Rainwater harvesting in ancient civilizations in Jordan

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Abstract One might think that locations of settlements through history depended on the existence of a nearby permanent water source. Wåhlin thinks that anthropologists and geographers seem to have missed that people in settlements in many parts of the Middle East were able to create for themselves a near-permanent water supply in places where nature was not kind enough to place a river or a spring. Several sites in Jordan provide examples of these creations. Despite an arid to semi-arid climate, several civilizations have started and flourished in these conditions. This paper summarizes the types of systems that people have used through history to develop reliable water supplies in this part of the world. Jawa was a settlement in northern Jordan during the Bronze Age that built an extensive hydraulic system. At Um El Jimal, a city in northern Jordan during the Byzantine era, deflection dams, canals and reservoirs provided a local water supply. Nabateans excelled in water management using cut-stone reservoirs in their capital, Petra, and their empire flourished more than 2500 years ago in what is now southern and central Jordan. Underground cisterns found in Umayyad desert castles in different parts of the country reveal similar activities during the Islamic era. Examining how water resources were managed long ago can provide relevant information in facing the water-resources challenges of today in arid lands.

Keywords Ancient civilizations; Nabataean; rainwater harvesting; water management

Introduction
Jordan is currently one of the ten poorest countries in the world with regard to its water resources. Rainfall ranges between 50 mm in the eastern and southern desert regions to 600 mm in the northern highlands. More than 90% of the country receives less than 200 mm of rainfall per year. As an arid to semi-arid country, with limited surface water, Jordan is facing substantial challenges in managing its water resources.

Examination of how ancient peoples managed to survive and flourish without streams and wells can provide insight to measures that perhaps can be used today. One technique that has been extensively used was rain water harvesting. One example of this is the famous “Moabite Stone” where King Mesha of Moab commemorated proudly in about 850 BC:

‘I made two reservoirs in the midst of [Qerkhah]. Now there was no cistern in the city, so I said to all the people, Make you every man a cistern in his house’ (Wåhlin, 1997).

While this is perhaps the first written mention of water cisterns, it is clear that the technique had been used earlier. According to Archaeological Encyclopaedia of the Holy Land (1972 p.332), “The first cisterns were dug in the Middle and Late Bronze Age [2200–1200 BC; LW]. The rainwater that collected in them during the short rainy season would be enough for at least one dry season. In some parts of Palestine cisterns were the main (sometimes even the only) source of drinking water in peace time as well as in war.

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time. In the early Iron Age [1200–1000 BC; LW] the sides of cisterns began to be covered with watertight plaster, which considerably prolonged the time for which water could be stored. It was this important innovation that made it possible to extend the areas of settlement into the mountainous parts of the country.

The occurrence of the first cisterns, however, likely was earlier. At Jawa in the black lava desert of north-eastern Jordan a sophisticated water-collecting system was planned and built before 3,000 BC.

Although evidence for earlier cisterns seems clear, technology limitations restricted the scale and numbers of cisterns that could be constructed the Iron Age. At Hesban, during Iron I (1200–1150 BC), “a significant water management complex consisting of at least one, and probably many…cisterns, and an overflow tank, which possibly also served as a channel for leading water to a yet-to-be-discovered reservoir” was used (Wåhlin, 1997). Through the following Hellenistic, Roman and Byzantine Periods, construction of wells and cisterns increased and continued (Abujaber, 1995).

This paper aims at investigating major water harvesting schemes that were developed by different ancient civilizations that, for a time, flourished in this part of the world.

**Jawa**

Jawa ruins date to the Bronze Age, about 5,000 years ago. The climate at Jawa today is characterized by intense rainfall for few days during the year and dry weather with high temperatures for the rest of the year. The technology used in Jawa was simple, and because it was constructed above ground, even today its operation was clear. Jawa is truly a good example in the history of urbanisation that has preserved a potential recognition of prehistoric scientific ideas (Helms, 1981). Residents of Jawa developed a reliable water supply by capturing winter rainfall runoff and and storing in man-made reservoirs or cisterns.

The Jawa water supply depended mainly upon a large macro-catchment and a number of micro-catchments. Wadi Rajil catchment was the major supplier of water for the town and judging from its size it can be imagined how difficult it was for the people of Jawa to control such a wadi. It has been estimated that currently an average of 2,000,000 m³ of water is discharged every year, and one can assume that similar volumes of water were discharged in the past (Helms, 1981). From this huge amount of water that discharges, the amount that passed through the town’s system was only 3 per cent (around 70,000 m³; Helms, 1981).

Water was retained at Jawa by deflection dams. The construction of such dams directed only a small part of water from Wadi Rajil to the canals leading to the storage areas (Helms, 1981). Design, construction and operation of these structures required a fundamental understanding of weather patterns as well as hydrodynamics, surveying and earth mechanics. In addition, it required the understanding of basic science in terms of observation, recording, evaluation and prediction (Helms, 1981).

Helms (1981) recognized that the Jawa water system comprises three sub-systems that reflect the three catchment areas that the city could use. The first sub-system consisted of a canal that led water from a deflection dam through a number of irrigable fields to an outflow gate where some of the flow entered an underground reservoir. The main canal continued to another outflow where it divided in order to fill three water reservoirs utilized for drinking purposes. A branch of the main canal bypassed the storage area, passed through fields and reached an animal watering point. All the excess water was returned to Wadi Rajil. Additional run-off was captured with three linked micro-catchments that used deflection walls. The water from these was directed either to the bypass canal or to the three reservoirs. The second sub-system used a second deflection dam opposite the eastern quarter.
of the lower town to raise water along the steep eastern shore of Wadi Rajil (Helms, 1981). A canal transferred water to an outflow gate that fed two storage pools. As in the first system, a micro catchment was added. The run-off from the additional catchment passed through a number of fields to a pool. The third sub-system was also based on a deflection dam and routed water through a gravity canal to a number of outflow gates. This urban water system is the oldest and most complex yet discovered (Helms, 1981).

Dams in Jawa mainly consisted of a stone water face and stone reinforcement downstream with an earth fill in the middle. The fill was made up from rock-hard clay, silt and packed with layers of ashes (Helms, 1981). The builders constructed a stone-paved apron at the upstream feet of the dams (Figure 1) to protect them from wave action that may have affected the structure (Alkhaddar et al., 2005). The use of ash as a water-resistant material has proven to be very effective.

The general structure of the dam, apart from the water face, is very modern in that the down stream revetments have a function similar to the drainage blanket of more recent embankment dams (Helms, 1981). The anticipated silting of the reservoirs served multiple purposes. First it would fill any gaps between the basalt rocks to prevent any leakage and secondly when it was removed it was used for house building (Alkhaddar et al., 2005). The same technique that was used to build the dams was used to build the pools.

The ancient people of Jawa used the technology and an awareness of the seasonal distribution of rainfall to design, build and operate a water-supply system that supported the community’s needs. Jawa provides an example of the potential for water harvesting in arid regions.

**Umm el-Jimal water harvesting system**

Umm el-Jimal was an extensive rural settlement in the Hauran region. It was constructed of black basalt in the lava lands 20 kilometres east of Mafraq, Jordan. The settlement lies on the edge of a series of basalt flows that slope down from Jebel Druze, a basaltic volcanic cone 50 km to the northeast. The essentially continuous basaltic layers provided ancient Umm el-Jimal with two basic resources: stone for construction and water for drinking and agriculture (de Vries, 1997). The city was founded in the Early Roman period and experienced considerable Nabataean influence. It flourished as a frontier city of the Roman and Byzantine Empires and continued to prosper in the Umayyad period, perhaps because of its proximity to the Desert Castles and the Pilgrim Route. Umm el-Jimal was destroyed by an earthquake at the end of this period and not rebuilt because the region lost its pre-eminence when the seat of government shifted to Baghdad under the Abbasid Caliphs (de Vries, 1982).

![Figure 1](https://iwaponline.com/ws/article-pdf/7/1/85/418455/85.pdf)
A sophisticated hydraulic system was constructed in Um el-Jimal to supply both town and countryside. The water supply system was constructed in order to utilize a few intensive rainfall events that today occur in the rainy season between December and early March. After that period the average rainfall drops to a very small value. This compelled the founders/builders of the town to develop a water harvesting system to sustain them through the long dry periods between significant rains.

The water system of this ancient town is a combination of dams, channels and underground reservoirs that were constructed during the Late Roman Period (de Vries, 1993). The dams were built in the higher parts of the mountains to collect and divert the water to the channels and into the reservoirs (Alkhaddar et al., 2005). Records show that, although rainy days do not exceed 30 to 40 days per year, seasonally intense rainfall has the potential to supply large quantities of water. Because the area has a very long summer with temperatures that can reach up to 50°C, the annual evaporation rate is greater than the annual rainfall rate. These extreme conditions of heat and rain forced the people at the time to develop methods to work within weather conditions (Alkhaddar et al., 2005).

Three rock/stone dams were built that included a release mechanism that was operated manually in case of extreme flooding. These diversion dams were designed to delay the water and enable it to be led via canals to the reservoirs (Alkhaddar et al., 2005).

The three dams fed a network of surface canals that carried the water inside the walls of the town. The main canal was built entirely of stone and was around 4 km long. The width and the depth of the canal varied according to the topography and the slope of the ground. Outside of the town the canals were between 30 cm and 60 cm wide and 20 cm and 60 cm deep. Within the town the canals varied between 120 cm and 80 cm in width and between 60 cm and 50 cm in depth (Alkhaddar et al., 2005). The various sizes of the canals served a number of purposes. It was necessary for the water to reach the town quickly to minimise evaporation. However it was also important for the water to travel at a relatively slow speed to avoid any damage to the canals (Alkhaddar et al., 2005).

The Umm el-Jimal system also included ten totally covered reservoirs inside the town’s walls and a number of open ponds inside and outside of the town. Once the reservoirs filled, water was diverted to the secondary ponds. These ponds mainly were used for irrigation or watering animals. The underground reservoirs served not only to prevent evaporation, but also to protect the public and animals from falling in since most of the reservoirs were inside the town limits. The reservoirs were roofed by spanning with traverse arches. These were levelled with the help of filler blocks, then covered with rock slabs. The slabs were covered with about 1.5 m of soil to prevent evaporation and enable traffic above the reservoirs (Alkhaddar et al., 2005).

The main reservoir was much larger than reservoirs built in other towns in the same period. It was rectangular and had a length of about 40 m, a width of 30 m and a depth of 4.3 m, yielding a total capacity of about 5,100 m³ (Khoera, 1990). The size of this reservoir suggests that it was not entirely artificial but may have been a natural cavity or depression that was improved. After the original inhabitants abandoned the reservoir and the town, Bedouins utilized the reservoir until the present day. Destruction over time and changes subsequently made removed any evidence of how this large structure was roofed.

The town also had 28 ponds, which were built for use during the construction of the town. Later they were used to store the excess water from the overflowing cisterns and run-off (Alkhaddar et al., 2005).
Even though it was not common at that time, water was treated in Umm el-Jimal. The system that was used was a simple but effective system for removing suspended solids in the water. The method used was based on a small settling tank with three different compartments located upstream of the main reservoir (Figure 2). The tank had a total capacity of about 41 m$^3$ and each one of the three compartments had a capacity around 14 m$^3$. The depth of the tank was 2 m.

Water was allowed to enter the settling tank and solids were removed by gravity as it flowed through the three compartments. After the final stage of settling in the third compartment the water entered the main reservoir. Cleaning of the settling tanks was probably done manually when sufficient sediment had been deposited to degrade system performance. This very simple method of water treatment enabled the people of Umm el-Jimal to remove much of the suspended materials that might have entered the water during its journey to the reservoirs. This simple technique is still a component today in wastewater treatment (Alkhaddar et al., 2005).

As Jawa, the town of Umm el-Jimal is an example of the water management techniques developed by the ancient peoples of Jordan. The techniques used in Umm el-Jimal can be adapted in current water management strategies in order to improve their efficiency. They could be used in similar areas to capture and use water that otherwise would evaporate, or perhaps use to recharge the ground-water system.

**Nabataeans**

The Nabataeans civilization emerged in southern Jordan more than 2,500 years ago. Originally a nomadic tribe, they began migrating gradually from southern Arabia around the sixth century BC. Over time they abandoned their nomadic ways and settled in a number of places in southern Jordan. Their capital was the historic city of Petra. The Nabataeans carved grandiose buildings, temples and tombs out of the sandstone layers that are exposed throughout this region. They also constructed a wall to fortify the city, although Petra was largely naturally defended by the surrounding sandstone mountains (www.KingHussein.gov.jo/history.html).

To survive and prosper in this arid region the Nabataeans also had to develop and maintain a relatively advanced water-management capability. They were skilled at collecting, transporting and storing water, and irrigated their land with an extensive system of dams, canals and reservoirs. As the Nabatens gained more wealth and prospered, their increasing standards of living and expanding settlement likely created an increasing demand for water. To meet this they expanded the use of traditional water
harvesting techniques of the area. They also started using new techniques learned from their contacts with other parts of the civilized world, the principal influence being Hellenistic (Oleson, 1995).

Forder (1923) wrote that “In Petra […] huge cisterns were hewn in the rocks into which the rain water was run through surface channels. These cisterns were high up in the side of the rock, so as to prevent defilement. The interior was divided by rock partitions into reservoirs, oft-times many in number, and so arranged that when one was full it would overflow into another. In these rock-hewn reservoirs millions of gallons of water could be stored and be always cool, clean, and available.”

Two Nabataean settlements, Humeina and Nakhl, are examples of rainwater harvesting schemes that were developed in areas outside of Petra.

Humeina

Humeina was the major Nabataean settlement in the Hisma, Jordan’s southern desert. The average rainfall in the 240 km² catchment area is about 80 mm per year. A survey conducted in 1986 identified sixty one sites outside the settlement centre. The sites were categorized as 51 cisterns, 4 springs, 1 aqueduct, 1 dam, 2 sets of wadi barriers, and 6 sets of terraces or stone piles (Nydahl, 2002). A survey conducted in 1987 on the water supply system inside the settlement documented 16 structures: 11 cisterns, 2 reservoirs, 2 sets of conduits or drains and 1 bath building (Nydahl, 2002).

Cisterns were either unroofed, roofed with stone slabs, or beneath undisturbed bedrock. Fourteen are roofed in the typically Nabataean fashion using transverse arches (Oleson, 1992). Two cisterns, Nos. 67 and 68, are two good examples of a rainwater harvesting technique the Nabataeans used. One has a capacity of 445 m³ and the other a capacity of 486 m³. Both are rectangular, narrow and roofed with stone slabs carried by sixteen transverse arches. They were built to harvest water from a large field that covers approximately 100 ha north of the settlement. The area was protected from habitation throughout the history of the settlement. Cistern 67 has a 25 m long intake channel. The cistern 68 intake channel was built of large, heavy slabs of stone, has a deep settling tank and was roofed with a slab carried with two transverse arches. Major parts of the roof are still supported by the fourteen remaining arches. The stones were carefully cut and placed and were waterproofed with a hard sandy plaster containing pebbles (Oleson, 1988). Figure 3 represents a reconstructed perspective view of the cistern. Because of the size, interrelationship, quality and location of these two cisterns, Oleson (1988) suggests that a municipal authority built them for public use.

The other nine cisterns within the settlement also were built of stone. All but one are circular in shape and much smaller than Nos. 67 and 68. Oleson (1988) concluded that the smaller size and the fact that they are usually buried in structural remains suggest they were built for private use by individual families.

Nakhl

Nakhl is one of the larger antiquities sites on al Karak Platateau. It is situated at the confluence of three wadis in a 52,000 m² catchment that receives about 300 mm per year of winter rainfall.

The Nabataeans (and later Roman and Byzantine populations) at Nakhl built low dams to store water in the upper reaches of Wadi Nakhl. The dams were constructed to fill sequentially. Cisterns were used to store surface runoff from streets and buildings.
Wells were constructed to allow inflow as well as overland flow for replenishment (Nydahl, 2002).

In the catchments area, there are preserved lateral walls that were constructed to capture and hold runoff for crop and animal uses. The walls enclose about 34,000 m$^2$ of the catchment and were built using local unquarried stones. Furthermore, there are low walls dividing the areas between the walls into smaller spaces that might have been pools or reservoirs. It is also possible that the walls may have retained soil which would have been used for agriculture. However, no remains exist today (Nydahl, 2002).

**Ummayyad desert castles**

Ummayyad desert castles mark a period of flourishing Arab civilization. They were built mostly by the Ummayads (AD 661–750), Muslim Arabs who succeeded in transforming the fringes of the deserts into habitable settlements with their water management systems. Desert castles are found mainly to the east and south of Amman (further information is available in brochures from the Jordan Tourism Board). Examples of those desert castles are:

- **Qasr al Hallabat site** which comprises a group of discrete, widely separated units. These include a castle, a mosque, a huge reservoir, eight cisterns dug into the western slopes of the Qasr, an irregularly shaped cultural enclosure with an elaborate system of sluices, in addition to a cluster of houses which extend to the northwest of the reservoir.

- **Hamam Al Sarah desert castle** which comprises three principal elements: the audience hall, the bath complex and the hydraulic structure. However, this castle suffered from damage in the 1950s, when it was pilfered for its stones.

- **Qasr Al Haraneh** which is situated about 65 km east of Amman. It consists of 61 rooms arranged into two levels surrounded by a central courtyard. This desert castle has a small water tank standing in the middle of the courtyard to collect rainwater from roof tops. Additional water was obtained from seep-holes dug in the adjacent wadi bed.

![Figure 3](https://iwaponline.com/ws/article-pdf/7/1/85/418455/85.pdf)
Al Qastal desert castle which lies 25 km south of Amman. Unfortunately, the site has been built on and a large portion of the main building has been covered by a modern house. More than 100 cisterns and a substantial dam, 400 m long and 4.25 m wide, have been identified. Plans are underway to restore the castle and the ancient water system.

Figure 4 presents a water harvesting system built in Amman Citadel, which was also built in Ummayyad times.

Conclusion

In the third Millennium, when we say we strive for sustainability and good husbandry of the earth’s resources, people sometimes appear to know less (or, worse, care less) about such matters than did people who lived centuries and even millennia ago. One field in which this is obvious is water management and conservation (Wåhlin, 1997).

Lessons learned from old civilizations surviving and flourishing in arid zones, including their solutions to water supply, can be starting points for new solutions today. A number of ancient examples of effective water harvesting systems have survived in the country, and are examples of the successful efforts that peoples have made to live and survive in this part of the world.

This is of special importance to Jordan, as development of a sustainable water supply is one of the major challenges that it faces today. The increasing water demands and the shortage of current water supplies to meet those increasing demands made looking into how water resources were managed in the past inspiring in facing the challenges of managing today’s water resources.

Rainwater harvesting can help supplement potable water resources in Jordan. For centuries people have relied on rainwater collected from surfaces, and stored in cisterns to supply water before water supply systems were developed. Nowadays people have to think how to combine modern supply systems with old harvesting methods.

References


