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WATER INFRASTRUCTURE IN ANCIENT CITY OF TROWULAN MAJAPAHIT. A LESSON FROM THE PAST FOR PLANNING A NEW CAPITAL CITY OF INDONESIA.

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ABSTRACT

Indonesia plans to move its capital city from Jakarta on the island of Java to a jungle city on the island of Borneo called Nusantara. However, a large sceptical arose when planning a smart and sustainable city from scratch. This paper examines in a broad manner of water infrastructure situation during the ancient period of Indonesia, Majapahit period from the historical literature. The present paper aims to show the water management and sanitation practices from Trowulan peoples which have survived and managed their civilization in harmony with nature over a century. The results suggest that water infrastructure in Trowulan city not only used for agricultural purposes (irrigation) but also used for environmental protection such as drainage and flood control. We believe by reconsidering the historical approaches to water management of Trowulan people and applying modern technologies to improve its functionality is expected to give a solution to current water-related environmental problems in Nusantara the new capital city of Modern Indonesia.

Keywords: water infrastructure, majapahit, capital city

1. INTRODUCTION

Majapahit Kingdom (1293-1520) was the greatest of the early Indonesian kingdoms. It was founded in 1294 in East Java by Raden Wijaya prince of Singhasari, who defeated the invading Mongols (Tartarian army) in Java. The golden era of Majapahit reached in the mid-14th century under the ruler King Hayam Wuruk (1350-89) and the military leader Gajah Mada. Majapahit territories expanded across Java and gained control over much of present-day Indonesia as well as the Malay peninsula [1][2][3]. The remains of Majapahit Kingdom were discovered through extensive and lengthy research as mentioned by Miksic and Soekanto [5].

The results from extensive research in the Trowulan site evidently shows that the Trowulan is the location of the remains of the capital city of the Majapahit Kingdom for more than 200 years between the 13th - 15th century [3]. The heritage findings in the forms of the remains of buildings and human settlements in the Trowulan have shown the structured city organization, while ancient hydro structures like ponds, reservoirs, and canals emphasize the concern of Trowulan people the environment as stated in Miksic, J. N. [5] and Winarto Y et al [6]. A recent report by Gomperts et al [7] on the discovery of 33 terracotta wells in the Trowulan site also suggest the presence of public area for sanitary purposes.

With a population of 273.7 million as of 2021, modern Indonesia has become the fourth most populous country in the world, while Indonesia is still facing many sanitation

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problems with almost 14 percent of urban dwellers still practice open defecation with other Southeast Asian countries [8]. Development of science and technology has made human life more comfortable and easier. However, rapid development also causing environmental degradation particularly water-related problem due to urbanization and over extraction of natural resources [9]. Jakarta is the capital city of modern Indonesia and recent study showed that Jakarta is one of the world's fastest sinking cities primarily caused by excessive groundwater extraction, damages infrastructure and buildings, and contributes to worsened flood events and tidal inundation [10] as it predicted that Jakarta's annual flood damage costs will increase by up to 400% by 2050 [11].
Consequently, as the capital city of Indonesia is currently experiencing complex socio and environmental issues, the Indonesian government is considering the relocate the capital city from Jakarta (Jawa Island) into Kalimantan Utara (Borneo Island). The new capital city envisioned to be a smart, green, and sustainable city in the centre of Jungle city called "Nagara Rimba Nusantara". Within this context, it is interesting to look back to the history of water infrastructure in the ancient city of Indonesia and summarizing the past civilization experience (local genius) and possibly give the solution to water-related environmental problems from currently planned new capital city of Indonesia.

2. METHODS

This study is conducted as desk study by reviewing several literatures and data from many sources related to ancient city of Trowulan. In particular, the study on archeological discoveries of Trowulan from Miksic, J. N. [5], Miksic, J. N [12] and Gomperts et al [13] were used as major references. This study also reviewed the existing water management and sanitation practices of modern Indonesia and analyze the possible implementation of traditional local genius from the past to cope the water related problem of a newly planned capital city of Indonesia.

3. RESEARCH AND DISCUSSION

3.1 *A Brief History of Ancient Indonesia*

The Indonesian Archipelago (Nusantara) has been known as the land of spices (cloves, nutmegs, pepper, and cinnamon) and other strategic natural resources (rattan, damar resin, gold, and diamond) since centuries ago. Moreover, Indonesia's geographical traits lying in the center of the East Asia-Europe traditional trade route suggest that it could bring enormous potential for politic and economic activity [14]. The emergence of big ports in Java, Sumatera, and Moluccas as the main trade harbors connecting India, the Middle East, China, and Europe. Resulting in many cultural practices of Indigenous Indonesian people being strongly influenced by a multitude of religions. Brown [15] believed that history of Indonesia was shaped by some external forces, including the religion of Hinduism, Buddhism, Islam, and Dutch colonialism.

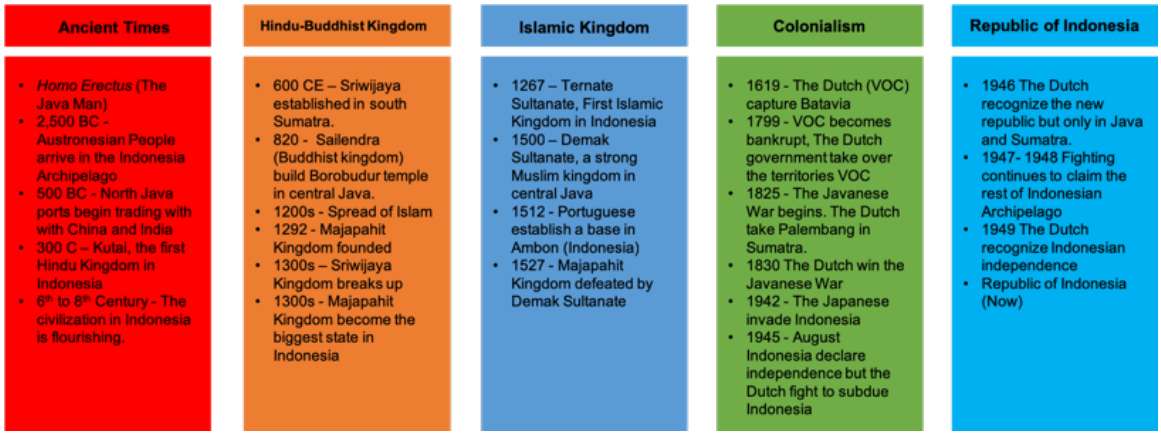

Figure 1. Timeline of historical event of Indonesia (Adapted from Drakeley., 2005)

Throughout most of history, Indonesia's inhabitants were divided in many ways as many kingdoms rose and fell and political situation changes within the region. Indonesia as a nation state did not exist until early 20th century marked with the end of the Dutch colonial authority by declaration of Republic of Indonesia on August 17th, 1945. Resume of notable historical event of Indonesia as presented in the Figure 1. The first people of Indonesia discovered in 1892 by a Dutch paleoanthropologist and geologist Eugène Dubois from the fossilized remains of Homo erectus (later known as Java Man) on the island of Java (Indonesia) as stated in Bartstra [16]. The evidence indicates that Indonesia archipelago was inhabited by the Java Man at least 1.5 million years ago [17]. Drakeley [1] reported that Indonesians are predominantly the descendants of Austronesians who reach archipelago around five thousand years ago through Taiwan and Philippines. Indonesian early inhabitants lived by hunting animals, collecting shellfish, and gathering plants for food.

From about 400 BC Indonesians begin to trade with other nations such as China, India, and Arab. In a recent excavation of the ninth-century wrecked cargo ship in the Indonesian water's territories support strong evidence of direct trade with China [18]. During 7th to 8th century Indonesian civilization was flourishing. Among the kingdoms was great Buddhist kingdom of Sriwijaya in south Sumatra. From the 7th Sriwijaya became a maritime empire that control trading centers at the Malay Peninsula [19] However, Sriwijaya was weakened by a tense aggression from other kingdom, and thus in the 13th century the Sriwijaya Empire broke up into separate states [20]. There was also an agricultural Buddhist kingdom in central Java called Sailendra. Borobudur temple is the most important monument in Sailendra, it is one of the biggest Buddhist monuments in the world and have been inscribed on the UNESCO world heritage list since 1991 [21]. Majapahit kingdom was the last Hindu-Buddhist kingdom and regarded as one of the greatest kingdoms in Indonesia [1][3]. Majapahit Kingdom has a proud history with civilization fame and a shiny legacy. During the golden period of Majapahit in 13th century, many literary works were produced. Among them was Nagarakertagama by the famous author Mpu Prapancha [22]. According to the book of Nagarakertagama Majapahit controlled most of Indonesia including Java, Sumatra, Malay Peninsula, Kalimantan, and east Indonesia, though the territory is still debated by historians [23][24]. Nagarakertagama also described the advancement in civilization of Majapahit kingdom as they have a constitutional system that is highly organized, has uniqueness in socio-political life, religion, culture, customs and literature [6].

ISSN 2541-223X
Volume 4 2022

Meanwhile Islam was brought to Indonesia trading activities. Muslim merchants from Gujarat and Persia began visiting Indonesia in the 13th Century and established trade links between this country and India and Persia [25]. During the trade, muslim merchant propagated Islam among the Indonesian people, it first gained support in Aceh of Northen Sumatera, and particularly along the coastal areas of Java and converted Hindu kings to Islam. Ueda et al [26] highlighted the Demak Sultanate (Islamic Kingdom) spreading Islam along the Java Island. In the later stage, it brought the downfall of the powerful kingdom of Majapahit. Islam became the dominant religion in Java and Sumatra by the end of the 16th century. For the most part, Islam overlaid and mixed with existing cultural and religious influences [27].

3.2 The City of Trowulan-Majapahit

Trowulan site is the only city site of ancient Hindu-Buddha in Indonesia that can still be found, its located 55 kilometers southwest of Surabaya, East Java. The site covers an area of 11 km x 9 km after a series of extensive archeological works as detailly described by Gomperts et al [3] and Miksic, J. N [5]. Major event of archeological works in the Trowulan site as being resumed in Table 1.

Table 1. Chronogical order of major studies in Trowulan. Adaptep from Winarto Y et al [6]

No	Year	Researcher	Main finding
1	1815	Wardenaar	First research on Trowulan site and exposed the various archaeological objects.
2	1849 - 1916	R.A.A. Kromodjojo Adinegoro	Excavation of waterways in the Tikus (Mouse) Temple
3	1924	Maclaine Pont	Excavation in Trowulan begins, provided an early reconstruction sketch of Majapahit capitol Trowulan
4	1926	Maclaine Pont	Finding of 18 large and small dams connected to an irrigation system with wide and narrow channels
5	1948	Stutterheim	Reconstructed the Majapahit palace in comparison with the Keraton Yogyakarta (Mataram Muslim) and Puri Klungkung Bali (Mataram Hindu)
6	1962	Pigeaud	Proposed hypothesis that Majapahit capitol complex follow dualistic pattern of Ciwa and Buddha
7	1968	Slamet Muljana	Proposed hypothesis that Majapahit capitol complex follow monocentric pattern
8	1980	Indonesian Gov	Aerial photograph interpretation of structured canals that symmetrically built in Trowulan site
9	2007	Yuwono	Make an overlay between early sketch of Trowulan by Pont (1926) and topographic map of Indonesia. Support the structure of canal (waterways) in Trowulan

Figure 2. Artist visualization of Trowulan, based on Maclaine Pont's 1926 reconstruction of Majapahit's capital. Inset showing Trowulan location in East Java, Indonesia (Source: KOMPAS, [28])

In 1920s Ir Henry Maclaine Pont a Dutch chief of Trowulan sugar plantation explored the site and elaborate with the local in attempt to reconstruct of Trowulan Area. The spatial perception used by Pont to reconstruct the Trowulan area was based on the mandala concept (Figure 2). According to oral tradition, Pont exposed buried ruins with high-pressure water hoses while the villagers took advantage to carry off the bricks. However, several researchers argued whether the Pont reconstruction was mainly based on observation or merely his own imagination [12].

Based on several sources of archeological artefact, the site of the former capital city of the Majapahit Kingdom believed as a dense settlement since 10th century. Trowulan was built on flat terrains at the foot of three mountains, namely the Penanggungan, Welirang, and Anjasmara Mountain. Geographically, the Trowulan area was suitable for human settlement since it was supported by plane topography with relatively shallow ground water [2].

Until now many building sites and remnants of human settlement have been excavated, restored and maintained by Indonesian Government under Balai Pelestarian Cagar Budaya (BPCB) Jawa Timur in Trowulan. More than a hundred thousand of archaeological remnants of the old city in the Trowulan Site were found buried underground as well as on the surface. These archeological objects found in the form of artifacts, temples and gateway made from bricks, ponds, canals, and terracotta wells. Since 2009 The Ministry of Culture and Tourism of the Republic of Indonesia submitted Trowulan into UNESCO world heritage list to. However, the Trowulan site still enlisted as a tentative list.

3.3 Water Infrastructure in Trowulan City

Water supply might be one of the most critical factors in the ancient city, this since human dependence on the availability of water. The hydro building (water infrastructure) found

in Trowulan were large reservoirs, ponds, canals, water well, and terracotta wells, which are still found today. Muljana. S [2] believed that the Majapahit government made the water infrastructure for the benefit of agricultural irrigation, water storage, and flood control. The remnant of water infrastructure found in Trowulan as will be discussed in the following section.

3.3.1 Waduk (Large Resevoir)

The activity of Majapahit civilization in Trowulan areas was shaped by nearly 20 ancient reservoirs (Waduk), Waduk Komas, Waduk Kumitir, Waduk Temon, and Waduk Keraton were prominent reservoir associated with Trowulan. Among those reservoir, Waduk Kumitir seem to be the main reservoir for clean water source and rice field irrigation through the canals and smaller pond (Figure 3).

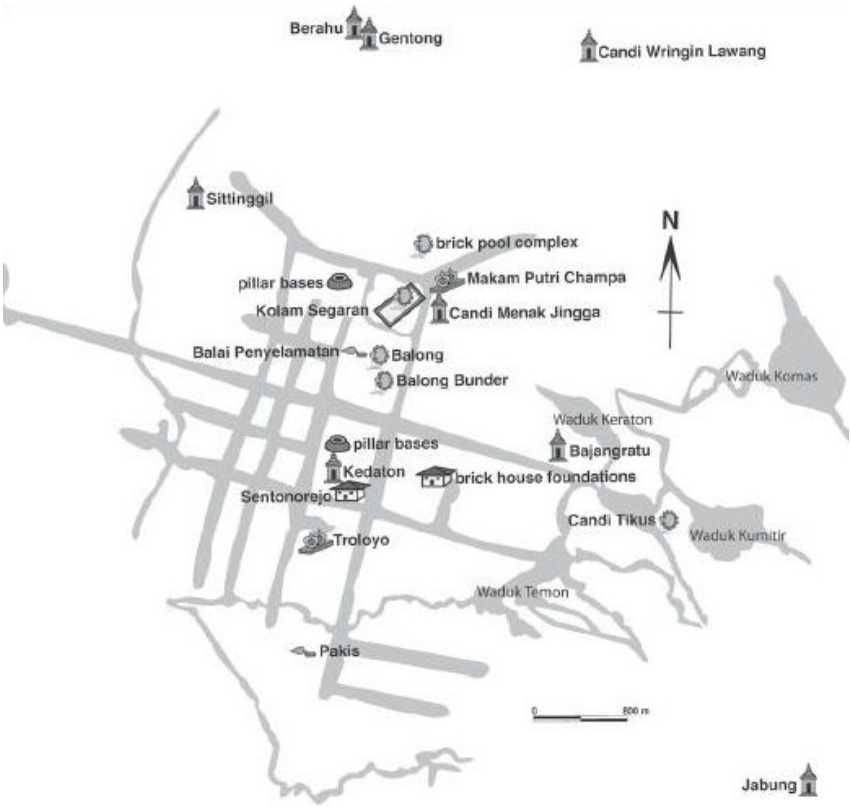

Figure 3. Hypothetical system of canals and reservoirs (waduk) in 14th-century Trowulan (Source: Miksic, J. N [12])

Miksic, J. N [12] mentioned that the reconstruction of the water infrastructure in the Trowulan area was the most useful contribution from the study of Maclaine Pont. The hypothetical water system was able to identify the various reservoir, watersheds and show interconnectivity among various canals and smaller reservoirs were built by the civilization.

3.3.2 Kolam (Small Resevoir)

Beside the large reservoirs, Trowulan's artefact also shows at least three artificial ponds (*kolam/balong*) namely Kolam Segaran, Balong Bunder, and Balong Dowo. Kolam Segaran water was conveyed through an open channel from the Kraton Reservoir. Segaran ponds has 375 meters long and 175 meters wide and about 3 meters deep,

stretching northeast-southwest direction. Segaran ponds is reinforced with thick walls (1.6 m) made of bricks on all four sides. Segaran outlet in the northwest side leading to Balong Dowo and Balong Bunder. The interconnected Segaran ponds-Balong Dowo-Balong Bunder serves as a retention pond of overflowed Brantas River during the rainy season [2].

Figure 4. Photograph of Segaran Ponds in Trowulan (Source: Balai Pelestarian Cagar Budaya, BPCB, Jawa Timur)

3.3.3 Canal waterways

Wells lined canals with bricks or clay rings have been found in several parts of the Trowulan site in a structured grid pattern as previously constructed by Maclaine Pont (Figure 3). The traces of canal in Trowulan also have been confirmed by the aerial photograph investigation by Yuwono (2007) as cited in a report by Winarto Y et al [6]. Trowulan's canals constructed from brick with a wide of 3.57 meters and 45 centimeters in deep. Trowulan's canal also supported by smaller waterways, which are part of the water network system in Majapahit. Other water appurtenances such a culvert has been discovered in the Candi Tikus (Bathing Temple), it possibly used as water channel into and out of the temple. In addition, the findings of terracotta pipes (Figure 5) were most likely used to channel water to houses, as well as gutters from brick structures among the remains human settlement provoke how Majapahit civilization have practicing remarkable the sanitation and water control Miksic, J. N [5].

Figure 5. Photograph of T shaped terracotta water pipe in Trowulan (Source: Balai Pelestarian Cagar Budaya, BPCB, Jawa Timur)

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Volume 4 2022

3.3.4 Water wells and sanitation

As a densely populated city, significant amount of water is needed to fulfill the lives of Trowulan peoples. During this period, clean water was obtained by digging soil to make wells. according to Miksic, J. N. [5] the hydrological condition of Trowulan consisted of a porous layer of volcanic sand as aquifer and resulting in favorable water access by using dig well. Muljana. S [2] reported that the edge of the well was reinforced with brick and pottery structures called *Jobong* (Figure 6-1).

Figure 6. Photographs of three types of wells found in Trowulan (Source: Gomperts et al [7])

Another study by Miksic, J. N [12] found an interesting pattern in the distribution of wells location and religious structures (temples). It mentioned that wells have been dug in certain places with a shallow water table near the settlement area. On the contrary, temples were in higher area with less dense population. However, recent work by Gomperts et al., [7] reported a different point of view. Gomperts and his team mapped three types of well including: 350 unit of round brick-walled wells (*Jobong*), 80 unit of rectangular brick-walled wells (Figure 6-2), and 150 units of terracotta-ring stacked wells (Figure 6-3). Interestingly, during the survey the terracotta-ring stacked wells could not be found near of the clean and sacred place for worship such as temple. According to the Javanese villagers, terracotta-ring stacked wells refer to *Jumbleng* used for sanitation purposes (pit latrines). After deeper investigation, Gomperts *et al* [7] proposed a theory that terracotta-ring stacked wells (*Jumbleng)* was influenced by the Indian culture and it has function as sealed cesspits. The cesspits were necessary to avoid leakage of pit latrines, it was due to ground water level at Trowulan could reach less than 1.5 m during the monsoon season. This new theory also in line with the previous report by Miksic, J. N [5] that Majapahit civilization presumably have a basic sanitation knowledge.

Figure 7. Spatial concept of IKN – Nagara Rimba Nusa (Sumber Urban+)

3.4 Nusantara, A new Capital City of Indonesia

Indonesian government officially start to move the capital city from Jakarta to Nusantara in North Kalimantan as stated in the Indonesian decree No. 3 (2022). The new capital city also called Forest City or Ibu Kota Nusantara (IKN). The proposed city will be named after ancient Indonesian archipelago (Nusantara) or Nagara Rimba Nusa (Figure 7). This newly planned IKN is a national identity to show characteristic of: (1) identity (nationalism); (2) green environment (sustainable); (3) future city (smart); and city for the world (livable). The total area of IKN will cover more than 256 hectares that divides into several zone/district including: (1) Main zone for Government office; (2) settlement; (3) commercial; (4) green space: (5) utility. Until 2045 the IKN area will accommodate approximately 2.75 million peoples.

3.5 Reflection from the Past

Jakarta, the capital city of modern Indonesia is very vulnerable to flood disaster. It lies in the delta of the Ciliwung River and has a population of about 10.6 million. About 40% of the city is below sea level and large areas are flooded during the rainy season each year. Whereas wastewater management also still a big problem in Jakarta. Being a river city, Jakarta could not control their domestic wastewater resulting in a heavily polluted of majority rivers in Jakarta. On the contrary the ancient capital city of Indonesia (Trowulan-Majapahit) has been a unique water infrastructure with respect of its functional and environmental sustainability. Indeed, lessons should be learned from such creations for newly planned Indonesian capital city (Table 2).

Table 2. Reflection from ancient capitol city to new capital city of Indonesia

Trowulan (Ancient Indonesia)	Jakarta (Modern Indonesia)	Reflection	Strategic Action for Nusantara (New Capital City)
Reservoir/Waduk	Water reservoir	Currently available reservoir (dam) in Jakarta were heavily polluted with domestic waste. The government	Improve the dam design as infrastructure in the integrated water resources (water loop) within the city
Small Pond/Kolam	Retention lake	Due to rapid urbanization and land use change, the normal capacity of a	Retention lake as monument and main attraction of city

		retention pond in Jakarta have been exceeded	
Canal/Waterways	Drainage system	The siltification occurred in major rivers (primary waterways) in Jakarta was caused by domestic waste deposition and eutrophication	Connecting dam-river as integrated waterways for interconnectivity of drainage control within the city.
Water & Sanitation	Water & sanitation	Access in water sanitation have been improved but still lack of awareness in the domestic wastewater management	Implementing the resources recovery technology in the sanitation sector, and improving the capacity building and people engagement in the city

Water resources management within the IKN city should be integrally designed for achieving: (1) save drinking water sources;(2) reliable sanitation; (3) pollution control, and (4) flood control. One example for integrated water resources management concept that can be adapted is sponge city. A sponge city refers to sustainable urban development including flood control, water conservation, water quality improvement and natural eco-system protection [29]. In applying sponge cities, the city should adopt the natural water cycle incorporate with the urban water cycle that involves infiltration, stagnation, storage, purification, utilization, and discharge is expected to be achieved, to use the full potential of rainwater under the premise of not suffering urban flooding. In a brief, we propose a concept of integration water infrastructure (Ponds, canals, reservoir) form of ancient Indonesian capital city of Trowulan and newly planned capital city of Nusantara as displayed in Figure 8.

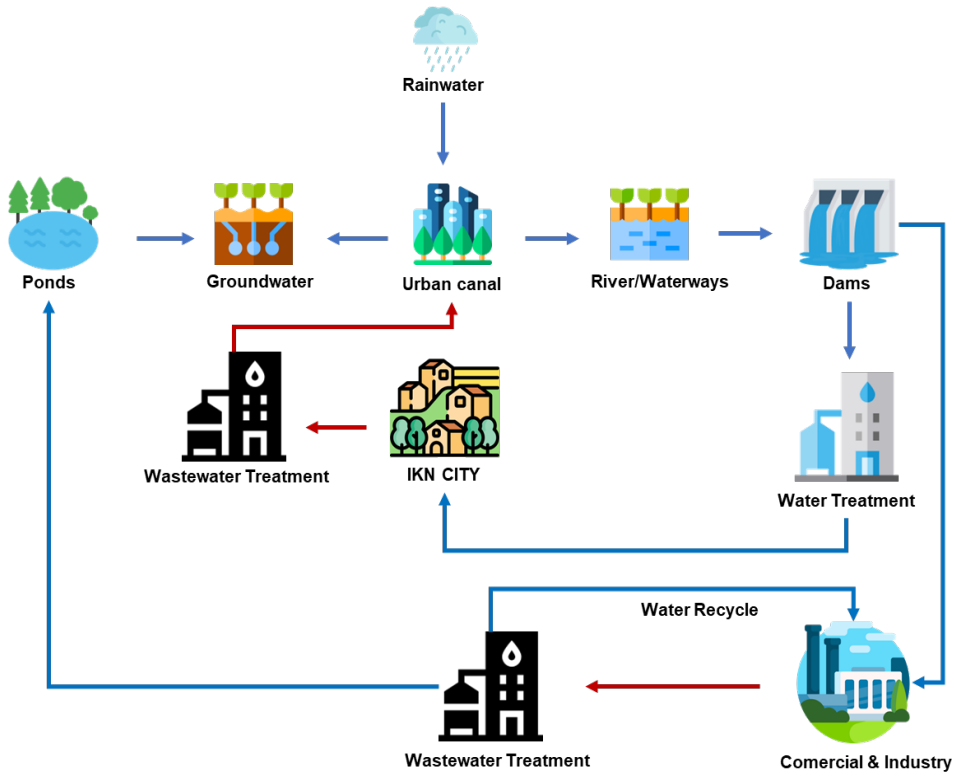

Figure 8. Proposed integrated water resources management concept of IKN

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4. CONCLUSION

In synthesis, the following conclusions can be drawn: (i) Majapahit Kingdom is one of the greatest kingdoms in Indonesia; (ii) Trowoulan the ancient capital city of Majapahit have shown unique water infrastructures including: reservoir, ponds, canals, and water wells; (iii) Water infrastructure in Trowulan not only used for agricultural purposes but also used for environmental protection; (iv) integration of historical lesson of Majapahit golden era could be elaborated to solve the water-related problems in newly planned capital city of Indonesia using integrated water resources management.

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