Chapter 3: Water-lifting devices

3.1 Introduction

Two seminal synthetic works exist on this class of water installation, but it is striking, particularly in Oleson's work, that there is a paucity of evidence from the Near Eastern provinces.[1] To some extent this reflects a survival bias in the archaeological record, but also a geographical bias in research. Evidence for some technologies such as simple water-lifting devices over wells is particularly limited, though it must have been in frequent use. Rabbinical literature seems to provide evidence for the use of water-lifting devices, such as water screws and compartmented wheels, in the Roman period of the Near East, but chronological problems make these data very difficult to use convincingly.[2] This chapter will assess the present state of evidence for water-lifting devices in the Near East.

3.2 *Shaduf* and *čerd*

Both of these devices have a long history in the Near East (see Chapter 2.1; Figs 2.1 and 2.3). Although evidence for the use of the *shaduf* in the Roman period in the Near East is sparse, their use in Tunisia, Egypt and Europe would make it likely that they were used frequently in the East. The only possible archaeological evidence comes from a 4th-century fortress at Deir al Kahf in the Hauran, southern Syria. Butler records a reservoir (6 m x 7.7 m) with a 2.85 m wide platform on the fortress side.[3] It is possible that *shadufs* were erected on this platform to raise water out of the reservoir, but no mention is made of any postholes, which would make this argument conclusive.

Evidence for the use of the *čerd* in our period comes from literary sources. Firstly, there is the work of the anonymous author of the *De Rebus Bellicis* (c. AD 370) who attributes the Arabian skill of softening calf-skins to the fact that Arabs needed such skills because they used leather bags to draw water from wells.[4] References to the constituent

[1] Schiøler 1973; Oleson 1984.
[2] Oleson 1984, 7-9.
[3] Butler *et al.* 1907, II A, 148.
[4] Wilson 2003a, 127.

parts of the *čerd* in pre-Islamic Arabic poetry also suggest that this technology was known and used in (modern) Arabia in our period.[5]

3.3 Water screw

The water screw was a wooden cylinder with a double or triple helix driven by treading [see Fig. 2.4].[6] It had several applications including agricultural irrigation, municipal water supply and mine drainage.[7] The screw could only lift water a few metres (approximately half the length of the barrel), but had a good capacity: a 1.65 m long screw, 0.3 m in diameter, operating at 30% efficiency could lift c. 27.57 m^3 of water per hour.[8] To increase the height of the lift, water screws could be used in series, as at the Posadas mines where each screw discharged into a wooden trough that served as the sump for the next screw in the series.[9]

An inscription from Samosata, south-east Turkey, points to its use in the East during the Roman period:

[imp Cae]sar Vespasianus Aug./ [pont.] max., trib. potest. III[I i]mp. X, [p. p.,/ cos.] III[I] designat. V [et/ T.] Caesar Vespasianu[s i]mp./ [I]II, trib. potest. II, co[s.] II design. III, /[c]ensores designati, su[b/ P.] Mario Celso leg. Aug. pro. pr./ e[t]…leg. [leg.] opus cochli/[ae d]e communi…fecerunt.

'The emperor Vespasian Augustus, *pontifex maximus, tribunicia potestate, pater patriae* and T. Caesar Vespasianus, *tribunicia potestate*, consuls designate, under Publius Marius Celsus, legate of Augustus, *pro praetore,* and … legion constructed the water screw installation at their common [expense].'[10]

The inscription was found to the left of a monument featuring a sculpture of a figure in the style of river or water gods and commemorated the construction of a water screw

[5] Jamil 1999, 19-25, 28; Wilson 2003a, 127.
[6] Oleson 1984, 242.
[7] *Ibid.* 300.
[8] Decker 2001, 125; Oleson 2000, 251.
[9] Oleson 1984, 249-50.
[10] *ILS* 8903; Oleson 1984, 55.

during the reign of Vespasian, notably with the involvement of the military.[11] The screw was probably designed to provide irrigation water.[12]

3.4 Force pump

The force pump sits in water, pushing it up a discharge tube by means of pistons working in a pair of cylinders, and was commonly used as a fire extinguisher [Fig. 3.1].[13] The average pump discharge of known bronze pumps was 1.134 litres and the average of known wood block pumps (not including St Malo 2) was 1.92 litres.[14] The 19 known wooden force pumps all come from central and northern Europe (Britain, France, Switzerland and Italy). None are known from Spain, North Africa and the East.[15] This uneven distribution may be due to the lack of suitable timber (oak was the preferred material in all cases, where the material of the block is known) or due to a lack of recognition of the remains of a wooden force pump.

There is, however, some literary evidence pointing to the use of force pumps in the Near East. Firstly, a papyrus fragment of an account of expenditures from Nessana, Palestine refers to a σίφων ὀρευχαλκοῦν, which must mean a bronze force pump.[16] In addition Isidore of Seville describes the force pump being used as a fire extinguisher and, more unusually, as a vault washer in the East.[17]

3.5 Water-lifting wheel

Terminology for water-lifting wheels can cause confusion, so in general the terminology used here (and in section 3.6) follows that used by Oleson; where *noria* is used it refers to a hydraulic (water-driven) wheel and *saqiya* to an animal-driven wheel.[18] These wheels come in two main types: wheels with a compartmented body and wheels with a compartmented rim [Figs 3.2-3].

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[11] Chapot 1902, 205-7; Oleson 1984, 55-6.
[12] Oleson 1984, 56.
[13] Oleson 2000, 272.
[14] Oleson 1984, 321, Table 1.
[15] Oleson 1984, 303; Stein 2004.
[16] P. Ness. III.176; Kraemer 1958, 3267; Oleson 1984, 131, 158.
[17] Isidore XX 6.9; Oleson 1984, 56.
[18] *Ibid.* 11.

Wheels with a compartmented body had a large, thick hollow-bodied wooden wheel built around a heavy axle; radial interior divider walls divided this drum (*tympanum*) into equal-sized compartments [Fig. 3.2].[19] There were openings for water entry in the outer face of the wheel in the wheel-turning direction of each compartment and in one side wall of the narrow end. Close to the axle each compartment had a small, circular exit, through which water flowed out into a catch trough. This type of wheel could only be turned by treading or by a right-angled (*saqiya*) gear (see below Section 3.6) because the torque was too great for paddles. Although this type of wheel could lift large volumes of water, it could only do so over a short distance that was less than its own radius.

The wheel with a compartmented rim was an improvement on the previous design: it could be water- or animal-driven and used for greater lifts. This wheel had long, thin spokes that supported a narrow, hollow rim divided into separate compartments by divider walls held between pairs of spokes [Fig. 3.3]. Each compartment had a single intake/discharge hole in one sidewall in the wheel-turning direction; when the compartment reached the top of the wheel, the water was spilled out into a catch trough.

This second type is well known in the Near East and is commonly called *noria* [Fig. 3.4].[20] Today *norias* are associated particularly with medieval aqueducts in Hama, where examples can be up to 20 m in diameter; modern examples are also found in other regions of Syria at Lattaqia, Damascus, Euphrates, Antioch and Aleppo.[21] It is noteworthy that even these more modern cases are difficult to date because the wood and masonry are regularly replaced.[22]

The Septuagint probably refers to a wheel with a compartmented rim turned by treading or by a *saqiya* gear that ran backwards at a well.[23] The most famous piece of evidence, however, for the use of *norias* in antiquity in the Near East is the 5th-century mosaic from Apamea [Fig. 3.5]. This mosaic, found in the east portico of the grand colonnade, seems to depict a wheel with a compartmented rim in a rural or garden scene

[19] The description is from Oleson 2000, 229-232.
[20] NB: Schiøler 1973, 15 calls this type a hydraulic *noria*.
[21] Hama: Dalman 1932, 228; Girard *et al.* 1990; Zaqzouq 1990. Lattaqia: Weulersse 1940a, fig. 70. Damscus: Moussly 1951, 145, fig. 28. Euphrates: Schiøler 1973, 37; Girard *et al.* 1990, 381. Antioch and Aleppo: Dalman 1932, 228.
[22] Girard *et al.*1990, 374.
[23] Oleson 1984, 100. Septuagint *Ecclesiastes* 12:6.

with strong local elements (eg a camel caravan).[24] Dulière notes that this is the only known example of this subject on a mosaic and suggests that this is because this mosaic reflected the local nature of the subject.[25]

Norias are also known and used in modern Spain and Morocco.[26] It has been proposed that *norias* were used in Roman Spain, but with no firm evidence, this is only hypothesis.[27] The most convincing piece of literary evidence for the use of *norias* elsewhere in the Roman world comes from Lucretius (95 BC) where he compares the eternal rotation of the heavens to 'wheels and pots…turned by the river.'[28] This passage does suggest that these installations must have been known reasonably well outside the East. Another literary reference, in *SHA Heliogabalus*, tells a story, set in Rome, of punishment by tying people to a waterwheel, which has been interpreted as a *noria*.[29] It has been suggested convincingly that this was used because Elagabalus would have been familiar with them from his upbringing in Emesa (modern Homs) on the Orontes.[30]

3.6 Bucket chains and pot garlands (including *saqiya* gear)

Bucket chains and pot garlands both comprised a string of containers hanging on a turning shaft or drive wheel. The containers scooped up water at the bottom of the loop and dumped it into a conduit [Figs 3.6-7]. By fastening a series of containers to long loops over a wide axle, one could combine the efficiency of a rotating series of scoops (as seen in the waterwheels) with the depths possible when using a simple bucket on a rope or a *čerd.* [31] These were expensive devices usually only used where water was too deep to be lifted by other devices.[32] Both devices needed to be propelled by a tread wheel or a *saqiya* gear.[33] The *saqiya* gear comprised a pair of large gear wheels with short, thick radial cogs that

[24] Mayence 1933, 4-6; Schiøler 1973, 157 [NB: gives the wrong date]; Dulière 1974, 26, 36-7, pls 25, 26, 62, 63; Oleson 1984, 185-6.
[25] Dulière 1974, 8, but wrongly says that norias are only found on the Orontes in Syria.
[26] Baroja 1954, 7; Wilson 2003a, 123-125.
[27] Proponents of this idea are: Glick 1970, 178-80; Oleson 1984, 57;Wilson 2003a, 123-125.
[28] Lucretius *De Rerum Natura*, V.515.
[29] *Scriptores Historiae Augustae: Heliogabalus* XXIV 5; Oleson 1984, 96-7.
[30] Baroja 1954, 37.
[31] Oleson 2000, 251: Most water-lifting devices only have a short lift: a wheel can lift water only approximately the height of the radius; the *shaduf* c. 78% the length of the tip-beam and a water screw less than half the length of the barrel.
[32] Oleson 2000, 256, 258.
[33] Schiøler 1973, chapter 1.

were oriented at right angles to each other, changing the direction of torque by 90º. The animal(s) walked in a circle around a central pivot that carried the horizontal gear wheel. This wheel meshed with the second, vertical wheel, which turned around a horizontal beam either above the treading circle or in the machine pit below. This is essentially a watermill gear in reverse (see Chapter 10.2).[34]

Bucket chain types are known from, for example, London (four examples, the latest dating to AD 108-9), Pompeii (four examples dating from the late 2nd to early 1st century BC) and Cosa (two examples dating from 150-125 BC and the first quarter of the 1st century BC respectively); these all have wooden buckets.[35] Conclusive evidence for bucket chains has not been attested archeologically in the Near East. It is possible that the evidence for the wooden buckets has not survived due to unfavourable preservation conditions. A shortage of timber in large areas of the region also may have hampered their use. It could be argued that where timber was more easily available, for example in the Lebanon and Anti-Lebanon mountain ranges, the *noria* was the water-lifting device of choice, especially on the Orontes River. The pot garland was a late variant of the bucket chain and seems to have come about with the 'invention' of *saqiya* pots (see below) that could be lashed to a wheel or looped as a necklace over the turning shaft. With the use of pots, rather than wooden buckets, cheaper, mass production became possible, probably giving rise to their increased use.[36] So, it is also possible that, by the time of the introduction of this kind of technology to the Near East (see below), pot garlands had largely superseded bucket chains.

Archaeological evidence for pot garland installations in the East is more widespread, though limited to the well from which the water was lifted and the pots in which the water was raised (Gazetteer 1). It is possible that wells without *saqiya* pots may have functioned with bucket chains. *Saqiya* pots often have a characteristic knob at the bottom, are ribbed and have wear marks caused by the rubbing of the rope. Some also have air holes in the base to allow air to escape from immersed pots [Fig. 3.8].[37]

Of the 46 sites in the Near East with *saqiya* pots of the Roman and late Roman periods, 41 are in Israel; this reflects a research bias in the Middle East and it is very likely

[34] The description is taken from: *Ibid.* 267.
[35] London: Blair 2002; Fitzpatrick 2002; Blair and Hall 2003. Pompeii: Oleson 1984, 177. Cosa: Oleson 1984, 361.
[36] Oleson 2000, 350, 354.
[37] Schiøler 1973, 101; Oleson 1984, 358; Guz-Zilberstein 1995, 324; Ayalon *et al.* 2000, 220.

that more sites exist in the rest of the Near East. The pots were found in late Roman contexts at 43 of these sites. This pattern seems to match that found in Egypt.

Eight occurrences are attributed to the Roman period. One pot from Dor was attributed to a 1st century BC – 1st century AD context [L4042];[38] if this is correct, this pot would be one of two of the earliest known *saqiya* pots in the Roman world.[39] Context L4042, however, was a slab floor in the area above a Phoenician house.[40] It is unlikely, if not impossible, for a complete pot to have been part of the floor. The pot almost certainly must have come from a deposit overlying the floor or (less likely) under the floor. Without clearer stratigraphic description, unfortunately, this evidence appears unreliable. A *saqiya* pot has also been attributed to a mosaic floor at Caesarea.[41]

Only 13 pots (not including the 2 above) have recorded contexts (Table 3.1). Dimensions were only given for the Roman well at Zenobia: 3.1 m long x 1.6 m wide.[42] Qasr ibn-Wardan and Andarin, both in Syria, also have wellheads of a similar size (c. 3 m x 1 m) and it is thought that wells of this size and shape are ideal for use with a *saqiya,* for example at Ptolemais, North Africa.[43] The two bathhouse examples have parallels in Egypt and Italy; we can now add the province of Syria to Oleson's list of sites with *saqiya* pots (see below).[44] It is unclear in the case of the pot associated with a kiln whether the pottery was being manufactured at the site or whether a *saqiya* was being used in the production of the pottery, lifting water from the pool recorded on site, or even both.[45] If a *saqiya* was being used for industrial purposes, this would add a so far unattested (but not unexpected) use of this device in the Roman empire.

[38] Stern and Berg 1995, 233, 264.
[39] The other pot with this date comes from Kom Ausin, Keranis, Egypt, but is also unverified: Oleson 1984, 218, 354.
[40] Stern and Berg 1995, 104.
[41] Peleg and Reich 1992, 143, 146.
[42] Lauffray 1991, 125.
[43] Mango *et al.* 2001; Wilson 2003a, 120-1.
[44] Oleson 1984, 369.
[45] Getzov 1993, 21.

Table 3.1: Contexts of *saqiya* pot finds.

Context	Number of pots
Well	3
Bathhouse	1
Well in bathhouse	1
Cistern	2
Drain	1
Pottery kiln	1
Burial	3
Near wall	1

Two late Roman *saqiya* sites at Yavne Yam and Tel Ashdod in Israel have been excavated recently in enough detail to reconstruct the installations; both were used for irrigation. At Yavne Yam the base of the *saqiya* (8 on figure) was found comprising two stone piers and the base of the axle [Fig. 3.9].[46] The bell-shaped cistern (9) was built from kurkar ashlar and was plastered. Piers (2, 7) supporting the drawing wheel were also found. A reservoir (1) with a capacity of 30 m^3 was found to the north of the cistern; its walls and floor were plastered. There were steps in the north-western corner. Three outlet points fed channels leaving the reservoir, one of which terminated in a small pool (5) with a capacity of 0.2 m^3.

At Tel Ashdod the installation comprised a well, the *saqiya* installation, a settling pool and a reservoir [Fig. 3.10].[47] The *saqiya* and turning shaft were operated from the roof of the building, over the mouth of the well. Two grooves to guide the bucket chain were found opposite each other on the interior of the well. The reservoir (5.0 m x 5.7 m) and the settling pool were both paved with a white mosaic; a ceramic pipe connected them. Another ceramic pipe left the reservoir and fed water to a stone-built irrigation channel.

There is archaeological evidence at two other sites in northern Syria that points to the possible use of pot garlands. The bathhouse at Serjilla, dated by a mosaic inscription to AD 473, is a well-known example in which there is a large, arched cistern (16 m x 12 m x 4 m deep minimum) with a stone superstructure, almost certainly to support a water-lifting

[46] Ayalon 1999, 72*-73*.
[47] Baumgarten 1999, 66*.

device, perhaps a *saqiya*, in order to fill the reservoir [Fig. 3.11].[48] The opening (c. 2 m x 0.7 m) would be at the smaller end of the scale. This, in combination with the small size of the pools in the bathhouse, makes it possible that, if any water-lifting device was used, it was a *shaduf*. The bathhouse at Moudjeleia shows a very similar set-up to Serjilla [Fig. 3.12].[49] Their identification as *saqiya* wells may be supported by their association with bathhouses, which follows the pattern seen above with the *saqiya* pots.

A further piece of evidence for the use of *saqiyas* comes from an inscription from the Negev, probably of a 6th-century date.[50] This inscription refers to the λαμπρότατος Hilarion who builds a ὑδατος μηχανή, which points to some kind of machinery. Decker reasonably rules out both a *čerd* as being too simple to merit an inscription and a *noria* as being unsuitable due to the lack of perennial streams, thus leaving a *saqiya* as the only other possibility.[51] Another inscription, of either 3rd-century or 5th- to 6th-century date, found south of Caesarea outside the Herodian city wall may also refer to *saqiya* construction.[52] The inscription commemorates Symachos μηχανικός; the title suggests that Symachos may have been some form of water engineer, but of what exactly is unclear. It is also possible that it may refer to a millwright or aqueduct engineer.[53]

It can be seen, therefore, that there is a large amount of evidence for the use of pot garlands in the Near East, in particular in bathhouses and also possibly in industrial applications. While Oleson may be correct to suggest that this kind of technology was largely restricted to Egypt in the Roman period, it had certainly reached the Near East by the late Roman period, if not before.[54]

[48] De Voguë 1865, 95; Butler *et al.* 1907, II B, 121; Schiøler 1973, 155.
[49] De Voguë 1865, 95.
[50] Schwabe 1950-1, 50, 52; Oleson 1984, 95; Decker 2001, 128.
[51] Decker 2001, 128.
[52] Schwabe 1950-1, 49-51.
[53] *Ibid.* 50; Oleson 1984, 95; Decker 2001, 128.
[54] Oleson 1984, 354, 379.

3.7 Conclusions

It is clear that there is a large amount of information in the Near East that contributes to our knowledge about water-lifting devices across the Roman Empire. In particular, the Near East exhibited a wide range of devices and can be compared to Egypt. Although Egypt undoubtedly possesses more evidence, particularly papyrological, devices that Oleson believed to be in common use only there, such as the pot garland, were obviously in widespread use in the Near East too. Indeed, with more awareness of the traits of these installations, for example pottery forms and the shapes and sizes of wells, it is certain that further fieldwork will add many more installations.[55] This use of pot garlands makes the East, and Egypt, stand out from other regions of the Empire. In addition, there may have been more use of *norias* in the East than elsewhere. There is less evidence for bucket chains and force pumps, particularly wooden ones, than in the western parts of the Empire. While this may in part be due to a preservation bias, it is also possible that it reflects the availability of certain materials, for example wood (though this would also have been needed for *norias*), or a chronological difference, for example with pot garlands in the East being generally later than bucket-chains, their western counterparts.

[55] See Schiøler 1973, 101-103, 130-2 on methods of identifying these features.