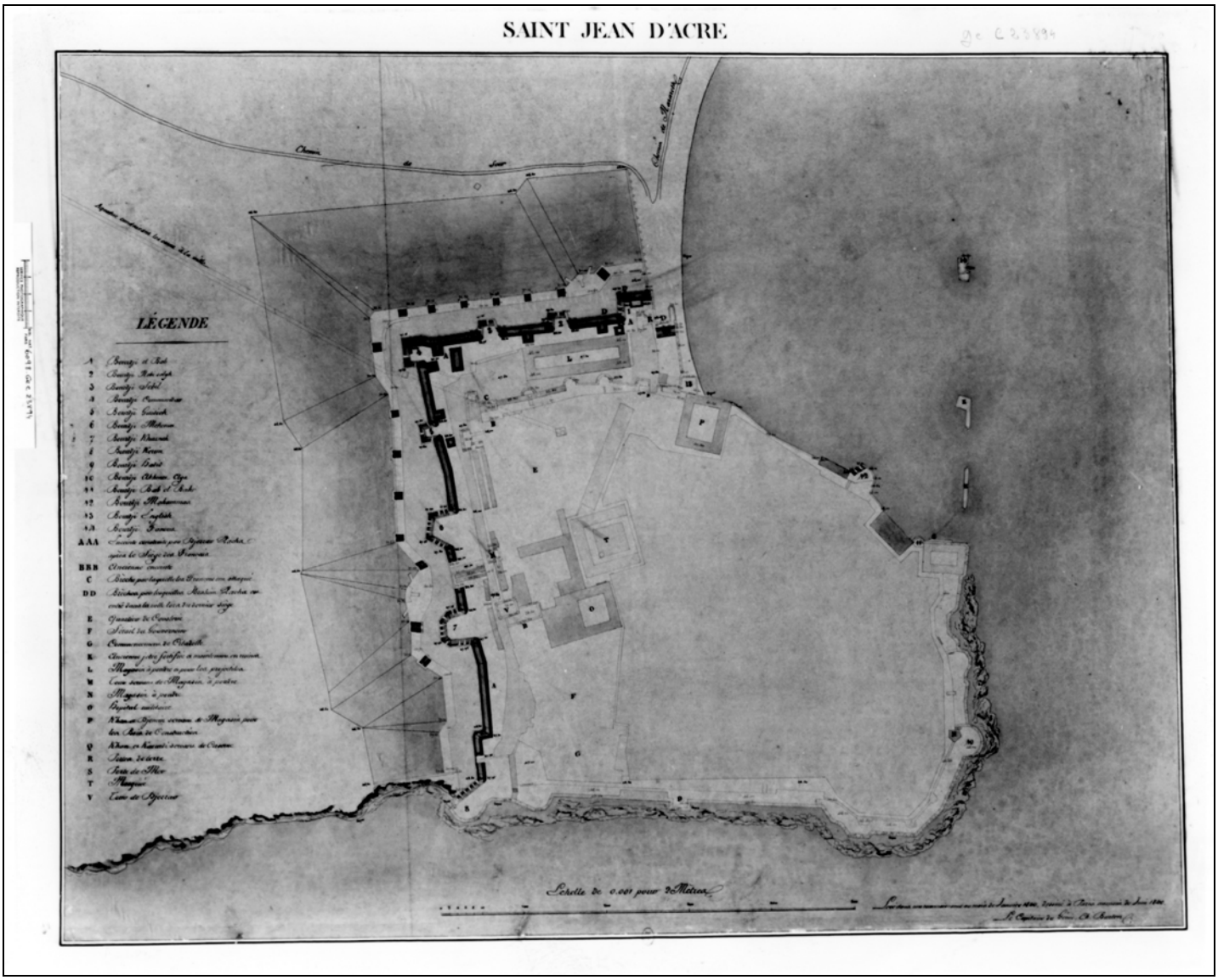


Fig. 8. Map of Akko showing water infrastructure. Note the absence of Basin 1. Burton, 1840.

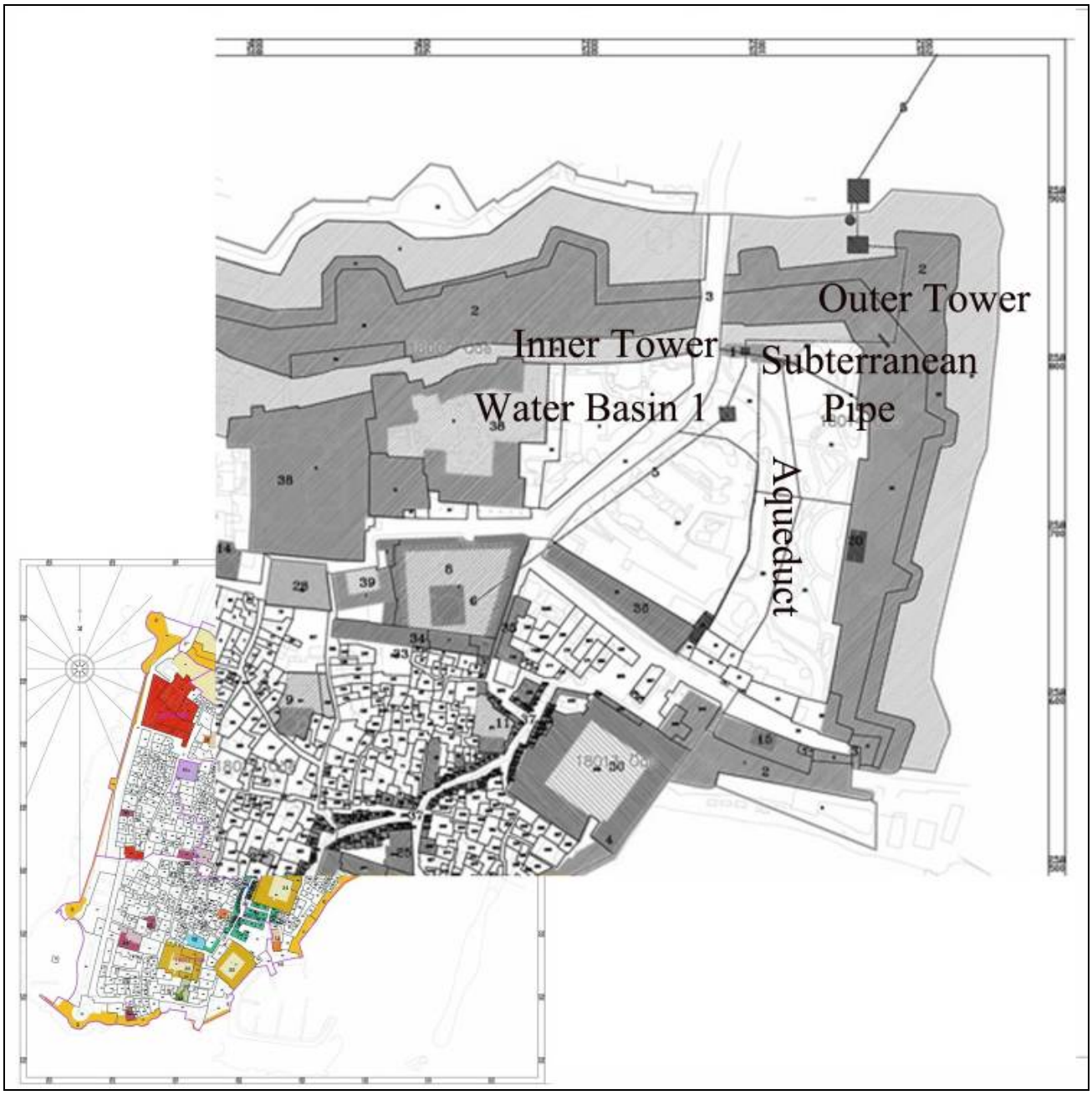
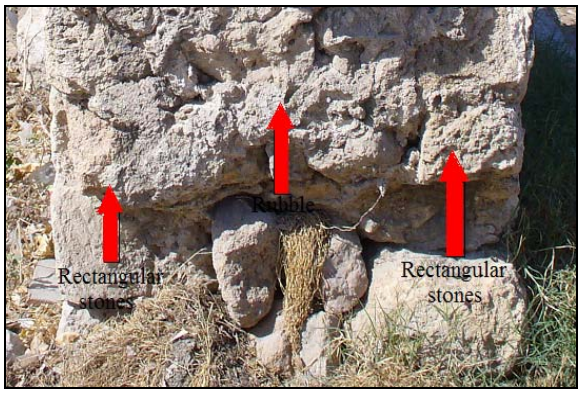


Fig. 9. Map of old Akko; NE corner magnified to show the path of water conveyance system within the city.

Hydraulic structures of the Ottoman period were built using a conventional set of materials. The exterior of the walls of standing structures was first laid out with heavy rectangular stones then filled with rubble; this was set using a mixture of lime (marble burnt at high temperature), sand, clay powder, and water. A topcoat of hydraulic mortar infused with olive oil and eggs served to insulate the structure.



Figs. 10 & 11. Rubble between columns of rectangular exterior stones and layers of rubble and mortar.

The pipes serving such structures outside the city were typically cut in rectangular stone blocks, while those inside the city were cast of clay. Both had interlocking ends and an inner diameter measuring roughly 20cm. Ottoman engineering used a standard measurement for pipe construction to regulate the output of water (see Appendix B), but the remnants of pipes in Akko considerably exceed this size.

Figs. 12 & 13. Segments of stone pipe from the front and side.

Figs. 14 &15. Segments of clay pipe from the side and front.

Having passed through the final distribution basin, the water then traveled in underground clay pipes laid out in tight loops throughout the city. Public fountains, which were available on tap to the city's residents, proliferated above the routes of the pipes.

Water served a religious, as well as a domestic function in Old Akko. Ablutions being a necessary component of muslin prayer, a significant amount of water was needed to supply the city's numerous mosques. This is especially relevant in the case of Ottoman populations, who as Hanafi Muslims were required to make their ablutions in running water,[15] and may also account for the need for an aqueduct supplying the city.

The *hammam*, likewise, occupied a major role in the cultural practices of the Ottomans and Arabs, alike. Akko gained its first bathhouse, which was constructed as part of the al-Raml mosque (one of Akko's earliest) in 1704-5.[16] For the public, it functioned not only as a cleansing ritual, but also as a venue for social gathering. A separate *hammam*, Hammam al-Pasha, served the pasha, his family, harem and guests exclusively. In the Akko of today, it has been converted into a tourist museum, and its luxurious interior reveals a structure that attests to the grandeur of a ruler who could afford to be liberal with water in a land where resources were scarce.

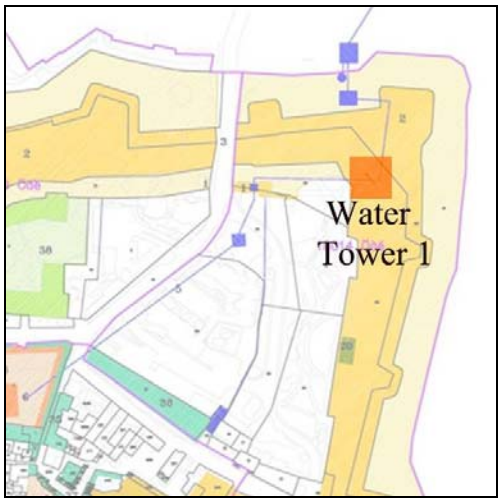
The aqueduct continued to serve the public until 1948, when it was retired in favor of a modern water system. The long stretch of arches that constitute the bulk of the structure have recently undergone a major conservation effort and are a picturesque addition to the countryside of northern Israel. The structures within the city, however, are suffering rapid deterioration.

The following section attempts an introductory survey of the elements of the Ottoman water distribution system located in the NE corner of the city that connected the aqueduct to Old Akko. In some cases it was difficult or nearly impossible to obtain complete and accurate statistics due to environmental circumstances such as construction, accumulation of debris, or simply advanced structural decay. A much more comprehensive survey and salvage operation would be needed to fully document and restore these structures. If undertaken, their preservation would undoubtedly add an interesting element to the physical and cultural landscape of the city.

[15] Rogers, J.M., Sinan. London: I.B. Tauris and Oxford University Press. 2006, 17.
[16] Dichter, B., Akko: Sites from the Turkish Period, ed. Carmel, A. and Baumwoll, Z. (Haifa: Gottlieb Schumacher Institute, 2000) 186.

DOCUMENTATION OF STRUCTURES

Water Tower 1, Outer Wall



Location: Northeastern corner of outer wall.

Fig. 16. Location of Tower 1 as seen from main entrance to the old city in between inner and outer wall.

Function: Maintained water level and pressure between the aqueduct and city.

Fig. 17. West elevation

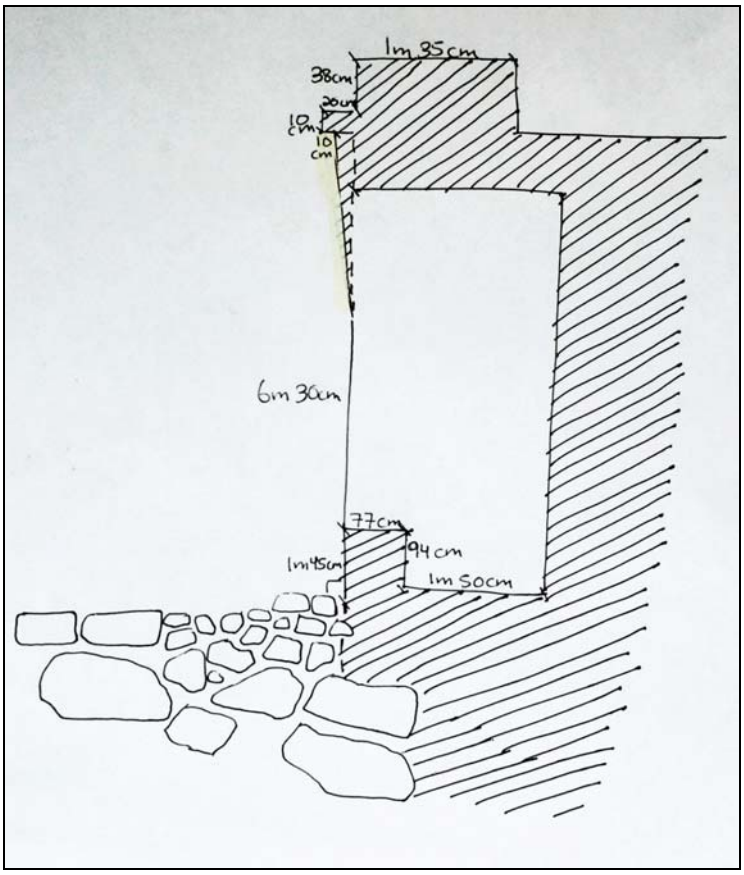


Fig. 18. Cross section.

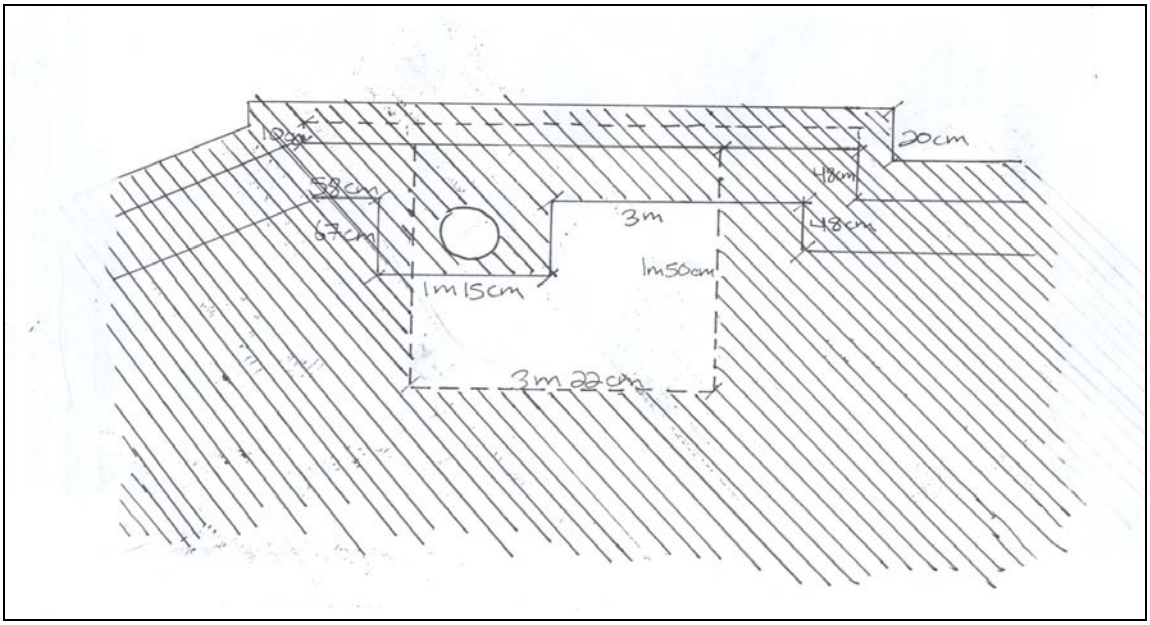
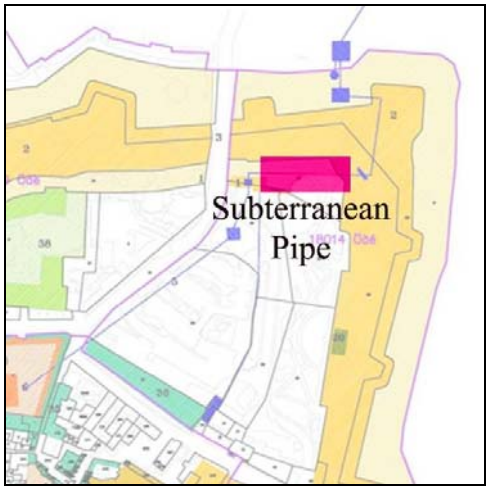


Fig. 19. Plan.

Description: The interior of the wall features a grand hollow arch. The arch sheltered a tub below that could have accommodated a volume of 4.5402cm cubed. Water entered the tub from the SE corner through a standard clay pipe. A hole in the top of the arch (see fig. 20) made the water in the tub accessible to the soldiers who occupied posts atop the wall.

Fig. 20. Hole in arch through which the water in the tub below could be tapped.

Subterranean Pipe



Location: Between outer wall and wall of Daher el-Omar (inner wall).

Figs. 21 & 22. Stretch of pipe as seen from Tower 2 and Tower 1.

Function: Conveyed water under the moat between the two towers.

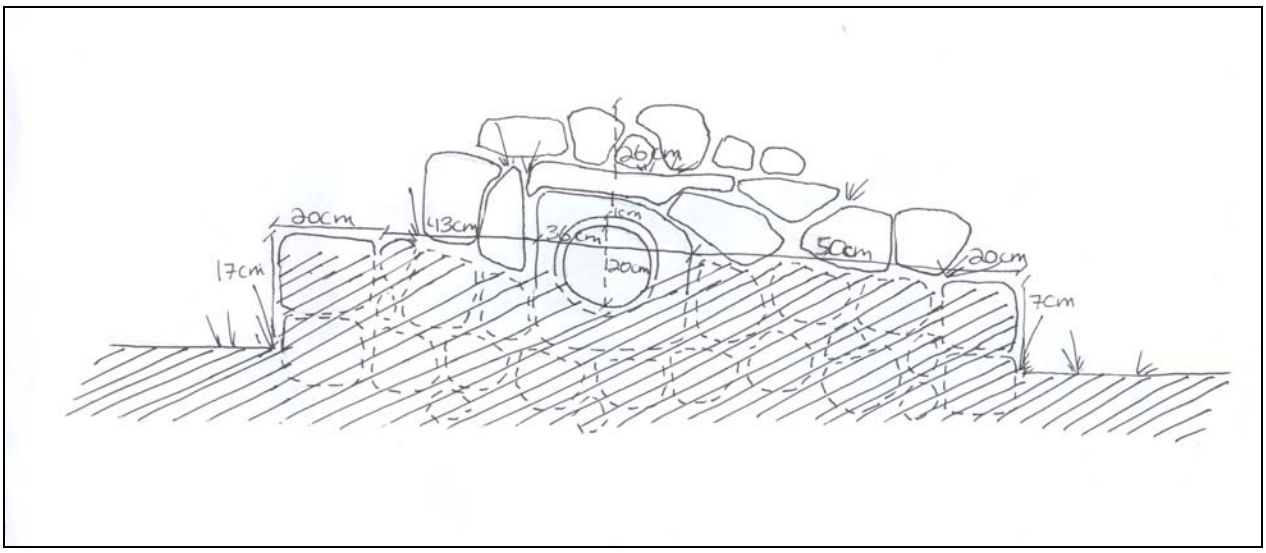


Fig. 23. Front elevation.

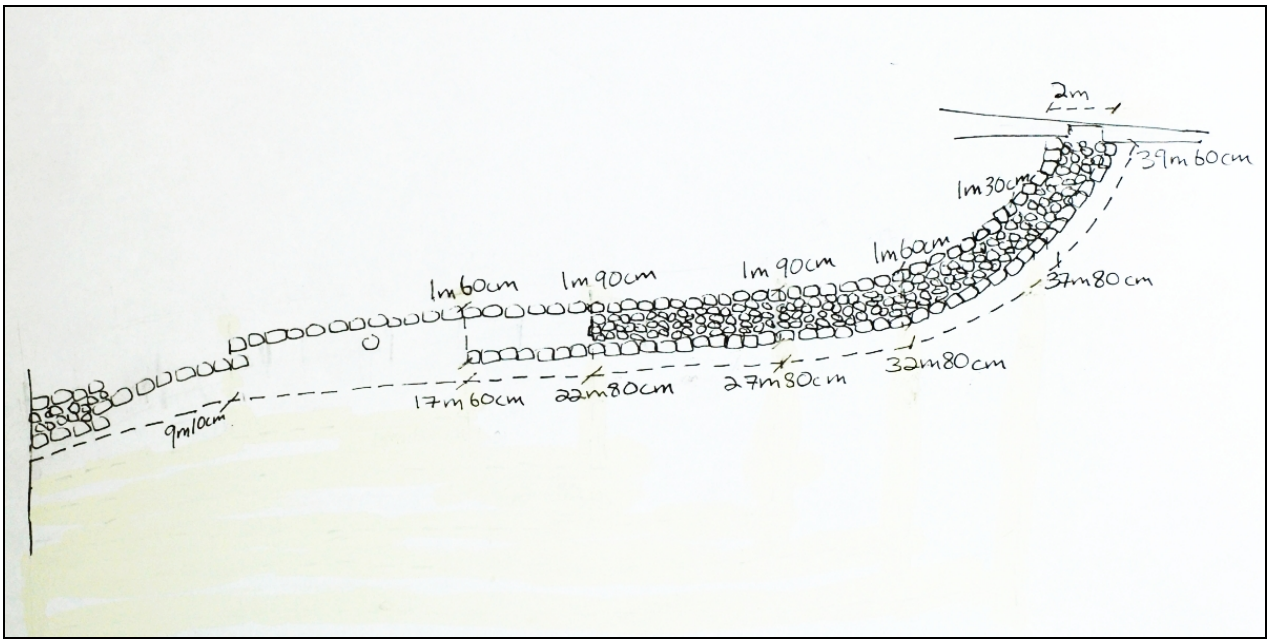
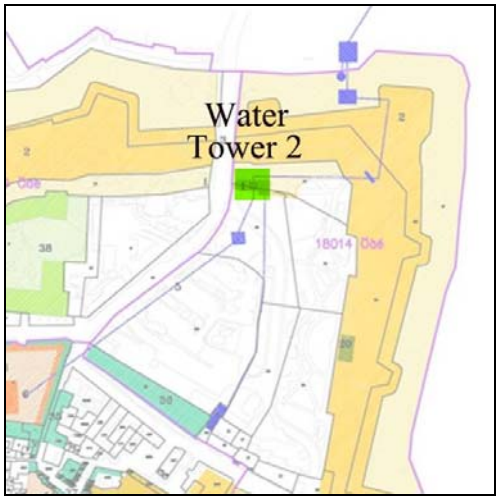


Fig. 24. Plan.

Description: A stone pipe covered by a thick encasement of rubble carried the water to the last tower, built into the wall of Daher el-Omar. A significant portion of the pipe and the surrounding rubble is now exposed; at the time of usage it was probably located10-15cm below ground.[17]

[17] Stern., E. Private interview. Israel Antiquities Authority, Akko. July 2009.

Water Tower 2, Wall of Daher el-Omar



Location: Northeastern corner of the wall of Daher el-Omar

Fig. 25. Tower 2 as seen from inside the inner moat.

Function: Maintained water elevation and pressure as it entered the city.

Fig. 26. North elevation.

Fig. 27. South elevation.

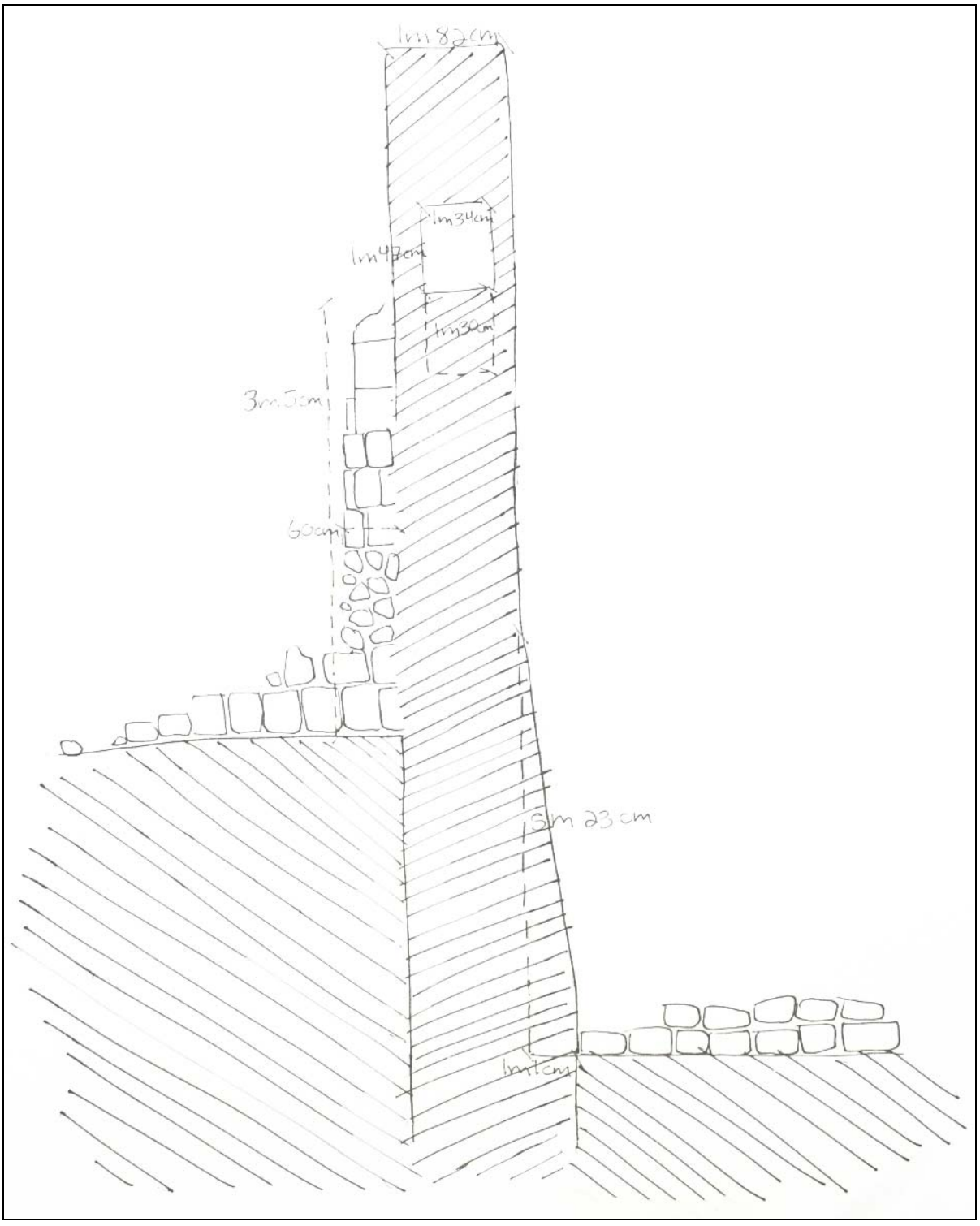


Fig. 28. Cross section.

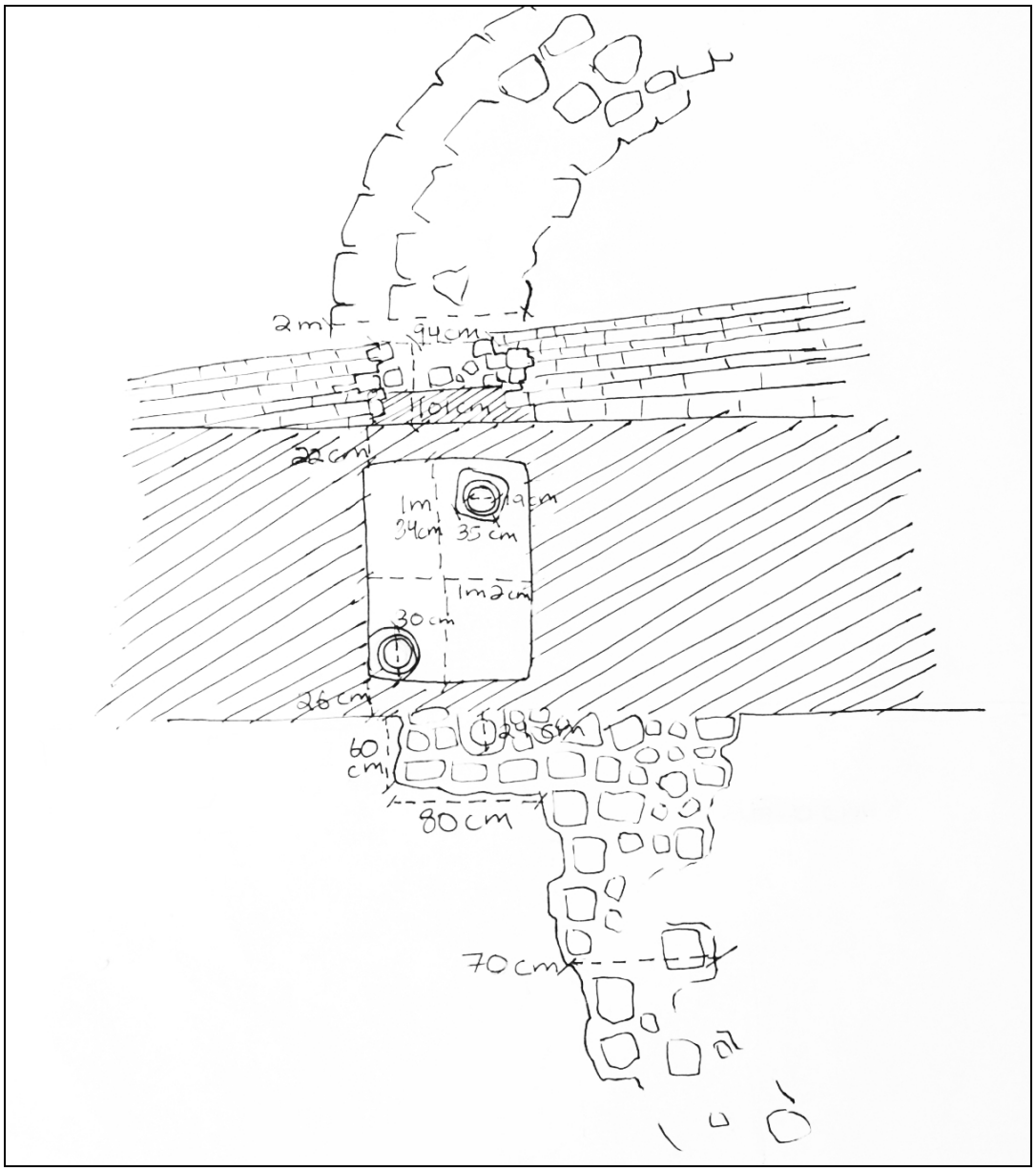


Fig. 29. Plan.

Description: The subterranean pipe led to a final water tower built into the inner wall of the city fortifications. The water rose via a stone pipe to the height of the tower and passed through a tub with a potential volume of 1.77684cm cubed before descending by one of two vertical pipes into the city. The first pipe, which led to the aqueduct, was built as an attachment onto the wall and is surrounded by a rectangular encasement of stone. Another pipe located inside the tub on side closest to the town, presumably led to the underground conduits that fed Basin 1. The remnants of the two pipes inside the basin of the tower (see figs. 29 & 30) illustrate the transition between the different materials used without and within the city.

Figs. 30 & 31. Stone pipe through which water entered the basin of the tower and clay pipe through which it exited.

Water Basin 1

Location: Pasha's orchards and stud farm.

Fig. 32. Basin seen from entrance to the old city with Mosque of al-Jazzar in background

Function: Primarily to irrigate the pasha's fields and assure a regular flow of water to the Mosque and *hammam*. Additionally, it functioned as a settling tank before conveying the water to the city for human use.

Fig. 33. North elevation.

Fig. 34. East elevation. As with South elevation it was not possible to obtain measurements at the time of research due the use of the surrounding area as a depository for debris.

Fig. 35. West elevation.

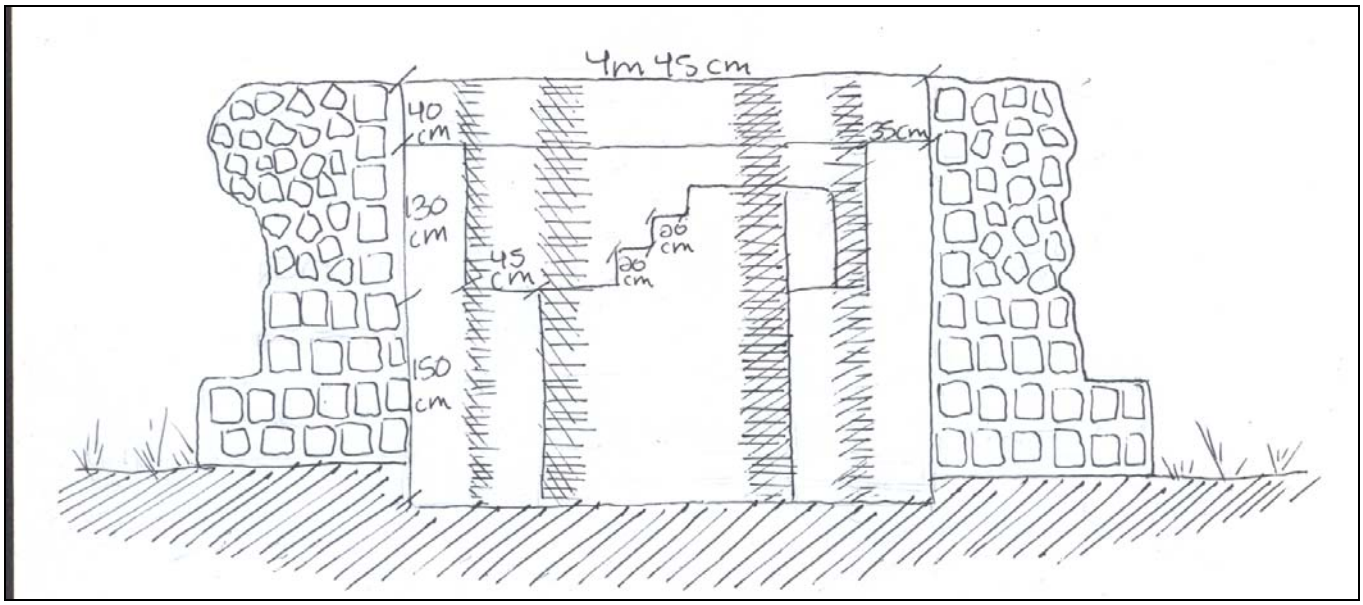


Fig. 36. Cross section.

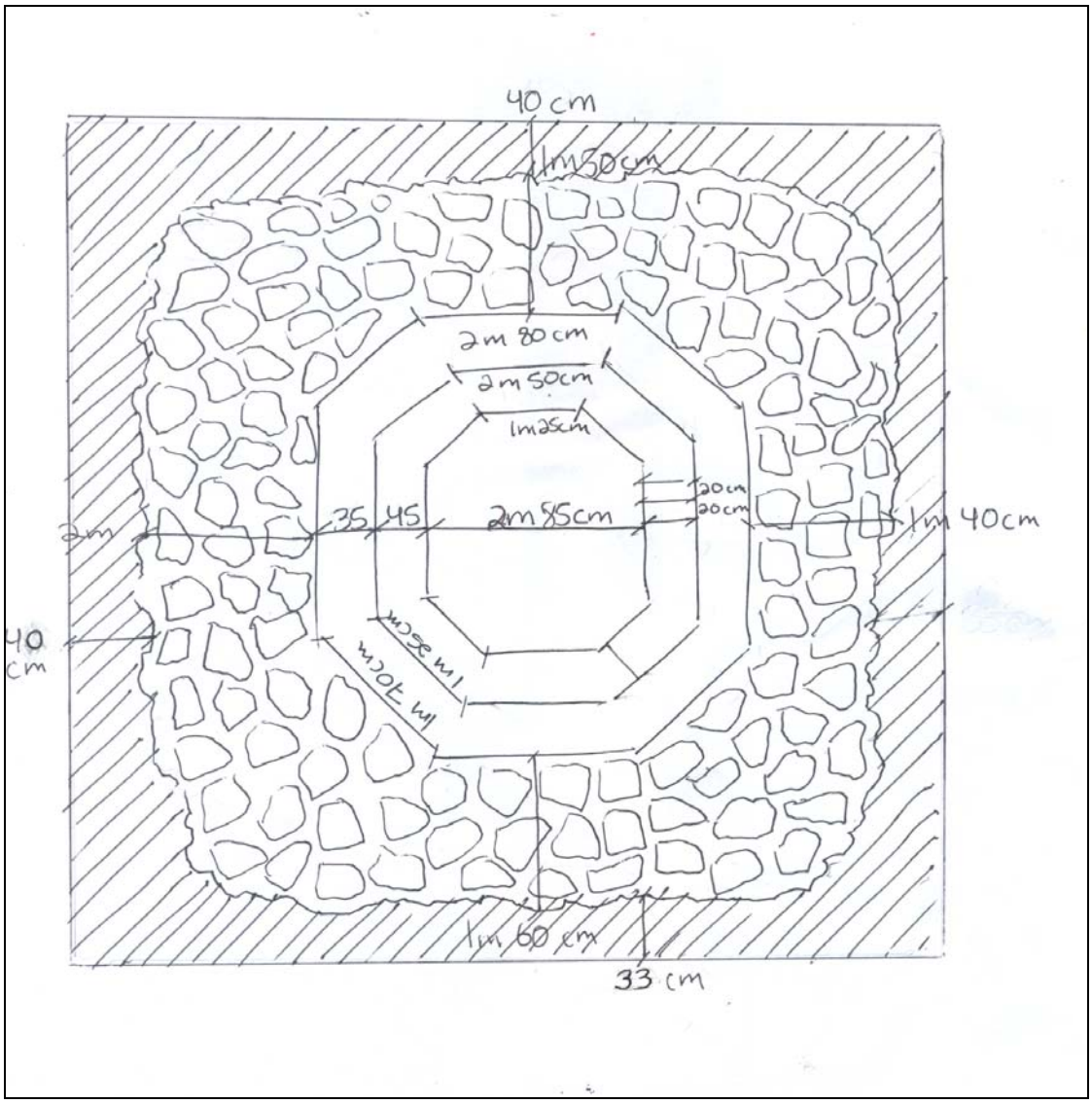


Fig. 37. Plan.

Description: The inside of the basin is of octagonal shape and terraced into three layers. The bottom section (the largest) is accessible by three small steps that presumably ended right above the water level.

The basin is encased within a larger square stone exterior, which has been gradually eroded and lost several stones to theft. From the northern side it is possible to see how the encasement was constructed in two layers: a foundation made of two rows of large, rectangular cut stones located below a mass of irregular rubble stones. Between the two layers there appears to be a thin sheet of clay pipe shards encased in hydraulic mortar, which served as insulation (see fig. 38).

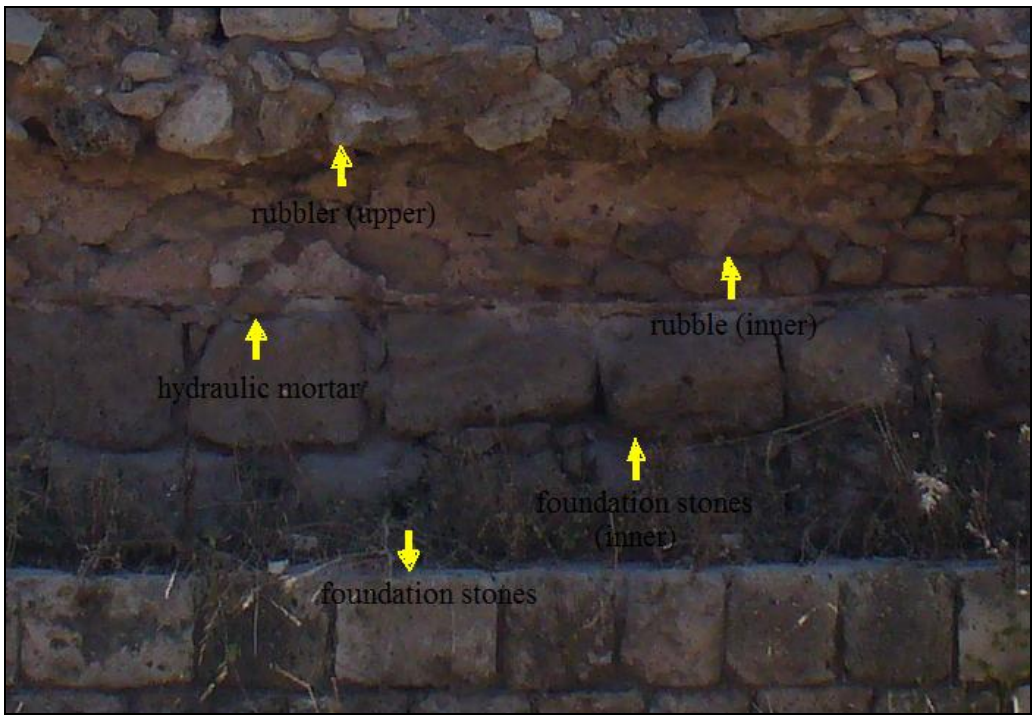


Fig. 38. Detail of construction materials.

Roughly in the center of the eastern side a large brick bears two holes, one of 3 centimeters in diameter located above another of 6 centimeters in diameter; these most likely fed water to the irrigation ditches of the fields at a slow and regular measure and could have been stopped up with a cork when needed.[18]

Fig. 39. Detail of hole on Eastern side.

[18] Stern., E. Private interview. Israel Antiquities Authority, Akko. July 2009.

Fig. 40. Basin at the site of Sataf, near Jerusalem, used for irrigation.

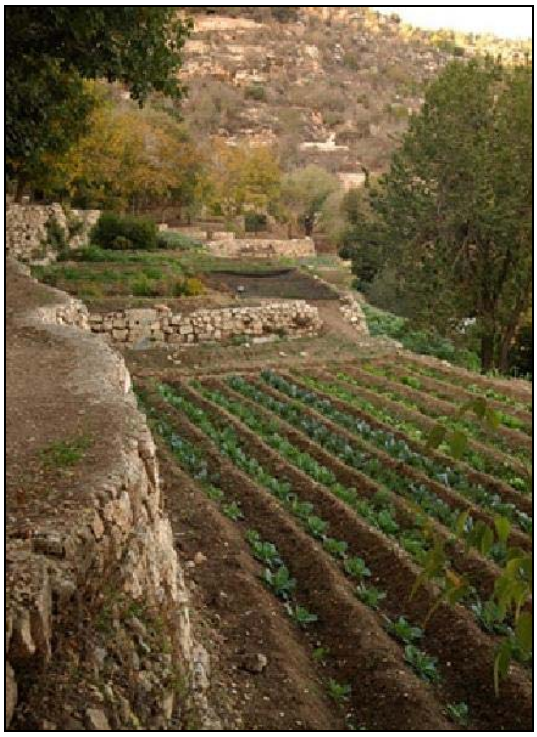
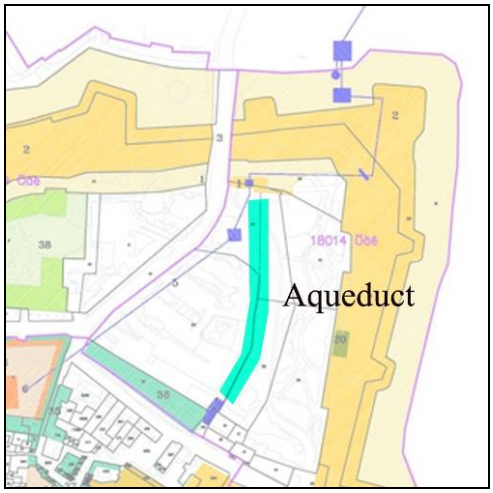


Fig. 41. Irrigation ditches in Sataf, of the type used in Akko.

In the mid to late 20th century the inside of the basin was plastered leaving no indication where the pipes serving the city entered or exited. The southern side, however, shows evidence in the form of a vertical circular indentation of a pipe that was located within the stone encasement of the basin (it was not possible to visually document this at the time of writing due to the use of the use of the southern wall of the site being used as a rubbish heap).

Aqueduct, inside city



Location: Ran in a perpendicular line to the North of the White Market.

Fig. 42. Fragments of aqueduct inside city with mosque of al-Jazzar in the background.

Function: Maintained water elevation and pressure and transported it to the final collection point.

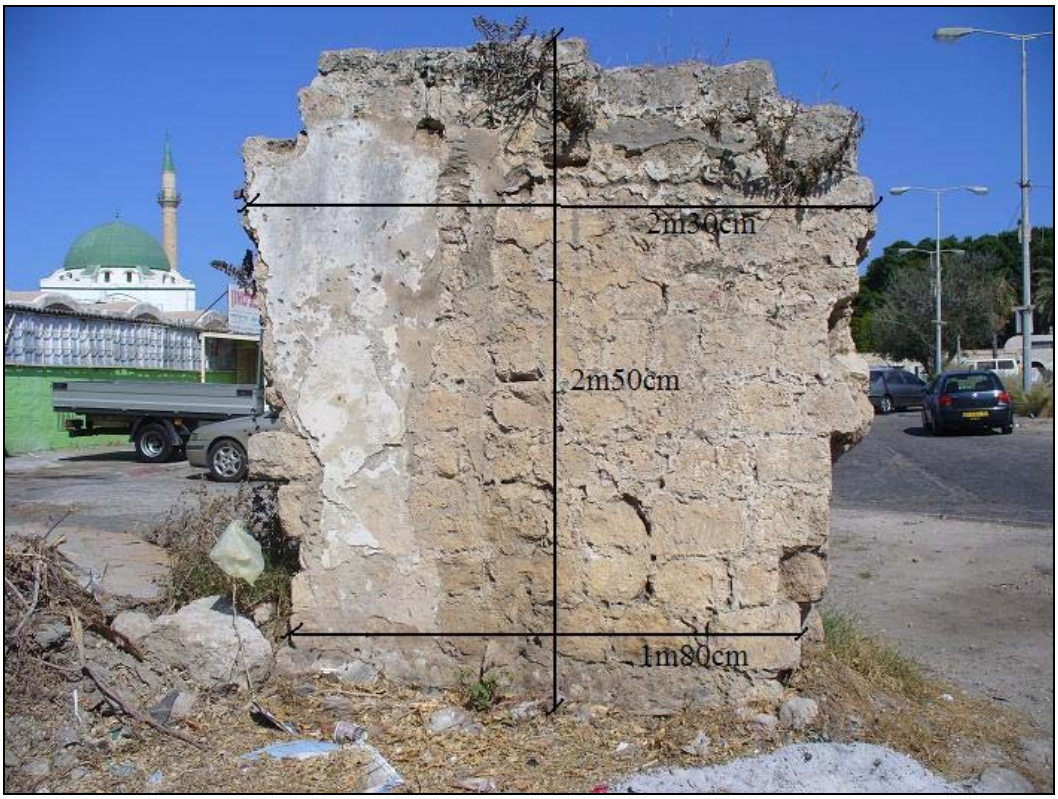


Fig. 43. Fragment 1, East elevation.

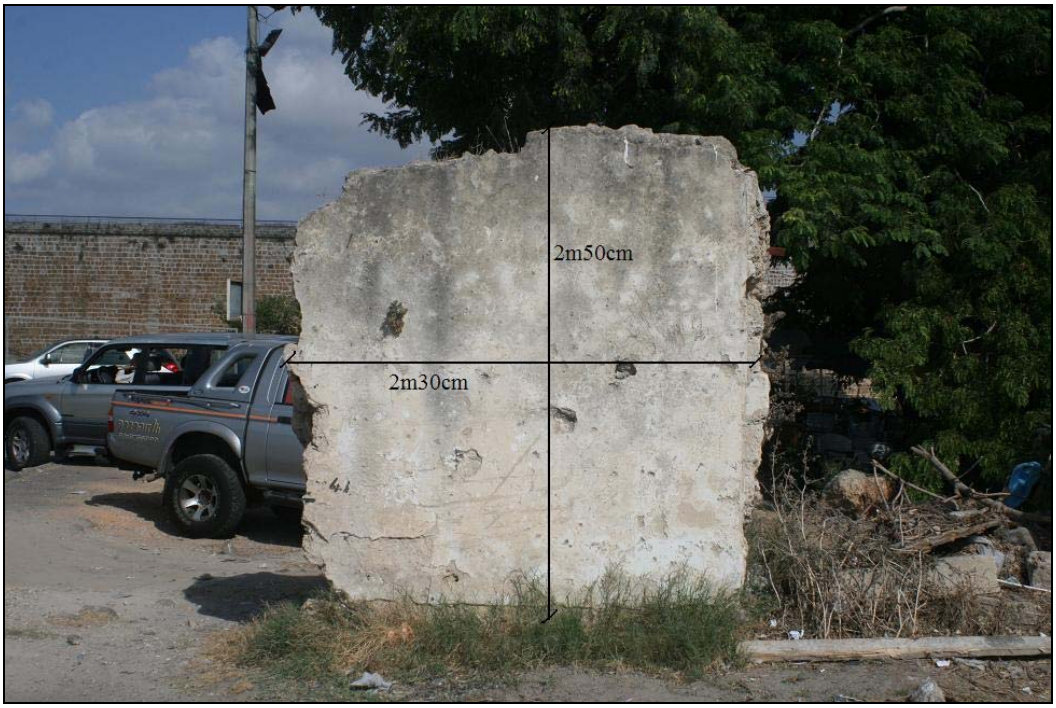


Fig. 44. Fragment 1, West elevation.

Fig. 45. Fragment 1, North elevation.

Fig. 46. Fragment 2, East elevation.

Fig. 47. Fragment 2, South elevation.

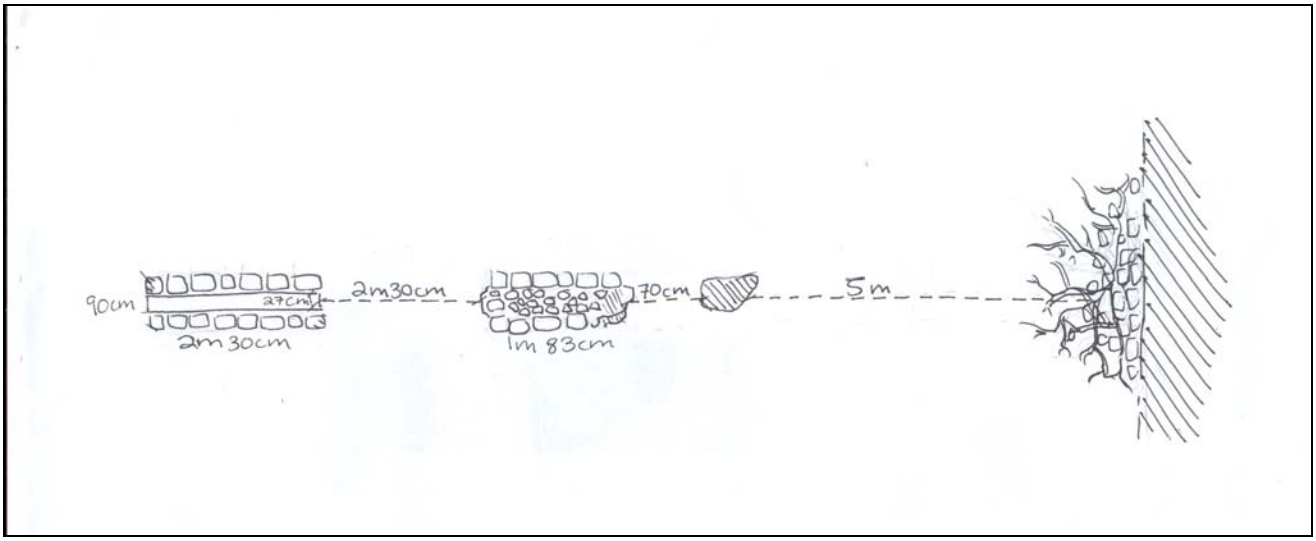
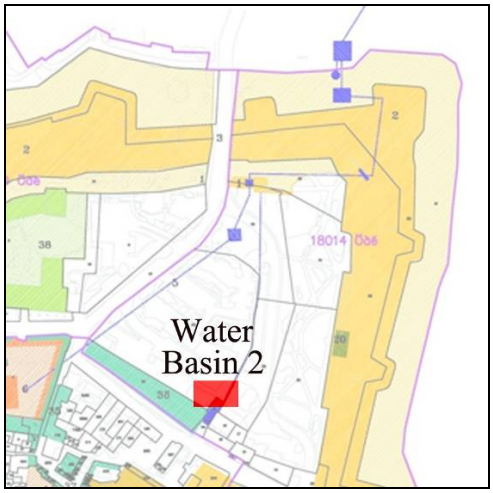


Fig. 48. Plan.

Basin 2



Location: At the entrance of the White Market at the SE end, close to what was previously the sole land gate to the city.

Fig. 49. Remnants of basin, obscured by fig tree.

Function: Acted as a collection and settling tank from where the water would be channeled to various points around the city. It also directly fed the *sibil* on the other side of the wall.

Description: The structure is in an advanced state of ruin making it difficult to accurately document its features. Traces of the clay pipes that fed the basin still cling to the sides in some areas. Entire segments of pipe are still present in what has become a trash deposit at the foot of the structure.

According to archaeological conjecture, the basin would have sat upon a platform even with the height of the last segment of aqueduct. It was most likely covered.[19]

Fig. 50. Distribution tank (*maksem*) in Istanbul, Turkey.

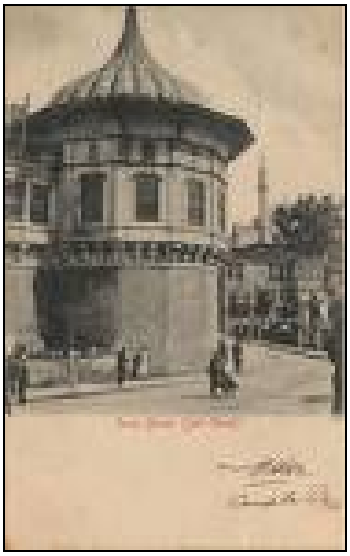


Fig. 51. Historic drawing of a *maksem*.

[19] Stern., E. Private interview. Israel Antiquities Authority, Akko. July 2009.

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APPENDIX A:

Glossary

The following is a summary guide to Ottoman Turkish hydraulic terminology used in the report, as well as several terms not referred to, but related to the work.

Cökertme (lit. 'precipitation tank') A series of connected tanks where the water rested so that any gravel or sand was precipitated before being piped to the *maksem* and distributed to the various city mains.

Hassa State supplied water.

Havuz Mainly circular basins ranging in diameter from 2 to 30 metres and 2 to 20 metres in depth, which served as intermediary collection points for the water. Some had two sections, and some two levels.

Lökün Plaster with which the joins of water pipes were coated to prevent leakage was made by mixing lime with olive oil.

Lüle (lit. 'pipe) The most common standard of pipr in Ottoman water measurement. The inside diameter of the *lüle* pipe was defined as that through which a lead sphere weighing 30 dirhem (approximately 96.5 g) would pass, i.e. 73.58 mm. The term *lüle* was also used in a general sense to refer to such water measuring spouts.[20]

Maksem Domed or vaulted buildings containing large water tanks with spillways and distribution chambers divided into compartments and fed by nozzles called *lüle*. Some of these *maksem* were above ground, such as those in Taksim, Eyüp, and Harbiye, while others were below ground, like the Hacı Osman Bayırı maksem.

Maslaks (lit. 'water tank') Placed at points where the main supply line branched. They consisted of a tank with a discharge measuring system consisting of numerous spouts for adjusting and determining the quantity of water which flowed in each direction. The presence of a discharge measuring tank has led some sources to confuse these with *maksem*. They were always located outside the city.

Miri See *Hassa*.

Mülk Private water sources allocated to individuals by the sultan (in deeds known as *Temlikname*).

Sibil Fountain for dispensing water on tap.

[20] Other standards included the *kamış, masura, çuvaldız and hilal*. See Appendix B for measurements.

Sukemeri (lit. ‘aqueduct’)

Suterazi /Su terazisi/Su teraziyleri (lit. ‘water tower", ‘water scale’) Inverted siphons used to maintain water pressure as it descended the aqueduct towards its destination.

Taksim See *Maksem.*

Tersip See *Cökertme*.

Vakıf Water sources in the form of pious endowments for the public benefit.

APPENDIX B:

Ottoman Water System

Distribution chambers known as *maksem* served as central reservoirs where water from the aqueduct would be channeled to various destinations in the city via pipes set 96mm beneath the surface of the water in a long rectangular sluice. The amount of water released to each location could be regulated according to the diameter of its respective pipe. The most common measurement was the *lule*, which measured 73.58 mm, the space through which a lead sphere weighing 30 dirhem (approximately 96.5 g) would pass.[21] One *lüle* equaled 4 *kamış*, the equivalent of 8 *masura* or 32 *çuvaldız* or 64 *hilal*. [22]

[21] "Fountains in Ottoman Istanbul." Kultur.gov.tr. <http://www.kultur.gov.tr/EN/BelgeGoster.aspx?17A16AE30572D3137EE1F1486EE5030E1A46C5FBFA979D0C

[22] "The Thermal Springs at Çekirge." Kultur.gov.tr. <http://www.kultur.gov.tr/EN/BelgeGoster.aspx?17A16AE30572D313A79D6F5E6C1B43FF44378E39D910E761>

The Water Distribution System of Ottoman Acre

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Akko, Israel 2009