WATER CASCADE AT ANDRIAKE

NEW OBSERVATIONS AND INSIGHTS

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Cura Aquarum in Israel

In memoriam Dr. Ya'akov Eren

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The Water Cascade at Andriake. New Observations and Insights

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At the 10th International Cura Aquarum held in Sicily, Melissa Mengel and I presented a paper on an unusual stair step structure situated along the course of the aqueduct which was built to service Myra and its port city of Andriake in antiquity.

This article reviews recent observations and provides new insights not only into this unique stair step structure but also into a retaining pond that the authors had the opportunity to research on subsequent visits to the Myra area.

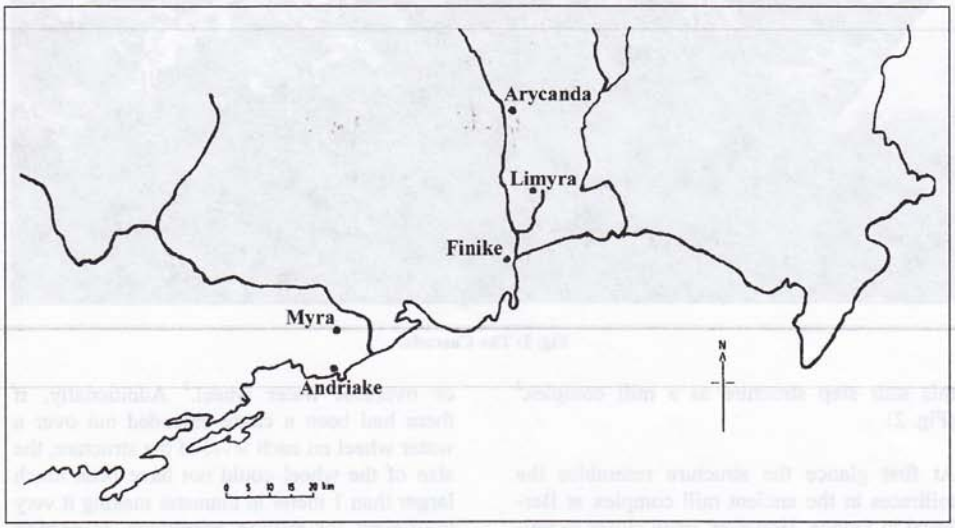

Fig. 1: Lycia.

Andriake grew up at the mouth of the Andrakos River and is first mentioned in the records as a Hellenistic settlement. The harbor city prospered under Roman influence and became an important shipping center for grain from Egypt as well as local agricultural products from the hinterland. Water sources in the immediate area of Andriake were of poor quality being both sulfurous and saline. The Romans located an acceptable fresh water source in the foothills above Myra.[1] Utilizing a combination rock cut and surface built aqueduct, fresh water was brought to Andriake (Fig. 1).

Roughly 6 kilometers from Myra the aqueduct makes a sharp turn and drops in elevation from the hillside to the level of the alluvial plain. This was accomplished by the means of a short raised arcade, which ends in a large stone structure made up of levels or steps. Our original research focused on an earlier archaeological survey of Myra, which identified

1 Borchhardt 1975

Fig. 2: The Cascade.

this stair step structure as a mill complex[2] (Fig. 2).

At first glance the structure resembles the millraces in the ancient mill complex at Barbegal in France. However, upon closer examination several fundamental elements are found to be missing. There is no evidence of an associated mill house. The adjacent area around the stair step is close to bedrock and no foundations are evident that would have indicated a mill house. Even if a building had been constructed using only timbers, postholes in the ground nearby and attach points for the building would have been evident in the outer walls of the structure. The size of the individual stair step tanks would not have properly accommodated either an undershot or overshot water wheel.[3] Additionally, if there had been a chute extended out over a water wheel on each level of the structure, the size of the wheel could not have been much larger than 1 meter in diameter making it very inefficient for milling operations. Inspection of the structure showed no signs of mounting points to support a water chute either on the top or the front of each tank. The conclusion then was that the stair step structure was simply an energy dissipation device utilized to accomplish a significant drop in the aqueduct's elevation over a relatively short distance and that it was not a mill complex.[4]

2. Ibid 71-72

[3] Moritz, L., 1958, 132-33, provides the reader with simple illustrations of the various types of water mills. Wikander, Ö., 2000, 373-378, classifies types of ancient mills and discusses archeological evidence for vertical and horizontal mills.

[4] Murphy, D., Mengel, M., 1998, personal discussions with attendees at the Cura Aquarum in Sicilia suggested that this structure was not a mill.

On subsequent visits to Andriake we continued to explore both of these ideas. The present day owner of the property had removed much of the thick undergrowth, which revealed additional features not previously observed. Additional levels of the stair step have been exposed along with several small rock-cut channels and rock-cut rooms in the adjacent area. A retaining pond was located further upstream on the Andriake aqueduct which raised new questions as to the function of the water conduit. It is these new features and observations that are the topic of this paper.

The Arcade

The channel directly upstream of the cascade is carried on an arcade approximately 40 meters in length with an estimated slope of 2 degrees. It is constructed of mortared masonry and consists of eleven arches. Each arch averages 2 meters high by 2.75 meters wide. These dimensions are fairly typical for a small arcade. The channel on top averages 33 cm wide by 38 cm deep and is constructed of mortared masonry in the same style as the arcade. The walls of the channel are 28 cm thick and lined with a 2 to 3 cm waterproof layer of *opus signinum*. There is evidence that the original channel had been filled in and a new section of channel constructed on top of it at some point in time. Whether this was due to an error in the slope of the aqueduct by the original builders or whether it directly related to the construction of the stair step cascade could not be determined at this time.

The Cascade

The stair step cascade is located approximately midway between Myra and Andriake along the course of the aqueduct. The structure is orientated in a southeasterly direction and in what appears to be away from the port city. This cascade is constructed of the same mortared masonry as the arcade. It was previously thought to consist of only five levels or tanks, which would have served the function of dropping the level of the aqueduct approximately 11 meters in the relatively short distance of 18 meters. It now appears that the cascade consists of at least seven levels. This increases the known drop to 15 meters over a length of 25 meters distance.[5] This is considerably more than the original estimate. (Fig.3)

The size of each tank is fairly uniform varying from 1.75 meters wide by 3.30 meters long to 1.85 meters wide to 3.70 long. The thickness of the walls averages from 70 cm to 73 cm. The height from the floor of each tank to the top of the preceding level measures 3 meters. The front of each tank adjacent to the next lower level is only about 78 cm in height.

We were able to determine that the waterproof layer of *opus signinum* only extended approximately three-quarters of the way up the sides of each tank. Furthermore the waterproof layer did not extend all the way up the back wall of each tank where the water would normally have flowed down from level to level as in a simple cascade. This brings into question the earlier hypothesis that this structure was just a simple energy-dissipation device.[6] Excavation is required to determine exactly how many levels there ultimately may be and what type of terminus might lay at the bottom.

Located in the southwest corner of the level 5 tank, counting down from the top of the cascade, is a 35 cm diameter terracotta pipe which went through the wall of the tank and allowed water to flow out the south side of the cascade. The pipe is set 35 cm above the floor of the tank, so it would not have completely

[5] Hodge, T., 1992, 160-161 provides a concise explanation of open and closed cascades, Leveau and Paillet, 1976, the steep chutes at Chabet ilelouine (Cherchell) were wider then the main channel., Chanson, H., 2000, see AJA 104 for detailed information on cascades and dropshafts, 55-56 suggests that the design of the chutes at Cherchell was introduced to maximize flow resistance.

ously throught to consisted of only five levels or 6. Chanson, H., 2000

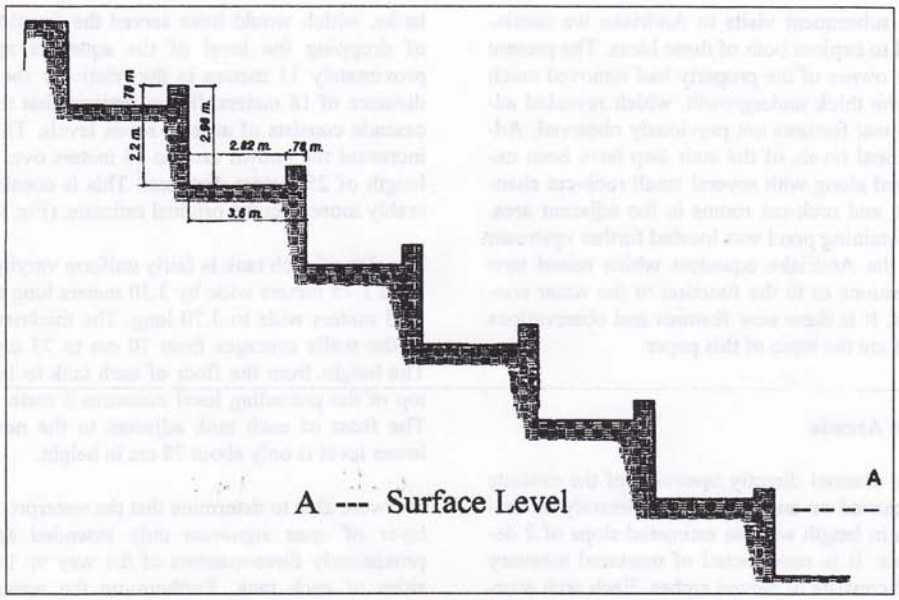

Fig. 3: Cascade Cross Section.

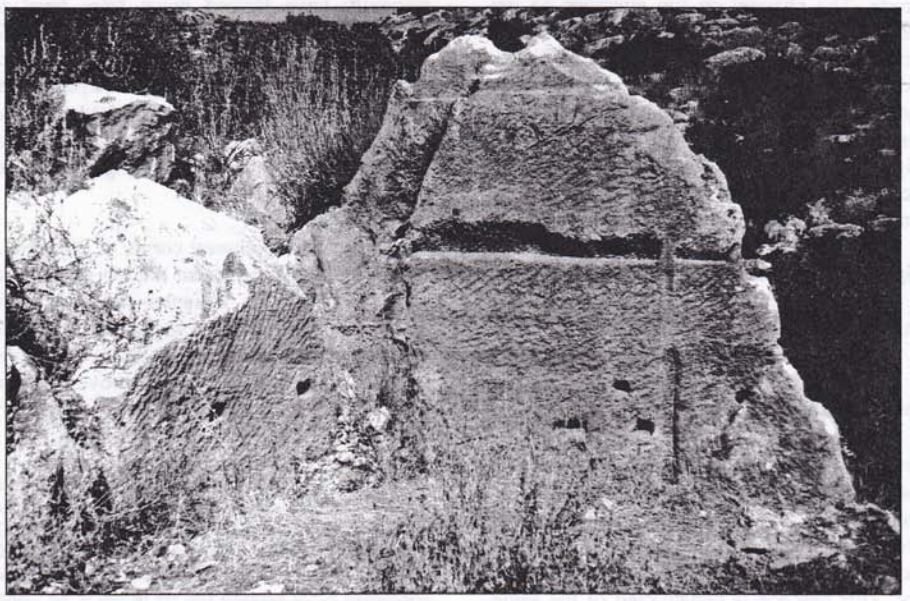

Fig. 4: Rock Cut Room.

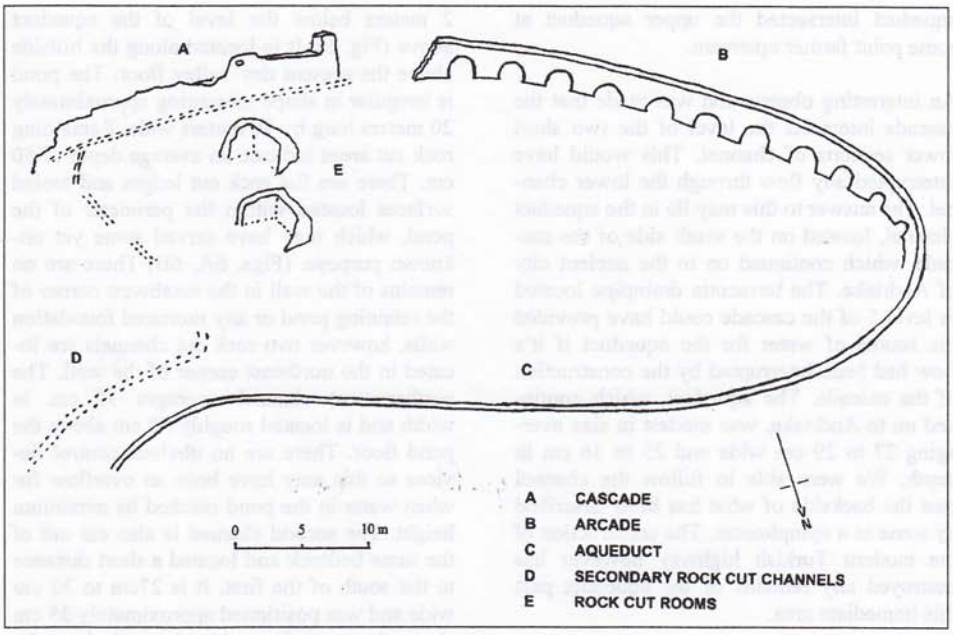

Fig. 5: Site Plan.

drained the tank. The waterproofing is finely contoured around the pipe and does not show any evidence of wear that might have indicated use of a plug inside of the tank. This indicates that water could have flowed freely out of this level or there might have been a valve at the outer end of the pipe that would have controlled the flow. It is obvious that it was placed in such a way as to maintain a minimum amount of water in level 5 before allowing the water to exit the tank. It is also likely that as the water exited the cascade via the pipe, it flowed into a near by rock cut channel that continued on toward Andriake.

Secondary Channels

There are several rock cut channels in the vicinity of the cascade. One channel is cut out of bed rock at the base of the cascade and extends the entire length of the north east side of the cascade. This channel is located on the uphill side of the cascade and could have possibly served as a conduit for run-off water in order to protect the structure from erosion (Fig. 5).

Remnants of two short sections of channel are cut into the bedrock and located to the north east of the cascade. The first section of the channel is perpendicular to the cascade and in line with the last step of the structure that is left exposed at current ground level. The second short section of the channel is located at a slight upward angel to the first and appears to follow the contour of the hillside to the north.

These two short sections of channel appear however to be on a level with another rock cut channel located 24 meters farther to the north and quite possibly were a continuation of it. It was not possible to follow the course of this lower aqueduct due to thick brush and undergrowth. It is unknown whether this lower

aqueduct intersected the upper aqueduct at some point farther upstream.

An interesting observation was made that the cascade intersects the level of the two short lower sections of channel. This would have interrupted any flow through the lower channel. The answer to this may lie in the aqueduct channel, located on the south side of the cascade, which continued on to the ancient city of Andriake. The terracotta drainpipe located in level 5 of the cascade could have provided the source of water for the aqueduct if it's flow had been interrupted by the construction of the cascade. The aqueduct, which continued on to Andriake, was modest in size averaging 27 to 29 cm wide and 25 to 36 cm in depth. We were able to follow the channel past the backside of what has been described by some as a nymphaeum. The construction of the modern Turkish highway however has destroyed any remains of the aqueduct past this immediate area.

General Vicinity

There are also two rock cut rooms located to the north of the cascade. The first room is located 6.6 meters from the cascade and is in line with the end of the third level tank. This room is approximately 4 meters by 7 meters in size. The second room is a little farther to the north and a bit smaller at roughly 3.6 meters wide by 7 meters. There was no evidence of a front foundation wall or doorway, which might have closed off these rooms to the elements. There is evidence of cut ledges and niches in the sidewalls, which might have supported timbers or possibly a floor. The function of these rooms or how they related to the cascade could not be determined at this time (Fig. 4).

Retaining Pond

The remains of a rock cut retaining pond were found approximately 300 meters upstream and 2 meters below the level of the aqueduct above (Fig. 6). It is located along the hillside above the present day valley floor. The pond is irregular in shape measuring approximately 20 meters long by 10 meters wide. Remaining rock cut areas indicate an average depth of 50 cm. There are flat rock cut ledges and tooled surfaces located within the perimeter of the pond, which may have served some yet unknown purpose. (Figs. 6A, 6B) There are no remains of the wall in the southwest corner of the retaining pond or any mortared foundation walls, however two rock cut channels are located in the northeast corner of the wall. The northernmost channel averages 35 cm in width and is located roughly 50 cm above the pond floor. There are no obvious control devices so this may have been an overflow for when water in the pond reached its maximum height. The second channel is also cut out of the same bedrock and located a short distance to the south of the first. It is 27cm to 30 cm wide and was positioned approximately 35 cm above the pond floor. Also located along the length of this channel is a 30 cm diameter hole cut to a depth of 17 cm. This might indicate that a control device of some type had been installed since this channel was approximately 15 cm below the depth of the first one. It appears that at some point in time water was diverted from the main aqueduct channel to supply the retaining pond. The purpose of this pond is not exactly known, however it would have been well suited to support agricultural activities in the fertile valley below.[7]

The section of aqueduct that runs above the pond indicates at least two construction phases. The original channel in this area is rock cut and about 33 cm wide. There is evidence of the channel being filled with mortared masonry at a later point in time in order to narrow it to 20 cm. Since this modification is centered in an area above the pond, it is tempting to say that it was related to the diversion of water to this holding pond.

7.Even today, this narrow vallay is highly cultivated

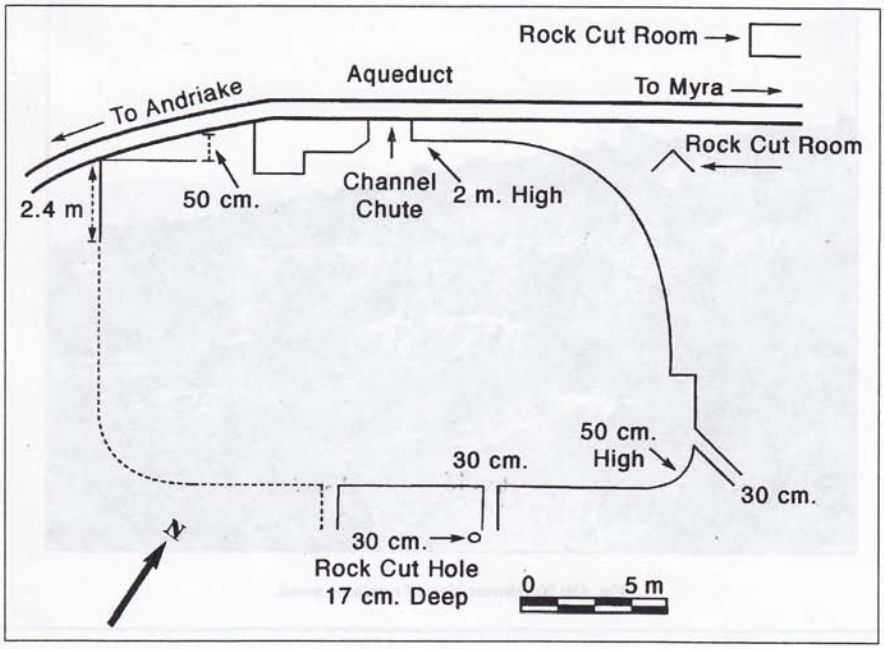

Fig. 6: Retaining pond.

Fig 6 A: Northeast view retaining pond Northwest view of retaining pond

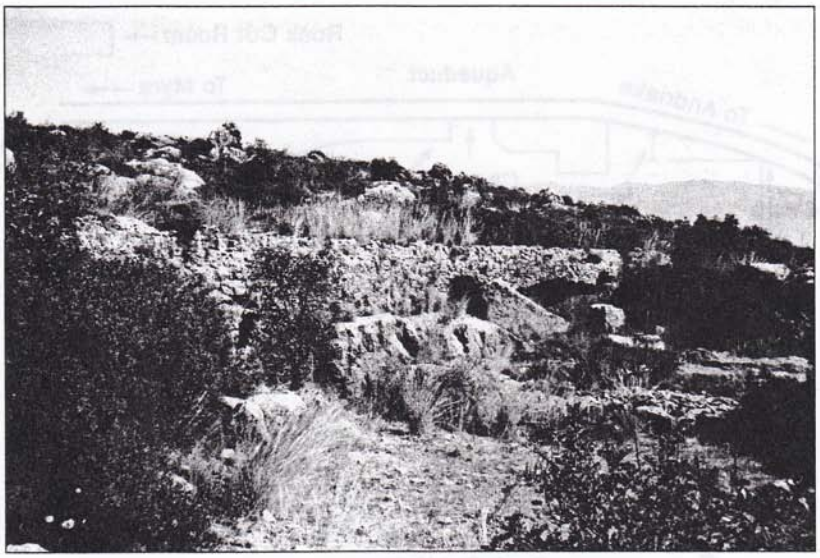

Fig. 6B: Northwest view of retaining pond.

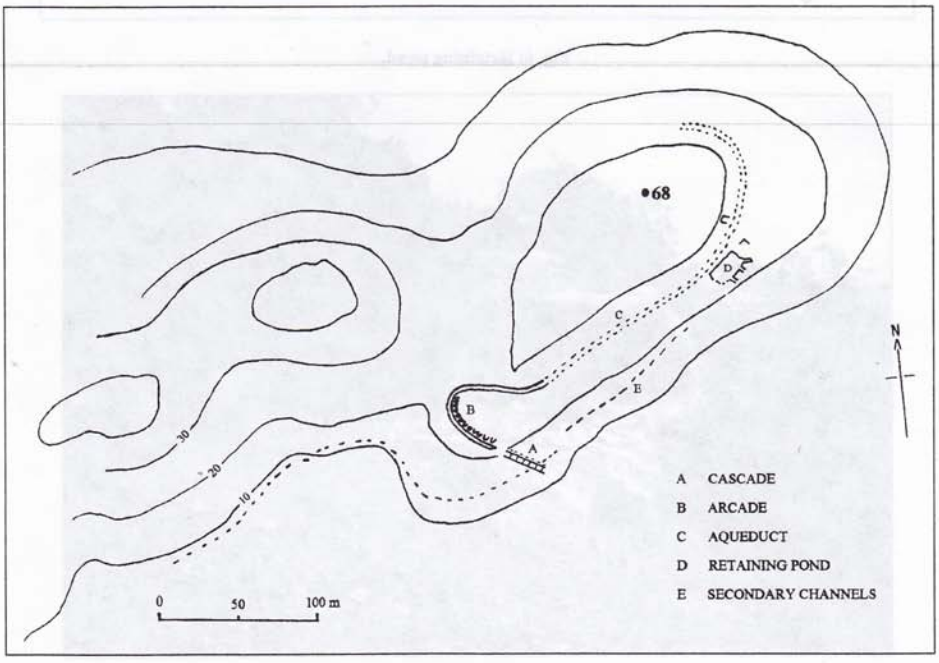

Fig.7 : Area plan

Discussion

The exact function of the cascade continues to be in question. The nature of its construction does not indicate that it could have utilized either undershot or overshot water wheels in a milling operation. There are no holes in the floor of the tanks themselves that would have indicated the use of any type of horizontal mill. However it has been suggested that that the stair step structure might have supported some yet unknown type of horizontal water wheel mechanism located outside of the cascade itself or possibly in conjunction with the terracotta pipe located in level 5.[8] (Fig. 7)

Several other possible industrial applications for this cascade have been researched however none seem to fit the design of the structure. Tanks of similar size have been identified as fresh water fishponds (*piscinae*) some of which were even supplied with water diverted from an aqueduct. The stair step tanks however lack several features required for *piscinae* i.e. recesses (*specus, similes, cellae)* necessary to shade the fish and facilitate internal water circulation.[9] Likewise, the cascade does not fit manufacturing processes such as dyeing, glass-making, pottery production, textiles or metal production.

The recent observation that the waterproof lining does not extend all the way up the full length of each tank makes the idea that the stair step structure was simply an energy dissipation device, problematic. The cascade might have served a re-aeration purpose or could very well have supported a yet unknown mechanical function of some kind. The location of the terracotta pipe in level 5 of the cascade would have allowed water to exit the aqueduct at a point closely in line with what appears to be the continuation of the main aqueduct to the harbor city of Andriake thus allowing the cascade to serve several purposes. The presence of the retaining pond upstream of the cascade increases the likelihood of industrial/agricultural use of the aqueduct channel in addition to serving some of the fresh water needs of Andriake or the surrounding countryside.[10]

A great deal remains unknown about the date and use of the aqueduct between Myra and Andriake. Excavation of the terminus of the cascade and the surrounding area coupled with a ground survey of the entire length of the water conduit is necessary to determine the nature of the cascade and any other agriculture or industrial applications however time is fast running out. Urban development as in the case of many countries is fast destroying much of the course of this ancient aqueduct.

[8] Drs. Paul Kessener had the opportunity to visit the area in 1998 and has been very helpful in presenting the possibility that this structure may yet have functioned as a horizontal water mill with wheels external to the cascade. While this is an intriguing possibility, the authors have not as yet been able to observe any external foundations to support this type of machinery to date.

[10] This paper has benefited from the discussions with H. Chanson, P. Kessener, R. Kreiner, and P. Leveau. The authors are grateful for their patient discourse however the ideas expressed in this article and any errors are the authors

9.Higgingbotham, J., 1997, 27-30

Bibliography

Aicher, J., 1995, *Guide to the Aqueducts of Ancient Rome,* Wauconda.
Ashby, T. 1935, The Aqueducts of Ancient Rome, edited by I.A. Richmond, Oxford.
Bedon, R. 1997, *Les Aqueducs de la Gaule Romaine et des Régions Voisines*, Limoges.
Borchardt, J. ed., 1975, *Myra, Eine Lykische Metropole*, Berlin.
Burdy, J. 1979, *Lyon:* Lugudunum et ses quartre aquedcucs, *Dossiers de l'archéologie, Séries les aqueducs romains* 38, 62-73.
Chanson, H., 1994, *Hydraulic Design of Stepped Cascades, Channels, Weirs and Spillways*, Brisbane.
Chanson, H. 2000, Hydraulics of Roman Aqueducts: Steep Chutes, Cascades, and Dropshafts, *AJA 48-72.*
Chanson, H. 2000, A Hydraulic Study of Roman Aqueduct and Water Supply, Brisbane.
Duval, P. 1946, *Cherchel et Tipasa*, Paris.
Grenier, A. 1960, *Manuel D'Archéologie Gallo-Romaine,* Paris.
Higginbotham, J. 1997, *Piscinae*, London.
Hodge, T.,1992, *Roman Aqueducts and Water Supply,* London.
Kessener, P., 2000, The aqueduct at Aspendos and its inverted siphon, *Journal of Roman Archaeology,* Portsmouth.
Leveau, P. and Paillet, L. 1976, *L'Alimentation en eau de Caesarea de Mauretanie*, Paris.
Leveau, P. 1984, *Caesarea de Maurétanie,* Paris.
Murphy, D. and **Mengel**, M. 2000, The stair step structure at Andriake, *Cura Aquarum in Sicilia,* Leiden, 155-157.
Moritz, L. 1958, *Grain-Mills and Flour in Classical Antiquity*, Oxford.
Ovens, W. 1975, *A Design Manual for Water Wheels,* Mt. Rainer.
Wikander, Ö. 1979, Water-mill in ancient Rome, *Opuscula Romana* 12: 13-36.
Wikander, Ö. 1991, Water Mills and Aqueducts, *Future Currents in Aqueduct Studies,* Leeds, 141-148.
Wikander, Ö. 2000, *Handbook of Ancient Water Technology,* Leiden.
Wilson, A. 1995, Water-mills in North Africa and the development of the horizontal water-wheel, *JRA* 8, 499-510.
Wilson, A. 1998, Water supply in ancient Carthage, *Carthage papers, JRA (Suppl. 28)* 65-102.
Wilson, A. 1999, Deliveries *extra urbem:* aqueducts and the countryside, JRA 12,1, 314-331
Wilson, A. 2000, Industrial uses of water in the ancient world, *Ancient water technology,* Leiden, 308-317.
Wilson, A. 2001, The water-mills on the Janiculum, *Memoirs of the American Academy at Rome* 45.
Wilson, R. 1996, *Tot aquarum tam multis necessariss molibu...* * Recent studies on aqueducts and water supply, *JRA* 9, 5-29.