JARASH WATER PROJECT: REPORT ON 2013 FIELD SEASON

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Abstract

Despite the frequent references to water installations in publications describing the results of excavations within the Decapolis city of Gerasa (modern Jarash), very little has been published on the sources and water management system that sustained them. The purpose of the Jarash Water Project is to fill this knowledge gap through the analysis of historical records, photographs and archaeological reports and by conducting new field surveys. The 2013 field program included a pedestrian survey of selected areas in the valley and hills to the north, south and west of the city to locate and trace the historic aqueducts to the city and its hinterland, and a preliminary survey of selected areas within the upper Wādī al Majar-Wādī Tannur valley to gain an understanding of water management in the rural context. A total of 36 elements were recorded at 35 sites during the survey.

A potentially significant aqueduct has been confirmed approaching the city down a steep gradient from the north-west, and there is evidence from carbonate sediment deposits within this aqueduct of its use over a period of about 100 years. This aqueduct would have entered the city close to the North-West Gate. It is not known what this water was used for, or the period it was in use, but the high elevation of its likely entry point into the city (ca 630 m) means that theoretically its water could have been delivered to virtually any point within the city. Earthquake damage at one location points to a possible reason for its ultimate closure. Several aqueducts approach the city from the north on both sides of the Wādī ed Deir valley; aqueducts on the west side are sourced from ‹Ain esh Shawāhid and possibly ʹAin el Birketein, and an aqueduct on the east side sourced from ʹAin Bisās er Rūm may have supplied the eastern side of Gerasa. A masonry aqueduct of likely Roman - Byzantine date that crossed the central part of the valley immediately north of the city may have been sourced from Birketein, however its function and destination remain uncertain. None of the northern aqueducts can be observed to enter the city, however reuse of several of these aqueducts in the late Ottoman period to provide irrigation water for fields in the northern valley and within the city walls points to the possibility of the original aqueducts having the potential to deliver water to the city at a level that could have supplied the major water installations on the west side of the city. There is evidence of rock-cut aqueducts on both sides of the Wādī Jarash south of the city, including a rare section of tunnel that would have provided irrigation water to the rich soils of Wādī Jarash valley south of Jarash; a function that some of them still fulfil today.

While the results to date are sufficient to show that water from Birketein was not the sole source of water supply for the water monuments on the west side of the city, many uncertainties remain. Future work will seek to determine when the main aqueducts to the city were in use and went out of use, their ultimate destinations, the consumption requirements of the main water installation within the city and the importance of irrigation requirements in the overall water management system.

Introduction

Brief History of Gerasa

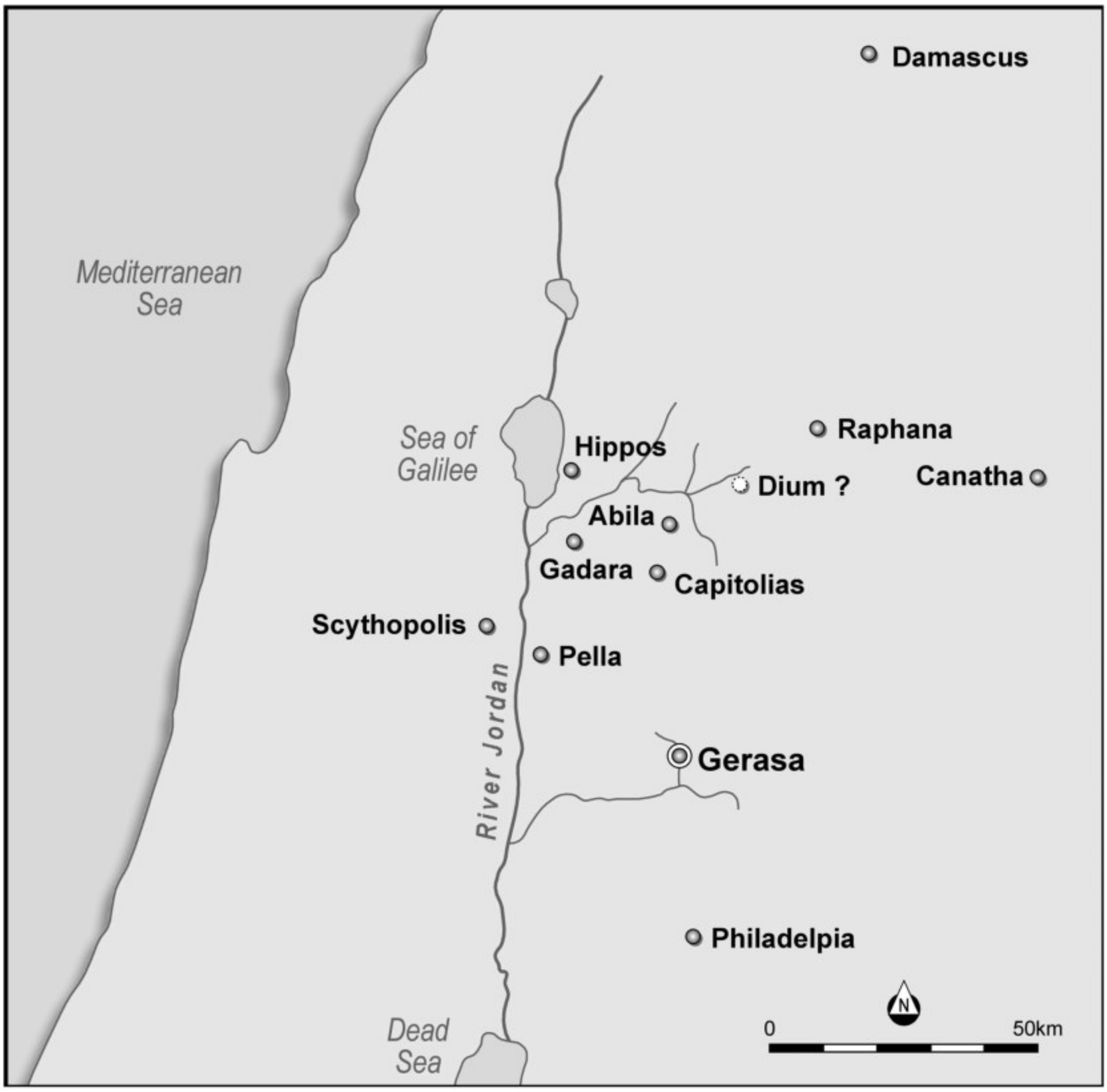
The ancient site of Gerasa lies in a fertile, and at one time, well-watered valley in the eastern ´Ajlūn highlands in north-west Jordan. The valley's natural advantages attracted human occupation from as early as the Lower Palaeolithic (Kirkbride 1958: 9-11). A Middle Pre-Pottery Neolithic settlement was subsequently established at nearby Tell Abu Suwwan (Al-Nahar 2010) and Chalcolithic settlements were established on the hills to the north east of Gerasa (Kirkbride 1958: 15-20), but the earliest evidence of occupation within the city area dates to the Bronze Age (Braemer 1989: 318). There is evidence of Iron Age occupation within the city in the vicinity of the small tell of Camp Hill (= museum hill) (Braemer 1987: 525). A Hellenistic colony and pottery industry were established on the site by the end of the 2nd century BC (Braemer 1989: 318; Kehrberg and Manley 2002: 197) - one of a number of similar colonies in the region that together formed the Decapolis **(Fig. 1)**. As only a relatively small part of Gerasa has been excavated the size of this early colony is uncertain, but the settlement grew rapidly in the early Roman period.

The 1st and 2nd centuries AD were marked by a sustained burst of city planning and public building activity on both sides of the Wādī Jarash, especially on the west side where city gates were established at either end of the main colonnaded street (the Cardo), the temples of Artemis and Zeus were monumentalised, fountains were established along the Cardo, and major water monuments were erected, including the West Baths and the Nymphaeum **(Fig. 2).** The separate parts of the city either side of the wadi were linked by at least two bridges. The extent of building that may have occurred on the east side of the city during this same period is largely unknown, as the Circassian village began to be built over the ruins in 1878 (Schumacher 1902: 115) and expanded before any systematic survey of this side of the city had been carried out. There is, nevertheless evidence for the construction of the East Baths (Lepaon 2008: 60-65), the monumentalisation of the Qairawan spring area (Seigne 2004: 175) and the building of residences for the rich elite[1].

New public monument construction activity had largely ceased by the end of the 2nd century AD, but the construction of occasional small bathing establishments continued. On the west side of the city the Central Baths were built immediately south-west of the South Tetrakionion in the second half of the 4th century (Walmsley *et al*. 2008: 126) followed by the Baths of Placcus in AD 455 (Lepaon 2008: 57-59), and on the east bank the small Byzantine Baths were in use by the mid 4th century AD (Lepaon 2008: 65-67).

Church construction started in earnest in the second half of the 4th century AD with the construction of the Cathedral and continued into the early 7th century AD, having reached a peak in the 6th century AD. Urban life survived the Islamic conquest and continued until the 9th century AD after which it declined. Very little is heard about Gerasa after the 9th century AD. A small fortress was established briefly in the 12thcentury, but in AD 1225 the Arab geographer Yāqūt described it as "a total ruin" (Le Strange 1890: 462). There is evidence of occupation in the late Mamlūk period (14th - 15th century) at several locations within the city (Stewart 1986: 239; Clark 1986: 315), and some sort of settlement probably continued on the site until at least the end of the 16th century, when a settlement of a dozen families is recorded in an Ottoman census (Hütteroth and Abdulfattah 1977: 164). The site had no permanent settlement

1.This is evidenced from the high quality mosaic attributed to the house of a rich Roman resident discovered beneath the house of the Ottoman Mudir by German archaeologists in 1907 (Kraeling 1938: 351-2). Kraeling attributes a 3rd century AD date to the mosaic, as does Piccirillo (1993: 283), however Joyce (1980: 321) argues convincingly for a mid 2nd century AD date. More recently, a late 2nd to early 3rd century AD date has been proposed by Grossmann (2006: 151).



1.The Region of the Decapolis.

at the time of the first European visit to the site recorded by Seetzen in 1806 (1810: 32-34).

The Principal Water Installations

Aside from domestic-sized cisterns the main water installations within the city comprise bath complexes and fountains, with the greatest concentration lying on or adjacent to the Cardo on the west side of the city **(Fig. 2)**. A total of six bath complexes are known within the city and a further two outside - one at Birketein 1.6 km north of the city, and another probable site at el-Hammām thermal spring beside the R. Zarqa near its junction with Wādī Jarash 7 km south of Gerasa **(Table. 1)**.

The first construction dates of the two largest bath complexes - the West and East Baths - are not precisely known, but Lepaon's suggested early-2nd century AD date for the first phase of the West Baths makes this perhaps the earliest major installation within the city. A number of fountains have been located in the west side of the city between the Macellum and the North Theatre - in particular along the Cardo - that can be dated from the end of the first quarter of the 2nd century AD to the beginning of the 3rd century AD, implying a steady increase in reticulated water supply requirements through the 2nd century AD (Seigne 2008: 49). Likewise, in the eastern part of the city a supply would have been needed during the 2nd century AD to the East Baths, if the tentative late-2nd century

Table 1: *Summary of Bath Complexes.*

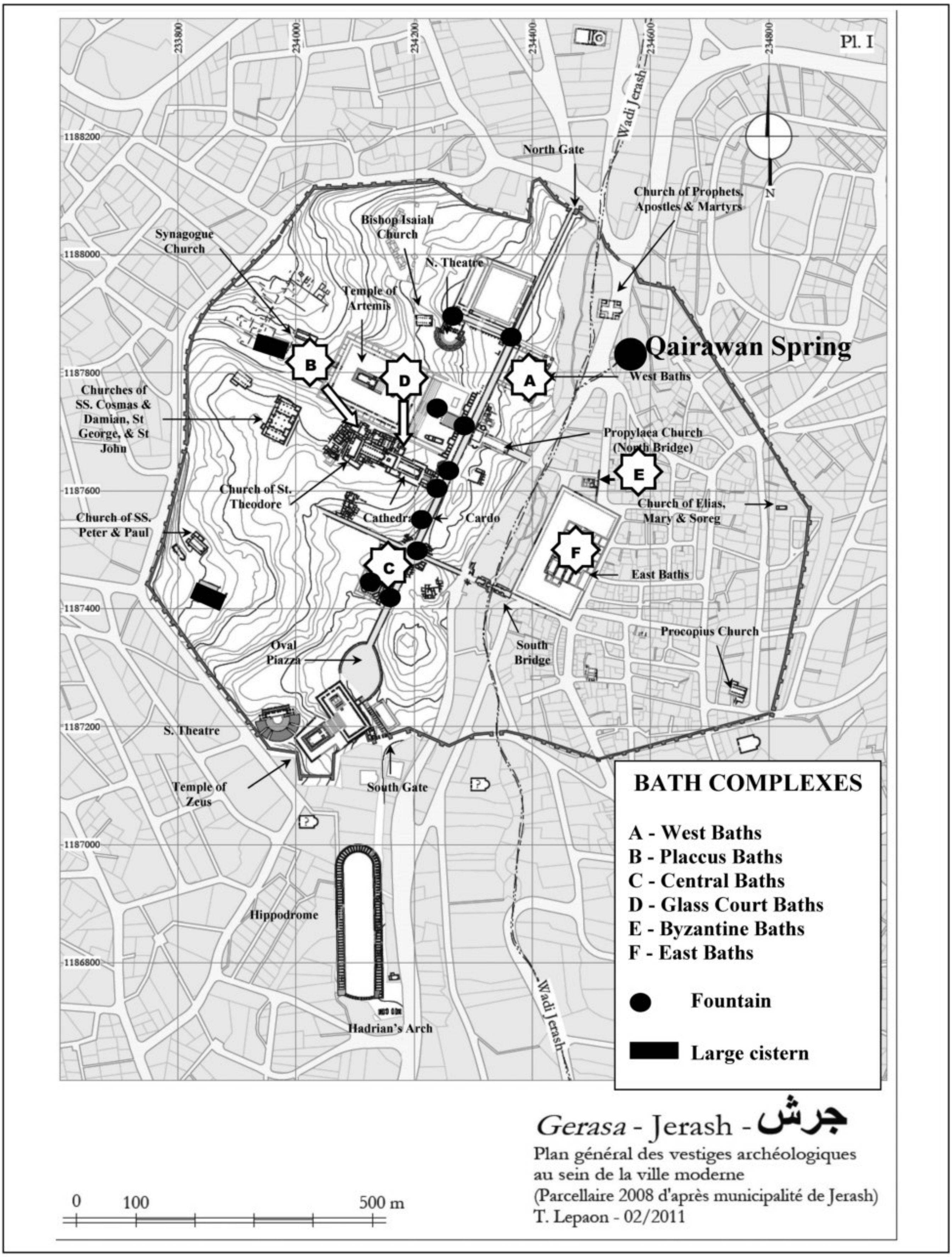
Bath	Location	Construction Date (AD) First Phase	Final Size (m^2)	Reference
East	City East	?2nd c.	15,000	Lepaon 2008: 60-65
Byzantine	City East	Mid 4th c.	373	Lepaon 2008: 65-67
West	City West	Early 2nd c.	4,500	Lepaon 2012: 117-123
Central	City West	Late 3rd/early 4th c.	>280	Walmsley *et al.* 2008: 126; Blanke *et al.* 2010: 312-317
Placcus	City West	454-455	780	Lepaon 2008: 57-59
Glass Court	City West	?5th c.	105	Lepaon 2008: 59-60
Birketein	Birketein	?	>990	Lepaon 2008:67-68
El-Hammām	Zarqa	?	?	Glueck 1939:III: 220-221

date for the first stage of this bath complex is correct (Lepaon 2008: 65). It is not presently known when the West Baths and East Baths went out of use, but the Central Baths remained in use - albeit on a reduced scale – until the early 8th century (Walmsley *et al*. 2008: 126). The Byzantine Baths on the east side of the city were built in the 4th century using the same aqueduct from Qairawan spring that is believed to have supplied the East Baths 100 m further south, implying that the aqueduct to the East Baths was still available in the 4th century AD. No specific source(s) of supply have yet been identified for the major water consuming installations on the west side of the city, which all lie below an elevation of 600 m and above the elevation of Qairawan spring (566 m).

It would be expected that the aqueducts to the city would have delivered their supply to a castellum divisiorum for distribution to various end-users. While no such structures have yet been identified in Gerasa, the ruins of two large unexcavated cisterns or reservoirs that may have provided storage and/or distribution functions have been identified: one on the hill to the west of the Temple of Artemis at an elevation of approximately 616 m (40 x 20 m), and another on the hillside below the Church of Ss. Peter and Paul in the south-west corner of the city at an elevation of approximately 610 m (15 m x 35 m). The depth of these cisterns is not presently known but, if a depth of at least 2 m is assumed, would have been in the range 1000-1500 m^3.

Previous Studies

Hydraulic system studies have been published for most Decapolis cities in northern Jordan and adjacent areas - especially Gadara (Döring 2005; Kerner 2005) and to a lesser extent Abila (Mare 1995; Döring 2008), Hippos (Ben David 2002; Tsuk *et al*. 2002), Scythopolis (Fahlbusch 2002) and Pella (Watson 2001). There has been no similar published study for Gerasa. While publications on groups of water installations in Gerasa exist - examples being architectural studies of the baths (Lepaon 2008, 2012) and fountains (Seigne 2008), there has been little work published on the water sources and the overall water supply network to the city and its hinterland. Comment by Seigne (2002) and a subsequent brief study (Seigne 2004) have been the only recent published accounts on the supply of water to Gerasa in the context



2. Plan of Gerasa showing major water installations (base plan from Lepaon 2012: Pl. 1).

of its hinterland, but are limited by a lack of archaeological evidence, are preliminary in scope and have been superseded by new discoveries. Seigne's principal conclusions regarding the city's potable water supplies were that the open reservoir at Birketein was an unlikely source, due to its elevation relative to the monuments in the city and issues related to potential contamination. He suggested instead that the water supply came from another source or sources further upstream (2004: 176-177); the " 'Ayn ash-Shawāhid" spring was one suggested source, although this is a different spring to the esh Shawāhid spring referred to in this paper.

The most recent advances in understanding the area's water management system have come from the Jarash Hinterland Survey, which recorded 92 water installations in the city's immediate hinterland. The majority were found in the Wādī ed Deir valley north of the city, where elements of a masonry aqueduct of likely Roman-Byzantine date were identified, and south of the city where sections of aqueducts were recorded on both banks of Wādī Jarash (Baker and Kennedy 2011: 455-461). These results are discussed more fully below.

Questions to Be Answered

The project is critically examining the evidence for the water management system of Gerasa and its hinterland in the period 200 BC to the Islamic conquest in the 7th Century AD, from written and visual sources and from new field surveys. The study seeks to identify the system's main components, understand how it operated and determine to what extent it contributed to the region's growth, importance and ultimate decline. Answers are needed to a number of fundamental questions relating to the water management system, including:

1. What were the sources of supply?
2. Did these sources change over time, and if so why?
3. Were these sources close to the city or is there evidence of, and was there a need for, aqueducts bringing water from some distance away, as in the case of the system that supplied Adraa, Abila, and Gadara (Döring 2008)?
4. What were the delivery capacities of the aqueducts servicing the city and hinterland?
5. Do elements of the reticulation network predate the Roman period?
6. Were certain sources and aqueducts dedicated to certain water installations or uses?
7. What were the demand requirements of the main water installations within the city?
8. When did the system go out of use and why?

Jarash Water Project

Project Area

The project area is defined by the watersheds of the Wādī Sūf / ed Deir / Jarash valley (60 km^2) and the tributary valley of Wādī el Majarr and Wādī Tannur (47 km^2), a combined area of 107 km^2. It includes the site of the ancient city, the entire valley in which it sits and the adjacent valley to the east which, because of its proximity and the large area of rich soil within it, would have formed a key part of the city's agricultural hinterland **(Fig. 3)**.

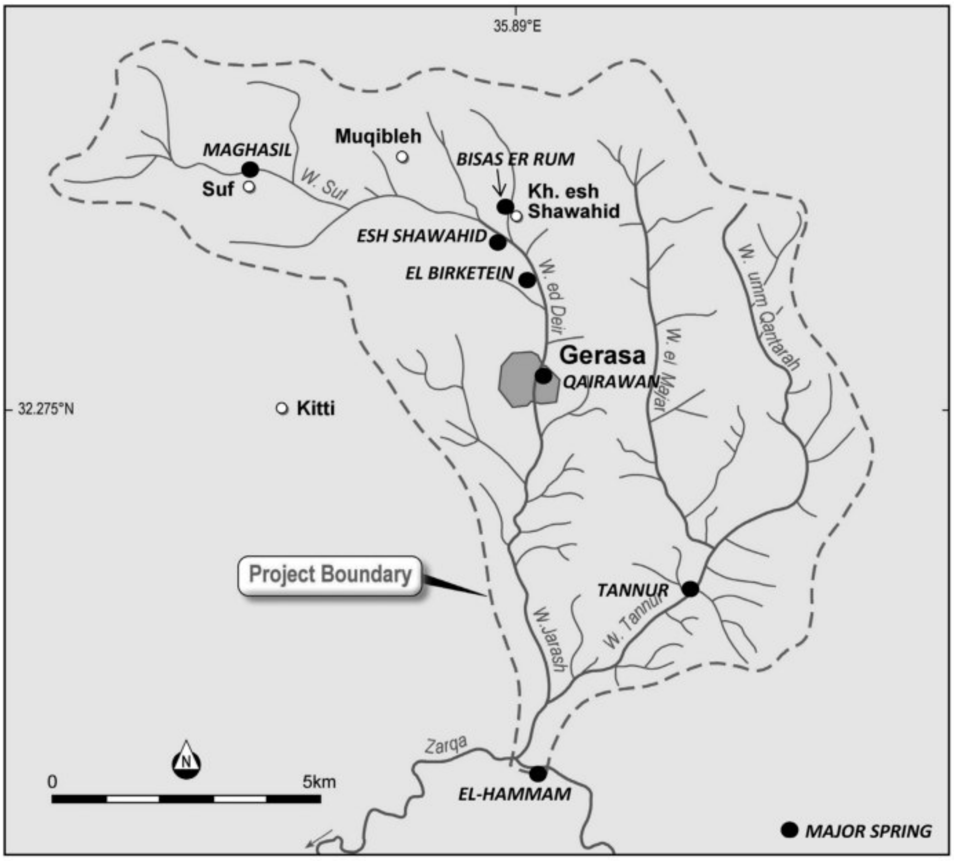
In a regional context the study area lies in the northern part of the Jarash Basin as defined by Kennedy (2004: 205, **Fig. 8**), which itself forms the western part of the much larger Zarqa River Basin as defined by Al-Abed and Al-Sharif (2008: **Fig. 3) (Fig. 4)**.

Objectives

The principal objectives of the field survey are:

1. To record surviving archaeological remains relating to water management.
2. To record the water installations in a database.
3. To date when the water installations were placed in use, and went out of use, and determine the water sources; and
4. To identify archaeological remains for conservation.

The primary aim in the 2013 field season was to survey selected areas in the Jarash Valley to the north, south and west of the city, with a view to locating and tracing the historic aqueducts to the city and its hinterland. A secondary aim



3. *Project Area showing drainages and major springs (D. Boyer).*

was to survey selected areas within the adjacent Wādī al Majar-Wādī Tannur valley to the east, to investigate water related sites (especially springs) to gain an understanding of water management in the rural context. The 2013 survey covered only a portion of the project area and it is anticipated that it will be followed by one or more additional field seasons.

Methodology

The survey focused on locating and recording sites related to water management. The survey involved:

1.Pedestrian survey of selected areas previously identified from a study of published material, plans, satellite imagery and aerial photography to identify water-related sites of any period. (All periods are covered because the dating of site elements is problematic especially when, as in the case of this project, no excavation is carried out. Also it is evident that there has been reuse of ancient aqueducts in the late Ottoman period and in particular the post-Circassian settlement period. Future surveys will also include the collection of mortar and/or plaster and carbonate sedimentary material (tufa, or calcareous sinter) for dating, chemical analysis and stable isotope determination (δ18 Oxygen and δ13 Carbon).

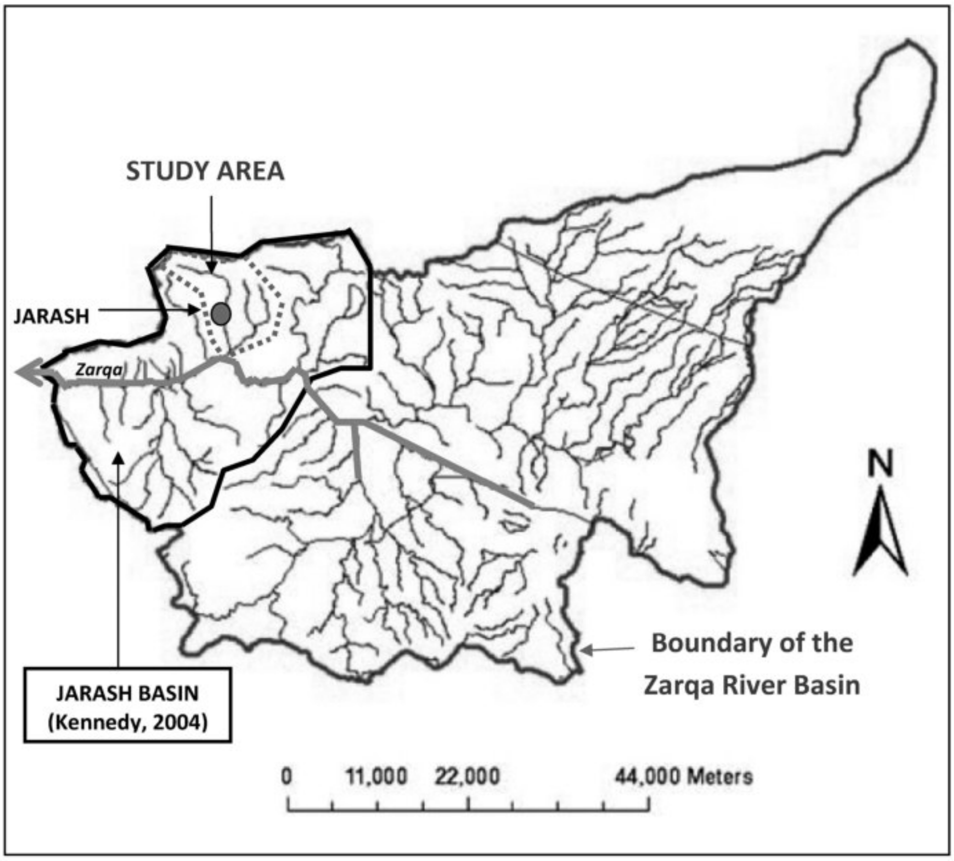
2.Location of all sites by hand held GPS (WGS84 datum).

3.Use of dumpy level to confirm gradients at selected locations.

4.Recording of all sites by allocating a unique project site number, providing a written description, taking colour digital photographs, making sketches and the entry of information onto *MEGA* Jordan forms.

5.For consistency, location names and spelling are taken from 1:10,000 series topographic plans (Department of Lands and Surveys of Jordan 1950) where possible.

Positioning in the field was by reference to hand held GPS (*Garmin GPSMap 76Sx*); generally



4. The boundary of the study area in the context of the boundaries of the Jarash Basin (Kennedy, 2004) and the Zarqa River Basin (plan modified from Al-Abed and Al-Sharif, 2008, Figure 3).

to an accuracy of +/- 4-6 m. Coordinates were recorded in decimal degrees (WGS84 datum). Elevations were also taken at each location; however this information should be taken as a rough guide only. Reference was also made to Jordanian 1:10,000 and 1:50,000 scale plans, however these are generally not accurate enough for in-field positioning.

Site Types

Site information, including GPS location, GPS elevation, and site type are presented in Appendix 1. Given the focus on water-related structures, there were only a limited number of site types recorded. A total of 36 elements were recorded at 35 sites; a breakdown by site type is shown in **Table 2** and site locations are shown in **(Fig. 5)**.

Geographic Landscape

Gerasa lies in the centre of a 15 km long valley that is a minor tributary of the Wādī Zarqa. The walled city straddles the floor of the valley, with the incised Wādī Jarash dividing the site into two distinct but unequal parts. Although a single drainage system, the valley is known by several names; the upper section, between Sūf and the junction with the north bank tributary Wādī Asfūr is named Wādī Sūf, the central section between Wādī Asfūr and Jarash is named Wādī ed Deir, and the lower section from Jarash to the junction with the Wādī Zarqa is named Wādī Jarash. Within the Wādī Sūf / ed Deir / Jarash drainage (hereafter the Jarash Valley) rich Mediterranean soils can be found on the banks of the valley and on the ancient terraces that line its slopes, with a similar accumulation of Mediterranean soils in the adjacent Wādī Majarr valley to the east. Colluvium covers the valley floors.

Geologically and topographically the area can be described as a dissected limestone plateau formed from flat lying units of the Upper Cretaceous 'Ajlun Group, with the sandstones of the underlying Lower Cretaceous Kurnub Group exposed in the Jarash Valley below Jarash

Table 2: *Site statistics*

Site No (JWP_)	Aqueduct	Reservoir	Wine press	Spring	Mill	Unspecified	Total
102						1	
103	1						
104	1						
105	1						
106	1						
107	1						
108				1			
109		1					
110		1					
111	1						
112	1						
113		1					
114	1						
115	1						
116	1						
117		1					
118	1						
119	1						
120	1						
121	1						
122			1				
123			1				
124	1						
125	1						
126	1						
127	1						
128	1						
129		1					
130	1						
131	1						
132	1						
133		1					
134			2				
135	1						
136					1		
Subtotals	**23**	**6**	**4**	**1**	**1**	**1**	**36**

(Abdehamid 1995). The steep valley slopes are lined with natural and constructed terraces, some dating to antiquity, and cross-wādī walls are a feature of many tributary wadis.

The area enjoys a Mediterranean climate with wet winters and warm summers. It lies in the transition zone between the highlands in the west and the desert in the east, and this is reflected in the rainfall data; between 1950 and 2008 Jarash's annual rainfall averaged 356 mm, but rainfall reduces rapidly eastwards from the 'Ajlun highlands being 543 mm at Kitta 4 km west of Jarash to only 220 mm at Medwar 10 km east of Jarash (Al-Qaisi 2010, Table 11.1). The results of a recent study of palaeoclimate proxies for the southern Levant are interpreted by this author to suggest that the period of Hellenistic colonisation of the Decapolis coincided with the onset of wetter climatic conditions that persisted until around the 6th century AD (Mithen and Black 2011: Fig. 7.2), indicating that climatic conditions in this period may have been similar to those currently existing. Today, the project area enjoys relatively high levels of annual rainfall – nearly all of which falls in the winter months – supporting rain-fed farming wherever there are adequate soils[2].

The rainfall recharges groundwater stored in predominantly limestone aquifers that in turn supply a number of natural springs, with the spring flow fluctuating with the seasons. Early-19th century travellers noted strong natural springs at a number of locations within the Jarash Valley between Sūf and Gerasa. These remained in use until the pumping of groundwater wells in recent years lowered the water table in the esh Shawāhid - Birketein area, so that Qairawan within the ancient city of Gerasa is now the sole remaining high yielding spring of those noted by the early visitors. Historically, surplus flow from the many springs generated perennial flow along the streambed of the Jarash Valley, and these combined water sources sustained widespread irrigation opportunities within the valley. The aerial photographs taken by the Hunting Aerial Survey of Jordan in 1953 show that a 10 km section of the Jarash Valley - some 200 hectares - was under irrigation from north of Birketein to the junction with the Wādī Zarqa, but lowered water tables and a gradual reduction in annual rainfall have since reduced this area drastically in the Jarash Valley upstream of Jarash. These photographs also point to the irrigation potential that probably also existed in the Roman - Byzantine period within the Jarash Valley.

2.There is significant variation in total rainfall year on year and the timing of that rainfall, which has important implications for rain-fed agriculture now and potentially in the past. At Jarash, between 1970 and 2002 the average rainfall was 347.2 mm, but varied from a low of 145 mm in 1978/9 to a high of 668.7 in 1991/2 (Al Mahamid 2005: 53, Table 2.3). Al-Qaisi (2010: 30) notes that in the 1950's-1960's most rainfall within the Zarqa Basin fell in December-January but now (2010) occurs later in the season in February-March.

Overview of Water Sources

As is the case today, water sources in the project area in the Roman - Byzantine period would have included seasonal stream flow in the various wadis – probably perennial flow in the case of the Jarash Valley – and from natural springs. Spring sources in the Jarash Valley would have included high-yielding springs at Sūf, esh Shawāhid, Bisās er Rūm, Birketein and Qairawan **(Fig. 3)**, plus a plethora of smaller springs on the slopes and floor of the valley. Flow rates for the major springs are listed in **Table. 3**.

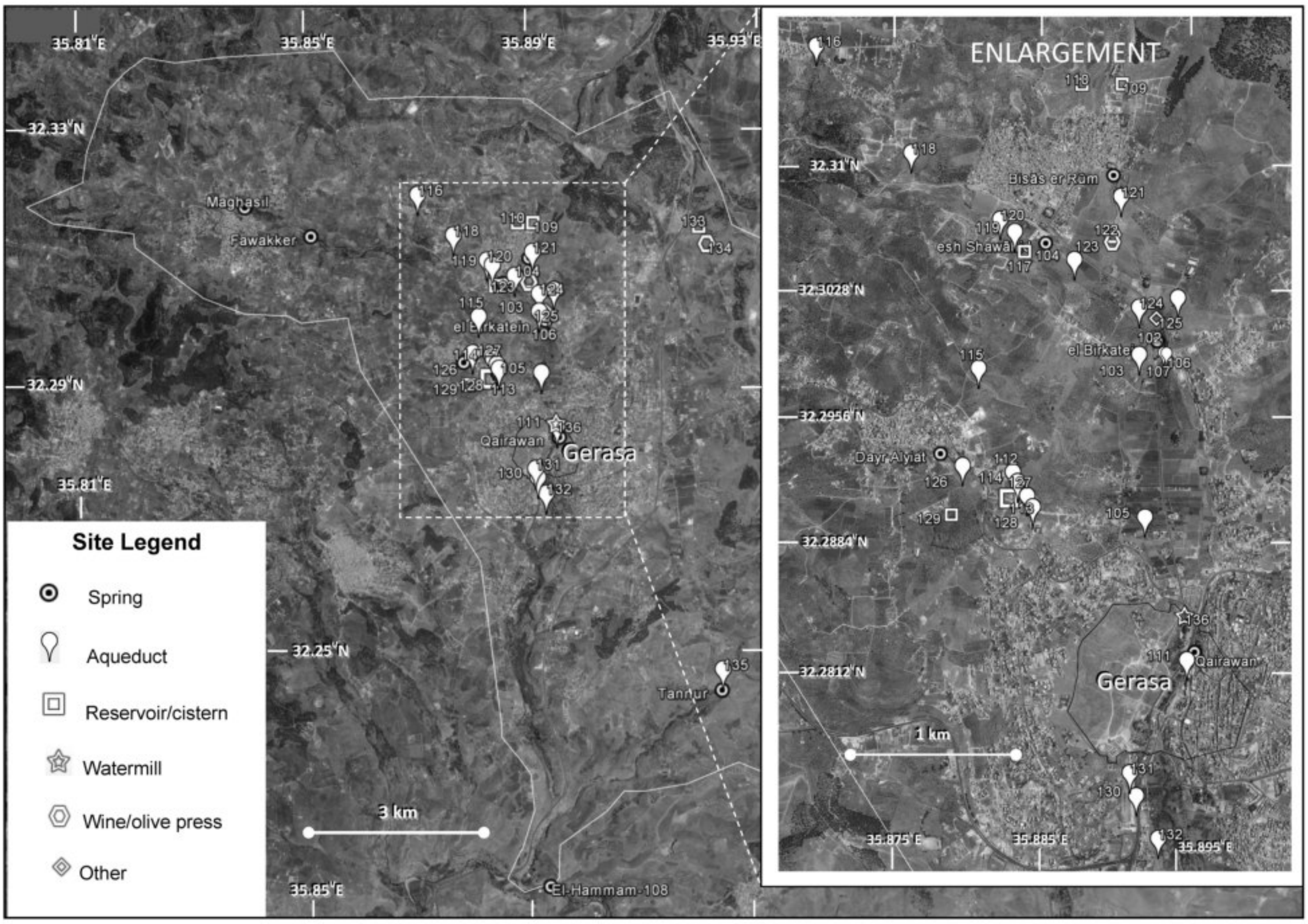
Wādī Sūf

The town of Sūf is located at the head of the Jarash Valley. It is an ancient site, with evidence of occupation from the Middle Bronze Age onwards (Mittmann 1970: 95). In 1812 the Swiss traveller Johann Ludwig Burckhardt noted "the stream [from Souf]…is supplied from three copious springs that issue from under a rock near the village …and with their united waters the narrow plain of Djerash is irrigated" and "at the spring of Ayn Keykebe, which is covered by an arched building, I copied some characters from a broken stone" (Burckhardt 1822: 248-251). George Robinson, who visited Sūf in 1830, reported similarly (Robinson 1837: 242). The springs lie at an elevation of approximately 880 m. A maximum discharge rate of 757 m^3/hr (210 litres/sec) has been reported by the Ministry of Water and Irrigation (MWI) for the Maghasil spring at Sūf and an average flow rate of 45.2 m^3/hr (12.5 litres/sec), however in summer the flow can be reduced to a trickle (MWI 1997: **Fig.5)**.

'Ayn ash-Shawāhid (elevation 650 m) lies on the south bank of the Wādī Sūf opposite the junction with Wādī Asfur and is identified from the 1:10,000 topographic plan (sheet 27/88)

Table 3: *Flow rates of major springs (from MWI 1997: Fig. 5)*

Spring	**Drainage**	**Max flow**	**Min Flow**	**Averag e Flow**
Name	**Name**	**m^3/hr**	**m^3/hr**	**m^3/hr**
Maghasil	Wādi Sūf	757.0	0.2	45.2
Esh Shawahid	Wādi ed Deir	162.6	0.0	44.9
El Birkatein	Wādi ed Deir	619.0	0.0	98.0
El Qairawan	Wādi Jarash	359.0	60.0	148.1
El Tannur	Wādi Tannur	356.0	3.1	105.3



5. Site locations, 2013 field season. (D. Boyer and Google Earth).

published in 1950 and from a description by Steuernagel (1925: 270), which also refers to the ruins of Byzantine buildings. It is to be distinguished from a spring (ʻAyn Bisās ar-Rūm - see below), which lies 600 m to the north east, and which is named ʻAyn ash Shawāhid on some plans. A maximum flow rate of 162.6 m^3/hr (45 litres/sec) and an average flow rate of 44.9 m^3/hr (12.5 litres/sec) is quoted for ʻAyn ash-Shawāhid (MWI 1997: **Fig.5**), which can run dry in the summer months. It still flows intermittently but flow rates have been substantially reduced by pumping from the nearby Shawāhid borefield.

ʻAyn Bisās ar-Rūm (elevation 675 m) lies in Wādī Asfūr, a north bank tributary of Wādī Sūf, adjacent to Khirbet esh Shawāhid, close to the second Roman milestone on the Gerasa-Adraa road. Use of the spring in the Roman period is suggested by its name, and Roman occupation of the adjacent Khirbat ash-Shawāhid site in 2nd to 3rd centuries AD is attested by a number of inscriptions (Welles 205 and Welles 216 in Kraeling 1938: 448-51). It no longer flows, presumably as a result of pumping from the nearby Shawāhid borefield.

Wādī ed Deir

ʻAyn el Birkatein or Birketein (elevation 620 m) supplies the Birketein reservoir on the west bank of the Wādī ad-Deyr. The masonry reservoir at Birketein is of Roman date. Occupation of the site goes back to at least the Early Bronze Age (Mittman 1970: 98) and as noted by Seigne (2004: 177) the Roman reservoir may have replaced an earlier structure. McCown (Kraeling 1938: 167) suggested that the pools were constructed during the Antonine period at the latest, and Seigne argues that the construction of the pool postdates the construction or rebuilding of the adjacent Gerasa-Adraa road in Trajanic times

(Seigne 2004: 177). An inscription on a column fragment dates the construction of part of the colonnade around the Birketein reservoir to AD 209 to AD 211 (Kraeling 1938: 167), so the pool was constructed prior to this date. Current flow rates from Birketein are intermittent, but a maximum flow rate of 619 m^3/hr (172 litres/sec) and average flow rate of 98 m^3/hr (27.2 litres/sec) have been reported (MWI 1997: **Fig.5**).

Wādī Jarash

'Ayn al Qayrawān (Qairawan) (elevation 566 m) on the east bank of the Wādī Jarash is the most significant spring within the walled city of Gerasa and in the Wādī Jarash, and still contributes substantial water supplies to the town system. The spring source is contained within the remains of an original stone structure that Seigne dates to the 2nd century AD on the basis of the quality and style of the mouldings of the monumental wall that forms the east wall of the present site (Seigne 2004: 175). In the 1930s a team of archaeologists from Yale recorded on a 1:2500 scale plan that this monumental wall lay at the western end of a wall at least 40 m long (Yale University Art Gallery Negative number: 1938.5999.5004.30) **(Fig. 6)**. This wall is shown as being part of a pool on C.S. Fisher's plan of Gerasa (Kraeling 1938: Plan 1), however the nature and extent of the early structures in the vicinity of the spring requires further study. Although Seigne states that there is no evidence of deification or of a sanctuary in the vicinity (2004: 175), references made by several 19th-century visitors point to the existence of more extensive buildings than are now evident, including a possible shrine. Guillaume Rey visited Gerasa in 1858 and commented "…et autour d'une belle fontaine d'eau vive, nous voyons les restes d'une construction monumentale où nous remarquons des traces de niches destinées, sans doute, à recevoir des statues. Nous trouvons aussi quelques inscriptions chrétiennes, mais toutes sans intérêt." (Rey 1861: 251). Rey's reference to Christian inscriptions is unique (they do not seem to have survived) but the existence of altars in the vicinity of the spring is also noted in Baedeker's 1876 English edition of his *Handbook for Travellers* – "By a spring farther to the S. there seems to have been another handsome edifice containing altars" (Baedeker 1876: 397).

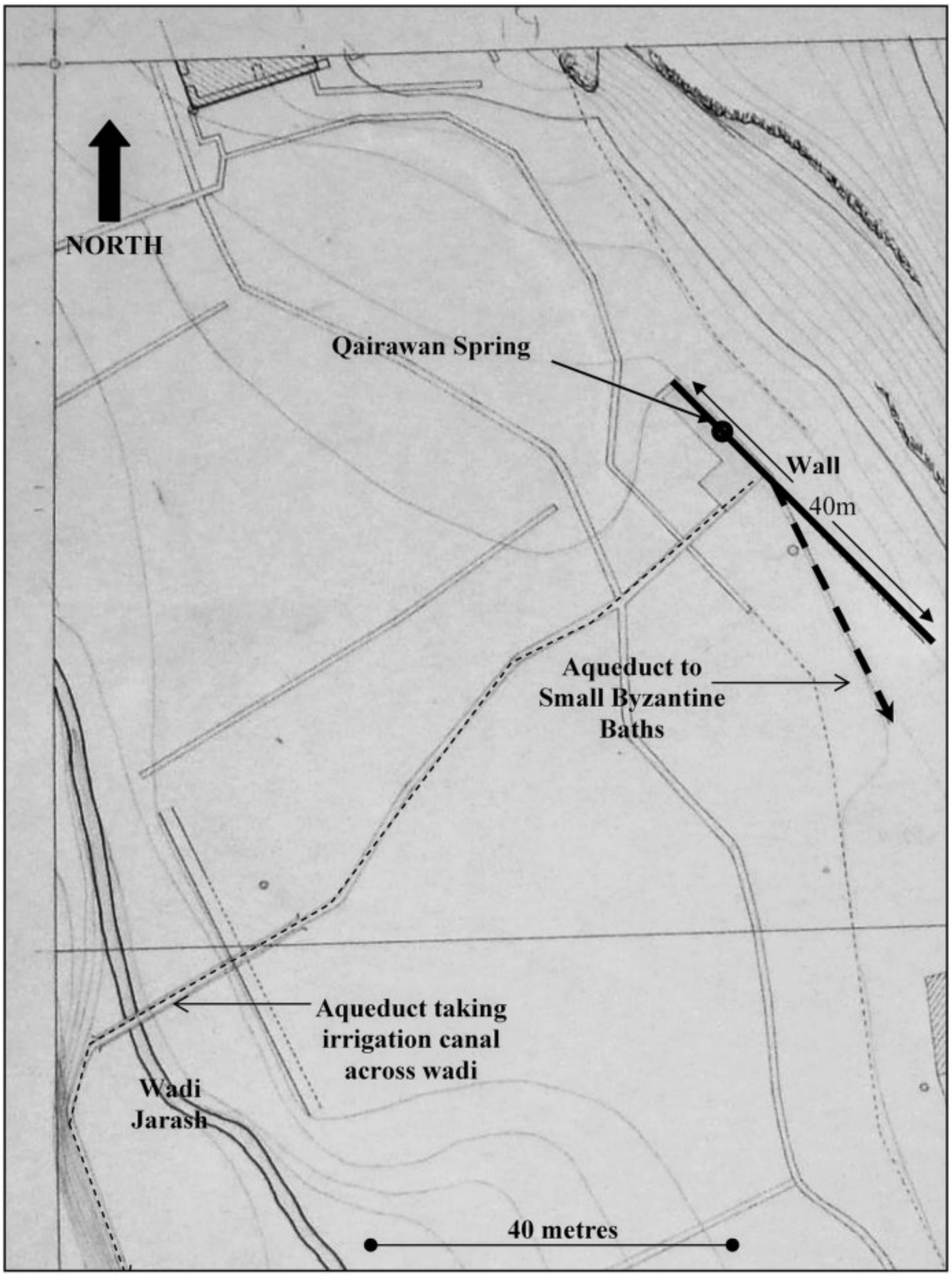
Qairawan was likely to have been a strong spring in ancient times and remains so today. A maximum flow rate of 359 m^3/hr (100 litres/sec) and minimum flow rate of 60 m^3/hr (16.7 litres/sec) were reported for the period 1938 to 1996 (Daane and McNeil 1997: 18). In the five years to 1996 the average summer flow was 120 m^3/hr and the average winter flow was 170 m^3/hr (Daane and McNeil 1997: 20).

Wādī Tannur

'Ayn Tannur lies at the head of Wādī Tannur, which forms the lower part of the Wādī al Majar-Wādī Tannur valley. There is evidence of early occupation near 'Ain Tannur; Khirbet el-Meshetta, with evidence of occupation dating back to the Chalcolithic or possibly Neolithic period, lies 700 m to the west of the spring. Evidence of Roman - Byzantine occupation has been reported from Khirbat Tannur immediately east of the spring, and occupation at Khirbat Mansub located 0.5 km south south-west of Khirbet Tannur dates from the Middle Chalcolithic period (Glueck 1951:IV: 87). The Roman site of Mehbethah lies to the east of Khirbet Mansub (Glueck 1951:IV: 89). There seems little doubt that the strong flow from 'Ain Tannur has been used since the prehistoric period and is still used today to irrigate the valley.

Wādī al Majar

No major springs are known within this drainage. The most significant are likely to have been at the southern end in the vicinity of the Roman - Byzantine settlement of Khirbet Shereiyit ('Ayn Shereiyit) (Glueck 1951, IV: 86) and particularly Khirbet 'Ayn Riyashi, where Glueck (1951, IV: 69-70) reports evidence of Early Bronze Age to Roman - Byzantine



6. Part of Yale 1: 2500 scale plan of Gerasa showing features recorded in the vicinity of Qairawan spring (Yale University Art Gallery Negative number: 1938.5999.5004.30).

occupation. ‘Ayn Riyashi lies 1 km upstream of ‘Ain Tannur, and it is likely that the *ca* 20 hectare valley floor between the two springs was irrigated during the Roman-Byzantine period.

There are several small springs at the northern end of the Wādī al Majar valley, but although there is evidence of occupation in this area in the Roman - Byzantine period at both ‘Ebta and Khirbat al-Hute (Mittmann 1970: 118-9), there is no evidence that the greater part of the rich valley was irrigated. If this is correct, then it means that farming would have been largely rain-fed, which would have reduced production capacity from the rich soils along the floor of the valley of which at least 300 hectares is potentially cultivable. This compares with roughly 350-400 hectares that is potentially irrigable in the Jarash Valley.

Aqueducts

Basic Typology

Around two thirds of the site elements recorded during the survey were aqueduct components. The aqueducts fall into three groups.

1.Rock-cut construction: the canal is cut directly into limestone bedrock. This is a very common form of construction; a good example is the 100 m long section of the aqueduct from 'Ain Bisās er Rūm at site 125. Other examples include sites 112, 114, 117-120, 124, 127-128, 130-131.

2.Masonry construction: with a 'U' shaped canal cut into a dressed limestone block. There is some variation of the size of the canal. The major masonry aqueduct of likely Roman - Byzantine date (DW01-see below) that crosses the valley floor of the west of the Wādī ad-Dayr and described by Baker and Kennedy (2011: 458-9) was constructed of dressed limestone blocks up to 1000 mm long, 800 mm wide and 700 mm high. A channel with a width of 300-450 mm and a depth of up to 300 mm has been cut into these blocks. Examples of similar sized elements were found at sites 103, 105 and 106. Blocks with a smaller channel width (150-200 mm) located in the Jarash Hinterland survey (Kennedy and Baker 2009: **Fig. 11**) were interpreted to be part of side channels supplying local agricultural users in the valley.

3.Masonry construction: with a cement canal lying on a frame support wall comprising a core of cemented rubble and an outer wall of dressed limestone blocks. The sole example of this is the remnant section of the Roman aqueduct from Qairawan spring located immediately north of the small Byzantine baths and 180 m south south-west of the spring (site 111).

There is evidence of the plastering or cementing of all three types, a good example being the buried rock-cut aqueduct at site 128 where there is a thick accumulation of carbonate sediment lying on a plaster base. There is some direct evidence of the covering of the aqueducts; some original capstones are still in place at site 111 and 135, and at Muqibleh (site 116) the underground canal from the spring is covered by a short section of tunnel. Individual aqueducts are shown in (**Fig. 7**) and are described in more detail below.

Wādī Sūf-Wādī ed Dayr

Muqibleh Spring Tunnel and Aqueduct

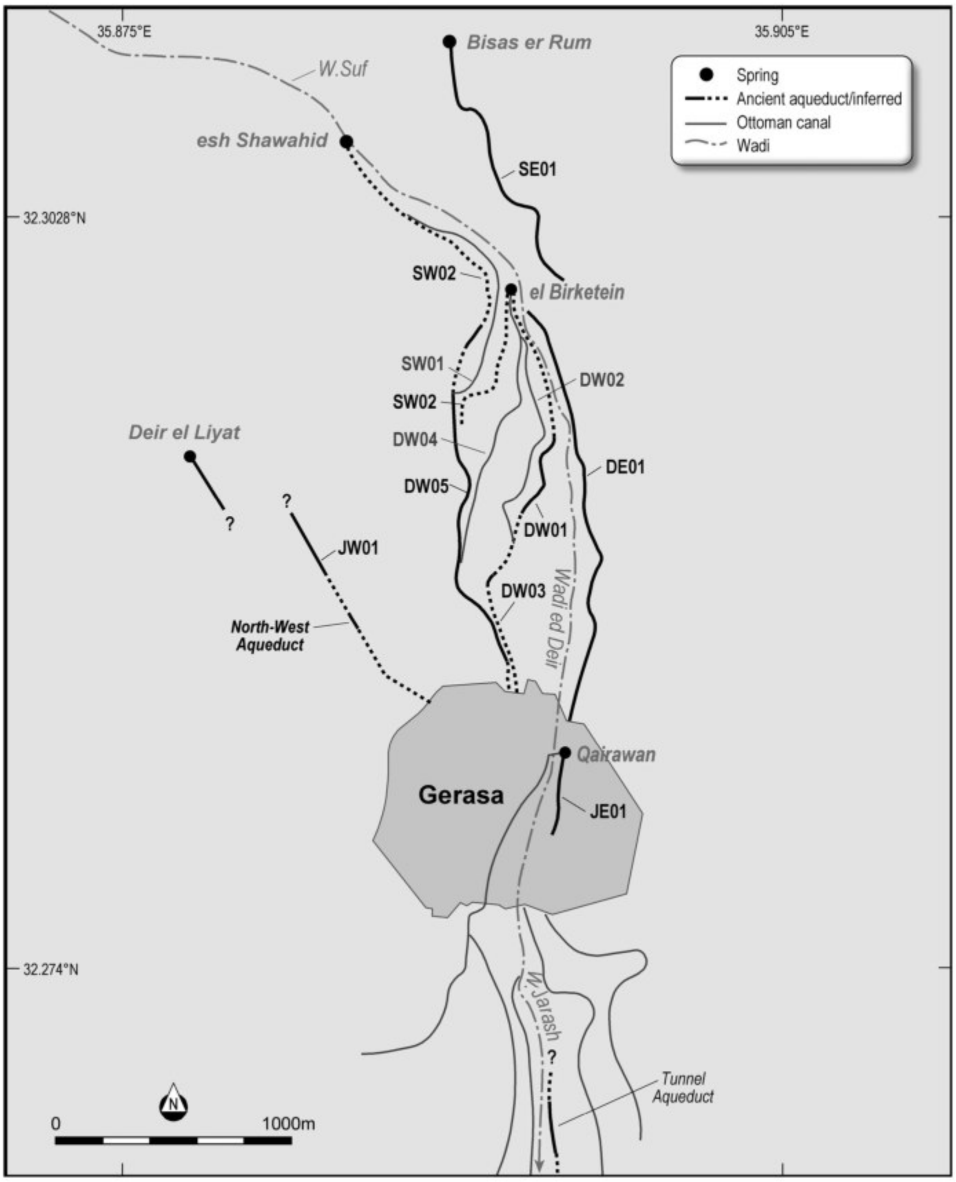
The small village of Muqibleh lies 3 km east of Sūf on the northern side of the Wādī Sūf valley. A spring is located on a south-facing slope, and at one time its waters irrigated fields on the north bank of the wadi. The site is unusual for the masonry tunnel constructed over a short length of aqueduct that carries water from the spring. It is one of only two tunnel sites in the project area - the other being a section of rock-cut tunnel 1 km south of the city in Wādī Jarash. The Muqibleh spring tunnel was excavated by Thompson and de Vries (1972), who considered it to be probably Roman - Byzantine in date based on the corbelled roof, the quality of well-dressed limestone masonry, and analogy with a similar tunnel at Balata (1972: 90). Thompson and De Vries recorded a canal 28 m long open at its northern end, with a 7 m long section of corbelled tunnel at the southern end. The corbelled tunnel is up to 2.1 m high and 1.3 m wide, with an aqueduct 0.4 m wide cut into the limestone bedrock **(Fig. 8)**.

The corbelled tunnel remains intact but the stonework at the entrance needs to be stabilised. Although the current flow is small - even at the end of the wet season - the size and quality of the structure, and the existence of a side canal 0.6 m above the floor of the aqueduct near the entry, point to higher flow rates in antiquity.

Wādī ad Dayr Masonry Aqueduct (Aqueduct DW01)

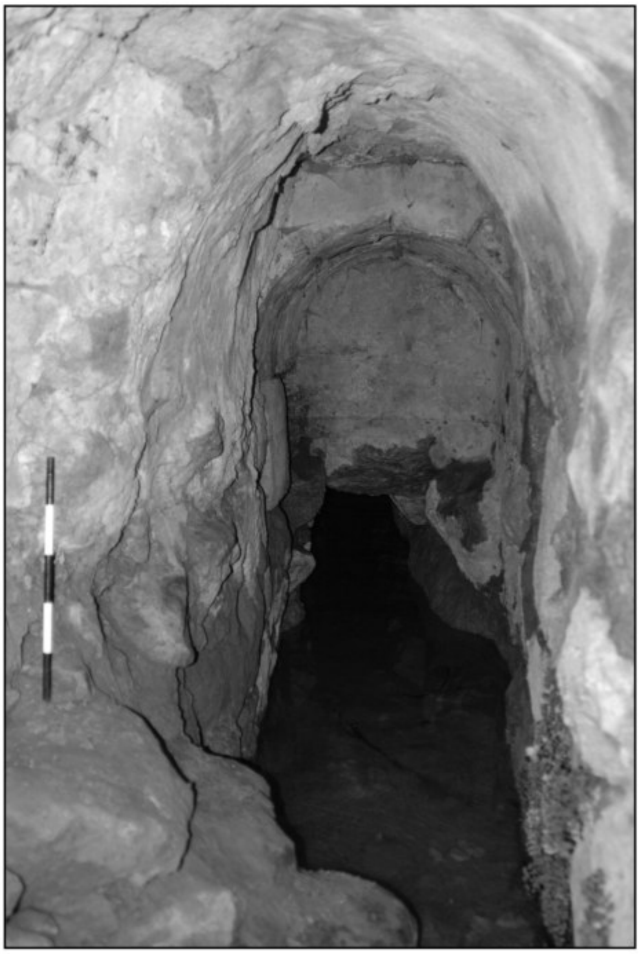
Displaced elements of this aqueduct were first recorded over a distance of 450 m across the floor of the valley by the Jarash Hinterland Survey (Baker and Kennedy 2011: 459). As the aqueduct crossed a soil covered area it was necessary to construct it of large limestone blocks with a 'U' shaped channel 0.35 m by 0.35 m in section cut into them **(Fig. 9)**.

While none of these elements are *in situ*, they lie very close to the position of a 370 m long section of an apparently *in situ* aqueduct (DW01) along the 608 m contour shown on a plan produced by



7. Aqueduct plan (D. Boyer).

the Yale team in the 1930s (Yale University Art Gallery: "Area south of Large Birketein Street", Negative number: 1938.5999.5004.50). The aqueduct blocks at site 105 in the 2013 survey represent the southern end of the masonry aqueduct on present information. The elements at this site are also not *in situ*, but lie very close to another section of aqueduct shown on the Yale plan approximately 450 m north of the north wall of the city. Downstream from this point the aqueduct alignment merges with the alignment of an irrigation canal re-established in the late Ottoman period (aqueduct DW02) that continued southwards and crossed the north wall of the city at *ca* 599 m elevation (see below). While occasional remnant sections of rock-cut aqueduct in the vicinity DW02 along this section point to its possible use as a supply to the city in antiquity, it is not certain that DW01 was used for this purpose. The uncertainty is exacerbated because the source for DW01 is unknown. The northern end of the known section of DW01 lies close to the Wādī ad Dayr stream, and this together with the position of the 608 m contour suggests that the Wādī stream may have been the source. If correct, this would almost certainly mean that DW01 was used only for irrigation as it is difficult to believe an irregular, potentially contaminated, source such as the wādī being used for a potable supply in the city. It is also



8. View of spring tunnel with corbelled roof at Muqibleh (D. Boyer).

possible DW01 was sourced from Birketein; the masonry aqueduct blocks at site 106, 70 m south-east of Birketein, have the same dimensions as those that make up DW01, 475 m to the south. If site 106 does form part of DW01 it means that the alignment of DW01 from Birketein would have closely followed the west bank of the wadi stream on a fairly steep gradient of close to 2%. If the aqueduct was merely designed to supply the city, then a shorter, more direct route with a lower gradient would have been possible, so the placement of DW01 appears to be specifically directed to end users in the lower half of the Wādī ad Dayr valley that is closest to the city.

Birketein Aqueducts

Water from Birketein reservoir is currently channelled along two concrete canals to irrigate the Wādī ed Deir valley when there is sufficient water in the reservoir to do so. Aerial photographs show that these canals are a modification to the system used in late Ottoman times. Up until the first half of the 20th century, prior to restoration, water from Birketein spring flowed over the rubble-filled reservoir and was directed into two channels. The path of these channels can be traced on early aerial photographs and on 1:2500 plans drawn by the Yale team in the 1930s and held in the Yale University Art Gallery archives. The upper channel (DW04) initially followed the 619-620 m contour and then trended south-westerly across the floor of the western part of the Wādī ad Dayr valley and linked up with the southern end of the lower esh Shawāhid aqueduct (SW01-see below) at a point approximately 550 m north of the city, before ultimately crossing the north wall of Gerasa close to 603 m elevation. The lower channel (DW02) initially followed the 618 m contour, and traversed the central part of the Wādī ad Dayr valley before crossing the north wall close to 599 m elevation, approximately 30 m east of the upper channel.

Between them, in the late Ottoman period channels DW02 and DW03 provided irrigation water to most of the western part of the Wādī ed Deir valley and to the Circassian fields within the north-west quarter of the walled city below 603 m elevation. DW03 and the first 600 m of the lower channel DW02 are still in use today when circumstances permit, although irrigation water is no longer supplied into the Gerasa Archaeological Park.

The survey has not yet resolved the issue of the importance, or even use, of Birketein as a source of water for the city; today, only modern canals can be seen carrying water from the reservoir. Many of the features that were observed by Schumacher when he surveyed the site in the late-19th century (1902: 165-171) can no longer be seen in the restored Birketein reservoir visible today, so his detailed description and associated plans and photographs provide a unique and valuable historic record of the site as it existed in the late Ottoman period. The Yale team

9. Masonry aqueduct block from aqueduct DW01 (D. Boyer).

subsequently did some excavation within the reservoir in the 1930s, which was reported by McCown (Kraeling 1938: 159-167). McCown was critical of Schumacher's work, but his own published work added little new information on the water installations.

Schumacher was perhaps the first to propose that water from Birketein supplied the city, and this explanation has been generally accepted (see for example Baedeker 1906: 142; Rostovtzeff 1932: 83; Freeman 2008: 21-22), although disputed by Seigne (2004: 175-178). Ian Browning is even more emphatic, stating "This was one of the main reservoirs for ancient Gerasa; indeed the Nymphaeum and the Fountain Court are known to have been supplied from here" (Browning 1982: 213). A re-examination of Schumacher's evidence in the context of what is known of the aqueducts that lie between Birketein and the city is therefore warranted in light of these disparate comments.

The key evidence regarding

the Birketein water installations supplied by Schumacher is as follows:

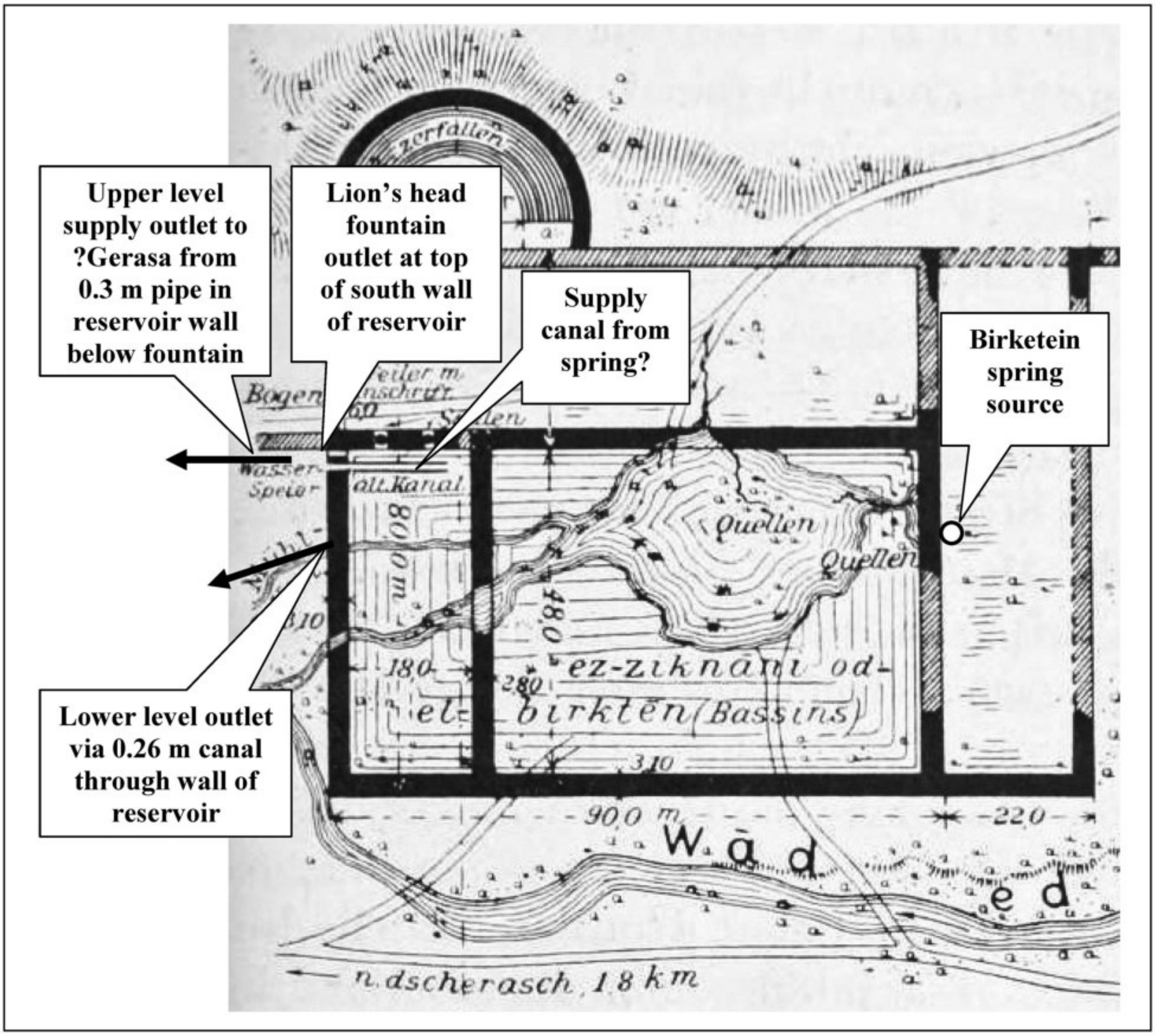
1.Schumacher states "In der südwestlichen Ecke des unteren Behälter finden wir als Wasserspeier einen Löwenkopf, durch dessen Maul ein Kanal von 0,40m Weite und 0,33 m Höhe nach Gerasa geführt wurde (s. Abb. 40)." (1902: 167), which translates to "In the southwestern corner of the lower basin, a channel 0.40 m wide and 0.33 m high discharged water to Gerasa through an outlet in the form of a lion's head". This is consistent with Schumacher's accompanying plan **(Fig. 10)**, which shows the supply channel located inside the reservoir and close to its west wall. Schumacher then describes a second outlet in the wall nearby but 0.6 m lower. This was cylindrical and 0.3 m in diameter. McCown's interpretation of Schumacher's description differs in that he describes "a spout through a lion's head leading the water into a canal 0.4 m wide and 0.33 m deep" (Kraeling 1938: 162).

2.A third outlet through the reservoir wall discharged water in a channel 0.26 m wide. Schumacher thought that this supplied the el-'adebije water mill at the North Gate, but he was mistaken as early aerial photography confirms that this mill was supplied directly from Wādi ed Deir via a purpose-built canal with its offtake 600 m from the North Gate.

3.Water also discharged over the threshold of the ruined south wall of the reservoir and joined with the stream in the nearby wadi.

4.At the time of Schumacher's visit the water level in the pool was 3 m below the lion's head spout, implying that the spout was located near the top of the reservoir wall.

On the above interpretation, Schumacher did not describe water flowing into a channel from the south-western corner of the reservoir, but rather that it flowed out of the lion's head fountain. It can be assumed that the purpose of this fountain was to deliver a potable supply to local residents since, being set near the top of the south wall



10. Interpretation of outlets from Birketein reservoir (from Schumacher 1902: 169, Fig. 41).

of the reservoir at an estimated elevation of around 622 m and above the level of the top of the dividing wall between the two reservoir compartments, it can hardly have been used as a reservoir overflow device. A potable supply would need a contamination-free source, and this would have been achieved by connecting the supply canal described by Schumacher on or parallel to the west wall directly to Birketein spring, although Schumacher's plan does not show the supply canal extending into the larger northern compartment of the reservoir. If this supply canal was also connected to the adjacent 0.3 m diameter pipe set 0.6 m lower in the wall, then a potable supply could have been directed to an aqueduct to Gerasa along the 621-622 m contour. On present information the only evidence for such an aqueduct is a channel element 275 m south of Birketein (Kennedy and Baker 2009: **Fig. 4**) and a linear feature on an early aerial photograph. The aqueduct would have followed around the western edge of the Wādī ad Dayr valley floor, possibly merging with the lower section of aqueduct SW01 650 m south-west of Birketein.

From Schumacher's description "Der heutige

Wasserspiegel liegt 3 m tiefer als der ehemalige Ausfluss durch das Löwenmaul." (1902: 168) the elevation of the 0.26 m wide channel outlet (to the North Gate mill) through the south wall of the Birketein reservoir is estimated to have been at an elevation of around 619 m. This outlet could possibly have connected with an aqueduct in the valley to the south that was re-established in the late Ottoman period and is still in use today (aqueduct DW04). An aqueduct block with a channel width of 0.19 m has been found next to this irrigation channel 60 m south of Birketein (site 107) but is not *in situ*. DW04 flows midway down the western part of the Wādi ad Dayr valley and is interpreted to have approached the North City wall close to 603 m elevation, and was used to irrigate Circassian fields within the city area.

Wādī ad Dayr East Bank Aqueduct

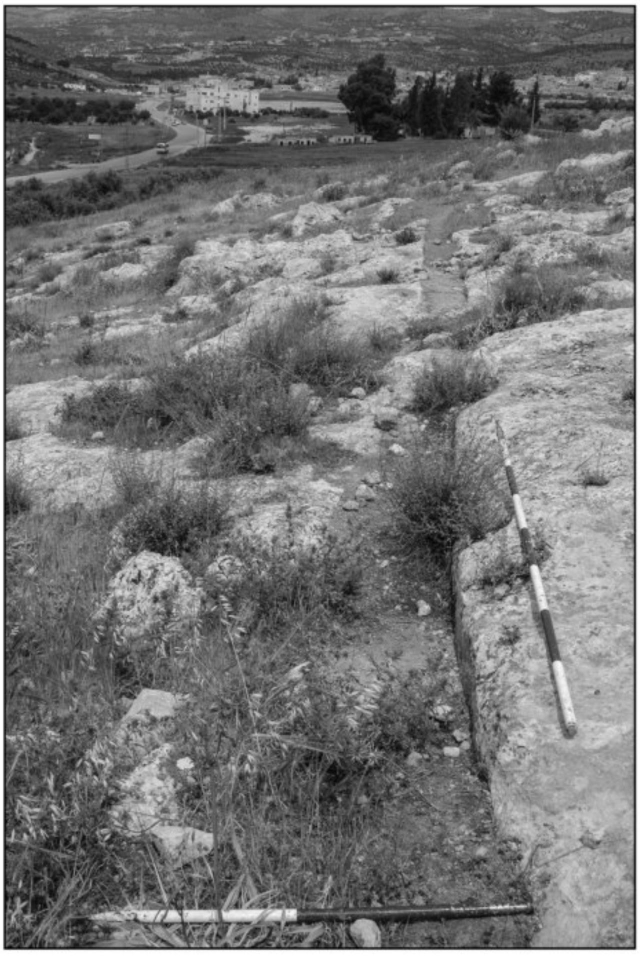
There is evidence of a channel (DE01) on the east side of the Wādī ad Dayr that was probably sourced direct from the wadi, with the offtake close to 620 m elevation located approximately 50 m east of Birketein reservoir. This channel lies just below the western edge of the modern road on the east side of the Wādī ad Dayr between Birketein and the city and would have irrigated the fields that occupied a narrow section along the eastern bank of the wadi – an area of only about 10 hectares - and any water mills located in the same area. It was in active use until recently but has largely disappeared, however occasional rock-cut sections point to construction in antiquity. It approaches the city wall at an elevation above 570 m and may have delivered a supply to the eastern part of the city above the level of Qairawan.

Bisās ar-Rūm Aqueduct

A 200 m long section of aqueduct (SE01) has been identified at approximately 640 m elevation to the north-east of Birketein on the east side of the Wādi ad Dayr valley (site 125). The channel is 0.5 m wide and mainly of rock-cut construction **(Fig. 11)**. The source is likely to have been the now defunct 'Ayn Bisās ar-Rūm (elevation 675 m) adjacent to Khirbat ash-Shawāhid, 1.1 km to the north-west, although some sections of the alignment are difficult to trace. The destination is uncertain, although an aqueduct at this elevation could have supplied the eastern side of Gerasa 2 km to the south.

Ash-Shawāhid Aqueducts

'Ayn ash-Shawāhid spring (elevation 650 m) to the south of the Sūf refugee camp is the source for at least one of two aqueducts that lie above the level of the Birketein Spring. In the Ottoman period the lower ash-Shawāhid aqueduct (SW01) supplied fields on the west side of Wādi Sūf and the water mill (tāhūnit as-samūri) installed in the Tomb of Germanus at Birketein. From here water was carried southwards in an earthen canal over the ruins



11. Rock-cut aqueduct from Bisās ar-Rūm at site 125 (D. Boyer).

of the festival theatre at Birketein[3] and then via an aqueduct along the west side of the Wādī ed Deir valley at an elevation of approximately 630 m. The southern rock-cut section of it can be traced to a point just north of the north wall of Gerasa on early aerial photographs. A section of it located just south of Birketein at an elevation close to 632 m is shown in a plan published by Kraeling (1938: 161)[4]. Early aerial photographs show that it went out of use prior to the early 20th century and was likely out of use prior to Circassian settlement. The section between ʻAyn ash-Shawāhid and the Tomb of Germanus is still used today for irrigation.

A short 70 m section of rock-cut aqueduct is located 120 m south-west of the Birketein reservoir. This aqueduct (SW02) has a 1 m wide channel and lies parallel to and to the west of the lower esh Shawāhid aqueduct SW01 at the higher elevation of approximately 640 m. Its source is uncertain but could have been ʻAyn ash-Shawāhid or another source higher up the Wādī Sūf valley. Its destination is also uncertain, but it may have been part of the system that also supplied the nearby Birketein baths and at one time perhaps joined with the lower esh Shawāhid aqueduct to the south closer to Gerasa. The existence of rock-cut side channels indicates that at least part of its function was to supply irrigation water. The working hypothesis is that the higher level aqueduct was constructed first – and from Steuernagel's evidence relating to esh Shawāhid spring (1925: 270) could have been in use in the Byzantine period – with the 1.5 km section closest to the source being replaced in the (?) Ottoman period by the lower level aqueduct. A later date for the lower aqueduct is implied by the fact that part of it passed over the ruins of the Birketein festival theatre.

North-West of the City, Including Dayr Aliyat
North-West Aqueduct

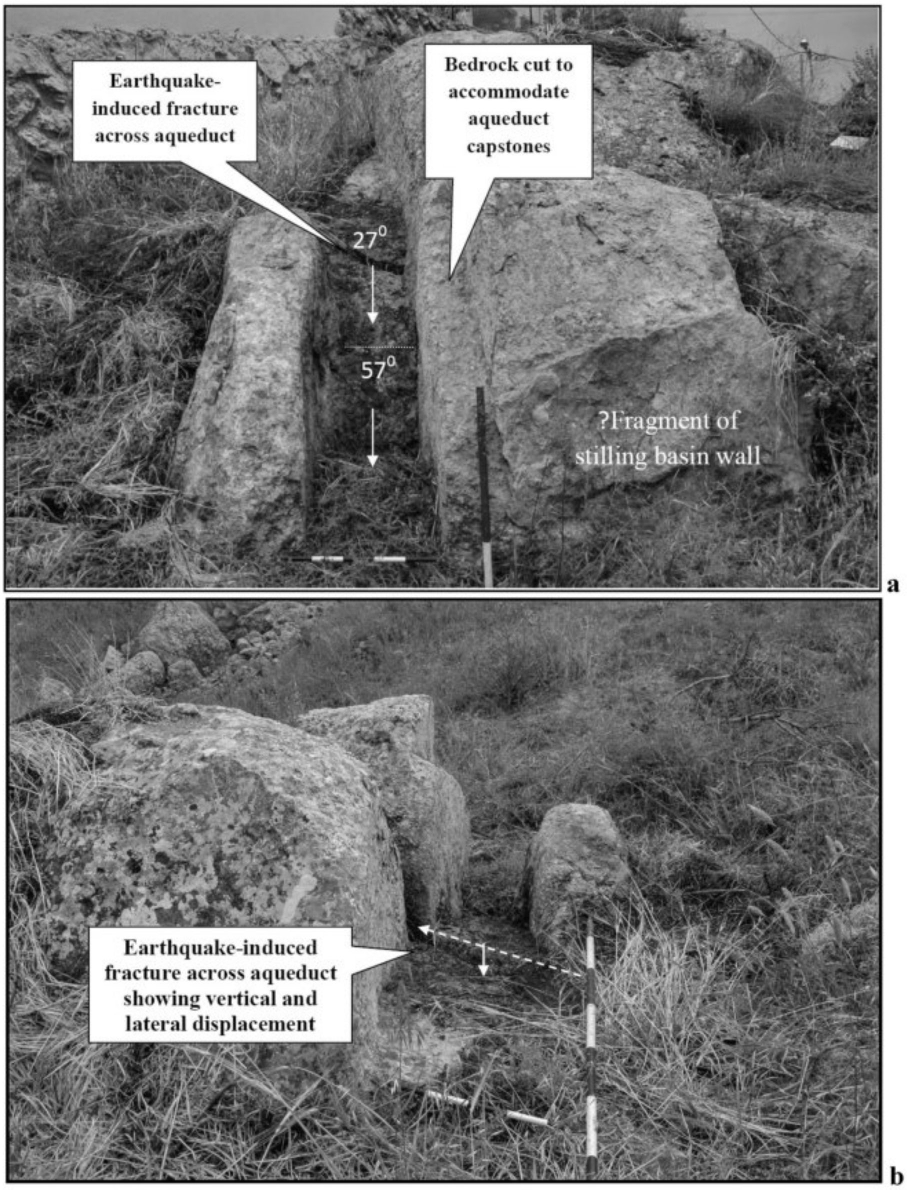
West of the city, important new discoveries have been made of elements of the aqueduct (North-West Aqueduct or JW01) that would likely have entered the city close to the North-West Gate. Three important new sections of this aqueduct were located during the survey, the longest being a 35 m rock-cut section at site 114.

Based on surviving in *situ* elements at six locations, the alignment of this aqueduct can now be traced for approximately 1 km north-west of the North-West Gate. Direct evidence of the aqueduct was first reported by the Jarash Hinterland Survey (Kennedy, Baker and Sharman 2005: Site 143), who recorded a southeast-trending 30 m long section of plastered rock-cut aqueduct about 170 m north-west of the North-West Gate of the city. This site has since disappeared under a building site. The source is not presently known, although it must lie above 740 m elevation. The steep 10% gradient of the 1 km section closest to the city would have caused engineering problems for this aqueduct. Water flow in aqueducts with such steep gradients had the potential to damage the structural components, so devices such as chutes, cascades and stilling basins were typically employed by Roman engineers to reduce the impact. An example of what is believed to be a stepped channel cascade (Chanson 2000: 47-8) has been identified in the rock-cut aqueduct at site 127. The base of the cascade is not exposed but there are two steps in the floor of the aqueduct – one with a gradient of 270 the other with a gradient of 570 – and a remnant of what may have been the wall of a settling or stilling basin at the foot of the cascade **(Fig. 12a).** The limestone bedrock had been cut to accommodate capstones over the aqueduct. The installation shows unrepaired earthquake damage in the form of a fracture with associated displacement **(Fig. 12b).**

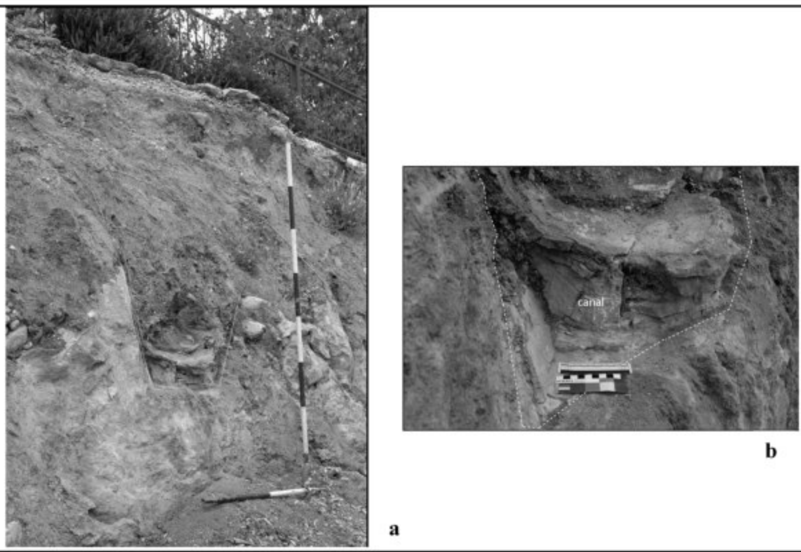
At site 128, 100 m down slope to the southeast of site 127, a cross section through another section of the aqueduct buried under 2.4 m of soil is exposed in a road cutting **(Fig. 13a).**

3.The Ottoman period earthen canal can be seen in photographs taken during the Yale expedition in May 1931. Examples include Yale University Art Gallery Negative number: gerasa-b287~01 b-287 and Negative number: gerasa-b273~01 b-273.

4.Seigne (2008: 176) postulates that the aqueduct at ca. 633 m elevation south of Birketein could have connected via a bridge or siphon with a spring (on the north side of the wādi) near the main pumping station, which he refers to as " ʻAyn ash-Shawāhid", although there is no evidence for such structures. The aqueduct he is referring to is in fact sourced from a spring on the south side of the wadi, referred to as ʻAyn ash-Shawāhid in this paper, and consequently there is no need to invoke a hypothetical bridge or siphon across the valley.



12. (a) Aqueduct with stepped chute and fragment of a possible stilling basin wall–site 127 (D. Boyer). (b) View down slope of aqueduct showing fracture and displacement by earthquake (D. Boyer).



13. (a) Buried section of North-West Aqueduct (JW01) exposed in road cutting at Site 128 (D. Boyer). (b) Detailed view of aqueduct showing plastered walls and rhythmic carbonate sedimentary layering representing approximately 100 years of stream flow (D. Boyer).

The aqueduct is trapezoidal in section, 0.35 m wide at the base, and was cut up to 0.7 m into limestone bedrock. A zone of rhythmically layered carbonate sediment or calcareous sinter (Sürmelihindi *et al*. 2013: 962) up to 145 mm thick lies on 10 mm thick plaster layer at the base of the aqueduct and is overlain by chaotic rubble fill. There is no evidence of capstones at this location. There is at least one major discordance in the layered carbonate sediment, but comparison with similar deposits described by Sürmelihindi *et al*. (2013: 961) – where the rhythmic layering of coarse crystalline carbonate alternating with finer grained layers has been shown to reflect seasonal deposition of carbonate in wet and dry seasons respectively – the layering in the aqueduct at site 128 indicates consistent aqueduct usage over a period of perhaps 100 years **(Fig. 13b)**.

Dayr al-Liyāt Aqueduct

The Dayr al-Liyāt Spring site was investigated as a possible source for the North-West Aqueduct. A section of a small rock-cut aqueduct was located 250 m south east of the spring at site 126, but at an elevation of *ca* 730 m it is too low to be the main source for the North-West Aqueduct and no trace could be found of a direct link between the two. The Dayr al-Liyāt spring may be the source of the small plastered aqueduct that passes under the threshold of the South-West Gate to a presumed destination in the south-west quarter of the city.

Wādi Jarash - East Bank

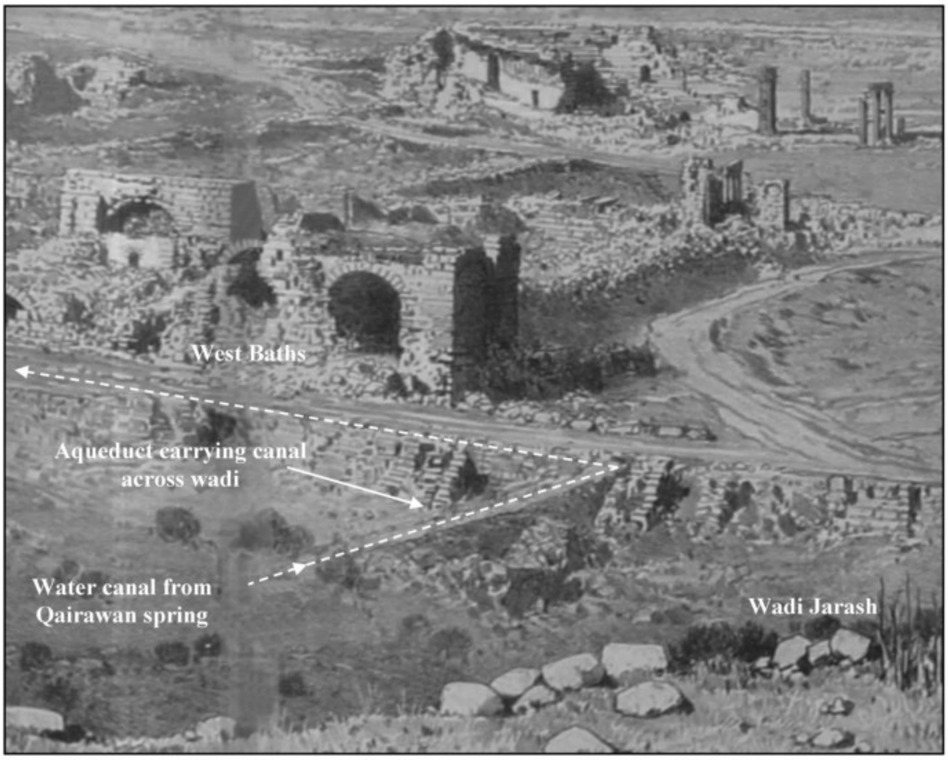
Qairawan Aqueduct

The low elevation of the Qairawan spring outlet at 566 m (Seigne 2004: 35) limited the potential use of its waters to destinations on the lower part of the eastern side of the city. Its use to supply the small Byzantine Baths is attested from the work done by Lepaon (2008: 65-67) and it is likely that the aqueduct continued a further 100 m to the south to supply the larger East Baths. It may also have continued beyond the East Baths to irrigate the Wādi Jarash south of the city, as it does today. Published reports by Buckingham (1821: 393) and many subsequent early-19th century visitors confirm that water from Qairawan was also carried westwards over the wādi via a crudely constructed aqueduct that connected with an aqueduct that carried water along the west bank to supply fields within the Hippodrome and further south. In 1816 Buckingham noted:

"From this fountain-head [Qairawan], the water goes off in two separate streams. One of these streams runs westward where it joins the channel worn by the rains, and joins the temporary brook….The other stream is carried by a sunken and stuccoed channel for about a hundred yards to the southward, when it turns off sharply to the west, and goes by a raised or arched aqueduct over the other portion of its own stream, now on a much lower level, until, gaining the brow of the western hill, it continues running along by it to fill the channels of the naumachia [Hippodrome] without the city walls." (1821: 393).

Robinson (1837: 234) describes the aqueduct over the stream as "a solid flat-looking structure, coming from the eastern hills, and not at all an attractive piece of architecture", and a rare image of this simple structure appears in a lithograph of a photograph taken by Rey in 1858 (Rey 1861: plate XX) **(Fig. 14)**.

A branch of this aqueduct carried water at a lower level along the west bank of the wādi to supply watermills and provide irrigation water. The system is poorly described by early visitors, but sections of it were clearly earthen canals dating to the Ottoman period prior to Circassian settlement. Charles Barry (1819: Diary 5th May 1819) refers to it as "an aqueduct formed of open channel stones" which could be a description of aqueduct blocks similar to those that form the DW01 aqueduct in the Wādī ed Deir valley. Despite the proximity of the West Baths to the aqueduct over the wadi and Qairawan spring, the West Baths and all of the water monuments on the west side of the city lie at a higher level and therefore the source(s) that supplied these



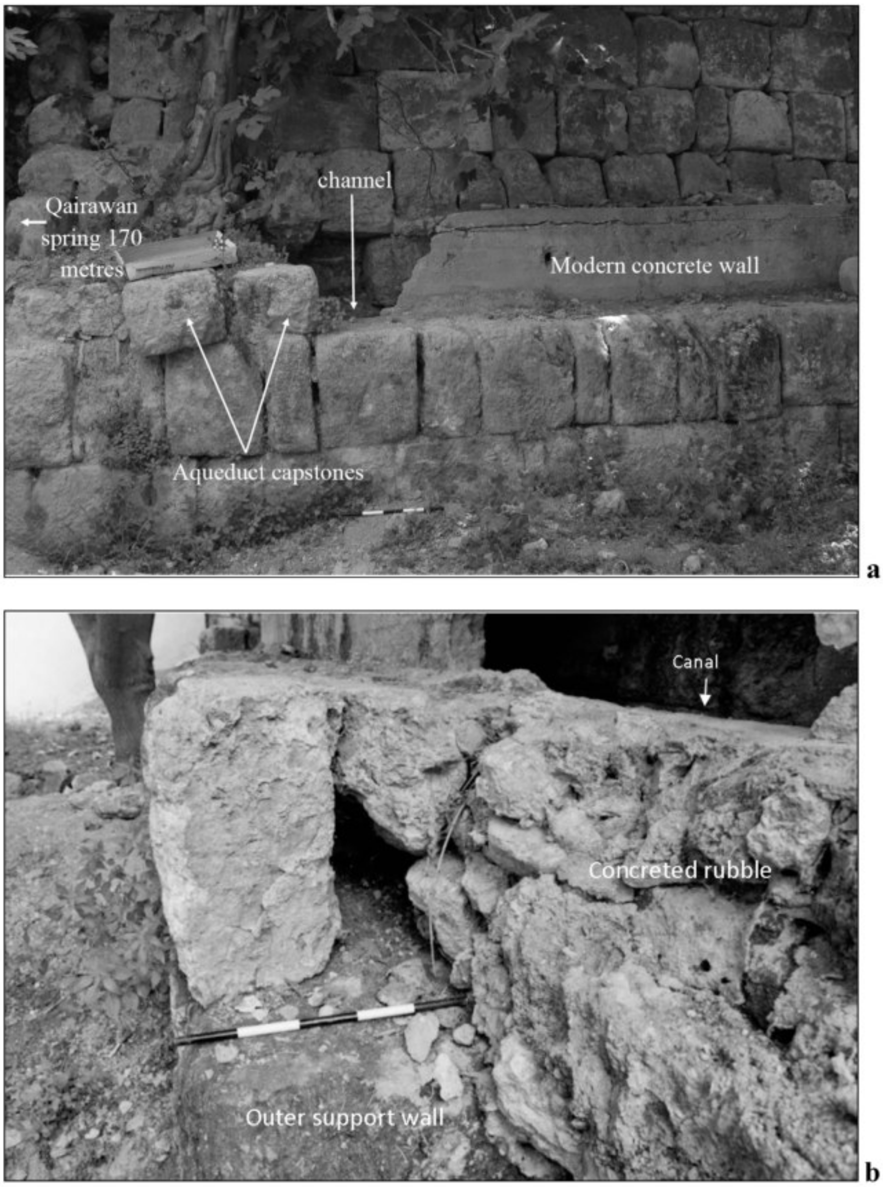
14. View of aqueduct carrying canal from Qairawan spring to west side of Wādi Jarash (From Rey 1861: Plate XX).

monuments must be found elsewhere. If water was supplied to the west bank from the east bank it must have come from a higher-level source than Qairawan.

A 25 m long section of aqueduct draining southwards from Qairawan spring was recorded by the Yale team in the 1930s on a 1:2500 scale plan (Yale University Art Gallery Negative number: 1938.5999.5004.30). A section of the aqueduct was recorded in the city in 2013, surviving as the rear boundary wall of a property (site 111). It is part of the section of the aqueduct that supplied the small Byzantine Baths - and almost certainly the larger East Baths further south – and is the only surviving section of the aqueduct on a 4 m high wall adjacent to the small Byzantine Baths reported by Lepaon (2008: 66-7). The plastered canal, 0.52 m wide and 0.62 m deep, lies on top of a masonry frame wall 20.8 m long **(Fig. 15)**. It stands 1.7 m above the present ground surface, but according to the property owner the wall was originally about 3 m high. Capstones are present over the canal at the northern end of the site, but they have been replaced by modern concrete at the southern end.

Tunnel Aqueduct

Approximately 1 km south of the city a 60 m long section of a rock-cut tunnel is preserved on the western edge of an outcrop of Kurnub Group sandstone that forms that east bank of the wādi at this point. It is the only known rock-cut aqueduct tunnel in the project area. The site was recorded by the Jarash Hinterland Survey in 2010 (Baker and Kennedy 2011: 459). The remains of what appear to be a group of rock-cut channels can be seen cut into the same limestone outcrop immediately down slope of the tunnel. The tunnel is at an elevation of approximately 500 m, but its source is not known. The tunnel has an irregular cross section, with a width of up to 0.75 m and a height of up to 1.5 m. It would have had a substantial carrying capacity, so the source is either a major spring - perhaps Qairawan - or stream flow from the wādi. Downstream from the tunnel an irrigation canal that was reused in the late Ottoman period can be traced down the east bank of the wadi for a

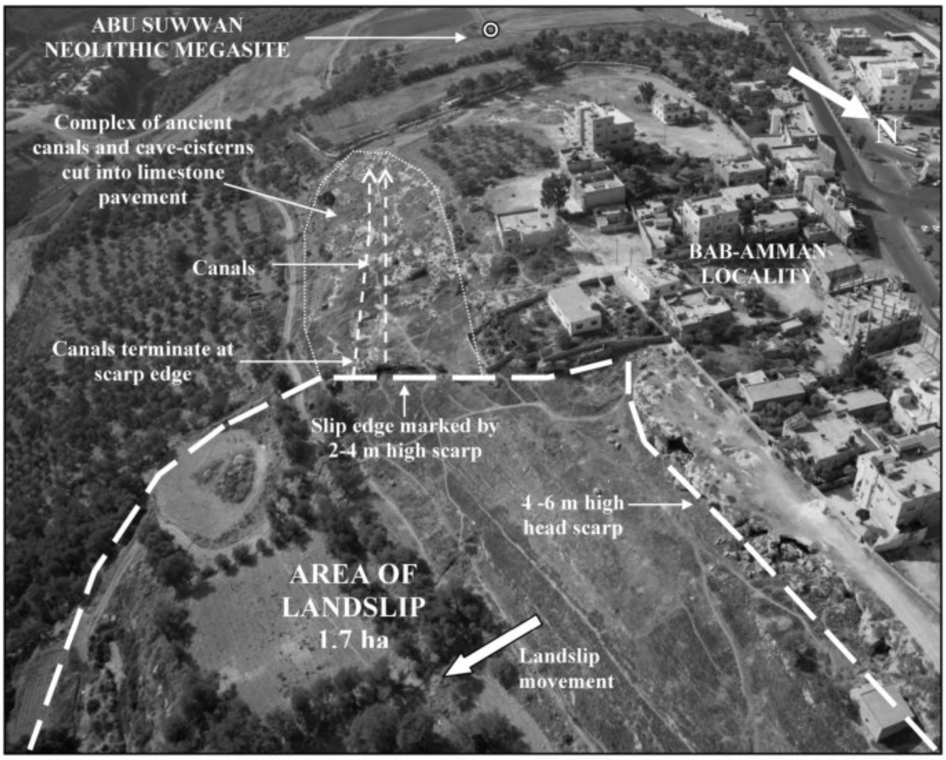


15. (a) Support wall and capstones of Qairawan aqueduct at site 111 (D. Boyer). (b) Construction components of Qairawan aqueduct (D. Boyer).

distance of almost 4 km.

West Bank Aqueducts

A system of rock-cut aqueducts and cisterns preserved in a limestone pavement over a distance of 150 m on the west bank of Wādī Jarash 250 m south east of Hadrian's Arch was visited to confirm the direction of flow. Levelling confirmed a southerly flow direction; the site had been recorded by the Jarash Hinterland Survey in 2010 (JHS site 744 - Baker and Kennedy 2011: 459). There is a particularly dense concentration of water installations at this location – collectively designated JW02 - which presumably directed water for irrigation to fields downstream in the vicinity of Bab Amman. To the north the aqueducts and limestone pavement terminate abruptly at a 4 m high scarp, which represents the southern edge of a large landslip that at some point in antiquity removed a 150 m long section of the eastern edge of the hillside above the location and also disconnected the aqueducts from their source. This slip - which is clearly visible on aerial photographs (**Fig. 16)** - covers an area of *ca* 1.7 hectares and was probably triggered by an earthquake. The source for the aqueducts is not known but must lie above 550 m elevation. The outflow from the



16. Bab Amman landslip locality showing termination of ancient canal complex. (Photograph Don Boyer © APAAME_20101021_DDB-0397).

drain east of the Hippodrome (see below) may have fed into these aqueducts.

<u>*Drain east of the Hippodrome*</u>

A short section of a rock-cut channel was identified under the east wall of the Church of Bishop Marianos (site 130) east of the Hippodrome. It is large, having a width of 1.7 m and a rock-cut depth of 1.0 m. The east wall of the Church of Bishop Marianos, built in AD 570 (Gawlikowski and Musa 1986: 137), was built over the drain **(Fig. 17a)** and provides a terminus post quem for its excavation and use.

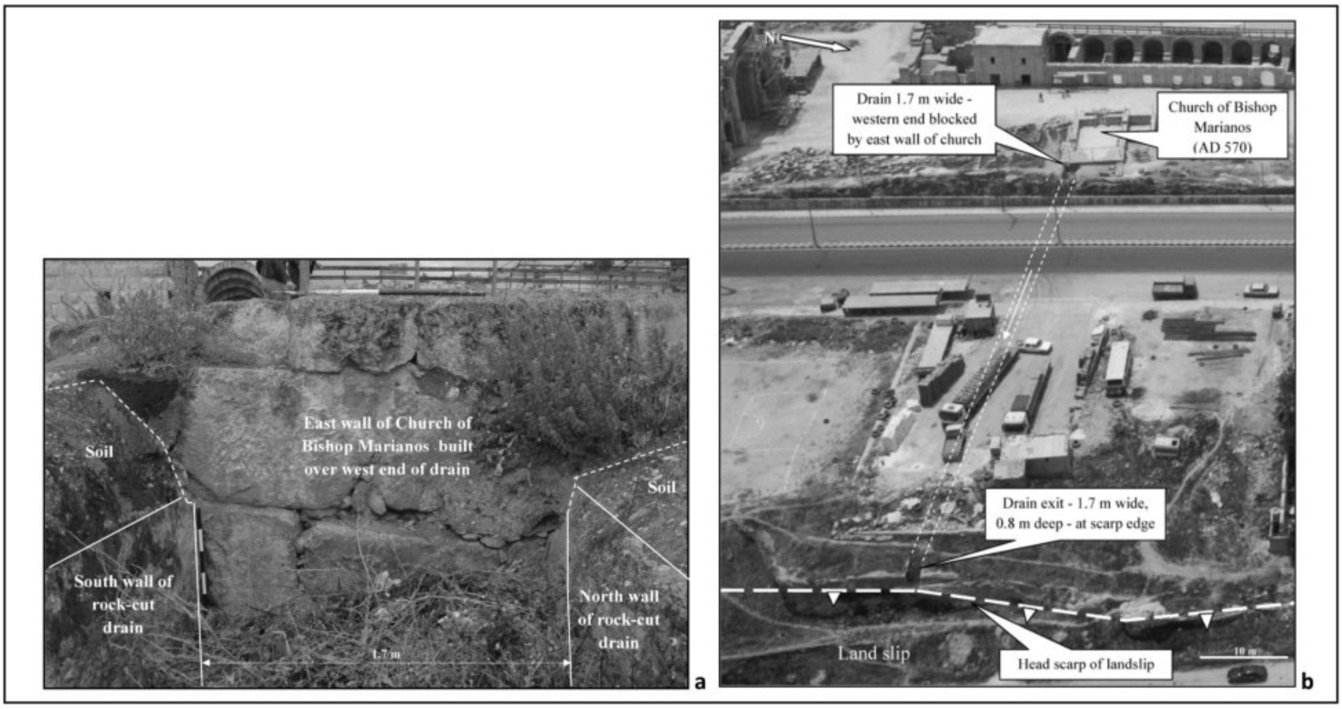
There is no trace of the channel west of the Church of Bishop Marianos but it can be traced on aerial photographs 80 m eastwards to the edge of the limestone scarp above Wādi Jarash where a short section is visible as a rock-cut channel 1.7 m wide and 0.8 m deep **(Fig. 17b)**. The size of the channel implies a high water carrying capacity, but its source is not known. It may have linked to the drains from the Hippodrome that exist under the north eastern section of the Hippodrome, but there is no direct evidence of such a link.

Wādī al-Majar

A very brief survey was conducted in the Wādī al-Majar and Wādī Tannur valleys to identify water structures. No spring-fed aqueducts were located within the Wādī al-Majar, which may be a function of the paucity of major spring sources in the valley and/or the preliminary nature of the survey, however a small rock-cut reservoir (site 133, previously a quarry) and a reasonably well preserved wine press and cistern installation (site 134) were recorded to the east of Khirbat al-Hute.

Wādī Tannur

Elements of a short, masonry aqueduct, including what may be a short cascade, were identified at Tannur spring (site 135). The channel is lined with *opus signinum* plaster and is entirely choked with carbonate sediment, which would have eventually caused it to pass out of use **(Fig. 18)**.



17. *(a) The drain at site 130 east of the Hippodrome, looking west. The east wall of the Church of Bishop Marianos can be seen built over the west end of the short section of drain, which is 1.7 m wide (D. Boyer). (b) Aerial view showing interpreted alignment of drain and drain end at edge of scarp. (Photograph Stafford Smith © APAAME_20100601_SES-0483)*

18. *Masonry aqueduct below 'Ain Tannur (site 135).The specus is entirely filled with carbonate sediment.*

Reservoirs / Birkets

Birketein

With a length of 88.5 m and a width of 43.5 m, the Roman reservoir located adjacent to the spring at Birketein 1.6 km north of the city is the largest reservoir in the project area. It is built of strong masonry, with a cross-wall dividing it into two unequally sized compartments; there is no evidence that it was roofed. A study of photographs in the Yale University Art Gallery collection suggests that the outer walls were originally 4 m high, with the top of the dividing wall being about 1 m lower. These dimensions give the reservoir a theoretical maximum capacity of 14,900 m^3 with the compartments having a reduced capacity of 11,100 m^3 to the top of the dividing wall. The smaller southern compartment has a maximum capacity of 2,300 m^3. Water flow from the larger to the smaller compartment was controlled via a sluice gate in the dividing wall (Kraeling 1938: 162). The reservoir is interpreted to have had the joint functions of storage and flow control.

The water from the southern reservoir

compartment would have been distributed via outlets in the southern wall, but there are few original features remaining as a result of the modern restoration of the reservoir. Today, the only outlet is a concreted irrigation canal that supplies the valley downstream but in the late 19th century there were two outlets in the south-west corner - a lion's head fountain and a lower ceramic pipe – and a canal through the central part of the south wall (Schumacher 1902: 165-171). There has been no published excavation of the area immediately south of the reservoir that could provide information on the distribution system downstream of the reservoir in the Roman period.

Other Reservoirs

Small reservoirs with original capacities estimated to be in the range 50-250 m^3 were identified at six locations. They have all been at least partly cut into limestone bedrock, and reuse of pre-existing quarry areas is suspected. There is one case (site 133), which is entirely rock-cut, and sites 109, 119 and 129 have evidence of masonry construction on at least one wall. Where observable, the floors are bedrock, but site 117 is unusual in that it had a mosaic floor.

The source of water for the reservoirs is sometimes difficult to determine. In the case of sites 109 and 133 the reservoirs stored water from the harvesting of rainfall from adjacent limestone pavements. An aqueduct source is suspected in the case of sites 113, 117 and possibly 110, although rainfall harvesting may also have been a factor in the latter case. The reservoir at site 129 stored water from a nearby (unnamed) spring.

Springs / Sources

The only spring site recorded during the survey is that of el-Hammām on the Wādī Zarqa near its junction within the Wādī Jarash (site 108). This is a *MEGA* site but very little information is available on it. El-Hammām is a mineral spring but is not very warm, and today the flow is weak. The spring is enclosed by a horseshoe-shaped platform of ancient concrete incorporating miscellaneous materials including some of dressed stone that is presumably the foundations of a spring-house or fountain-house dating to the Roman period **(Fig. 19a).** This was originally faced with a variant of *opus testaceum* known as *structura testacea*, made of level courses of tiles and mortar rather than bricks (Van Deman 1912: 390-1), and a small exposure of this facing material is visible on the west side of the structure **(Fig. 19b).** Schumacher visited the site in 1902 and referred to it as a Roman bath (1904: 74) but provided no description of the ruins. Glueck (1939, III: 220-221) reported evidence of what he thought to be a bathing establishment dating to Roman times, including fragments of Corinthian columns and an inscription, but no trace of these remain.

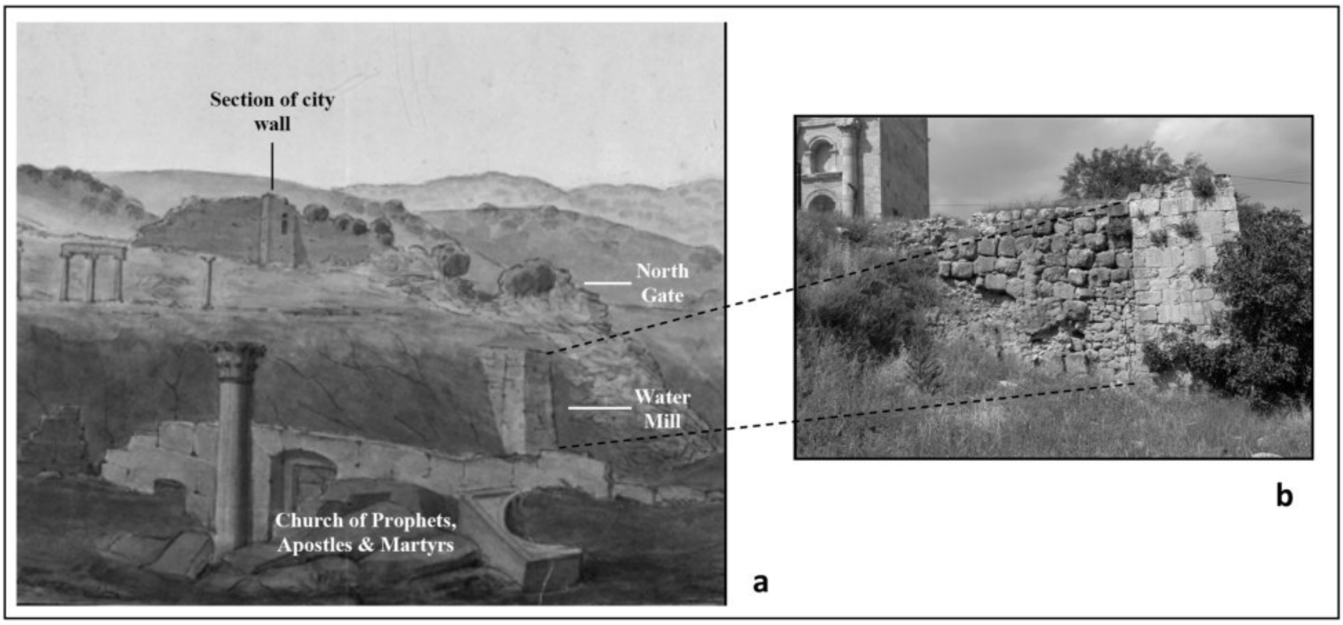
19. (a) Roman concrete foundations surrounding el-Hammām mineral spring (site108) (D. Boyer). (b) Ancient concrete, faced with structura testacea, on west side of structure (D. Boyer).

Water Mills

The water mill near the North Gate of the city was recorded. It is of the penstock (Arubah) type, and one of the few water mills in the district where there is some documentary evidence as to its age and use. The 6 m high penstock tower is constructed of well-dressed and squared limestone blocks and ashlars taken from buildings in the city, and includes at least one architectural piece. Some care was taken in the construction of the tower, and the reduction of the footprint of the courses with height results in an elegant design not often seen in such utilitarian structures **(Fig. 20b).** The arcuate support wall for the 15 m long mill canal is more crudely constructed. It has an outer course of large squared and roughly dressed stone, with a core of rubble and mortar. Only a small section of the base of the mill canal remains.

A pre-1816 construction date is indicated by the appearance of the mill in a plan and a watercolour by W.J. Bankes dating to around 1816 **(Fig. 20a)**, and Charles Barry also described it in his travel diary of 5th May 1819 (Barry 1819). Evidence from Bankes' watercolour drawing and the fact that Barry did not recognise the structure as a water mill, despite the fact that he would have seen similar mill structures in use during his travels to and from the site, indicates that the mill had been out of use for some time prior to the visit of these two men. It was recommissioned some time after Barry's visit, and was certainly in use in the post-Circassian period of settlement. Aerial photographs from the 1920s show a 600 m long canal on the west bank of the Wādī ad-Dayr that carried water from the Wadi to the mill through the North Gate via a crude masonry canal constructed over the Roman pavement (Fisher 1934: 5). The canal was in place at the time of Schumacher's visit in 1898 and the mill at that time was known as al-'Adabijeh (Schumacher 1902: 119).

A water mill was built into the ruins of the Tomb of Germanus near Birketein, with the two levels of the tomb substituting for the conventional penstock tower. It was recorded as tāhūnit as-Samūri (as-Samūri mill) by Schumacher (1902: 162-164; **Fig. 36**), and the ruined state of the water supply canal evident from Schumacher's photograph suggests that although of likely Ottoman date, its construction and use predates Circassian settlement. This mill was supplied via an aqueduct (SW01) from ash-Shawāhid spring.



20. (a) Penstock water mill at site 136 near Gerasa's North Gate as it appeared in 1816 watercolour by William John Bankes (Bankes Archive, Dorset History Centre ©: D/BKL:HJ IIIA). (b) Same water mill as it appears today (D. Boyer).

Wine Presses

A number of rock-cut wine presses were recorded in the survey. They comprise a treading floor that drains into a cistern or tank at a lower level, and fall into two groups. The first is a small, domestic sized installation with a treading floor <1.5 m2 draining to a small cistern – examples are sites 122 and 134; the second is much larger with treading floors of 5-20 m2, draining to one or two large vats, examples being sites 124 and 134.

Overview of the 2013 Survey Results

A total of 36 elements were recorded at 35 sites during the 2013 survey, the majority being aqueduct elements (23), reservoirs / tanks (6) and wine press installations (4). Most of the sites had not been previously recorded.

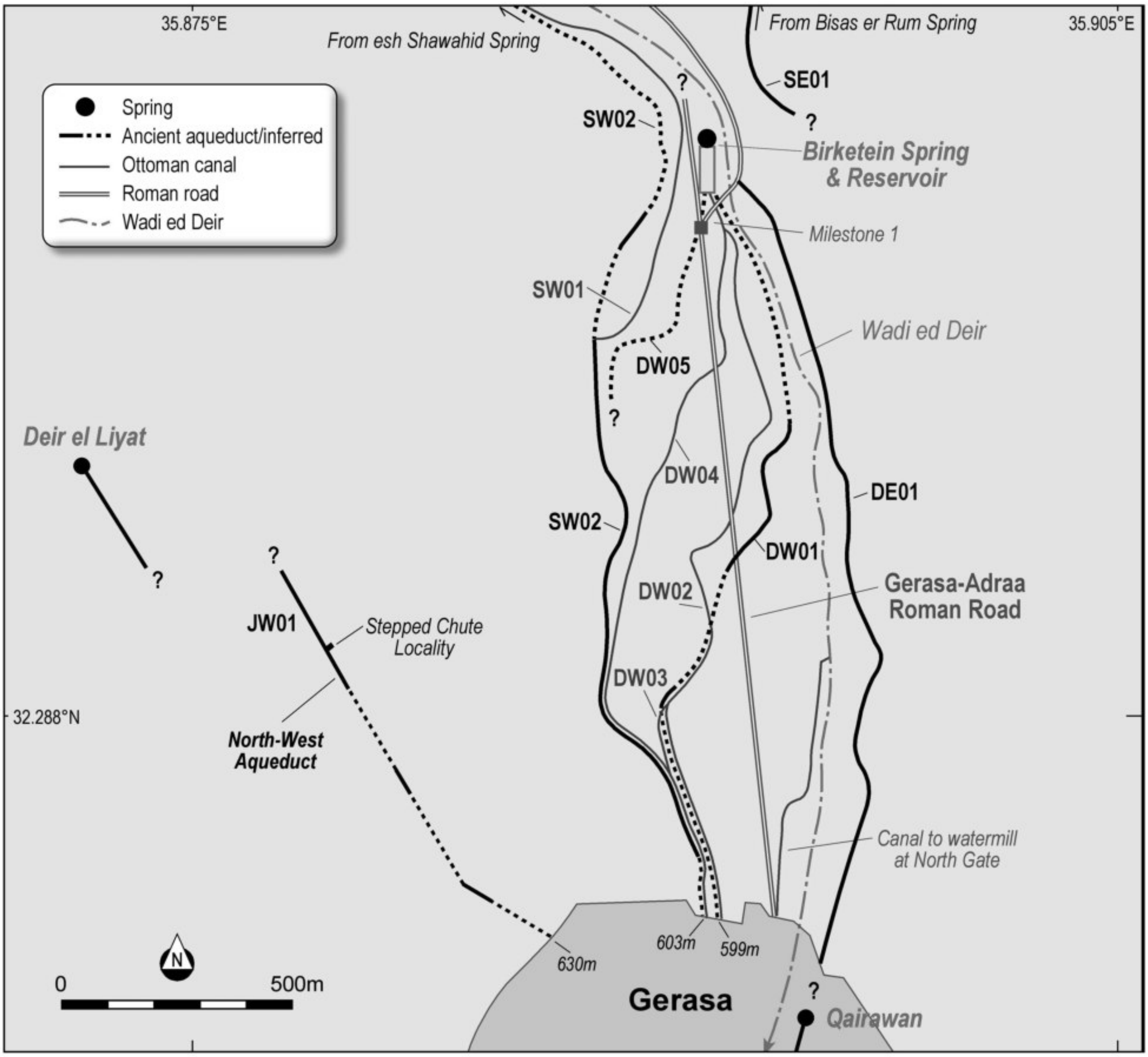
In 2008 the Jarash Hinterland Survey identified displaced elements of a masonry aqueduct of likely Roman - Byzantine date strewn over a distance of 450 m across the fields immediately west of the Wādī ad Dayr stream (Baker and Kennedy 2011). Unpublished evidence from the Yale mission in the 1920s and 1930s shows that although these aqueduct elements were not *in situ*, they closely relate to a section of aqueduct that could be traced over a distance of 370 m close to the 608 m contour. This aqueduct (DW01) lies close to the Wādī ad Dayr stream bed and may have been sourced from either the wadi stream itself or from Birketein 500 m upstream to the north-west. **(Fig. 21)**

DW01 can be traced to a point 450 m north of the north city wall, and may have continued to the city as a rock-cut aqueduct and entered the city close to 599 m elevation, however no point of entry of the aqueduct into the city dating to the Graeco-Roman period has been identified. Early aerial photographs and evidence from the Yale mission show this 450 m section certainly formed part of a larger system that supplied irrigation to the city area in the late Ottoman period. The function of the DW01 aqueduct is likewise unclear; it crosses the western part of the fertile valley of Wādī ad Dayr and the existence of aqueduct blocks with smaller channels suggests that at least a portion of the supply was directed to agriculture in this area.

The 2013 survey of Wādī ad Dayr area identified several masonry aqueduct blocks immediately south of Birketein. These are similar in size and design to the aqueduct blocks that make up JW01 500 m to the south, but there is no hard evidence of a connection between the two.

Elements of higher-level aqueducts exist on both sides of Wādī ad Dayr valley. On the east side, a 200 m long section of a largely rock-cut aqueduct exists to the north east of Birketein at *ca* 640 m elevation. The source is probably the now abandoned ʻAyn Bisās ar-Rūm Spring adjacent to Khirbat ash-Shawāhid, but the destination is uncertain. An aqueduct at this elevation could have supplied the eastern side of Gerasa, but no link to this area has been found to date. On the west side of the valley there is evidence of at least two aqueducts above the level of the Birketein spring; one definitely sourced from the esh Shawāhid spring on the south side of Wādī Sūf that was used in the late Ottoman period to deliver water to the city area via a channel that crossed the wall at *ca* 603 m elevation, the other probably an earlier aqueduct from the same source. The latter aqueduct is only known from a single rock-cut section <100 m in length south west of Birketein reservoir. While its destination is not currently known, it may have formed part of an aqueduct that supplied the west side of the Wādī ad Dayr valley and Gerasa.

West of the city, important new discoveries have been made of elements of the aqueduct (North-West Aqueduct) that would have entered the city close to the North-West Gate. Based on surviving *in situ* elements at six locations the alignment of this aqueduct can now be traced for approximately 1 km north west of the gate. The source (or sources, as the aqueduct may well have drawn from a number of springs) is not presently known, although from the elevation of the highest known section it must lie above 740 m elevation. Springs at around 800 m elevation located midway between Dayr al-Liyāt and Sūf are considered to be the likely source; if correct,



21. *Details of aqueducts north of Gerasa (D. Boyer).*

this would give the North-West Aqueduct a length of around 5 km from the North-West Gate, its likely entry point into the city. The approximate 10% average gradient of the 1 km section of this aqueduct so far confirmed would have created a number of constructional problems related to high water flows. Flow reduction methods such as the use of cascades and stilling basins were in use during the Roman period, and part of a probable stepped cascade was discovered *in situ* in a short section of the aqueduct during the survey (Site 127).

Aside from the well known reservoir at Birketein, which had a theoretical maximum capacity estimated to be 14,900 m^3, reservoirs of likely Roman-Byzantine date were identified at six locations outside the city. All were either entirely or partially of rock-cut construction, probably representing a reuse of previously quarried areas. Only one is complete, with original capacities estimated to be in the range 50 to 250 m^3. While some were connected to local spring supplies, others (e.g. site 133) represent likely opportunistic reuse of a quarry area for rainwater catchment. The reservoir located on the hillside west of the esh Shawāhid Spring is unusual in that it had a mosaic floor (site 117). The existence of well-dressed blocks in a nearby farm wall, including a Christian cross cut into one block, suggests some early Christian occupation and raises the possibility that the structure had some other use – perhaps as a bathing pool.

A very brief survey was conducted in the Wādī al-Majar and Wādī Tannur valleys to identify water structures. Elements of a masonry aqueduct (including what may be a short cascade) were identified at the Tannur Spring, where it carried spring water to a possible tank at its base, and the spring also supplied rock-cut aqueducts for downstream use on both sides of the Wādī Tannur. No spring-fed aqueducts were located within Wādī al-Majar during the brief survey, which may be a function of the limited survey coverage.

Water installations are often difficult to date, and this is particularly the case in surface surveys where there is no excavation to place the structures in context. None of the sites recorded has been dated, with the exception of the large drain from the Hippodrome area that was built over by the construction of the Church of Bishop Marianos that effectively gives a pre-AD 570 date for the construction of the drain (Gawlikowski and Musa 1986: 137). However many of the sites recorded during the survey have vestiges of wall and floor plaster, and the possibility of dating the plaster will be investigated. There is evidence of several applications of plaster over time in the case of the buried section of the North-West Aqueduct (site 128), and the dating of these components could provide a valuable insight into aqueduct use. Use of the distinctive red coloured *opus signinum* plaster was noted on walls at a number of sites, including aqueducts, reservoirs, cisterns and wine presses. In rural settings, domestic sized rock-cut wine press installations (treading floor area <1.5 m2) were recorded at two locations; in both cases larger, probably commercial scale installations lay either immediately adjacent or close by (sites 123 and 136).

Preliminary Conclusions

A substantial and relatively sophisticated water delivery system to and within the city must have been in place by the beginning of the 2nd century AD in the case of the west side of the city, and probably sometime in the 2nd century AD on the east side, but the actual date of the establishment of the hydraulic system is not known. The existence of an irrigation system between the Birketein reservoir, 1.6 km north of Jarash, and the western side of the city in the late Ottoman period demonstrates that it would have been possible to have delivered water from Birketein to the city in the Roman - Byzantine period at a level (599-603 m) that would have been adequate to supply all the major monuments on that side of the city[5]. While there is little substantive evidence of water actually being supplied to the city by an aqueduct directly from Birketein during the Classical period it is possible that this was the case, however it would likely have been one of a number approaching the city from the north and therefore the popular hypothesis that the spring and reservoir at Birketein was the sole source of water to the monuments on the west side of the city is not supported by the available evidence. To the north of the city there is evidence of aqueducts approaching the city on both sides of the Jarash Valley. On the west side, potable water from two west-bank springs - esh Shawāhid and probably Birketein - was carried in mainly rock-cut aqueducts and delivered to the city at approximately 599-603 m elevation. On the east side, an aqueduct from Bisās ar -Rūm spring at Khirbat ash-Shawāhid may have delivered potable water to the eastern part of the city at a higher elevation than Qairawan spring,

5.This resolves the levelling concern expressed by Seigne: "De plus leur niveau de départ, situé à ± 618 m, et la topographie locale ne leur permettaient apparemment pas de rejoindre la cité à un niveau suffisant." (2004: 176).

and within the city an aqueduct delivered water from Qairawan to and the Byzantine Baths and probably the East Baths. From the north-west, a major aqueduct (North-West Aqueduct) approached the city from a high level on a steep 10% gradient and would have entered the city close to the North-West Gate, however the source has not yet been identified. It is likely that water from the North-West Aqueduct was delivered to large cisterns or reservoirs located on the hills on the west side of the city - such as the 40 m by 20 m cistern located west of the Temple of Artemis. It could have readily provided supplies to virtually any part of the city, but the reticulation network remains to be demonstrated.

In the late Ottoman period much of the Jarash Valley was irrigated by a network of canals from spring and wadi sources over a distance of 10 km from Khirbat ash-Shawāhid to the junction of Wādī Jarash with the Wādī Zarqa, and it is likely that this was also probably the case in the Roman - Byzantine period. Cultivation of the floor of the Wādī ad-Dayr valley over the centuries has removed much of the evidence of the early aqueduct system from Birketein reservoir, but displaced sections of a major masonry aqueduct discovered by the Jarash Hinterland Survey in 2008 probably formed part of an irrigation system – perhaps shared with a supply to the city - sourced from either Birketein or the wadi stream. The agricultural areas in the Jarash valley south of the city were well serviced by a number of aqueducts on both sides of the wadi, including one aqueduct on the east bank that includes a rare tunnel section. To the east of Gerasa the absence of major springs and of any evidence of aqueducts point to the soils of the Wādī al-Majar valley not being irrigated during the Roman - Byzantine period, however the strong springs in the Wādī Tannur valley downstream probably sustained an aqueduct system that serviced both sides of the small wādī as is the case today.

While the sources of water supply to Gerasa have been clarified, there is much that is still obscure or uncertain. Fundamental questions still remain as to when the various aqueducts were in use, when they went out of use and where the supplies were directed. The aqueducts approaching the city from the north may have served dual functions in supplying both the city and the agricultural hinterland, whereas the North-West Aqueduct probably only supplied potable water to the city. While the evidence of carbonate sediment in the North-West Aqueduct indicates continuous use over an extended period – perhaps 100 years – it is not known when the system was constructed or when it went out of use, however evidence at one locality points to severe earthquake damage that would have rendered it inoperable if the aqueduct had been in use at the time. There is a critical need to date the construction and use of the various elements of the hydraulic system, and to identify where the various water supplies were used. Future work will include the sampling of plaster and cement lining the water installations to obtain dating information and the sampling of the carbonate sediment to yield climate proxy data and data on the chemistry of the various water sources.

Ongoing housing development in the Jarash area is destroying many archaeological sites before they can be recorded, and housing development is now moving away from the immediate city area to include neighbouring rural areas. The recording of sites is therefore a race against time. Experience from the Jarash Hinterland Survey has shown that even important sites where further work or preservation has been recommended are not immune to this destruction.

Acknowledgements

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Appendix: Site details

Site No. (JWP_)	lat (N)	long (E)	Elev	Remarks
102	32.30124	35.89284	628	Kerb of part-dressed stone in Wādi
103	32.29798	35.89167	635	Aqueduct *specus*
104	32.30342	35.88726	644	?part of stone aqueduct
105	32.28872	35.89203	609	Aqueduct *specus*
106	32.29836	35.89358	623	Aqueduct *specus*
107	32.29848	35.89329	617	Aqueduct *specus*
108	32.21409	35.89371	234	el-Hammam mineral spring
109	32.31461	35.89049	724	Rock-cut reservoir
110	32.31465	35.88779	738	Rock-cut reservoir & quarry
111	32.28055	35.89484	562	Roman stone aqueduct
112	32.29129	35.88309	743	Rock-cut aqueduct
113	32.29095	35.88286	735	Rock-cut reservoir
114	32.29077	35.88352	730	Rock-cut aqueduct
115	32.29722	35.88078	760	Rock-cut aqueduct & ? reservoir
116	32.31563	35.86983	770	Muqibleh Spring water tunnel (Ain Hussein)
117	32.30507	35.88397	671	Rock-cut reservoir + mosaic floor
118	32.30952	35.87624	690	Rock-cut aqueduct-part plastered
119	32.30501	35.88323	689	?aqueduct
120	32.30571	35.88223	681	Rock-cut aqueduct
121	32.30702	35.89041	669	Stone & rock-cut aqueduct
122	32.306	35.88986	663	Small wine press
123	32.30559	35.88989	668	Large wine press
124	32.30071	35.89164	637	?aqueduct
125	32.30124	35.89426	642	Rock-cut aqueduct
126	32.29165	35.87971	731	Rock-cut aqueduct
127	32.28991	35.88402	718	Rock-cut aqueduct--chute cascade
128	32.28931	35.88449	710	Rock-cut aqueduct, plastered
129	32.29001	35.87904	692	stone & rock-cut reservoir
130	32.27281	35.89141	574	Rock-cut drain/aqueduct
131	32.27414	35.89101	565	Aqueduct, rock-cut and concrete
132	32.2704	35.89297	553	Rock-cut aqueducts & reservoir
133	32.31403	35.92029	840	Rock-cut reservoir (ex quarry)
134	32.31165	35.92198	820	Wine presses & cistern
135	32.24372	35.92457	473	Stone-built aqueduct
136	32.28422	35.89476	588	Water mill, Arubah type

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