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WATER ARCHITECTURE IN MALAYSIA: A CASE STUDY IN PENANG, 1957-1985

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Abstract: This research is driven by a fundamental recognition of the pivotal role played by water infrastructure in shaping urban environments, particularly within post-colonial settings. Focusing on the transformative period from 1957 to 1985 in Penang, marked by significant governance and societal changes, our objective is to comprehensively analyse the development of post-colonial water architecture. By identifying key factors influencing the design, implementation, and outcomes of water infrastructure projects, we aim to shed light on both successes and challenges faced during this era. Our motivation lies in extracting valuable insights from historical experiences to guide contemporary policymaking and scholarly efforts, with a specific emphasis on enhancing functionality, efficiency, and sustainability. Employing a history methodology encompassing historical analysis, archival research, and case studies, this research aims to provide a nuanced understanding of post-colonial water architecture in Penang, contributing to the broader goal of fostering efficient, sustainable, and aesthetically pleasing water infrastructure for improved urban living. This study found that the evolution of water infrastructure during this period in Penang was not merely a response to increasing urbanisation, but was intricately linked to policy decisions, technological advancements, and societal dynamics. One significant discovery pertains to the impact of governance changes on the efficiency and effectiveness of water projects. The shift in governance structures influenced decision-making processes, project implementations, and overall outcomes in the realm of water architecture.

Keywords: Water architecture, post-colonial water architecture, water supply development, Penang, Malaysia.

Introduction

Water architecture refers to the design, construction, and management of structures and systems that facilitate the storage, distribution, and treatment of water (Wylson, 2013). It encompasses a range of physical infrastructure, including reservoirs, dams, canals, pipelines, water treatment plants, and distribution networks (Gooden, 2020). Water architecture plays a crucial role in providing access to clean and safe water for human consumption, irrigation, industrial use, and environmental sustainability. It involves the careful planning and engineering of infrastructure to ensure a reliable and efficient water supply, as well as effective wastewater management (Mathur & Mulwafu, 2018). The design of water architecture considers factors such as water availability, quality, and resilience to natural disasters and climate change. It involves considerations of environmental impact, ecological sustainability, and the social and cultural needs of communities (Hegewald, 2022). One notable example of ancient water

architecture is the Roman aqueducts. These marvels of engineering were intricate systems of stone channels, tunnels, and arches that transported water over long distances to supply cities and settlements with water (Butler, 1901).

Water architecture can be influenced by geographic, climatic, and socioeconomic factors, as well as historical and political contexts (Woodhouse & Muller, 2017). In some cases, colonial powers have significantly shaped water architecture during their rule, leaving a legacy that persists in the post-colonial era (Acey, 2012). In the context of this study, water architecture in Penang refers to the structures and systems put in place to manage water resources after the British colonial period. It includes the infrastructure established during colonial rule and the subsequent modifications and developments made to address changing needs and challenges in the post-colonial era. The colonial period in Penang, which lasted from the late 18th century until the mid-20th century, had a significant impact on the development of water infrastructure (Abdullah & Mohd Noor, 2017). British administrators and engineers introduced a system of dams, irrigation systems, and reservoirs to support trade, agriculture, and urbanisation (Broich, 2007). These structures were intended to serve the interests of colonial powers, but their effects on the indigenous communities of Penang were often complex and far-reaching.

After independence, Penang's water infrastructure was deeply intertwined with its colonial past, as the region was once under British colonial rule (Snider, 1968). The influence of colonial powers on water architecture can still be seen in the idea, design, construction, and management of water systems in Penang today (Ujang, 2022). This study aims to trace the development of water infrastructure in Penang and explore the evolution of post-colonial water architecture. This study has significant relevance in addressing the issues of water architecture in Malaysia and around the world today. By examining the postcolonial period, specifically in the context of Penang, the study aims to shed light on how colonial influences have shaped water infrastructure in urban environments. Understanding the historical impact of colonial rule on water architecture is crucial for the development of sustainable and efficient water management systems in Malaysia. This study could provide insights into the legacy of colonial era designs and technologies still in use today and their potential strengths and weaknesses. By analysing the postcolonial water infrastructure in Penang, researchers can identify areas for improvement, such as upgrading ageing systems, enhancing water conservation measures, and implementing more environmentally friendly solutions. Furthermore, the findings of this study can have broader implications beyond Malaysia. Water architecture in postcolonial settings has been influenced by various colonial powers worldwide. Therefore, examining Penang's case could serve as a representative of similar issues faced by other countries with a colonial history. Ultimately, this study can contribute to the development of sustainable water architecture practices around the world. By acknowledging and understanding past influences, researchers, policymakers, and urban planners can work towards creating more resilient and innovative water infrastructure that addresses current and future challenges, such as population growth, climate change, and limited resources (Abdullah *et al.*, 2023).

Methodology

The methodology for this research was primarily historical, employing qualitative research methods to achieve the study objectives. To comprehensively explore the period from 1957 to 1985, various actions and processes were undertaken, including critique, analysis, heuristics, and historiography. Collecting a compilation of relevant sources was crucial, and library research was employed to gather primary and secondary sources. Visits to institutions, such as the National Archives of Malaysia, National Library of Malaysia, Penang Water Supply Corporation and public institutions of higher learning in Malaysia, were conducted

to acquire the necessary materials. The research heavily relied on official documents, particularly colonial office documents (CO), secretary files, and journal books. Commencing with a heuristic process, information was gathered and scrutinised from sources such as official documents and other relevant materials. Subsequently, a source critique was employed, comparing the obtained information with other sources like books, journals, and scholarly training to eliminate inaccuracies. This critical process was instrumental in determining the accuracy and validity of the information. An analytical process followed, involving inferences drawn from primary and secondary sources, leading to the synthesis of specified sources to generate study findings. The final stage encompassed the writing of history, known as historical historiography (Mohd Noor, 2006).

The Background of Water Architecture in Penang

There has been limited studies on water architecture before and after independence. However, to identify the background of water architecture in Penang before independence, it is better to examine the colonialism era in this state. The development of water architecture in Penang is believed to have started as early as the 19th century, when the British introduced the first modern water supply system in Pulau Pinang in 1804, known as the aqueduct (Abdullah & Mohd Noor, 2017). The term "aqueduct" refers to a water reservoir or channel created to convey water, originating from the Latin words "aqua" (water) and "ducere" (to lead). The British authorities employed forced labour construct the aqueduct. The system served as an improvement for the inhabitants of Penang Island, who lacked a systematic water supply facility at that time. Upon completion, numerous water pipes were installed along the roads, particularly in the city of Penang, and water supply could be obtained from these pipes (Teo, 2003).

In 1877, the British authorities replaced the aqueduct system that had been in use for 81 years with a superior system known as the "cast iron main". This system was only recorded in Penang Island (Abdullah, 2019). Afterwards, the British introduced the Bukit Panchor Dam in South Seberang Perai in 1888 (Penang Water Supply Corporation). The Bukit Panchor Dam was not only used in South Seberang Perai but also provided water supply to the residents of Nibong Tebal in 1906 (CO 275/70: CO 275/72: CO 275/74). In 1894, the Waterfall Reservoir was established in the Penang Botanic Gardens (CO 275/47: CO 275/49). The construction of this reservoir aimed to store clean water for the respective areas. This reservoir served as one of the measures undertaken by the stakeholders at the time to address water shortage issues, particularly during the dry season (Jones 1997, 75-96). However, it must be acknowledged that Penang is renowned for its waterfalls, which have provided a natural water source to the inhabitants

Figure 1: Waterfall "Lake" (reservoir) in Penang, 1890s

both before and after the arrival of colonial powers. For instance, when Penang received a visit from the British royal family in 1867, the Duke of Edinburgh, better known as Prince Alfred Ernest Albert, arrived for an official visit, which also included exploring various attractive sites on the island. Among the locations visited by His Highness was the waterfalls in Penang. This event was documented by the Illustrated London News in 1870 (Tahir *et al.,* 2021). In 1934, the first water treatment plant in the Straits Settlements (Melaka, Singapore, and Penang) was constructed in Ayer Hitam, Penang (Annual Report on the Social and Economic Progress of the People of the Straits Settlements 1935). The purpose of this plant was to supply water to the state of Penang for domestic use at that time (Williamson, 2020). In 1939, the Penang Rural Board approved an allocation of $40,000 for the initial instalment of the Balik Pulau water supply scheme. The total cost of the scheme, including the water supply filtration system, amounted to $525,000. The allocated amount is indeed substantial, and it was intended for the benefit of the water supply in the Balik Pulau area. The Rural Board emphasised that the water supply scheme would provide water facilities to the residents along the main roads of Balik Pulau, rather than focusing solely on the town area (The Straits Budget Correspondent 1939, 29 Jun).

Results and Discussion

Dam Construction

The British built dams in their colonies to exploit natural resources, develop infrastructure, generate power, control waterways, and ensure strategic military and economic advantages (CO 275/70; Binnie, 1974). These dams provided a stable water supply for irrigation and industrial activities, facilitated resource extraction, protected against floods, and supported British economic interests and colonial administration (CO 275/72). Post-colonial governments around the world continue to build dams for a variety of reasons. Firstly, dams are crucial for economic development, providing a reliable water supply for agriculture, enabling hydropower generation, and supporting industrial activities. Governments see dams as essential infrastructure to enhance productivity and improve the standard of living for their citizens. Secondly, dams contribute to energy security by offering a stable and renewable source of power, reducing dependence on fossil fuels. Additionally, dams help manage water resources, ensuring irrigation, providing drinking water, and mitigating the impact of floods and droughts (Abdullah, 2019). With the increasing challenges of climate change, dams also play a critical role in adaptation strategies by regulating water supply and facilitating flood control. Furthermore, the legacy of British-built dams, along with existing infrastructure and expertise, often influence governments' decisions to continue construction. Finally, governments may seek partnerships with international organisations or collaborate with other countries to gain knowledge and expertise in constructing and managing dams (Biswas & Tortajada, 2001).

In Malaysia, the government has also continued to build dams for various reasons, including in Penang (Aiken & Leigh, 2015; Abdullah, 2021). Firstly, dams in Penang contribute to water management and supply, ensuring a reliable water source for the growing population and industrial activities. As an urbanised state with limited water resources, dams play a crucial role in meeting the water demands of both residents and businesses. Secondly, dams provide hydropower generation, contributing to the state's energy mix and reducing dependence on non-renewable energy sources. This helps in achieving sustainable development goals and decreasing carbon emissions. Moreover, dams in Penang serve as flood control mechanisms, mitigating the risk of floods, especially during the monsoon seasons. By regulating water flow, dams protect communities and infrastructure from the destructive impacts of excessive rainfall (PKR (N2TM) W 37/121 Vol 8). Lastly, the legacy of British-built dams, such as the Bukit Panchor Dam, may have influenced and paved the way

for the construction of new dams in Penang. The experience gained from managing and maintaining these existing dams has provided valuable knowledge and expertise to local authorities in the planning and implementation of new dam projects. Overall, the construction of dams in Penang after colonialism reflects the government's commitment to ensuring a sustainable water supply, generating clean energy, managing flood risks, and leveraging existing infrastructure and expertise. These dams contribute to the overall development and resilience of the state, aligning with Malaysia's broader goals of economic growth and environmental sustainability (City Council of Georgetown, 1966).

After the Federation of Malaya achieved independence, the government constructed the Air Itam Dam as a continuation of the Air Itam Water Treatment Plant before independence. This can be seen in the following excerpt:

> Commissioned in 1962, the Air Itam Dam has a maximum effective capacity of 2.16 billion litres of water. The Air Itam Dam still serves as an important component of Penang's water supply infrastructure. The top water level is 235 metres above sea level and its storage capacity is tapped to sustain continuous good water supply in the Air Itam township and nearby highland areas (*Portal Rasmi Perbadanan Bekalan Air Pulau Pinan*g).

The Air Itam Dam was completed in 1962 and was inaugurated by the first governor of Penang, Tuan Yang Terutama Tun Uda Al-Haj bin Raja Muhammad. The dam has a capacity of 2.16 billion litres and could cater to the needs of the Air Itam town and its surrounding areas. The construction of the Air Itam Dam was influenced by the high demand from consumers due to the annual increase in population on Penang Island (Yunus & Nakagoshi, 2004). In 1973, the Penang Water Authority was established through state legislation to consolidate the management of water resources within the state of Penang [Hutchinson & Saravanamuttu (Eds.), 2012]. At the same time, it aimed to coordinate the Sungai Muda Water Supply Scheme (Muda Dam, Kedah), which was launched by Tun Abdul Razak bin Hussin during his tenure as the second prime minister of Malaysia [PKR (N2TM) W 37/121 Vol 8 (413): SUK Ps 510 SK 3 (42)]. The Penang Water Authority was established under

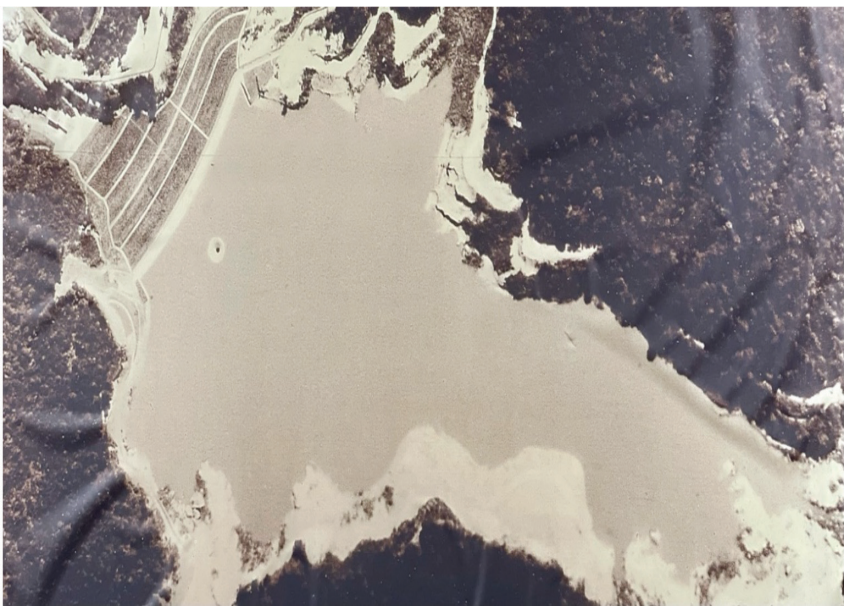

Figure 2: Air Itam Dam, 1962

a state statutory body in Penang and served as the supplier of domestic water supply in Penang.

Following that, in 1982, Penang saw the construction of the Mengkuang Dam, which was completed in 1985. The dam was inaugurated by the governor of Penang, Tun Datuk Dr. Haji Awang bin Hassan (Taylor *et al.*, 1992). The Mengkuang Dam is located in the district of Central Seberang Perai, Bukit Mertajam. It is part of the Mengkuang Pumped Storage Scheme and serves to meet the increasing demand year after year. The dam is also fed by the Muda Dam, which is situated on the border between Kedah and Penang (37/121, *Bekalan Air Mengkuang Pulau Pinang*).

Table 1 shows information on the Mengkuang Dam. The dam has a reservoir area of 3.9 square kilometres, making it the largest dam in Penang at that time. A rough estimate of the daily water yield is approximately 368,000 cubic metres per day or equivalent to 81 million gallons per day. This indicates that the production from the Mengkuang Dam was high to meet the demands of users at that

Figure 3: Air Itam Dam today

Figure 4: Mengkuang Dam, 1982

Table 1: Mengkuang Dam data, 1982

Reservoir Area	3.9 square kilometres (1.5 square miles)
Gross Storage	23.6 million metres (5.2 billion gallons)
Water Yield	368,000 metres per day (81 million gallons per day)
Maximum Water Surface Area	174 hectares (483 acres)
Elevation	31 metres (102 feet)
Crest Length	1,006 metres (3,300 feet)
Spillway Capacity	12.2 cubic metres per second (430 cubic feet per second)
Volume of Earthworks	1.45 million cubic metres (1.90 million cubic yards)

time, including industrial, agricultural, and educational sectors. The water surface area covers 174 hectares, which is equivalent to 483 acres. The construction of the Mengkuang Dam was one of the alternative measures undertaken by the Penang state government at that time. Although the physical scale of the reservoir is not comparable to the Muda Dam in Kedah, it serves as a storage area for water. Its primary purpose is to provide a reservoir for water storage rather than being a large-scale dam like the Muda Dam (37/121, *Bekalan Air Mengkuang Pulau Pinang*).

Through the dam, several water supply projects have been implemented, for example:

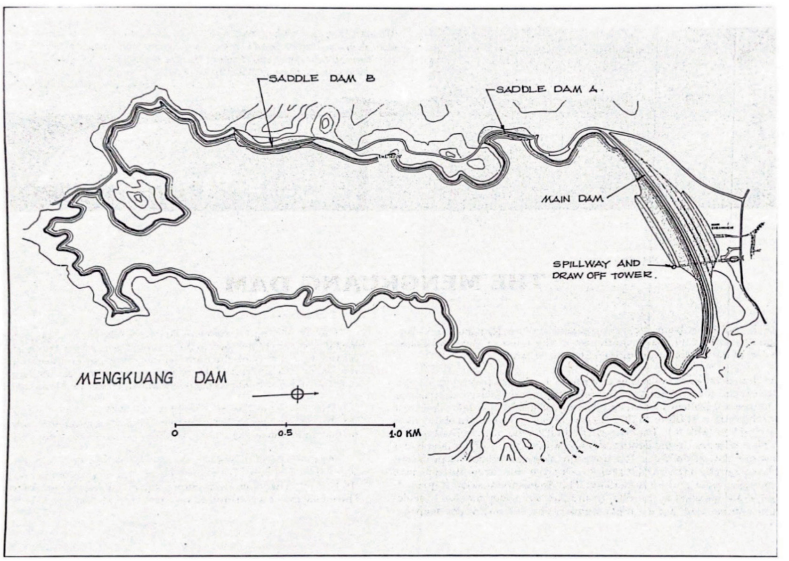

Figure 5: Water supply from the Mengkuang Dam for Penang

Table 2: Water supply development loan allocation

Project Name	Allocation 1983 Latest Amendment	Allocation 1984
(1) Muda River Water Supply, Phase II	MYR2,000,000	MYR4,000,000
(2) Mengkuang Scheme Water Supply	MYR24,000,000	MYR10,600,000
(3) Bukit Dumbar/Bayang Baru Water Supply	MYR800,000	MYR1,100,000

The post-colonial era witnessed a shift in the approach to water dam construction and management in Penang. With the departure of colonial powers and independence, there was an increased emphasis on inclusivity, equity, and sustainable development. Post-colonial water dams were designed and operated with a broader perspective, considering the water needs of all communities, including marginalised and indigenous populations. Post-colonial water dams in Penang strived to address the disparities in water access and distribution that were prevalent during colonial rule. The focus shifted towards a more inclusive and equitable approach, ensuring that water infrastructure benefited all residents, regardless of their background or socioeconomic status. Additionally, there was a greater emphasis on sustainable water resource management, considering factors such as environmental conservation, water conservation, and the impacts of climate change.

The post-colonial era also saw advancements in dam construction techniques and technologies. Modern engineering practices and an improved understanding of the environmental impacts of dams were incorporated into the design and construction processes. This included considerations for mitigating negative ecological impacts, preserving biodiversity, and ensuring the long-term integrity and safety of the dams. Overall, the major difference between water dams during colonialism and post-colonialism in Penang lies in the intentions, priorities, and approaches towards water infrastructure development. Colonial era dams focused primarily on serving the interests of the colonial powers and industries, while post-colonial dams aimed to address historical imbalances, ensure equitable water distribution, and promote sustainable water management practices [Report by Messrs. Steen Sehested & Partners, Vattenbyggnadsbran (VBB), 1962].

Water Treatment Plan in Penang

During the colonial period, British authorities introduced water treatment systems in various regions of their colonies, including Malaya. In general, British water treatment plans during colonialism aimed to provide clean and safe drinking water for both the colonial administration and the local population. These plans typically involved the construction of water treatment facilities, such as reservoirs, filtration systems, and disinfection methods (Broich, 2007; Moo & Fernando, 2018). The British colonial government prioritised the establishment of water treatment plans in major urban centres and areas with a substantial European population. These plans often drew inspiration from British practices and technologies used in the United Kingdom (Hassan, 1985).

One well-known example of British water treatment infrastructure in Malaysia is the Air Itam Dam located near George Town, Penang. This dam was built by the British colonial administration in the early 20th century and served as a crucial source of clean water for both the British residents and the local population. While the specific details and design of these water treatment plans would vary depending on the specific colonial context, the overall goal was to provide a reliable supply of treated water. These systems were often an improvement over traditional local water sources, which might have been contaminated and posed health risks. It is important to note that since the end of colonial rule, the management and expansion of water treatment infrastructure in former British colonies have largely been taken over by local governments and authorities (Annual Report on the Social and Economic Progress of the People of the Straits Settlements 1935). These entities have adapted and modernised the water treatment plans to address the changing needs and challenges of their respective regions. Following the end of colonial rule, Penang has undergone various developments in its water treatment plans to meet the needs of the post-colonial era (City Council of Georgetown, 1966).

Overall, the post-colonial water treatment plan in Penang has focused on expanding and modernising infrastructure, ensuring water

quality, promoting sustainability, engaging the community, collaborating with international partners, and adapting to climate change. These efforts aim to provide a safe and sustainable water supply for the growing population and fulfil the needs of the post-colonial era (Blacklock, 1943).

The Sungai Dua Water Treatment Plant was built in 1973 and is located in Seberang Perai, Penang. The construction of the Sungai Dua Water Treatment Plant took place on a 13-acre land and is considered the most important water treatment plant for the Penang state government as it supplies 80% of the treated water volume in the state. The plant was initially built in 1973 and has undergone several upgrades in 1994, 1999, 2004, and subsequent years. Its storage capacity is 1,113,792 cubic metres per day. These upgrades were carried out to meet the increasing water demand of the population in Penang. The primary water sources for the Sungai Dua Water Treatment Plant are Sungai Muda and Mengkuang Dam, which serve as the secondary or backup water source. Referring Table 3, the water supply area not only caters to a specific area but also distributes water to the entire Penang state, including areas in Southwest Penang, Northeast Penang, and other regions (Vijayan & Vel Murugan, 2016).

Table 3: Sungai Dua water treatment plant

Location	Seberang Perai, Penang
Year Built	1973
Raw Water Source	Sungai Muda (primary source) and Mengkuang Dam (secondary source)
Maximum Design Capacity (m^3/day)	1,113,792
Operational Capacity (m^3/day)	1,002,412
Number of Workers	120
Water Quality	Meets the drinking water standards set by the Ministry of Health.
Supply Area	Seberang Perai, Pulau Pinang

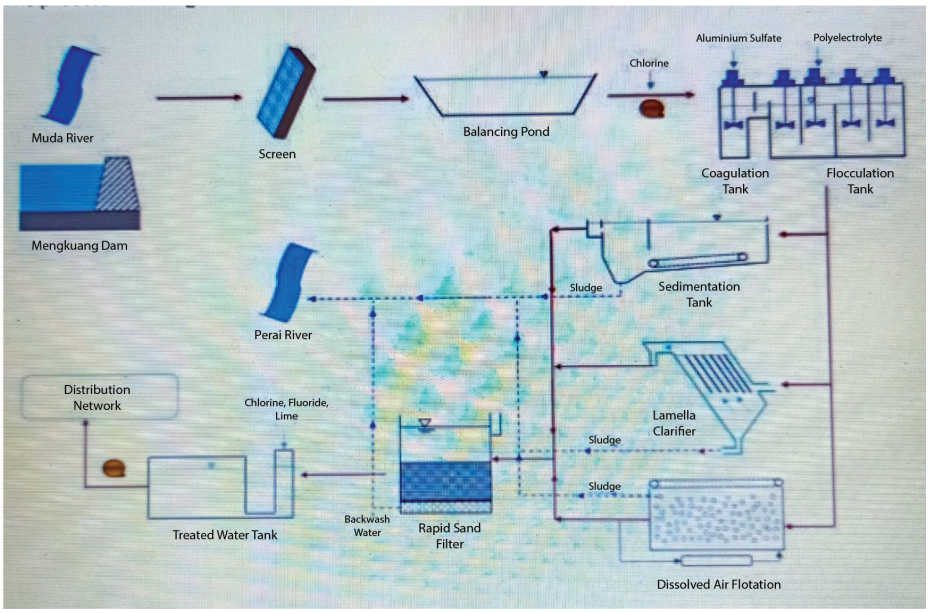

Figure 6: The process flow of water treatment at the Sungai Dua Water Treatment Plant

Figure 6 illustrates the flow of the water treatment process at the Sungai Dua Water Treatment Plant. The process begins with the intake of raw water from Sungai Muda as the primary source and Mengkuang Dam as the secondary source. It then continues with the balancing pond, pre-chlorination, coagulation, flocculation, sedimentation/dissolved air flotation, rapid sand filtration, water storage tanks, and distribution to consumers through pipelines (Vijayan & Vel Murugan, 2016). After the processing is complete, the water will be further distributed to the Bukit Dumbar pumping station for distribution purposes. The distribution of water is carried out in stages, prioritising the surrounding areas first before being channelled to specifically designated areas determined by the Penang Water Supply Corporation.

The Problem of Water Architecture Development in Penang

During the development of water architecture mentioned earlier, several issues arose. One of the main issues at the time was financially related, as financial allocations were under the jurisdiction of the federal and state governments. The allocations were divided into two categories: Loans and direct funding. In the government's efforts to strengthen water architecture in Penang, financial problems were seen as one of the major challenges. This can be observed through the following statement:

> In 1976, the Penang Development Corporation applied for a loan of $47,419,000, while the Water Authority applied for a loan of $8.8 million. However, both statutory bodies were not granted the loans by the Federal Government through the state government. As a result, the state government provided a guarantee of $1.2 million to the Penang Development Corporation for development projects, and it was fully utilised (37/121, *Bekalan Air Mengkuang Pulau Pinang*).

This indicates that to address the financial issues in developing a water supply system in Penang, the state government sought loans from the federal government, which has approved many of the state government's applications for water supply infrastructure development. For example, based on the loan allocation applications approved by the federal government through the Malaysian Treasury, in 1983, an additional loan was granted for the Mengkuang water supply scheme amounting to RM22.1 million. In 1984, an additional loan was granted for the Mengkuang water supply scheme amounting to RM14.0 million. In 1985, a loan application was approved to finance Phase 2 of the Sungai Muda water supply project (37/121, *Bekalan Air Mengkuang Pulau Pinang*).

Several clear effects can be observed when financial issues are resolved, such as the smooth construction and timely completion of projects. This can be seen through the construction of the Mengkuang Dam, the Sungai Dua Water Treatment Plant, the Bukit Dumbar water pumping station, and more. As a result, the water supply in Penang becomes more reliable, encouraging rapid economic growth. This is evidenced by the influx of domestic and foreign investors seeking to establish factories in Penang, both on the mainland and the island (37/121, *Bekalan Air Mengkuang Pulau Pinang*).

In addition, the lack of experience or expertise has also contributed to the problems in the development of water supply in Penang. It is well known that the Penang Water Authority was established in 1973 and is relatively new compared with other water companies. This has resulted in a lack of experience on the part of the water authority in managing large-scale water supply systems, such as the Mengkuang Dam with its significant capacity and high production, the Sungai Dua Water Treatment Plant, and the Bukit Dumbar water pumping station. This problem is not unique to the Penang Water Authority, but is also faced by other states. For example, Kedah sought expertise from the Kuala Lumpur water company, while Perlis faced similar challenges and obtained expertise from

Nama Syarikat	Jumlah Pelaburan pada 6.4.77	Nilai Equiti Pemegang	Modal Syarikat yang dikeluarkan	Peratus Equiti Pemegang
	$		$	
Milik Penuh				
1. Penang Electronics Sdn. Bhd.	2,500,000.00	2,500,000	2,500,000.00	100.0
Anak-anak Syarikat				
2. Penang Shipbuilding Corp. Sdn. Bhd.	2,246.000.00	6,489,000	6,846,000.00	94.8
3. Malaysia Foods Bhd.	2,100,000.00	2,100,000	4,000,000.00	52.5
4. Mushroom and General Trading Bhd.	787,500.00	787,500	1,500,000.00	52.5
Usaha Bersama/Penyertaan Equiti Kecil				
5. Penang Construction Sdn. Bhd.	25,000.00	25,000	35,000.00	45.0
6. Panelex Sdn. Bhd.	125,000.00	125,000	250,000.00	42.0
7. SIKA (M) Sdn. Bhd.	115,200.00	115,200	360,000.00	32.0
8. Australasia International Developments Sdn. Bhd.	150,000.00	150,000	500,000.00	30.0
9. Syarikat Nusantara Bhd.	60,000.00	60,000	132,795.00	30.0
10. Austral-Asia Developments Pty. Ltd.	30,828.25	30,828	130,000.00	20.0
11. Penang Commercial and Industrial Development Sdn. Bhd.	200,000.00	200,000	1,000,000.00	20.0
12. Kanebo (M) Sdn. Bhd.	850,000.00	850,000	5,000.000.00	17.0
13. Atlas Electronics Sdn. Bhd.	150,000.00	150,000	1,000,000.00	15.0
14. Hitachi Semiconductors (M) Sdn. Bhd.	400,000.00	400,000	4,000,000.00	10.0
15. Schott Glass (M) Sdn. Bhd.	595,000.00	595,000	5,950,000.00	10.0
	10,334,528.25	14,577,528	30,703,795.00	
Pembelian Saham Syarikat Swasta Yang Disenaraikan				
16. Hume Industries ...	100,077.50	193,358	33,770,835.00	0.6
17. Malaysian International Shipping Corporation	500,000.00	1,250.000	25,000,000.00	5.0
	10,934,605.75	16,020,886	89,474,630.00	

Figure 7: The total investment of each company in Penang in 1977

Kedah for water supply development reference. Therefore, the lack of experience and expertise posed challenges in the development of the water supply in Penang during the specified period (37/121, *Bekalan Air Mengkuang Pulau Pinang*).

To solve this problem, the government has taken steps to import private water experts to provide exposure to members of the Penang Water Supply Corporation. These experts are recruited from states or areas that have developed a good water supply system, such as Kuala Lumpur, Perlis, Kedah, and others. These water supply experts guided the management of the water supply system in Penang so that it smoothly. The knowledge shared by these experts also enhanced the existing knowledge and provide advantages to Penang, particularly the water supply corporation, as they gained training in management and problem-solving techniques. The inclusion of experienced individuals in the water supply sector is appropriate as they can share their experiences and expertise with the relevant water corporation (Abdullah & Mohd Noor, 2018: Abdullah & Mohd Noor, 2020).

Lessons from Post-colonial Water Architecture in Penang

This study offers several valuable lessons. Firstly, it provides an opportunity to conduct a historical analysis of how colonial rule influenced the development of water infrastructure in Penang. By understanding the historical context, the study can shed

light on the challenges and opportunities that arose from this legacy, informing present-day decision-making. This historical analysis can also highlight any disparities or imbalances that need to be rectified, such as unequal distribution of water resources. It also sheds light on the governance and institutional arrangements in the development of water infrastructure. This could include an examination of decision-making processes, the role of various stakeholders, and the effectiveness of coordination mechanisms. Identifying successful governance models or institutional frameworks can guide the establishment of effective collaboration among different actors in water infrastructure development. Conversely, it highlights any gaps or challenges in the existing governance structure, leading to recommendations for improvements. Furthermore, this study explores how technology and innovation have been utilised in water infrastructure development. Assessing the use of innovative technologies, such as smart metering or advanced water treatment processes, can offer insights into efficiency, cost-effectiveness, and resilience. Successful examples of technology and innovation can inform future investments and strategies for water infrastructure development.

This study also highlights the power dynamics between the state and the country regarding water resources, governance, and decision-making. It also shed light on the implications of these dynamics for water management, infrastructure development, and the well-being of communities. One implication of this interplay is the potential for unequal distribution of water resources. If the state holds significant power and control over water resources, it may prioritise the allocation of water to certain regions or sectors. This can result in disparities in access to clean and sufficient water, with marginalised communities or regions facing water scarcity or inadequate infrastructure. Understanding this interplay can help identify such disparities and prompt actions to address them, such as advocating for more equitable distribution or improving water infrastructures in marginalised areas. The interplay between the state and Malaysia also has implications for governance and decision-making processes. If the state has a dominant role in water control, it may lead to centralised decision-making, limited public participation, or reduced transparency. This can hinder accountability, inclusivity, and responsiveness in water management. Evaluating this interplay can highlight the need for more participatory governance models, increased transparency, and stronger community engagement in decision-making processes related to water control.

This study provides valuable lessons for water architecture and the built environment in Malaysia. One significant lesson is the importance of considering inclusivity and equity in water infrastructure. The study highlights potential disparities in access to water resources and infrastructure and stresses the need to prioritise equitable distribution. This lesson suggests that water architecture should be designed and built to meet the water needs of all communities and regions, including marginalised areas. Another crucial lesson is the significance of participatory decision-making in water control. The study emphasises the inclusion of local communities, stakeholders, and experts in the planning, design, and management of water architecture and infrastructure. This lesson underscores the importance of engaging a diverse range of perspectives to make well-informed decisions and foster a sense of ownership among stakeholders.

The study also underscores the need for transparent and accountable governance in water management. It highlights the potential limitations and implications of centralised decision-making and limited transparency in water control. The lesson derived from this is that water governance frameworks should prioritise transparency, open access to information, and accountability. Through transparent and accountable governance mechanisms, trust can be built among stakeholders, and decisions can be made in the best interest of the public. Sustainability is another crucial lesson addressed by the study. It emphasises the integration of sustainability principles in water architecture

and infrastructure. This involves considering factors such as environmental protection, water conservation, efficient water use, and resilience to climate change impacts. By incorporating sustainability principles, water infrastructure can be designed and built to be environmentally friendly and resilient in the face of future challenges.

Lastly, the study emphasises the importance of collaboration and coordination in water management. It highlights the potential for conflicts and the need for effective collaboration between different levels of governance and regions. The lesson derived from this is that effective coordination and cooperation among state authorities, national government, and other stakeholders involved in water control are essential. This can be achieved by developing mechanisms to resolve conflicts, promoting collaboration in decision-making, and sharing knowledge and resources to ensure efficient and effective water management. By incorporating these lessons into water architecture and the built environment in Malaysia, policymakers, water architects, and urban planners can work towards developing sustainable, inclusive, and resilient water infrastructure that meets the needs of all Malaysians.

Conclusions

In conclusion, the Penang government was responsible for the development of water architecture in Penang from 1957 until 1985. Water architecture in Penang during the colonial and post-colonial eras underwent significant changes, reflecting the shifts in governance, urban planning, and technological advancements during these periods. During the colonial era, water architecture in Penang was characterised by a centralised system, implemented by colonial authorities to meet the demands of the growing population. Water infrastructure, such as reservoirs, pipelines, and water treatment plants, was primarily designed and controlled by the colonial administration. The focus was on providing water primarily to the colonial settlers and industries, neglecting the needs of the local communities. This approach resulted in limited transparency and participation in decision-making processes, as well as disparities in access to water resources between different sections of the population.

In contrast, the post-colonial era witnessed a shift towards more inclusive and participatory water architecture. With the departure of colonial powers, the newly independent government recognised the need to address the challenges of water supply and management more equitably. Efforts were made to engage local communities, stakeholders, and experts in the planning, design, and management of water infrastructure. Post-colonial water architecture in Penang also saw advancements in technology and infrastructure. This included the modernisation of water treatment methods, the expansion of water supply networks, and the introduction of efficient water conservation practices. The focus shifted towards sustainable water management, considering factors such as environmental conservation, efficient water use, and resilience to climate change impacts.

Moreover, the post-colonial era brought about a greater emphasis on transparent and accountable governance. There was a push for open access to information, public participation in decision-making, and the establishment of regulatory mechanisms to ensure accountability in water management. These changes aimed to address the shortcomings of the colonial water architecture and promote inclusive and equitable water distribution. Overall, the transition from colonialism to post-colonialism in Penang's water architecture involved a shift towards inclusivity, sustainability, and transparency. While colonial water architecture prioritised the interests of the colonial powers and industries at the expense of local communities, post-colonial approaches sought to rectify these imbalances and ensure that water infrastructure serves the needs of all residents more equitably and sustainably.

This study also encourages further discussion and exploration of the topic. By examining the successes and challenges of

post-colonial water architecture in Penang, the study provides a foundation for ongoing conversations among policymakers, urban planners, and scholars. It prompts discussions on lessons learned, best practices, and future possibilities for improving water infrastructure design and management. Additionally, it opens up avenues for research on the impact of water architecture on urban liveability, environmental sustainability, and social inclusivity. Moreover, this research offers practical implications for policymakers and scholars involved in water infrastructure planning and design. By understanding the historical context of post-colonial water architecture in Penang, policymakers can learn from past experiences and ensure more efficient, inclusive, and sustainable water infrastructure projects. Scholarly research in this area can provide valuable insights and contribute to the development of innovative approaches to tackle current and future challenges in water infrastructure design and management. In summary, the research on post-colonial water architecture in Penang has established a strong connection to design, water architecture, and the built environment. It encourages further discussion and exploration of the topic, offering practical implications for policymakers and scholars. Through a deep understanding of the historical context and lessons learned, this research contributes to the development of more efficient, sustainable, and inclusive water infrastructure projects that enhance the quality of urban living in Penang and beyond.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

References

37/121, Bekalan Air Mengkuang Pulau Pinang.

Abdullah, M. F. (2019). *Pembangunan bekalan air domestik di Negeri Kedah, 1957-1992*. [Doctoral dissertation, Universiti Malaya].

Abdullah, M. F. (2021). "If you can control water, you can control everything": Pembangunan Sumber Air Mentah di Negeri Kedah, 1957-1992. *Asian Journal of Environment, History and Heritage*, *5*(1), 1-24.

Abdullah, M. F., *et al.* (2023). Hydrological legacies of colonialism: Examining water systems in Perlis, Malaya (1909-1950). *Journal International Studies*, *19*(2), 215-243.

Abdullah, M. F., & Mohd Noor, A. (2017). Sejarah perkembangan bekalan air domestik di negeri Kedah sehingga tahun 1957. *SEJARAH: Journal of the Department of History*, *26*(2), 24-37.

Abdullah, M. F., & Mohd Noor, A. (2018). Kerjasama Kedah dan Perlis dalam pembangunan sistem bekalan air domestik di negeri Perlis, 1969-1978. *JEBAT: Malaysian Journal of History, Politics & Strategy*, *45*(1), 56-78.

Abdullah, M. F., & Mohd Noor, A. (2020). Pembangunan bekalan air domestik di negeri Kedah, 1957-1992. *Kajian Malaysia*, *38*(1), 89-113.

Acey, C. (2012). Forbidden waters: Colonial intervention and the evolution of water supply in Benin City, Nigeria. *Water History*, *4*, 215-229.

Aiken, S. R., & Leigh, C. H. (2015). Dams and indigenous peoples in Malaysia: Development, displacement and resettlement. *Geografiska Annaler: Series B, Human Geography*, *97*(1), 69-93.

Annual Report on the Social and Economic Progress of the People of the Straits Settlements 1935.

Binnie, G. (1974). The evolution of British dams. *Transactions of the Newcomen Society*, *47*(1), 207-224.

Biswas, A. K., & Tortajada, C. (2001). Development and large dams: A global perspective. *International Journal of Water Resources Development*, *17*(1), 9-21.

Blacklock, D. B. (1943). Water supply in the British Colonies. *Annals of Tropical Medicine & Parasitology*, *37*(3-4), 211-220.

Broich, J. (2007). Engineering the empire: British water supply systems and colonial societies, 1850-1900. *Journal of British Studies*, *46*(2), 346-365.

Butler, H. C. (1901). The Roman Aqueducts as Monuments of Architecture. *American Journal of Archaeology*, *5*(2), 175-199.

City Council of Georgetown, 1966.

CO 275/47, Penang Annual Report 1893.

CO 275/49, Penang Annual Report 1894.

CO 275/70, Penang Annual Report 1904.

CO 275/72, Penang Annual Report 1905.

CO 275/74, Penang Annual Report 1906.

Gooden, M. (2020). Colonialism, water and the Black body. *Design Ecologies*, *9*(1), 9-27.

Hassan, J. A. (1985). The growth and impact of the British water industry in the nineteenth century. *Economic History Review*, 531-547.

Hegewald, J. (2022). *Water architecture in South Asia: A study of types, developments and meanings* (Vol. 24). Brill.

Hutchinson, F. E., & Saravanamuttu, J. (Eds.). (2012). *Catching the wind: Penang in a rising Asia*. Penang Institute.

Jones, D. S. (1997). The ‘ Waterfall’ Botanic Garden on Pulau Pinang: The foundations of the Penang Botanic Gardens 1884-1910. *Journal of the Malaysian Branch of the Royal Asiatic Society*, *70*(2), 75-96.

Mathur, C., & Mulwafu, W. (2018). Colonialism and its legacies, as reflected in water, incorporate a view from Malawi. *Wiley Interdisciplinary Reviews: Water*, *5*(4), e1287.

Messrs. Steen Sehested & Partners, Vattenbyggnadsbran (VBB). (September 1962). The State Government of Kedah Federation of Malaya, *Report on The Development of The Alor Star Water Supply*.

Mohd Noor, A. (2006). *Ilmu sejarah dan pensejarahan*. Kuala Lumpur: Dewan Bahasa dan Pustaka.

Moo, H. P., & Fernando, J. M. (2018). The role of the public works department in the development and administration of waterworks in Kuala Lumpur, 1900-1941. *SEJARAH: Journal of the Department of History*, *27*(1), 26-42.

Perbadanan Bekalan Air Pulau Pinang. (n.d.). *History & Water Supply*. https://pba.com.my/history-water-supply/

PKR (N2TM) W 37/121 Vol 8, Bekalan Air Sg. Muda Pulau Pinang (Draf 4).

PKR (N2TM) W 37/121 Vol 8 (413) Pinjaman BPA No. 4 MAL Projek Bekalan Air Pulau Pinang – Perjanjian Tripartite.

Snider, N. L. (1968). What happened in Penang? *Asian Survey*, *8*(12), 960-975.

SUK Ps 510 SK 3 (42), Bekalan Air Pengairan Muda.

Tahir, A., *et al*. (2021). An analysis of reports by The Illustrated London News (ILN) and The Graphic against social activities in Malaya in the 19th century. *Wacana Seni Journal of Arts Discourse*, *20*, 55-71.

Taylor, E. H., Wagner, C. M., & Meldrum, J. H. (1992). Design, construction and performance of Mengkuang Dam. In *Water resources and reservoir engineering:*

Proceedings of the seventh conference of the British Dam Society, University of Stirling, 24-27 June 1992, 271-286.

Teo, P. (2003). Limits of imagineering: A case study of Penang. *International Journal of Urban and Regional Research*, *27*(3), 545-563.

The Straits Budget Correspondent. (1939, 29 Jun). Penang Rural Water Supply: $525,000 Scheme. *The Straits Budget.* https://ere sources.nlb.gov.sg/newspapers/digitised/article/straitsbudget19390622-1.2.19

Ujang, Z., *et al*. (2022). *Air dan pembetungan di Malaysia, sejarah serta perspektif.* Kuala Lumpur: Kementerian Alam Sekitar dan Air, Institusi Penyelidikan Air Kebangsaan Malaysia, Jabatan Perkhidmatan Pembetungan.

Vjayan, T., & Vel Murugan, V. (2016). *Sungai Dua water treatment plant Seberang Perai Malaysia*. Penang: Universiti Sains Malaysia Press.

Williamson, F. (2020). Responding to extremes: Managing urban water scarcity in the late nineteenth-century Straits Settlements. *Water History*, *12*(3), 251-263.

Woodhouse, P., & Muller, M. (2017). Water governance—A historical perspective on current debates. *World Development*, *92*, 225-241.

Wylson, A. (2013). *Aqua texture: Architecture and water*. Elsevier.

Yunus, A. J. M., & Nakagoshi, N. (2004). Effects of seasonality on streamflow and water quality of the Pinang River in Penang Island, Malaysia. *Chinese Geographical Science*, *14*, 153-161.