Twentieth-century modern-colonial irrigation development in Banten: Technological review of Pamarayan Old *Stuwdam*

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ABSTRACT

The Bendung Lama Pamarayan in Panyabrangan, Serang, is an old movable weir vital in regional irrigation and cultivation in Banten's history. However, current historical and archaeological studies provide limited technical analysis of how its system and management worked in the past. To address the issue, this study focuses on the technological significance of the Pamarayan weir or *stuwdam* as an integral part of the water resources improvement program in the early twentieth-century Banten. Archival records and a heuristic approach of *Digging 4 Data* are employed to understand the dynamics of the Pamarayan water catchment project at Ciujung riverine constructions throughout history. The study identifies several factors that led to the failure of its sustainability, including changes in the natural hydrological regime of the Ciujung River and ineffective maintenance practices. The research findings also retrospectively highlight the early development of modern hydraulic engineering in Indonesia, and suggest potential extensions for heritage conservation and community empowerment of the historical civil engineering structure.

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1. INTRODUCTION

Bendung Lama Pamarayan, located in Panyabrangan village, Serang district, is an unfunctional old and monumental *stuwdam* or a movable weir structure. It is considered a local cultural heritage object in Banten (*No. Inventaris* 022.01.01.04.07) that once played an important role in succeeding regional irrigation and cultivation works in modern history. Recently, there has been an official plan to upgrade its stipulated status to a national heritage level since it is well-known as the first largest modern irrigation structure in Indonesia [1], as well as becoming an emerging potential site of tourist attraction and destination managed by the local community [2]. However, only a few or no sufficient and proper historical and archaeological studies support this claim [3]. Apart from the database inventory of *Balai Pelestarian Cagar Budaya* (BPCB) Banten in 2017 [1], the latest extensive research on colonial heritage in Serang, including the object done under the Culture and Tourism Agency of Banten (2012) is limited only to narrate general historical information [4], yet leaves questions on technical aspects of how the structure functioned and malfunctioned in the past.

This article aims to review the technological significance of the Pamarayan old movable *stuwdam* structure as part of colonial-modern irrigation and hydraulic engineering management and practices in Banten in the early twentieth century, primarily assessing its technological uses and values. The research also explains the dynamic processes of the water catchment (*prise d'eau*) and Ciujung River irrigation project constructions, its technical operations and problems dealt with throughout history. This type of study is a compulsory developmental activity that would be helpful as guiding references required for further heritage conservation actions and supporting community empowerment according to the Cultural Heritage Act 11/2010 and Advancement of Culture Act 5/2017. [5]

2. METHODS

Historical review on colonial-modern technology relies much on a heuristic approach toward archival and literature research. Data are collected by applying the *Digging 4 Data* method (2016) to gain information, understand the socio-political and economic context, and investigate the development of Dutch colonial built environmental heritage in Indonesia [6]. The research findings are narrated to answer specifically about: (1) project description and background; (2) temporal and spatial/site context; (3) subjects and stakeholders involved; (4) technical aspects regarding construction processes; and (5) problems and factors causing the structure malfunction. Other than 1913 *Burgerlijke Openbare Werken* (B.O.W.) or the Department of Public Works annual report by engineer A.A. Meijers, the two foremost excerpted accounts for this article's sources are B.B.C. Felix's text of broad irrigation projects in Banten including Pamarayan water catchment [7]; and Niels L. Thiele's who shared the project execution from his own experiences as an on-site B.O.W. engineer [8]. Both published their similar topics correspondingly in different volumes but the same year in *De Waterstaats-Ingenieur*, a Dutch engineering journal (1921). Other sources are cited from contemporaneous twentieth-century news articles, books, and regulations, while the cited latest publications help to correspond the research results' relevance to the nowadays context.

3. RESULTS AND DISCUSSION

The discussion of the Ciujung river water catchment (*prise d'eau*) and the Pamarayan movable weir (*stuwdam*) as a colonial-modern irrigation project in Banten is divided into four parts: historical background, design development, construction processes, and the problems and setbacks.

3.1. Historical background: Irrigation work and the late nineteenth-century Banten

The decision of the colonial Dutch East Indies authority to improve the irrigation system quality in Banten was started with early attempts since the mid-nineteenth century after the region suffered recurring water problems. The main issues were repeated floodings on both banks upstream of the Serang-Batavia Great Post roads, the lack of competent personnel involved, and complaints about poor irrigation and drainage in Cikande Udik and surrounding private agricultural estates of *tanah partikelir* appeared in 1893. The idea also cited political motives for increasing support for Dutch rule and the potentials for economic repair in Banten following the 1888 peasants' uprising, followed by the urge for technical investigation inspired by Resident Banten in 1892 [7]. Consecutively, the colonial state in the following years implemented the Ethical Policies (1901) and Decentralisation Act (1903) which emphasized state's vast regional development services on a well-known slogan *Irrigatie*, *Educatie*, *en Emigratie*, as a moral responsibility to the indigenous' welfare and life improvement, while to keep maintaining colonialism in the Dutch East Indies now Indonesia. [9]

The colonial-modern irrigation project in Ciujung River—North Banten, along with Citarum-Karawang, Indramayu, Bedadung-Besuki, and others, focused on building water catchment facility in order to distribute sufficient water supply to agricultural fields in Java [10]. Pamarayan was selected as the site location after several considerations. It was initially started tapping into the Danu

(Cidanau) River as a water reservoir in 1897, yet it was deemed too expensive. Later on, a project commission and a B.O.W. engineer Van Marleen Jhr. Van der Does de Bije were assigned to investigate the technical and financial feasibility of identifying the Ciujung River as a potential source, estimated to irrigate up to a height of +15 meters and an area of ±43.000 *bouws* (1 *bouw* ≈ ±7096,5 m^2). However, due to an extremely low slope downstream condition, a water catchment area further upstream should be preferred over a dam further downstream and was only limited to a maximum height of ± 9 meters. This also led to building a dam upstream of the siphon culvert to divert water at Ciujung river and build a separate spigot, or treating Ciberang pipelines as a new connection to the river with a dam downstream and sluice inlet on the left riverbank. Besides, the Pamarayan site also offered the advantage of not cutting through the newly constructed railway between Rangkasbitung and Serang at the time. [7]

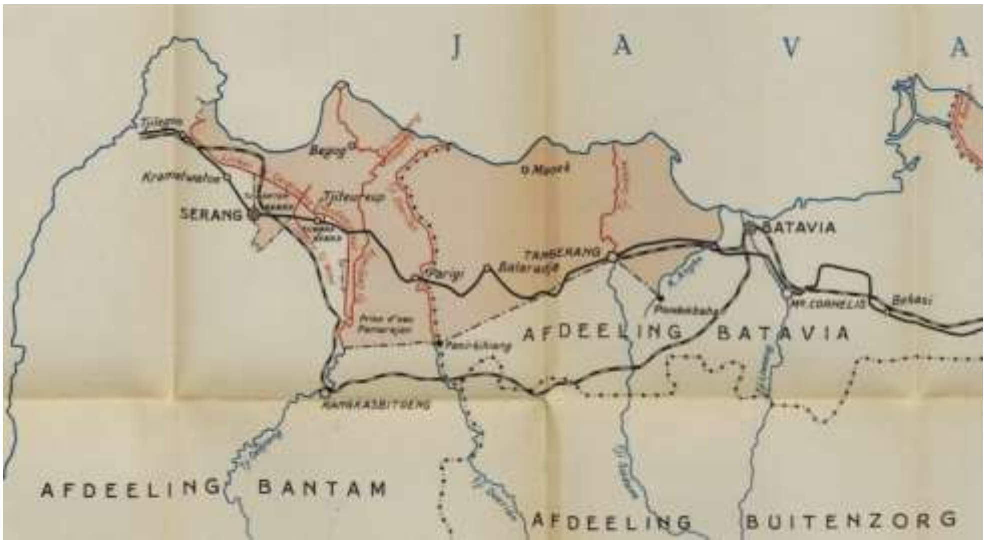


Figure 1. Cropped map of Banten areas in the twentieth-century colonial irrigation, including Pamarayan work. Source: G.R. Erdbrink, *Staatsblad van Nederlandsch-Indie* Act No. 177/1926 [11]

In 1899, the Dutch-East Indies government finally granted permission to prepare a preliminary design of water catchment. The B.O.W. chief engineer of irrigation works in Banten, S.W. Becking, together with Van Marleen, submitted their first proposal to the government in May 1904. [7]

3.2. Design development of *prise d'eau* and *stuwdam*

In general, there were two main phases of design development. The first 1904 proposal was estimated to cover a net rice field area of +34.450-45.000 *bouws,* and was able to have a water availability of at least +40 m^3/s in the West monsoon and at least +15 m^3/s during the East monsoon months. The maximum flow rate in the Ciujung River was +1740 m^3/s, with a maximum flood level of +14,30 meters. The initial plan for the *stuwdam* or weir's length was 133 meters, and its maximum height was +11,40 meters. However, problems in ongoing construction over 1905-1912 were resolved with a better method in a new second design proposal submitted by an engineer A.A. Meijers in December 1912. The next construction followed this proposal in 1913, where N.L. Thiele oversaw the project calculation and execution. The total cost for this phase was about 1,5 million guilders, including river diversion and closure costs. The latter design did not undergo any changes. [7]

3.2.1. Lower structure

The lower weir walls were made of 50 cm thick rubble masonry works, but only the outer shell of the pillars and the inner part were filled with reinforced concrete mixed with 40% rubble stones to increase their weight [8]. The sluice gates are designed as tubes to avoid heavy masonry work, with ten openings of 12 meters long each, the piers of 2,50 meters thick, and two abutments, hence the total width between sluice heads was 142,5 meters. The sluice's floor length was 98 meters, while the ratio between its height and path length traveled by water particles under the structure is +5,90 meters : +16,6 meters. This concept was based on Brown & Wegmann's theory for building dams on permeable soil, to ensure water particles' velocity low enough to prevent the sand grains from moving to sluices. [7]

(a) TM-10007884

(b) TM-60016497

(c) TM-60016504

(d) TM-60016503

Figure 2. (a) Aerial view of water catchment work; (b) Newly built lower structures; (c) Weir inlets and gates; and (d) Exterior view of the weir. Source: G.F.J. Bley, Tropenmuseum (1915-1926)

The left intake gates had five openings for a flow rate of 34 m^3/s, and the right gates had two openings for a flow rate of 11 m^3/s. Five openings were formed with a height of 2,10 meters and a width of 2,00 meters generated 34 m^3/s in normal times. The right inlet lock was calculated for a capacity of 11 m^3/s with a head loss of about 0,18 meters, and consisted of 2 inlet openings of the same dimensions as those on the left bank. The opening and the inlet sluices were able to be opened and closed using slides. The upstream part of the floor was filled with a clay and concrete layer for protection, whilst the downstream part was designed to withstand hydrostatic pressure. The floor is reinforced with steel bars, and a large outfall basin was located at the sluice gates downstream. [7]

3.2.2. Upper structure

A B.O.W. engineer named Ir. Snuyf created the architectural design of Pamarayan's upper weir structure. He also designed a similar *stuwdam* at Pasar Baru, famously known as "Pintu Air Sepuluh" in Tangerang (1925). The B.O.W. sought to obtain a more monumental style of Pamarayan weir, with 7,50 meters height of rigid overheads formed by eight beams made of Portland Cement (P.C.) reinforced concrete, and connected to crane bridges at the bottom and upper bridge at the top. The weir was designed as an elegant structure with two towers connected to the upper bridge by an additional span, whilst the inspection sluice storage and an overhead crane were located to the left bank (Figure 3) [8]. The lower tower provided staircase access to the upper bridge and the upper tower provided office space, storage, archives, and a water reservoir. The upper pillars supported a bridge for wind works to open and close the masonry gates. Two control gates, each weighing ± 9 tons, used to drain the sluice openings, with a crane required a traverse between double-set rails. [7]

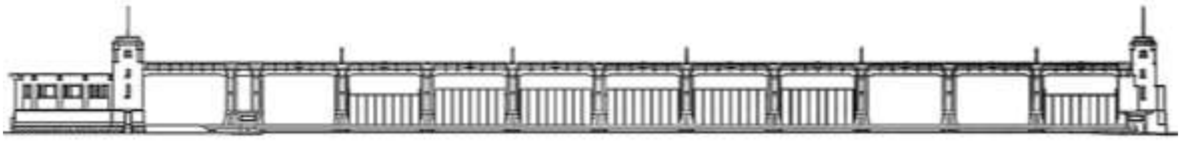


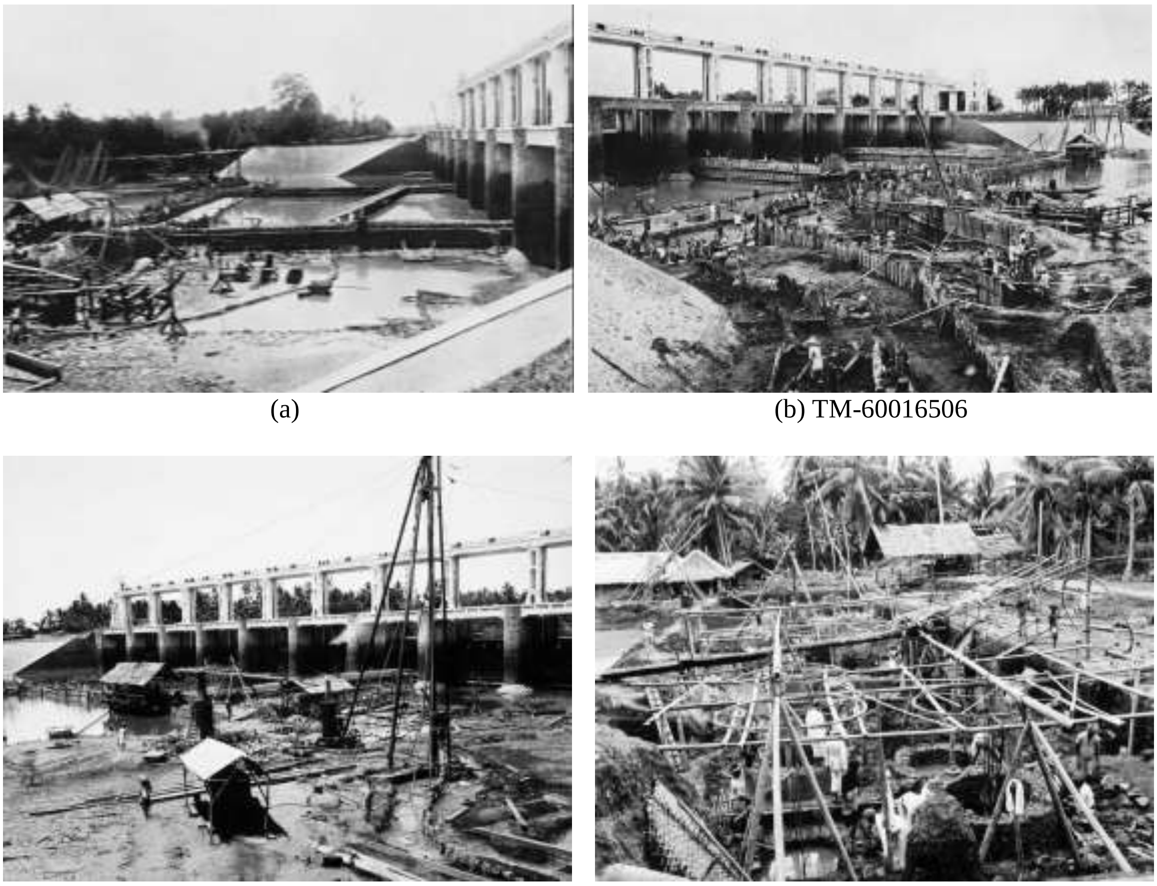
Figure 3. Front elevation of Pamarayan *stuwdam* or weir structure. Source: BPCB Banten (2017) [1]

The heavy tower edifices were constructed on the left bank for the inspection gates and crane, partly standing above the inlet pipes with an underground cellar. Crane and pedestrian bridges with the supporting piers below were made of concrete beams for 3 meters-wide decks and a placement of crane tracks for maneuvering inspection. The weir's sliding doors were delivered ready-to-fit by the supplier, and only needed to be riveted on-site using pneumatic hammers. Besides, reinforced concrete counterweights were made onshore as U-shaped beams to balance sliding doors, which were transported to their positions and hung in place using the available overhead crane. After filling the cavity with concrete and large amounts of scrap iron, each counterweight was weighed individually to ensure it was proportionate to the connected sliding door. A lightweight concrete was made from pumice instead of gravel to achieve the correct weight and fill the last 15 cm of the cavity. [8]

3.3. Dynamics of the construction process

There were four phases of the Pamarayan water catchment construction in history: 1905-1912; 1912-1919; 1928-1929/31; and 1935-1939. It was started in 1905, when a ring dam of sandbags was set to protect the site. In February 1906, a budget of *ƒ* 360.000 was approved for the dam construction. The B.O.W. engineer A.A. Meijers later started building a dam and water diversion system at Ciujung River for construction purposes in 1912 following the approval of the design proposal. The first step was to close off the Ciujung River and dig a new channel to redirect the water during construction. Previous attempts to close off the old estuary had failed due to floods, but groins made of stone and bamboo were built at the new channel entrance in July and August 1912.

The next step was pouring quarry-stones dam into the river, forming an upstream barrier for an earthen dam. The upstream floor consisted of a 75 cm thick layer of clay covered by a 30 cm thick layer of trasbeton to prevent erosion. The clay layer was compacted and covered with stones to avoid disturbance in wet weather. This work was reinforced and served as an upstream closure of the construction pit. The downstream dam was also reinforced with sand. Despite the flood and sandy water problem washing away much of the initial materials, the intake foundation and discharge sluices were finally laid in the following years, along with most of the vole basin behind the intake sluice. [8] The reinforced concrete floor under the weir was designed to evenly distribute the upper structure's weight against the groundwater pressure. The floor's total volume was approximately 6.000 m^3, consisted of red cement concrete with a ratio of 1 quil of limestones : 1/2 red cement : 3 sand : 6 gravel, with 1 m^3 of quil $\approx$ 1.5 m^3 of dry limestones. A separating wall was built between the downstream red cement-concrete floor and the latter reinforced concrete floor under pillars. Three concrete mixers were used simultaneously for the floor, and the railway was built to transport the concrete from Catang train station, then the pouring was done from a movable cross track. [8]



(a) (b) TM-60016506

(c) TM-60016505 (d) TM-60016507

Figure 4. The on-going construction of Pamarayan water catchment at Ciujung River from around 1915-1928. (a) Earthwork on the riverbed; (b) Extensive scale of bamboo rods and poles; (c) Vast sedimentations surrounding the riverbed; (d) Crossing bridge construction, by which "Panyabrangan" toponymy was originated. Sources: *Tropisch Nederlands* (1928) [21] & Tropenmuseum (1915-1926)

The construction materials were gathered for construction, quarry stones (*breuksteenen*), gravels, concrete sand (*betonzand*), red cement (*roode cement*), limestone (*kalk*), wood logs (*hout*), and others. Portland Cement (P.C.) reinforced concrete and steel materials were supplied from Hollandsche Beton Mij company, costing about *f* 123.000,- [12]. Quarries were obtained through purchasing from small contractors; the gravel was mainly taken from the Ciujung River upstream and required 30 boats to load; and quality sand was sourced from the flowing water near the sluice entrance. Approximately ±300 m^3 of red cement was produced by building four ovens, 36 m^3 for each, and only required half the amount of firewood compared to conventional methods. Unslaked limestones were transported by rail and stored in large pits to preserve quality. Jatiwood logs were cut and transported by raft, whilst wildwood was locally purchased. The *Staatspoorwagen* railway in Catang post on western side of the site transported P.C. reinforced steel and other materials. [8]

Shortly after A.A. Meijer's work, the head of North Banten irrigation project engineer, L. Valk, took over the project but faced construction challenges. Engineer Levert took over after Valk chose a different location for the damming (*afsluitdijk*). The work progressed enough to begin the damming process, but monsoons repeatedly damaged the construction in 1918. The wind works on the upper bridge were built prior. In contrast, the upper maneuver bridge and removal of the temporary coupure sluice were completed after 1918, as indicated by N. L. Thiele's absence in being promoted as the new head of Ciujung's work irrigation project and he moved his office to Serang [13]. Finally, the entire Ciujung River flow was rated through the *prise d'eau* for the first time on January 1919, and the finishing was done on April 1919, costing around *f* 1,260,000 in total. The whole Ciujung river irrigation system achieved about 450,000 *bouws* coverage. Besides, several other smaller systems in different parts of Java were on-going in parallel, such as Citarum in Karawang (110.000 *bouws*), Bedadung in Besuki (90.000 *bouws*) and others, costing a total budget of 600 million guilders. [10]

The second phase of work (1912-1919) was done in three shifts of six hours each, with exploitative 18 hours of work per day involving outsourced laborers of *kuli*. Around 540 people of *kuli* work daily and would spend about 3.5 years finishing the project [7]. Unfortunately, the project was eventually delayed due to the World War I excess (1914-1918). In 1918, about 350 *kuli* from Rangkasbirung and Petir districts were forced to work in Pamarayan daily, where each *kuli* only got paid about 20-30 cents or about *f* 0,10 for each 1 m^3 of ground they loaded and moved [14]. Another source stated a more conservative number of about 300,000 people of *kuli* working in Pamarayan. [3] [4]

Entering the new developmental phase, there was a plan for further work to irrigate other 10,000 *bouws* on the right bank after years in a vacuum, following major irrigation works in Batavia and Tangerang since 1925. This third phase included main canal work, water pipelines, and their associated structures. The work tender resulted in Van de Laar, an engineering office in Garut appraised as the lowest bidder with a budget of *f* 183,000. The conduit designs were prepared at the Irrigation office in Weltevreden, and the total cost for the left and right bank construction was estimated at 11 million guilders. The secondary and tertiary pipelines would be built respectively by the community. Other smaller held projects were draining and transforming swampy areas into fertile rice fields. In 1929, approximately 25,000 *bouws* were already finished on the left bank of Ciujung, with a 50 kilometers long main channel being built reaching Cilegon areas. [19]

Due to the delay of the third phase, the Provincial Representative of West Java later approved to continuation of Ciujung irrigation canal construction in two sections in 1935, and this was considered a new phase. The project costed a total of *f* 31,720. The project management provided much-needed employment opportunities for the locals, but still relied on the more adequate local workers from Batavia and Cirebon [20]. The developed weir was temporarily opened in 1936, according to the *De locomoti*ve news (16 June 1936). This fourth phase project of *prise d'eau* and *stuwdam* was finished in 1939 [17], and had succesfully supplied water throughout a 48.135 kilometers long main channel and branching into a secondary and tertiary pipe to irrigate rice fields and 2,820 *bouws* in Ciwaken and Cibanten, which costed *f* 1,365,083 in total. [21]

The Pamarayan work had received special attention from both states of colonial Dutch East-Indies and Indonesia. In 1918, the impression was given by Dr. R. Broersma in the *Kolonial Studien*, stating the work was '*a boon to Bantam, a true symbol of the Dutch government's goodwill towards children of the country, a monument to the conception which nowadays governs the national interest care*' [14]. On numerous occasions, site visits to Pamarayan were done. The *Algemeene Vergadering* members were reported to have visited the monumental weir, guided by B.O.W. irrigation head J. H. Thal Larsen, the engineer N. L. Thiele and L. Valk on March 26, 1916 [15]. Another official excursion by *Vereeniging van Waterstaats—ingenieurs* was also held in 1920 [16]. In 1926, amidst the regional decentralization, Pamarayan and other Banten's water management would not even be transferred to the West Java regional administrative (Figure 1) [10]. During the revolution times of Indonesian independence (1945-1949), Pamarayan was considered one of the strategic water infrastructure in Java, and fully guarded by the Dutch army base for months [17]. In 1951, President Sukarno also visited the structure that had irrigated 24,000 hectares of rice fields. [18]

3.4. Recurring problems, repairs, and setbacks

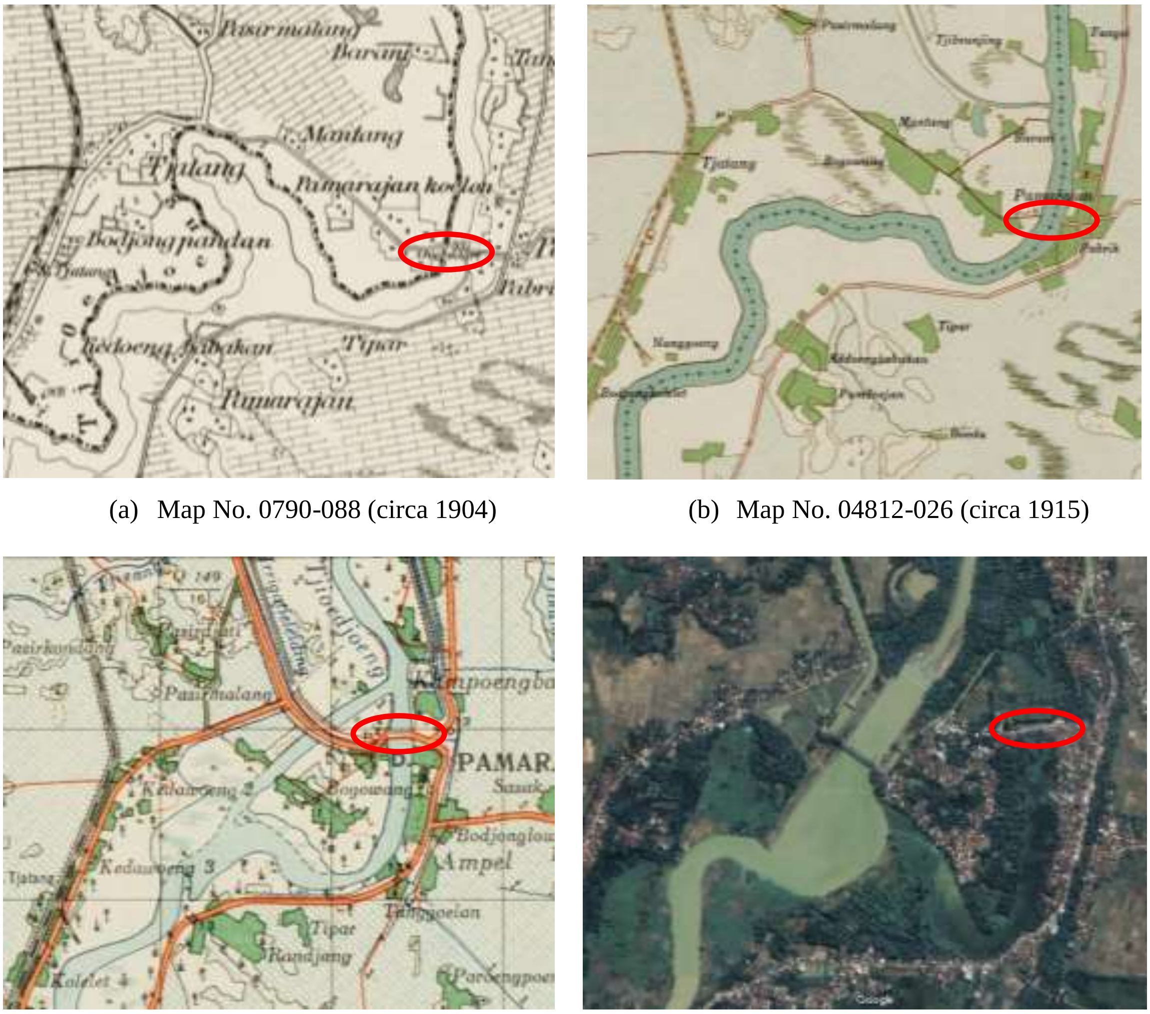
In spite of its exceptional size and monumentality, the Ciujung River work was a big deal, in which the Dutch engineers had contended with numerous setbacks over time. The early construction phase

(1905-1912) was initially planned to finish in 2 years. However, the project encountered technical difficulties and met its first failed attempt in erecting a permanent dam due to the water-permeable sandy bottom. The sand riverbed caused technical problems during excavation, such as the discovery of fossilized tree trunks in the ground. The ground drilling yielded unsatisfactory results in soil consisting of sand, and it was advised to install coffers of plaster walls (*damplankwanden*) [7]. As the consequence, too much calcification of soil and tuff sand in the area became the major cause of massive sedimentation even in today's landscape, which totally covers the eastern Ciujung tributary river flow on the weir's side. (Figure 5)

In 1909, a new idea was proposed to build the structure on dry land by damming the river and redirecting Ciujung water through a cut, and it was approved in November 1910. The project was halted in the same year because the extant design needed to be fixed. It was found that the irrigation of a particular land was impossible with the assumed water level, so its level should be raised by an underground water barrier. The four sections of feeder channel length had changed regularly, from 20 kilometers in 1917, 15 kilometers in 1918 to 20 kilometers, and back to 20 kilometers in 1928. The 5 meters deep pipeline had to be repeatedly repaired due to landfills, shears, and subsidence. The side walls were pressed in places, and the bottom had to be deepened each time. The agricultural fields alongside the Ciujung River are rich in tuff but poor in fertile soil. Its irrigation water quality was one of the poorest irrigation waters in Java. If one wanted to increase the yield per construction of a rice field, one would have to use phosphoric acid and other manure. This was undoubtedly a great disappointment after spending resources on the big project [22]. The water catchment work also proved to fail in preventing floodings that happened at Pamarayan in 1932. [23]

Another issue was indeed related to the construction budget. In the 1899 report, the project committee had already considered the work would have been expensive in the first place. The failed execution of the first original project had financial spendings with over *ƒ* 252,000 wasted [7]. As aforementioned passages show, the work progress was delayed and divided into phases due to budget cuts. The second phase (1912-1919) was delayed in 1914-1915 due to World War I, and the third phase (1928-1931) was held temporarily due to an impactful Great Depression or infamous *malaise* crises until 1931, and was just started again until the fourth phase (1935-1939) [24]. The uncalculated calcification repairs at the Pamarajan and Walahar costed nearly 1 million guilders of downstream floor expansion, because holes had formed beneath these floors, over 1.5 meters high in 1934. [25]

A half-century long after the final construction phase, the Indonesian government created a masterplan for flood control in the Ciujung River between the Pamarayan water catchment and Rangkasbitung in 1983 and 1985, in response to the floodings along the Ciujung middle section and lowlands in 1977 and later 1992. The Directorate General of Water Resources at the Department of Public Works developed the masterplan from the studies on water resource development in Jabotabek in 1989, and asked for technical assistance from Japan in 1991. Thus, JICA and Nippon Koei began a further study on the Ciujung-Cidurian River development in 1993-1995 to fulfill the request. [26]



(a) Map No. 0790-088 (circa 1904)

(b) Map No. 04812-026 (circa 1915)

(c) Map No. 05120-023-B (circa 1940)

(d) © Google satellite view (2023)

Figure 5. Ciujung River and its surrounding land transformation over time. The red ovals indicate the Pamarayan old *stuwdam* location. Source: Leiden University Colonial Maps & Google Earth

In the end, the new Pamarayan dam project was established under the Indonesian New Order's five-year development program (*Pembangunan Lima Tahun*, or Pelita) during 1994-1997, aimed to repair and rebuild the existing irrigation facilities, especially the headworks after the old structure was gradually inactive and neglected. In 1998, the Jabodetabek Water Resources Management System (JWRMS) conducted a study and suggested the national government through *Balai Besar Wilayah Sungai* (BBWS) Cidanau-Ciujung-Cidurian to build two dams in the river basin at a separate location. Nevertheless, these perennial issues of flooding and sedimentation are still occurring today. The latter appears even in the new weir structure, especially during the dry season [27], reducing its performance and even damaging its structure [28], albreit a sand trap controlling equipment has been installed and performed in the location. [29]

4. CONCLUSION

The archival research results show the technological significance of Pamarayan water catchment in Ciujung River irrigation work throughout history, while underlining several factors leading up to the failure to maintain its sustainability. The issue of selecting the project site location, on-site natural constraints of abundant sand materials on the riverbed, floodings, and destructive monsoons disrupting the construction processes, become several key factors causing the weir structure malfunction. Nonetheless, this historical review has shed light on the early development of twentieth-century modern-colonial hydraulic engineering practices in Indonesia. These research materials would be beneficial for the community improvement of *Desa Budaya*, a thematical cultural village official programme, in which the historical narrative is empowered as an integral part of the cultural heritage conservation and revitalization according to the National Cultural Heritage Act 11/2010 and Advancement of Culture Act 5/2017.

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