The confluence of water and power: water management in the Brantas river basin from the tenth to the sixteenth century CE
Prasodjo, T.

Chapter 5

Archaeological Records of Brantas River Basin Water Engineering

In the previous chapter, I explored the textual sources (Old Javanese texts and inscriptions) that can be used to reconstruct the water management of East Java. In this chapter, I will present non-textual material culture and archaeological records to reconstruct further Old Javanese hydraulic infrastructure. Most of the archaeological records I use are findings from East Java. They range from ancient monuments, such as bathing places (*patirthaan*s), through archaeological features such as dams, canals, ponds, tunnels, and wells, to relatively small archaeological data like temple reliefs, water pipes, and waterspouts.[1]

The populations of the East Javanese states occupied both the upland and the lowland zones of the region. Because of the variation in the geomorphological characteristics of the landscape from the mountainous areas to the lowland zones—such as the delta areas—communities were forced to develop various water control strategies in order to secure a supply of water for their populations and agricultural activities. Thus, mastery of engineering skills was essential to secure a water supply, something that included everything from planning and designing to practical building skills. In Charles R. Ortloff's study comparing the water control systems practised by ancient New World and Old World societies, he concluded that societies coped with their water supply needs by using different ways of developing water

1 An archaeological feature is any material remains, such as a physical structure, that has been made or modified by humans. The term refers specifically to non-portable material remains that cannot be removed from their site.

management skills, ones which varied in accordance with the distinct environment of each area. Some left traces that can be seen in their archaeological remains, and a few of them preserved their water control system for many centuries, on occasion until today.[2]

Archaeological remains related to water engineering in East Java, especially in the Brantas river basin, are spread across the entire Brantas area, in both the highland and the lowland zones, from the Malang highlands to its delta. In this area, the East Javanese polities set up many hydraulic systems to support their way of life. The archaeological evidence I will present below demonstrates that the East Javanese polities had consistent water control regimes for the whole of their existence. I will present the archaeological records related to East Javanese water engineering on the basis of scale: first, large-scale water engineering and, second, small-scale water engineering.

5.1. LARGE-SCALE WATER ENGINEERING

For the communities of the early East Javanese kingdoms, a basic water supply that was used to support the population and agricultural activity was provided by springs, rivers, wells, and rainfall. The springs and wells allowed people to draw water from groundwater, a natural underground reservoir that lies in the earth's water-table, while rivers acquire their water from groundwater discharge such as springs and from surface rainfall run-off. For many centuries, humans have used such freshwater supplies to support their lives as well as employing them in engineering projects in order to improve their quality of life.[3] The provision of fresh water sometimes requires human involvement, leading to innovations in water supply technology that are used alongside the natural water supply. Two of the main mechanical problems related to water technology that require solving are: how to lift water to a higher level; and how to divert or distribute the water somewhere else. One example of a water lifting technology is a well, in which the water is lifted vertically, either through a well fitted with a lifting device or just a dipping well. An example of the latter technology is the diversion dam and a weir, sometimes equipped with sluice gates.[4]

Both these principles of water technology were followed by ancient builders

2 Ch. R. Ortloff, *Water Engineering in the Ancient World: Archaeological and Climate Perspectives on Societies of Ancient South America, the Middle East, and South-East Asia* (Oxford: Oxford University Press, 2009): 383.

3 Helen Chapman Davies provides many examples of the technology of the utilization of groundwater; see: H. C. Davies, *The Archaeology of Water* (Gloucestershire: The History Press Ltd., 2008).

4 V.L. Scarborough, *The Flow of Power: Ancient Water Systems and Landscapes* (Sante Fe: School of American Research, 2003): 39-40.

of the East Javanese waterworks, and they can be seen in water engineering archaeological finds in the Brantas river basin. Such remains can be found in many areas of the river basin, in both upland and lowland areas, and as regards large-scale water engineering projects there are remains of dams, ponds, weirs, canals, underground tunnels, and wells, among others.

The majority of the large-scale water engineering within the Brantas basin is related to irrigation and to settlement water supply systems. The ancient irrigated region that stretches between the Anjasmoro-Welirang mountain ranges and the Brantas river is the best example of large-scale water engineering in East Java. This region, which currently is in the Mojokerto and Jombang districts, is around 30 x 30 km. In the southern part of the region are two mountain ranges, called Anjasmoro and Welirang; as such, this southern area is steeper than the northern part. Streams and small rivers flow from south to north and eventually join with the Brantas river. The two main rivers are the Gunting and the Brangkal, but on the mountainous slopes of the southern part run smaller rivers like the Pikatan, Kromong, Landean, and Boro. The region has been an agricultural area at least since the early tenth century CE, as evidenced by the Sarangan inscription 851 Śaka (929 CE) and the Wulig inscription 856 Śaka (934 CE), which demonstrate that dams were built for irrigation purposes and that the area became more intensively cultivated in the period of the Majapahit kingdom.[5]

The slopes of the Anjasmoro and Welirang mountain ranges were an important part of the region's hydrological system because they functioned as a water catchment area for the whole region. The western part of the region is fed by two rivers, the Gunting and the Brangkal. The Gunting runs northwards from the western slopes of Anjasmoro mountain, while the Brangkal is fed by a number of streams and small rivers from the central part of the Anjasmoro-Welirang mountain ranges—including small rivers such as the Pikatan, Kromong, Landean, Pandaan, Mantring, Grosok, and Boro—which merge to become the Brangkal. These two rivers, the Gunting and the Brangkal, were important parts of the region's hydrological system, especially in the Majapahit period when a large urban settlement known as Trowulan flourished there.

In 1926, Maclaine Pont published a report in *Oudheidkundig Verslag* concerning archaeological information related to the area between Majapahit (Trowulan) and Penanggungan. He cooperated with the Eschauzier sugar factory to investigate a disused irrigation works. This investigation resulted in a map of the dams (*waduks*) in the region, which identified around 18 of them, although he describes only 11 in detail.

Based on his field observations, especially of the geomorphology and topography of the landscape, as well as the characteristics of the river's flow, he explained that the region—which was, as he put it, the "Uncultivated lands

5 See the discussion of inscriptions in Chapter 4.

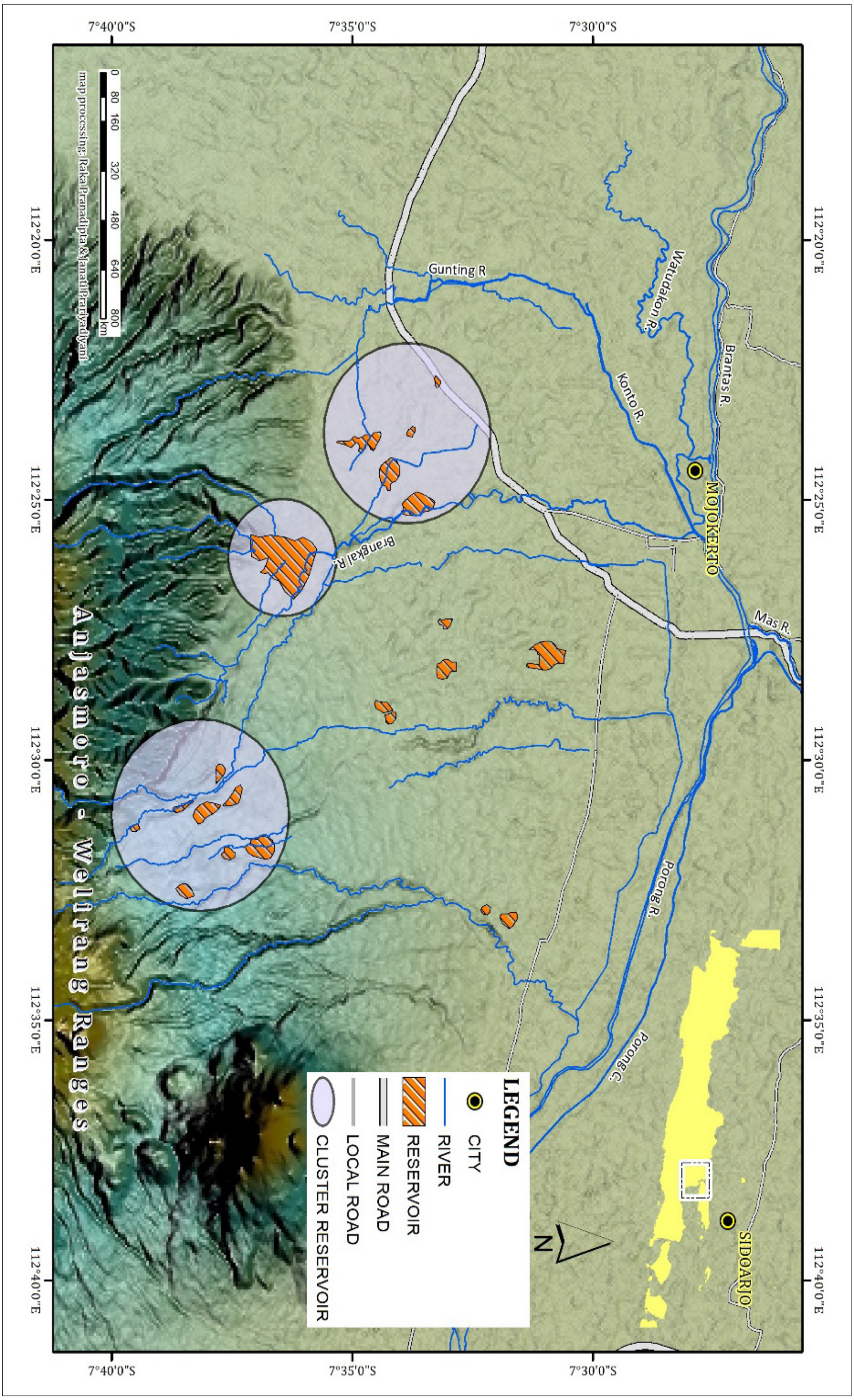

Fig. 5.1. The irrigated region between the Anjasmoro-Welirang ranges and the Brantas river, with its rivers and dam clusters (redrawn from Maclaine Pont's map by Tjahjono Prasodjo).

of the people of Trik"—was safe and prosperous for the Majapahit people.[6] The map and the list of the dams he provided give some idea of how large-scale water engineering was carried out by both rulers and subjects at least since the tenth century CE. The dams' functions seem to have varied in the details, although their main purpose was as a place to collect and hold a body of water. I observe at least three different variations regarding the functions of the dams in the region (Fig. 5.1.). The first of these groups of dams is located in the south-eastern part and consists of dams near the villages of Ketanen, Slawe, Kemiri, Wates, Candirejo, Randegan, and Wonokerto. The location of each dam is high on the mountain slopes—more than 350 metres above sea level—with steep terrain in which rivers, like the Pikatan and the Kromong, flow very fast. In order to slow the river's flow, the dams were built to collect and store some of its water, which could then easily be horizontally distributed for irrigation via man-made canals linked to it. Several of these dams date back to the tenth CE century, according to inscription records.[7] The second group can be found in the central area of the region around the Baureno dam(s), about 100 metres above sea level. Baureno was probably either a single large dam or a cluster of small dams, and the site was located in a large valley formed by a number of streams (the Boro, Mantring, Grosok, Pandaan, and Landean). Today, the area is a wide natural basin with a small modern dam on it. Near the dam is a small ruined temple called Candi Lima. The ancient Baureno dam clearly served as a reservoir for irrigating the surrounding areas and as a barrier meant to capture the debris flows that occasionally occurred on mountainous slopes and thereby protect areas downstream. The final group of dams is located in the western part of the central area, which is to the southeast of the Majapahit urban settlement of Trowulan. It seems that, in addition to the dams' purposes related to irrigation, they also served as a means of protection against flooding for the settlements to the north. As well as providing water for agriculture and drinking water, four dams in this area—the Temon, Kumitir, Domas, and Kraton—were built to control the river flow, especially as the Brangkal river becomes bigger after a numbers of rivers merge with it near Baureno.

As well as those large water reservoirs, there are smaller reservoirs or ponds. The best example of the existence of smaller reservoirs for community water supply is the presence of reservoirs on the Trowulan archaeological site, where there are two types. The first type is a man-made reservoir with a brick-constructed wall. In Trowulan, this type of water reservoir is represented by Kolam (pool/pond) Segaran; there were probably many more in the Majapahit period, but most have vanished. The Segaran pond is 375 metres long, 175 metres wide, and 2.88 metres deep, with pool walls 1.60 metres thick. The other type of reservoir is a natural

6 Maclaine Pont, "Eenige Oudheidkundige".

7 See: Chapter 4, especially Chapter 4.5, which contains information about this from the inscriptions.

Fig. 5.2. Kolam Segaran (left) and Balong Dowo (right). (Photos by Tjahjono Prasodjo)

pond called a *balong* by the locals. There are two *balongs* that can be seen now, Balong Dowo and Balong Bunder. Today, these standing bodies of water get their water from rainfall only, but it is possible that in the past a small water channel also supplied them.[8] Furthermore, other man-made ponds can be found at various other archaeological sites in East Java. One of these is at the Semarum site in Trenggalek, at a village in Semarum, which is a sub-district of Durenan. Like the Segaran in Trowulan, the pond at the Semarum is made of bricks. Unfortunately, the brick structure of the pond wall is in ruins and only part of it can be found. The structure is 1.10 metres high, 67 cm wide, and 24 metres long. Based on research conducted by Balai Arkeologi Yogyakarta, the man-made pond is estimated to measure at least 24 x 24 metres and dates from the eleventh to the thirteenth centuries CE.[9]

Regarding the irrigation systems of ancient East Java, the archaeological records show that *sawah* fields were mainly located outside the urban settlements and were provided with irrigated water from the dams via their water delivery systems. Relief panels from the Minakjinggo temple, now kept in Museum Majapahit in Trowulan, contain landscape scenes in which people cultivate the land. The first relief (left side) in Fig. 5.3, below, depicts a man working on the land with a tool, probable a hoe, and it is clear that the cultivated land is outside the area of settlement. The second panel depicts *sawah* fields that have dykes bordering each swathe of *sawah* fields, and it is clear that the *sawah* fields are located in a non-urban landscape or outside a settled area. This situation concurs with the ancient Javanese text records that most of the *sawah* fields were cultivated on the borders of or away from settled areas.

Landscapes containing *sawah* (paddy fields) are frequently mentioned in Old

8 See also A.S. Wibowo, "Fungsi Kolam-Buatan di Ibukota Majapahit", *Majalah Arkeologi* 1/2 (1977): 47.

9 H. Priswanto, "Hasil Penelitian Terbaru: Bentuk dan Karakter Situs Semarum", *Berkala Arkeologi*, 35/2 (2015): 140-141. The date is relative, and is based on the interpretation of ceramics found at the site (Majapahit-like ceramics and Song ceramics).

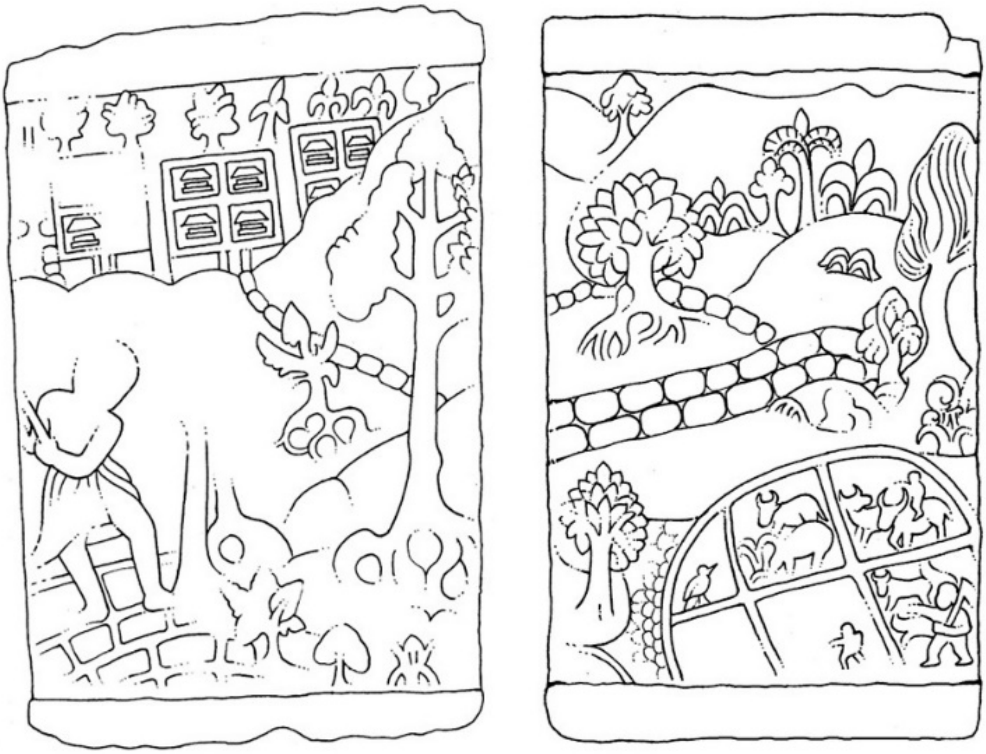

Fig. 5.3. Two sketches of two relief panels. Collections of Museum Majapahit, Trowulan, but originally from Minakjinggo Temple, Trowulan. (Sketched by Swa Setyawan Adinegoro).

Javanese texts.[10] This sort of irrigated rice field was located both in valleys far from the capital and in villages surrounding the capital itself. In Old Javanese texts this paddy field landscape is called a *pasawahan*, and the activity of working in paddy fields is called *asawah-sawah* or *masawah*.[11] In canto 22: 5, Arjunawijaya illustrates the activities of people farming in a rice field:

Sampun prāptěṅ těgal mwaṅ sawah i těpi nikaṅ rājyakaṇṭhâtiramya,
kirṇěkaṅ wwaṅ makāryâṅgaru hana maṅurit mwaṅ tikaṅ wahw atandur;
rary aṅhwan riṅ galěṅ söh sapi nika malayū lěmbu goñjoṅnya meṅas,
kagyat de niṅ kudôṣṭrâṅhrik adulur i harěp sāmajanyâtirodra.[12]

10 Tjahjono Prasodjo, "Penggambaran Lanskap Jawa Kuno dalam Kakawin", in: *Kuasa Makna. Perspektif Baru dalam Arkeologi Indonesia* (Yogyakarta: Departemen Arkeologi, FIB UGM, 2019.): 151-178.

11 Zoetmulder, *Old Javanese-English Dictionary*: 1715.

12 Supomo, *Arjunawijaya. A Kakawin of Mpu Tantular. Vol. I: Introduction and Text* (The Hague: Martinus Nijhoff, 1977): 119.

> The procession now came to a beautiful scene: an area of dry-fields and rice cultivation, just at the outskirts of the city.
> A great many people were working there: some harrowing, some making seed plots, others transplanting rice seedlings;
> on the dykes, children were tending many cows, which scattered in all directions as they were startled by the neighing of the horses and the braying of the camels passing by in procession, preceded by fearsome elephants.[13]

To irrigate the *sawah* fields, equipment was required to move water from the store or source to the fields. The ancient East Javanese developed a variety of means of supplying water to irrigate the land, some of which were canals and underground tunnels. The remains of this hydrological engineering were discovered in many sites within the Brantas river basin, many of which are still in use. In 1923, E.W. Maurenbrecher made an archaeological inventory of the Malang District and reported in *Oudheidkundig Verslag* at least five underground tunnels, in the villages of Oro-oro Dowo, Bunulrejo, Arjosari, Jedong, and Guyangan, in the district of Malang.[14] Blasius Suprapta mentions at least three more underground tunnels in Malang, namely at Lowokwaru (sub-district Lowokwaru), Karuman (sub-district Lowokwaru), and Polowijen (sub-district Blimbing).[15] Another report, in *Oudheidkundig Verslag over 1936*, states that three underground tunnels were found in Selaliman, Jenggring, and Keputren, all around Mojokerto.[16] In Selaliman, an inscription with the date of 1280 Śaka (1358 CE) was found inside a 40-metre water tunnel, while in a similar tunnel at Keputren was discovered an inscription with the date of 1227 Śaka (1355 CE).[17] These dates detail the time of the waterworks'

13 Supomo, *Arjunawijaya. A Kakawin of Mpu Tantular. Vol. I;* and S. Supomo, *Arjunawijaya. A Kakawin of Mpu Tantular. Vol. II: Translation* (The Hague: Martinus Nijhoff, 1977): 217. An interesting aspect here is its mention of a camel (*uṣṭra*). The camel is not indigenous to Indonesia, but three old Javanese texts, namely *Arjunawijaya*, *Sutasoma* and *Nāgarakṛtāgama* (*Deśawarṇana*), mention camels. Pigeuad's comments on non-native animals in Java is probably correct: "Donkeys and camels are not native to Java. Just like elephants they were probably imported (from India) only to be used in Royal processions to enhance the splendour of the display", see: Th. G. Th. Pigeaud, *Java in the 14th Century. A Study in Cultural History*, Vol 4 (The Hague: Martinus Nijhoff, 1962): 158.

14 E.W. Maurenbrecher, "Verbeteringen en Aanvullingen op den Inventaris der Hindoe-Oudheden (Rapport 1923) voor de Districten Malang, Penanggoengan en Ngantang van de Afdeeling Malang, Residentie Pasoeroean", *OV* (1923): 173 and 180.

15 B. Suprapta, *Makna Gubahan Ruang Situs-situs Hindhu-buddha Masa Sinhasari Abad XII Sampai XIII Masehi Di Saujana Dataran Tinggi Malang dan Sekitarnya*, Dissertation, Universitas Gadjah Mada, 2015.

16 W.F. Stutterheim, *Oudheidkundig Verslag 1936* (Bandoeng: A.C. Nix & Co., 1937): 16. Selaliman village now is called Seloliman, and is in the sub-district of Trawas, Mojokerto. Keputren is now probably called Keputran, a small village in Kutorejo, Mojokerto.

17 For descriptions of the inscriptions, see: Chapter 4.

construction. Besides finding such remains in the areas of Malang and Mojokerto, other waterworks were discovered in the vicinity of Kediri, as seen in the table below:

Tabel 5.1. List of Water Tunnels in Kediri and its surrounding Area. This list is based on my visit in 2016 and additional information from Novi Bahrul Munib (personal communication).

No.	Tunnel Name/Location	Village (*Desa*)	Sub-District (*Kecamatan*)
1	Goa Surowono	Canggu	Bada
2	Jlurung Sentono Maling	Gambyok	Grogol
3	Goa Baruklinting	Bogem	Gurah
4	Arung Sukorejo	Sukorejo	Gurah
5	Sumber Sumurup	Karangtengah	Kandangan
6	Sumber Jeblok	Keling	Kepung
7	Sumber Beji	Brumbung	Kepung
8	Sebanen	Nambaan	Ngasem
9	Sumber Gumuling	Bulupasar	Pagu
10	Situs Semen	Semen	Pagu
11	Mangiran	Lamong	Pare
12	Sumber Bringin 1	Bringin	Pare
13	Sumber Bringin 2	Bringin	Pare
14	Sumber Corah	Pare	Pare
15	Tegalarum	Langenharjo	Plaseman
16	Sumber Begendul	Sidowareg	Plemahan
17	Genukwatu/Genukrejo	Puhjarak	Plemahan
18	Sumber Bulu	Pagu	Wates
19	Kali Pesu	Pagu	Wates
20	Sumberjati	Pagu	Wates

Most of the water tunnels listed in table 5.1 were constructed underground and either carved through a compact sedimentary rock layer or constructed out of brick (see: Fig. 5.4 for the sedimentary rock carved-construction water tunnels and Fig. 5.6 for the brick water tunnels). The tunnels are of differing lengths, heights, and widths; some are 2 to 4 metres in length while the others are hundreds of metres long. The width and height of the tunnels are likewise varied. Subterranean water channel technology in East Java was occasionally linked to surface canal technology, with the result that, along a single water stream system, there would alternately be underground tunnels and surface canals.

Another type of subterranean water channel is demonstrated by an

Fig.5.4. Water tunnels at Begendul, Kediri (left) and Genuk Watu, Kediri (right). (Photos by Tjahjono Prasodjo)

underground water tunnel called the Surowono tunnel, in the village of Canggu (sub-district of Badas, Kediri), which is similar to the water-tapping technology known as *qanat* that is used in many areas of Western China, Central Asia, and the Middle East. The Surowono tunnel is around 400 metres long, has 4 access shafts with an outlet, and was carved through compact sedimentary rock. There is a distance of 50 to 60 metres between the shafts, each of which is 5 to 10 metres deep. Moreover, the width of the tunnel is also varied, being around one metre in some places but much less in others, while the height of the tunnel also varies, with the largest distance to the roof of the tunnel from the bottom being 170 cm while, near the outlet, the height narrows. Water flows through the underground water gallery and disgorges into an outlet, before flowing on to join a small river. The Surowono tunnel is still used by the local community for irrigation and domestic use today.

As well as underground water tunnels that were constructed by cutting through compact sedimentary rock to make a water gallery, ancient East Javanese engineers constructed underground tunnels using bricks. One example of such ancient water works is found near Pagu village, in the Wates sub-district of Kediri, on the bank of a small river called the Pesu. There are at least three tunnels along the riverbank, one of whose remains are 5 metres long, 1.5 metres high, and 1.6 metres wide at the widest point. The tunnel walls are constructed of brick veneer, with bricks being piled one on top of another without mortar. Each brick measures 21 x 42 x 8 cm.[18] The dimensions of the bricks are reminiscent of the ancient bricks used during the classical period of East Java, but no absolute dating has yet been carried out. Not far

18 BPCB Mojokerto, *Ekskavasi Penyelamatan Situs Pagu Kecamatan Wates, Kab. Kediri 2012* (Mojokerto: Balai Pelestarian Cagar Budaya Mojokerto, 2012): 18-20.

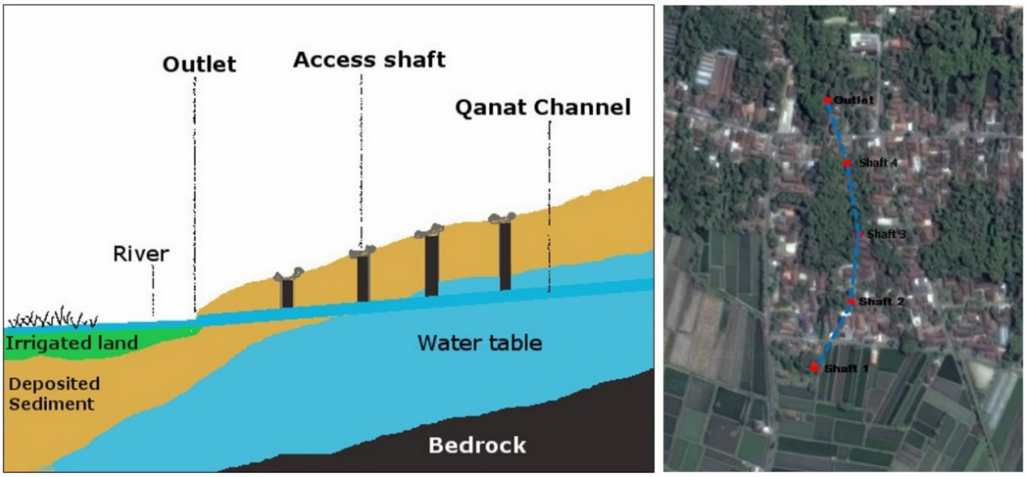

Fig. 5.5. Section of a *qanat* (left) and the Surowono tunnel (right). (Drawn [left] and plotted on Google Map [right] by Tjahjono Prasodjo)

Fig. 5.6. Brick constructed water tunnel near Pesu River, village of Pagu, Sub-district of Wates, Kediri. (Photos: BPCB Mojokerto, *Ekskavasi Penyelamatan Situs Pagu Kecamatan Wates, Kab. Kediri*: 32, 36, 37.).

from the riverbank, a *yoni* (the pedestal for the *liṅga*, a form of the Hindu god Śiwa), two statues, and a brick foundation were found. If both remains have a contextual function, then it would confirm that the tunnels were from the same period as the *yoni*, statues, and foundation, which themselves were from the classical period of East Java. Since only part of the tunnel remains have been found, the source of the tunnel's water cannot be identified. However, to the east of the site and not far from it are two springs that were probably the water sources of the tunnels in the past.

Another part of the large-scale water engineering projects are the debated archaeological remains of the Trowulan canal. In the past, it was believed that there was a large canal system at the Trowulan site, formed of criss-crossing canals, each of around 12 metres wide, and which were built in the ancient city of Trowulan. Earlier archaeological researchers believed that the canals functioned as both a means of transportation and irrigation infrastructure. In 1981, a team of geographers undertook research at Trowulan using a remote sensing technique and found on an aerial photograph of the Trowulan area a landscape feature that they took to be an ancient canal system (Fig. 5.7.).[19] This canal network was believed to be 20-45 metres wide, 4 metres deep, and around 23 kilometres long in total[20] However, this interpretation of the Trowulan "canal" has been challenged by Hermanislamet, Gomperts *et al.,* Yuwono, and Munandar.[21] Both Hermanislamet and Gomperts *et al*. question the existence of these canals. According to Hermanislamet, it is not possible to identify the feature as constituting a canal system, while Gomperts *et al*. explain:

> However, taking into consideration Stutterheim's map, our observations at the site, as well as expert hydrological considerations, it is possible that these canals could have been ditches, vallums or drains a few metres wide running along the four main roads leading to the crossroads, rather than fully engineered broad waterways per se.[22]

Additionally, Yuwono states that some archaeological findings, such as ancient wells, were found in the feature that was believed to be a canal, while some parts of it even contain roads that have a higher surface level than the surrounding areas. Moreover, a canal network that was almost 50 metres wide would need a large number of

19 However, the photogrammetrists were not able to determine whether it was a canal or a road network. See: K. Darmoyuwono, et al., *Penerapan Teknik Penginderaan Jauh untuk Inventarisasi dan Pemetaan Peninggalan Purbakala Daerah Trowulan, Mojokerto, Jawa Timur* (Jakarta: Badan Koordinasi Survey dan Pemetaan Nasional, 1981): 15, 31. On the interpretation of the canal, see also: Mundardjito et al., *Rencana Induk Arkeologi Bekas Kota Kerajaan Majapahit Trowulan* (Jakarta: Departemen Pendidikan dan Kebudayaan, Direktorat Jenderal Kebudayaan, Direktorat Perlindungan dan Pembinaan Peninggalan Sejarah dan Purbakala , 1986); K. Arifin, *Waduk dan Kanal di Pusat kerajaan Majapahit Trowulan-Jawa Timur*, Diss. University of Jakarta (Jakarta, 1983); K. Arifin, "Sisa-sisa Bangunan Air Zaman Kerajaan Majapahit di Trowulan" in: *Pertemuan Ilmiah Arkeologi IV. Buku I Evolusi Manusia, Lingkungan Hidup, dan Teknologi* (Jakarta: Pusat Penelitian Arkeologi Nasional, 1986): 169-187.

20 S. Simoen et al., *Penelitian Geolistrik Detail di Sepanjang Saluran Bekas Ibukota Kerajaan di Trowulan, Mojokerto, Jawa Timur*. (Yogyakarta: Gajah Mada University, Faculty of Geography, 1983): 30-47.

21 B. Hermanislamet, *Tata Ruang Kota Majapahit: Analisis Keruangan Bekas Pusat Kerajaan Hindu Jawa Abad XIV di Trowulan Jawa Timur*, Diss. Universitas Gadjah Mada (Yogyakarta: 1999): 69; A. Gomperts, A. Haag, and P. Carey, "Stutterheim's enigma: The Mystery of his Mapping of the Majapahit Kraton at Trowulan in 1941", *BKI* 164/4 (2008): 421; J.S.E. Yuwono, *Menelisik Ulang Jaringan Kanal Kuna Majapahit Di Trowulan, (http://geoarkeologi.blog.ugm.ac.id/files/2013/03/2013_kanal-trowulan1.pdf)*; and A.A. Munandar, *Tak Ada Kanal Di Majapahit* (Jakarta: Penerbit Wedatama Widya Sastra, 2013): 23-88.

22 Hermanislamet, *Tata Ruang Kota Majapahit: 69*; Gomperts, Haag, and Carey, "Stutterheim's enigma": 421.

Fig. 5.7. Map of the Trowulan canal network (blue colour), 1986 version. (Source: Mundardjito et al., 1986 with modification).

bridges to enable the inhabitants of the city to move around it, but so far no such bridge remains have been found. Based on these arguments, he seriously doubts the past existence of the canal network.[23] Munandar also casts doubt on it, arguing that the low and long features were in fact places where the common people lived, which would fit with the religious concept that the common people should live in the lower areas of the land while the more important people should live in the higher areas.[24]

23 Yuwono, *Menelisik Ulang Jaringan Kanal Kuna Majapahit Di Trowulan*: 3-4.

24 He uses the concept of *triangga (triloka)* and *sanga mandala* to explain that the religious

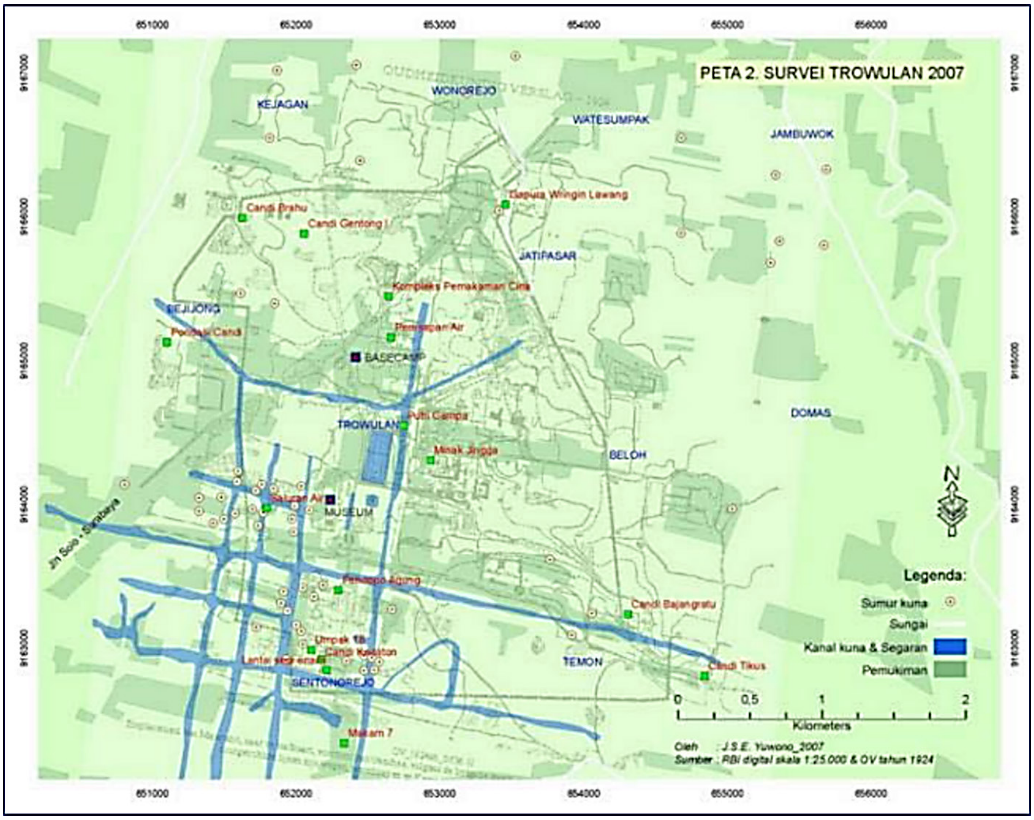

Fig. 5.8. The 2007 version Map of the Trowulan canal network. (Source: J.S.E. Yuwono in http://geoarkeologi.blog.ugm.ac.id/files/2013/03/2013_kanal-trowulan1.pdf).

I agree that interpreting the anomaly in the colour tone on the aerial photograph (Fig 5.7.) as demonstrating that they were canals should be questioned, but Munandar's interpretation of the low strip of land as the place of inhabitation of people from the lower caste is similarly weak. The concepts of *triangga* (*triloka*) and *sanga mandala* are not useful for explaining the settlement patterns of Trowulan because they are inconsistent with the grid pattern of the landscape as a result of being divided by the long and criss-crossing strips of low ground. If lower caste people did live along entire strips of the lower ground then they would also occupy the land that, according to both concepts, were the areas belonging to higher caste people because the strips of low ground cut across and crisscross the entire landscape of Trowulan. I prefer to interpret the anomaly of the colour tone on the aerial photograph not wholly as being evidence of ancient canals. Instead, only a

concepts were applied when setting up the settlement pattern of Trowulan. See: Munandar, *Tak Ada Kanal Di Majapahit*: 23-88.

limited number of them were small canals, while the majority should be viewed as ancient roads with, probably, ditches alongside them and most certainly not 50 metres wide.[25] However, significant attention should be paid to the landscape dynamic of Trowulan caused by human activities over time. The canals and roads of the past would not have been as wide as they are today, instead being much smaller than they are at present; humans most probably altered the topography of the landscape, including making the low land strips increasingly wide for reasons of agriculture or, for example, sugar cane plantation expansion.

5.2. SMALL-SCALE WATER ENGINEERING

In addition to the remains of large-scale water engineering, there are also the remains of water works on a smaller scale that can be traced back to the ancient East Javanese period. In small-scale water engineering, wells are the main source from which people could draw water. The use of wells was common in ancient East Java, especially in areas of settlement. They were dug by hand, probably using a shovel-like tool, until they reached underground aquifers. Most of the wells have a circular cross-section measuring 1 to 1.5 metres in diametre, but some are square with sides of one metre each. The well was lined with bricks, stones, or earthenware rings to prevent it from collapsing (Fig. 5.10.a,b,d.).[26] The upper part of the well, above the surface, had a stone or earthenware ring or bricks both for safety purposes and to prevent dirt and surface water from entering the wells. In one of the relief panels from the Panataran Temple, a water well with its upper wall is depicted; it also shows a man carrying a bucket approaching the well (Fig. 5.10.e.).[27]

It seems that these wells were not used solely for domestic purposes. Instead, their function was related to their location. While wells that were located near or had an association with a settlement were used to provide fresh water for households, wells located far from inhabited areas mainly had purposes related to a particular community activity, such as for watering plants or brick making, a process which requires water.

In the Trowulan site, several wells were found close together within a relatively small space, which seems to indicate either the use of communal wells—possibly because some kind of activity was performed there that needed a lot of water—

25 For this interpretation of the features as roads with small drains, see the cited statement of Gomperts et al. on the previous page.

26 The cylindrical earthenware ring has, on average, a diameter of 1 to 1.5 metres, is around one metre high, and 1 to 2 centimetres thick. A local term for this earthenware ring is jobong. There are two types of brick: a rectangular block brick used for lining square wells and a block brick with its opposite side curved which is used for circular wells. See also: A. Sukardjo, “Sumur”, *Warta Hindu Dharma* 506 (2009): 23-24.

27 A detailed description of the panel has been provided by Marijke Klokke in: M.J. Klokke, *The Tantri Reliefs on Ancient Javanese Candi* (Leiden: KITLV Press, 1993): 231-233.

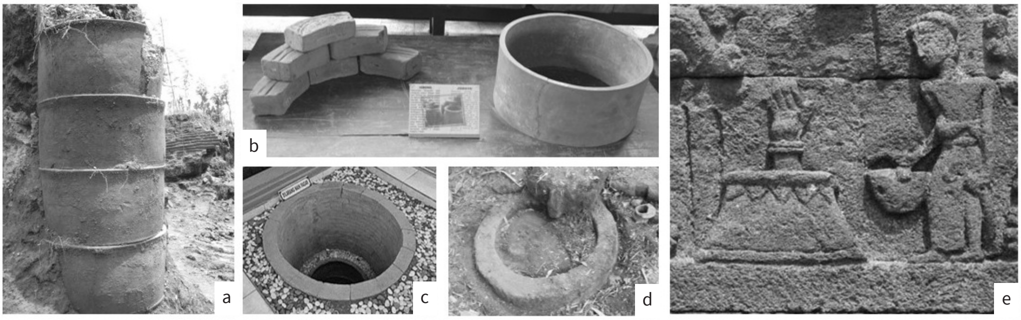

Fig. 5.10. Remains of ancient East Javanese wells (left and middle) and a well depicted on the Panataran Temple (right). (Photos: [a] and [d] by Novi Bahrul Munib; [e] from Lydia Kieven, 2013, Fig.7.32 cropped from the original)

Fig. 5.11. Sewage channel system at a house remain in Trowulan Open Museum.(Photos by Tjahjono Prasodjo)

or that different people built wells on the same location because it had the best underground aquifers in the area.[28]

Regarding the use of water for domestic purposes, the inhabitants of Trowulan created a drainage system in order to remove waste water from houses and their yards.[29] The remains of a Trowulan house that is displayed in the open-air Trowulan

28 Locations at Trowulan where a concentration of wells were found include Nglinguk, Sentonorejo, Kedaton, Batuk Palung, and Pandansili. See: Sukardjo, "Sumur": 23; and also the result of a recent archaeological survey on a high density of wells spreading over a 400 m^2 area at Nglinguk, Trowulan in: A.A. Munandar et al., *Air dan Kosmologi di Situs Majapahit* (Depok: Fakultas Ilmu Budaya Universitas Indonesia, 2014): 68.

29 In part of the Gomperts et al. article is detailed the water management of the Majapahit Capital, and it is demonstrated that such a sewage system existed in the city. See:

Fig. 5.12. The relief panel from Trowulan. (Photo: Krom, 1923: plate 67)

museum show part of a domestic sewage channel system. Fig. 5.11 shows a 10-20 centimetre wide brick-structured sewage channel network surrounding the remains of a chamber foundation with an earthenware water container in the middle, indicating that it was a bathroom. From each household the sewage ran out to an outer sewerage—most probably an open drain—which also collected surface water runoff from the whole settlement area.

A relief from Trowulan (Fig. 5.12) depicts a landscape of houses and their local setting, which contains a winding river with two bridges over it.[30] The most remarkable element of the depiction relating to sewerage is that, from a wall surrounding the houses, water flows from a conduit at the bottom and seems to run down to the river. This water channel is almost certainly a sewer channel from the settlement area, taking sewage to the river.

Outside Trowulan, a similar sewage system was recently found at the village of Semen, in the Pagu sub-district of Kediri. A rescue excavation was conducted at the site by *Balai Pelestarian Cagar Budaya Mojokerto* in 2014, producing some intriguing findings. Based on the relative dating of ceramic findings, the site dates back to around the fourteenth century CE. The team discovered the remains of a settlement and a small brick ditch measuring 30 cm wide by around 4 metres long (Fig. 5.13). The ditch starts from near the remains of this settlement and ends at the banks of

Gomperts, A. Haag and P. Carey, "The Archaeological Identification of the Majapahit Royal Palace: Prapañca's 1365 Description Projected onto Satellite Imagery", *Journal of the Siam Society* 102 (2014): 98-100.

30 According to Krom, the panel is part of series of reliefs, but the series is incomplete. Today, the relief is in the Museum Nasional Jakarta. See: N.J. Krom, *Inleiding tot de Hindoe-Javaansche kunst. Tweede Deel* ('s-Gravenhage: Martinus Nijhoff, 1923): 186-187.

Fig. 5.13. The brick ditch found at Semen site, Pagu, Kediri. Photo (a) was taken during the excavation in 2014 and (b) was the situation in 2016. (Photo (a): Balai Pelestarian Cagar Budaya Mojokerto, 2014: 28; Photo (b) by Tjahjono Prasodjo)

the small Kemanten river, which flows very close to the site.[31] It seems clear that this brick ditch was used to transport sewage to the river.

Regarding ditches, a number of Trowulan archaeological sites provide us with evidence of ancient ditches. There are two types of construction, underground water tunnels and open-air ditches, both of which are made of brick. One of the underground tunnels, found near the Brahu temple in Bejijong (Trowulan), was found to be 28 metres long and 1.5 metres wide when it was excavated in 2005 (Fig. 5.14, left-side photo).[32] The exact function of the tunnel is not yet known, although it may have been used as drainage for the area around the Brahu and Gentong temples. However, it was brick-built ditches that were most commonly built by the inhabitants of Trowulan. Recently, an ancient ditch was discovered at Nglinguk, Trowulan.[33] This is of brick construction and contains a number of interesting features, particularly a sluice-like gate, demonstrated by the presence of

31 Balai Pelestarian Cagar Budaya Mojokerto, *Laporan Ekskavasi Penyelamatan Situs Semen Kec. Pagu Kab. Kediri*. Excavation Report (2014). When I visited the site in August 2016, the channel was still intact, but it transversely crosses a small road, which threatens its preservation.

32 The height of the tunnel is at least 0.85 cm, but it is probably larger than that since the excavation was stopped at that level when water had started to flood the bottom of the pit. See: Kelompok Kerja Perlindungan, *Laporan Penyelamatan Temuan Saluran Air di Desa Bejijong, Kecamatan Trowulan, Kabupaten Mojokerto* (Balai Pelestarian Peninggalan Purbakala Trowulan Wilayah Kerja Propinsi Jawa Timur, 2005).

33 Balai Pelestarian Cagar Budaya Trowulan, *Laporan Ekskavasi Nglinguk* (unpublished, 2015).

Fig. 5.14. Underground brick tunnel at Bejijong (left). Nglinguk water controlling infrastructure (right). (Photos: Balai Pelestarian Cagar Budaya Mojokerto; The photos are taken from Kelompok Kerja Perlindungan, *Laporan Penggalian Penyelamatan Temuan Saluran Air di Desa Bejijong, Kecamatan Trowulan,Kabupaten Mojokerto* (Trowulan: Balai Pelestarian Peninggalan Purbakala Trowulan, 2005)).

Fig. 5.15. Nglinguk Ditch with sluice notch (left) and tranversed brick structure (right). (Photos: Balai Pelestarian Cagar Budaya Mojokerto)

a long vertical notch into which a sluice plate could be placed (Fig. 5.15). Moreover, a brick - or possibly a wood - structure was mounted transversely as a barrier across the width of the ditch to block water flow; as such, it probably functioned as a weir. It appears that people were attempting to control both the level of the water and its flow rate using both of these structures. Another brick structure was found at Nglinguk (Fig.5.14, right-side photo). It consists of a small brick building with a ditch underneath, and has been interpreted as a means of water control.[34]

Additionally, as part of their small-scale water management, the East Javanese developed pipe technology, and in particular pipes that were made of fired clay,

34 Suaka Peninggalan Sejarah dan Purbakala Trowulan, *Laporan Hasil Penggalian Penyelamatan Bangunan Air di Dusun Nglinguk, Kecamatan Trowulan, Kabupaten Mojokerto* (unpublished, 1999).

Fig. 5.16. Fired clay pipes and fired clay waterspouts: collections of Museum Majapahit at Trowulan. (Photos by Tjahjono Prasodjo)

Fig. 5.17. Reliefs depicting various water-spouts, from Candi Yudha (left, Photo: OD-12057, cropped from the original), Candi Rimbi (middle, Photo: Marine Schoettel), and Candi Kendalisono (right, Photo: OD-12637, cropped from the original).

bamboo, and stone (especially for the spout part). Pipes made of fired clay with a length of about 40 cm and a diameter of 8-10 cm were found across the Trowulan site, and some of them were collected and are now kept in the Museum Majapahit at Trowulan. The pipes were assembled as shown in Fig. 5.16 (bottom right-side photo), with two or more pipes being joined together to form a longer pipeline; to make it easier for them to be joined together, one end of the pipe was made narrower so they could fit inside each other. However, we do not know how the joints were made impermeable as no research has been carried out into this question. Most of the pipes are long and straight, but there are also T-shaped pipes and curved pipes as shown in Fig. 5.16 (top right-side photo). As well as pipes, the East Javanese also made small waterspouts from fired clay, which have various different shapes.

Concerning waterspouts, some East Javanese reliefs depict bathing places which exhibit various types of waterspouts. Two reliefs, seen in Fig. 5.17, portray

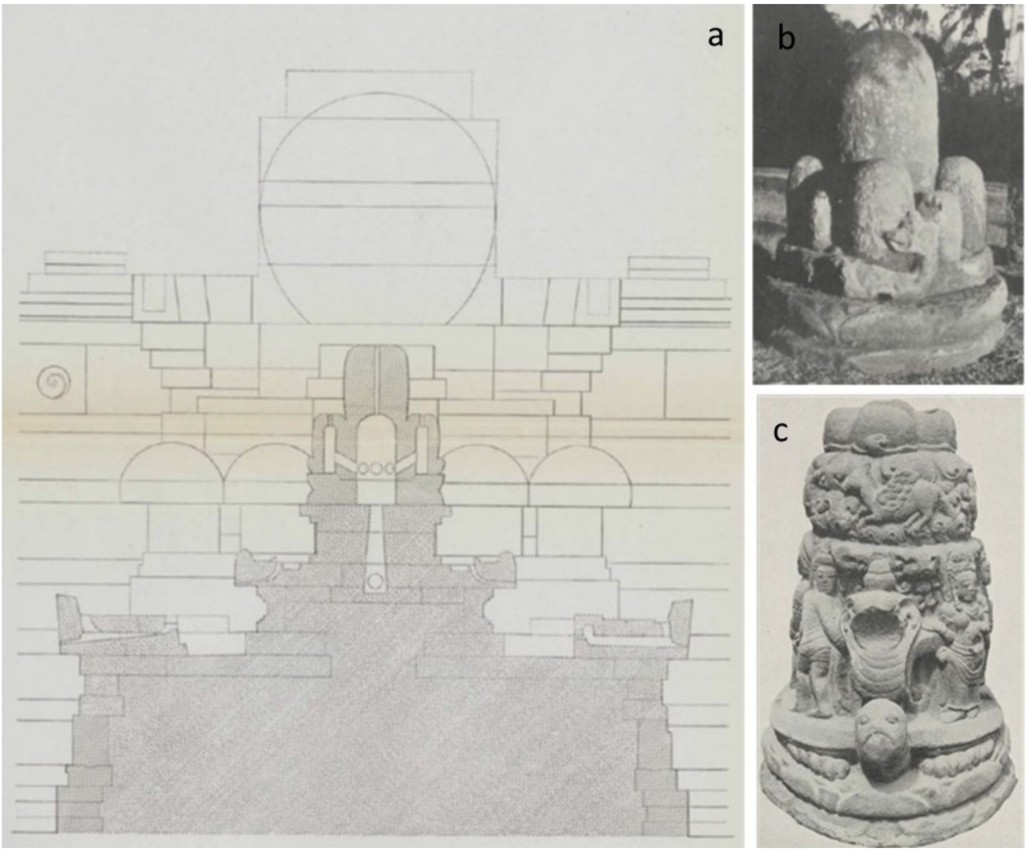

Fig. 5.18. Stutterheim's sketch of pipe engineering in Jolotundo temple (a) and a photo of the waterspout (b). Another type of a waterspout from Sirahkencong (c). (Photos and sketch from Stutterheim, 1937: 212, 214, 215)

people taking a bath and, in front of them, water coming from waterspouts. These waterspouts have the shape of *makara* (Hindu mythological water-creature) and were probably made of stone. Similar *makara*-shaped waterspouts are on display at the Majapahit Museum in Trowulan. The last relief (on the right-side in Fig. 5.17) depicts a couple sitting together—a woman is sitting on the lap of a man who is playing a musical instrument—near a lake that has three streams emanating from different water pipes. In this case, the waterspouts and the pipes were made of bamboo, demonstrated by the small lines, carved like bamboo nodes, on the pipe. The use of bamboo in pipes is also confirmed by Old Javanese texts, for example in the *Śiwarātrikalpa*, an old Javanese text from the fifteenth century CE, in which it is said that water is conveyed from a spring using bamboo pipes.[35]

35 A. Teeuw *et al.*, **Śiwarātrikalpa** *of Mpu Tanakuṅ. An Old Javanese Poem, its Indian Source,*

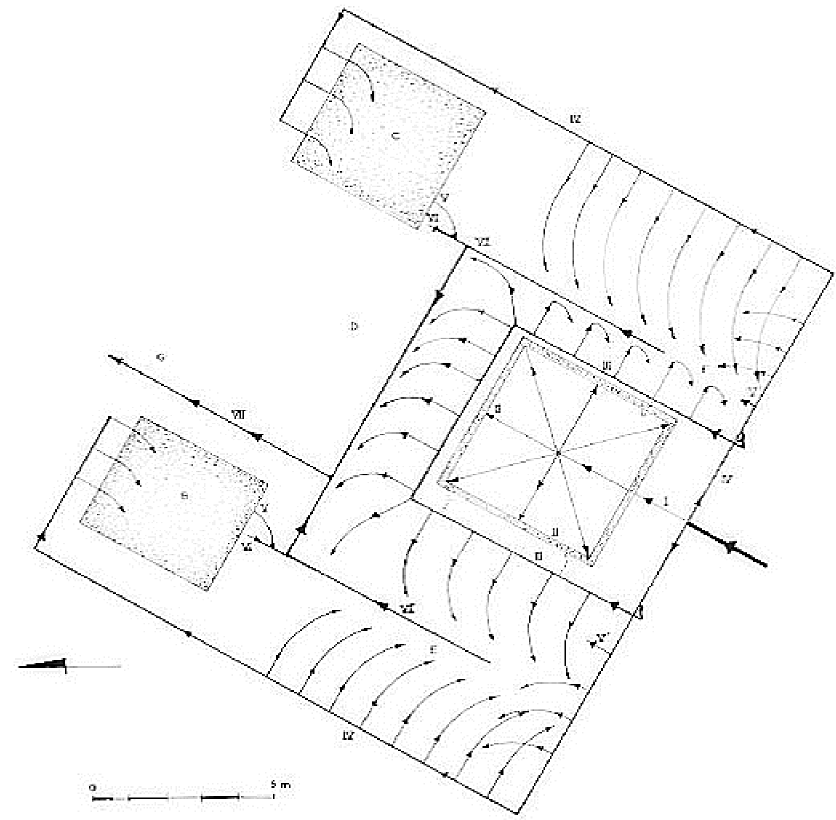

Fig. 27 SR 66. — Candi Tikus, schéma de circulation de l'eau.

Fig. 5.19. Dumarçay's illustration of water circulation in the Tikus temple. (Source: Dumarçay, 1982: Fig. 27)

Relatively small-scale water infrastructure was also employed in temple buildings, and more specifically temples in which water was used as the main component in rituals and/or structural architecture. These temples are known as *petirtaan/pathirth*ān, meaning bathing places or, as I prefer to call them, holy-water temples.[36] As Judith Patt has emphasized, there was an association between water symbolism and how technology was used to manipulate water, and the holy-water temples contain good examples of the sophisticated water engineering of the East

and Balinese Illustrations (Amsterdam: Springer-Science and Business Media, B.V., 1969): 74-75.

36 Ninie Susanti *et al*. conducted research on *Patirth*ān and made a list of 24 East Javanese *Patirthān*, 18 of which are located in the Brantas river basin area: Malang (10), Mojokerto (3), Kediri (1), Tulungagung (1), and Blitar (3). See: N. Susanti *et al*., *Patirthān. Masa Lalu dan Masa Kini* (Jakarta: Wedatama Widya Sastra, 2013): 74-77.

Javanese.[37] They utilized two principal properties of water—fluidity and gravity—to convey water from the source to a holy-water temple. In many cases, they also created a system of pipes within the temples and fashioned decorated waterspouts. Stutterheim has described one such ancient waterwork, found in the *pathirthān* of Jolotundo,[38] and has produced a drawing that explains the piping system of the Jolotundo waterworks (Fig.5.18). Another example of pipe engineering within a temple is to be found in the Tikus temple, Trowulan. Fig. 5.19 illustrates how water circulated in the Tikus temple, as reconstructed by J. Dumarçay.[39]

5.3. CONCLUSION

Water management practices in ancient East Java were not solely carried out for agricultural purposes. While ancient Javanese communities did rely on agriculture and thereby tried to maximize its production by managing the water supply, the water management practised by the East Javanese was a much broader phenomenon. The archaeological survey that I have conducted for this dissertation demonstrates how water management was applied to many aspects of daily life.

At the very least, I propose there were four aspects of water management practises in ancient East Javanese societies. First, for agriculture they built large-scale engineering because agriculture requires water. *Sawah* cultivation would have required the vast majority of the agricultural demand for water. To convey water to the fields, a community—probably without the support of the ruler—built water channels in the form of open canals or subterranean tunnels to cope with topological barriers. Secondly, large-scale engineering was also constructed to prevent natural disasters, primarily large-scale flooding. When creating dams for irrigation, Old Javanese community sought to avoid subjecting the inhabitants to flooding, meaning that they were both knowledgeable about and put into practice flood management. Thirdly, in smaller-scale water engineering, the community who lived in urban and sub-urban areas developed various ways of ensuring that their living conditions were comfortable and healthy. They created a sanitary sewage system at the level of individual households as well as at settlement level. Moreover, they ensured that there was enough water brought to the settlement by constructing water control installations. Fourthly, on the smallest-scale water engineering level—that of a single building, and specifically holy-water temples—the design of the water control not only had a material relevance but may also have had an aesthetic or religious basis.

37 J.A. Patt, *The Use and Symbolism of Water in Ancient Indonesian Art and Architecture*, Dissertation (1979): 492.

38 W.F. Stutterheim, "Het Zijnrijke Waterwerk van Djalatoenda", *TBG 77* (1937): 21-50.

39 J. Dumarçay, "Notes d'architecture Javanaise et Khmère", *Bulletin de l'Ecole française d'Extrême-Orient* 71 (1982): 91-94 and Fig. 27. See also: I. G.N. Anom, *Pemugaran Candi Tikus* (Jakarta: Departemen Pendidikan dan Kebudayaan, 1994): 13-14.

The concept of *amṛta* (holy water) was part of the water engineering of the holy water temples and the temples are adorned with beautiful ornamental elements.

There is one question remaining. The archaeological data related to water engineering in ancient East Java provide enough information to reach some conclusions about water technology and the hierarchical water engineering levels. However, a clarification of the relationship between water infrastructure, East Javanese society, and the rulers requires discussion. The next chapter will do so.