Chapter 2: Water technology in the Near East before 63 BC

The Near East contained a wealth of water technology in the pre-Roman periods. A review of that technology, which is necessary in order to make any valuable comment on the technology of the Roman period, is presented here by type of technology as in Chapters 3-11. A summary of the technologies ordered by type of technology and the date of their introduction to the region has been provided in Table 2.1. A chronological summary has been provided in Table 2.2.

2.1 Water-lifting devices

The Bronze Age saw a development in water-lifting devices with the *shaduf*: the earliest known mechanical water-lifting device [Fig. 2.1].[1] The *shaduf* is a lifting mechanism mounted on a framework above or next to a water source with a cross-beam along the top.[2] A tip-beam is suspended beneath the cross-beam and a stick with a jar, skin bag or basket is suspended from the end of the tip-beam closest to the water; a counter-weight is attached to the other end of the tip-beam. The disadvantage of the *shaduf* system is that there is a limit to the height of its lift (c. 78% the length of the tip-beam), so it can only be used on cisterns, shallow wells and river/lake banks. Advantages of the *shaduf* include the ergonomic advantage of using the *latissimi dorsi* (the broad flat muscles on either side of the back) to raise the counter-weight and lower the basket and the practical advantage that the container is pulled inwards as it rises. In addition, it is a large output device. Although the actual origins of the device are obscure, a Mesopotamian seal dated to 2400-2200 BC depicts a *shaduf* with a relatively mature design, suggesting that it was used from the early Bronze Age onwards. Furthermore, such a device is more suited to the settled communities of the Bronze Age, rather than Neolithic subsistence living.

One of the most important inventions attributed to the Neo-Assyrian period is the pulley. The earliest known representation of a pulley device appears on a mid-9th-century BC relief at Nineveh [Fig. 2.2].[3] It has been argued that this scene depicts raising of water

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[1] Oleson 2000, 225-6.
[2] *Ibid.*
[3] Oleson 2000, 221.

from the reservoir next to the gate at Megiddo.[4] This may suggest the use of the pulley at various sites, including Hazor and Gibeon, in Israel during this period. The change in direction of force caused by a pulley enabled multiple operators on a well at a single time.[5] In addition, the pulley was sound economically since it allowed the use of ceramic containers for lifting the water, as they would no longer keep hitting the sides of the well.

In the Neo-Babylonian and Old Persian periods (7th to 4th centuries BC), another step forward was made in water-lifting technology: the *čerd* [Fig. 2.3]. This installation has not yet been identified in the archaeological record. Although Oleson presents arguments from the documentary sources for their use from as early as the 6th century BC in the Hanging Gardens at Babylon, this argument is unconvincing.[6] A more plausible reference comes from the 4th-century BC historian Ctesias of Cnidus who refers to buckets raised by wheels (περίακτα ἀντλήματα) that irrigated the royal garden at Susa.[7] The *čerd* makes use of animal labour to lift water and is a more sophisticated version of a single pulley.[8] The animal walks down a narrow path away from the well shaft. Two ropes are fastened to the animal's yoke. A pulley wheel is mounted over the well for the thick rope that lifts a funnel-shaped bag, open at both ends. A second, thinner rope runs over a second pulley mounted over a catch trough at the side of the well. The water fills the bag through the upper opening and the exit spout is held above the rim by the second rope. The first rope lifts the bag of water when the animal walks down the treading path. Above the catch trough, the first rope hits a stop, while the second rope pulls the spout into the trough and the water is poured out.

The wheel with a compartmented body or rim was a particularly important innovation because the most efficient water-lifting devices use a continuous circular motion rather than an intermittent oscillating motion.[9] Both types of wheel have slightly obscure origins as no inventor is recorded. Although there is no archaeological evidence until the

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[4] Baumgarten 2002, 234.
[5] Oleson 2000, 221.
[6] Oleson 2000, 224.
[7] *Ibid.*
[8] Oleson 2000, 222-3.
[9] Oleson 2000, 229-233.

2nd century BC, there is literary evidence for its existence in Egypt from at least the 3rd century BC.[10]

The water screw was a pumping device and stands out among water-lifting innovations because of its simple and effective design: it has not been much improved by modern adaptations [Fig. 2.4].[11] This device had far-reaching consequences in the field of irrigation, as attested by the 2nd-century BC author Agatharcides:

'Since (the Nile delta) is formed by river alluvium and is well watered, it produces fruit of all sorts in great quantity; for the river in its annual inundation always deposits new mud, and the inhabitants easily irrigate the whole region by means of a certain device which Archimedes the Syracusan invented, called the water screw [κοχλίας] on account of its design.'

The widely-accepted view, and that held by Oleson, is that Archimedes must have been the inventor of the screw because the ancient sources agree unanimously on this point.[12] Dalley, however, has suggested that Sennacherib may have been the original inventor. Dalley cites a passage describing how water was supplied to Sennacherib's palace at Nineveh using 'ropes, bronze wires and bronze chains' and 'great cylinders (*gišmahhu)* and *alamittu* palms' set up over cisterns, which she believes describes a water screw.[13] On the basis that Nineveh may be the actual site referred to as Babylon in later sources, it is also possible that the descriptions, given by Strabo and Philo of Byzantium, of the water supply to the Hanging Gardens may also refer to Sennacherib's water screw.[14] Dalley also notes that the verb used to say Archimedes 'invented' the screw (εὗρεν) may also mean that he discovered or found it. So, it is possible that the device was originally invented by Sennacherib, but fell into disuse and so was re-invented by Archimedes. There are, however, no surviving images of this device from that period and no further references, however ambiguous, until it is attributed to Archimedes in the Hellenistic period. Without further evidence the debate cannot be satisfactorily resolved. We can, however, claim that it

[10] Philo of Byzantium chapter 61 talks of a water-driven compartmented wheel that whistles.
[11] Oleson 2000, 242.
[12] On the debate about the invention of the water screw see: Dalley 2001-2; Dalley and Oleson 2003.
[13] Dalley and Oleson 2003, 7.
[14] Strabo *Geography* 16.1.5; Philo of Byzantium 1.4.

was under Archimedes that the water screw came to its full potential and found extensive and continued use in irrigation projects.

2.2 Dams

In Egypt, a dam was built at Sadd al-Kafara c. 2650 - 2465 BC.[15] To the south of Ugarit (Ras Shamra), a dam lay across the course of the Nahr al-Delbe.[16] Although there was no dateable material in the alluvial layers abutting the dam, the construction technique is similar to that of Ugarit, placing it in the mid to late Bronze Age.[17] Many of the elements of the dam are now missing, but it is clear that the dam was quite small, though adequate for the needs of the city.[18] A larger dam would have been inappropriate, probably expensive to construct and maintain and potentially destructive by preventing water reaching other thirsty areas further downstream. Sennacherib (704-681 BC) constructed at least four dams on the Tigris, to feed Nineveh.[19]

The Nabataeans also made extensive use of dams, which are discussed in more detail in Chapter 4 [Fig. 2.5].[20] The Nabataeans are often referred to as innovators in water technology, but with the exception of dams, their technology is quite standard for the Hellenistic world.[21] Their reputation is mostly due to a comment in Diodorus Siculus (19.94.8) that says that the Nabataeans alone know where to find their cisterns in the desert.[22] This passage has often been misinterpreted and has been thought to mean that only the Nabataeans knew where to find water in the desert. It seems, however, that there skill was in hiding their water by covering their cisterns and so, by protecting access to water, controlling who was able to pass through their lands.

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[15] Hodge 2000c, 331.
[16] Calvet 1990, 488.
[17] Calvet 1990, 490.
[18] Calvet 1990, 489.
[19] Jacobsen and Lloyd 1935; Hodge 2000c, 331.
[20] See Oleson 1995.
[21] See for example Oleson 1991; Oleson 1995; Al Muheisen 1990; Al Muheisen and Tarrier 2001-2; Glueck 1959; Hammond 1973.
[22]ταῦτα δὲ τὰ ἀγγεῖα πληροῦντες ὕδατος ὀμβρίον τὰ στόματ′ ἐμφράττουσι καί ποιοῦντες ἰσόπεδον τῇ λοιπῇ χώρᾳ σημεία καταλείπουσιν ἑαυτοίς μὲν γιγνωσκόμενα, τοίς δ′ ἄλλοις ἀνεπινόητα.
'Having filled up the containers with rainwater, they block up the mouths and making them level with the rest of the ground, they leave signs, which they themselves know, but which are not known by others.'

2.3 Irrigation

In the period between 8300 BC and 7600 BC there was a transition from the Natufian hunter-gatherer lifestyle to Neolithic subsistence agriculture with irrigation.[23] Artificial irrigation from the Zagros Mountains has been noted, for example, in 7th-millennium BC Khurzistan.[24] These irrigation systems, making use of channels and dykes, would have allowed the expansion of areas for cultivation and agriculture. Furthermore, late Neolithic and Chalcolithic sites (6000-3200 BC) are located in better watered environments more suited to arable farming, exploiting river valleys (Hama) and coastal alluvium zones (Byblos, Soukas and Ras Shamra).[25] There is evidence to suggest that Chalcolithic floodwater farming developed partly in response to increasing aridity in 5000-3500 BC in some areas (see Chapter 1.1).[26] Some of these responses at Wadi Faynan, for example, included cisterns and circular depressions that were water catchment structures, which were similar to microcatchment systems found at Shiqmim in the Negev.[27]

Irrigation techniques in Bronze Age southern Mesopotamia were heavily influenced by the flood seasons of the Tigris and Euphrates (see Chapter 1.5).[28] Fields sown in the spring needed protection from flooding later in the season. Crops sown in flooded ground must have protection from the summer heat and needed extra irrigation. Therefore, a dyke system of irrigation and drainage channels was set up in the fields, as well as dams and reservoirs to store water for the dry season.

Remarkably, the *Georgica Sumerica* (2100 BC/1700 BC), with its description of a system of basins, dyked fields and channels, attests to this awareness of seasonal water and how to harness its power.[29] In addition, maps drawn on clay tablets can give us some idea of how these channels were laid out and their relation to neighbouring land and water sources. Furthermore, the Law Code of Hammurabi (1792-1750 BC) seems to clarify the legal practices concerning water and the problems that can be caused by negligent upkeep of water management systems, for example:

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[23] Miller 1980, 331.
[24] Wikander 2000e, 607.
[25] Miller 1980, 333.
[26] Barker *et al*. 1998, 24.
[27] Barker *et al*. 1998, 24; Barker *et al.* 1999, 258—262; Levy 1987.
[28] Oleson 2000, 189.
[29] Oleson 2000, 192.

§ 53: If a man has been slack in maintaining [the bank of] his [field] and has not maintained [his] bank and then a breach has occurred in his [bank], and so he has let the waters carry away (the soil on) the water-land, the man in whose bank the breach has occurred shall replace the corn which he has (caused to be) lost.
§ 54: If he is not able to replace the corn, he and his goods shall be sold and the tenants of the water-land, whose sesame the waters have carried away, shall divide (the sum so obtained).[30]

These administrative processes for water are also brought out in documentary evidence from Larsa (c. 1800 BC):

A 7552: With regard to the field of Sin-Asû I went to the inspector of channels, but he would not give me the water…The gentleman is trying to put me off, he will not give me the water.

A 7542: He is holding us by force, and it is five months now that he has taken water from our irrigation channel; we have only been able to irrigate two *BUR* of field.[31]

Although these latter two examples show a failure in the system, they do, nevertheless, show that organisational systems, such as an irrigation channel inspectorate, were in place, even if corrupt. Moreover, they illustrate clearly the importance and great need for water in the region. Indeed, water was so important that it became the subject of an international agreement between Rim-Sin of Larsa (1822-1763 BC) and the king of, probably, Eshnunna (see also Chapter 4.5).[32]

Further information can be gleaned about the state of water supply techniques in the Bronze Age from the texts connected with Mari. These texts provide a vast amount of information about the climate, water resources, the agricultural land and the large channels around Mari.[33] There is a lot of information about the different methods of irrigating land, from large irrigation channels (*rakibum*) to irrigation by wells (*daluwatum*). Of particular interest, are the textual references to the quality of the land. The land is divided into three classes: good soil (*damqum*), bad soil (*lemnum*) and saline land (*eqel idrâni*). There is no mention of the cause of the salinity, but it is possible that its mention in association with irrigation techniques points to an awareness of the problems associated with over-irrigation.

[30] Bruun 2000a, 543. This translation is taken from Driver and Miles 1955, II, 30-1.
[31] Bruun 2000a, 543. Quotes from Rowton 1967, 271-2. *BUR* is a unit of land area, for which the value in modern terms is not known.
[32] Bruun 2000a, 543.
[33] Durand 1990.

The problem of salinization in the Bronze Age is also possibly attested to by the switch from wheat to the more salt-tolerant barley in southern Mesopotamia after 2100 BC.[34]

Under Tiglath-Pileser I (1114-1076 BC), there is a clear concern for water supply as illustrated by his laws on wells, dykes and irrigation. Unlike the Law Code of Hammurabi that concentrates on compensation for the injured party, Tiglath-Pileser's laws focus on the punishments to be given in the event of negligence:

> Tablet B § 10: If a man has dug a well (or) made a dyke in a field which is not his, he shall forfeit his well (or) [his] dyke; he shall be beaten 30 blows with rods (and) [shall do] labour for the king for 20 days.

It is not entirely clear what the reason for this difference is and possibly it represents only a different judicial tradition. Bruun, however, suggests that the difference lies in the situation dealt with: emergencies in the Law Code of Hammurabi versus the ordinary processes of irrigation in Tiglath-Pileser's laws.[35]

Neo-Assyrian legal transactions provide insights into water rights during the 8th and 7th centuries BC.[36] We find the common use of wells attested in land sales as well as the right to use water for two days and two nights in a vineyard sale.[37] Two centuries later in Achaemenid Babylonia, there is evidence for a contract under Artaxerxes I (464-424 BC) allowing farmers access to water from the royal reservoir for three days every month.[38]

Wilkinson's survey work has illustrated irrigation techniques in Upper Mesopotamia (a zone of mostly rain-fed agriculture in northern Iraq, northern Syria and south-eastern Turkey).[39] His work on the Balikh Valley, for example, has shown how environment, rainfall, irrigation and settlements all worked in a close relationship.[40] Rainfall in the Balikh Valley varies from 300 mm in the north (i.e. where rain-fed cultivation is possible) to 200 mm in the south where the Balikh joins the Euphrates (i.e. where rain-fed cultivation is not possible and therefore irrigation is necessary; see Chapter 1.1).

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34 Oleson 2000, 192.
35 Bruun 2000a, 534.
36 Bagg 2002, 225.
37 State Archives of Assyria, Helsinki 6, 115; 119; 201; rev. 15-16.
38 Bagg 2002, 227.
39 Wilkinson 1995; Wilkinson 1998a and b; Wilkinson 2000a and b; Wilkinson and Barbanes 2000; Wilkinson and Tucker 1995.
40 Wilkinson 1998b.

The settlement patterns provide an indication of how agriculture may have functioned in this area. In the Iron Age sites in the zone of rain-fed cultivation were located both along the Balikh River and away from it. Conversely, Iron Age sites in the south were clustered alongside the river, which must have been their source of irrigation water. In the Hellenistic period there was a noticeable shift of sites away from the river in this irrigable zone. This must have been made possible by the construction of the major, valley-length Sahlan-Hammam irrigation channel, which conducted water onto formerly uncultivated land (see Chapter 5.2). A similar pattern, though at an earlier date, has been observed in the Lower Khabour region, where the construction of major irrigation channel systems allowed settlement densities in the Iron Age to increase far above levels reached previously.[41]

Under the Assyrians there was a move towards large hydro-technical constructions, especially irrigation channels. Ashurnasipal II (883-859 BC), for example, dug a channel from the Upper Zab to Nimrud to irrigate his garden and orchards.[42] Dalley has cited this work as possible evidence for the origin of qanat technology in the east because 7 km of the channel was a tunnel dug by joining the bottoms of vertical shafts (see Chapter 5.3).[43] The problem with this theory, which includes tunnels at Arbela and Babylon as supplementary evidence, is that none of the tunnels tap groundwater sources as in a true qanat, but rather springs or rivers. These tunnels may, however, have been a step on the path towards qanat technology, i.e. putting this tunnelling technology together with the knowledge of water-bearing qanats in piedmont zones.

The origin of qanats is a highly contentious topic, with two main camps arguing that qanats originated either in 8th-century BC Persia or in the Arabian Peninsula in Iron Age II (c. 1000-600 BC).[44] The traditional viewpoint is that qanats originated in Iran in the 8th century BC and the technology was then transferred to Arabia and the rest of the Middle East during the period of the Achaemenid Empire (538-332 BC). This is based on an inscription saying that channels were seen by Sargon II in his campaign against ULHU and a passage in Polybius (X.28), which suggests that in the battle between Arsakes I and

[41] Morandi 1996; Wilkinson and Barbanes 2000, 416, 420.
[42] Wikander 2000e, 618.
[43] Dalley 2001-2, 445-6.
[44] Lassøe 1951; Goblot 1979; Costa 1983; Magee 1999; Lightfoot 2000; Briant 2001a and 2001b; Magee 2003; Magee 2005.

Seleukos II, qanats, which had been constructed under the Achaemenids, were put out of action.

It has been suggested recently, however, that this argument lacks any sound archaeological basis, unlike an early date for qanats in south-eastern Arabia.[45] It is argued that, in the face of increasing aridification, the rapid settlement expansion in south-eastern Arabia towards the end of the 2nd millennium BC must have been reliant on qanat technology. In defence of this is cited archaeological evidence for qanats at Iron Age II settlements (al Ain, Bida Bint Saud and al Thuqaibah). It is not clear, however, that the qanats at these sites must be dated to the earlier part of the Iron Age II period, which once again leaves the origin of qanats open to question. In the absence of any resolution to this argument, our oldest firm archaeological evidence for qanats comes from 5th-century BC Achaemenid Egypt at ʻAyn Manawir.[46]

2.4 Long distance water transport

On the Levantine coast, in the Bronze Age, advances were made in tunnelling techniques. The Gezer tunnel system, which comprised a slanting tunnel system c. 40 m long, may date from as early as 2000 – 1800 BC [Fig. 2.6].[47] In the 12th century BC at Megiddo, for example, a 63 m long tunnel was constructed to channel water from the underground spring.[48] Also dating to the late Bronze Age – Iron Age I is Hezekiah's Tunnel in Jerusalem that brought water from the Gihon Spring to the Pool of Siloam. It has been suggested that this tunnel was dug in imitation of Sennacherib's great engineering works at Nineveh.[49] Sennacherib also constructed a 55 km long channel to serve Nineveh, which canalised the waters of the Atrush and Kohar rivers and included the 300 m long dyke at Jerwan over a wadi.[50]

In the Uruk period (3500-2900 BC) a long distance pipeline was constructed to Tell Habuba Kabira, on the Euphrates near the modern Tabqa-Thaoura dam.[51] This terracotta

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[45] See for example Magee 2005.
[46] Wuttman *et al.* 1996; Wuttman *et al.* 1998; Wilson 2003a, 134.
[47] Macalister 1912. Reich and Shukron 2003.
[48] Wikander 2000e, 620.
[49] Dalley 2001-2, 460.
[50] Jacobsen and Lloyd 1935; Wikander 2000e, 618; Hodge 2000b, 40.
[51] Jansen 2000b, 105 n 3; Wikander 2000, 608; Meyers 1997, 446.

pipeline already made use of flanges and sockets to make the joints more efficient.[52] Terracotta pipelines were also features of the archaic Greek world, for example the 10 km pipeline at Athens and the 8 km pipeline at Olynthus.[53] The 6th-century BC Samos aqueduct also used a terracotta pipeline, which was spring-fed via a collecting reservoir.[54] The most famous section of this aqueduct is the Tunnel of Eupalinos, which ran for c. 1 km through Mount Ampelos. The tunnel was 1.8 m wide x 1.8 m deep with a trench in the floor of the main tunnel, in which the terracotta pipeline ran. Tunnels were also used at Athens, Syracuse and Acragas.[55]

The use of terracotta pipelines in longer distance aqueducts was a Hellenistic phenomenon, particularly associated with Pergamon (for example, the 20 km long Attalus and Demophon pipelines; the 42 km long pipeline and the 3.5 km long, 201 m deep inverted siphon on the Madra Dag aqueduct). Rather than using bridges, Hellenistic aqueducts traversed valleys in pressurised pipelines, known as inverted siphons (as arches were not generally used in this period) [Fig. 2.7].[56] There is some debate over the date of stone pipes in inverted siphons; traditionally they have been thought to be Hellenistic, but it is probable that many may in fact be Roman.[57] These tend to be found in Asia Minor, for example at Ephesos, Methymna, Magnesia ad Sipylum, Philadelphia, Tralleis, Trapezepolis, Antioch in Pisidia, Apamea Kibotos, Akmonia, Laodicea and Pergamon. Examples are now also known, however, from Italy (Libarna, Padua, Ateste, Aquileia, Arezzo and the Caelian Hill, Rome) as well as North Africa (Rusazus, Ain al-Kerma (Algeria) and Bled Zehna).[58]

In the 2nd and 3rd centuries BC several major technological advances in long distance aqueducts occurred, which may be attributed to the powerful centres of Rome and

[52] Wikander 2000e, 609.
[53] Lewis 1999, 157; Tölle-Kastenbein 1996; Crouch 1993, 171-5.
[54] Kastenbein 1960; Hodge 1992, 27-29.
[55] Hodge 1992, 29
[56] An inverted siphon from Zincirli comprising 0.3 m long terracotta pipe sections with flanges and clay sealant may predate the Hellenistic versions: Dalley 2001-2, 460.
[57] Hodge 1992, 33, 110-111. Stenton and Coulton 1986, 52, argue a Roman date is preferable, with the possible exception of Pergamon.
[58] Colini 1944, 82-4; Lombardi and Coates-Stephens 1996, 8; Bodon *et al.* 1994, 261; Gsell 1901, vol. 1, 257; de Vigneral 1868, 66; Gsell 1911, fol. 18.371 (p. 29); Carton 1896, 544-45; Wilson 1997, 70-71; Wilson 2000e, 599.

Pergamon. [59] The links between these two centres brought about a blending of Roman technologies (channels and arcades) with Pergamene technologies (steeper gradients and inverted siphons). This resulted, for example, in the Alatri aqueduct with a Roman channel and arcades as well as a Pergamene gradient and siphon.[60]

In the Near East, the Nabataeans also used long distance aqueducts. Leading to Auara, for example, was the aqueduct from Ain al Ghana [Fig. 2.8].[61] The main line ran 18.9 km from Ain al Ghana to a reservoir to the north of Auara and a branch line 7.625 km long connected Ain al Jamam and Ain Sharah to the main line.[62] The aqueduct structure comprised a heavy rubble foundation (0.8 m wide), carrying long stone conduit blocks set in mortar and rubble; into these blocks a 0.12 m wide and 0.14 m deep channel had been cut.[63] In addition, six settling tanks were noted along the Jamam branch.[64] In addition to the dam and aqueduct, were 19 cisterns, mostly rock-cut and roofed with stone slabs over arches, and a runoff system based around land-clearance and terracing of slopes.[65]

2.5 Urban water supply, storage and drainage

Waterholes (irregular features that access a shallow water table and lack visible reinforcement) dating to the Neolithic have been excavated in the northern Jazira at Gar Sur (ceramic Neolithic: Hassuna and Samarran periods) and Tell Hilwa (late Uruk period).[66] The Gar Sur waterhole was dug to a depth of 4.5 m below the ground surface, but was not bottomed. In general, they were used at sites away from wadis that would have needed to rely on a combination runoff and groundwater for their water supply. Other early examples come from Neolithic sites in the eastern Sahara.[67]

As well as being used for irrigation (see section 2.3), wells (deep, cylindrical features that are often lined with stones, baked bricks or an organic framework) have been found at Tell Hamoukar, (Syria: Uruk period), Tell al-Hawa (Syria: 3rd or early 2nd

[59] Lewis 1999, 170-1.
[60] *Ibid*.
[61] Oleson 1991, 48.
[62] *Ibid.*
[63] *Ibid.*
[64] Oleson 1991, 49.
[65] Oleson 1991, 48 and 50.
[66] Wilkinson 2003, 47; Wilkinson and Tucker 1995, 30-31.
[67] Wendorf and Schild 1980, 135-7.

millennium) and Kurban Höyük (south-eastern Turkey: mid to late 3rd millennium).[68] The well at Tell al-Hawa had a 1 m diameter shaft and was comparable to an example from mid-late 3rd millennium levels at Kurban Höyük.[69] It seems that the shallower Chalcolithic waterholes were replaced either by these shaft wells or by deeper waterholes with enclosed depressions, such as that found at Mowasha. This is similar to the pattern observed at Kurban Höyük where the mid 3rd millennium well replaced the spring or seepage that had been used previously in the Chalcolithic. It is unclear whether this pattern was due to moister conditions in the Chalcolithic than the Bronze Age (see chapter 1.1) or whether the decline in groundwater may have been man-induced.

The Bronze Age saw a continuation of the technologies used in the preceding periods, alongside an increase in urbanisation (particularly in the form of tell sites). This led to new responses to the problem of water supply, especially in the emergence of a native tradition of runoff storage systems (open reservoirs and covered cisterns) that ensured perennial supplies of water for towns, thus supplementing the natural resources.[70] In the Hauran, for example, the installation of cisterns and channels represents a general Bronze Age development and differentiates it from the preceding periods.[71] On the small scale, early Bronze Age Bab adh-Dhra featured a cistern, Hazor (middle Bronze Age) also contained cisterns as did Ta'annek (late Bronze Age), all of which were waterproofed with plaster.[72] On the larger scale, some early Bronze Age towns, for example Arad, Ai and Byblos, featured intramural open reservoirs. The example from Ai had a capacity of c. 1800 m^3.[73] It has been suggested that these formed part of the town defences against water shortages during a siege.[74]

The idea of planning ahead for water shortage in times of civil strife suggests that the artificial provision of water had become an integral part of town life. This was reflected in Bronze Age towns where the water supply was planned as a coherent whole from the

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[68] http://oi.uchicago.edu/01/PROJ/HAM/NN_Sum00/NN_Sum00.htm. Miller 1980, 333-4; Wilkinson and Tucker 1995, 31; Wells seem to occur at an earlier date (Pre-Pottery Neolithic B) at Mylouthkia, Cyprus: Croft 2003, 3-6.
[69] Algaze 1990, 48.
[70] Miller 1980, 335.
[71] Braemer 1988, 133.
[72] Miller 1980, 337f.
[73] Tsuk 2001-2, 377-8. The reservoir was 25 m wide x 2.5 m deep.
[74] Miller 1980, 336f.

inception of the town plan. These systems show a sophisticated and, most significantly, a centralised approach to water storage. At Jawa, which relied on the seasonal flooding of Wadi Rajil, a complex system of diversion channels and underground cisterns was installed to extend the use of the floodwater runoff [Fig. 2.9].[75] At Byblos the water supply system evolved as the level of the town rose, for example the sides of the pool crater were reinforced with retaining walls and a flight of stairs.[76] Even more sophisticated was Arad where the water supply was integrated into the town plan: the runoff of a small catchment basin was channelled by radial streets to a central storage installation.[77]

Terracotta drainage channels are known from the 6th millennium BC, and those of fired bricks from the 4th millennium BC.[78] Although many of these drainage systems do not appear to represent integrated drainage networks,[79] there was nevertheless a clear concern for domestic hygiene even in early Neolithic dwellings.[80] These dwellings were equipped with lime plaster or clay surfaces extending part way up the walls, making them ideal for washing down with water.[81]

In the Bronze Age, drainage in the Near East discharged into the streets, but did not yet form part of a more integrated network. In First Dynasty Ur (c. 2600-2450 BC), for example, vertical terracotta ring-drains acted as soakaways [Fig. 2.10]. These were replaced in the later First Dynasty by drains into the streets, but switched back to the ring drain system soon after, possibly as a reaction to waste in the streets.[82] Drainage into the streets is also found at Eshnunna (Tell Asmar), alongside ring drain soakaways.[83] Meanwhile in Egypt (in the early Bronze Age) and Knossos (in the middle Bronze Age) more sophisticated and integrated drainage networks appeared, particularly in palaces [Fig. 2.11].[84] This private development of drainage networks suggests that as yet drainage had not become significant enough to merit the centralised management and organisation seen in the provision of storage facilities.

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[75] Miller 1980, 335.
[76] Miller 1980, 336.
[77] *Ibid.*
[78] Wikander 2000b, 608.
[79] Wilson 2000b, 156.
[80] Miller 1980, 335.
[81] *Ibid.*
[82] Wilson 2000b, 153.
[83] *Ibid.*, 156.
[84] *Ibid.*, 158.

2.6 Water storage and use in domestic contexts (including baths, latrines and *miqva'ot*)

In the Neolithic, ceramic storage vessels were developed to avoid water shortages. This technique developed into waterproof lime plaster vessels built into the floors of houses in Syria and Palestine.[85] The water stored in these vessels, especially those lined with lime, must have been unpalatable and so probably used for purposes other than drinking.

The Neo-Hittite palaces were equipped with baths and floors waterproofed with bitumen.[86] The drainage systems were mostly constructed from stone, but terracotta pipes were also used,[87] which represents an improvement from the Bronze Age systems.

While one would expect to find Hellenistic bathhouses in the Near East, the evidence for them is limited and mostly restricted to the Hasmonean palaces and private houses. Although there is some literary evidence for *gymnasia* in the Hellenistic Near East, their integration into urban life does not seem to have been as profound as in Asia Minor, Greece and Cyrenaica, which may explain the paucity of archaeological evidence for Hellenistic baths.[88] One small, possibly public, bathhouse has been excavated at Gezer.[89] It was a self-contained unit with seven rooms, three of which had two tubs in them. There was a basin in one room; the other four rooms were empty. The Hasmonean palace bathhouses usually had a changing room from which there was access to a *miqveh* (see below) and/or a bathing room with a plastered tub.[90] The private bathhouses at Beth Yerah, Nablus and Horvath Ma'agura were similarly small with just a single tub in a small room.[91] The private bathhouse at Tel Anafa comprised three rooms with sloping floors connected by interior drainage and had a primitive heating system.[92] Water seems to have been supplied by runoff from the roof, which would suggest that the baths may not have been in constant use.

Jewish ritual baths (*miqva'ot* (pl.); *miqveh* (s.)) are stepped pools that are used for the purification of the body by immersion in water [Figs 2.12-13]. A substantial

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[85] Miller 1980, 334.
[86] Wikander 2000e, 619.
[87] *Ibid.*
[88] Nielsen 1993, 103. On *gymnasia* built by Antiochus Epiphanes: I Macc. 1.12-14; II Macc. 4.9-12. On the early inclusion of baths in a *gymnasium* in Syria: Posidonius *Hist.* 16 (*Ath.* 12.527 c/e and 5.210 f).
[89] Macalister 1912, 223-228.
[90] Hoss 2005, 39.
[91] *Ibid.*
[92] Herbert 1994, 62-71.

bibliography has built up around these installations and their use in antiquity, particularly at Qumran, though much of this is in Hebrew.[93] *Miqva'ot* first seem to appear in the Hasmonean palaces and have been identified at Masada, Jericho and Herodium.[94] Other examples have also been discovered at Samaria, Sepphoris, Jerusalem and Qumran.[95] These pools seem to have been concentrated in residential areas at these sites.[96] The only exception to this is Jerusalem where stepped pools were found in a public setting on the Temple Mount.[97] After the destruction of the Temple in AD 70, there was a decline in the number of *miqva'ot* from two to three installations per house to one or two installations per village or neighbourhood.[98]

There are two main types of *miqva'ot*.[99] The first type comprises two basins; one basin functions as the immersion pool and one for water storage. The second type has just one basin, the immersion pool, which is often deep (over 3 m). It appears that the first type was often used in arid areas where water storage was necessary. The capacity of a *miqveh* must be above 40 *seahs* (40 *seahs* is roughly equivalent to 1 m^3).[100] The installations identified as *miqva'ot* at Qumran (68, 69, 144, 138) had relatively low volumes (c. 10 m^3), though two others (117, 118) that might also be *miqva'ot* were larger (50 m^3 and 40 m^3 respectively).[101] It would not be necessary, therefore, for these installations to be filled to capacity all year round.

According to Jewish law, water for *miqva'ot* should not be drawn. Preference was given to rainwater, though if drawn water was brought into contact with rainwater, it too became acceptable.[102] At Herodium and Jericho pairs of *miqva'ot* were found that were connected by a pipe or channel. Both *miqva'ot* were originally filled with pure rainwater,

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[93] The major recent works in English are: Wood 1984; Reich 1997; Reich 1998; Hidiroglu 2000; Galor 2002; Hoss 2005. For references to the works in Hebrew see Galor 2002. Galor also presented a paper on *miqva'ot* in Sepphoris at *Cura Aquarum in Ephesus 2004*.
[94] Masada: Yadin 1965, 91; Jericho: Netzer 1977, figs 3, 6 and 7; Herodium: Corbo 1967, figs 7, 18 and 19; Foerster 1970, pl. 16b.
[95] Samaria: Crowfoot *et al.* 1942, 122, 132, 134-5; Sepphoris: Galor paper at *Cura Aquarum in Ephesus 2004*; Jerusalem: Mazar, B. 1975, 146-7; Shanks 1977, 21; Reich 1998; Qumran: De Vaux 1973; Wood 1984; Hidiroglu 2000; Galor 2002.
[96] Galor 2002, 42.
[97] Reich 1998; Galor 2002, 42.
[98] Reich 1997, 431.
[99] Hidiroglu 2000, 37.
[100] Reich 1997, 430.
[101] Hidiroglu 2000, 28-9.
[102] *Ibid.* 38.

but only one was used for immersion. This *miqveh* could be re-filled using drawn water that was brought into contact with the pure water fed through the connecting pipe or channel.[103] Aqueduct water from a spring was also permissible. Six of the installations at Qumran were fed directly or indirectly by water channels, presumably supplying either rainwater or spring water. In addition, 19 of the 20 Hasmonean and Herodian *miqva'ot* at Jericho were fed by aqueduct water.[104] Provisions for draining *miqva'ot* were not provided as it was always necessary to maintain the 40 *seahs* of pure water.[105] This lack of drainage facilities would mean that the water in the *miqveh* was stagnant and probably very dirty. Although we refer to these installations as 'ritual baths', they were not used for bathing in terms of getting physically clean: pure and impure were not equivalent to clean and dirty.[106]

Two main distinguishing features can be used to identify these installations as *miqva'ot* rather than cisterns or other cavities. The first is the steps, which usually extend across the full width of the pool, rather than being confined to one corner as is usual in a cistern [Fig. 2.12]. The width of the steps points to a ritual, rather than a functional purpose; if these pools were intended for water storage, this would be an inefficient design because the steps take up a large percentage of the potential volume of the tank.[107] In addition, the steps provide easy access for several people.[108] On the Temple Mount in Jerusalem there were 37 cavities of different shapes and sizes and 2 of these (36 and 6) have been claimed as *miqva'ot* on the basis that they may have had steps.[109] These cavities were similar in plan, both resembling a capital T with the 'bar' across the top aligned east-west (dimensions and volumes were not provided). In cavity 6 the bottom of the southern extension was 4.8 m higher than the east-west aligned cavity, which suggests that the southern extension originally may have contained a staircase. This staircase may have been removed in subsequent remodelling of the cavity as a cistern.

The second feature is a method of dividing those who are entering from those who are leaving. This can be in the form of double doors or more frequently low walls or

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[103] Reich 1997, 430.
[104] *Ibid.*
[105] Wood 1984, 51.
[106] Galor 2002, 44.
[107] Wood 1984, 47.
[108] *Ibid.*
[109] Reich 1998, 63f.

partitions running down the steps [Fig. 2.12].[110] At Jerusalem there was just one partition running down the steps, but at Qumran there were two.[111] The extra partition at Qumran may have been used to direct water into the pool.

A final method of distinguishing *miqva'ot* from cisterns is to analyse whether the stepped pools are located close to unstepped pools, which would suggest that they have different functions. At Jerusalem, Sepphoris and Jericho stepped pools were often found in close proximity to other unstepped plastered installations that have been identified as cisterns.[112] This theory, in combination with the two other identification methods, has been used to prove convincingly that the plastered installations at Qumran were a combination of ritual pools and cisterns.[113]

The roles and purposes of *miqva'ot* were distinctly different from those for Roman baths. *Miqva'ot* were predominantly private ventures rather than public. Most importantly, *miqva'ot* were for ritual cleansing of the body, rather than physical washing and cleaning of the body as indicated by the use of stagnant, though 'ritually pure' water.

2.7 Watermills

The watermill was closely connected to *norias* (water-lifting devices) and it is the opinion of Lewis that the watermill came into being during the 3rd century BC.[114] His hypothesis is based upon a passage by Philo in the 230s BC comparing the gearing mechanism in Archimedes' clock to a watermill.[115] Thus, we begin to see the use of water for power in the Hellenistic period, though no pre-Roman examples have been discovered archaeologically.[116] It seems that milling technology began to spread from Asia Minor in the early 1st century BC and, according to Lewis, reached Syria and Palestine by the 1st century AD.[117]

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[110] Wood 1984, 49; Hidiroglu 2000, 38.
[111] Jerusalem: Shanks 1977, 21; Qumran: Wood 1984, 49.
[112] Galor 2002, 42.
[113] Wood 1984; Galor 2002.
[114] Lewis 2000, 644.
[115] *Ibid.*
[116] *Contra* Avitsur 1960 and Avitsur 1993, who presents little compelling evidence for their early use in Israel.
[117] Lewis 1997, 72, 122.

2.8 Conclusions

It can be seen from this overview that there was an extensive range of pre-Roman water management technologies employed in the Near East. Their importance extended from the countryside into the urban environment. Furthermore, the inhabitants of the various kingdoms and regions developed a sensitive approach to water supply, harnessing its power for their benefit and advantage by making use of the resources available to them and by maintaining an intimate knowledge of the potential of their landscape and its resources. From relatively simple beginnings with the development of irrigation systems to complex water-lifting devices, the Near East showed a consistently innovative and sophisticated attitude to water provision and capture. Indeed, the extent of the knowledge and innovation is such that by 63 BC most areas of the Near East were already equipped with water-lifting devices, dams, tunnelling technology, water storage facilities and well-developed irrigation systems as well as a legal infrastructure for the protection of the water supply.

Table 2.1: Summary of water technologies in the Near East before 63 BC, their earliest attested date and place.

Technology	Date	Place	Evidence
Water lifting - *shaduf*	Bronze Age	Mesopotamia	Depiction on seal
Water lifting - pulley	9th century BC	Megiddo?	Relief from Nineveh
Water lifting - *čerd*	7th – 4th century BC?	Susa?	Literary
Water lifting – wheel with compartmented body or rim	3rd century BC	Egypt	Literary (archaeological evidence from 2nd century BC)
Water lifting – water screw	3rd century BC	Egypt	Literary (possible earlier version at Sennacherib's palace, Nineveh)
Dams	Bronze Age	Ugarit (particularly associated with Nabataea in 1st millennium BC)	Archaeological
Irrigation – channels, dykes etc.	7th millennium BC	Zagros Mountains	Archaeological (literary evidence from Bronze Age)
Irrigation – qanats	5th century BC	Ayn Manawir, Egypt	Archaeological
Long distance water transport – terracotta pipeline	3500 – 2900 BC	Tell Habuba Kabira	Archaeological
Long distance water transport - tunnels	1st millennium BC	Nimrud; Levantine coast	Archaeological
Long distance water transport – inverted siphon	2nd century BC	Asia Minor (possibly Zincirli earlier in the millennium)	Archaeological
Long distance water transport - aqueduct	Early 1st millennium BC	Pergamon (then Nabataea); Erbil; Nimrud, Samos, Athens	Archaeological
Urban - waterholes	Ceramic Neolithic	Gar Sur, North Jazira	Archaeological
Urban - wells	Uruk	Tell Hamoukar	Archaeological

Technology	Date	Place	Evidence
Urban water storage: reservoirs and cisterns	Bronze Age	Hauran; Bab adh-Dhra; Hazor; Ta'annek; Arad; Ai; Byblos; Jawa	Archaeological
Urban drainage into streets	Bronze Age	Ur	Archaeological
Domestic water storage (in ceramic vessels)	Neolithic	Syria and Palestine	Archaeological
Private baths	1st millennium BC	Neo-Hittite cities	Archaeological
Watermill	3rd century BC	Alexandria/Byzantium	Literary; archaeological evidence from 1st century AD

Table 2.2: Chronological summary of introduction of water technologies into the Near East.

Period		**Technology**
Neolithic (9th to 4th millennia BC)		Irrigation Waterholes Wells Ceramic storage vessels Long distance pipeline
Bronze Age (3rd to 2nd millennia BC)		Cisterns and reservoirs Dams Legal infrastructure for irrigation Drainage into streets *Shaduf*
End of 2nd millennium and 1st millennium BC		Large irrigation channels Tunnels Private baths *Čerd*
	9th century BC	Aqueduct (?) Pulley
	3rd century BC	Water screw (?) Watermill Wheel with compartmented body or rim
	2nd century BC	Inverted siphon (?)