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Locales of happiness

Colonial irrigation in the Netherlands East Indies
and its remains, 1830 - 1980

Locales of happiness

Colonial irrigation in the Netherlands East Indies
and its remains, 1830 - 1980

Maurits Ertsen

VSSD

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Preface

I have not been really good at writing prefaces. Perhaps thanking people is not my thing, but I do like to think that is not the case. I may just not see the need to thank people who know they helped me on the first page other people will read in any book (that is, after checking the references to see whether they are in...). But I was persuaded to write a preface for this book, so here it is. First, I would like to apologize to Paul Josephson, for using the I-word throughout this book. Sorry Paul, your advice on this matter came too late. And I may disagree as well. Second, I would like to thank the many people that helped me to do the work leading to this book, particularly the colleagues from Indonesia and the very helpful staff of the Dutch National Archives. Third, I apologize for the mistakes in the book. I have tried to assure the book is free from mistakes, but I know I failed. Hopefully, the book is still interesting to many. Finally, and this may be the subject I tend to be bad at expressing, but consider it as the main reason to write a preface in the first place, allow me to assure you that publishing a book is fun, but that having the greatest children of all and being with the cutest woman on the planet is much, much more satisfying...

Maurits

Delft, April 2010

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1 Tracing back a river

Introduction

In 1993 I graduated as an irrigation engineer at Wageningen University. I must confess that I did not really consider that as strange. Obviously, as anyone, I did know that the Netherlands' international reputation is one of water excess, or drainage, not of water needs, or irrigation. Furthermore, with an MSc thesis on irrigation in the Netherlands East Indies, I knew that Dutch irrigation efforts on Java were substantial. It was not until I started working at Delft University of Technology, however, that I realized that at least two questions needed explanation. The first issue, why one could graduate in irrigation in a drainage country, seemed rather straightforward. One could still graduate in irrigation engineering in the late 20th century in the Netherlands, in Delft or Wageningen, because the Netherlands promoted its water knowledge within the international arena of development cooperation. Irrigation projects were vital elements within development policies. A second issue popped up, however, when I started looking at irrigation education in Delft. Within the lecture notes, I encountered many elements apparently taken directly from examples from the Netherlands East Indies. Specific discharge measurement structures were to be applied, and canal capacities were to be calculated according to a certain procedure. How could I explain the survival of these Dutch colonial elements within the general discipline of irrigation? This apparent persistency of colonial irrigation elements in Dutch irrigation practice and education is the main source of inspiration for this book; the Netherlands East Indian irrigation regime, consisting of explicit and implicit rules for irrigation design is its subject. Many studies discussing irrigation development in the Netherlands East Indian colony exist¹. A study trying to understand the technical development process of irrigation seems to be missing; this book claims to fill (part of) this gap. I intend to explain two related issues: (1) how did the Netherlands East Indian irrigation school develop and (2) what happened with this school after Indonesian independence?

Persistency

Accounts of persistency of colonial irrigation practice have been made by several authors. Colonial British irrigation design and water management concepts still shape to a large extent daily irrigation practices and discourses in Pakistan and India². Different 'schools' of irrigation development, similar to the British example, emerged in the context of colonies, as the Dutch did in the Netherlands East Indies and the French in north-western Africa. The American school may be the only one without colonial

connotation, although elements of Spanish influence can be detected³. An irrigation school is a tradition of practice, comprising information physically embodied in a community of practitioners and in rules for action which these practitioners master. Traditions define accepted technical operations and encompass aspects of relevant scientific theory, engineering design formulae, accepted procedures, specialized instrumentation, and usually some kind of ideological rationale⁴. An important mechanism in this process of preference-guided selection of design solutions is engineering education; graduating from engineering programs is like passing the preparatory demands for community membership.

In the 1960s and 1970s, irrigation engineers developed irrigation schemes applying the well-known design practices of their respective schools, which were treated as 'the best possible method'⁵. Nowadays, modern irrigation science appears to the observer as an international, homogeneous body of knowledge. There seem to be no different schools of thought; one could speak of the modern paradigm of irrigation promoted by the World Bank, the International Commission on Irrigation and Drainage and other international organizations. Perhaps this international paradigm is dominated by American irrigation science. However, when looking closer, a somewhat more complex picture showing different approaches to irrigation and its problems replaces the picture of uniformity. Within irrigation modernization discussions French-based downstream controlled demand management and American-based upstream controlled arranged management approaches seem to be contrasted⁶.

With an obvious restriction in the empirical material being limited to Dutch irrigation, even such a limited focus should allow me to contribute to a continuous debate within the community of those who engage with the history of technology⁷. Traditionally, studies on histories of technologies focused on the bolts and nuts of technologies and its great inventors, with hardly clear and systematic exploration and explanation of the societal context. Brave men and their machines was the discourse. As a response, particularly in the last three decades, studies of technological systems, social construction of technology and the influence of class and gender have enriched the field of history. There is not much sense in denying that in many of the earlier studies the relation between technical development and society has been represented quite one-sided in terms of discoveries, inventions and successful applications of individuals who brought their discovery from its isolated niche in the open for society to prosper. On the other hand, though, new approaches focusing on understanding technical development as determined by societal forces allow society to determine shape and selection of technology, but technology hardly overcomes a status of passive artifact. Furthermore, daily activities of those engaging in developing technologies, our former heroes, are usually left out.

Technological regimes

When this well-known discourse between internal and contextual approaches is presented, the author usually claims that he has overcome the differences. Indeed, my claim is not very original, but I intend to do credit to both approaches in my analysis of Dutch colonial irrigation. I discuss technical development as a process influenced by societal forces as well as by successful discoveries or applications by individuals. The concept of technological regime I apply aims to link the two positions⁸. The regime concept is based on the recognition that

‘invention and innovation are conditioned by such factors as earlier innovations, the search heuristics of engineers in an industry, available technical knowledge, market demand and industrial structure.’⁹

The regime concept bridges another gap as well, as

‘[b]etween the formalized knowledge that can be traced through courses and treatises, and the everyday decisions made by engineers, there must be for sure some kind of intermediate know-how.’¹⁰

This intermediate know-how, transformed in rules structuring the how and what to do, shapes a technological regime. Engineering education, transferring existing knowledge and design rules to new engineers who have no direct link with the practice in which the rules were developed, can be considered as a structuring element. Another such a structuring element closely related to education materializes in engineering handbooks. Successful approaches become examples, even blueprints for technological design. Selected examples are presented to students at engineering schools. The professional engineering organizations, including educational institutions, but also Departments of Irrigation (or generally Public Works), select, discuss and promote successful technological solutions. Gradually, a technological regime develops¹¹.

Technological regime development is a two way process between structures and actors. I define a technological regime as a set of rules structuring activities of actors involved in development and use of a certain technology¹². Rules can vary in form and content; some are related to design of technologies, others to use, others to divisions of labor.

‘Some rules will be explicitly laid down in requirements and technical norms. Other rules will be tacit and implicit and will be followed by the actors on the basis of habits or tacit knowledge. [...] Rules in technological regimes can also be embodied in production apparatus or technological artefacts.’¹³

The totality of relevant rules shapes the technological regime. Within a technological regime different categories of rules can be ordered hierarchically; I employ five of these categories¹⁴. Together these five categories shape the irrigation regime (Figure 1.1). Basic founding premises are (1) ‘guiding principles’, which relate the design of a

technology to doctrines and values used to legitimize a tradition and its outcomes. Closely related to these principles are the (2) 'promises and expectations' about a future technology, which will be translated into more specific requirements for new technologies. I employ the term (3) 'design requirements' to describe functions to be fulfilled by an artifact and boundary conditions that are important in the design of a technology. To enable the fulfillment of requirements, (4) 'design tools' are employed, including scientific knowledge, design heuristics, technical models and formulas, design methods and approaches. Category (5) 'artifacts and operation' includes the result of any design activity; both in the meaning of physical objects as in the meaning of operation and management procedures. Artifacts may not be considered as rules, as they only fulfill functions and have to meet design criteria and requirements. On the other hand, artifacts can and certainly do function as exemplars: future designers still apply them because they are known or have been proven in practice.

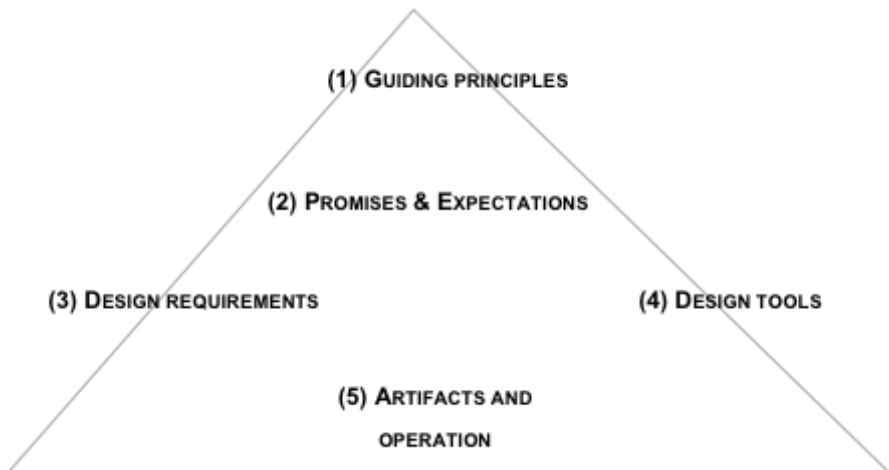


Figure 1.1 The technological regime triangle
15

The categories are structured in a hierarchy; guiding principles are on a higher level than design tools. In the Netherlands East Indian context, higher level not only refers to the more abstract nature of guiding principles in contrast to for example design tools, but also to the larger number of stakeholders involved in and the political connotation of formulating guiding principles. As we will encounter in this book, debates on the appropriate foundations for colonial water policy involved civil servants and engineers, government and private industry. On the other hand, discussions which discharge measurement structure to be used to realize this water policy were exclusively situated within the civil engineering circle. Higher level rules structured the development process of lower level rules like design tools and artifacts.

Even though drawing boundaries exactly of a technological regime beforehand might not be needed¹⁶, one could define regimes rather broad or rather narrow. I tend to start from a relatively narrow definition, perhaps even a rather traditional position, analyzing

the development process of Netherlands East Indian irrigation focusing on the rules that structure activities of actors involved in its development. To narrow down my approach even further: I am mainly interested in the actions, discussions and positions of Dutch irrigation engineers in shaping their irrigation design approach. Some authors would regard this as a rather restricted interpretation of the concept of technological regime, but I will show that such a restricted regime concept has strong explanatory power to understand the development process of Dutch irrigation. I would even like to claim that my restricted concept has more explanatory power than a broader conceptualization, as restriction allows pointing out key elements of the regime and explaining preferences and actions of the main actors involved much better.

Structuration

The extremely simplified description of regime development given above has some apparently functionalistic connotations: rules on one level shape rules on lower levels. Such a description obviously will not do at all for a better understanding of technological regimes. Functionalism is the last thing I want to defend; humans, not abstract forces, created the irrigation works and knowledge in the Netherlands East-Indies. I am much more interested in conceptualizing technological traditions in the way Giddens discusses the concept of structure¹⁷.

'Structure' refers to 'structural property', or more exactly, to 'structuring property', structuring properties providing the 'binding' of time and space in social systems. [...] [t]hese properties can be understood as rules and resources, recursively implicated in the reproduction of social systems.'¹⁸

Structures do not exist; they manifest themselves through the constituting moments of social systems. This

'[...] implies recognising the existence of: (a) knowledge – as memory traces – of 'how things are to be done' (said, written), on the part of social actors; (b) social practices organised through the recursive mobilisation of that knowledge; (c) capabilities that the production of those practices presupposes.'¹⁹

Regime development is a social activity; in social interaction human actors construct technological regimes as they construct society.

'Human social activities, like some self-reproducing items in nature, are recursive. That is to say, they are not brought into being by social actors but continually recreated by them via the very means whereby they express themselves as actors. In and through their activities agents reproduce the conditions that make these activities possible.'²⁰

Generally, in daily practice we reproduce existing, historically grown sets of rules by applying and changing them. To know a rule is to implicitly know what one is supposed

to do in particular situations and rules are widely used and sanctioned. Although they show a tendency to be stable, rules are not static²¹. Rules do not develop by themselves, nor are they followed simply because they are there. Actors, real people, make and break rules. Actors will follow the relevant rules, or in my case act within the technological regime, not just unconsciously or routinely, but also because they think they have something to lose by not acting in accordance with the rules, or something to win if they do²². Human activities are recursive. Structures, regimes or rule sets, do not exist as patterns in time and space by themselves, but only become concrete through human action; society is reproduced through human action. What remains somewhat unclear from the discussion above is where the action actually is. In this book, the social construction process of the irrigation regime is located in the East Indian colony between 1830 and 1940, and after World War II in independent Indonesia and the Netherlands.

This book

Stressing continuity²³ in the social construction process of the Dutch irrigation regime does not imply that the regime developed like some external force, with a will of its own, without any possibility for actors, either engineers, farmers, civil servants or any other, to influence its course. Fierce debates took place in the colony and the Netherlands, in particular on the issue of water allocation, regulation and distribution. Different social groups disputed over policies to develop, about the rules for irrigation development. Actual outcomes of this confrontation between social groups have been influenced by changes in colonial political, economic and institutional settings. I intend to show throughout this book, that the basic guiding principles of Dutch colonial irrigation and its related design practice were set relatively early, that is before the First World War, and have not been transformed afterwards, despite continuing debates. Furthermore, I will defend the position that irrigation engineers were the dominant group to determine requirements, shape and format of colonial irrigation systems and consequently of most of the colonial irrigation regime.

In Chapter [two](#), I discuss guiding principles and promises/expectations for colonial irrigation development processes in British India, British and French Africa and the Netherlands East Indies. Irrigation development in colonies did not only have to serve the colonial powers, but also the colony itself; it would not serve mere exploitation, but also become an element of a policy of productive imperialism. I take the analysis to a more detailed level in Chapters three and four, when I discuss the process in which guiding principles, design requirements and artifacts in the Netherlands East Indies developed. The agrarian policy of the Dutch colonial powers is vital in explaining why a Netherlands East Indian approach could develop. The most important founding element in Dutch colonial irrigation, or guiding principle, was the mutual presence of food and commercial crops, respectively rice grown by peasants and sugar cane by the industry, in the same irrigated area. Consequently, the need for adjustable water control

was defined as a design requirement; to realize such control two types of artifacts were needed: management regulations and structures.

In Chapters five and six, I discuss the design of the West-Javanese Tjipoenegara irrigation system. The period in which this system was designed and built, roughly between 1920 and 1935, is a key period for two reasons: from a theoretical point of view a closer analysis of the timeframe sheds light on the question of regime construction and continuity; from design point of view this timeframe brought a series of new elements. Most design decisions appear to have been the responsibility of engineers; most of them relate to the regime categories of design requirements, tools and artifacts. An important design rule appears to be anticipation on the presence of sugar cane next to rice in the irrigated area, requiring control over flows varying in time and space in the irrigated area. Within this guiding principle, the engineers constructed their design approach.

In Chapters seven and eight I discuss irrigation planning and engineering after World War II, when Indonesia became an independent republic. The case study of the Lampung area, Southern Sumatra, shows that irrigation activities in Indonesia were influenced by design rules developed by Dutch engineers in colonial times, even when representatives of other irrigation regimes were involved. Although Dutch irrigation engineers started working in other regions, irrigation education at Delft Polytechnic did not reflect such interest for a long time. Delft irrigation education remained based on the colonial technological regime up to the 1980s. In the conclusions, I will distinguish between two phases in the development process of the Netherlands East Indian irrigation regime. Between 1870 and 1910 the guiding principles, promises/expectations and the majority of the design requirements took shape. The focus in this phase was on developing prescriptions for irrigation design. The phase between 1910 and 1940 was an elaboration phase, in which tools and artifacts to translate general rules into infrastructure were defined. Focus was on perfecting tools and artifacts applied in irrigation design.

2 A juggling act

Exploring colonial irrigation development

Irrigation was an important field for most major European colonial powers. Irrigation systems were, and are for that matter, constructed to achieve certain goals; irrigation was the material translation of colonial agrarian principles. Irrigation was perceived as a very good instrument to assure both economic development and food production; many colonial irrigation efforts were aimed at combining profitable cash crops with food production. For the two most important colonial irrigation projects in Africa, at least in terms of command area, the British Gezira Scheme in Sudan and the French Office du Niger Scheme in Mali, the potential to grow cotton for the European market was an important stimulus to start the systems, but the ability to grow food crops (grains) was also considered. Whatever crop selected, economic development should not only serve the colonial powers, but also the colony itself; it should not only be mere exploitation, but also become an element of a policy of productive imperialism.

In this chapter, we take a colonial irrigation tour from British India to the Netherlands East Indies to end with British and French irrigation activities in Africa, including Egypt, the British Sudan (1880–1950), the French Sudan (1830–1960) and French Northern Africa (1830–1965). For many colonial powers, British India set the standard for a successful colony. One could fill many libraries with documents produced on efforts and results of India, and irrigation is not neglected in these documents. British policies and projects to develop irrigation were driven by two issues, which continuously had to be balanced¹: (1) irrigation could be an immensely profitable undertaking creating wealth, prosperity, productivity and political-economic stability; and (2) it was a precarious undertaking that required continuous fine-tuning of technical and managerial issues in order to create and maintain conditions for such profitability. I will show that these two issues were also important in other colonial areas. The answers colonial powers defined, however, differed per colony. As a result, guiding principles and promises/expectations differed between India, the Indies, the Sudan, the Niger Delta and Northern Africa.

British India

British canal-building activity in India started in 1817 and concentrated largely on the plains to the north of Delhi and the deltaic regions of Madras, South India.² Annexing

the Punjab in 1849 meant that the British gained control over the Indo-Gangetic plain. They lost little time in starting the construction of several canal systems. There were several reasons; improvement of the revenue-producing capacity of the lands they annexed was one, another was fear of famine. However, a most important objective was to provide employment for Sikh Army veterans, from the army disbanded in 1849.³ A focus on easy returns reinforced the already existing focus in canal irrigation development on the alluvial plains of the North and the deltas of the South.⁴ In these areas system construction was relatively cheap. However, some of the most drought and famine prone areas were located in interior areas of India, particularly in the Deccan region, where many rivers were not perennial or had very low base flows. Irrigation systems in this region were more expensive to build and therefore less remunerative. Some of the most drought and famine prone areas were not provided with irrigation facilities.⁵

The new irrigation efforts took place in a relative knowledge-vacuum.

‘The builders of canals needed [...] to devise economical ways of tapping the great rivers, with their tendency to wander and their variable flow over the year, and to convey that supply to and along the watersheds of the tract via a network of canals and distributaries, taking care to avoid interruption to the complex and often subtle drainage lines. They had also to avoid the danger of damage to the works posed by the boulders carried by the flow of the rivers emerging from the hills, the serious scouring effect of water travelling at excess velocity in unlined alluvial soil channels, and the problem of the channels filling with silt where the flow speed was inadequate to keep the material suspended in the water.’⁶

Most of these problems were new and could not easily be tackled with existing experience on (smaller) irrigation works in Europe. In terms of irrigation systems and water management, the early British systems

‘were no more than sophisticated man-made river diversions, rather than controlled water distribution systems [...]’⁷

Command areas were large, with canals up to several hundreds of kilometers; control structures were lacking and available management capacity was low. British attention focused on constructing the main canal system, and water users had to construct the canals to bring water to the fields. In most cases, the connection between the main and field systems

‘consisted of nothing more than a simple open-cut, there was virtually no control on water being taken by each farmer or village channel.’⁸

Notwithstanding the difficulties the uncontrolled systems posed to the design engineers, from a policy perspective it was much more important whether land could be irrigated than how it was irrigated. A major governmental interest to develop

irrigation was the possibility to increase land revenues from irrigable areas. Land taxes were based on the possibility to irrigate the land, not on production increases resulting from irrigation. The British provided Indian agriculture with water, but what India did with it was India's own case, as long as it paid revenues. Such approach fits with the policy of indirect rule in India. The British tried to preserve the existing social structure as much as possible, using existing institutions and only replacing the top layers with British servants.⁹

The British focus on revenues through taxation of land posed a dilemma:

'[...] how to derive as much revenue as possible, without causing pauperisation, famine and/or revolt?' ¹⁰

The British choice for indirect rule, leaning on local, traditional rules and rights potentially could contradict another aim of the colonial authorities. The British, as most colonial powers, stressed their role as modernizer of the colony, in order to promote and impose a

"fair and equitable" political-economic system' ¹¹

Developing irrigation was a key element in modernization, especially as the results of the first irrigation projects were highly satisfying: they prevented famines and gave handsome returns even in rainy years.¹² In summary, the objectives, or guiding principles of the British colonial involvement in irrigation were already developing in these early decades of irrigation efforts¹³:

1. To increase the collection of land revenue
2. To provide a means of famine protection
3. To maintain political and social stability

British colonial irrigation design

One of the first British colonial irrigation systems was the Ganges Canal, opened in 1854, constructed as a response to a severe famine in 1837-38¹⁴. Construction of the canal started in 1843 and the canal became fully operational in 1857. The Ganges Canal is associated with engineer Cautley¹⁵, who referred to the northern plains of India as

'[...] designed by nature as a great field of artificial irrigation' ¹⁶

The way Cautley became involved in irrigation appears to be typical for British irrigation involvement in the early decades of the 19th century. Cautley's education was minimal; he had received one year's training as an artillery cadet before being sent to India in 1819.¹⁷ During a three-year home leave in Britain, he studied the Caledonian Canal, built from 1803 to 1822. On his way back to India in 1848, he stopped off in

Italy and Egypt, to study what was considered the most advanced irrigation then to be found.¹⁸ At that time, little was known about flowing water in large earthen channels. One of Cautley's major problems was to calculate the correct slope of the Ganges Canal, to avoid both scouring and silting. Using the formulas devised by two French hydraulic engineers, Dubuat and Prouy, and experiences from the Doab and Delhi Canals, he designed an incline of 24 centimeters per kilometer in order to obtain a water velocity of 1.08 to 1.23 meters per second.¹⁹ After the inauguration of the Ganges Canal, a serious defect became apparent: the water flowed too fast.²⁰ The main errors were corrected during the late 1860s. The remodeling consisted of adding protective works to the fourteen masonry falls and raising the crests to reduce the slope of the canal.²¹

After the Mutiny (1857-58), the Crown took over the rule of India from the East India Company. As a result, a change in modernization policy occurred, with technology, especially irrigation and railways becoming the main tool of modernization.²² Between 1858 and 1866, the government experimented with irrigation development through private irrigation companies, because the cost of irrigation construction, in terms of initial capital outlay, was beyond governmental means at that time. In 1866 the government decided that canal irrigation should again be a state activity.²³ State control implied also a reformulation of goals to be achieved by irrigation. From approximately 1860 onwards, irrigation schemes would fulfill many goals, including famine protection, revenue stability, the settling of unruly tribes, expansion of cultivation, extended cultivation of cash crops, enhanced taxable capacity, improved cultivation practices, and political stability.²⁴ In short, irrigation was an important instrument for almost all fields of governmental policy.

Not surprisingly, the Canal and Drainage Act of 1873 extended the responsibilities of the Irrigation Authorities, strengthening its control over the canal network, outlets (thus tertiary command areas) and rotation schedules.²⁵ However,

[...] the fundamental duality in colonial policy was reproduced in irrigation policy: increase revenues and promote cash cropping, and simultaneously maintain stability and ensure continuation of British rule, threatened by famines and social unrest.' ²⁶

Discussions were stimulated by a concern over financial returns on irrigation.²⁷ The major administrative problem of irrigation remained its financing. Projects were expensive, took decades to be completed and required long-term financing.²⁸ Perhaps the government should diminish its public works program. As the railway lobby was particularly powerful, irrigation financing was cut back sharply in 1875, while expenditure on railways rose.²⁹

Productive and protective irrigation

In 1879, a Parliamentary Select Committee, the Indian Famine Commission was established to examine how loan capital raised in London for Indian irrigation works might be safeguarded.³⁰ In financial terms, the early irrigation schemes mainly aimed at maximum returns on minimum investments, which was generally very remunerative. These irrigation systems were called 'productive' systems. Extending the goals of irrigation by the state made less financially remunerative systems an option, so-called 'protective' works.³¹

'This change in policy was formalised after the report of the Indian Famine Commission 1878-80, which drew attention to the indirect returns related to irrigation in terms of protection against famine. [...] In protective schemes irrigation water was supposed to be supplementary, enough to save the traditional food crop during a drought. Protective works were not required to pay back interest on capital expenditure, but were primarily aimed at famine protection.'³²

The Committee had to examine the history of famines as well and to assess the value of famine relief and protection measures.³³ In its report, the Committee concluded that irrigation actually yielded a small profit. Financing the construction of irrigation schemes with loans could be continued³⁴, but new schemes had to pass the productivity test of 1879, which had been designed by the Committee. The test distinguished between protective and productive schemes.

'A profitability criterion expressed as the percentage return over total capital outlay was fixed (varying over years) which was the cut-off point for approving new projects. Projects with direct financial returns lower than that percentage were rejected. Schemes approved were called 'productive irrigation' schemes. The Famine Commission recommended to construct schemes with lower returns as well, with the aim to prevent famines and thus depress famine relief costs.'³⁵

An area was considered protected when 42.5 percent of it could be supplied with water; either from wells or canals.³⁶ A designation as productive work did not mean that the scheme would not have a role in combating famine.³⁷ Adding a category of protective schemes, however, broadened options, as it enabled the government to continue with irrigation schemes, which were not remunerative. To finance the schemes, the Famine Fund was created.³⁸

Although protective works had been made possible, the investment criterion from the productivity test actually preserved the focus on the North(west) and the deltas of the South, as irrigation development in these areas was cheaper and thus more remunerative.³⁹ The area irrigated by productive works increased from 1.9 million ha in 1878 to 4.4 million ha in 1900.⁴⁰ The area covered by protective irrigation covered 0.14 million hectare by 1900⁴¹; in 1902-03 a total of 0.37 million acres was counted⁴². Some

new famines increased the popularity of protective irrigation. The Indian Irrigation Commission (1901-1903) reported how irrigation could be used as a protection against famine.⁴³ The Commission report gave a stimulus for increasing protective irrigation areas, although the gradual exhaustion of suitable sites for productive schemes may have helped too... The Commission suggested that investments of up to three times the projected savings in famine relief costs might be considered, thus extending the scope of protectivity.⁴⁴

Over time, protective irrigation received three different meanings, although overlapping, in chronological order. The term was used to indicate the protection against famine by irrigation (before the Famine Commission), as a financial-administrative class of works in colonial irrigation policy (based on the productivity test of the Famine Commission), and as a specific type of irrigation (during the 20th century, especially after the first decades).⁴⁵ Generally speaking, protective irrigation systems were designed and operated on the principle that the available water in rivers or reservoirs has to be spread thinly over a large area, in an equitable manner.⁴⁶

By 1921, 57 million pounds had been spent on productive works for 17.3 million acres and 12 million pounds on protective works for $\frac{3}{4}$ million acres in India; the net revenue was about 9% and 1% respectively, with a combined net annual profit of 3.1 million pounds.⁴⁷ Even with increased attention, in 1947 just 16% of the total area of colonial canal irrigation accounted for protective systems. Most protective schemes constructed after 1900 were located in the Bombay and Madras regions.⁴⁸ These protective schemes had serious competition from colonial irrigation development in the Indus-basin,

‘where huge tracks of crown-waste land could be converted into the granaries of the Raj, by means of the so-called ‘colony irrigation systems’, that yielded impressive levels of remuneration of up to 45 percent.’⁴⁹

Modern India has about 12 million hectares of protective irrigation, about 40% of total canal irrigation; modern Pakistan has about 12.5 million hectares of protective irrigation schemes, roughly 85% of large scale canal irrigation in that country.⁵⁰ The rationing of water in Northwest India and Pakistan is controlled under the so-called ‘warabandi’ system of water distribution, in which water is allocated to landowners or plots for a fixed time period proportional to the size of the landholding.⁵¹ The rationing of scarce water in the Southern systems is controlled by ‘localization’, prescribing which crops are to be grown on what plot in which season.⁵² In Maharashtra and Gujarat farmers request water before the season to the Irrigation Department. These demands are sanctioned by the Department and distributing of water is rotational.⁵³

British-Indian irrigation will return in Chapter four, when the relation between water management goals and irrigation infrastructure is discussed further. For this moment,

the main message is that irrigation systems in British India were aimed at maximizing economic profit through an increased land tax from irrigated land in contrast to dry land. In addition, after 1860 and in response to severe famines, the British introduced the concept of protective irrigation: schemes were designed to provide small amounts of water to large numbers of acres; these small amounts should be enough to save food crops during drought. Productive or protective, British irrigation approaches employed the principle that ‘water follows irrigated surface’. This coincided with the British indirect colonial rule, which depended on land exploitation through a land revenue system; land that could be irrigated was taxed higher than un-irrigated land; actual harvests were not taken into account.

Dutch colonial irrigation on Java

When the Dutch arrived on Java they found people who were making a living from farming, either rain fed or irrigated. Irrigation technology has been an important factor in the expansion of wet rice farming in the Indonesian archipelago from early times.⁵⁴ In the beginning the Dutch were impressed with Indonesian irrigation technologies and results, but this soon changed. Especially the engineers stressed that indigenous irrigation structures were unsatisfactory. Of course, it was in their interest to do so too, given their relatively weak position within the early colonial state; developing engineering irrigation was important to strengthen the position of engineers within the colonial bureaucracy. Early colonial engineers were raised in the Dutch water tradition; they were experienced in the struggle against water. Next to confronting the engineers with severe drainage and flooding problems, however, Java demanded a struggle for water quite different from the mother country; in this respect the engineers had to start pretty much from scratch. Until about 1885 the Dutch usually designed the main structures, like weirs in rivers and feeder canals, and connected them to existing Javanese irrigation systems. Afterwards, the approach focused on comprehensive irrigation schemes, based upon the experiences of the earlier period.

Dutch colonial irrigation activities started on behalf of the European sugar cane cultivators in the 19th century, but later efforts were also directed at supporting and improving the rice-cultivation methods of the indigenous population. An early issue was irrigation revenue. Within the so-called Cultivation System (‘Cultuurstelsel’), introduced by Governor General Van den Bosch in an attempt to make a profit from the colony after the Java war (1825–1830), Javanese farmers had to cultivate certain cash crops. When in the second half of the 19th century the Cultivation System was gradually replaced by a policy of free trade and production, the colony still had to deliver a profit for the mother country. Irrigation development was seen as one of the areas for the colonial government to endorse profitable economic production as well as food security. The commercial crops were grown in the same areas and fields as used for rice; the commercial agricultural enterprises did not own land as they would have done in a plantation system, but rented land from the Javanese farmers. From the first

colonial irrigation efforts onwards the irrigation systems in the East Indies irrigated both sugar cane and peasant crops, rice in the wet West Monsoon between October and March/April and dry crops ('polowidjo') in the dry East Monsoon. Water had to be distributed to all these crops through the same canal system. Therefore, water distribution methods were designed to divide, distribute and measure the water between commercial and food crops in a just way. After discussions at the end of the 19th century on what 'just' actually meant and how it could be achieved, a centralized water management system developed, with engineers in charge⁵⁵. The simultaneous presence of commercial and food crops within the same irrigation system shaped both colonial Dutch irrigation infrastructure and management.

Admiring the pioneers

In the beginning of the 20th century, when colonial irrigation engineers had established the foundations of a more systematic approach to irrigation design, many engineers admired their pioneering colleagues.

'Precipitate working, without preceding study of water levels and discharges, let alone of other hydrographically important circumstances, virtually became the rule. Therefore, works [...], designed with gross underestimation of flash flooding capabilities of the rivers, often flushed away. Others, constructed without knowledge of lower discharges, disappointed in their water delivery' ⁵⁶

Especially in the first half of the 19th century the 'permanent' engineering structures were destroyed or seriously damaged by 'bandjirs' (flash floods) as quickly as the indigenous 'temporal' structures. One of these early structures constructed by Dutch engineers was a weir in the Sampean River, on the eastern outskirts of Java, in 1832. This dam was replaced several times by others, which suffered heavily from flash floods too. In 1887 a more satisfactory solution was established, with a combination of weirs, sluices, river improvements and bypasses. Even then, the rapid floods of the Sampean river could damage the structures considerably, as in 1916.⁵⁷ The Dutch colonial engineers struggled with the hydrology of Java. Nearly all Javanese rivers show a flow pattern with large fluctuations within and over days and seasons. Knowledge of the behavior of Dutch rivers was not applicable on Java. Irregular abundant rainfall and very steep slopes in the Javanese catchments resulted in large flash floods. Discharge measurements were not available and required too much time anyway; the Dutch engineers needed a method to calculate the expected peak flood discharge. Extensive visits to other irrigation regions, including British India, Spain, Italy, and France, and mountainous areas like Austria, Germany, and Switzerland were made; documents from these countries were studied. Between 1890 and 1940, Dutch engineers studied the matter; in 1895 engineer Melchior proposed a methodology that was used throughout the colonial period, despite occasionally severe criticisms on its appropriateness⁵⁸.

The Bureau of Public Works

The establishment of the Bureau of Public Works in 1854 was a political recognition of the potential role of engineers and technical support in colonial irrigation development; a main task of the Bureau was constructing irrigation works on Java. The engineers remained subordinate to the Civil Service, however; the 'Resident' (administrative representative of the Civil Service on regional level) usually took the initiative for irrigation development. Civil servants did not always call for the help of engineers though. Furthermore, the Bureau had to cope with lack of financial means and personnel; even in cases civil servants required support the Bureau could not always provide it. An engineer who devoted his career to improve the position of the irrigation engineers within the colonial state was H. de Bruyn, director of the Bureau between 1861 – 1868 and 1874 – 1877. Although he certainly did manage to increase attention for irrigation expressed in the growing number of preparatory studies, the actual number of projects realized was low before the last decennium of the 19th century. The quality of the works realized did improve, however, which strengthened the position of engineers.

In 1885, the Bureau of Public Works became independent from the general Civil Service. The new Department of Public Works became the centre of irrigation activities. A so-called Irrigation Brigade had to study possibilities to provide all governmental lands with modern irrigation facilities. In 1890 the General Irrigation Plan for Java defined 19 irrigation projects to be developed; some other projects were included in 1907. Most of these projects were located in East or Central Java. The importance of preparatory research increased, and the new approach of the engineers reflected the idea that irrigation systems needed to be considered as a 'coherent organism'⁵⁹. Research on rainfall, river flows, soils etcetera was to be used for the design of irrigation systems with both head works and a network of canals and drains. Just two years before the General Plan, the first Irrigation Divisions ('Irrigatie-afdelingen') had been established. These management units on the level of river basins were responsible for design, construction, exploitation and maintenance of irrigation. Daily management within irrigation systems was arranged through regulations defining procedures for the allocation and distribution of irrigation water to different crops and use(r)s. Generally speaking, water distribution to sugar cane was separated from distribution to rice.

The economic aspect of irrigation works, although considered important before, was emphasized in 1897 with the establishment of the Rentability Commission. This Commission had to study the costs and benefits of irrigation projects; the economic effects of irrigation development had to be quantified. The cost-benefit criterion increased in importance in the context of the Ethical Policy introduced in 1901⁶⁰. New welfare measures had to improve the position of the Javanese, but although the focus on profit from the colony was softened somewhat, measures on the terrains of

irrigation, emigration and education were to be checked from an economic point of view. Another influence of the welfare policies was a growing attention for Javanese agriculture. As a result, agricultural experts from the Department of Agriculture, which was established in 1905, entered the irrigation scene, amongst others through a representative in the Rentability Commission.

It is not all gold that shines ...

Irrigation was important in the welfare approach. Not everything the irrigation engineers did, however, was successful. The plans in the Solo Valley proved to be a case in point. At the end of the 19th century some 720,000 people lived in this area, basically the lower Solo basin, on a surface of half of the Netherlands. The first irrigation plans for the Solo Valley dated from 1852, but things speeded up in the 1870s. Irrigation plans were developed in connection with plans to divert the river outflow away from the Surabaya area to prevent sedimentation. The plans included a canal to Surabaya for transportation and drinking water purposes. This canal could also bring irrigation to more than 200,000 bouw (one bouw equals 0.7 hectare). The entire system would consist of a main canal of 165 kilometers and 900 kilometers of smaller canals. At the end of the 19th century it became clear that the project costs were much higher than anticipated and the project was suspended in 1898. The Minister for Colonial Affairs appointed a committee to study the Solo plans. The committee advised continuing the irrigation part of the plan.⁶¹ On the technical feasibility the members of the Commission agreed unanimously; concerning the social-economic benefits of the Solo project, however, one of the members had strong doubts. In 1903, Minister for Colonial Affairs Idenburg decided to follow the minority advise to cancel the project altogether.

The abandonment of the Solo project caused much consternation among the Dutch engineers. It was perceived as a lack of confidence in engineering and seemed to set a temporary halt to larger-scale irrigation development. The General Irrigation Plan, however, was continued as planned. The irrigation engineers had successes to show too, with as main example of a successful irrigation system the Pemali system, with an irrigated area of about 45,000 bouw. As will become clear in this book, both the Pemali design process and water management regulation became the standard for irrigation in the East Indies. Developing water infrastructure was too important for colonial policies not to involve specialists who had proven their capabilities. In the early 1920s, when the first General Irrigation Plan was completed and colonial policies returned to normal after the First World War, a new set of irrigation projects was defined. The budget for irrigation reached its peak in this period with around ten million guilders per year. The number of engineers employed by the Department of Public Works passed 200 in the early 1920s and reached its maximum of 263 in 1930. Among these engineers, from whom the majority had graduated from Delft Polytechnic, were several who graduated from the new Polytechnic in Bandoeng.

Irrigation design procedures in the 1920s did not differ much from those applied in the 1890s, although formulas and artifacts had changed. Hydraulic laboratories in which designs could be tested brought a new dimension to design, although irrigation practice remained a determining factor within the engineering community. Both the economic recession of the late 1920s and the growing nationalistic sentiments on Java reinforced governmental attention for irrigation development, as it served food security and thus social stability. The political context changed somewhat, as irrigation works became the responsibility of the Provincial Public Works Departments. These provincial departments were the result of colonial decentralization policies; three provinces were established on Java, each with its own Public Works Department. In 1936 a General Water Regulation for Java was established; it was the first general water regulation in the colony, and the last ... As a result of colonial irrigation policies, independent Indonesia counted 1.3 million hectares of land irrigated by engineering systems on Java in 1950; although considerable enough, this amount was less than half of the 3.3 million hectares of land in use for irrigated rice farming all together on Java in the same year.

British colonial irrigation in Africa

At the time that British and Dutch engineers were already at full speed in developing irrigation in Asia, colonial Africa was still relatively untouched by irrigation engineers. In November 1884, colonial powers like France, Great Britain and Germany settled their disputes over Africa territory at the Berlin conference in Germany. Egypt was an important subject on the agenda. The British occupation of Egypt in 1882 was not recognized by other European powers; nor was it in Berlin. Egypt remained, at least from legal point of view, part of the Turkish Empire. In March 1899, France finally had to give in after the Fashoda affair. In return, Britain recognized France's hegemony over the French Sudan. Through these political developments, the British assured that the cotton farms of Egypt, important for the British textile industry, were relatively certain that their water supply from the Nile would not be interfered with by other colonial powers. Within Britain's policy, controlling the water sources of the Nile and the territories the river passed through was highly important⁶². Thus, the Sudan, south of Egypt, became a subject of the strategy of the British Empire. Furthermore, Sudan formed an important link from the Cape to Cairo; it was essential in safeguarding the Suez Canal and the route to India. The Sudan had to be controlled by Britain and was conquered in 1898.⁶³

The Gezira Irrigation System, British Sudan, 1900 – 1949

Shortly after the turn of the 20th century, in 1904 Sir William Garstin published a plan involving the entire Nile Basin – the first overall plan for the control of the waters of the Nile. Garstin's plan was the first to look beyond the needs of Egypt alone, but still directed the largest part of the waters of the Nile to Egypt. The position of Egypt remained one of the crucial issues to be negotiated, but the Sudanese British colonial power gradually succeeded in developing large-scale irrigation in their own territory.

Garstin had entered the Indian Public Works Department in 1872, and had been sent to Egypt in 1885. He suggested, among other things, increasing the storage capacity of the Aswan Dam, the first stage of which had barely been finished. Garstin proposed to use the Gezira plains as a wheat-producing area for the nearby Arabian market, with only a small emphasis on cotton; wheat would not need water in the scarce months. He proposed the building of a dam or barrage at Sennar on the Blue Nile to provide irrigation for part of the Gezira. With Garstin's report, despite its favoring cereal production, the cotton cultivation lobby was stimulated.

As mineral wealth appeared to be absent, the potential regional capital of the Sudan was to be found in the land with its crop production; the most certain way of increasing yields was by irrigation. In 1900, Governor-General Wingate had introduced the idea of irrigated cotton production in the Gezira creating irrigation revenues as a source of profit.⁶⁴ Gezira is an Arabic word, meaning 'island' or 'peninsula'. The word is not restricted to the Sudan, but in (modern) irrigation circles worldwide Gezira refers to just one thing: the vast triangle of irrigated land south of Khartoum between the Blue and White Niles. The Gezira Irrigation Scheme has become a kind of legend. Following his visit to the Gezira in 1946, Sayed Mohammed Afzal, Director of Research, Pakistan Central Committee, remarked:

'The Gezira Scheme is one of those outstanding experiments on socio-economic problems of the current century and its success is so great that it deserves to go down in history as a great romance of creative achievement . . . The rich fields and the smiling faces of the workers on the land, who were till recently nomads of the deserts, going back and forth eking out a miserable existence from an inhospitable country, are a running commentary on the success of this great experiment, and anybody who visits the Scheme cannot but be strongly impressed with the success of the experiment.'⁶⁵

This 'experiment' is located in one of the flattest areas to be found.

'It would be difficult to imagine anything flatter than the great Gezira plain, two hundred miles long and eighty miles across'⁶⁶

Covering an area of some 5 million feddan (one feddan equals about 0.4 hectare) sloping gradually from south to north, its most outstanding feature is

'its crushing monotony'⁶⁷

The erratic rainfall could not ensure a crop year after year. Nevertheless, in years with good rainfall, cereal crops in the plain provided a good harvest. In years with little rainfall, waterwheels in the river watered narrow strips on the banks. This land was relatively cheap to irrigate.⁶⁸ Given the political circumstances and a lack of capital in the early 20th century, the Sudanese Government first focused on a number of smaller-scale flood irrigation projects not needing Nile water, such as those of the Gash and

Tokar deltas. Tokar proved to be the birthplace for one important feature of the future Gezira scheme: the delta was declared government land and each year allotments were made by the government to those who wished to cultivate.

‘Tokar thus gave the Government its first experience of the immense advantage, to the budget and to the individual peasants, of an agricultural policy which both controlled and helped them.’⁶⁹

Tenancy was the model to choose, enabling stronger control over farmers. Other test areas for the Gezira Scheme were the small-scale pump irrigation systems along the banks of the Nile in which the Sudanese Government and commercial growers laid the foundations of their future co-operation in the Gezira. In 1904, Leigh Hunt, an American, founded the Sudan Experimental Plantations Syndicate (SEPS), which was granted a cotton concession for 10,000 feddan at Zeidab, 180 miles north of Khartoum along the Nile.⁷⁰ In 1910, the Department of Agriculture proposed testing whether high-grade cotton could be produced in the area. As a result, in 1911 the Tayiba pump-irrigation project was established in order to grow long staple cotton and dura (sorghum vulgare). The Department did not have the personnel to manage the scheme, however, and the SEPS was asked to assume responsibility for managing the project. It accepted the offer and extended its operation to Tayiba.

Even with these favorable developments in Tokar and Zeidab, a powerful lobby of commercial cotton companies was needed to get the Gezira Scheme really underway. The reason for increasing interest in the Sudan was the situation in Egypt, where cotton production had been static for the ten years since 1900. The experiences at Tokar, but especially at Zeidab, showed that quality cotton production was possible in the Sudan. The influential Lord Kitchener of Khartoum

‘displayed great personal interest in the Gezira and subsequently visited the plantations there on several occasions.’⁷¹

The British Cotton Growing Association (BCGA), founded in 1902 to promote growth of cotton in the British Empire, played a part in interesting the British Government and the Lancashire Cotton Industry in the development of the Scheme. The SEPS and the BCGA joined forces; in 1911 the BCGA took up 5000 new one pound shares in the SEPS and their chairman joined the board. The vast Gezira irrigation project became a concern of the British government when, after a powerful lobby of the British cotton industry, the government guaranteed a loan of three million pounds in 1913. World War I interrupted the plans, but in 1919 the area to be irrigated was set at 300,000 feddan. A delegation from the BCGA visited Gezira in 1919 to stimulate the construction of Sennar Dam and the irrigation system. A total of 13 million pounds was finally reserved for the project: £11.5 million for Sennar Dam and 300,000 feddan, £700,000 for railways and £400,000 for cotton ginneries.⁷² In 1922, the contracts for dam and canal construction were given out and the work started. Confronted with huge

cost overruns, but fearing the political and economic effects of abandoning the project, the British government guaranteed loans totaling almost 15 million pounds in 1924.⁷³ In 1925, the High Commissioner for Egypt and the Sudan, Lord Lloyd, officially opened the dam.

Sennar Dam, on the Blue Nile 260 kilometers south-west of Khartoum, supplies the canals on the left bank by gravity. Main canals are designed as regime conveyance channels, with water flowing continuously day and night. In the original design for the minor canals, practice from India and Egypt had been followed to maintain stability of discharge in the canal system by keeping the water flowing day and night. Farmers were expected to handle their ration efficiently whenever it came, even at night. The Gezira tenants, however, who

‘had already accepted immense changes in daylight farming’⁷⁴

were in the end not expected to be able and/or willing to irrigate during the night. Cutting off the water during the night, however, was not an option in a system the size of the Gezira; filling times would be indefinite. Uncontrolled water flows at night were not desirable either. Therefore minor canals were constructed as night storage canals. Cotton was the main crop in the Gezira, but other crops were also cultivated. Dura was the staple food crop; lubia (*dolichos lablab*) was grown as animal fodder. Agriculture in the system began with a three-step rotation: cotton, followed in the next season by dura and lubia each taking half of the field, followed in the third season by fallow. The dura and the lubia exchanged sides at regular intervals in order to maintain fertility. Grain and fodder were, like cotton, irrigated free of charge, and designated for the use of the tenant; marketing of the cotton crop was the responsibility of the Syndicate. Balancing one field outlet against another was essential to maintain stable discharges into the canal system. Without a strict timetable, the immense volume of water discharged into the main canal could not be evenly distributed over the network of canals; therefore a strict rotational schedule was designed and maintained. The irrigated area was divided into blocks, varying in size with boundaries reflecting the canal system. An average block amounted to 15,000 feddan; each had a block inspector and two junior field officers, who already had experience from the pilot stations. A group inspector supervised six to ten blocks. The field personnel responsible for the project was

‘superimposed like the canal system itself on the life of the Gezira.’⁷⁵

Such a structure, linking British inspectors directly to the farmers, was unusual for British colonial rule, usually referred to as ‘indirect rule’.

A tripartite partnership with two main partners

In the meantime, the Government and the Syndicate had defined arrangements under which the Gezira Scheme would function. In 1919, a ‘tripartite partnership’ was

formulated, stating the different responsibilities and gains of the three partners, with the 'tenants' as third party.

The Sudan Government was responsible for Sennar Dam and received 40% of the total net profit from cotton production. The government rented the land from its official owners in order to let the land annually to tenants.

These tenants, organized in farming units of 30 feddan, received 40% of the net profit but had to provide the production costs until cotton was delivered.

The concession holder, the Syndicate, was responsible for scheme management and for providing field and accountancy staff, buildings, loans to farmers, and transport of the cotton; it received 20% of the net profit.

In 1921, the partnership was effectuated with the Gezira Land Ordinance.⁷⁶ In 1925, the Gezira cotton acreage consisted of 80,000 feddan; in 1926 this was 100,000 feddan. Because of the increase in costs, however, the Gezira Scheme became once again a point of discussion. The original 300,000 feddan already challenged Egypt's level of acceptance, but would still result in a recurrent loss. A larger acreage was needed. To cut a long story very short, political negotiations culminated in the Nile Waters Agreement of 1929. The Gezira would not draw more than 126 m³/s before 1936. The Sudan and Egypt agreed in 1936 that the Gezira could receive 168 m³/s in 1940; the final widening of the main canal to take this discharge was completed in 1956. Subsequent extensions steadily increased the command area to around one million feddan by the early 1950s. In 1944 it became clear that the Sudanese Plantations Syndicate's concession to operate the Gezira Scheme would not be renewed in 1950. In July 1949, a governmental Gezira Board took over the management. The Syndicate's 20% share of profits was to be used for research, social development and management costs.⁷⁷

The Office du Niger, French Sudan, 1920 – 1964

The British may have been actively involved in colonial irrigation matters in Africa, but the French were not sitting still either. French engineers introduced one of their most challenging plans for irrigation in the inner delta of the Niger River, in modern Mali. There were actually two Niger Deltas, due to the river changing its course over time. The old delta, close to Sansanding, did not receive floodwater from the Niger. The new delta, originating at Diafarabé, was flooded annually in October up to 350 kilometers in length with a width as large as 100 kilometers, and an average surface of almost 20,000 km².⁷⁸ It was the old delta that attracted the attention of the French colonizers, because of its enormous potential for cultivable land and the presence of two old river branches, which could serve as main canals for an irrigation system. The region was an important area for the cultivation of cereals like millet and sorghum, as both crops

could adapt to poor soils, low rainfall and dry spells. Farmers practiced flood recession agriculture, timing their activities to the rise and fall of the flood and the arrival of the rains. One of the greatest hazards for the delta farmers was the floodwater rhythm: when the floods arrived too early or too late, harvests were low. The French colonialists recognized that, despite its perceived high potential, the Inner Delta posed a number of problems, such as drought, locusts, and termites. According to the French, problems also were found in the

‘prejudice and apathy of the Africans.’⁷⁹

Nevertheless, many French people envisioned European-managed plantations worked by African laborers; development of irrigation-based plantations would increase the number of consumers with an improved standard of living to purchase manufactured goods which France wished to export to its colonies. The irrigated area in the Inner Delta had to provide these potential consumers with the necessary means to buy French goods. The goal was to equip about 1 million hectares in the central delta of the Niger River in Mali with irrigation. This plan has become known as the ‘Office du Niger’, the name of the French public enterprise created in 1932 to develop irrigation and settlement in the area.

Already in 1899, Emile Zola expressed the hope that the Niger, as it conquered the invading desert and created a fertile valley, would become the Nile of the French Empire⁸⁰; the region was also seen as the

‘Mésopotamie Nigérienne.’⁸¹

Both qualifications showed high expectations. In 1919, Emile Bélime, an engineer, travelled through the Niger valley to investigate irrigation possibilities.⁸² Bélime had worked in French colonial Asia and had visited British India. In 1920 Bélime concluded that the Middle Niger area was highly suitable for irrigating cotton. He designed a plan to develop 1,850,000 hectares for pastures, legumes, rice, millet, wheat and cotton in the delta of the Niger River, as well as the vast areas to the north of it.⁸³ The program developed by Bélime served as the foundation for future projects aimed at exploiting the French Sudan.⁸⁴ The plans were included in those developed in 1920 by the Minister of Colonial Affairs, Sarraut. His central idea was ‘la mise en valeur’, or investment in public works instead of mere exploitation.⁸⁵ The plans included constructing transportation infrastructure, health programs and improvement of agriculture through irrigation.

Discussions on irrigation in the Niger delta before World War I focused on the apparent potential of the area to become as important a cotton growing area as British Egypt. Climatic conditions were perceived as favorable for cotton; an important factor would be regular water availability. With the development of British plans for Gezira, the French were even more convinced that the Office should be a centre for cotton

growth. Results from pilot irrigated cotton schemes at El-Oualadji, close to Tombouctou (1917 – 1923), apparently confirmed the high expectations.⁸⁶ Although many actors involved had great expectations for the new irrigation scheme, not everyone was convinced that the Niger delta would fulfill such promises. The proposal of Béline met with strong criticism. Béline presented the colony as a potential region of incredible wealth, and gave the impression that

‘Eldorado will be forthcoming once the irrigation systems are realized.’⁸⁷

This optimism was based on the assumption that the Niger delta was comparable with the Nile valley. It was argued, however, that Egypt, with its ancient history of irrigation, and its much denser population was not to be compared with the Niger Delta. Furthermore, the Nile carried much more water, the floods were fertilizing the soils, and the distance to Europe was considerably less than from the French Sudan. Nevertheless, French colonial attention aimed at irrigated cotton production in the Niger valley. In 1922, an experimental station for cotton production was opened in Niénébalé, 50 kilometers south of Bamako. It was not too successful, reaching about 200 hectares. In 1925, the Service Temporaire des Irrigations du Niger (STIN) was created, which took over management.⁸⁸ The STIN constructed the Sotuba barrage to irrigate about 7500 hectares: 3000 for cotton, 3000 for rice and 1500 for pasture.⁸⁹ Opened in 1929, it served a main canal of 22 kilometers, with a maximum flow of 10 m³/s. This first larger irrigation system in French West Africa was

‘le champ d’expérience’⁹⁰

for the Niger delta. The results in this area, including the colonization of more than 6000 people, were considered such a success that they opened the way for a program for the general development of the Middle Niger.

Cotton or cereals

Cotton played an important role in generating the Niger irrigation proposal, but the project included large areas for cereals, legumes and pasture for cattle too. Governor-General Carde stated in 1924 that the project’s primary purpose was producing rice to end famine in French West Africa. World War I had shown the vulnerability of France and the colonies regarding food security. Adequate agricultural production should provide the colony with its own food – not just the Niger area, but also Senegal, which was no longer producing food itself because of the spread of peanuts, a cash crop of increasing importance to the French oil-seed industry. Thus, the food to be grown in the Office was part of the grander plan for imperial autarky. The aim of such a policy was threefold: to assure French industry of a supply of raw materials; to expand the market for manufactured goods; and to guarantee buyers in the colonial areas.⁹¹ Raising the income of colonial subjects and enabling them to purchase French goods, or ‘colonisation indigène’, would generate an agricultural revolution in Africa.

The Niger valley irrigation scheme as the food source, the grain basket for French West Africa, was not inconsistent with the role this region had played before colonial occupation. Geographically and ecologically, the inland delta was well located for grain production. Rice, however, was never a major crop. The decision to include large areas in the Office for rice fits within French colonial policy favoring rice. Actions of colonial officials, such as tax collection in rice, stimulated an increased demand for the grain. As a result, both the cash crop cotton and the food crop rice were included in the Office design. Bélime and other advocates of the project planned to construct a large barrage at Markala, about 300 kilometers downstream from Bamako, diverting water to two old watercourses of the Niger through the Sahel and Macina canals. In 1929, Bélime presented an elaborate plan to the Minister of Colonial Affairs, proposing to irrigate 960,000 hectares: 510,000 for cotton and 450,000 for rice. The plan would need 300,000 settlers and would cost some 300 million francs, plus an extra 40 million for the colonization program. On March 16th 1931, the Minister of Colonial Affairs, Reynaud, gave his approval. On January 5th 1932, the organization to create and manage the irrigation system was officially established; the Office du Niger was an autonomous governmental organization. Construction of Sansanding barrage near Markala began in 1934 and was finished in 1947. The conveyance canal was designed with a maximum capacity of about 500 m³/s. The Sahel Canal was completed in 1935, the Macina Canal in 1937.⁹²

Irrigation was only possible when the annual Niger floodwaters filled the new canals. A provisional barrage was installed in 1941. One problem was that the irrigation scheme was designed using limited and sometimes incorrect technical information. The topographic surveys lacked the detail and precision necessary. An additional problem was the attraction of settlers. The Office should have drawn settlers from the French Sudan and Upper Volta. In the Sudan, however, demographic pressure was low, and in Upper Volta inhabitants generally preferred temporary migration rather than permanent settlement abroad. To reach an acceptable number of settlers, the Office used

‘a certain amount of compulsion to recruit settlers’⁹³, or, stated otherwise,

‘forcibly recruited most settlers.’⁹⁴

The French government prohibited this practice after World War II. Many settlers fled from the project. Nevertheless, in 1945 about 20,000 persons had colonized some 22,000 hectares in two regions of the central Niger Delta⁹⁵, even before completion of Sandanding. Cotton cultivation proved to be difficult, however, as rainfall was plentiful and poorly timed for long-staple cotton. The poor results were the prompt for another effort to boost the scheme’s development. The ‘Commission de Modernisation et d’Équipement des Territoires d’Outre-Mer’ proposed a 10-year plan (1947-1957) for the Office du Niger, during which 180,000 hectares should be developed: 105,000 for cotton and 75,000 for rice.⁹⁶ The execution of this plan would enlarge the existing area eightfold! In 1948 the Office resumed its development work in a new sector. Instead of

assigning the new land to farmers, which were hard to find, the Office began to farm itself. Almost 6000 hectares were developed for rice near Molodo, and the autonomous enterprise 'Centre Rizicole Mécanisé' (CRM) was responsible for farming.⁹⁷ The CRM experienced such technical and economic difficulties, however, that it was abandoned in 1961 and its land allocated to settlers.

In 1957, the irrigated area in the Office du Niger covered a little over 47,000 hectares.⁹⁸ In 1960, at Mali's independence, 54,000 hectares had been developed.⁹⁹ Even if it did not fulfill its high expectations, the Office had become an enterprise with a comprehensive jurisdiction extending to commercial as well as administrative and agricultural questions. The Office was a public works contractor, an administrative service recruiting labor, and an entrepreneur concerned with agricultural production and supervising settlers. The Office performed all these roles and duties in an enormous area. The hectares that had been developed were scattered over several hundreds of square kilometers. The principal administration headquarters were at Ségou, 40 kilometers upstream from Markala; the Kolongo sector extended almost 150 kilometers towards the east from Ségou, and the Kourouma sector more than 200 kilometers towards the north from Ségou. The irrigation canals comprising the basic irrigation network covered a length of 280 kilometers. In 1955, the administration employed almost 7000 people. In 1964 it still retained a large staff of about 4700 employees.¹⁰⁰

The irrigation factories of French Northern Africa, 1930 – 1956

Despite all the debates and developments in the Niger Delta, it was in the Northern African territory that the French colonizers developed the irrigation technique using concrete, raised canals constructed as a fixed grid erected over the area. The French colonial territories in the northern part of Africa include the present-day countries of Morocco, Algeria and Tunisia. Algeria is the oldest North African colony of France; it was already occupied in 1830. In 1881, the French invaded Tunisia, which was made a Protectorate in 1882. In 1911, thus much later, Morocco was included in the French North African colony. The area has a long history of irrigation. Technologies such as spate irrigation, oasis irrigation using water wheels, underground reservoirs and terraces were widespread. The concept of 'turns' was generally used, but written proof of water rights was non-existent and water shares were adapted each year¹⁰¹. The colonial administration could not function well in these circumstances.

In 1914 the French colonial government decreed that surface waters were public domain; in 1919 groundwater and marshlands were included. The gradual move to state control was further strengthened in 1925, when irrigation development was officially declared to be a state-led initiative, and private initiative was forbidden.¹⁰² Two issues influenced the development of irrigation in the early 20th century: (1) what was the target group for irrigation, French settlers or native settlers; and (2) what was the target

production sector for hydraulic engineering, irrigation or hydropower? In the first decades of the 20th century, French irrigation policy stimulated French settlement in new irrigation systems. If an area was suitable for irrigation, and the native population was small in number, the population would have to make room for the colonists. In areas with many natives, irrigation would not be developed. The turn came in the 1930s, due to a growing population, droughts and a more 'nationalistic' colonial government. Irrigation for native farmers became an important instrument in French colonial policy.

In the early discussions on irrigation, the French colonizers planned to produce wheat on a large scale in the North African region. The region was supposed to have been the 'Granary of Rome' or 'Eldorado'¹⁰³ during the Roman Empire, and the French liked to see themselves as the successors to this Empire. The wheat strategy was abandoned when climatic conditions appeared to be unfavorable and French wheat growers protested against the competition. The potential for cotton production in Morocco was also discussed: Indeed, the nascent 'granary of Rome' image was initially challenged by an 'Egyptian image'. Some noted that a native cotton industry formerly had flourished. One early authority claimed that wise harnessing of Morocco's rivers would convert Morocco into 'a little Egypt'; another described the Sebou Plain as a vast delta where cotton could generate untold wealth as it had in the Nile Delta.¹⁰⁴

In 1917, a mission on the possibilities of Morocco supplying France with cotton, the Cosnier report, concluded that potential harvests were too low. Instead, French cotton growers developed activities in promising colonial areas, such as the Niger Delta. Disputes over which groups and sectors should be supported by irrigation and which department, Agriculture or Public Works, should lead the irrigation program caused a delay in the actual construction of irrigation schemes. With the government decree of 1925, the development process accelerated. The basis for the 1925 decree was a growing necessity for new lands. Most readily available water and land resources were used; new lands were needed for settlers from the region itself. The governor in Morocco advocated a focus on settlement, with less emphasis on 'mise en valeur'. In 1927, a central fund for irrigation was founded with a starting loan from the central government in France.¹⁰⁵

Californication

Around 1930, 'la politique des grands barrages' was formulated. This was the first irrigation development program for Morocco and indeed North Africa.¹⁰⁶ Another crucial decision by the colonial government was to focus on developing high-value crops such as citrus, other fruits and vegetables. After Rome, Eldorado and Egypt, the rapidly developing irrigated agriculture of California, USA, served as the development model. Although the crisis in the late 1920s and early 1930s did not speed up developments, the Californian dream had taken off. In contrast with the older role

models, the California model proved to be relatively successful. Morocco was not the only country to be influenced by California. Countries as diverse as Spain, South Africa, Argentina, Russia, Canada, and other French colonies such as Tunisia and Algeria, studied California's innovative fruit industry. In Morocco, however, the aspiration to create

‘une nouvelle Californie’¹⁰⁷

was particularly strong. As one Casablanca reporter proclaimed in 1931,

‘[...] the reputation of California's wealth through irrigated agriculture is worldwide and it is so striking [...] because the majority of these crops have been developed on formerly worthless land, indeed on desert wastelands [...] Throughout the entire world the California example has attained the force of dogma, and symbolizes the modern miracle of irrigation.’¹⁰⁸

‘Their dream was to create a new California in Morocco. Struck by analogies of climate and natural conditions – as well as by the results of a dynamic irrigation policy that had succeeded in transforming a near-desert into a magnificent orchard, furnishing the entire world with choice fruits – settlers wanted to achieve the same miracle in Morocco.’¹⁰⁹

Between 1929 and 1933 at least six French missions visited California. French commercial attachés and agents in California were involved in agricultural espionage. Agricultural methods, irrigation techniques, especially buried pipe systems and selected crop varieties were brought to Morocco. In 1938, a comprehensive irrigation plan for Morocco was defined in an attempt to respond to a number of issues, such as drought, the rise of a national movement and a growing population. An irrigated area of one million hectares was foreseen; implementing the plan would take a period up until the year 2000, and a new Irrigation Office should execute the plan. Between 1939 and 1956, large parts of the many plans for new schemes were not realized. In 1956, the year in which Morocco became independent, the country counted about 36,000 hectares with modern perennial irrigation, with a potential area served by existing dams of 250,000 hectares.¹¹⁰

Materializing a vision

Having a vision is one thing; creating irrigation systems based on that vision is something else. The Beni Amir irrigation scheme was a major test area for French irrigation engineering and one of the most important colonial irrigation schemes for the native population. Kasbah Tadla Dam, with the potential to feed a system of 45,000 hectares, and the main canal were constructed in 1930. The combination of a Californian dream, a colonial policy strongly focused on planning and control and a strive for efficient new irrigation schemes resulted in a highly regular irrigation landscape, consisting of a series of long strips planted with different crops, about 80

meters wide and 1000–1500 meters in length. The strips were perpendicular to secondary canals and parallel to tertiary ones. This regulated landscape was the result of a process of ‘remembrement’, land consolidation¹¹¹. A pattern of small, dispersed holdings of irregular sizes and shapes created by population pressure and inheritance was transformed into a geometric landscape conforming to the requirements of what was defined as modern irrigation. The expropriation of existing holdings and the redistribution of them in regular rectangular parcels shaped the contours of the new canal network. This procedure had been introduced in 1935 in the Oulad Ziane experiment at Kasbah Tadla and was extended to the Beni Amir irrigation perimeter in 1937.¹¹² Consolidation was an important instrument to the French to reach their goal

‘to make an occasional farmer an ‘intensive farmer’.’¹¹³

It was a vision of a rationalized landscape composed of the lush, rearranged, privately owned parcels of peasant farmers, who would grow crops required by the state according to a rigid, predetermined production plan and adhering to strict rotation schedules. These settled people would be supervised and assisted by the government, but they would be fully charged for water to ensure the economic viability of the development scheme.¹¹⁴ Within a highly regulated irrigation landscape, water delivery to the field could not be other than regulated. The earthen canals of the 1930s did not perform according to standards, with canals being long in relation to the irrigated area and water losses considered too high. Attempts were made to modify the canal system, but the real breakthrough from an engineering point of view came after World War II. In that period of renewed modernization in Morocco, Algeria and Tunisia, the Beni Amir system covered about 18,000 hectares with canals dug out of earth.¹¹⁵

In 1947, 1600 hectares, and 2800 hectares in 1949, used the type of canal that made French irrigation engineering famous: concrete, semi-circular raised canals.¹¹⁶ The availability of pre-fabricated, reinforced concrete elements with a length of 6.80 meters and diameters of 30–185 centimeters enabled French engineers to restructure the landscape completely. The canal system became virtually independent of available slopes and landscapes, as the canal supports could be adjusted in height to arrive at the optimal slope and layout. The

‘friendly disorder of the old perimeter with its English park style’¹¹⁷

was tempting, but

‘technicians preferred the long straight lines in the style of an immense French garden.’¹¹⁸

Colonial Production Regimes

The Gezira scheme, developed with input from British engineers with working experience in India and Egypt, served as a point of reference, or competition, for

French irrigation activities in the Niger Delta. The French tried to construct their own Gezira scheme; they were not successful in the Sudan. It was in North Africa that the French engineers created their own success. With inspiration came from American ideas, the systems in North Africa were developed along similar lines as in both the French and British Sudan. The colonial African irrigation systems share many characteristics of an imposed production regime. The farming community was expected and often forced to cultivate what and how the colonial management prescribed. Not only was the farming community to act according to prescription; the landscape had to be changed into a new, modern and particularly geometric form. In the same way as they could transform the landscape, the colonial powers could also force peasants to grow certain crops, or organize the management of facilities, as they considered best. However: the degree of control exercised by the central irrigation authorities, and their manipulative powers with respect to agricultural improvement, were limited. This has to do with the larger scale of many canal schemes and the administrative framework in which they operated. Furthermore,

‘colonial rule was always a juggling act’¹¹⁹

between available labor from colonizers and colonized, available financial resources and political goals.

Accepting the general applicability of the juggling act metaphor to colonies worldwide, one can distinguish differences between colonial irrigation policies in territories with recognized histories of irrigated agriculture, recognized by the colonial powers that is, such as British India, Egypt and the Netherlands East Indies, and territories without such recognized histories, for example the French and British Sudan. Whether such differences in guiding principles are solely products of the Eurocentric framing of non-European histories remains to be studied, although there is material to support the argument that Eurocentric framing has been a determining factor. Africa was often described by Europeans as a continent without history, whereas the East has long been a source of inspiration for Europeans. In 1965, the English historian Hugh Trevor-Roper wrote that African history had nothing more to offer than

‘the unrewarding gyrations of barbarous tribes in picturesque but irrelevant quarters of the globe.’¹²⁰

Although many Europeans considered the East as below European civilization, Eastern civilizations was recognized, seen as stagnating, and their pasts were studied extensively.

‘Towards Africans the attitude was very different. For them the image of an important, old, but later stagnated civilization did not exist. On the contrary, for centuries the African was considered as backward, primitive, barbarian.’¹²¹

I will show in this book that in the Netherlands East Indies several rather strict management principles and systems were developed. Irrigation scheme management in

these Indies, however, restricted itself mostly to water management and did not attempt to manage complete production processes as in the colonial irrigation systems in Africa. East Indian farmers in general were landowners, or at least not tenants of the irrigation agency. Farmers on African schemes were tenants, not landowners. Dutch colonial settlement schemes, which mainly developed in the 1930s, were planned by a top-down perspective, which is obvious in a colonial context. Nevertheless, the future farmers were treated as future owners, different from Africa where people were treated as having no relevant history in an area likewise without relevant history. The East Indian settlements aimed to recreate the Javanese village in new areas, to recreate a better history and not to create a completely new modern reality, as was the case in Africa.

3 Impressing the Germans

Water regulations on Java

Interference with and interventions in water distribution in Javanese irrigation by the Dutch colonial government was a major activity of a growing Dutch colonial bureaucracy in the Netherlands East Indies in the 19th century. The 19th century Dutch administrators and engineers acted in the spirit of their predecessors. Already officials from the East Indian Company inspected cultivated fields on Java and issued instructions to improve production¹. Over time, the Dutch colonizers developed a thoroughly bureaucratic system. Everything had to be controlled by governmental agencies and agents. Initiatives that did not fit in governmental plans were called ‘wild’, without exception, whether it concerned education, irrigation or rice growing. Anything which could not be forbidden, but nevertheless was not considered acceptable, was labeled ‘wild’ as well². Foreign colonial experts did notice this characteristic of the Netherlands East Indies³. The remark of a French observer in the early 20th century that

‘Java est trop gouvernée’ ⁴

was affirmed by a German observation more than thirty years later:

‘On average the Dutchman is not a good organizer. He is far too individualistic, far too oriented to freedom and independence to voluntarily take upon him the necessary side-effect of every organization, subordination. In the Netherlands Indies the colonial Dutchman shows an ability to organize, which occasionally must even impress the most organization-minded German’ ⁵

In this chapter, I explore how this colonial bureaucracy, with its agrarian policies as guiding principles, developed colonial irrigation management. I will take the analysis to a more detailed level than in Chapter two; in terms of the regime-triangle, East Indian colonial agricultural policies – guiding principles – were reflected in water distribution policies – artifacts and operations. ‘Developed’ or ‘were reflected’ may suggest a linear representation of processes; I repeat that this is not the type of process description I had in mind. The guiding principles, requirements and operations are not the result of any linear logical process. The concepts being analytical categories and not real-life concepts of the period studied is one obvious reason, but even if the actors of the colonial days would have recognized the concepts I apply, they would have discussed

the meaning of the concepts as thoroughly as they did discuss irrigation. What I will analyze in this chapter is how water management in East Indian irrigation was

‘shaped and acquire[d] [its] meaning in the heterogeneity of social interactions’⁶

Several social groups interacted throughout colonial history in several arenas, including irrigation systems, governmental circles and newspapers. The meaning and interpretation these social groups attached to several irrigation options, problems and goals occasionally coincided, but could also be different. We will encounter a number of relevant social groups, including engineers, civil servants, sugar manufacturers and agricultural engineers. It will also become clear that such a profession-based interpretation of what ‘relevant’ means is quite helpful, but does not satisfactorily explain all differences in opinions between the actors within these groups. In the colonial irrigation arena, disagreement based on political views will be found within two dominant social groups, civil servants and engineers. As I will show, closure on water management policies, defined as agreement, or the disappearance of interpretative flexibility, on this issue between different social groups⁷, was reached in the late 1930’s with a central water regulation for the colony.

Irrigation policies in the Netherlands East Indies

Irrigation management on Java typically differed between the dry East Monsoon and the wet West monsoon, although the tasks to be performed were comparable. These tasks included discharge measurements in supply and drainage canals, rainfall measurements, experiments on water use, and determining water losses in canals. Regulating, operating and guarding irrigation and drainage works and canals, and occasionally management of rivers and embankments was needed too. In some areas, shipping business was looked after as well, when it affected irrigation and drainage. A last task was conducting research into works to be constructed for irrigation and drainage, both for systems of the Government and private actors. Javanese irrigation systems supplied water to a diversity of crops, but three main crops stand out.

First, sugar cane was grown on irrigated land. The cane was an important irrigated crop since the Cultivation System⁸. The sugar estates produced the sugar, but did not own the land on which the sugar cane grew; they rented the land for a period of three years from Javanese farmers⁹.

If not rented to sugar estates, the farmers grew rice on their lands in the wet West Monsoon.

In the East Monsoon, with much lower water availability from the rivers, Javanese peasants used part of their land to grow polowidjo crops, like root crops, beans and ground nuts.

This cropping pattern resulted in specific irrigation demands. Both rice and sugar cane needed quite intensive irrigation, but in a different rhythm. Rice needed irrigation water in the West Monsoon, whereas sugar cane had its highest irrigation water demand in the East Monsoon. In the wet West Monsoon, sugar cane did not require irrigation. Thus rice and sugar cane did not compete for irrigation water during their growing seasons. However, there was a potential problem with the moment that lands formerly grown with sugar cane became available again at the start of the next West Monsoon for rice. If the rice on these lands was sown too late, the crop could not take full advantage of the wet season. As sugar factories hired new land every year, each year different sawahs were planted with sugar cane, and each year new land became available again for rice.

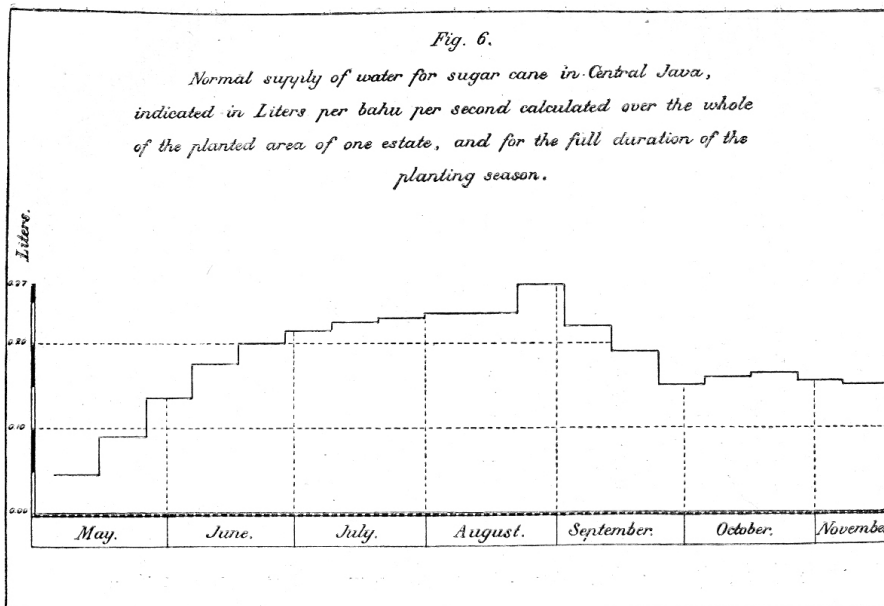


Figure 3.1
Sugar cane
irrigation needs
in the East
Monsoon¹⁰

In the dry East Monsoon, sugar cane needed irrigation (Figure 2.1), but polowidjo crops needed water too. Water was distributed to polowidjo and sugar cane separately in time, but through the same canal system. Sugar cane received water during the day, whereas polowidjo could be irrigated during the night. Apparently, this custom originated from the Cultivation System; we will discuss this day-and-night regulation in much more detail below. In my view, the co-existence of the peasant crops rice and polowidjo and the commercial crop sugar cane in the irrigated areas on Java has been a determining factor in Dutch colonial water management. In the chapters to follow, it will become clear that the presence of both crops has been fundamental to irrigation engineering, for example with regard to structures used in irrigation systems or to calculations of necessary canal flows. I will show below how water management policies

on Java were continuously related to the relation between peasant crops and commercial crops.

Early discussions

In the period roughly between 1830 and 1870, Javanese farmers had to cultivate certain cash crops within the Cultivation System¹¹. Two of the prescribed crops needed irrigation: sugar cane and, to a lesser extent, indigo. Sugar cane, the most important irrigated commercial crop by far, was particularly grown in East Java. When in the 1840's and 1850's several famines occurred on Java, colonial policy began to be directed at supporting rice farming through irrigation development too. The famine in 1850/51 in Demak, central Java, certainly stimulated criticism on the Cultivation System; this criticism coincided with a general call for liberalization of economic activities. Sugar cane was regarded a major constraint for peasant production to reach a sufficient level. First, sugar cane claimed valuable irrigation water, both for the crop as for driving the water mills with which the cane was crushed; second, when sugar cane was removed too late from the sawahs and the West Monsoon had already started, rice could not be grown successfully anymore in that West Monsoon season.

In the early 19th century, during the Cultivation System it had started and benefitted from itself, the colonial government was hardly interested in such problems. With the sugar industry for the greater part still under governmental control, as a rule the interests of the native agriculture came second¹². After the gradual abolishment of the Cultivation System and the increase of private economic activities the government no longer benefitted directly. This change in interest coincided with a growing concern about the welfare of the Javanese peasant. One of the first measures the government took in order to strengthen the position of rice compared to sugar cane aimed at decreasing water use by watermills of sugar factories (1870). Another measure concerned the cropping dates of sugar cane (1871). In the West Monsoon, all irrigation water was to be made available for rice after October 15th ¹³.

In 1872, a Commission was appointed to develop ideas for a legal and institutional basis for water management in the Netherlands East Indies¹⁴. Such legal basis would ensure that water distribution regulations for irrigation systems would be as equal as possible, in particular when it came to the rights and duties of the different stakeholders. The Commission had four members, among which irrigation engineer De Bruyn, the former Director of Public Works, and De Pauly of the Department of Legal Matters seem to have been the main participants. At least, this is suggested by the discussions in and about the report. De Pauly referred to the Commission report of 1873 as

‘the personal labor of member of the commission H. de Bruijn’ ¹⁵

De Pauly himself was allowed to write a personal reaction to the report. Basically, De Pauly disagreed with the main report, and therefore apparently with De Bruyn, on specific legal matters, like state ownership of rivers and water streams, and the need to regulate certain issues through law, Governmental decisions or nothing at all. The two did not disagree, however, on the main foundations for water distribution or the need for water management arrangements in the first place. The report of the Commission clearly shows the admiration of De Bruyn for the way irrigation matters were arranged in Italy. He had visited this country himself and had reported his visit extensively elsewhere¹⁶; when organizing water matters on Java, Italy was to be the role model. The Commission report stressed

‘the bad situation of irrigation on **Java** and [...] the minimal way, in which profit is drawn there from the water in comparison to the benefit it could give’¹⁷

A lack of proper education of engineers and Javanese farmers was identified as one of the causes, although lack of proper water distribution arrangements and responsibilities in general for water affairs were stressed as being more important. The report discussed the establishment of irrigation divisions as part of the Department of Public Works and water boards, representing irrigation stakeholders. The Commission distinguished between boards with Javanese and European stakeholders, which were supposed to be supervised by the irrigation divisions, and boards with Javanese members only, which were not. Although the issue of water boards was not really elaborated upon, the distinction between the two potential types of water boards emphasizes the main concern of Dutch colonial water management: balancing the interest of Javanese and European demands, rights and positions in irrigation.

As a standard of a kind did not exist, differences between distribution practices to deal with this balance in different regions on Java were considerable. Even within one region the lack of a clear standard could cause considerable differences in water distribution over days in terms of allowable flows and irrigation times¹⁸. The Commission report, in this case quite definitely De Bruyn, made a strong plea for a clear ‘water module’, again based on the Italian case.

‘A discharge of hundred liters of water per second is the water measure (module) for **Italy**. Taking into account the metric system, this amount is a useful standard unit for every irrigation country.’¹⁹

De Bruyn proposed to use standard outlet dimensions to ensure that the correct water module could be employed. He even suggested standard artifacts, for example Italian Soldati and Brunacci outlets. Reference to the British Indian situation was not made by De Bruyn, although the module-based approach of the British irrigation engineers was similar to his own ideas²⁰. De Pauly did not oppose the water module as such, but he did object to defining any exact amount in the water laws themselves.

‘Establishing and describing the measure for regulating the use of water by agriculture and industry is as little a part of civil law as is establishing the measures of length, volume, weight, time and value (money).’²¹

De Bruyn foresaw an important role for engineers in arranging proper irrigation management and wanted to define their position in the new law. Again, De Pauly disagreed on this matter, apparently not so much for the position of engineers as such, but because he considered it unnecessary to define such a role in the law itself. A governmental decision would be sufficient. The tasks for the engineers were not really contested either: they had to protect regions against flooding, give their attention to the use of rivers and canals for shipping and industrial use, and they had to prepare irrigation works. Concerning irrigation, they had to make proposals

‘to prepare judicious water distribution for irrigation of areas brought under cultivation, particularly rice fields, for every river water level’²²

All these issues were so closely related that

‘proposals on these issues need to be formulated at the same time’²³

The changes of 1885, when the ‘Irrigation Brigade’ was erected, certainly promoted a planned approach to irrigation development. Standardization of the different arrangements for water distribution between and within systems, however, was not brought any further.

Value of irrigation water

What was brought further, was finding a guiding principle for irrigation water management. This principle was found in the idea that colonial water management should maximize the economic value of irrigation water. This value, already mentioned in the report of 1879, could be expressed in monetary terms and should be created by applying correct amounts of water²⁴. In theory, the productive potential of irrigation water could be valued differently depending on location and time of water being available. Supplied to a standing crop, which just received enough water for a certain period or to fallow land, water had lost its value or could have a negative value as it could be harmful. In case of crops needing water, water had a very high value, depending on the type of planting and the growing stage. From all these different values and their respective surfaces, a total value for all the available water for an area could be calculated. This total value would typically vary from moment to moment, depending on the moment in the season and the situation of the crop. Adaptation to actual circumstances and demands was a key element to ensure maximum values for water use. This created the necessity to adapt and control flows of water to different parts of the irrigation system, units, fields or even crops, to allow for changing demands for water at different places in the system at different times. How the Dutch dealt with this issue is subject of Chapter four.

Growing sugar cane was regarded as very valuable and a very good example of maximization of the value of the water. The harvested value of sugar per bouw amounted to about 1000 guilders, where polowidjo, the main competitor for irrigation water, yielded on average about 30 guilders. On polowidjo, two families could make a living, whereas one bouw of sugar cane would provide up to six families with an income²⁵. Even with its high profits, however, it was not desirable to allow unlimited growth of sugar cane. Javanese agriculture had to be able to exist and grow too, not only because the Javanese had to eat, but also because exporting rice could become an interesting future economic option. Maximizing rice production would also maximize land tax, as this was based on the crop harvested. Governmental care should not just focus on creating maximum financial returns, stimulating sugar, but also on the distribution of these returns, stimulating rice²⁶. In practice, distribution arrangements showed elements of both aspects; the discussions on water distribution in the late 19th and early 20th century, including the day-and-night-regulation, basically tried to clarify how an appropriate balance between financial gains and welfare security could be assured.

Over time, governmental concern about food security for the growing population on Java increased. In 1883, the Director of the Civil Service could still order the Service to intervene in water use conflicts with the expectation that such intervention would

‘as a rule [...] result in unhindered cultivation for the cane planter, without resistance from the interests of the population in any way.’²⁷

In 1893, Minister for Colonial Affairs Van Dedem expressed his desire to be informed

‘how providing irrigation water to the sugar industry was treated and how it was safeguarded, that native agriculture did not experience harm, and further, if a regulation for this issue was under consideration.’²⁸

Proper irrigation water management was seen as a key element in ensuring food security on Java. Where no European estates were present, existing Javanese water distribution regulations and measures were regarded sufficient, at least for the near future. Where European estates were present, native regulations and measures were considered insufficient to reach an acceptable water distribution between sugar cane and peasant crops. Obviously, local management arrangements to distribute water already existed for a longer time, but were often not written down; the Dutch Civil Service would only be confronted with them in case of problems²⁹. Furthermore, Javanese irrigation systems did not have enough possibilities to measure and regulate water flows. The regulations were not based on separating sugar cane and rice, let alone that they had been developed taking into account larger areas cropped with sugar cane in the dry East-Monsoon. Competition between sugar estates on water, which grew as a result of the sugar crisis at the end of the nineteenth century, was also reason to develop colonial policies for water management. The irrigated area of the Goeng and

Koemissik rivers was one of the first regions in which an attempt was made by Dutch civil servants to develop regulations for water distribution between sugar estates in 1885³⁰. Throughout the colonial period, the main debate on colonial water management has centered on the power balance between sugar estates and Javanese farmers. The position of the sugar estates as a group was considered to be (too) powerful compared to Javanese farmers. Estates had much to lose when irrigation water was not available in sufficient quantity and they had the means to provide themselves with it³¹.

Experimenting

In 1893, the request from Minister Van Dedem mentioned earlier started a large-scale investigation into the question to what extent water use of sugar estates hampered Javanese agriculture. In the same year, in a letter dated September 21st, the colonial Government invited the Director of Public Works to

‘design, in consultation with his colleague from the Civil Service, regulations for distribution of irrigation water in the catchments of the Pekalen and Pategoean Riviers, respectively in the residencies of Probolinggo and Pasoeroean, which could be applied as a test, which, when they prove to perform well in practice, can be definitively established later.’³²

An experiment in these two small irrigation systems on East Java had to provide experience to decide what colonial water management regulations in irrigation systems were appropriate. In both test systems, sugar cane received water separately from rice. Sugar estates had to apply for water in writing to the Irrigation Service. After checking applications, the Service informed estates when water would arrive; typically, this would be during the day (between 7.00 am and 4.00 pm). When sugar estates were irrigating, all inlets to rice fields were to be closed³³. The Pekalen-works were designed by engineers Lamminga and Ypelaa³⁴. Its water distribution was designed by Obertop, who worked as controller, within the Civil Service; the assistant-resident of Kraksaan, De Jaager, was involved in setting up the water management regulation³⁵. The technical design of the Pategoean-works was made by engineer Weijs³⁶. Ter Meulen of the Civil Service and Weijs designed the Pategoean distribution method together³⁷.

The Pekalen works (Figure 3.2) were located in the residence of Probolinggo³⁸ in the district of Kraksaan, East Java. The system had a surface of some 10.000 bouw (7000 hectares). An extended design history of the system is given in Chapter five; for now it suffices to go to the end of 1893, the year in which the physical irrigation infrastructure was finalized and cultivation could start. At that time, however, a clear water distribution arrangement had not been made yet.

‘In the exploitation problems were felt forthcoming, as every cultivator was left free to determine the point of time when he wanted to start preparing and planting his field. Consequently, water needs for fields within each others immediate

neighborhood were often very different and in case soil preparation was started on large surfaces, insufficient water could be delivered.’³⁹

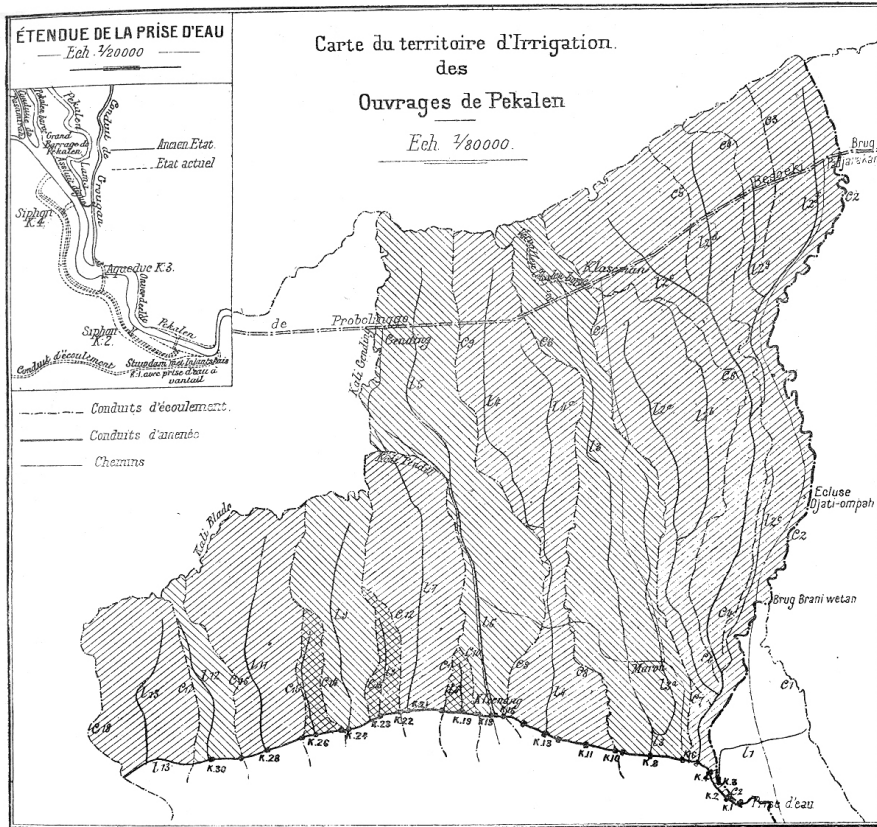


Figure 3.2 The Pekalen works⁴⁰

Especially timing of planting the young rice crop caused problems. Most Javanese farmers wanted to plant their rice early in the West Monsoon; early rice plants could not only profit optimally from the rainfall, but also be harvested when prices for paddy were higher. As early rice planting meant that sugar cane could also be planted early, early planting of rice was encouraged by sugar estates and colonial government. All in all, most farmers wanted planting rice in November, when irrigation water was usually not abundantly available yet. To overcome this problem, it was decided that cultivation practices had to be managed on system level, in particular the time frame of activities for rice cultivation, including soil preparation and transplantation of young plants.

‘Therefore, in the West monsoon of 1894-1895, a cultivation plan is defined in consultation with the native and European administrations.’⁴¹

Water distribution was planned in accordance with the cultivation plan. As in November and December the available amount of water from the river was only sufficient to irrigate part of the command area, only this part received permission to

plant rice. With the increase in water availability in the course of the West Monsoon, the command area with rice could be increased step by step. The successive groups of sawahs, each with a rice crop in a certain stage receiving water, were called golongans⁴². The Pekalen area was divided into six golongans⁴³. The first golongan would receive water from the 16th of November and finish soil preparation and rice planting one month later, the second would start on the 1st of December, etcetera. The last golongan could start irrigating at the 1st of February. In the original golongan planning, different fields would become part of the first golongan each consecutive year, to give all farmers equal advantage over time. In actual practice, however, this circulation of 'first right' was not completely applied. Following the wishes of the sugar estates, with their big interest in early rice planting on the fields they rented, especially the first two golongans included all those fields which would be planted with cane after the rice harvest. As some sawahs were never rented by the estates, they would never become part of these early golongans.

'From the side of the administration an investigation was started, whether the population really considered this as illegitimate favoring of the sugar industrial; this proved to be not the case.'⁴⁴

Another modification over time was that the early golongans were defined as separate, concentrated areas, either based on topography or canal units. In either case, complete *desas* (villages) were part of such a golongan. However, after first experiences, *desa* authorities objected to such a division, as available man and animal power in a *desa* would not be sufficient to finalize all the necessary work within one month. Therefore, another way to divide the command area into golongans was selected. Each *desa* was divided in six parts, with the total group of *desa* parts with equal number forming the golongans. For each golongan, a cultivation plan was formulated,

'enabling the direct stakeholders to exercise their influence and know about it immediately; the cultivation plan defined in the *desa* connects very well with the general *desa* economy.'⁴⁵

The consequence of the selected golongan division method was that each *desa* and irrigation unit would include sawahs with all cropping stages of rice and sugar cane, from young rice to already growing rice. This resulted in different water needs within relatively small units. As exact crop water requirements were not known, actual water distribution by the irrigation personnel was based on the demands made by the Javanese farmers and/or village chiefs. Lamminga considered this a disadvantage to be solved as soon as possible, as the system would not hold long in terms of justified and equal distribution.⁴⁶

'In this system, the one shouting loudest and asking most has always the best chance to profit compared to the one who quietly assumes that he can leave his faith to the powers positioned above him.'

In apparent contrast with the picture sketched above by Lamminga for Pekalen, interactions within the Javanese farmer community free from direct engineering interventions was the key to the water distribution regulation tested in the Pategoean area (Figure 3.3). The separation between sugar cane and rice was similar to the Pekalen system. The Pategoean works are located in the residence of Pasoeroean, in the district of Bangil, and count 9000 bouw (6300 hectares). The area was divided in several sub-areas, like Tanggoel, Kapoeloengan and Pategoean. In first instance, in the early 1890s, a similar golongan-based method as in the Pekalen system was employed. The diversity of the command area, however, with many small units and variable soil conditions, created difficulties in planning the water distribution⁴⁷. Closer involvement of local knowledge on the area, that is knowledge from Javanese farmers in water distribution on the lower levels in the system, was perceived as necessary. The goal of the Pategoean arrangement was

‘to arrive at a situation, which will enable the native to arrange his water distribution himself as much as possible, in accordance with the demands of his agriculture to be completely determined by him.’⁴⁸

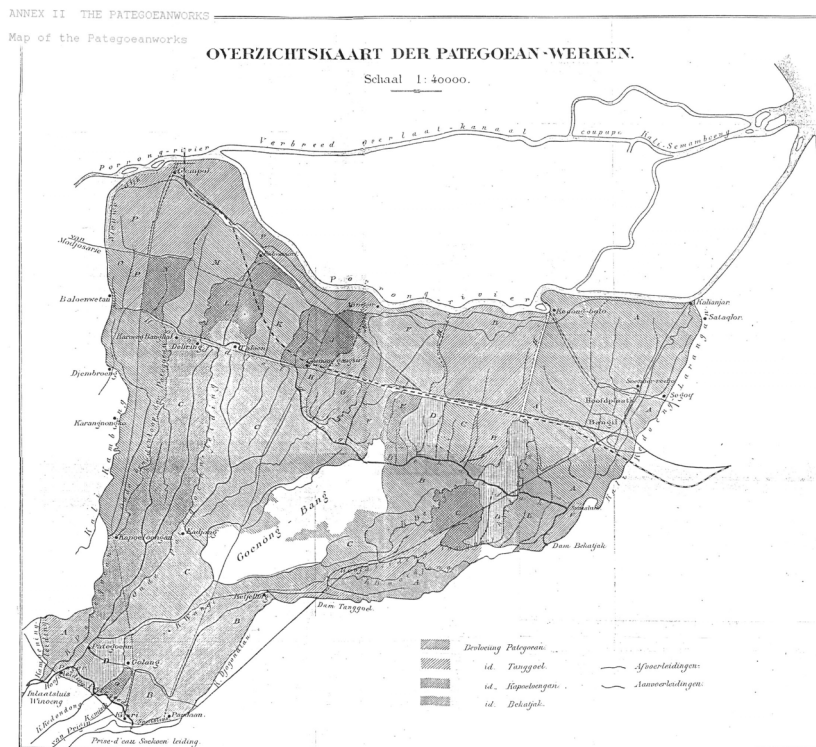


Figure 3.3 The Pategoean works
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The command area was divided in parts of about 200 bouw, which were called water courses ('waterkringen') or 'golongan-ajer'⁵⁰. One golongan-ajer usually encompassed sawahs from different desas; given the large amount of relative small units with separate

intakes within the area, one golongan-ajer could have several intake structures. Engineers in particular have discussed this last feature in relation to the success rate of the Pategoean arrangement (see below), but more important is the political reasoning behind the arrangement, which was discussed much wider in the Netherlands East Indies than just within the community of engineers.

Fundamental to the Pategoean arrangement was the conception of water rights as formulated in an undated concept regulation.

‘The right on irrigation water [...] is not defined per field, but commonly by all fields, which are united in so-called water courses.’⁵¹

In water distribution practice, the Irrigation Service distributed water to a golongan-ajer area in proportion to its surface; within a golongan-ajer the water users distributed the water themselves. The water distribution within the golongan-ajer areas appeared to be based on a cultivation plan, like in Pekalen, but the Pategoean plan was defined without direct engineering involvement. Each desa designated an oeloe-oeloe, member of the desa board, to arrange water distribution for desa members. Golongan-ajers included fields from different desas, reason why oeloe-oeloe's from different desas with sawahs in the same water course formed a commission for water distribution. In 1895, the Pategoean distribution system started in the Tanggoel area. The water was distributed to water courses with surfaces of 162 to 197 bouw. In 1896, the method was also implemented in the Pategoean- and Kapoeloengan areas. Here golongan-ajers were formed with surfaces of 89 to 331 bouws⁵². Similar experiments started in other irrigated areas in the Brantas Irrigation Division, like the Soerak and Koendang areas⁵³.

The debate on the Pategoean experiment

Governmental decision No. 181a of January 24th 1899 informed the Directors of Civil Service and Public Works that according to the Government the Pategoean distribution method was to be considered as

‘[...] the designated direction to bring water distribution for agriculture on firm foundations [...]’⁵⁴

The colonial government considered the Pategoean method as the best solution, because the intensive interference with native agriculture in the Pekalen method would put a very large responsibility on the shoulders of the administration. The Pategoean method made an attempt to lead the native peasant to self-reliance; the Pekalen approach would block this.⁵⁵ Despite this clear direction chosen by the colonial government, the Pategoean-method has not been implemented on larger scale. It never even moved beyond the experimental phase. Instead, the water distribution regulation developed in the Pemali irrigation area (Figure 3.4), Central Java, has become the standard approach. Although some considerations of the Pategoean method have been included, generally the line of thought of the Pekalen approach has been used as

inspiration for the formulation of the Pemali regulation. The Pemali regulation was initiated by Lamminga and brought to further perfection by Numans ⁵⁶.

The Pemali regulation will be discussed further below, but before doing that, the debate on Pategoean and Pekalen arrangements needs more attention. Applying the Pategoean approach in the Pekalen system was discussed at least two times, on June 22nd 1895 and November 23rd 1895⁵⁷. The first meeting was organized by Mullemeister, a member of the Indian Council ('Raad van Indië'); no conclusion was reached. During the second meeting, when the ideas of Inspector of Cultivation ('Inspecteur der Cultures') Lieftrinck ⁵⁸ were discussed, the representatives of the local Civil Service opposed changes in the Pekalen experimental regulation. The matter was not discussed further. In 1901, the original Pekalen regulation was formalized with publication in the Staatsblad No. 177, as Governmental Decision No. 35 of April 25th 1901⁵⁹. Lamminga himself discussed the opposition to the Pekalen arrangement. The approach would be too expensive. Furthermore, management by engineers would be too dominant in relation to the influence of the Civil Service. Lamminga pointed out, however, that the Pekalen regulation remained popular by those who worked with it, even though many different people from both Public Works and the Civil Service were involved during the many years the experimental status was used and discussed.

'And then, after several civil servants had been replaced by others, as a consequence of the many personal changes in the Indies, it became clear that the new administrative civil servants were satisfied with the established regulation as well.' ⁶⁰

Weijs points at the same mechanism of replacement of civil servants and engineers, when he refers to the temporary regulation in Pategoean, which

'[...] fell into oblivion, immediately after the promoters of the regulation had left because of transfer or foreign leave.' ⁶¹

Such frequent changes in personnel, however, do not explain why the Pategoean methodology has been unsuccessful, as the Pekalen case shows.

Another potential explanation could be the continuous struggles between the Departments of Public Works and Civil Service. Engineers would favor approaches focusing on central management, and civil servants would be more open to regulations which gave opportunities to existing Javanese rules. This explanation, however, does not provide a satisfactory answer either. Weijs, one of the important irrigation engineers in the late 19th and early 20th century, presents himself as the most important defender of the Pategoean method. He does so next to civil servant Ter Meulen. Weijs mentions De Jaager, member of the 'Raad van Indië', as a major opponent of the Pategoean regulation⁶². Furthermore, Weijs disagreed with other engineers on matters that appear to be technical. For example, Weijs and the section engineer of Brantas, Steup, agreed that the Pategoean scheme area was a difficult area, with different parts of the system

differing in infiltration rates and topography. However, they came up with quite different solutions. Weijs proposed to take these differences into account to modify the proportional shares between the water courses, whereas Steup proposed to change the distribution method altogether. These solutions appear to be based upon on political and economical views, not at all on purely technical issues. Where Steup did not agree with proportional distribution and thus would be more inclined to use the difficulties to change the distribution method, Weijs, as the father of the proportional distribution, perceived the difficulties of the terrain as issues to overcome. According to Ter Meulen, a civil servant, terrain differences were a reason to start with the Pategoean arrangement in the first place...⁶³.

Although professional positions and departmental context may have played a minor role in the debate, an answer to the question why the Pategoean method has not been implemented on a larger scale needs to take into account the nature of the Dutch colonial bureaucracy as a whole. The bureaucratic system aimed at information gathering and control⁶⁴. It did have its positive aspects too. Given the focus on policy development, an activist flavor was added to the bureaucracy⁶⁵. Often, reforms were first tested before being implemented, for example with a new land tax system at the end of the 19th century. Irrigation divisions were organized experimentally as well, one at the time; only when the experiment was considered a success, divisions became standard. The experiments with water distribution fit in such a context, including the focus on ways to organize the Javanese input in irrigation affairs. One way was establishing an institution similar to the water boards in the Netherlands. The Pategoean regulation potentially was a first step towards water boards. Within a *golongan-ajer*, different users could start to negotiate about the water. Those who were willing to pay for water could buy water from others. In the end, the value of the water would be maximized on the level of the *golongan-ajer*⁶⁶. Weijs recognized the difficulty to organize Javanese influence in irrigation management given the political-economic context of Java with its strong sugar estates and centralistic government. In a handwritten note of 1893 on water boards on Java, he suggested to start at the lower level of the *golongan-ajer* precisely for this reason⁶⁷. After a certain period, *golongan-ajer* units of one secondary canal could be grouped into sub-water boards; the sub-water boards which received water from the same main canal were grouped into a water board. In such a way, water boards should be established as governing institutions for irrigation affairs⁶⁸.

Establishing water boards would solve discussions on responsibilities for irrigation management within the colonial bureaucracy as well. To Weijs, water boards were to become the responsibility of the Civil Service as their equivalents in the Netherlands. He did exclude the possibility for

‘technical forces as elements when composing the administrations’⁶⁹

Irrigation departments were to stay, but as technical advisors to the water boards; a similar position would be reserved for agricultural expertise. Weijs discussed his ideas in the same period with for example Mullemeister, but admitted that the idea for Javanese influence was probably introduced too early given the colonial setting⁷⁰.

‘But when I [Weijs] at that time brought this idea concerning his [the Javanese farmer] water interest to the forefront, I was simply laughed at and what I said was considered ridiculous. That is, within the Irrigation Unit of Public works.’⁷¹

A similar remark is made by Cramer some years later:

‘Engineer Weijs was far ahead of his time and the idea to create water boards was then considered ridiculous.’⁷²

The bureaucratic colonial system provides many elements for answering the question why the Pategoean method has not been implemented on larger scale. A focus on detailed, government-planned water distribution is hardly surprising in such a bureaucratic environment. The option itself to experiment is perhaps not too strange itself; what could be perceived as odd with the experience of hindsight, however, is that the colonial government initially preferred the Pategoean method⁷³.

The struggle within the colonial bureaucracy between civil servants and irrigation engineers does not offer an explanation for this initial preference nor the final outcome of the continuing debates. Political and economical visions of the social groups and actors were important though. Two main actors from the engineering profession in the water regulation debate, Lamminga and Weijs, did not disagree whatsoever on the need for technical expertise in water distribution in general; they disagreed on specific tasks, level of interference and terms of reference for technical expertise. As we shall encounter below, when the Demak area is discussed, it was even possible that Weijs advised to introduce the Pemali regulation in Demak on technical grounds; the fact that it was developed by Lamminga on the basis of the Pekalen experiment, and had replaced the Pategoean regulation as favorite, seemed not to be an issue at all.

And the winner is ... Pemali!

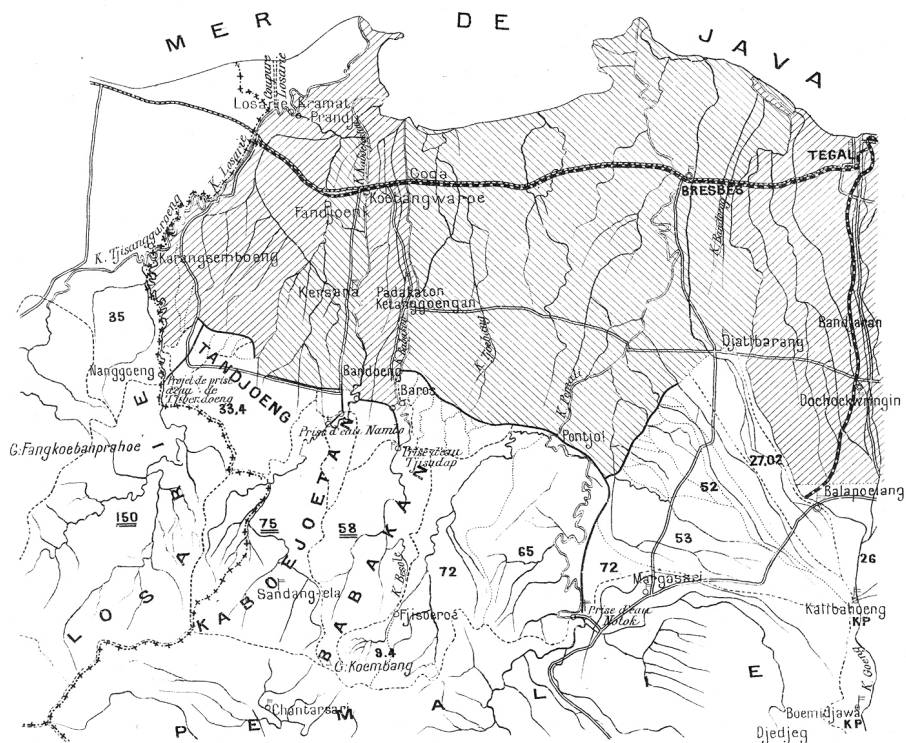
The Pategoean approach may not have had the perfect match with the Dutch colonial bureaucracy, but it was initially selected as the way to go forth in developing colonial water regulations by that same bureaucracy before its role model was replaced by the Pemali regulation. The main reason that the colonial government preferred the Pategoean approach may have been the lower requirements for colonial officials. Redirecting the favor to Pemali is explained by the continuing irrigation development practice. Both Pekalen and Pategoean schemes were relatively small irrigation systems, particularly compared to the systems designed and exploited since the last decade of the 19th century. Both systems were basically improved Javanese systems, unlike many of the new systems. Both systems were located in hilly, even mountainous areas, whereas

the younger engineering irrigation systems were typically found in the extensive coastal plains of Northern Java. In other words, the irrigation environment of the experiments was probably not too representative for newer systems anymore; the governmental decision in favor of the Pategoean experiment did not match with daily practice in the majority of new irrigation systems to be managed.

Fig. I.

Travaux d'irrigation de la Province de Tégâl.

Plan d'ensemble.

Figure 3.4 The Pemali system⁷⁴

Légende de la figure I.



Régions arrosées par la même rivière.

75Bassin d'une rivière en amont de la prise d'eau. Surface en K.M²

Canal principal.

18Bassin d'un affluent. Surface en K.M²

Chemins de fer.

Les parties couvertes de hachures représentent les terrains irrigués par les rivières suivantes:

Le Losari prise d'eau à Tjibendoeng.

Le Kabogoean id. — id. à Numbo.

Le Babakan id. — id. — id. à Tjisailap.

Le Pemali id. — id. — id. à Notok.

The main example of such a new system was the Pemali system, irrigated area about 45,000 bouw on Central Java (Figure 3.4), designed by Lamminga⁷⁵. The water distribution methodology was based on the Pekalen regulation. Naturally, Lamminga played his role in this transformation, but others were involved as well, for example the engineers Numans and Kruimel, both successors of Lamminga. Pemali, and Lamminga as its designer, were such strong examples and role models, that even in 1936 engineer Polderman could start his report on irrigation water management during the economic crisis with the remark that

[i]t is a big privilege for a Public Works engineer to have been allowed to work for some years in an Irrigation Division like Pemali-Tjomal. Both the work of someone like Lamminga in construction-technical sense and that of someone like Numans in exploitation-technical sense has inspired many successors to build further on the indicated direction through its grand style and sound foundation [...].⁷⁶

One founding element of the Pemali water distribution regulation was the golongan, in the meaning as employed in the Pekalen system. Unlike the Pekalen golongan, however, the tertiary unit served as the basic planning unit; a typical tertiary unit encompassed 150 to 200 bouw. A single tertiary unit was part of one single golongan, and there were five golongans in total. Within one secondary unit, tertiary units could be part of different golongans. As golongans were spread over the total command area, the demand for and availability of human and animal labor could also spread over larger areas. The division in golongans was permanent, but each year another golongan was allowed to start with irrigation. The standard starting date for West Monsoon irrigation was October 16th, but in case of water scarcity this date could be postponed. Each year a cultivation plan was made, like in the Pekalen system. The irrigation season was divided in three main phases: seeding (15 days), soil preparation and bedding of rice plants (45 days) and growth of the crop (90 days). In terms of flows, the first phase typically allowed 0.8 liters per second per bouw concentrated on the seed-plots, the second required 1.2 l/s per bouw and the third phase would again receive 0.8 l/s per bouw. Although the idea of small, permanent surface units receiving water was adopted in Pemali, comparable to the Pategoean approach, a main difference with the Pategoean system was the way water distribution to the tertiary unit was determined. In the Pategoean idea water supply to tertiary units was independent of actual cropping and therefore constant in proportion to the total area. In Pemali the water was delivered according to the needs defined in the cultivation plan and the golongan ranking.

‘The above-mentioned sketches the intervention of the Irrigation Service. This reaches until the end unit of irrigation; each unit is provided with a permanent sluice, which is operated by the Irrigation Service. However, once the water has been delivered in the unit, intervention of the Irrigation Service stops when the distribution of the water over the fields within the units is concerned [...].’⁷⁷

The Irrigation Service did interfere with maintenance of tertiary canals, as the

‘[...] experience has learned that maintenance of tertiary canals can not be left to the population.’⁷⁸

Water distribution within a unit, thus within the *desa*, was the responsibility of an ‘*oeloe-oeloe golongan*’ (or ‘*kepala golongan*’)⁷⁹. This *oeloe-oeloe*, another founding element of the Pemali arrangement, was responsible for water distribution for the rice crop in one tertiary unit. Sugar cane irrigation remained under the responsibility of the Irrigation Service. In the West Monsoon this would not have had much impact, as sugar cane did not need irrigation water in this period. The East Monsoon was different.

‘In the end units, in which sugar cane is on the field next to *polowidjo*, the so-called day and night regulation for irrigation water is working between both crops.’⁸⁰

A tertiary unit with an *oeloe-oeloe* comes close to the water course in the Pategoean regulation; even the size of a water course was similar to the units in Pemali with their 150 to 200 *bouw*. However, the position of the *oeloe-oeloe* within the *desa* was changed in Pemali in comparison with Pategoean. Originally, an ‘*oeloe-oeloe desa*’, as in the Pategoean area member of the *desa* board, was responsible for water distribution in Pemali.

‘The *oeloe-oeloe*’s *desa* were dependent on the *desa* administration, which did not promote fair water management [...]’⁸¹

The new *oeloe-oeloe* *pembagian* or *golongan* in Pemali was neither a member of the *desa* government nor an employee of the Irrigation Service; in practice his relations with both institutions were tight, but he was supposed to be independent. The position was sanctioned by several Residential decisions⁸², which on their turn were sanctioned by the ‘*Inlandsche Gemeenteordonnantie*’ published in *Staatsblad* No. 83 1906⁸³. This ‘*Native Municipality Act*’ gave the option to employ others than the *desa* board with daily supervision of municipal works⁸⁴. In other words, up to the late 1920s and even beyond, one of the backbones of irrigation water management regulations on Java relied on Residential Decisions. The different roles and responsibilities in water management were not sanctioned by a Governmental Decision for Java as a whole. In 1936 a General Water Regulation for Java would finally provide the legal base for local water distribution arrangements. This General Regulation is basically a copy of the Pemali regulation.

Water regulation in practice

The Pemali regulation did not really need any formal Governmental sanction to be the guiding framework in practice. The case of water distribution regulations in Demak (Figure 3.5), central Java, is illustrative. Demak, one of the regions showing early colonial irrigation interventions, had its own version of a *golongan* arrangement for irrigation water management, introduced by engineer Heijning in 1897⁸⁵. Each tertiary

unit was divided in six parts or golongans, like in the Pekalen arrangement. Within a tertiary unit, these golongan areas would receive water with a 14 days phase difference (Figure 3.6) ⁸⁶.

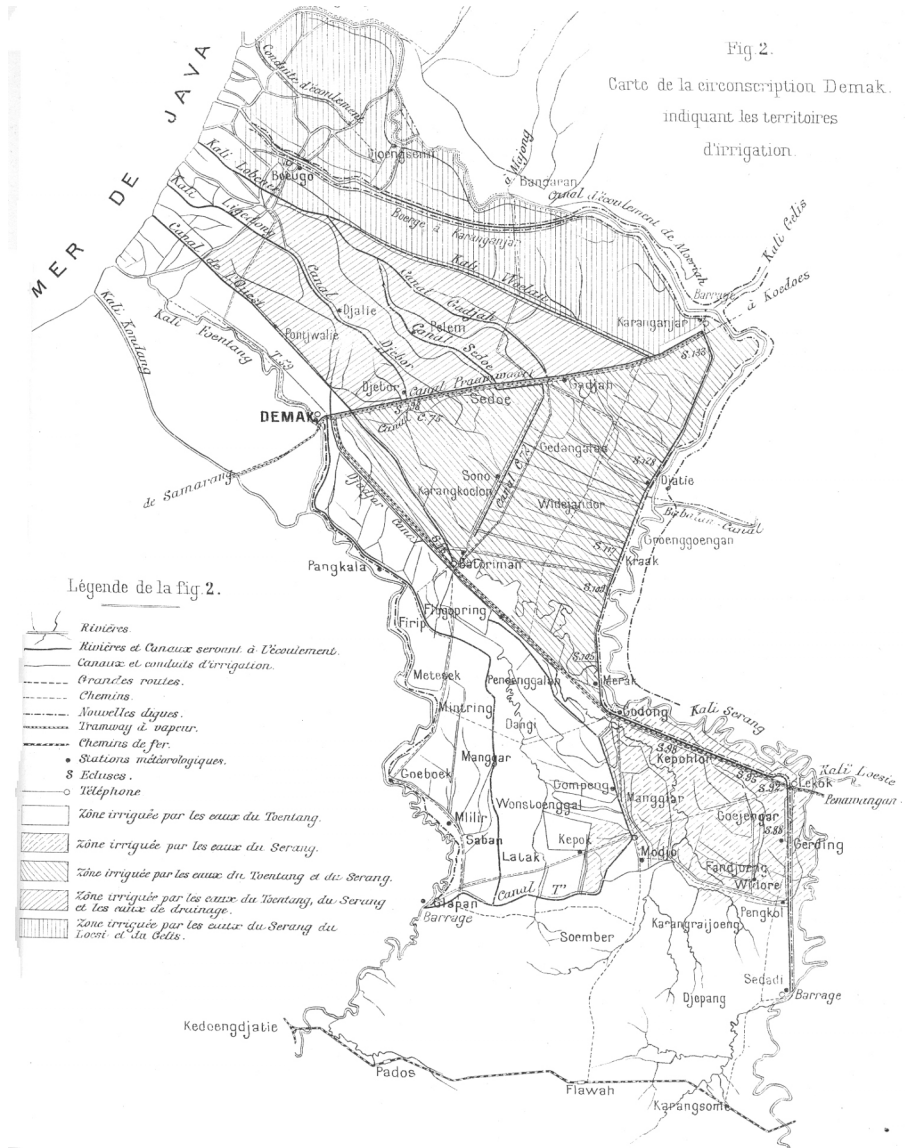
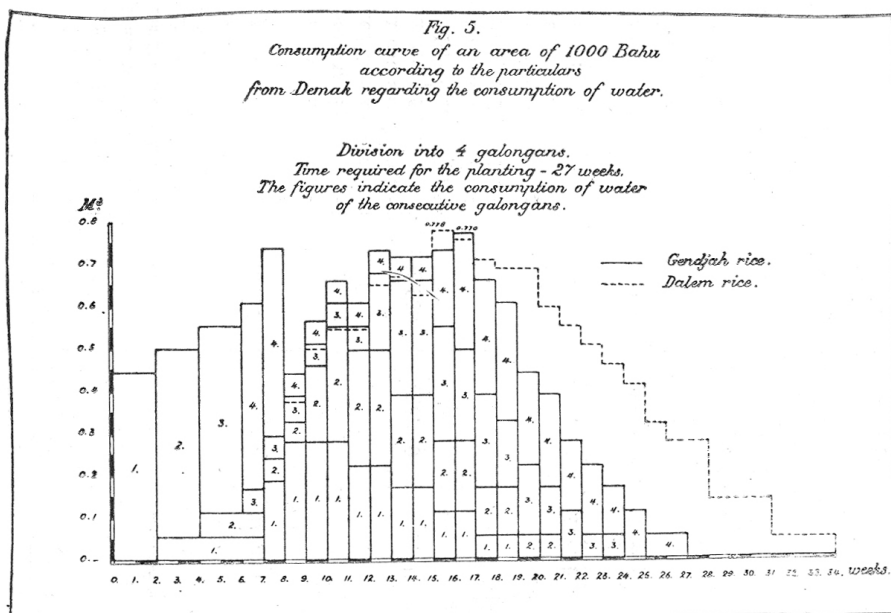


Figure 3.5 The Demak system ⁸⁷

Figure 3.6 The
division in
golongsans⁸⁸



Unlike the Pekalen arrangement, however, one could never be sure that the golongsans with equal ranking in different tertiary units would be in the same growing phase of the crop. The start of the growing season in Demak was set at October 1st each year; on the basis of estimations of available discharges the number of tertiary canals that were allowed to irrigate ('be opened') was determined. Within some units, the fields in the first golongsan could be irrigated; in other units, which were not allowed to be opened, fields in the first golongsan were not irrigated yet. Each week a new estimation was made. Thus, there was a difference in phasing of rice cropping and irrigation on two levels: between tertiary units (opened or closed) and within tertiary units (different golongsans). The regulation, complicated as it may sound, actually had improved existing water distribution from before 1897; even the critical Commission which studied the Demak regulation some years later admitted that the regulation had decreased water use, tried to take into account available discharges and enabled relative simple division structure operation⁸⁹. At the same time, the Commission concluded that the water savings were mainly caused by providing rice with less water during the season, with which the Commission disagreed. One of the main criticisms of the Commission was, however, that it was highly unpredictable for farmers when irrigation water would become available. A related problem with the regulation was that within a given tertiary unit some fields could be irrigated, where others were not allowed to be irrigated.

The Demak regulation stipulated that it was forbidden for late golongsans to sow before certain dates, unless this would result in an impossibility to sow rice at all. An exception was thus included in the regulation. For those fields which could not be planted before the end of February within the rhythm of golongsans and opening of canals, the

regulation itself could be suspended. In all other cases, the planting dates set by the Irrigation Service had to be respected. In practice, a much higher number of Demak farmers would plant their fields before the date they were allowed to. Especially in case of good rains, they tried their luck. They probably tried to use irrigation water too if possible; after all water flowed in their unit, perhaps even through their field to another field. After years of discussion, including critical articles in the local newspaper and many reports⁹⁰, the Demak regulation, including the planting date stipulation, was sanctioned in *Staatsblad* 1903 No. 269. Already in 1904, the difficulty to maintain the regulation became again apparent.

‘At that time, the local Administration recalled the decision of the Resident of Semarang. In a writing dated January 16th 1904 No. 867/3 from that side, the Chief of the Irrigation Division was ordered “to meet the desire of the population, in so far as to allow the farmers involved to, for those units which would be last in turn and thus would have to be planted after 10 February coming at the earliest, to start before”. In such a way, it was prevented that as a cause of the ordinance of July 18th 1903 the many farmers from Demak, who despite their reputation of laziness and lack of feeling for the agricultural interests and straight against all threat of fines and punishment still went to their fields, had to be declared guilty.’⁹¹

This problem of too many penalties, however, seems to be a Demak property: on January 31st 1895, thus before the new *golongan* regulation, one *mantri* or Javanese lower official of the Irrigation Service reported 188 (!) offences to the planting date.⁹² To put it simply,

‘in such a way the untenability of the Demak regulation was demonstrated.’⁹³

In 1903 Weijs accepted the task given to him by the Director of Public Works to study water regulations on Java and discuss, and occasionally propose, potential adaptations in these regulations⁹⁴. From July 25th to August 2nd 1904, Weijs visited Demak; his report was very critical about the local regulation. He compared Demak with the *golongan* regulations of Pekalen and Pemali and advised to implement the Pemali regulation. Advantages of Pemali were the clear planning in advance of irrigation and the uniformity in one tertiary unit. Furthermore, employing Pemali-like *golongans* consisting of tertiary units in the whole command area would leave the option open to classify some units as rain-dependent, which could be planted freely. The risk of crop failure for these rain-fed units would be spread over the entire area over the years, as each year other fields would fall in this category. The report of Weijs also suggested that the Pemali arrangement should be a step towards implementing the Pategoean regulation; he suggested to give the preliminary responsibility in the new situation to Javanese irrigation personnel (*mandoer*), as the farmers themselves (that is their representatives: the *oeloe-oeloe*) might not be able yet to take full responsibility. However,

‘[I] trust, that the latter will soon realize that they can reach a supply to everyone’s desires without the mandoer as well. Than by itself the course committees of the Pategoewan regulation will be created, which I, even better than the kepala ajer of the Pemali regulation, consider capable of managing water supply and from which one of the members, like the aris Oeloe-Oeloe, will be able to adopt the role fulfilled in first instance by the canal mandoer.’⁹⁵

His technical arguments appear not to be completely technical after all... After criticizing the Demak regulation on technical grounds and acknowledging the improvements the Pemali regulation would bring, one of his main reasons to prefer the Pemali system appears to be because this approach would bring the Pategoean regulation with its water board development closer. The 1904 report of Weijs was offered to the Resident of Semarang on July 21st 1905⁹⁶. The Resident was requested to share the report with the engineers involved in Demak, including Heijning. On his turn, the 22nd of February 1906, the Resident sent a report made by Heijning to the Director. In short, Heijning disagreed with Weijs. This continuing disagreement between such important engineers may have been the final push for nominating the ‘Commission for conducting research into the functioning of the ordinance in Governmental Journal 1903 No. 269 concerning the water distribution in the Division of Demak’ by Governmental decision No. 23 of June 9 1906⁹⁷. The Commission reported in June 1908; the report appeared in print in 1913. Members were De Bie (Adjunct-inspector for Native Agriculture), De Roo de la Faille (Inspector for Agrarian Affairs) and Lamminga (Chief of the Third Public Works Unit)⁹⁸.

The Commission agreed with Weijs that the Pemali regulation would be the way to proceed for Demak. This is not a surprise, with Lamminga in the Commission, but the report is extensive and includes detailed discussions on existing regulations and problems associated with the Demak case. The Commission also considered both Pemali and Pategoean, but, compared to Weijs, turned priorities around. In case the authorities considered it too difficult to manage lower units in Demak, they could consider leaving these under desa responsibility. Apparently desa responsibility was not useful to stimulate local involvement, but only in case governmental officials did not know what to do anymore. The Pemali regulation would be preferable for its clarity in demands and responsibilities and from a viewpoint of standardization.

‘Finally one could refer to the organization of water management, which again completely deflects in the Demak system from regulations made elsewhere; this is an objection which has not been particularly complained about from the side of administration or population, as far as has become clear to the Commission, but nevertheless appears to be important to her and to which she would like to attract attention.’⁹⁹

On April 12th 1910, Lamminga formally accepted his appointment as professor in irrigation at Delft Polytechnic with a speech entitled ‘Considerations on the current

state of the irrigation issue in the Netherlands Indies'; water distribution regulations were a major subject in this speech. The distinction between the golongan system in Pemali and the golongan-ajer in Pategoean was emphasized by Lamminga¹⁰⁰: a golongan approach concentrated available flows to part of the irrigated area according to a pre-defined cultivation plan, a golongan-ajer approach distributed available water proportionally to smaller areas. Both approaches applied to the irrigation of rice in the West Monsoon, as in the dry East Monsoon available water was distributed proportionally to areas, after which fields receive water based on the actual crop requirement. For Lamminga, the choice between the two West Monsoon systems was still open: either the Pategoean or the Pemali systems were the options; Table 3.1 lists the different golongan systems discussed in this chapter. The debate on the Demak regulation had already shown that the two regulations were closely connected, although for Weijs the Pemali regulation was to be seen as the stepping stone to the Pategoean situation, whereas for Lamminga the Pemali regulation was the one to prefer.

	Pategoean	Pekalen	Pemali	Demak
Crop	Rice and sugar cane	Rice and sugar cane	Rice and sugar cane	Rice
Cropping calendar	Not explicitly made	Drawn before the West Monsoon irrigation season in exchange between Civil Service (Javanese and Dutch) and Public Works	Drawn before the West Monsoon irrigation season in exchange between Civil Service (Javanese and Dutch) and Public Works; 3 cropping phases	Not explicitly made; cropping phases per tertiary unit depended on water availability (opening of the canals).
Golongan	Golongan-ajer: proportional distribution between fixed areas consisting of sawahs from several desas	Originally groups of tertiary units (based on secondary or topographical borders); later each desa divided in six golongans	Each tertiary unit has a position in one golongan; one secondary unit includes several golongans	Tertiary unit divided in six golongans
Golongan phases	None	6, first one starts irrigation at November 16 th ; new golongan starts every two weeks; final golongan starts February 1 st	5, first one starts at October 16 th ; 14 days phases	14 days phases from October 1 st ; equal golongan phases include different rice growing stages for different tertiary units
Oeloe oeloe	Cooperation required of several oeloe oeloe desas	Not clear	Originally oeloe oeloe desa; later oeloe oeloe golongan or pembagian	-
Engineering involvement	Distribution up to the golongan-ajer	Water distribution within tertiary unit	Water distribution up to tertiary unit	All water distribution levels

Table 3.1
Overview of
management
arrangements in
the four cases

'To which of these systems, the golongan and the water course system, preference will have to given in the end cannot be determined yet, as experience gained to do

this is from too short duration. In general one could indeed say – in contrast to what can be remarked on the construction of works – that water management is still in the first phase of development; this also is shown by the lack of positively outspoken Governmental insights on this matter.’¹⁰¹

The legal status of irrigation regulations

An important issue underlying the debate on water distribution was the legal status of claims to irrigation water: would water rights be based on water requirements of the crop, would it be based on an area, which would imply that if the land would be sold, the irrigation right would be sold too, could one only claim water for areas in case one would actually grow crops on these? The issue might have been even more fundamental: was it indeed possible to speak about a right to water for individuals, or groups for that matter, or would the Government be the sovereign authority over all water on Java

‘with the power to use this at her discretion?’¹⁰²

Lamminga did not foresee any problem from the perspective of possibilities of the irrigation systems, as

‘with these every desired water distribution can be obtained’¹⁰³

A legal base for Javanese water regulations on local level, however, was still not available. Similar complains were made by others¹⁰⁴. In 1923, a contributor to the discussion on water rights and other legal matters in colonial water management could still refer to it as

‘a typically Indian history of suffering’¹⁰⁵

Many water regulations existed on Java, most designed by local and temporary coalitions of participants, including engineers, governmental authorities and occasionally others. In 1920, Java showed a conglomerate of irrigation systems, each with their own local water distribution regulations; some were sanctioned by decisions of Residents, others were not. Most regulations focused on distribution when water was relatively scarce, for example the start of the West Monsoon; some regulations had to be adapted because of water abundance. The Tjihea system on West Java, for example, did not have a colonial water regulation when it opened in 1894, as European industries were not present in the area. In 1912, regulation of water distribution in the Tjihea area was

‘open for improvement’¹⁰⁶,

as too much (!) water entered the canals. This may have been a cause for repeated outbreaks of malaria in the region. In the Kening system, East Java, drainage seemed to be of much more importance for successful harvests than irrigation. The Irrigation

Welfare Report includes descriptions of many of the local regulations¹⁰⁷; an annex to the annual report of Public Works of 1911 is reserved for them too; Table 3.2 gives an overview. Different irrigated areas could have their own specific mix of distribution principles, showing a variety of options and what might be labeled as ‘general confusion’ when water regulations on Java were discussed in Dutch colonial circles. The Pekalen arrangement, for example, was supposed to divide water to *desas* and hand over responsibilities for distribution within the *desa* to the Javanese; one could argue that this description does not reflect the Pekalen *golongan* as described in most other sources and in this chapter above.

Water management. As far as main canals are concerned custody of public servants, if possible head public servants. Within the end units management is completely left to the population in the so-called course system (Pasoeroean, Kediri, Soerabaja, Madioen, Pekalongan), elsewhere the water is first subdivided over the <i>desas</i> and is management within these custody of the population (Cheribon, Pekalen); sometimes all interference of the population is excluded (Demak). Where the population arranges the detailed distribution, one distinguishes between distribution by the <i>desa</i> (Cheribon, Pekalen), by a course committee or by a servant elected and paid by the population (Pemali).
Water distribution; 1: between upper and lower region; with regard to this no fixed rules are established or can be established; 2: between fields themselves; with regard to this a distinction is made between three methods, which are division proportional to the needs of the crop (Cheribon, Pekalen), to the surface area of the crop (Madioen, Kediri), to the surface area (Pategoean, Samirangebied on Madoera, Demak, Sampeangebied in Bezoeki).
Irrigation turns. Applied in the course system within courses (Pasoeroean, Kediri, Zuid-Soerabaya, Madoera) and within the <i>golongan</i> system within the <i>golongan</i> (Bezoeki, Probolinggo, Pekalongan) (this similarly in the complexes system Goeng- and Koemisik and Samirangebied). In Madioen one has “temporary sub-courses” for sugar cane plantings, which are treated as water courses. Furthermore one distinguishes between systems with fixed turns (complexes system in the Goeng- and Koemisik- and in the Samiran area) and with rotation (Pekalen, Demak and Pekalongan).
Cultivation plan. Prescribed among others in Cheribon, Demak, Sampean area, Pekalen area, as well as in Kediri, where the courses system is used. Elsewhere it is left too much to the <i>desa</i>, causing arbitrariness and favourism.
Water for soil preparation. Accounted for in Demak and Madoera; in the Pekalen area water must be delivered for preparation of cane gardens. Elsewhere regulations remain silent or set water distribution dependent on the water demand of the plants standing or to be planted on the fields.
Priority for sawahs planted with sugar cane. Sawahs to be planted with cane go first in Madioen, Besoeki and old Panaroekan in the preceding West monsoon. In the Pekalen area nothing on the subject is arranged, but one brings the sawahs referred to into the first <i>golongan</i>. In Kediri – Berbek excepted – this one is also given priority. In Pemalang and Poerworedjo the industry rents the fields already from January 1st; reason to plant these fields with rice already in the East monsoon of the preceding year.
Water for sugar cane cultivation. Everywhere separate articles determine water distribution for cane cultivation. The usual principles are: for cane no water distributed in the West Monsoon unless there is abundance; in the beginning of the East Monsoon only, when it does not hamper the padi crop; further as much as needed for the most demanding polowidjo; water is, if wished for, continuously distributed; water, which, depending on the area planted, during a pre-defined time is allocated, can be concentrated in a defined timeframe on part of the crop; when water for cane is distributed in the day, water is for polowidjo at night; before sunset the native needs to express the need for water.
Irrigation of crops on tegallans [rainfed land]. In general tegallans have no right on irrigation water. Exceptions to this rule are only found in Madioen and Semarang.
East Monsoon padi. Water deliveries for padi on sawahs, which are not quite or do not qualify for West Monsoon irrigation, have first right in the East Monsoon.
Withholding water. In Cheribon and Madioen rules exist, which stipulate, in case of illegal derivation of too much water, a certain amount of water or its use during a certain timeframe can be withheld at the benefit of the aggrieved. Applying this rule occurs without suspending the legal punishment, which appeared to be less useful in case of offences by natives on order of European managers.

Box 3.1 Water regulations on Java in the late 19th and early 20th century¹⁰⁸

Another example of the confusion quite often encountered in water regulation related discussions is found in the discussion during a meeting of the Association “Motherland and Colonies” in 1912. In the meeting, Lamminga had presented his views on the issues facing the Department of Public Works; the main issue was the possibility to hand main responsibility for irrigation, including the Irrigation Divisions, to the new Department of Agriculture, an option not at all favored by Lamminga¹⁰⁹. But water regulations were discussed too after his speech; at least one engineer questioned the abilities of civil engineers to manage irrigation properly. This engineer, Ypelaar, based his opinion on the impression that

‘[h]ardly any regulation [...]’¹¹⁰

had worked properly, but he made an exception for the regulation of Demak.

‘I would say, it cannot have been better than in those first years (which are the 7 years of HEIJNINGS residence) in **Demak**’¹¹¹

Ypelaar had read a favorable account of Demak in the Welfare reports. After some discussions and clarification of Lamminga, it became clear that Ypelaar did not know about the existence of the Demak Commission; he immediately excused for his strong tone in the discussion, but gave as his impression that under the direct guidance of Heijning the Demak regulation worked properly. Apparently the ongoing discussions already developing during Heijnings time in Demak had not reached Ypelaar either. I mention this specific little debate because it reflects the circumstances in which debates on water management on Java took place, in particular when actors from different circles were involved (civil servants, engineers from different departments, sugar manufacturers, etcetera). There was a torrent of reports, discussion notes, and newspaper articles; there were many impressions, personal anecdotes and even rumors; and there was the general context of difficult, time-consuming connections between locations on Java itself, let alone between Java and the Netherlands.

Another Commission

In 1916, the ‘Commission for Irrigation Affairs on Java and Madoera’ was established. This Commission was a merger of the Rentability Commission, established in 1897 to check costs and benefits of irrigation, and the Permanent Irrigation Commission, established in 1906, three years after the appointment of Weijs in 1903 to study water regulations on Java. The 1906 Commission had had as tasks to study possibilities to promote contributions of stakeholders in the costs for constructing and exploiting irrigation works, with ‘stakeholders’ in this context referring to the sugar industry, and to establish general principles for water distribution¹¹². The new Commission of 1916 had as task

‘to arrange technical and administrative provisions for use and distribution of irrigation water on Java and Madoera and establish theoretical principles on which these are to be founded’¹¹³

At first, the Commission focused on technical and administrative aspects of one of the main issues in colonial water management: the day-and-night-regulation. This regulation was an issue which was not just discussed within the enclosed environment of a commission; on the contrary, the pros and cons of the arrangement have been the subject of fierce public debate. The material available in the engineering journals alone is quite substantial¹¹⁴. Participants in the debate came from many different backgrounds, including civil and agricultural engineers, civil servants, both Dutch and Javanese, and sugar industrials; the debate has been conducted in different circles, including the Dutch parliament, the parliament (‘Volksraad’) in the East Indies and irrigation areas.

The debate shows the close interrelations between political, technical and economical aspects of the regulation and indeed of colonial irrigation itself: how to ensure that commercially interesting crops like sugar cane could prosper, without too serious constraints for Javanese food crops.

‘Taking into account, that next to the big advantages, which the sugar industry directly and indirectly offers to the general interest and also to the native population in a wide neighborhood; that on the other hand it is not indifferent whether the native agriculture, sharing the same irrigation, can prosper independently from the industry mentioned, it shall be taken into consideration when regulating irrigation, also already existing, whether irrigation privileges (day-and-night-regulation, supplying water first to future cane gardens) can be allowed without limits, without harming the prosperity of native agriculture too much.’¹¹⁵

The basics of the fierce debates on the day-and-night-regulation cannot be stressed enough: the irrigation infrastructure on Java had to irrigate both sugar cane and peasant crops within the same system. In the West Monsoon, sugar cane did not need irrigation; therefore, the day-and-night-regulation was a typical East Monsoon arrangement. Water availability was relatively low in this season, reason why the Javanese farmers typically planted polowidjo crops, which needed less water. With low water availabilities, flows in the irrigation canals would be very small if the water available would not be concentrated to certain fields. The day-and-night-regulation stipulated a certain type of concentration: available water in an area was reserved for sugar cane during the day. During the day usually meant from 7.00 a.m. until about 4.00 p.m..

‘Usually, however, the consequence of the mentioned rule that private plantings are considered for water supply **by day first**, is that during the day the water has to be used **exclusively** for these plantings.’¹¹⁶

Consequently, polowidjo crops could only be irrigated during the night. Apparently, the custom to allow sugar cane to be irrigated during daytime in the East Monsoon originated from the Cultivation System, although defendants and opponents of the regulation did not always agree on its origin. Circumstances had changed though, as in earlier times surfaces planted with both cane and dry crops were much less, whereas East Monsoon river discharges were perceived as being generally higher in the 19th century than in the early 20th century. Furthermore, early cane cultivation used much less water than the crop types of the 20th century¹¹⁷. One of the early measures to change the division of water between day and night was already proposed in 1899, the so-called 'passardan' arrangement: water was reserved for sugar cane for three consecutive days and nights, the next two days peasant crops could use the water. Apparently, the measure was not applied on larger scale. Several arguments were exchanged between participants in the debate in the first decades of the 20th century. Many arguments dealt with irrigation practices related to the different crops. It was argued that Javanese farmers preferred to irrigate during early morning and late afternoon; the fierce sun in the daytime could be avoided that way. In contrast, sugar cane had to be irrigated during the day as the irrigation method, usually furrows, required good control over the water flow. This control could not be guaranteed during the night; although defendants of the day-and-night-regulation acknowledged that this lack of control could be seen as a problem for the Javanese farmers too, they argued that the polowidjo crops did not require very sophisticated irrigation methods. Furthermore, sugar cane factories would encounter difficulties in hiring labor for night work.

Closure in water regulation

The 1916 Commission tried to define a general water regulation for Java; on September 8th 1925 the Commission presented a draft regulation¹¹⁸. As this draft had not taken into account the establishment of provinces, it needed to be reformulated soon afterwards. The establishment of three provinces on Java in January 1930 and the related shift of responsibilities in irrigation affairs from the Irrigation Departments to these provinces created an atmosphere in which clarification of rights and responsibilities was a necessity¹¹⁹. On top of this, the economic crisis after 1929 changed irrigation practice drastically: sugar cane almost disappeared from the fields¹²⁰. Rice replaced sugar cane. As sugar cane did not need water in the West Monsoon but rice did, this change in cropping pattern actually increased pressure on water. In such circumstances it is not surprising that water regulations became even more important. The debate included and repeated several topics, ranging from water boards, including the Balinese subak system, to detailed obligatory planting regulations, from the tasks of the oeloe-oeloe in its different shapes to the responsibilities of engineers and civil servants. Although the debate showed certain changes in regulations or tasks over time¹²¹, the context of and the positions within the debate had not changed much.

The outcome should not come as a surprise either. Responses to the economic crisis were found in increasing interventions and management by colonial services. The wish that

‘[...] the method so soundly tested from the division mentioned [Pemali] more often [may] find broader and more systematic application’¹²²

expressed by an engineer working in the Pemali-Tjomal region became reality. The ‘General Water Regulation for Governmental Lands of Java and Madoera’ was published in the ‘Indisch Staatsblad’ of 1936¹²³. The general regulation determined that all local regulations on Java had to provide rules for certain issues, including planning of cultivation in the different Monsoons, setting the timing for irrigation and defining responsibilities for maintenance of irrigation infrastructure. Basically, the 1936 general water regulation was the Pemali regulation extended to Java. The foundation for water distribution was the immediate need of the crop or the soil prepared for the crop (article 17); article 16 determined that these crops were to be planted only on soils with irrigation rights¹²⁴. Sugar cane had to receive water separately from non-commercial crops; water distribution for this last category was to be arranged by

‘the interested farmers, who can elect or appoint certain persons for this.’¹²⁵

Cultivation plans on which water distribution could be based had to be defined (articles 7 and 10); the day-and-night-regulation could be applied in the East Monsoon if necessary, for example due to a lack of night reservoirs or other infrastructure (article 12)¹²⁶. All together, the general water regulation of 1936 can be regarded as a symbol of closure of water management debates and developments in the Netherlands East Indies.

‘On this successful road of gradual development of self-activity, which one needs to and will continue in the future on the understanding, however, that on Java, in connection to the often so complicated and vulnerable economic relations, with strange, often very radical influences on native farming, intensive guidance and control by appropriate public services will always stay, which should also guarantee that broadness of interest and insight, through the regular cooperation and discussion already mentioned, which the concourse of the Eastern and Western elements demands in these countries if she wants to be fruitful and victorious for both cultures.’¹²⁷

Unfortunate for those with similar aspirations, the international political reality of the early 1940s soon ended these optimistic ideas of cooperation and victory.

4 One equation with many variables

Artifacts in water management

Once upon a time there were two discharge measurement structures. One was called Crump Adjustable Proportional Module (APM) and lived in British India, whereas the other, named Crump-De Gruyter, lived in the Netherlands East Indies (Figures 4.1 and 4.2). As the names suggest, the structures were brothers.

Figure 4.1 A
Crump
Adjustable
Proportional
Module

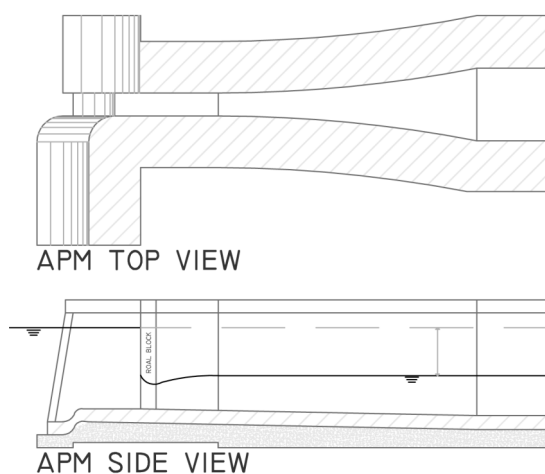
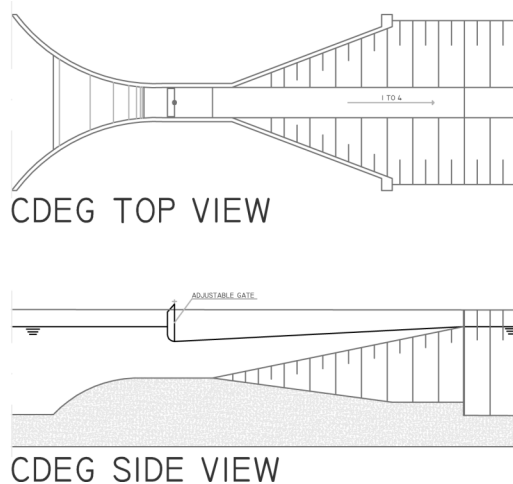


Figure 4.2
A Crump-De
Gruyter



The British engineer Crump made his original design in the Punjab-irrigation works¹. The Dutch engineer De Gruyter adapted the Crump structure for use in Javanese irrigation. The difference between the structures is found in the ability for daily regulation expressed in the presence of an adjustable gate in the Crump- de Gruyter design in contrast with the Crump structure. The roof-block of the Crump structure could be moved with some effort to allow for seasonal differences in water requirements; adjusting the structure daily was not intended. Its design was for constant seasonal flow.

De Gruyter was one of the actors in the Javanese debate on water distribution and ways to achieve this. As discussed before, around 1900 the contours of a highly centralized water management system with engineers in key positions materialized. Although the position of the engineers was contested throughout the colonial period, their position in daily water management was strong. It was within the group of engineers that water distribution structures were selected. In the Netherlands East Indies before the 1930s, engineers did not agree on what structure performed best. Basically, engineers proposed and designed their own structures, with Cipoletti measuring weirs being widely used. Engineering handbooks described the main works, like intakes and larger canals, but hardly the smaller division structures. In the late 1920s and early 1930s hydraulic research became an instrument for standardization of irrigation structures. Finally, in the 1930s, engineer Romijn proposed an adjustable, broad-crested weir, which still has his name attached to it². The Romijn weir (Figure 4.3) is symbol of stabilization, or agreement within a single social group, in this case engineers³. Civil servants or other stakeholders had not participated in the debate at all.

With the introduction of the Romijn weir, the technical debate on discharge measurement structures in irrigation in the Netherlands East Indies was closed. The foundation, on which structures like the Romijn or Crump-de Gruyter could be proposed in the Netherlands East Indies, was already laid in the early decades of colonial rule, as discussed in the preceding chapter, in a debate involving many other actors and social groups. Any attempt to understand the development process of the artifacts needs to be related to this general discourse on water regulations; in the specific debate on the artifacts, however, no reference was made to general political-economic discourses whatsoever by participants. The need for discharge measurement structures in colonial water management probably was uncontested; the debate on structures did not question outcomes from general discourses nor really needed them.

Figure 4.3
A Romijn
adjustable weir
(scale-model)



Night storage reservoirs

The importance of practice and the relative luxury of a debate within a single social group in terms of less politically-laden discussions is shown by the example of another artifact proposed and studied to ease colonial irrigation water management, which did involve many more stakeholders than just civil engineers. One of the measures which could potentially enable colonial irrigation management to abolish the disputed day-and-night-regulation was constructing night reservoirs ('nachtwadoeks' or 'wadoeks')⁴. In 1908, a civil servant in the Kraksaän region proposed to construct reservoirs which could store water during the night and make a higher amount of water available during the day⁵. Although this proposal probably was not followed up directly, it reflected the main technical direction studied and debated to change the day-and-night-regulation.

In the context of the 1916 Irrigation Commission, engineer Cramer was given the task to study possibilities for night storage reservoirs; he presented his first report on May 16th 1916. First experiments started shortly after this date. Originally, the idea behind storage was that sugar estates could store their share of night water and use it during the day; in this way objections of the sugar industry against abolishing the day-and-night-regulation could be anticipated upon. Experiments with reservoirs for sugar cane ('tuinwadoeks') showed the technical applicability of the system, although the number of reservoirs needed would be considerable, as the location of the fields with cane changed over the years. Soon, however, it was realized that the option of storage could also be applied for Javanese agriculture, not just because of equity but also for economic reasons.

'Where aspirations have to be aimed at increasing harvests per surface unit, where in view of this, among other things, there are pleas to intensify native agriculture every time, certainly one has to assure in the first place that irrigation is performed as intensively as possible, something which is out of the question with irrigation during the night.'⁶

'The wadoek system offers the opportunity to particularly increase cultivation of secondary crops, which start to perform a very important role in the native economy to an unprecedented level in the East Monsoon, which would be out of the question with the day-and-night-regulation.'⁷

This shift in focus resulted in experiments with 'kringwadoeks' or tertiary wadoeks, in which night water for one tertiary unit was stored. Experiments were extended to include secondary wadoeks, but the majority concentrated on tertiary wadoeks. The minimum volume stored in these wadoeks was 14 m³ per bouw of sawah, mean volumes were about 17 m³/bouw. The mean gross surface area of a wadoek was about half a percent of the irrigated surface from that wadoek. The water stored during the night would flow in the canal during the day, effectively doubling the water flow. How

this water was to be distributed between the different crops was an open question: it could be with turns, proportionally, etcetera.

‘With the support of these wadoeks, – which serve as accumulators, as regulators –, there are many opportunities to distribute the water, because one can open or close them at pleasure.’⁸

Clear water regulations and dedicated personnel were still needed, even if wadoeks were constructed. A wadoek itself did not improve water management. In Modjokerto and Kediri, wadoek water mainly benefitted sugar cane cultivation, because the population thought that it did not have a right on water supplied during the day, whatever the source. In some cases, it was actually specifically forbidden for the population to use the water⁹. In general, however,

‘[...] from the tests conducted in 1916 and 1917, the practical feasibility of the wadoek system became virtually apparent, our commission considered it nevertheless desirable, before making final proposals on introducing the system and the connected abolishment of the day-and-night-regulation, to conduct extensive tests on the wadoek system even in 1918.’¹⁰

Apparently, these tests have never resulted in abolishment of the day-and-night-regulation as such, nor in a general introduction of the wadoek system. The budget proposal for Public Works of 1926 gives financial reasons for discontinuing with wadoeks on a general scale¹¹. It also is mentioned that the

‘Change of directors at the Department of Public Works’¹²

did not have any influence! Perhaps, it would even have been strange when the wadoek system would have been generally applied. In 1916, the Permanent Commission itself had asked the Government to send a letter to its civil servants to discourage changes in water distribution measures and regulations, to avoid that these regulations had to be changed when the Commission would present its proposals. As we have seen, however, such a General Water Regulation for Java would not be ready before 1936. The General Water Regulation itself keeps the possibility to apply a day-and-night-regulation open. In the 1920s and 1930s, discussions on wadoeks continued. Haringhuizen, professor of irrigation at Delft Polytechnic in those days, knew why the wadoek system had not become standard and why the day and night regulation had not been abolished yet¹³. In short, there were too many stakeholders involved, who did not agree on pros and cons of the issue itself – the day-and-night-regulation –, the potential solution – wadoeks – nor the interpretation of experimental results, as with the water regulation experiments in Pekalen and Pategoean. It will certainly not have helped that the Department of Agriculture was not in favor of the wadoek system, as costs were supposed to be too high and benefits too low¹⁴. But even within the civil engineering circles, not all were in favor of the wadoek system, although not always because of the technical or other feasibility of the system itself.

‘Without wishing to reduce the big importance of this case [the day-and-night-regulation], the writer nevertheless argues, that those improvements need to be established first, which can result in a complete economic and just application of already existing, valuable systems [...]. At this moment the issue of water distribution and supply can be compared with an equation with several variables; should a new variable [the wadoek system] be added now, before the other ones are solved properly?’¹⁵

It is very likely that the engineer writing this will not have had any problem with another debate within the general discussions on colonial water management on Java. This debate also centered on translating goals of irrigation water management into physical structures, but this time on selecting suitable control structures to realize the desired water distribution in irrigation systems. In the East Indian case, the control structures involved are discharge regulation and measurement structures. As we will encounter in this chapter, the Dutch irrigation engineers looked for an adjustable structure combining two functions: measurement and discharge control, and a small head loss. From the early irrigation systems onwards, the move was made from separate structures for water discharge control and flow measurement towards a single structure which could perform both tasks simultaneously.

Unlike the discourse on water regulations and unlike the wadoek-debate, the question which structure performed best was exclusively situated within the civil engineering circle. This quest for the perfect discharge measurement structure was not an organized research program, with well-set goals and a fixed budget, but rather a gradual evolution of individual attempts, discussed in engineering periodicals and other publications. The journals of civil engineering associations (‘De Ingenieur’ in the Netherlands, ‘De Waterstaatsingenieur’ in the East Indies) were the prominent forums to introduce new proposals, discuss hydraulic issues related to the structures or describe experiences. The performance of a structure had to be shown in irrigation practice, with hydraulic research becoming available as well in the late 1920s and early 1930s.

A passage to India

As argued before, the Dutch colonial political-economic setting with its strong bureaucracy employing an agrarian policy aimed at producing both sugar cane and rice. This yielded other irrigation system design requirements than the British colonial setting in India. Regarding discharge structures in irrigation, the main difference between Dutch and British approaches is found in adjustability (Table 4.1). To meet the requirements, certain artifacts were necessary: artifacts embody design requirements. The Dutch engineers were looking for a structure, that could regulate and measure water flows in canal systems; in technical terms, there was a need for physical shapes performing discharge measurement, not just discharge control. One candidate structure

was the Crump-De Gruyter discharge and measurement structure. The Dutch engineer De Gruyter replaced the roof-block of the Crump with an adjustable sliding gate¹⁶.

‘The design comes from Mr. Crump of the Punjab Irrigation. He designed this construction without closing device – the upper threshold is a wooden block – the author of this would like to replace this threshold with a movable closing device.’¹⁷

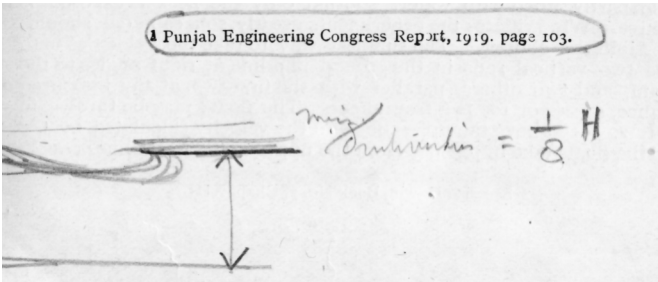
Table 4.1
Requirements
for structures in
India and the
Indies¹⁸

Netherlands East Indies	British India
(Adjustable) Division between the different canals must be possible with sufficient accuracy.	The module must provide a constant (proportion of the) discharge under varying upstream and downstream water levels (different 'heads').
The established division must not be changeable by unauthorized persons.	The module must be so designed that it cannot easily be tampered with.
Changes in canal flows must result in as low changes as possible in the set division between the canals, in order to minimize gate changes.	'[C]lockwork and similar complications must be regarded as out of the question'.
All flows ranging from smallest to highest needed must be measurable with sufficient accuracy.	The module will have to work with a very small and often hardly appreciable head.

The result was an adjustable structure that could be used for discharge measurement and regulation. De Gruyter clearly knew his classics. His personal copy of an important British irrigation handbook¹⁹ contains notes and sketches on many pages (Figures 4.4 and 4.5). From this book, but probably also from many other sources, De Gruyter knew that the irrigation systems on the Indian sub-continent had long canals and many outlets.

‘On an extensive canal system the irrigation officer has to arrange for delivering a certain volume of water at a point which may be more than 200 miles away from the source of supply.’²⁰

Figure 4.4
Notes of De
Gruyter in a
British irrigation
handbook²¹



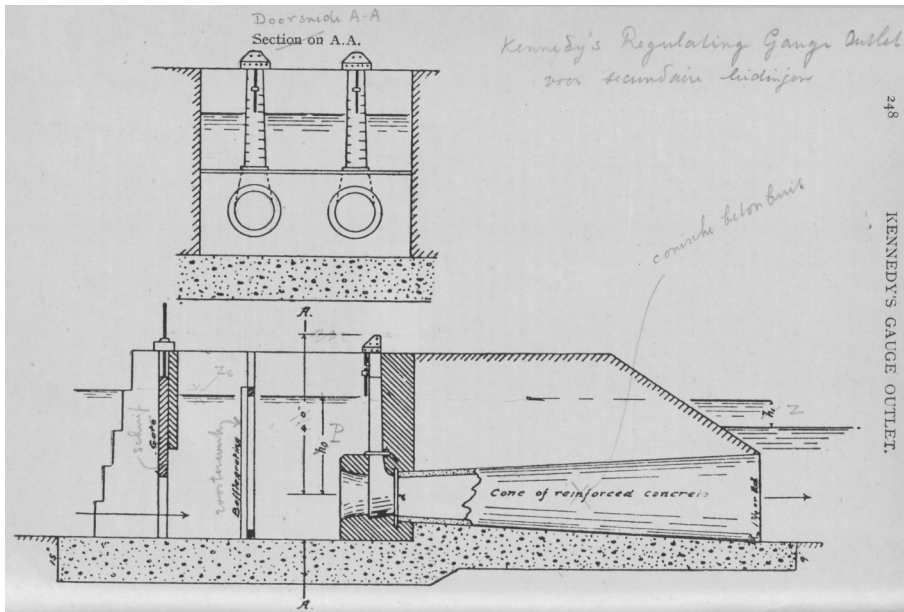


Figure 4.5 Note by De Gruyter in a British irrigation handbook ²²

With British indirect colonial rule, operation of the large irrigation systems had to be simple, by as few people as possible and cheap. What the British were looking for was an irrigation system, which would function without management, by itself as it were. The existing division structures, mainly gated pipes, were considered inadequate, as their discharges neither were guaranteed nor stable. Adapting water gifts to changing demands to increase harvests was not wished for, as this would increase management requirements, but providing known, fixed amounts of water to the land in many different situations was. The British set higher taxes on land that could be irrigated, and even in a colony levying taxes without some guaranteed delivery of water was not done! With artifacts, in this case discharge structures, the desired water distribution was to be realized.

‘The functioning of a module is not to **measure** the quantity of water supplied, but to **control** it. A module gives a certain volume of water, and the action of the module keeps that volume constant, whatever may be the fluctuations of water level in the supply channel – this, of course, within certain limits. It is therefore possible to charge a rate for the module based on the supply which it discharges, whether the full discharge be utilised or not. The cultivator can lessen the discharge from the module, or he can shut it off altogether; he cannot increase the discharge.’ ²³

This general idea for a module was translated differently in different local contexts in the immense Indian colony. In the Bombay Agency, British engineers developed artifacts discharging a constant volume independent of changes in canal flow²⁴; in the Punjab they developed an artifact delivering a fixed proportion of the canal flow²⁵.

Both options worked for the typical British Indian irrigation systems. In the Bombay Agency

‘[n]umerous fascinating structures were developed and tested during this period, aiming to produce an outlet structure that would supply a constant discharge to the tertiary unit, independent of the flow variation in the parent channel and the downstream water conditions in the tertiary water course.’²⁶

Many of the outlets, however, were expensive, as they incorporated fragile mechanical devices; many were vulnerable to manipulation by users or to siltation; some concentrated fluctuations in supply in the tail ends of the canals. In 1922, Crump introduced two new outlets in the Punjab: the Open Flume and the APM, basically similar structures consisting of a narrow throat with a sloping sill. The APM had a rounded roof-block on top of the throat to create an orifice. Crump took into account the issues of fluctuations in supply levels intrinsic to run of the river systems and the gradually rising and falling of water levels due to silting or scouring of canal beds²⁷. Both issues required a device functioning relatively independent from water levels.

‘By placing the APM and Open Flume outlets at an exact hydraulically specified depth, the allocated discharge can be cast in bricks for each outlet by setting the width and height according to the stage-discharge relationship. Once thus built, a ‘Crump canal’ would be self-acting in its water distribution between flow fluctuations of 70 to 120 percent of full supply (or design) discharge. Within this range, the Open Flumes deliver (when installed correctly) the exact proportion of their design discharge as on which the distributary is operated, while the APM function proportionally for small fluctuations around full supply, while delivering closer to design discharge under larger fluctuations.’²⁸

In 1944, Open Flume and APM outlets covered 67 percent of all outlets in the Punjab²⁹; the simple and robust devices could be constructed at relatively low cost and required minimal hydraulic heads. This last property made them highly suitable in the flat areas of Punjab and Sindh and may have been a reason why De Gruyter selected the Crump APM to modify for Java; the new engineering systems of the late 19th and early 20th century were mainly located in the flat coastal plains of Java.

No proof of the pudding...

De Gruyter proposed this structure in 1925 in an extensive overview of possible discharge measurement structures.

‘This type [...] is a hotch-potch of the broad crested weir, the regular sluice and the Venturi-flume. It possesses such particularly suited qualities, that in my view it is the most ideal type by far.’³⁰

De Gruyter was not completely satisfied with the way Crump had discussed the hydraulic properties of the structure; nevertheless, with his own discussion of the structure he had good hope

‘to convince the reader about the eminent properties of this construction’³¹

He proposed to experiment with the structure. De Gruyter discussed the suitability of the Crump-de Gruyter sluice using the example of the Kandanghauer secondary canal in the Tjipoenegara works, which we will encounter in Chapter five. Originally standard gated pipes with Cipoletti weirs were selected for secondary discharge regulation and measurement in this system. Lowering head losses would increase the irrigable area and De Gruyter proposed to use his discovery. As we will discover later, Venturimeters were finally employed and De Gruyter had to look for other options. When given the opportunity to experiment with his structure in the Irrigation Department Tjimanoeck, he provided an extensive description of the structure, especially its hydraulic behavior; the experiments had shown him that the structure was even better than he had thought before! Nevertheless, the apple of his eye was never really considered by his peers from civil engineering as the breakthrough for colonial irrigation on Java. It is very likely that the way the structure was introduced in the debate has influenced its success; De Gruyter could not show results from Javanese irrigation practice, he proposed a structure based on theoretical considerations. This experimental status was hard to overcome in the practice oriented network of civil irrigation engineers, as De Gruyter himself acknowledges.

‘The writer fully acknowledges the general need, before importing new constructions, not to take chances, not to ban the old before the new has sufficiently proven in practice to possess bigger advantages than the old.’³²

But he continued somewhat disappointed

‘[n]evertheless one should still give the new a chance and this can only be achieved by constructing it.’³³

Apart from the experimental status of the structure, there were some considerations, which made it less appropriate for discharge measurement in tertiary canals, the main places of application. An imperfection of the Crump-De Gruyter structure was the complicated water measurement: two scales had to be read and readings had to be converted using a table. Furthermore, energy head loss over the structure was still considerable, especially with lower discharges. The structure could be operated with lower head loss and thus with higher downstream water levels, but this would decrease the measuring range. Maintenance put great demands on exploitation: it was an expensive structure in daily practice.

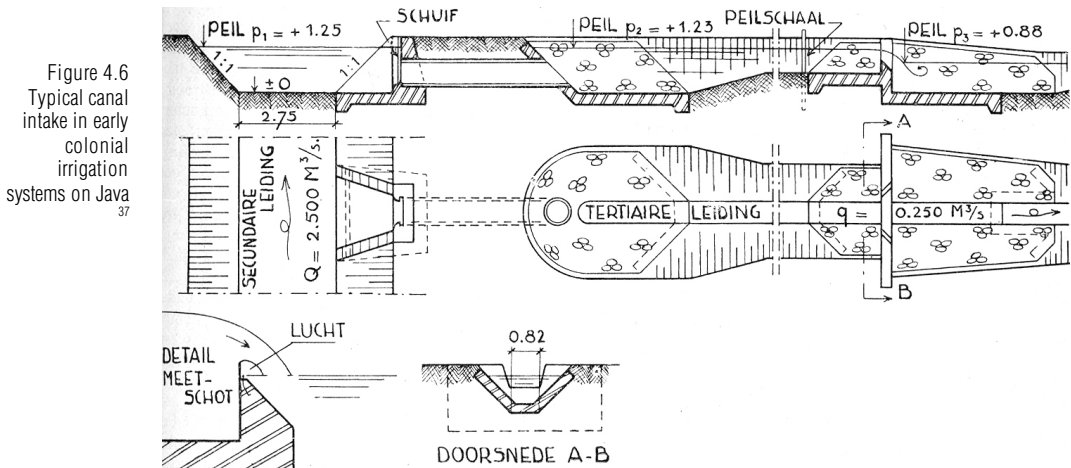
‘As such, this sluice type combines relatively low construction costs with relatively high exploitation costs’³⁴

Especially the head loss of structures was a major point of attention for the selection of discharge measurement structures, as the lowlands areas of Java have little natural head loss available. One of the structure's main advantages was that decreasing downstream water levels did not increase the flow through the structure. Farmers could not manipulate flows by changing their canals. Furthermore, an increase in downstream water levels, for example due to silting caused by insufficient maintenance, decreased the flow through the structure. This was considered positive, as it would encourage farmers to maintain their irrigation canals!

Water measurement and discharge on Java

It goes without saying that the Dutch engineers had measured water for a longer time before the 1920s; measuring water started in the early 19th century. Until deep in the 20th century, the most common measuring structures were Cipoletti and Thomson measuring structures. These devices were easily relocated and accurate, but sensitive for silting and required a relatively large energy head. They were usually employed when flows to the sugar cane fields had to be determined, as water distributed to sugar cane was measured just before the water entered the field(s)³⁵. In many cases, however, permanent Cipoletti weirs were placed in the canal downstream of the intake (Figure 4.6).

‘Although this position does have its advantages, it cannot be denied that as one of its largest disadvantages the increase in head loss in the canal needs to be mentioned.’³⁶



The head loss of the Cipoletti weir added to the already existing head loss of the intake structure. It is therefore not surprising that in many irrigation systems engineers did not use structures at all; instead they measured the velocity of the flow with a floating device in a straight canal section. By multiplying velocity and the surface of the canal profile the discharge was found. Both the 1924 and 1931 editions of the popular

irrigation design handbook of Van Maanen include descriptions of floaters. Floaters required a relatively high labor input; another disadvantage was the need to recalculate canal profiles regularly³⁸. To overcome the disadvantages of available structures and the floater method, the Dutch engineers looked for other possibilities.

'It has again become very clear in the past year, that proper water distribution is not well possible with floaters and results in water shortages on the one hand and water spillage on the other, all as circumstances may be. Thus, replacing floaters with measuring devices must be referred to as urgent.'³⁹

In the Pekalen system, Lamminga developed one of the first permanent control structures to discharge and measure water from secondary into tertiary canals (Figure 4.7), a type very similar to the modern American constant head orifice⁴⁰.

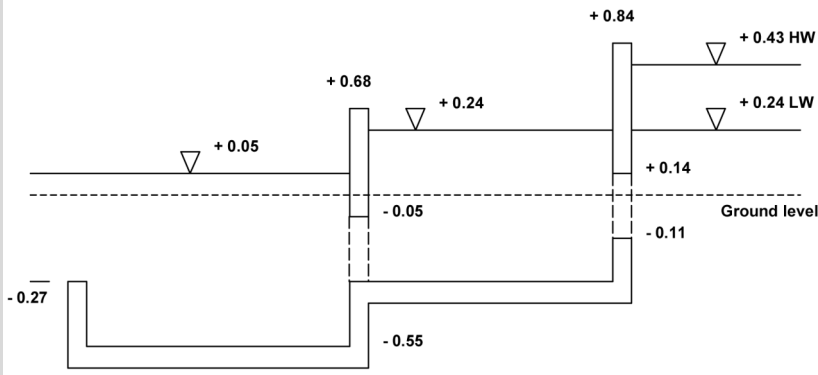
'The idea was to design the discharge sluices in such a way, that the quantity of water, which is supplied to each tertiary canal, could be measured accurately; for this it was necessary to calibrate the measuring sluices. Based on this calibration, the supplied quantity of water could be registered immediately for every position of the gate at later moments.'⁴¹

Although the necessary calibration had started, it was not pushed through. One reason was that water distribution remained based on the needs as formulated by the farmers themselves; accurately determined crop requirements were not available, so why measure exactly? Another reason was that good calibration required stable tertiary canal profiles. Despite a wall-like structure to maintain the canal profile immediately downstream of the structure, however, the tertiary canals in the Pekalen system eroded quite heavily. In 1905 Lamminga admitted that the structure was not to be recommended; he himself had never employed the type again either.

'Free-flowing weirs perform better as measuring device'⁴²

The original Pekalen structure could be adapted by removing the lower gate and construct a weir instead⁴³. Although Lamminga's discharge measurement structure may have been a failure, it did combine for the first time in the East Indies the ability to discharge and measure water in one structure. In the Pemali system, Lamminga did not design a discharge measurement structure; he used gated pipe intakes for discharge control⁴⁴. Measuring water with structures was not perceived as feasible in the short term anyway around 1900⁴⁵; however, weekly floater measurements were still normal practice in Pemali some 20 years later⁴⁶. In a document probably from the early 1930s, experiments with several measuring devices in the Pemali system are discussed. This indicates that standard measuring structures were not used in Pemali at that time yet. The devices tested were the Cipoletti weir, Venturimeter, broad crested weir and Crump de Gruyter gate (see Table 4.2)⁴⁷.

Figure 4.7 The control structure designed by Lamminga in Pekalen⁴⁸



(Side view cross section) 'In a two-stone wall, which separates the little sluice from the secondary canal a gate opening is spared, through which the water enters a tank, which on the lower end again is closed with a two-stone wall, in which again a gate opening is placed; through this the water flows in a second tank and from this in the tertiary canal. In the upper tank a constant water level is maintained; the water level in the lower tank determines the amount of water discharged. It is clear that through manoeuvring with both gates the constant water level in the upper tank can be reached independently from what the water level in the secondary canal will be or which amount is tapped for the tertiary canal. The advantage of this constant water level is that an operation can be determined for the position of the lower gate which is always valid for the different discharges of the tertiary canal.' (p154) 'The right discharge into the tertiary canal] is arranged by giving the lower wall of the lower tank the cross section of the canal and to build a second little brick wall with the canal cross section at 10 m downstream of the tank wall, which also gives the right slope to the canal.' (p. 155) 'The locations of the gate openings are designed such that at the lowest water level [LW] in the secondary canal they stay with their upper edge still 10 cm under the water; this is mainly done to distract the gates from the sight of the village youth of Madura, which otherwise could easily be tempted to let herself go on these.' (p. 155)

After the occasional discussion in the engineering journals⁴⁹, the introduction of the Venturimeter (Figure 4.8) was the first breakthrough in terms of standardization of discharge measurement structures in the East Indies. Dutch irrigation engineer S.H.A. Begemann introduced the Venturi structure in the Penewon area in 1923 (Brantas region)⁵⁰. Venturis were known in the Netherlands East Indies, but only as measuring devices in closed conduits for drinking water. In British India and the U.S.A., Venturis had been used with satisfactory results⁵¹. The Venturis became quite popular on Java, as they combined discharge and measurement in one structure; furthermore a Venturi structure was accurate and required only a small head loss.

Type of structure	Description	Remarks
Cipoletti	Sharp-crested weir. Not adjustable. Can be moved. Developed by Cipoletti in the 1880's.	The structure is easily movable to other locations in the system, and was used to measure the flow to the sugar cane fields (which changed over seasons)
Crump-De Gruyter	Short-throated flume with gate. Adjustable. Modification of an originally British-Indian structure of Crump by Dutch engineer De Gruyter in the 1920's.	
Constant Head Orifice	Combination of an adjustable submerged orifice and an adjustable turnout. Developed by the United Bureau of Reclamation.	Lamminga designed a comparable structure in the Pekalen-area in the 1890's.
Venturi	Flume with sub-critical flow. Based on studies by Italian Venturi around 1800.	Introduced in Java by Begemann.
Romijn	Broad-crested weir. Adjustable. Developed in the Netherlands East Indies in the 1920's and 1930's.	An adapted version (Hobrad) is in use in the Netherlands nowadays

Table 4.2
Discharge
measurement
structures on
Java

‘Perhaps one may point to the possibility that in cases, when an assumed irrigation level in a tertiary canal appears to be taken about 20 cm too low, this problem can be repaired with very low costs by replacing the Cipoletti measuring weir with a Venturi meter (reconstruction of the intake).’⁵²

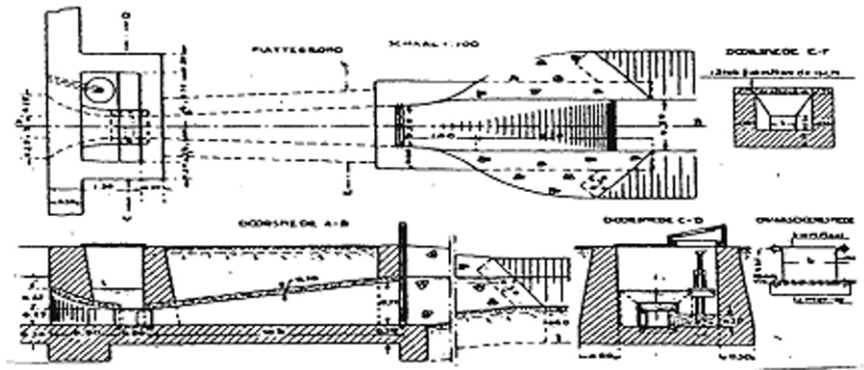


Figure 4.8
Venturi
discharge
measurement
structure⁵³

From the second half of the 1920s onwards, Venturi structures appear to have become a popular discharge measurement structure in new irrigation systems, sometimes in existing schemes as well. In the Krawang system, on West-Java, Venturi structures were built; in Demak, Venturi structures gradually replaced existing structures, with such success that the same was planned for the whole Serang Irrigation Department

‘to replace successively the improperly functioning measuring devices with Venturi meters [..].’⁵⁴

The popularity of the Venturi did not mean that the discussion stopped, as reports in the 1930s documenting experiments with different measuring devices, including older ones like floaters and Cipolettis, show⁵⁵. Continuing preference for Cipoletti weirs in

new irrigation systems was probably caused by certain objections to the Venturi⁵⁶. First, it had a relatively small measuring range: the structure could only measure a relatively small range of flows accurately, although one could put it a bit less diplomatic.

‘For smaller discharges readings become completely unreliable.’⁵⁷

The small measuring range was a problem on Java, with its large differences in available water flows and actual flow requirements between East and West Monsoons. For Venturis, the range was even more problematic as readings were in millimeters instead of centimeters like other devices; this caused an increase of

‘the unavoidable casual reading error for decreasing discharges in a more pronounced way [...] than for Cipoletti measuring weirs [...]’⁵⁸

To overcome the small measuring range, the option to construct two small Venturis next to each other instead of one bigger one was discussed; this gave the possibility to close one of the structures when low discharges were passing⁵⁹. This gave satisfactory results, but it also made the structure more expensive⁶⁰. The second disadvantage received more attention: a Venturimeter is not a modular structure; the water flow through the structure depends on the tail water level. In other words, activities below the structure are of influence.

‘Once the sluice has been set at a certain discharge, an interested party can enlarge the passing discharge considerably by lowering the level in the tertiary canal.’⁶¹

This potential influence of interested parties, being farmers or sugar factories, was not acceptable to the colonial authorities. Vlugter proposed application of a metal flap with its rotating point close to the bottom of the canal at the tail of the venture; experiments in controlled laboratory circumstances showed that constructing the flap did improve the modularity of the structure, as long as

‘one does give the concept **modularity** not too narrow a meaning’⁶²

The flap was moved with a chain.

‘A chain instead of a cable is applied on purpose, because there is grounded fear that the malevolent desa inhabitant would cut the cable thread by thread, for which a chain gives no opportunity.’⁶³

The construction was tested for smaller Venturis, as the full water load on the chain would probably become too high for bigger ones. Other disadvantages included high maintenance requirements with a rotating point under water and the possibility for the Javanese farmers to manipulate the flap with the chain⁶⁴. Another comment on the Venturimeter concerned the irrigation personnel involved.

‘Applying more modern measuring devices in their current stage of development requires good insights from all personnel working with them. It cannot come from

the engineers alone, as particularly the supervisors gain daily experience and must gain this 'intelligently' to reap the fruits. Working according to prescription is only possible when applying technically perfect constructions.' ⁶⁵

The solution was proposed immediately.

'However, in the group of supervisors the correct ideas about the functioning of the devices not always rule either and it may be allowed in this context to point to the desirability, if not the necessity, to start lessons in which these matters can be dealt with extensively.' ⁶⁶

This must have been enough reason for the Director of Public Works in those days to consider the improved Venturi not suitable as formal standard discharge measurement structure for the East Indian Department of Public Works ⁶⁷.

Romijn or Verwoerd weir?

Another potential improvement of the Venturi was better received ⁶⁸; engineer Verwoerd proposed to provide the Venturi with a movable weir at the downstream side (Figure 4.9) ⁶⁹. The weir consisted of two parts: the lower part, a flat gate, could be opened to flush sediments; the upper part included a broad crested weir and was used to regulate the flow. The Demak measuring report of 1931 ⁷⁰ was too early to include measurement results of the device, but it already included a clear perspective on the applicability of the structure.

'The curious thing is, however, that applying overflow gates makes the complete Venturi meter obsolete, as with these overflow gates one can measure at the same time [...]' ⁷¹

Just applying the single weir promised to give an excellent measuring range with a low head loss! A handwritten comment ⁷² already points to the successful tests which Romijn would present in the 'Waterstaatsingenieur' in 1932. The same comment defines some points for improvement of the weir, but concludes almost lyrically that

'[t]his measuring device promises much success, because it is simple, cheap and sufficiently accurate!' ⁷³

Before results with the gate proposed by Verwoerd were available, another candidate was presented ⁷⁴. The new structure was an orifice gate, somewhat comparable to the Crump de Gruyter; its proposer, Vlugter, had tested several alternative shapes of the gate, including a version which included the Verwoerd gate. In his article Vlugter provided argumentation why the devices available so far were insufficient; his own invention would overcome all the problems. In a comment, engineer Verschoor challenged the conclusions of Vlugter. Basically, the two only agreed on the difficulty to apply Crump de Gruyter devices en Venturis. Verschoor also objected to the focus on small head losses. In new systems quite often some adaptations in leveling of fields

‘design a simpler device, suitable in case of small head loss too and with a large measuring range, but which would not show the objections referred to.’⁷⁸

Designing the new structure (Figure 4.10), however, apparently was not too difficult, as Romijn himself points out.

‘The overflow weir [...] only differs from the one already described in this journal in the sense that a broader and rounded upper sheet has been applied and that the screw bar is fastened in such a way that it does not disturb the water movement.’⁷⁹

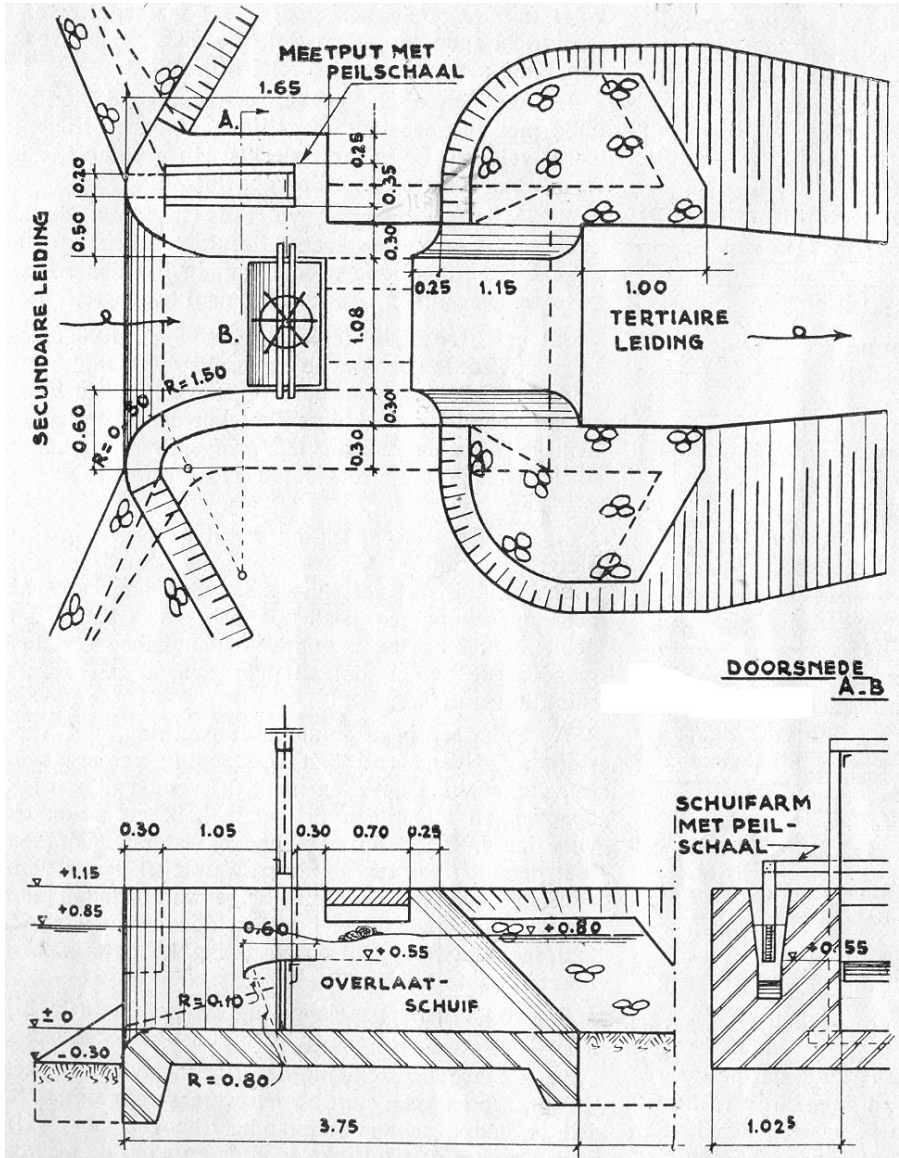


Figure 4.10
Drawing of the
Romijn weir⁸⁰

In other words, Romijn had adapted the Verwoerd gate slightly; he does not mention or refer to Verwoerd directly though. The biggest advantage of the new gate was that only one variable had to be determined: the water level above the crest of the weir H ⁸¹. This follows from the discharge formula for a broad crested weir⁸², as it reads

$$Q = m \cdot b \cdot d \{g \cdot d\}^{1/2}$$

In which $m = 1$, $d = 2/3 H$ and $H =$ ‘de hoogte van den ongedaalden waterspiegel boven de kruin’ (Romijn 1932; p. 287) (*the height of the unlowered water level above the crest*). This formula can be rewritten as

$$Q = 3.13 \cdot b \cdot d^{3/2}$$

or

$$Q = 1.70 \cdot b \cdot H^{3/2}$$

Furthermore, daily use of the structure was relatively easy. It was just a matter of moving the top-gate with the weir attached to it up or down.

‘[...] this is one of the outstanding attractions of the whole.’⁸³

For a detailed discussion on the advantages and disadvantages of the gate, Romijn directly related his work to the work of Vlugter published one year before. The support of Vlugter was acknowledged, as he had provided Romijn with the opportunity to test the gate in the hydraulic laboratory of Semarang. When he discussed the advantages of the new weir, Romijn also acknowledged the discussion by Vlugter on the other structures available; Romijn presented his structure as a better answer to the problems associated with these structures than the device proposed by Vlugter.⁸⁴ After some considerations on the head losses and measuring accuracy, especially the number of measurements needed, Romijn concludes that

‘with the device with constant inflow velocity [the structure proposed by Vlugter] accurate measurement will be possible, but it is unlikely that this will indeed happen. Precisely opposite is the matter for the overflow weir [the one proposed by Verwoerd and tested by Romijn].’⁸⁵

The overflow gate proposed by Romijn was sensitive to changes in upstream water levels, expressed in factor H .

‘Therefore it is highly desirable to apply sensitive water level devices in combination with measurement overflows, e.g. similar overflows, broad stop log openings or sensitive flap gates and than this large sensitivity has the advantage that changes in the level of the conveying canal are stabilized.’⁸⁶

All in all, Romijn considered the structure as the most appropriate answer for engineering irrigation systems; in Javanese systems the sensitivity of the weir might cause problems, as up- and downstream water levels in these systems could not be controlled. He was not the only one to be enthusiastic about the weir; the structure was generally considered as the answer to the most important design demands for a new structure⁸⁷: it could discharge and measure water, had a small head loss and a good sensitivity, it was relatively easy to construct and easy to manage. An extra advantage was that even in situations in which upstream and downstream water levels are almost equal, a so-called drowned situation, the structure functioned quite well. In practice this meant that downstream effects on water levels hardly influenced the structures discharge, which made it semi-modular. In irrigation systems of the late 1930s, like the Tangerang system on Java and the Sadang system on Sulawesi, Romijn weirs were the standard division structure. Furthermore, we will see in later chapters that the Romijn weir has become one of the symbols of Dutch irrigation technology. It fitted perfectly within the broader goals set earlier; it also performed convincingly in practice.

‘The sluices always perform well.’⁸⁸

Closure

The development process in which the Romijn weir has come to the front to become a main symbol of closure in Javanese colonial irrigation has not been an organized research program, a deliberate, planned process of development. The general water management context may have been uncontested; other goals remained under discussion, for example the need to stress low available head or to minimize head losses. There was no fixed budget, but rather a gradual evolution of individual attempts and measurement programs in irrigation schemes like Pemali and Demak, discussed in engineering periodicals and other publications. The final solution may have been tested in the hydraulic laboratory of Semarang, but had been proposed originally as a potential solution for a problem associated with Venturimeters in daily water distribution practice. Up to the end of the debate, the perceived inventor of the final solution himself kept a careful approach to the issue of selecting an appropriate discharge measurement structure. For new irrigation systems, Romijn considered his weir⁸⁹ the best option; in cases with higher available head loss, even in case of drop structures, he advised to select the Romijn weir⁹⁰ too. In other cases, however, for example in less controllable irrigation areas, he advised to use Venturimeters. When a constant discharge was needed, a Crump-de Gruyter would be the best choice⁹¹.

Despite all the nuances of Romijn himself, one particular advantage of the Romijn weir, not unwelcome in the Netherlands East Indies, was the potential to standardize water distribution in technical sense. The structure could be used in situations with larger and smaller flows and larger or lower available energy heads.

‘As a result, in each new area only one type of measuring device can be applied in a single management unit, which next to simple operation and setting is very important with the eye on the development level of the lower personnel responsible for supervision.’⁹²

Another long-existing wish for standardizing water management on Java had not been realized yet. When Romijn published his results in 1932, there was still no generally applicable legal base for water regulations on Java. When he discussed discharge measurement structures in his 1938 publication, the situation had changed, as the General Water Regulation had been published in 1936.

Linking policies, regulations and measurement

As Chapters two, three and four showed, differences in agrarian policies of the colonial powers are vital to explain differences in irrigation approaches between colonies. In a reconstruction of the processes in which policies, management approaches and artifacts were contested and developed, I argued that guiding principles and design requirements were formulated relatively early, whereas the artifacts, defined as both water regulations and water structures showed continuous development over time. Closure, understood as disappearance of interpretative flexibility between social groups, of principles and requirements for colonial irrigation management occurred much earlier than stabilization, understood as agreement within the single social group of engineers of the artifacts required to achieve principles and requirements. This also illustrates that different debates in different colonial circles involving social groups like engineers, politicians, general public did not necessarily coincide; debates on one issue or within one specific arena or community did not always influence debates in another ones.

The most important founding element in Dutch colonial irrigation, in regime terms the main guiding principle, was the co-existence of food and commercial crops, rice grown by peasants and sugar cane by the industry, in the same irrigated area. This has been the case from the Cultivation System onwards; associated with this co-existence was the colonial optimization approach based on the value of crop productivity per unit of land. Consequently, the need for adjustable water control was agreed upon, or in other words the design requirement was socially constructed; to realize such control two types of artifacts were needed: management regulations and structures. With the new wave of political debate developed in the first years of the 20th century, colonial policies including water distribution between commercial and food crops were heavily discussed. The relation between sugar cane and rice remained on the agenda up to the 1930s, but their co-existence itself was not discussed. What had been stabilized in the early colonial period was not re-opened again. Thus, new social groups may have entered the arena in which elements of irrigation in the Netherlands East Indies were debated, for example the agricultural engineers, but the political aspects had had its

influence already; the agricultural context which was translated in guiding principles and design requirements of Dutch colonial irrigation had been set in the Cultivation System.

What did remain was the interpretative flexibility on the shape of water regulations; debates on the distribution principles between sugar cane and rice included many options for proper and just water management. The day-and-night-regulation was heavily debated upon. Nevertheless, despite these debates and although many other social groups were closely involved in the debate on colonial water distribution regulations, stability was reached with the final General Water Regulation for Java of 1936 basically through a copy of the Pemali regulation initiated by Lamminga around 1900 and detailed by Numans around 1910. I showed that within the engineering community the opinions on the best water regulation were divided and that others, particularly civil servants, were usually involved in the development of regulations. Nevertheless, I would argue that concerning management aspects of irrigation the influence of engineers has been pretty strong if not dominant in the Netherlands East Indies.

For the technical side of irrigation development, like design of discharge measurement structures, engineers would be the logical social group to dominate. The irrigation engineering community was a thriving community in the sense that discussion was stimulated; many subjects were included in journals, books and presentations. The guiding principles, however, were not contested: the discussions were always about how to realize certain principles, not why these principles should be realized. Based on the guiding principles, Dutch engineers proposed structures to regulate and measure discharges within irrigation systems. Approaches and methods developed between 1885 and 1910 in the context of the first General Irrigation Plan formed a stable foundation on which a new generation of engineers could enrich the Dutch irrigation tradition after 1920 with new artifacts. For discharge regulation and measurement artifacts, stabilization came in the 1930s, when Romijn could present the answer to the question how to discharge and measure simultaneously without large head losses. This 'final answer', however, started as a proposal of Verwoerd to adapt the Venturi to make it a modular structure. It would never see the light as the Verwoerd weir. The structure became famous under the name of its researcher Romijn; its proposer Verwoerd is forgotten

In the East Indies the proof of the pudding was in the eating: irrigation systems served as a kind of niches⁹³ in which new approaches were developed. For discharge measurement structures the importance of practice has become clear in the case of De Gruyter, who could not show results from irrigation practice on Java with his modified Crump flume; he proposed the structure based on theoretical considerations. This singular theoretical basis was hard to overcome in the practice oriented network of civil irrigation engineers, as De Gruyter himself acknowledged. Begemann proposed the Venturi structure based on his own trials and experiences in a Javanese irrigation

system, and it became a success. Venturis were already known as well, although not in irrigation as such. Problems raised in practice with the dominant Venturi structures, in particular on the modular behavior of the structure, resulted in the Romijn weir. Already before test results from the hydraulic laboratory were available, it was recognized that the improvement in the shape of the downstream overflow weir proposed by Verwoerd could very well function as a discharge measurement structure on its own. Laboratory research acknowledged the suitability of the improvement; hydraulic research was not the starting point of improvements!

This importance of irrigation practice may explain as well why the influence of engineers was pretty strong concerning the management aspects of colonial irrigation too. Many regulations existed, which were usually designed by local and temporary coalitions of participants, including engineers, local governmental authorities and occasionally others. Nevertheless, the engineers were the stimulating force behind most regulations. After all, they and their Javanese staff were in charge of daily activities in Javanese irrigation systems. It was the engineers' responsibility to control and shape water distribution practices in irrigation.

5 A coherent organism

Irrigation design procedures

In a letter to the Director of Public Works, with an Explanatory Memorandum and seven annexes, dated December 27th 1922, the 'N.V. Ingenieurs Maatschap 'Eigen Beheer'" presented a design for a diversion structure in the Tjipoenegara river in West-Cheribon, Java¹. About five years later, on December 2nd 1927, the structure, Salamderma, was officially opened. Although the canal system was far from complete, from that moment Tjipoenegara water could be brought through the main and Andjatan canals to an existing water reservoir, sitoe Andjatan, irrigating some 5,000 bouw during the West Monsoon in the 1927/1928 season². These were the first results of governmental plans to irrigate former private lands from the three rivers Tjipoenegara, Tjimanoeck and Tjipanas, up to a total surface of almost 90,000 bouw³. The Tjipoenegara, or in modern spelling Cipunegara Irrigation System still exists today. Bendung (weir) Salamderma continues to derive water from the Cipunegara into the main canal and at Bugis the water is still distributed to secondary canals. The physical and management context, in which the system functions, however, has changed dramatically. With the construction of the East Tarum Canal in the last decades of the 19th century, the possibility to supplement the Cipunegara River just upstream of Salamderma with water coming from the Citarum river was realized. This canal and its brothers, or sisters, North and West Tarum Canal derive water from Waduk Jatiluhur, a multipurpose reservoir realized in the 1960s. A French contractor completed the Jatiluhur reservoir in 1967, but the plans for this extended water system were made by the Dutch engineer Van Blommestein⁴. The Cipunegara system has become part of the Satuan Wilaya Sungai Citarum, or Citarum River Basin.

I provide a rather detailed discussion of the Tjipoenegara irrigation system in this chapter, as its design history is quite representative for irrigation design in the Netherlands East Indies in general.⁵ The design process of this Tjipoenegara irrigation system (Figures 5.1, 5.2 and 5.3) can be roughly dated between 1920 and 1935. Analyzing the design timeframe sheds light on the question of regime construction and continuity, including the meaning of a series of quick changes, for example in water distribution structures available for designers, as we have seen in Chapter four. To determine the validity to conceptualize the period as a key timeframe, discussions on the design process in the Tjipoenegara area need to include the manner in which design approaches had developed before 1920. The Pekalen and Pemali cases will illustrate these earlier developments. A social construction perspective shapes my focus on

actions and discussions of colonial irrigation engineers in their respective professional circles: design team of the Maatschap, Irrigation Division Tjimanoeck and Department in Batavia. Most decisions appear to have been the responsibility of engineering circles alone and relate to regime categories of design requirements, design tools and artifacts.

Figure 5.1
Layout of the
Tjipoenegara
irrigation
system⁶

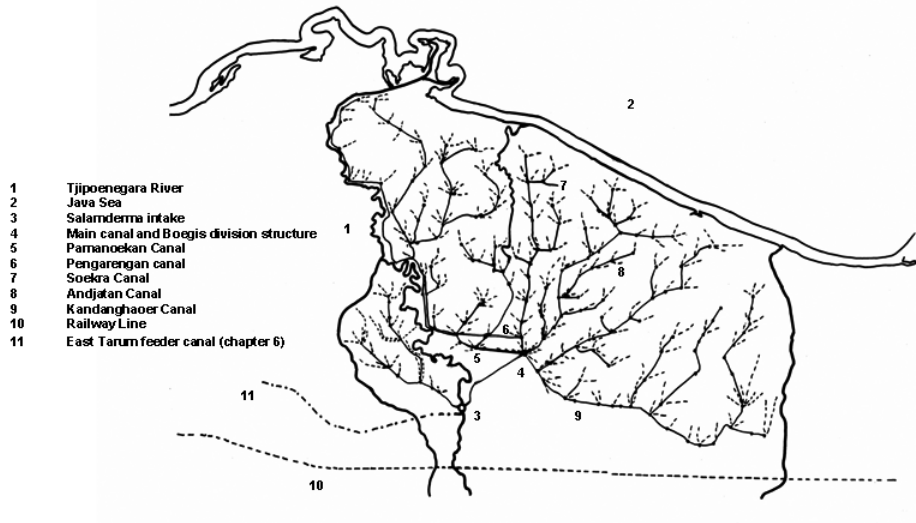


Figure 5.2 The
modern weir
Salamderma





Figure 5.3
A canal in the
modern
Tjipoenegara
irrigation area

Nigging

When designs and associated design documents were to be finalized in the Netherlands East Indies, the engineer designer sent the document to the Department of Public Works. In the Tjipoenegara case, the design engineers of the *Maatschap* sent documents to the Chief of the Irrigation Division Tjimanoeck or the special irrigation service of Public Works for the Krawang works, immediately to the west of the Tjipoenegara area. After approval, the documents would be sent to the Director of the Department of Public Works, who would ask for a Governmental Decision. Such a procedure was not always appreciated by engineers in the field.

‘The project was approved [by Public Works] but with the announcement that it had to be completely rewritten. [...] One of my engineers worked on it for half a year. [...] Another remark concerning that project was that in future I had to send such projects for approval in pencil first. [...] one was exceptionally surprised there that I reacted somewhat annoyed; one of the subordinated engineers even signified that actually all projects should be send in pencil to Batavia; probably to be nigged on by him.’⁷

Furthermore, a Governmental Decision (GD) did not necessarily mean that discussions on proposed designs were over; not all design decisions needed to be sanctioned in a GD. Many Tjipoenegara decisions, usually concerning smaller components or issues, were sanctioned in letters from either the Director of Public Works or the Head of Tjimanoeck. A number of decisions were discussed in meetings. Other decisions were discussed when governmental representatives visited the design area. Based on references from other East Indian design processes, including the Pekalen, Pemali and

Krawang systems, I conceptualize the Tjipoenegara irrigation design process as an iterative, but linear sequence of decisions: design decisions were made in a process roughly going from larger-scale –main works, major characteristics of the system like size, rough layout – to smaller-scale – secondary canals, layout of units, drainage. In successive later design documents, parts of the irrigation system were determined in more detail based on earlier decisions. Each successive step in the design process increased the finality of the design, corresponding with a decrease in freedom in the design as more design conditions were translated into set design components. The design space decreased throughout the process; although this could imply that decisions taken at an earlier stage were more important than those taken at a later stage, early decisions were adapted to a certain extent. Alterations in later design phases were possible, as long as alterations fitted earlier designs or allowed workable adaptations to earlier decisions. I discuss two basic clusters of decisions in this chapter: (1) size of the command area, water availability and location of intake; and (2) layout of canal grids and irrigation units. In Chapter six I will continue the discussion focusing on what design tools Dutch irrigation engineers used to design the irrigation and drainage canals. But before we move to the details, we have to learn a little bit of background of important actors involved in the Tjipoenegara design process.

“Eigen Beheer” and the Pamenoekan and Tjiassem Lands

The Tjipoenegara system was developed under the responsibility of the Department of Public Works, but the design was made by engineers from ‘N.V. Ingenieurs Maatschap ‘Eigen Beheer’. This private company was founded in 1917 with the aim

‘to execute works and all technical labor to be conducted, which is normally charged to an engineering firm, according to the system known in England and North America as “Cost plus percentage”, which is applied successfully under the name of “Kolonial Vertrag” system in Germany too.’⁸

On May 4th 1917, the Maatschap was registered with the Chamber of Commerce in The Hague⁹. The Maatschap presented itself as an expert to execute technical work, including advice and research; furthermore it could act as delivery service of materials for the Netherlands East Indies¹⁰. Many of the shareholders involved in the Maatschap were important members of the Dutch-Indian engineering community (Table 5.1). The Maatschap emphasised its new approach to financial matters, reflected in the ‘cost plus percentage’ system¹¹; the Maatschap worked for a given percentage of the budget

‘as reimbursement of the general knowledgeable engagement of the Maatschap’¹²

Name	Position	Remarks
Ir. W. Elenbaas ¹⁴	Managing Director	Former Professor at Delft Polytechnic; former Head-Engineer of Public Works, Netherlands East Indies
Ir. J.C. Voorduin		Former Head-Engineer of Public Works, Netherlands East Indies
Ir. J. Homan van der Heide	Member of the board	Former Director of Public Works, Netherlands East Indies
Ir. Th.L.W. Steinmetz		Former president of the Management Committee of the ' <i>Ned.-Indische Spoorweg-Mij</i> '.
Ir. N. De Vicq	Member	Former Head-Engineer, Head of ' <i>Stoomwezen</i> '
Ir. R.H. Bloemendal		Former Administrator of the ' <i>Ned.-Indische Tramweg-Mij</i> '
Ir. J. Haringhuizen		Former Head-Engineer of Public Works, Netherlands East Indies; lecturer at the ' <i>Rijks Hogere Land-, Tuin- en Boschbouwschool</i> ' te Wageningen
Ir. J.W. van Marle		Former Engineer of Public Works, Netherlands East Indies
Ir. G.J. Meijers		Advising Engineer in Amsterdam
Jhr. Ir. R.R.L. de Muralt		Former Engineer of ' <i>Schouwen</i> '; member of Parliament
Ir. H. Polano		Advising Engineer, Engineering Firm Cramer & Polano at The Hague
W.G.J. Vogelpoel		Former Governmental Delegate at the ' <i>Droogdok-Mij. Tandjong-Priok</i> '; former Head of Dredging Material of Public Works, Netherlands East Indies

Table 5.1
Members of N.V.
Maatschap
'Eigen Beheer'¹³

The Maatschap did not last long; on May 30th 1934 'Eigen Beheer' was dissolved¹⁵. The history of the Maatschap appears to be closely connected with the history of the Tjipoenegara irrigation system. Whatever its life cycle or background, the involvement of a Maatschap was not common on Java. This does not mean that the Tjipoenegara design differs from other irrigation system designs in the Netherlands East Indies. In a way, involvement of the Maatschap may improve the suitability of the Tjipoenegara case for my specific research purpose! In documents written by representatives of the Maatschap, explicit reference is made to a large variety of rules, decisions and options available in the Dutch-Indies irrigation design arena. It is not unlikely that this explicitness was particularly necessary to defend the work of the Maatschap in interactions between Maatschap, Department of Public Works and government. The influence of the Department appears to be strong. For example, originally the Maatschap held office in Cheribon; on July 1st 1926 the office was moved to Poerwakarta,

'in accordance with the intentions of the Director of Public Works'.¹⁶

The Tjipoenegara or Poenegara river, as 'tji' means 'river', has a catchment of about 1,500 square kilometers and a length of approximately 100 kilometers¹⁷. As many Javanese rivers, it has a mountainous headwater region and an extended coastal plain. The largest part of the Tjipoenegara irrigation system was to be located east of the river on governmental lands, with a smaller part west of the Tjipoenegara. Most of this western area was private property of the Pamenoekean and Tjiassem Lands, the largest privately owned area in Java¹⁸. The Lands are enclosed by natural boundaries: the Java

Sea on the north, the mountains that form the northern boundary of the Preanger Residency to the south, the Tjipoenegara in the east and the Tjilamaja in the west. The river Tjiasem marks the dividing line between the P and T parts. The extent of the combined properties was some 300,000 bouw, with some 250,000 inhabitants around 1915, including 99 Europeans and 747 'Vreemde Oosterlingen' ('Foreign Easterners')¹⁹. The Lands were pretty famous, as wealthy families once owned them; nevertheless, living there was not easy. As an observer notes:

'Once established on the P&T-lands, one has to let go hope to get away from there often. After all, the journey is horrifying!'²⁰

In 1910, despite occasional discussions to bring the P&T-lands back under government property, the lands were sold to the English Anglo-Dutch Java United Plantations Ltd for seven million guilders²¹. On June 26th 1914, however, the government issued a decree that it intended to resume the ownership of part of the Lands. The areas to be expropriated included both land already cultivated by the population and uncultivated land, which could be used to expand the first category or to be reforested to protect regional water supply. Issues to be settled between the P&T Lands and the government were the delineation of the areas that were left to the private property and the price to be paid for the expropriated parts. In 1914, a committee was installed; it started in 1916 to value the property of the Lands and propose an arrangement. The committee proposed to bring some 200,000 bouw of the P&T Lands under government property. When in 1922 the government announced the plans to construct the Tjipoenegara irrigation system, it was agreed that the P&T Company would participate in the project. It would pay a share in the expense of the dam; in exchange it could irrigate part of its lands within the new scheme, up to some 20,000 acres. These areas were located on the eastern side of the P&T Lands, in Blocks 26 and 28 of the new irrigation system.

In 1926, an agreement between the government and the P&T Company was reached, according to which the P&T Lands could claim 30% of the available irrigation water from the Tjipoenegara. For the period during which the system was not yet completed, the Company had to pay an annual installment on its share of the cost. The construction of Salamderma weir took some years; the Company could not proceed with their part of the work until the dam was completed. With the completion of the dam, however, development of the Blocks 26 and 28 became imperative, as the contract with the Government required the Company to bring the area under irrigation within a certain number of years after the dam's completion; otherwise it must forfeit the right to the water for the incomplete area²². The P&T eastern blocks became the Soekanagara Estate; in 1940 the Estate counted some 22,000 acres of paddy. The irrigated area

'which was absolutely flat and divided only by the irrigation canals, provided a wonderful sight when the paddy was ripening, glinting like a golden sea as the gentle tropical breeze rippled the surface of the paddy in successive waves.'²³

Although the P&T Lands played a significant role in the general development history of the Tjipoenegara area, its influence on the design approach of the modern irrigation system was not significant. Its irrigated area was separated from the main irrigated area and the P&T Lands were supposed to develop their own area.

Irrigation standards in the Netherlands East Indies

In the governmental area, the Dutch engineers from the Maatschap designed a system according to the standards expected in the Netherlands East Indies of those days. When starting the research and preliminary design activities, the engineers of the Maatschap encountered what they called unreclaimed terrain. The area was rather rain-dependent than irrigated. Although local water reservoirs, *sitoes*, were present, filling them was only possible irregularly. Drainage canals, often small streams, were occasionally blocked to bring water to fields nearby. Large terrains changed into swamps in rainy periods; many swampy areas fell dry in dry East Monsoon periods only. Although frequent inundations were a cause for lower harvests, harvest losses as a consequence of water scarcity were considered of much more importance. The area was not densely populated; especially in the first years, work progress remained behind schedule due to a lack of workers. The new irrigated lands were considered a colonization area, bringing new opportunities for many immigrants.

In the first half of the 19th century, Dutch colonial engineering irrigation design focused on constructing head works, like weirs and main canals; gradually engineering attention moved to designing complete irrigation systems at the end of the 19th century. As such, engineers had to deal with a growing number of related issues, from stability of intakes to ways of delivering water to fields. With main design activities taking place in the 1920s and early 1930s, the Tjipoenegara design process could incorporate experiences and lessons from earlier designs. This is reflected by several remarks made in the design reports. For example, the reports regularly mention that the design was made in accordance with the Krawang works or that the Head Engineer of Krawang agreed with the proposed design; the Head Engineer of the Krawang works was one of the representatives of the Public Works Department who had to agree with the designs made by the Maatschap. The Krawang works, with an irrigable surface of over 100,000 *bouw* located immediately west of the Tjipoenegara area, were opened officially in November 1925²⁴, when main intake and part of the main system were ready; completion of the works took up to 1936²⁵. A document dated April 7th 1928 entitled 'Basic rules for designing canals and structures' ²⁶ provides information on the types of issues, which had to be taken into account when designing an irrigation system (Table 5.2). The document contains the guidelines for designers of the Krawang system²⁷; the guidelines were applied in the Tjipoenegara design process too.

Table 5.2
Design
guidelines in
the Krawang
system²⁸

Subject*	General guideline
<i>Water requirement</i>	1.25 liter per second per bouw (l/s/b) for Tjitarong-area soil conditions, no decrease in water requirement in units above 200 bouw, sugar cane was not expected. 1.0 l/s/b in the Tjitaroem-Tjilamaja-area, decrease in water requirement in units above 1,000 bouw with 20%, as sugar cane was expected. Units below 200 bouw need a higher canal capacity; use the formula $(3x + 100)(3y - 2) = 700$, in which x = number of bouw and y = canal capacity in m ³ /s. For a unit of 200 bouw, $y = 1$.
<i>Irrigation canals</i>	Tables are provided in which the dimensions of canals are defined, showing (1) the relation between parameters Q (flow), side slopes in m/m and the ratio between canal bed width and water level; and (2) between water level and freeboard. Guidelines for widths of crest embankments in relation to canal type and need of roads on the crest Canals to be calculated using the Chezy formula and the new coefficient of Bazin Mean water velocity in tertiary canals between 0.25 – 0.40 m/s, in secondary canals between 0.50 – 0.70 m/s
<i>Structures</i>	Crest of drop structures at bed level of upstream canal, width of the crest equals bed width of upstream canal. Use stoplogs to maintain upstream water level. Head losses in pipe and sluice structures to be calculated using the Darcy formula. Calculation of sluices using the formula $Q = \mu F (2gh)^{1/2}$ (**) Sluices are to be closed using wooden or metal gates.
<i>Measuring structures</i>	All intakes are to be supplied with a measuring structure. In cases with sufficient head loss, Cipoletti sharp-crested weirs are used. For tertiary Cipoletti's 4 standard types are given. The crest of the weir is minimally 5 cm above the downstream water level. In cases with small available head losses, Venturi gates are used. For tertiary Venturis 3 standard types are given. Venturis of the Begemann-type as discussed in 'De Waterstaatsingenieur' 1924 No. 11 are preferred.
<i>Irrigation water level</i>	Water levels in tertiary canals are minimally 15 cm above field level; 5 cm head loss, resulting in a possible water height on the fields of 10 cm.

* Subject VI, Bridges, not included in the table.

** First factor difficult to read in the original document.

The Krawang works were not the first larger system on Java to be designed from scratch with a necessity to handle a larger number of issues simultaneously. Some 60 years before, around 1870, it was engineer Van Houten who presumably deserves the credits for being the first Dutch engineer to design a complete irrigation system based on extensive research in the Demak area²⁹. Engineer Lamminga, however, is credited as the one to establish the integrated approach.³⁰

'But that this example had to be followed in general, also for irrigation and drainage works of not such immense magnitudes as those mentioned last [Demak; ME], hereto indeed Lamminga has helped to settle the conviction with his Pekalen works, as one off the very successful first examples of its kind.'³¹

Lamminga himself gives all the credits to the Irrigation Brigade.

'This insight, viz. that it was necessary to treat the irrigation work as a whole, as a coherent organism, which cannot function properly when well functioning of all its components is not considered and assured, has given the push for erecting a

separate service for irrigation in 1885 with the reorganization of the Service for Public Works. Head of the service was Chief Engineer W.F. Heskes [...].³²

When the Irrigation Brigade was established, Lamminga worked in the Pekalen area. He had started his activities in the area as employee of the regional Public Works service, but awaiting the establishment of the Irrigation Brigade he was put under direct command of the Director of Public Works³³. 1885 can be set as the starting year of the Pekalen irrigation works, when referring to the first activities for a design of an overall irrigation system³⁴. Dutch civil servants and engineers had been active in the area long before that year though. Around 1850 an existing canal, the Taretta water course could not be used anymore; the new Kleenang canal was built including a new weir. The weir was flushed away by river floods regularly; in 1862 it was decided that the Pekalen River had to be blocked, becoming the Pekalen-lama; the new Pekalen-baroe was constructed³⁵. Apparently, all these structures were supervised by civil servants, as in 1877 help of the Department of Public Works was requested for the first time, when the water division between the Pekalen-baroe and the Kleenang canal had become difficult. Late 1878, a design for a masonry weir to regulate the division between the branches was made. After some discussion with the Director of Public Works, the design was approved. In November 1880, the structure, referred to as the big Pekalen weir, was ready. Meanwhile, another design was made for a similar problem with the Maron and Kleenang canals. Again the Director did not completely agree with the proposed design; he proposed to move the intake for the Maron canal. The Resident and the responsible engineer, however, objected to

‘any change in the existing situation’³⁶

and the weir, known as the small Pekalen or Maron weir, was constructed as designed. The damages to the big Pekalen weir in 1881 were reason for engineer Vredenberg to point out the problems of the existing situation. He proposed major changes in the division works, involving re-opening the Pekalen-lama applying a movable weir. Terrain measurements and research were necessary and these tasks were given to ‘adspirant-Ingenieur’ Lamminga in 1882³⁷. In August 1883, Lamminga presented a preliminary design for the improvement of both water division and drainage. A first problem Lamminga tackled was the water division, which was regulated through Javanese weirs (Figure 5.4), resulting in uncertain regulations

‘completely according to the arbitrariness of the native chiefs’.³⁸

Although generally water availability was good, certain parts of the area were regularly short on water; others would spill water. Flow velocities in canals were (too) high, which was caused by steep gradients and large flows during bandjirs. The right embankment of the Kleenang canal had almost collapsed. The capacity of the Pekalen-baroe was too small for diverting bandjirs and the big Pekalen weir did not function properly anyway. As a solution, Lamminga proposed to re-open the Pekalen-lama to

drain bandjirs over a new weir, to change the big Pekalen weir and to diminish the number of off-takes from the Kleenang canal – seventeen in total – with 50%. The plans were discussed throughout 1884, but given the upcoming re-organization of the Department of Public Works, major decisions were postponed. Nevertheless, in October 1884, Heskes came to study the situation in the Pekalen area. He concluded that only far-reaching interventions could bring the necessary improvements; in his view Lamminga had committed himself too much to the existing situation. In 1885, Lamminga could proceed with his measurements.

Figure 5.4
Example of a
Javanese weir³⁹



Foto No. 1. Dam Ngelo.

The Chief-Inspector of Cultivations, Sollewijn Gelpke, however, challenged the economic necessity of a new, extended irrigation system. The Government decided to continue, supporting the Director of Public Works who had argued earlier that further measurements and thus continuous activities were actually necessary to determine any economic necessity. In the meantime, Lamminga presented preliminary designs for the intake or prise d'eau, the first section of the main canal and the re-opening of the Pekalen-lama. He followed most recommendations made by Heskes and included the most recent results of his measurements. The Pekalen catchment was determined at 180 km²; the Pekalen River had a minimum flow of 4.8 m³/s in the East monsoon. Available flow in the West monsoon was set at 12 m³/s. The maximum design bandjir flow was set at 350 m³/s, with measurements showing a maximum of 318 m³/s. In 1886, the final designs were made. At December 1st 1889, most of the works were ready although a major bandjir in November 1889 caused some problems. This bandjir showed the relative inaccuracy of the peak flow calculations, as it was estimated at a discharge of about 550 m³/s from an effective catchment area of 169 km². The new prise d'eau was finalized in December 1891.

With the main works under construction, Lamminga made a preliminary design for the second part of the works in 1887, including the remaining sections of the main canal, a flushing sluice in the first section, preliminary connections of the new off-takes to existing canals and some other smaller works. The total gross command area included 14,156 bouw, with 4337 bouw used for villages, fishing ponds, roads, rivers etcetera.

The total irrigable area thus encompassed 9819 bouw: 6720 bouw sawah, 2795 bouw tegal (dryland) and 304 bouw djatti-forest. A total of about 1300 bouw was used for sugar cane cultivation. Research had shown that the mean water requirement for sawah land was 1.52 liters per second per bouw, enabling irrigation for 8,000 bouw of sawah in the West monsoon. This meant that in case all tegal and djatti areas would become sawah in a near future, a total of about 500 bouw sawah would have a water shortage. It was expected, however, that the areas occupied by villages and sugar cane would grow, as the local economy would grow because of the improved irrigation system. Redefining the limits of the irrigable area was considered unnecessary. In February 1892, the second part of the works was ready. The designs of this second part included a schematic overview of the routes of all irrigation and drainage canals, although the detailed designs of those canals would be made during the third part of the works. In June 1890, most designs for the third part were ready. One of the changes was the flow velocity in the secondary canals; instead of the maximum of 0.50 m/s in the second part, the velocity was enlarged to 1 m/s, as the soil was assumed to resist this velocity. This assumption considerably reduced the number of check weirs needed. After several years of exploitation, however, the assumed velocity proved to be too high resulting in scouring of some canals⁴⁰. The final designs were ready at the end of 1890. Construction of the works was finalized in December 1893.

Design procedures in the Pemali system

The Pekalen system can be considered as the experiential learning environment of Lamminga, as he did himself⁴¹; the bigger Pemali system in a much larger catchment area of 890 km² is generally considered his finest and major irrigation design, although Lamminga was not involved in the whole process⁴². As early as 1843, the Director of Cultivations ordered that measurements were needed for a canal west of the Pemali River. In 1851, Controller Sijthoff proposed constructing a canal for an irrigated area of 20,000 bouw. The same Controller presented a new design in 1855; it was approved of in 1861(!)⁴³. In 1863, a design by engineer Gast was presented, but this design was not realized either⁴⁴. In 1866 the Director of Public Works asked for a new design, a request which was repeated in 1876⁴⁵. In April 1882, the Resident of Tegal presented a new design, including maps, budget and detailed notes, made by the same engineer Gast⁴⁶. Gast proposed to relocate the intake in upstream direction, at a location with the name Pontjol, as this would require less head. Water availability, based on three years of measurements, was set at 35 m³/s in the West monsoon, which would have to irrigate 21,100 bouw. Water availability was set at 1.50 l/s/b, with water losses by evaporation and leakage estimated at 10%.

Despite the detailed plans (or perhaps due to), the project was postponed, as economic benefit through land taxes was not considered to be sufficient to cover the costs of the project. More urgent works had to be considered first. It was not until 1888 that new activities started in the region. New measurements were done and engineer Van Kol

presented a document in 1889⁴⁷. The Director of Public Works considered this document too much the result of estimation instead of design; he remarked also that it only covered the intake and main canal. In his view it was necessary to include much more. In 1891 Van Kol could show such a design⁴⁸. Van Kol proposed to relocate the intake even further upstream, enlarging the irrigable area from 21,000 bouw to 37,000 bouw. The intake was to be constructed at Notok, with the main canal branching off to the right bank with its easier terrain compared to the left bank. The main canal would have to cross the Pemali River through an aqueduct at Pontjol, the location where Gast had projected his intake. At Notok the main canal would have a capacity of 29.6 m³/s, with an eastern canal branching off just before the aqueduct with a capacity of 5.5 m³/s and a continuing main canal across the Pemali with a capacity of 24.1 m³/s. This main canal had to irrigate 24,000 bouw; the design capacity of the canal was 1 l/s/b, similar to Demak. The preliminary budget was 25 million guilders, but not all detailed designs were completed yet⁴⁹.

With the general design approved, the Director of Public Works ordered to make final designs of the diverse components of the irrigation system. In 1893, a detailed design for the weir and intake sluice was authorized, followed by authorization of a design of the first section of the main canal up to the off-take of the eastern canal in the same year, made by Van Marle. In the second half of 1896, Lamminga came with his contribution to the Pemali system, a design which projected all major elements of the system: main canals, secondary units, drainage canals and main structures⁵⁰. Apparently, detailed layouts of secondary units were not part of this design; these were probably defined in subsequent designs for each unit. When Pontjol aqueduct was opened in 1902, the design capacity in the main canal had been reset at a little over its original value to 36.6 m³/s. The irrigable area had been enlarged to 45,000 bouw, resulting in a water availability of 0.8 l/s/b in the West monsoon. As it was expected that the area used for sugar cane and villages would increase, water availability was expected to become 1 l/s/b in a near future.

The design histories of the Pekalen and Pemali systems show many similarities: first the main works were designed, with some major characteristics of the system, like size and rough layout, preliminary defined. In successive later designs, parts of the irrigation system were determined in detail. The design documents for the preliminary design of irrigation and drainage infrastructure in the area between the Tjomal and Tjatjaban rivers, also in the Pemali region, by Lamminga reflect the design process as encountered in the Pekalen and Pemali systems (Table 5.3). First, a general design was made, after which the future system was divided into smaller components, like intake structures or canals, or issues, like water requirements or layout. Earlier designs for main issues or components set the context for later components; occasionally later designs influenced earlier design outcomes. ‘Designing complete irrigation systems’, ‘taking into account issues simultaneously’, ‘integrated approach’, all these terms did not

necessarily mean that an irrigation system existed on paper completely before preparation or even construction of parts of the infrastructure could start, as we shall see in the Tjipoenegara case as well. ‘Integrated design’ did not take into account future management of the system either. Therefore, it is not completely accurate to state that Lamminga already took into account system management and operation in the design of the Pemali works⁵¹. As I explained in Chapters three and four, Lamminga and other Dutch engineers did anticipate on the possibility to measure and regulate water flows, due to the expected co-existence of sugar cane and rice. Water regulations, however, were not anticipated upon in the Pekalen or Pemali design. In the Tjipoenegara documents, day-to-day management is not discussed at all, but it is likely that the Pemali arrangements were taken for granted, as they had become standard in those days.

Year	Date	Description	Remarks
1895	October	1 st part encompassing an overview of the likely economic and financial results of constructing irrigation Works in the region mentioned above Annexes to this report: Overview of size of holdings their way of cultivation, by desa, located in the irrigation area Tjomal – Waloeh – Ramboet; according to data of the cadastral bureau at Tegal. (August 1895) Overview of the land tax now paid by desas located in the irrigation area Tjomal – Waloeh – Ramboet; according to the land tax overviews for 1894 concerning the ‘ <i>afdeeling</i> ’ Pamalang and for 1895 concerning the ‘ <i>afdeeling</i> ’ Tegal. (August 1895) Overview of land tax written off in the years 1885 to 1894, with the assessment for desas located in the irrigation area Tjomal – Waloeh – Ramboet; according to data of the Controllers of Pamalang, Tegal and Protjol. (August 1895)	Lamminga is engineer 2 ^d class
1896	April	2 ^d part encompassing the general plan of the canal and road routes and length and cross sections of the main canals	
	August	3 ^d part encompassing the designs of the prises d’eau at Sokorvatie, Tjipero, Kedjeneh and the change of the structure at Soengapan.	
	25 September	5 th part encompassing the design to modify the kali Tengah to discharge the bandjirs of the Waloeh; and further the designs for bridges across this river in the postal road and in the road along the main canals and the bridge across the Ramboet in the road mentioned last	Apparently not chronological
	8 December	6 th part, design of irrigation in the units	Lamminga is now engineer 1 st class. Apparently not chronological
1897	March	4 th part, structures in the main canals	Apparently not chronological
	May	7 th part, drainage canals	

Table 5.3
Design documents for the Tjomal and Tjatjaban area ⁵²

All elements of the design were written down in documents. Compared with the number of documents produced for the Tjipoenegara design, the number of design

documents in the late 19th and early 20th century, with an example in Table 5.3, appears to be relatively low (below 10 per system). In the Tjomal/Tjatjaban area, Lamminga produced seven documents in three years. In the Tjipoenegara design, between 1922 and 1933 several engineers produced 36 design documents at least (Table 5.4)⁵³. The difference in both number of documents and length of the process may reflect the growing attention for detail in irrigation design in the Netherlands East-Indies in the 20th century. It may also partially reflect the larger size of irrigation systems designed in the 1920s⁵⁴. The first group of Tjipoenegara documents covers the general design set-up; a second string of documents deals with secondary areas; documents on drainage flood protection are the last group. Within the frame of basic linearity, iteration or, more precisely, continuous feedback on adapting decisions taken earlier to produce new designs on increasing levels of detail, was another key in the design process. A short example is illustrative, with all changing design issues dealt with highlighted (Box). In the paragraphs following this detailed example, many issues will be discussed in a more general way.

Table 5.4
Number of
documents in
the
Tjipoenegara
process

	Main system	Secondary areas	Drainage/flood control	Total
1922	5	-	-	5
1926	3	1	-	4
1927	2	3	3	8
1929	-	3	1	4
1930	-	4	-	4
1931	-	2	1	3
1932	-	1	2	3
1933	-	1	4	5
Total	10	15	11	36

Bodjong
Keding

Originally, the Bodjong Keding⁵⁵ area, on the left bank of the Tjipoenegara, was irrigated from the Tjipitjoeng, a small river. Small earth weirs served as checks to bring water to fields, as unchecked water levels were below ground level. The engineers from the Maatschap considered the lack of measuring options a major drawback. Furthermore, in times of low river flows, conflicts between farmers emerged, whereas in times of high flows the area was flooded. New irrigation facilities had become an option after a *change in the originally authorized design for the prise d'eau* of the Tjipoenegara scheme⁵⁶. A total some 8,000 bouw gross would be irrigated on the left bank: The Governmental areas in Bodjong Keding (1815 bouw gross); Block 26 of the P.&T. Lands below 15.50 meter (2452 bouw gross); The remaining area of Block 26 irrigated through pumping (3604 bouw gross). 4266 bouw gross or 3413 bouw net were to receive water through the gravity system, requiring $3413 \times 0.74 \text{ l/s} = 2.526 \text{ m}^3/\text{s}$. The pumping area would require $0.8 \times 3604 \times 0.74 = 2.134 \text{ m}^3/\text{s}$, giving a total of $4.66 \text{ m}^3/\text{s}$ for the whole area. The *division of the required flow was adapted*, when it became clear that the pumping area counted 2848 bouw net, resulting in a water requirement of 2.11

m^3/s . The gravity system would count 3363 bouw net; it could be irrigated with the remaining $4.66 - 2.11 = 2.55 \text{ m}^3/\text{s}$ through the Djatiredja canal. The irrigation canal capacity was determined as usual for the Tjipoenegara area, explained later. For example, one canal section had to irrigate 1452 bouw net, meaning that that section would need $1452 \times 0.74 = 1.074 \text{ m}^3/\text{s}$. The next canal section had to irrigate 706 bouw, resulting in a flow of $0.536 \text{ m}^3/\text{s}$. *When the bandjir protection works were designed, the irrigable area had to be lowered with some 85 bouw net.* Therefore, *water availability per bouw increased* with a factor of $1452/(1452 - 85) = 1.062$, giving 0.786 l/s/b . *Canal capacities had to be increased with that factor*, resulting for example in a flow of $0.569 \text{ m}^3/\text{s}$ in the lower canal section. The canal was designed with a side-slope profile of 2:1; this value was taken from the Krawang irrigation works, as the soils were similar to that area. The hydraulic formulas used were similar as the ones presented in one of the Krawang design documents. The structures were also designed using rules from the Krawang area or from Public Works.

Water availability and water needs

Before one can start to irrigate, or determine system features, one has to determine how much water there is to be managed and which amount can be brought from which source(s) to which amount of land. Water availability at the source(s) has to be adequately matched with land available for irrigation. For gravity systems, an important factor in this matching is the location of the intake: the higher upstream an intake will be located, the larger the potential irrigated area will be. In early discussions on the Tjipoenegara system, a non-movable intake structure was planned south, thus upstream, of the railway line, close to the confluence of the Tjilamatang and Tjipoenegara rivers. In 1921, however, the Chief Engineer of the Irrigation Department Tjimanoek proposed a location north of the railway, as this was closer to the irrigated area and avoided an expensive crossing of the main canal with the railway. 'Eigen Beheer' proposed a movable weir, to avoid potential problems with high water levels during floods. After some discussion, a document from Public Works of April 4th 1922 (No. 11200/E) showed the possibility for a non-movable weir six km downstream of the railway.⁵⁷

On the 27th of December 1922, the Maatschap presented a design for a diversion structure in the Tjipoenegara to the Director of Public Works. The intake would divert water to the right bank; the P&T Lands would pump water from the river up to a maximum of $4 \text{ m}^3/\text{s}$ for their areas on the left bank. The weir would be constructed at a location 5315 meter north of the railway bridge. One advantage of the location north of the railway was that the main canal could be made considerably shorter, but it also meant that the border of the irrigated area had to be moved to the north, closer to the coast. This proved to be no problem⁵⁸, since the available land was plenty; it would still be possible to locate the main distribution structure at the most favorable location, close to desa Boegis. Furthermore, as the agreement between the Government and the

P&T-lands allocated part of the available water from the Tjipoenegara river to the P&T-lands on the left bank, the amount of land on the right bank was abundant in relation to the available water.

The early discussions on the intake structure in the early 1920s were followed by some years of relative silence in terms of design documents. In 1926 the Maatschap produced a new design document dealing with canal capacities of the system. Between 1922 and 1926, however, an intensive exchange between several parties took place on the design of the intake. Governmental Decision (GD) 41 sanctioned the design for the intake structure and the feeder canal on May 29th 1924. Three months later, however, the Director of the Maatschap wrote a letter concerning changes in this design to the Director of Public Works; the left bank was to be supplied with water from the structure too, as the Bodjong Keding area (1815 bouw) and part of the P&T Lands (2451 bouw) were to be included in the command area. A revised design was presented to the Head of Tjimanoeck, who sent it to the Director of Public Works on August 29th 1926. After some letters from this Director, including a letter to the Director of the Civil Service, a revised design was presented at July 3rd 1927, almost a year later (!). Eighteen days later, the Director of Public Works agreed with the design. Apparently, no new GD was needed. The selected intakes would divert 5 m³/s to the left bank and 36 m³/s to the right bank.

One of the other documents accompanying the main report of December 27th 1922 dealt with the command area. Measurements of Tjipoenegara discharges between 1916 and 1921 showed that the mean available West Monsoon discharge would be about 40 m³/s ⁵⁹. From this amount, 30% (about 12 m³/s) would be available for irrigating the P&T Lands. When determining the area to be irrigated through the new canal system, it was assumed that the P&T Lands would pump 4 m³/s of their amount. Remaining P&T water would be delivered through the regular canal system, mainly the Pamanoeckan canal. For the Governmental area, the total surface was calculated assuming that one irrigated bouw would need 0.8 l/s, a figure based on experience in Indramajoe. With 20% of the surface used for kampongs and other infrastructure, $40 - 4 = 36$ m³/s would allow an irrigated area of $(36 \times 1,000) / (0.8 \times 0.8) = 56,250$ bouw. A main canal located as much to the south as was considered possible would yield an available area of 64,097 bouw gross. Locating the main canal further to the north would be cheaper but diminished the gross available area with 4,300 bouw. Still, this left some 3,500 bouw more than needed. These could be accounted for by not irrigating the lower parts of the area near the sea, bringing the gross area at the desired 56,250 bouw. The irrigated area was to be divided into four secondary units; each unit would be commanded by its own canal from main division structure Boegis. As the Cipoletti measuring devices in Boegis would give head losses and thus a lower irrigable area, the sizes of the secondary areas were adjusted. The area not irrigated from the secondary

canals was to be irrigated directly from Boegis through direct tertiary off-takes, avoiding one level of head losses.

In a new design for Boegis presented in 1926, however, other measuring structures were selected. Instead of Cipolettis, the recently introduced Venturis were proposed, as these gave lower head losses⁶⁰. Together with adding an intake for the left bank at Salamderma, the final command area to be supplied with water from the Tjipoenegara was set at 67,557 bouw (Table 5.5). Of this total, 19,988 bouw were owned by the P&T lands; 47,569 bouw were property of the government. These were gross areas; net irrigable areas had to be determined yet. A standard approximation in the East Indies was to reserve 20% of the gross area for the future realization of villages, roads, canals, etcetera. This would result in a net irrigable area of 54,046 bouw, which had to be irrigated with the 40 m³/s West Monsoon discharge of the Tjipoenegara. This gave an available discharge of 0,74 l/s per bouw in the irrigated area, lower than the 0.80 l/s originally assumed. An advice from the Director of Agriculture of April 11th 1924, however, had already indicated that

‘a lower water requirement than the one assumed originally (i.e. 0.80 l/b/s for the whole of West Cheribon) is considered likely.’⁶¹

Area	Bouw
Right bank Pamanoekan canal	13,933
Soekra canal	11,547
Andjatan canal	9,086
Kandanghaoer canal	24,414
Directly irrigated from Boegis	707
Total	59,687
Added to this an area, to be irrigated from the diversion to the left bank	4,310
And an area, to be irrigated by pumping water to irrigate an area on the left bank	3,560
Total command area	67,557

Table 5.5
Command area
of the
Tjipoenegara
system⁶²

Water availability for the P&T-Lands, consisting of two blocks numbered 26 and 28, was larger than water available for the governmental area. The total irrigable area of the P&T blocks was a little below 10,000 bouw (block 28) and about 4,850 bouw (block 26), giving a total of 14,830 bouw after, excluding the 20% reserved for infrastructure. With the available 12 m³/s and assuming that the water would be evenly distributed between blocks 26 and 28, the available water would amount to $12,000/14,830 = 0.809$ l/s/b, which was considered sufficient for rice cultivation in the entire area.

When determining the potential irrigable area for sugar cane, the crop in which the P&T-Lands were mainly interested, the guaranteed available discharge in the dry East Monsoon was limiting, as West Monsoon discharges were limiting for rice cultivation only. From data collected between 1929 and 1931, it was deducted that the mean East

Monsoon Tjipoenegara discharge was about 7 m³/s. With 30% of the Tjipoenegara discharge for the P&T-Lands, 2.1 m³/s would be available for sugar cane cultivation. Sugar cane would require about 0.5 l/s/b during daytime. With water losses set at 30%, given the soils in the Tjipoenegara area, a minimum available discharge of 0.75 l/s/b at the intake was needed. Therefore, an available discharge of 2.1 m³/s could irrigate some 2,800 bouw at most. If, however, water flowing during the night could be stored in wadoeks, water availability and thus the potential area to grow sugar cane could be almost doubled to some 5,000 bouw⁶³. With extra losses set at 20% and a filling time of 12 hours, the required storage capacity would be $1.2 \times 0.75 \times 12 \times 3.600 =$ about 16 m³ for each bouw of sugar cane. Although tertiary wadoeks could be constructed at tertiary intakes, secondary wadoeks collecting water of a number of tertiary units and bringing water back in the secondary canal to be distributed downstream to tertiary canal, was a better option. Wadoeks demanded a certain head loss; in the relatively flat geography of the Tjipoenegara area wadoeks constructed along the distribution structures in the secondary canals could use the head loss already available at those locations. A smaller number of wadoeks was preferred too, both from management as from costs perspective. The disadvantage of secondary wadoeks, which enhanced travel times of the water, as they brought water in an empty secondary canal in the morning, was considered acceptable. The wadoeks received their water through pipes, equipped with a sluice gate at the downstream side, which made the inflow of water independent from the water level in the wadoek. The outlet sluice had to be regulated in such a way, that the wadoek would empty itself in a period of 10 to 12 hours. The total surface occupied by wadoeks was calculated at 18 bouw, embankments included, only a very small fraction of the available area on the P&T Blocks. Sedimentation was not expected to become a problem, as this would amount to only a few centimeters. Sedimentation had a positive side too; it made the wadoek floor waterproof.

Designing a proper layout

With the irrigable surface known, the general layout of the irrigation system could be determined. Size and number of tertiary and other units, the shape of the units and the number and routes of the canals supplying the water to the units had to be decided upon. A possible canal grid was mapped, with as main principle the separation of irrigation and drainage infrastructure.

‘Obviously, when executing a completely technical irrigation scheme the division between supply and removal will have to be carried through in this flat terrain [...]’⁶⁴

Supply, irrigation, canals were generally routed along higher ridges in the landscape, but not at all costs; occasionally the designers of the Tjipoenegara system decided to route a canal through lower terrain, for example to avoid excessive fills of canal alignments between two higher ridges. Detailing rough canal grids determined in earlier design documents at a later moment could result in other command areas of the canals than

originally calculated, but differences were usually in the order of magnitude of 20 to 100 bouw. For the Tjigoegoer area, in the north-west corner of the system on the right bank, it was decided that two canals instead of the originally planned single Pamanoekean canal had to be designed to separate the supply to the Governmental lands from the supply to the P&T Lands; the extra Pengarengan canal was the result⁶⁵. As a standard, existing small streams were used for drainage; occasionally new drains had to be constructed. Design of the canal grid was discussed between the Maatschap, the Head of the Krawang works and the Department of Public Works. For example, a proposal⁶⁶ for the canal grid and general layout of the Kadanghaoer area was sent back by the Department together with a new design.

‘On one of the unit maps a scheme for drainage and irrigation was sketched in red and blue by Unit E. of above mentioned Departement [...]’⁶⁷

How to draw a map with layout not only required colors, as irrigation and drainage canals and each secondary unit was given a separate color, but also systematic labeling of structures and canals.

‘In an irrigation area of certain meaning, one has to deal with a large number of canals, structures and units, which all have to receive a name to be able to indicate them during given meetings, execution, exploitation, in reports, etc. Therefore it is very important that the name is short and such that the structure, the unit or the canal can be found immediately by newcomers too, whereas one needs to know immediately whether one deals with a supply canal or with a drainage canal.’⁶⁸

In the standard system of the Netherlands East Indies⁶⁹, a main canal could be either given the letter ‘K’ or the name of an important desa close to it. Secondary canals could be named or given the letter ‘S’; structures were given Roman numbers. The system applying letters for canals had already been used by Lamminga in the Pekalen and Pemali systems; in the Tjipoenegara system secondary canals were named after desas, hence for example the Pamanoekean canal. Much attention was given to size, shape and amount of tertiary units. The canal grid gave the context for the design of secondary and tertiary units. As a rule, a tertiary unit was supposed to have a single intake, or off-take, depending on the perspective one takes, as this facilitated clear water management; multiple intakes for single units were considered to disturb management. Furthermore, not too many different desas should be represented in a tertiary unit. Size did matter in this context: distributing water to individual users would imply a canal network too detailed to be manageable by governmental officials, whereas distributing water to too many users would undermine the capacities of farmers to manage water within the unit. The balance between all these demands was not easily found.

The first irrigation systems constructed in the East Indies included tertiary units up to 500 or 600 bouw. In the 1880s, sizes of units were decreased considerably. Especially in the Pategoean system tertiary units were designed very small. In the area of the

Pategoean canal, designed in 1886, tertiary units varied between 20 and 153 bouw. The Kamoening-area counted 86 bouw, divided into 15(!) tertiary units, especially due to topographical circumstances. The Tanggoel-area, designed in 1890, was divided into tertiary units of about 25 bouw⁷⁰. As a letter from December 30th 1898 of De Meyier, then Director of Public Works, explains, the surface of a tertiary unit did not necessarily equal the surface of a 'golongan-ajer'; a golongan-ajer could include several tertiary units⁷¹. Standard size for a golongan-ajer in the Pategoean system was set at 200 bouw.

'[...] in that [Pategoean; MWE] area one came to the insight that for areas of 200 bouw the water requirement can be set proportional to the surface.'⁷²

For a hilly area as Pategoean, 200 bouw were considered the maximum; the letter of De Meyier gave 300 bouw as maximum for flat areas, as overseeing flatter areas was easier. The Pategoean irrigation system was managed with the idea that most water distribution tasks and responsibilities were given to the cultivators. Providing them with a system with smaller units would enhance the manageability of the system, and thus decrease water use. This decrease in water use was limited, however, by the presence of smaller tertiary units within a golongan-ajer; water demand in these small units fluctuated strongly, resulting in relatively high peak demands. Furthermore, each smaller unit had its own intake, which complicated water distribution. Dividing the available water into smaller portions increased relative water losses too. De Meyier acknowledged these difficulties; he only recommended applying the 200 to 300 bouw figure for the smallest management unit within a system for technical reasons, without any suggestion that the Pategoean distribution methodology itself was the one to follow.

Indeed, the Pemali design set the standard size of tertiary units at 200 bouw net too; one intake brought water to the fields in this 200 bouw unit, which was both tertiary unit and 'golongan-ajer', thus lowest unit in both technical and management terms. After 1915, the optimal size was decreased to 150 bouw for agricultural reasons; within such units water could be brought to the field directly from the canal instead of through other fields. For economical reasons, tertiary units were made larger than 150 bouw again after 1925, especially in flat areas. This larger recommended unit size was sanctioned in a letter of the Director of Public Works from April 1929; in the late 1930s, the economic crisis caused a further increase in recommended sizes of tertiary units up to 600 bouw.⁷³ Larger tertiary units saved on the number of structures to be constructed. In the Tjipoenegara area the 150 bouw net norm has remained the guideline in the design process. For example, the Eretan-area included 6518 bouw irrigable area, divided into 49 tertiary units, giving a mean size of 133 bouw. In the documents dealing with layout of units, it is mentioned many times that the layout was made in accordance with the views of Chief Engineer Gaade, Head of the Krawang irrigation works at the time⁷⁴. Final unit layouts usually depended on topographical

circumstances. Existing infrastructure, like roads and canals, and rivers, was used as borders for tertiary units as well; the border between Block 28 of the P&T Lands and Governmental lands served as a marker too for some units. Drainage canals, occasionally designed along other infrastructures, usually formed the borders of the tertiary units. Borders of desa's were also used to divide tertiary units, but as desa borders usually did not coincide with the natural terrain, they were not taken as that important.

The western borders of the Andjatan area⁷⁵ were primarily based on existing, natural watercourses, which were the Kali Kankoeng and Dikoer from Boegis up to desa Tjilandak, from which in the northern direction the kali Mangsetan was the border up to the Java sea. Near desa Tjilandak, as a short artificial boundary, a drainage canal was to be constructed. As the eastern boundary, from Boegis to the Haoergeulis – Andjatan road, a drainage canal between the Andjatan and Kandanghaoer areas formed a first boundary, which was continued by a natural one onwards up to the sea, the Kali Sarahasem. From Boegis up to the road, the Andjatan canal was designed roughly in the same direction as the main canal; from the road onwards it was constructed in such a way that its course was almost completely along the length-axis of the Andjatan area. Eight secondary canals received water from the canal, and a large number of tertiary units were irrigated directly from the primary canal. Due to a number of quite deep, existing canals, which used to be irrigation canals, but had to serve as drainage canals in the new system, new secondary canals occasionally had a course close to those existing canals. As in other areas, the design aimed at tertiary units of about 150 bouws net; the gross surface of the Andjatan area was 9086 bouws, the net surface was set at 7269 bouws, which was divided in 64 tertiary units. Thus, the mean net unit surface was $7269/64 = 114$ bouws.

Shape of units was a point of consideration too. Relatively long and narrow units had their positive sides, as water could be brought directly from canals to fields. A negative aspect was the length of the tertiary canal, which could give water scarcity for the tail-end sawahs. This potential unequal distribution between head and tail was used as an argument to decrease the length of tertiary units. Another disadvantage of long and narrow units was the potential higher water loss, as non-used water could flow easily into drainage canals without possibilities to re-use it in other fields. All in all, tertiary units of square-like shape were preferred, because water losses and tail problems were both less. The layout of the Eretan area, with the primary canal in the middle of area, dividing it in two halves, made it possible to design a relatively uniform layout, with two rows of tertiary units on either side of the canal. The layout in the Bodjong Keding area, to take another example, was complicated by the erratic course of streams intersecting the area and the existing canals, which were causing a somewhat distorted layout.

To manipulate and maintain water flows and levels in the system, several structures were necessary, like drops, checks and discharge regulators. As explained in Chapter four, the distribution structures in irrigation systems had to perform two tasks: discharge regulation and measurement. The first design for main division structure Boegis employed Cipoletti measurement weirs; the final design for Boegis of 1926 included Venturis. Outlets from the irrigation canals were to be supplied with measurement structures too. For these outlets Venturis were not selected as standard. Most of them consisted of a pipe construction with sliding gate in the off-taking canal and check weirs in the ongoing canal supplied with stop logs and drops if necessary. The concrete pipes, which could be constructed below the service road parallel to most canals, were usually supplied with a stilling basin at the downstream end. Several meters downstream of the stilling basin, Cipoletti sharp crested weirs were used to measure the flow. In exceptional cases off-takes in canals were constructed as expensive Venturis, usually because only low head losses were available. Although the design and construction of the Tjipoenegara system took several years, there is little evidence that other structures than Cipoletti's and Venturis have been used. Handwritten comments in one report ⁷⁶ suggest that Romijn weirs have been employed in the Eretan area, but this has not been confirmed in the design documents I found. In the Krawang system, designed and constructed more or less in the same period, indeed all sorts of structures were applied.

'Measuring tertiary off-takes went through the complete development process, from measuring weirs via several tertiary Venturi meters with different non- modular and later modular gates and many types of reading devices to the measuring overflow weir as described by ir. Romijn in the Waterstaats-Ingenieur No. 9 – 1932, which is now favorite.'⁷⁷

With the irrigable area known and layout of the system decided upon, the dimensions of the canal network could be determined. How Dutch engineers did this is subject of the next chapter.

6 Our calculations are approximations

Design tools in irrigation

With the general layout of the system decided upon, the engineers from the Maatschap could determine dimensions of the canal network. Two issues played a role, both for irrigation and drainage canals. First, the amount of water each canal had to transport, the water carrying capacity, needed to be specified. Second, the physical dimensions, like width, height, water depth, and slope of the canals had to be determined. As the main irrigation season on Java was the West Monsoon, with most of the land under irrigated rice, capacities for the canal system were based on water requirements for that period. Canals should bring the necessary water to certain amounts of land. How much water should be transported to irrigated areas with different measurements was the basic question. Statistically, water requirements expressed in volume per time unit per surface unit – relative canal capacity, expressed in the East Indies in liter per second per bouw or $l/s/b$ – are lower for larger areas compared to smaller areas. One reason for this is that in larger areas peak water requirements are spread, as they are less probable to occur simultaneously on all fields. Furthermore, in smaller areas water can easily flow directly into drainage canals, resulting in relatively higher surface water losses. The question is, of course, how much ‘larger’ and ‘smaller’ in a given situation is. The two reasons mentioned above are valid for almost all irrigation situations.

In the case of Java, two additional arguments determined relative canal capacities. First, Dutch colonial water management arrangements were usually based on rotational irrigation, in the shape of *golongan* arrangements; available flows were concentrated on smaller areas and not proportionally spread over the entire area. The total volume needed for a crop or field for a certain period was distributed in a shorter time; therefore, the canal capacity for smaller areas needed to be relatively high. Second, sugar cane, present or anticipated upon in most irrigation systems designed by Dutch engineers did not need irrigation water in the West Monsoon season. This could mean a general decrease of the canal capacity for all canals in the system, were it not that statistically it was quite possible that in smaller areas sugar cane was not present, whereas in larger areas it was most likely to be grown. Thus, canal capacities for larger areas could be decreased, but for smaller areas this was not possible. The relation between relative canal capacity and unit surface was graphically expressed in a ‘capacity curve’ (*capaciteitskromme*). Early capacity curves were rather crude estimations, but over time they developed into an elaborate and structuring tool for irrigation design. A

short overview of the development of capacity curves in the Pategoean and Pemali systems is illustrative of this process.

Everything you always wanted to know about capacity curves...

In 1889, when the first irrigation areas in the Pategoean system were designed, the starting point for determining canal capacities was that generally 1.5 l/s/b was sufficient, an assumption based on experience¹. Occasionally, for example during soil preparation, a larger amount of water was necessary. Therefore, the large secondary canals were given a capacity of 1.5 l/s/b, the smaller secondary canals 3 l/s/b and the tertiary canals 6 l/s/b, although unfortunately ‘larger’ and ‘smaller’ was not quantified. This crude estimation was changed for the Tanggoel area in 1890: the total area of 1090 bouw received water at a rate of 1.5 l/s/b, whereas areas up to 25 bouw received a maximum flow of 3 l/s/b. For areas between 25 and 1090 bouw, the capacity gradually decreased to 1.5 l/s/b for 1090 bouw. In the Kapoeloengan area (1891), the capacities were remodeled again. For larger areas, a capacity of 1.5 l/s/b was considered too high; sugar cane cultivation would certainly decrease the capacity needed. Therefore, it was assumed that for terrains of indefinite size, the relative canal capacity had to be 1.2 l/s/b; for 1,000 bouw it would become 1.5 l/s/b, and for 25 bouw 3 l/s/b (Table 6.1 and Figure 6.1). With this figures, a hyperbolic curve was constructed: a very early capacity curve! In the Bekatjak area (1891) the curve was adapted again. As much of the area was covered with sugar cane, it was assumed that the capacity of 1.2 l/s/b was already sufficient in areas of 500 bouw, instead of 1,000 bouw.

Table 6.1
Values for the
capacity curves
in the
Kapoeloengan
area

Bouw	l/s/b	Bouw	l/s/b
1	About 3.75	140	2.25
7	About 3.5	240	About 2
15	About 3.25	450	About 1.75
25	3	1,000	1.5
50	2.75	1600	About 1.4
90	About 2.5	3500	About 1.2

In other areas similar capacity curves have been developed, like the Bedadoeng curve in Irrigation Department Pekalen-Sampean, but, as in water management, the Pemali design of Lamminga has set the standard for capacity curve use in the East Indies². In a letter of December 9th 1896 to the Heads of the Irrigation Divisions, Director of Public Works Van Houten could still recommend the use of the Pategoean capacity curve; this recommendation was withdrawn in a letter just one month later. In the letter of January 7th 1897 to the same Heads, Van Houten requested that all capacity calculations were to be judged by him before canal design could proceed³. Although Van Houten did not recommended the Pemali curve as such in his letter, he did discuss it in detail and it is clear that he preferred this capacity curve above the Pategoean curve. The Pemali curve was based on an average water requirement of 1 l/s/b for a standard unit of 200 bouw.

The Pemali curve or ‘Tegalsche capaciteitskromme’ became the reference curve, which had to be adapted to the specific region, depending on soil, topography etcetera⁴. Differences between the area under study and the Pemali reference were accounted for by a coefficient ‘a’, which was based on soil conditions, slopes etcetera. For example, in areas with heavy clay, like Demak, Pemali, and Solo factor ‘a’ would have a value of 1, whereas in areas with light clay, like in Tjomal-Tjatjaban, ‘a’ could become 1.25. In the Pategoean system with its slopes, ‘a’ was set at 1.5⁵.

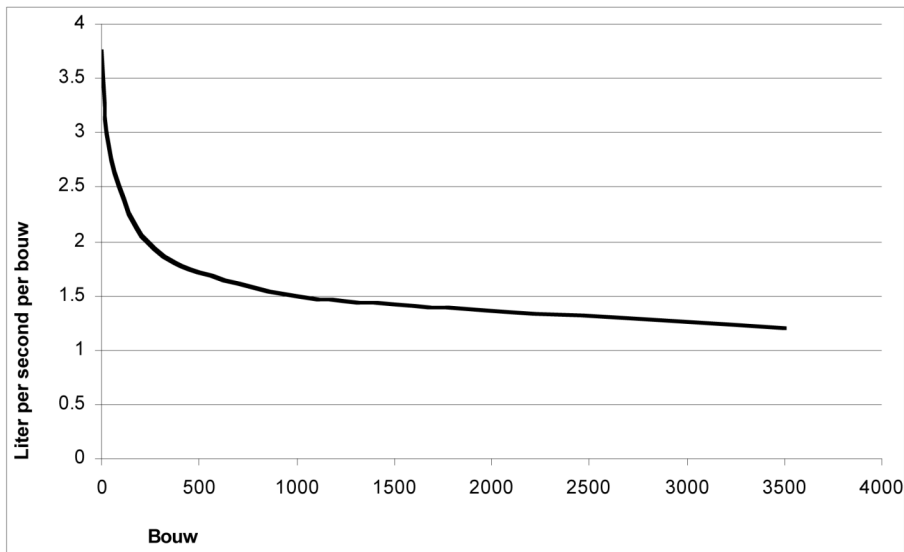


Figure 6.1 The Kapoeloengan capacity curve

In the Pemali curve, it was assumed that about 20% of the total irrigable area would be planted with sugar cane and thus would not be irrigated during the West Monsoon. Furthermore, it was assumed that this 20% reduction would be fully noticeable at a scale of 1,000 bouw. Units of 1,000 bouw therefore had to receive 0.8 l/s/b. In areas without sugar cane, an adapted version of the Pemali curve could be applied without reduction. As ‘experience learned’⁶, a small reduction of 5% could still be applied in areas completely covered with rice, as in practice not all the fields were planted. This specific rice curve seems to be forgotten quite early in the East Indies. A well-known book on irrigation design guidelines for the East Indies does not refer to it⁷. Instead, the book remarks that with a well functioning irrigation system, investors would be encouraged to start sugar factories, which in turn would lead to more sugar cane in the system and thus, finally, to lower water demands. In the 1930s, the preliminary design for the Sadang Works on Celebes, modern Sulawesi, applied the standard Pemali capacity curve including the sugar cane reduction percentage, even though in the Sadang area occurrence of sugar cane was not expected. The curve was applied

‘as irrigation practice has shown that also in regions where sugar cane is not present application of the Tegal capacity curve hardly causes miscalculations.’⁸

In another late-colonial, large-scale system, the Tangerang works on West Java, the Pemali curve was applied without the reduction for sugar cane; 200 bouw received 1 l/s per bouw⁹. Sugar cane cultivation was not to be expected in Tangerang. Apparently the East Indian designers maintained a certain room for specific decisions in the design process: the Pemali capacity curve was applied, but values could be adapted to local circumstances. Similar freedom can be observed in the Tjipoenegara design process.

The Tjipoenegara capacity curve

The Tjipoenegara area was considered to be an empty area, at least empty enough to assume that, besides the 20% reduction for cane, the available irrigable surface had to be decreased with an extra 20%, as canals, roads, villages and other infrastructure had to be realized yet. Although sugar cane was not cultivated at the time, the standard Pemali curve including the 20% sugar cane reduction was applied. The desire of the P&T-Lands to grow sugar cane in blocks 26 and 28 did not affect canal capacities in general, as water availability and supply for these blocks were arranged separately from the Governmental area. The P&T Company had plans at that time, however, to ask for a sugar concession in the Governmental area east of the Tjisewoe, which would create an area of some 7,000 bouw of sugar cane, about 15% of this area. Together with the infrastructure needed for sugar factories and extra roads, the 20% would have been in sight, was it not that the P&T-Lands never developed sugar cane cultivation or factories successfully. The Tjipoenegara area appeared to be not too suited for sugar cane; it was pretty much on the outside border of the Javanese area suitable for sugar cane¹⁰. Similar developments with sugar cane cultivation occurred in Krawang. In this area, the P&T Lands had requested for a sugar cane concession too,

‘even in 1926 the whole plan of execution for the Krawang Works was rewritten to adapt progress of the Works to the wishes of the Maatschappij tot exploitatie der Pamanoeckan- en Tjiasemlanden directly interested in sugar cane cultivation.’¹¹

A Governmental Decision dated August 6th 1928 opened the entire Krawang area for sugar cultivation.

‘However, applicants did not come forward.’¹²

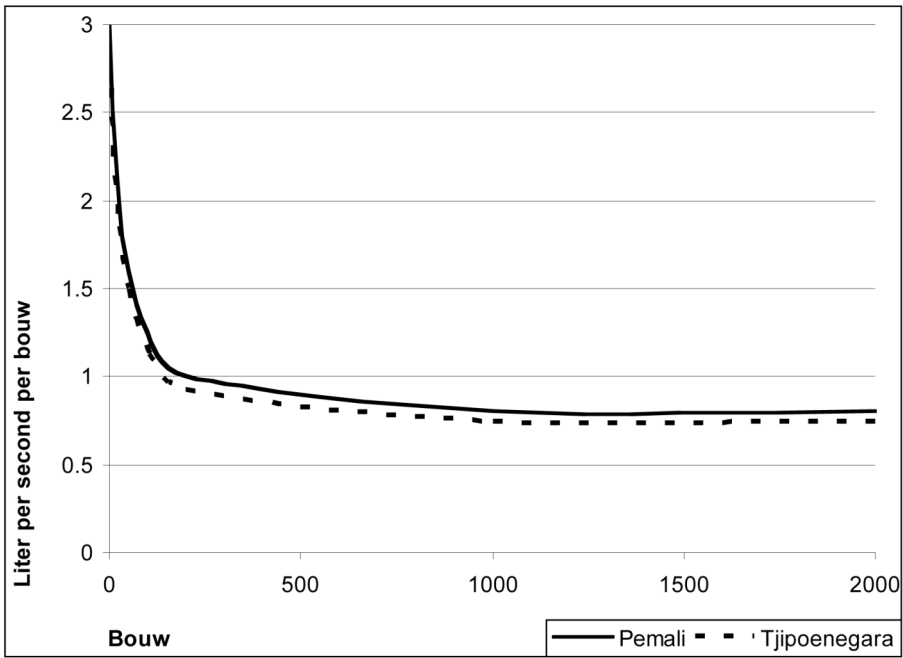
Perhaps, in hindsight, one could state that Tjipoenegara canal capacities have been determined too low; sugar cane was not grown on large scale in the area. If calculations would have to be made based on rice, the most probable alternative for sugar cane, water demands and thus required canal capacities would have been higher, as at least one 20% reduction factor would not have been applied¹³. The Sadang document quoted before, however, suggests that applying the extra sugar cane reduction in non-sugar areas hardly resulted in major problems.

Whatever the case, the design documents made by the Maatschap do not present the application of the reduction factor for sugar cane as an option, but as standard

procedure. Taking together, the two reduction factors of 20%, one anticipating on future infrastructure and one on sugar cane, a well-developed and well-functioning irrigation system would have 64% of the gross area covered with rice on irrigated sawahs in the West Monsoon. These sawahs would need to receive the well-known 1 l/s/b. With reduction factors being fully applied at areas of 1,000 bouw, such an area would need 640 l/s¹⁴. With the irrigated area determined at a little over 54,000 bouw, which had to be irrigated with the 40 m³/s West Monsoon discharge of the Tjipoenegara, the available discharge was 0,74 l/s per bouw, lower than the 0.80 l/s originally assumed. This meant that water availability per 1,000 bouw was also decreased, from 640 l/s per 1,000 bouw to 592 l/s or 0.935 l/s/b for each sawah cultivated with rice. An area of 5,000 bouw net was defined as the reference area. This amount was translated into $5,000 \times 1.05 = 5250$ bouw gross, of which 64% was covered with sawah's, giving 3350 bouw of sawah. An area of 5,250 bouw gross had to receive water at the rate of $3350/5250 \times 0.935 = 0.6$ l/s/b. Units of 200 bouw were supposed to be the areas needing the standard amount of 0.935 l/s/b without reduction factors. A canal to such a unit would have a capacity of $200 \times 0.935 = 187$ l/s. The 200 bouw standard unit is similar to the Pemali reference; it is not in line, however, with the 150 bouw applied as mean area for tertiary units in the Tjipoenegara area.

With the standard capacity set at 0.935 l/s/b, coefficient 'a' was set at 0.935 in the Tjipoenegara system. The coefficient was not determined, however, taking into account soil type or topography. In the Tjipoenegara case, coefficient 'a' had become less than 1 due to increases in the irrigable area during the design process! Leaking losses were set at 10%, decreasing water availability at the field with another 10%. The final capacity curve proposed by the Maatschap in January 1926 had the same shape as the Pemali curve until 1,000 bouw with a coefficient 'a' = 0.842, 10% less than 0.935. From 1,000 bouw a straight line was drawn to the 0.564 l/s/b for areas of 5,000 bouw and more. The Head of Krawang, however, did not accept and thus amended this curve. The new capacity curve, used throughout the design process, was still similar to the Pemali curve, but coefficient 'a' had been set at 0.925 after all. The required capacity for areas of 1,000 bouw net or more became 0.74 l/s/b; for areas of 200 bouw net a capacity of 0.925 l/s/b was set. This final result was achieved in a negotiation process between the designers and the Department of Public Works; occasionally the results from the Pemali curve had to be adapted because the command area changed. Pemali was the reference, but the curve was adapted to fit the design process (Figure 6.2).

Figure 6.2
Capacity curves
for the Pemali
and
Tjipoenegara
systems



Irrigation canal dimensions

With capacities of canals being determined, the engineers could calculate all respective dimensions of the canals (Table 6.2). For example, the Pamanoekan canal was divided in segments based on respective flows, calculated as canal capacities multiplied by the command area served by the canal. In the upstream canal segments with higher flows, the proportion between bed width and water depth was selected at $b:h = 3.5$. This proportion was lowered in the middle region segments to a value of 2.5 and in lower segments to value 2. Freeboards were set at 0.75 m in the first segment and 0.50 in other segments. The fifth segment, for example, irrigating about 7,000 bouw, had a design flow of $Q = 5,875 \text{ m}^3/\text{s}$. Dimensions were determined at $h = 1.28 \text{ m}$ and $b = 4.48 \text{ m}$, with bed slope set at 0.35 ‰ and a side slope at 2:1, a figure generally applied in the Tjipoenegara area. Deviations of the design flow were taken into account as well, as inflows could fluctuate over time. In case flows would be smaller than the design flows, regulating constructions would have to maintain water levels. When the flows would be larger, however, it had to be determined whether the canal could handle the extra flow. In order to do this, the engineers assumed that flows would remain uniform and water velocities and energy losses would not change. To take another example, the smaller Pengarengan canal had to bring water to the governmental lands close to Tjigogoer. The maximum design flow of the canal was $2,650 \text{ bouw} \times 0.74 \text{ l/s} = 1,961 \text{ m}^3/\text{s}$; the canal profile, with a velocity v set at 0.455 m/s , was determined at bed width $b = 2.45 \text{ m}$ and a water depth $h = 0.98 \text{ m}$, with a ratio of $b:h = 2.5$. With a higher water

level Δb , the relation between design flow Q and increase in design flow q would become¹⁵

$$Q/q = (b \cdot \Delta b)/F = (b \cdot (m + 2n) \cdot \Delta b)/(b^2 (m + n)) = \Delta b/b (1 + m/(m + n))$$

in which n = the canal side slope, and $m = b/b$

With $\Delta b = 5$ cm, $b = 50$ cm, $m = 2$ and $n = 1$, the canal capacity would increase with some 13%. In case $\Delta Q/q = 0.33$, thus an increase of one-third of the flow, Δb becomes 0.25 m. As the canal embankments were designed with freeboards larger than 0.30 m, flow increases could generally be coped with by the canal.

	Q	v	b	h	i
Pamanoekan	12.464	0.65	7.15	1.79	0.183
Soekra	4.879	0.60	3.83	1.28	0.284
Andjatan	5.245	0.60	3.96	1.32	0.275
Kandanghauer	12.974	0.65	7.30	1.82	0.177

Table 6.2
Dimensions of
the primary
canals
downstream of
Boegis¹⁶

Q = water flow volume in m³/s; v = flow velocity in m/s; b = bed width in m; h = water depth in m; i = energy slope in ‰ (in case of uniform flow energy slope = bed slope)

But how did the engineers of the Maatschap do the actual canal calculations? What formulas and tools did they have at their disposal? The design documents refer only a few times to way(s) in which the calculations were made and which formulas were used. The first reference to canal design in the Tjipoenegara area dates from July 31st 1927. It is mentioned that the Chezy formula for canal design was used together with the coefficient of Bazin – the formulas will be discussed below.¹⁷

‘These formulas are processed into a graph; limiting ourselves to values of R [explanation below; ME] smaller than 1.20 and larger than 0.20, with which almost all irrigation canals, except tertiary ones, can be determined; it appeared to be possible to express C [explanation below; ME] without too big mistakes as an exponential function of R.’¹⁸

For tertiary canals, a table was made giving capacities, water velocities and other dimensions. On May 29th 1930, when canal designs for the P&T-Lands were discussed, the Maatschap assured that all canals had been determined using existing graphs, probably referring to the graphs made by the Maatschap itself. On April 16th 1932, however, the message was that all hydraulic calculations were done as Verwoerd had proposed in an issue of ‘De Waterstaatsingenieur’ of 1931¹⁹. Verwoerds’ method was emphasized again in a document from November 11th 1932. Apparently, a shift in approaches how to calculate canals took place in the early 1930s. This shift is

confirmed by developments in the Krawang area²⁰, as should be expected, as Krawang was the reference system of the Tjipoenegara designers. Verwoerd's approach was based on the Strickler formula, whereas the older approaches, which accumulated in design graphs produced by engineer Steevensz used the flow formula of Chezy²¹, which reads

$$v = C \cdot (R \cdot i)^{1/2}$$

with v = water velocity in m/s; C = a coefficient; R = the hydraulic radius in m ; i = energy slope in m/m. A most interesting element in the Chezy formula is factor C , which is a coefficient dependent on the roughness of the canal – increasing roughness means an increasing value for C . How to determine the value for C was strongly debated in the Netherlands East Indies²². Three methods have come to the front, two of which have been the work of Bazin, one other method was developed by Gauguillet and Kutter. Originally, the formula for C developed by Bazin was used in the Netherlands East Indies²³:

$$C = 1/(\alpha + \beta / R)^{1/2}$$

in which α and β are coefficients dependent on canal properties (Table 6.3); R = the hydraulic radius, expressing the canal geometry.

Table 6.3
Coefficients in
the Bazin
formulas²⁴

Nature of side walls		Coefficient		
		α	β	γ
1	Very smooth walls (smooth plastering or wood)	0.00015	0.0000045	0.06
2	Smooth walls (unsmoothed wood, brick, cut stone)	0.00019	0.0000133	0.16
3	Less smooth walls (rubble stone)	0.00024	0.00006	0.46
3 ^a	Walls with stone alignment	-	-	0.85
3 ^b	Regular earthen walls	-	-	0.85 – 0.96
4	Common earthen walls	0.00028	0.00035	1.30
5	Rough walls (stony, grown)	-	-	1.75

In 1897 Bazin changed this formula into

$$C = 87 / (1 + \gamma / R^{1/2})$$

in which γ is a coefficient dependent on canal properties (Table 6.3), which was used almost exclusively since by Dutch engineers in the Indies²⁵. In the Tjipoenegara case, another formulation of the second Bazin formula was used

$$C = (87(R)^{1/2}) / ((R)^{1/2} + \gamma)$$

in which $\gamma = 1.3$. This value is mentioned as well by Van Maanen in the 1924 edition of his irrigation design guide²⁶. In the 1931 version of the book, however, Van Maanen remarks that

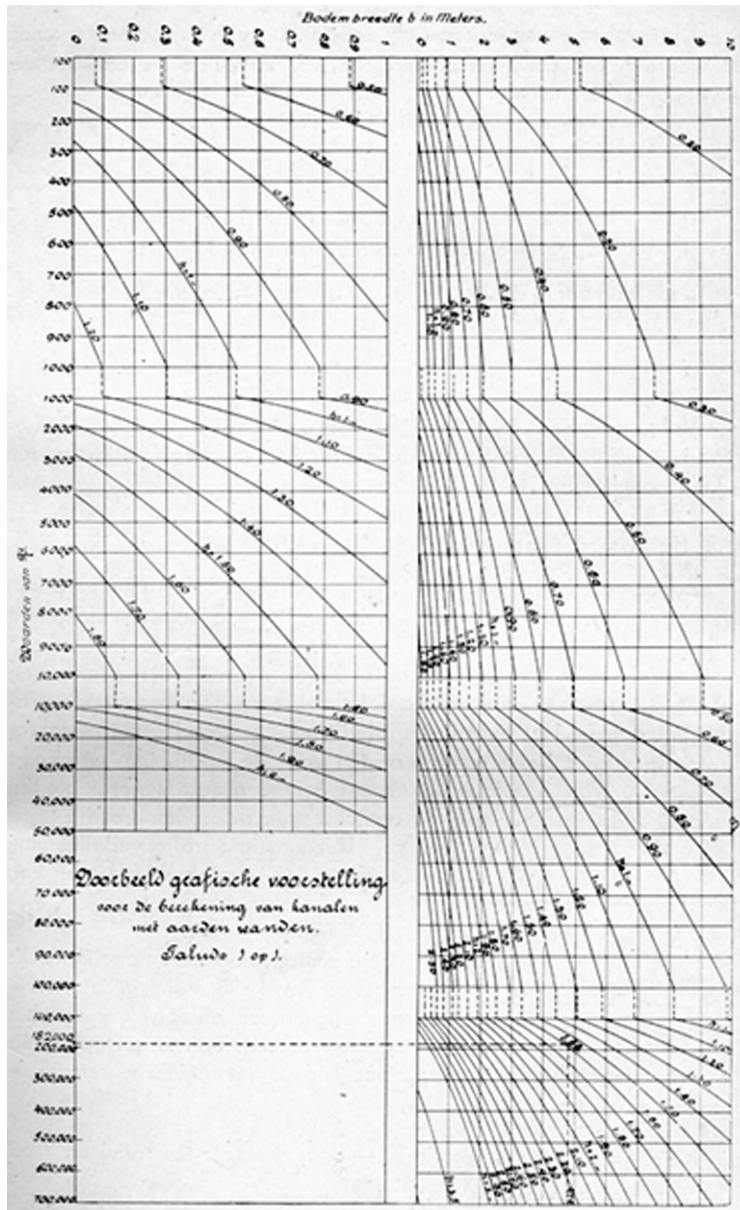
‘[e]xperience gained in later years has learned that when applying the coefficient for regular earthen side walls $\gamma = 1.30$ to calculate C in the new formula of Bazin, dimensions of our irrigation canals become too large. According to newer insights $\gamma = 0.85$ to 0.96 is considered more correct for calculating irrigation canals, which in general have regular earthen walls. For sediment-rich water it would be safe to take coefficient $\gamma = 1.175$.’²⁷

Doing the actual calculations by hand was time-consuming; therefore, the formulas were translated into graphs, allowing quicker graphical canal determination. The 1931 edition of Van Maanen includes graphs made by the Department of Public Works; these graphs showed the relations between b , h and Q^2/i for several side slopes (Figure 6.3). The graphs were based on the old formula of Bazin, indicating that they probably are to be dated around 1900 at the latest. One can only guess why Van Maanen included such old graphs, when new and popular alternatives were readily available, as he himself mentioned. After all, in the 1920s engineer Steevensz had developed design graphs, first for his own use, but as there was a strong request among other irrigation engineers to make the graphs available, the editors of ‘De Waterstaatsingenieur’ approached Steevensz in 1920 and published the graphs. In 1925, a new edition was published; the founding father of the graphs, however, had died by then. At least one of these graphs was used for Tjipoenegara drainage canals. Perhaps the Maatschap had made their own graphs for the Tjipoenegara system instead of using graphs of Steevensz, but I have not been able to trace these Tjipoenegara graphs.

Canal formulas

Steevensz can certainly be regarded as the main contributor to canal design before 1930. He published several contributions, culminating in his collected graphs being published in 1920. His first publication dealing with design of irrigation canals in February 1916 was a reaction to an article published one year earlier by Nijman. Nijman discussed research results of one Dr. Gröger²⁸. The research of Gröger focused on velocities in channels; he had developed formulas to calculate these velocities. His formula did not include a roughness coefficient like in formulas of the Chezy-type. As Nijman mentions several times, setting the right value for such a coefficient was not easy; canal properties were not constant, the coefficient itself was not independent of the water depth, and some empirical research even suggested that the Chezy formula was based on a non-existing relation between canal width and velocity²⁹. In reply, some formulas had been developed in which the water velocity was only dependent on slope and water depth.

Figure 6.3
Public Works
design graph³⁰



“That these formulas have found little application is largely due to the circumstance that they are complicated and awkward to use.”³¹

The formulas developed by Gröger were relatively simple. Using measurements, he found that the channel width has no influence on velocities when the width is above ten meters; furthermore, if water depths were above 0.20 meters, the relation between slope, water depth and velocity could be expressed as

$v_m = 23.781 \times T^{0.776} \times I^{0.458}$ for $T < 2$ meters; and

$v_m = 22.11 \times T^{0.58} \times I^{0.43}$ for $T > 2$ meters,

both with v_m = mean velocity; T = mean water depth; I = slope; $B_{\min} = 10$ meters; $T_{\min} = 0.20$ meters; $I_{\max} = 5$ ‰. Nijman emphasized that the validity of the formulas was limited, as canal widths of ten meters were not common in the Netherlands East Indies of those days; therefore, the graphs developed and used by Public Works based on Bazin were still valid.

‘Nevertheless, the new formula discussed has to be considered important, because it is derived from observations on natural water courses and therefore reveals those relations between bed widths and water depths which yield the best guarantees for maintaining the profile as designed for canal and river sections.’³²

Steevensz supported the general reasoning of Nijman and Gröger, as he proposed a similar approach for channels with bed width below ten meters based on experiences from Pekalen-Sampean and British India. After all, the British engineers had developed much knowledge of stable earthen canals³³. Steevensz combined experiential records from Pekalen-Sampean and British India to develop a formula of the type developed by Gröger, but for smaller channels. In Pekalen-Sampean a table (Table 6.4) giving maximum allowable velocities in canals, was used.

‘With higher flow velocities than given in this table, walls and bed of a canal in earth would erode. Therefore, maintaining these maximum velocities ensures that the canal will not erode.’³⁴

The table also presented the relation between canal width b and water level h , which according to Steevensz was ‘probably’³⁵ adopted to prevent sedimentation. The defined b/h ratios required ‘rather wide profiles’³⁶, similar to canals in British India. Water depths for which velocities in a given canal profile would be maintained could replace the b/h ratio, as was done in British India too. Steevensz used data from Buckley (1911) (Table 6.5) and made a similar table for Pekalen-Sampean, using a canal profile with side slopes 1 to 1.5 (Table 6.6). The tables show, that the Pekalen-Sampean values were between those from the Punjab and Sind,

‘so it seems they could be taken as target water depths.’³⁷

Table 6.4
Canals with side
slopes of 1:1 or
1:1.5³⁸

Capacity in m ³ /s	Maximum velocity in m/s	Relation bed width / water depth
Q tot 1.5	v = 0.50	b/h = 2.-
1.5 – 3.-	0.60	2.5
3.- – 4.5		3.-
4.5 – 6.-		3.5
6.- – 7.5	0.65	4.-
7.5 – 9.-		4.5
9.- – 11.-		5.-

Table 6.5
'Non-
sedimenting'
canals³⁹

Velocity in m/s	Target water level in m	
	Punjab	Sind
v = 0.30	h = 0.39	h = 0.62
0.40	0.62	0.97
0.50	0.87	1.37
0.60	1.16	1.82
0.70	1.48	2.30
0.80	1.82	-

Table 6.6
Channels with
side slope 1:1.5⁴⁰

Capacity in m ³ /s	Velocity in m/s	Water depth in m	Bed width in m	b/h
Q = 0.150	v = 0.30	h = 0.40	b = 0.65	1.5
v = 7.78 i ^{0.365} Q ^{0.27}	0.50	0.92 ⁵	1.85	2
1.5	0.60	1.29	3.90	3
4.5				
11.-				
	0.65	1.61	8.05	5

In a next step, Steevensz calculated what bed slopes would fit with the values of Q , v and b from Table 6.6; he applied the Chezy formula, but instead of the Bazin coefficient, he employed the C-factor of Ganguillet and Kutter,

‘as this one deviates the least from outcomes from direct measurements of all formulae’⁴¹

For sake of comparison, Steevensz calculated some situations using the new formula of Bazin, but the results were less satisfactory. Based on the calculations, he derived a formula expressing a practical relation between Q , v and I ,

$$v = 7.78 i^{0.365} Q^{0.27}$$

The inspiration to reformulate the dependencies between these variables in the general shape of $v = a(i^p)(Q^r)$ had come from an article in the ‘Gesuntheits-Ingenieur’ of 1914, in which a formula of this shape developed by Lindley was discussed. Lindley’s actual formula was unknown and untraceable in the Indies, however; therefore, Steevensz had to derive a version on his own. Based on his formula, Steevensz drew a graph. As

formula and graph were the result of quite a few steps, interpolating several results and formulas, Steevensz foresaw that his approach might be labeled as

‘not very rational’⁴²

It was not based on theory, but on empirical relations. But, Steevensz added, coefficient C was difficult to determine anyway and the relation between v and R began to be doubted by many engineers; his formula on the other hand gave satisfactory results and one had to use just one graph! As practical relations between flows, velocities and depths would be different for different regions, for example because of different soils, the exact values of the formula would be different too. Each important irrigation area would need to develop its own values.⁴³ The first formula of this type drawn by Steevensz was valid for earthen canals. In a new contribution of July 1916, Steevensz presented formulas for canals with smooth and irregular side slopes,

$v = 13.5 i^{0.368} Q^{0.264}$ for smooth canals

$v = 5.437 i^{0.364} Q^{0.271}$ for irregular canals

Again, the author gave a word of warning, that

‘these approximate formulae obviously lack all experimental basis.’⁴⁴

But he added

‘As long as for C [...], however, values are still given which are different from each other, in practice it is just as easy to apply the simple formulas derived here. All our calculations are approximations anyway indeed.’⁴⁵

Using the graphs gave some deviation from results when Chezy with the Ganguillet-Kutter coefficient was employed; for Steevensz these deviations were no reason to reject his graphs, as employing the new and popular(!) formula of Bazin resulted in even higher deviations. The graphs developed by Steevensz combined two requirements of design engineers.

‘[A]n engineer will always demand from his formulae, that they are reliable and lead to results quickly’⁴⁶

The graphs were made in such a way, that

‘without diminishing accuracy [...] 4 of such little graphs can be drawn easily on one page (folio format).’⁴⁷

Steevensz published an extensive article in 1918, with an extensive overview of all types of considerations used in developing his formulas and graphs. Based on the 1918 article, in 1920 his monograph was published, containing only the end result, design

graphs, not the discussions given in the article(s). Fortunately, all references were included.⁴⁸ This monograph is occasionally referred to, when reference is made to the application of design graphs in Tjipoenegara and Krawang design documents.⁴⁹ Steevensz had not used the Bazin coefficient for his graphs; nevertheless, Bazin was the popular formula in practice. In the Krawang area,

[a]t first the new formula of Bazin was selected for calculations, usually accompanied by using the book of graphs of ir. J.M. Steevensz.⁵⁰

Steevensz's preference for Ganguillet-Kutter above Bazin had apparently not diminished the general preference for Bazin nor the accompanying use of Steevensz's graphs! With the practical differences between different formulas for coefficient *C* being very small, the apparent contradiction could easily remain without real practical consequences.

Strickler enters the stage

Determining roughness coefficients in any of the flow formulas discussed, remained vital. In one of the first extensive papers on the subject⁵¹, engineer Vreedenburgh discussed roughness coefficients in detail. This paper brought the potential application of Strickler on the agenda in the Netherlands East Indies. Vreedenburgh referred to a paper of Forchheimer⁵², which on its turn discussed American research by Scobey. Scobey concluded that the Manning formula could very well be applied for canals lined with concrete. Manning had published his formula in 1890. The formula reads

$$V = 1/n (R^{2/3}) (I^{1/2})$$

in which *n* = the roughness factor of Ganguillet and Kutter, and is similar to the formula published by Gauckler in 1868, which reads

$$V = K (R^{2/3}) (I^{1/2})$$

In Februari 1923, Dr. A. Strickler published the booklet⁵³, which would connect him to the Gauckler-Manning formula; Strickler recommended the Gauckler-Manning formula, with the remark

‘to apply empirical k-values only’⁵⁴

In October 1923 Forchheimer came with a similar recommendation. Vreedenburgh explains the new attention for such an old formula not just for its good explanation of measurements, but also in terms of practical applicability.

[‘T]he exponential shape [is] particularly suited [...] to logarithmic calculations and [can] be easily presented graphically in a linear design graph.’⁵⁵

The working environment of Vreedenburgh also partly explains why he was interested in the formula of Strickler. He worked for the Hydropower Service. In contrast to irrigation, detailed knowledge of canal roughness was important for hydropower systems. Most canals were lined, many were quite long or had considerable slopes; in short, hydropower canals were expensive. When design of these canals could be improved, money could be saved. It is therefore not a real surprise, that Vreedenburgh discussed results of canal measurements. In 1934, Meesters presented a similar discussion on coefficients in flow formulas as Vreedenburgh had done in 1924, although without referring to the 1924 article; he concluded that roughness coefficient values from practice were still very much needed. In a short reaction⁵⁶, Vreedenburgh supports Meesters in his appeal to conduct measurements. A few years earlier, in 1931, Verwoerd⁵⁷ published a design approach, including graphs, based on a formula proposed by Strickler⁵⁸. Referring to a publication of Vreedenburgh in *De Waterstaatsingenieur* of 1924, Verwoerd proposed to apply the formula of Strickler,

$$V = K (R^{2/3}) (I^{1/2})$$

in which V = velocity; K = roughness factor; R = hydraulic radius; I = energy slope. He did not follow Vreedenburgh completely, however, as Verwoerd proposed to simplify the design graphs developed by Vreedenburgh considerably. Verwoerd considered the graphs drawn by Steevensz very practical in use for normal profiles, but in cases when less common canal profiles were needed or very accurate calculations had to be made, the results would be less satisfactory. Applying the Bazin formula would yield canal profiles becoming too wide, and thus expensive, and/or energy slopes too steep, causing erosion particularly in upstream canal sections. Verwoerd developed a reference design graph (Figure 6.4) for a standard canal profile with an open water surface, perpendicular sides and a bed width of twice the water depth. For each other type of profile, he drew another design graph with reduction factors (Figures 6.5).

For example, a required flow $Q = 6.05 \text{ m}^3/\text{s}$ needed to be transported with a velocity $v = 0.70 \text{ m/s}$ through a canal with side slopes of 1:1 and bed width b of five times water depth h . Roughness coefficient $k = 47$. What needed to be determined was energy slope I and the dimensions of the canal profile. As $b = 5 \times h$, the mean width with slopes of 1:1 is $b = 6 \times h$. According to graph 6.5, for $b = 6 \times h$ the relation between v and $v_m = 0.93$, which makes $v_m 100/93 \times 0.7 = 0.753 \text{ m/s}$. With this velocity, graph 6.4, for $Q = 6.05$ and $K = 47$, gives an energy slope $I = 0.00026$. Furthermore, flow area $F = 6.05/0.70 = 8.64 \text{ m}^2$. Also relation $F = b \times h = 6 \times h^2$ holds, which means that $6 \times h^2 = 8.64$. This gives $h = 1.2 \text{ m}$ and $b = 5 \times h = 6 \text{ m}$.

the East Indies seems to have missed canal design practice in the Netherlands altogether; in 1936 Breeman, who worked for the 'Cultuurtechnischen Dienst', published a similar book with design graphs as Steevensz had published 15 years earlier in the East Indies. Breeman preferred the new coefficient of Bazin; he does not refer to other documents or authors, but

[t]he reliability of this formula is also based on the judgment of the late Dr. C.W. Lely, our river expert par excellence, whose many important reports apply the formula of Bazin.⁶²

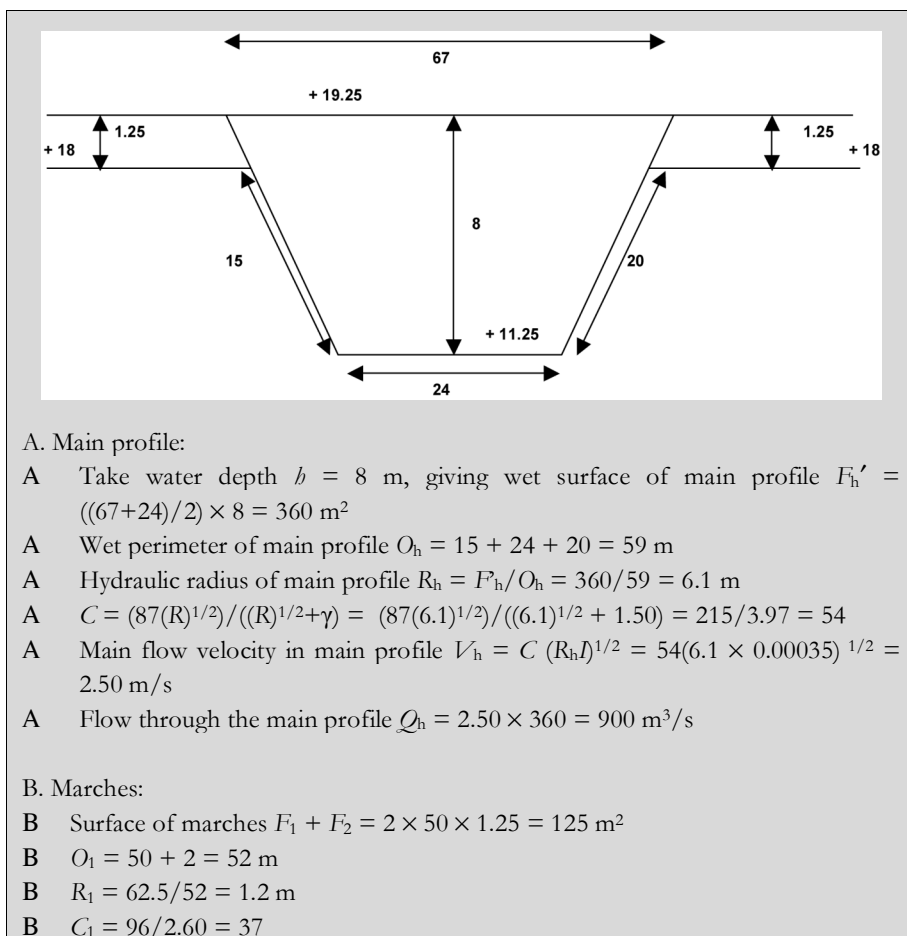
Design of river works and drainage canals

Breeman made his graphs for the design of drainage canals, obviously the most important canals in the Netherlands. In the East Indies, draining water was important too. Irrigation systems had to drain both excessive water from rainfall and irrigation. The drainage capacity of rivers, including potential influences of new weirs in riverbeds, had to be checked too; protecting embankments had to be constructed if necessary to allow peak flows to pass without damage. Furthermore, Salamderma weir in the Tjipoenegara caused higher water levels in the river on top of the already high levels during bandjirs; protective measures were needed. South of the railway, it was assumed that embankments were not needed, as the riverbed was wider, the terrain higher and the weir not supposed to have big influence. Furthermore, the lands that might be flooded were used extensively anyway. North of the railway, however, the situation was different. Not only were the new investments in irrigated land to be protected, available data showed that flooding already occurred occasionally without the new dam. In 1922, the highest water level measured below the first flushing sluice was already 0.50 meter above the adjoining terrain. The accompanying river flow was only 345 m³/s, much less than the maximum theoretically possible!⁶³ Existing local water reservoirs or sitoos, equipped with bandjir intake canals, were regarded as further proof for the need of protective measures. Among those reservoirs were Siteo Andjatan and Siteo Tjigoegoer, 4.5 kilometres downstream of the second flushing sluice.

Thus, protecting the irrigation system against floods upstream and downstream of the weir was a necessity. Obviously, constructing embankments would change the behavior of the river, as it could no longer flood the plain; this would result in even higher water levels during floods. A first action of the responsible designers was to study the existing situation. Water levels were measured, water flows were calculated and measured, and the local population was interviewed. In 1915, flow measurements started, which were used for a discharge curve. In March 1916, a huge bandjir occurred, which could be neither measured nor calculated; from 1917 onwards, however, bandjirs generally did not exceed 500 m³/s. Between 1922 and 1928 only one bandjir of about 750 m³/s – calculated discharge – occurred. The peak flood design discharge was set at 1,000 m³/s. Rainfall measurements, available since 1888, confirmed the rare occurrence of larger

bandjirs; extreme rainfall was measured in March 1895 (768 mm), February 1912 (681 mm), February 1915 (688 mm) and March 1916 (710 mm) – this last event obviously causing the bandjir of that year. With the maximum design discharge set at 1,000 m³/s and a known, measured river profile, it was possible to calculate the flood water level, against which the adjoining lands had to be protected. As a first approximation, potential water levels in the river profile with embankments were calculated, assuming that the river profile itself would not change. River profiles were simplified; embankments were assumed to stand at 50 meters from the riverbed. River discharges and water levels were calculated with the formulas of Chezy and Bazin (with γ set at 1.50, see Figure 6.6).

Figure 6.6
Example
calculation for
one
Tjipoenegara
river profile ⁶⁴



The mean slope of the riverbed was set between 0.00035 and 0.00025. Using the resulting maximum water levels in the different river profiles, a water level curve was drawn along the longitudinal profile of the river. This first curve did not necessarily relate in any way to the known levels at sea; furthermore, the water would change the

riverbed profile when its flow was restricted between the embankments. River depth or width would adapt to both discharge and sea level; these adaptations were assumed for the next step. New approximate water and riverbed level curves were drawn, assuming that these curves would represent the new situation. Based on these curves, control calculations with a similar set-up as the first calculation had to prove that, assuming a certain deepening and widening of the bed, the discharge would be about 1,000 m³/s. Finally, if the calculations fitted the curve, the curves were taken as representative.

The embankments which had to protect the irrigated areas from the river floods were designed with a top width of 2.50 meters and slopes of 2 to 1 at the riverside and 1.5 to 1 on the landside. In case the embankment was constructed close along an irrigation canal, the embankment served as main road and the top width was enlarged to 4 meters. The embankments would be constructed some 50 meters from the riverbed. As the Tjipoenegara was winding, making it costly to construct the embankments following its course exactly, the embankments were designed much further away from the riverbed for most of their length. When finally constructed, embankments were located even further away, minimally about 100 meters from the river bed, as experiences with the Tjitaroem River in Krawang showed that embankments too close to the bed were vulnerable to damages due to the changes in the riverbed, especially in the curves. Experience from Krawang also guided design of drainage canals within the Tjipoenegara command area. For given drainage units, a maximum flow per km² was determined,

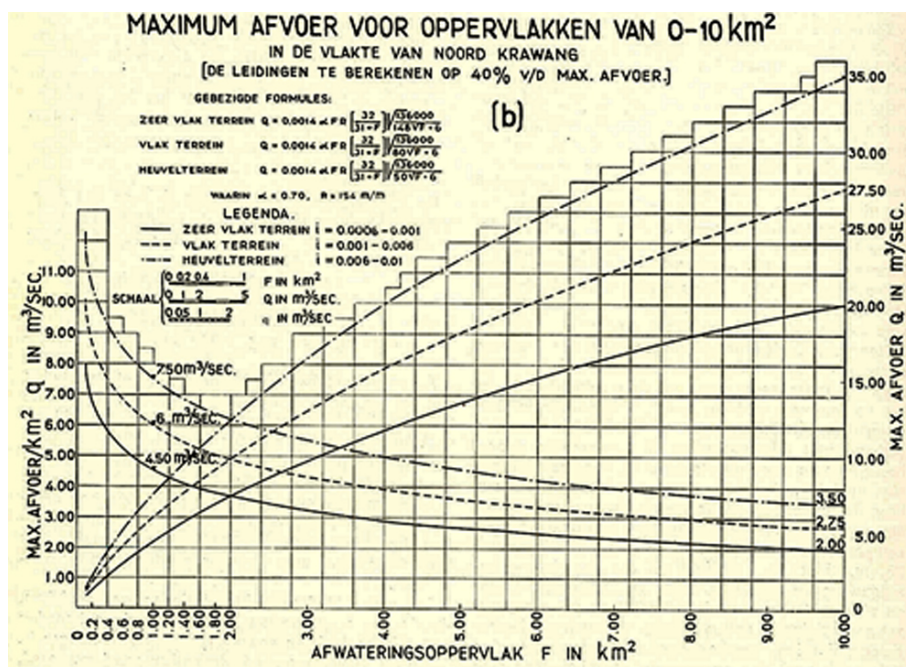
‘according to the assumptions from the Krawang works’⁶⁵

The assumptions in Krawang were shaped in a study by engineer Wassing, who had made a graph (again!) in which the maximum or design drainage flows per surface unit in m³/s for drainage units up to 10 km² were given (Figure 6.7)⁶⁶. For areas up to 25 km², the curve for q – the maximum discharge per km² in m³/s – was assumed to be horizontal⁶⁷. For larger areas in Krawang

‘the well known method Melchior was applied most of the time’⁶⁸

Modifying the approach of an engineer from Bern (Switzerland), Lauterburg (1887), Melchior developed a methodology to determine the design peak flows of Javanese rivers in the late 19th century. The design peak flow was the flow for which constructions need to be dimensioned; it was not a maximum which would never be exceeded. The Melchior methodology remained the standard method throughout the colonial period, despite sometimes severe criticisms on its appropriateness.⁶⁹ For the Tjipoenegara area I could not detect a similar firm statement as for Krawang, but it is likely Melchior was applied there too.

Figure 6.7
Drainage design
graph⁷⁰



Another direct copy from the approach in Krawang was the way capacities of drainage canals themselves were determined. Drainage canals in the Tjipoenegara system were designed with a capacity of 40% of the maximum potential drainage flow. In particular cutting costs for soil movement was a reason for this. Inundations caused by canals being too small, although considered unlikely, were an accepted risk. The minimal drainage canal profile was set at a bed width of 0.50 m with an equal water depth. In case structures were needed, for example when crossing other canals, the capacity of these structures was set at full capacity. In some cases drainage canals not only had to remove natural drainage water, but also water from emergency outlets in the irrigation system. Such was for example the case with the emergency outlet of the main division structure Boegis. The drainage canal routing had two options. The first option was to use the existing natural kali Digoer, which could drain without interfering with the irrigation canal system, in particular the Pengarengan canal. Another option was to divert the kali Digoer to another stream, the kali Mangsetan. This would affect the natural drainage situation more extensively, but was nevertheless selected, as it was not clear to what extent the kali Digoer could cope with the extra water without scouring and erosion. In a letter of the Director of Public Works⁷¹, costs appeared as main criterion; the second option would save money, as a relatively complicated study could be avoided.

The area to be drained was determined at three points along the drainage canal and kali; at the start of the canal the area was found to be 11 km², 6.5 km downstream it already counted 21.4 km² and at sea the area was found to be 44.7 km². With a capacity of 1.5

m³/s per km² the respective maximum flows became 16.5 m³/s, 32.1 m³/s and 67.05 m³/s. In this specific case, the assumption was made that half of this maximum flow had to be drained instead of 40%. Another potential inflow in the drainage canal came from division structure Boegis, with a maximum inflow of 14.45 m³/s. It was expected that this inflow would be very rare and a combination of natural and emergency outlet inflows was not expected either. Therefore, the design engineer assumed that the higher value of the two inflows should be set as the design discharge. Therefore, the outflow from Boegis was designed at 14.45 m³/s, until half of the natural drainage flow would equal the 14.45 m³/s from the structure. From this point onwards, the discharge was increased to 16.05 m³/s, where the drainage area was 21.4 km², and to 33.53 m³/s at the sea. Calculating the canal profile was done using nomograph B.II.4 made by ir. Steevensz.

Design decisions and procedures

The plans and designs discussed above amounted to a total cost of a little over 5,000,000 guilders; they resulted in an irrigation system of 65,000 bouw, which gives a figure of about 75 guilders per bouw or $75 \times 1.4 = 105$ guilders per hectare. About half, 2.4 million guilders, was reserved for constructing Salamderma weir. As a comparison, the Krawang system amounted to almost 16,500,000 guilders for some 125,500 bouw, about 130 guilders per bouw or 184 guilders per hectare⁷². A design document for the Sadang works in the 1930s mentioned different cost estimates for both Tjipoenegara and Krawang systems; both systems are projected as being more expensive⁷³. Whatever the budget, it could not be prevented that in 1931 serious erosion immediately downstream of the Tjipoenegara weir occurred⁷⁴. Model studies in the experimental tank at Tandjong Priok had to find solutions for the erosion problem. Similar problems occurred and similar studies were conducted for Walahar weir in Krawang in the early 1930s. After all, the Tjipoenegara system was designed keeping a close eye on the Krawang irrigation system.

Irrigation system	Total costs in million guilders	Total area in hectares	Costs per area (Guilders / hectare)	Costs for river weir (guilders / hectare)
Krawang	20	78,000	256	68
Tangerang	12	52,500	229	-
Tjipoenegara	6	28,400	211	84
Sadang	12	56,900	211	53

Table 6.7 Costs for several irrigation systems⁷⁵

In Chapters five and six, I focused on decisions in Tjipoenegara colonial irrigation design: what were these decisions about, who made them, which agreement was reached; in other words, I have reconstructed a social construction process of design related decisions. The decisions centered on the design of irrigation infrastructure in the Tjipoenegara area: the locus of the decision process was the Tjipoenegara area, even though most actors involved spent most of their time in other places. The Maatschap 'Eigen Beheer' held office in Poerwakarta, the Department of Public Works was

located in Batavia and many of the future irrigators were not even present yet. To answer the question who was deciding, a closer look at design decisions in the Tjipoenegara case may help. The description I provided suggests that most of the decisions made were the responsibility of civil engineers; either Public Works or the Head of the Krawang works formally confirmed or corrected the majority of the decisions made by the engineers of the Maatschap. From the about 120 decisions I have been able to trace from the design documents⁷⁶, about sixteen can be labeled as not related to civil engineering or not made by civil engineers. From these sixteen decisions, eight are governmental decisions, for example the decrees dated June 26th 1914 to partially expropriate the P&T Lands and June 17th 1915 to establish a commission to value the P&T Lands. For the remaining eight decisions (Table 6.8), influence of representatives of governmental agencies related to the agriculture domain is only visible for one decision, which is not even a decision as such, but an advice. On April 4th 1924, the Director of Agriculture advised that a net water requirement lower than 0.8 l/s/b would be appropriate for the Tjipoenegara design; we have seen that during the design process the engineers adapted the relative water availability for the Tjipoenegara crops when a larger irrigated area was finally selected. Therefore, one cannot argue that water requirement from an agricultural point of view has played a major role in the design process.

Year	Date	Description
1917	16/10	'Meetbrief' (Letter of Measurements) No 284 indicates P&T Blocks 26 and 28.
1918		Report of the commission to establish the value of the P&T Lands
1924	11/4	Advice of the Director of Agriculture, Industry and Trade No 3747/A: A water requirement lower than the 0.80 l/s per net bouw assumed is considered likely.
	12/11	Letter of Director PW to Director of the Civil Service No 35936/E, partial agreement with new design dated 21/8/24.
1926	8/10	Agreement between the Government of the Netherlands East Indies and the Mij. Ter Exploitatie van de P&T Landen on the division of Tjipoenegara water.
1930	30/5	P&T Lands present a design for the first 1,000 bouws of Block 28, No 741/G
1932	22/3	Visit of the Governor of West-Java, request to set the width of a road on an embankment at 7.50 m in relation to expropriation of lands
1933	20/6	After earlier discussions between the Head of Unit E of the Dep of PW and Head of Krawang, a meeting with deputy Head of the Provincial Irrigatiom Office at Cheribon, ir. Te Winkel is held concerning a sluice that has been flushed away.

Table 6.8 'Non-engineering' involvement in the Tjipoenegara design

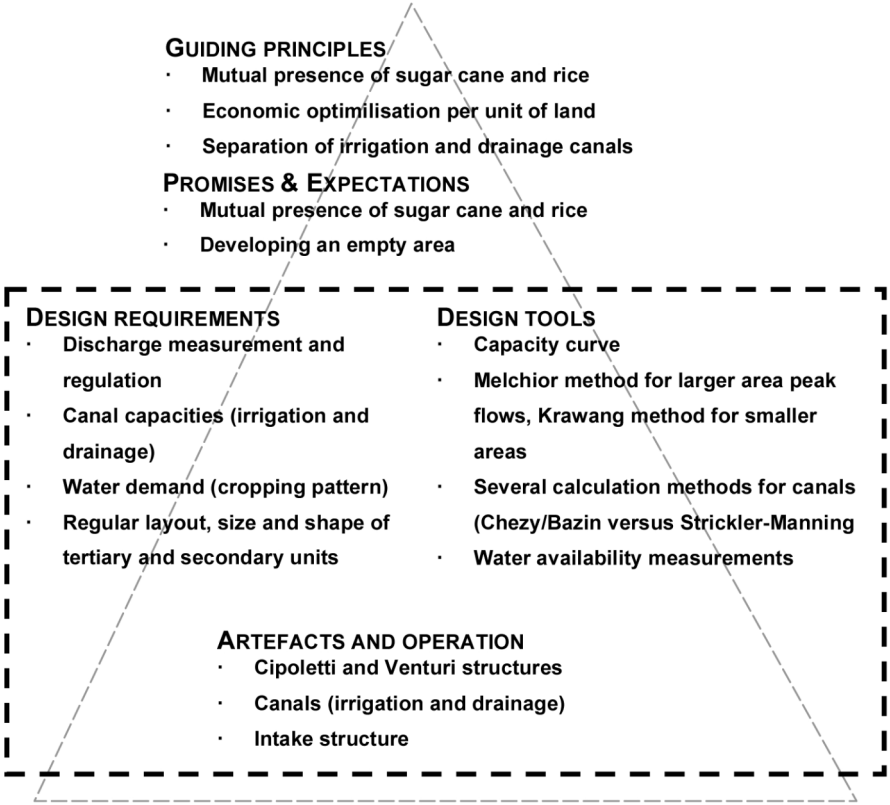
Thus, I would conclude that at the level of concrete decisions relevant for the shape and size of irrigation infrastructure, including the design tools applied, civil engineers were the relevant social group to structure and control the social construction process. In the Tjipoenegara design process, the internal decision process of the Department of Public Works and its representatives checked the design process; proposals made by the designers from the Maatschap had to meet the Departmental standards, unless there were reasons to do otherwise. In principal, the Krawang approach was applied in the Tjipoenegara area. Plans for designs had to be submitted to and approved by the

Head of the Krawang works before they could be sent to the Department of Public Works in Batavia for final approval. On their turn, the design guidelines of Krawang were based on several other sources, including earlier irrigation systems, the Pemali system in particular, reports, for example of the Solo Commission, and existing Departmental guidelines. I have shown that guidelines applicable to the Tjipoenegara case can be traced back to experiences from several of these earlier systems. The canal capacity curve is a case in point: already in 1897, Public Works requested that all capacity calculations were to be judged by the Department before canal design could proceed; preference for the Pemali curve was not official yet, but was clear enough.

The Tjipoenegara case has made clear that several types of rules have been employed in East Indies irrigation design (Figure 6.8); some of these rules were implicitly taken for granted, others were discussed more explicitly. The most important design rule to be taken for granted appears to be the anticipation of presence of sugar cane in the irrigated area, which is reflected in the capacity determination. Taking into account sugar cane almost appears like a ‘mantra’; its future presence was not doubted, although in the Tjipoenegara case sugar cane never prospered⁷⁷. As a result, the relative canal capacities of the Tjipoenegara system were designed lower than they may have been in case mono-cropping of rice were the reference pattern⁷⁸. Another major design rule was the application of discharge and measurement structures. Applying these is partly the result of the mutual presence of sugar cane and rice, but also of the East Indian principal guideline of economic optimization of water use. Based on these implicit rules, at the level of guiding principles and expectations, the design engineers shaped irrigation infrastructure as well as their own design approach. The procedure to follow for the design of the physical canal system was relatively one-dimensional. ‘Functional requirements’, for example canal capacities, were determined applying certain ‘design tools’, for example a capacity curve.

Another example of a functional requirement, a regular layout with a preferred shape and size of tertiary units has a similar history; discussions on sizes of units were more or less closed with the adapted Pemali reference numbers from 200 to 150 bouw, although in the 1930’s preferred sizes increased slightly for economic reasons. In case of other functional requirements, like canal calculations or the application of division and measurement structures, requirements could be fulfilled with different design tools or ‘artifacts’ over time. In canal calculation approaches, a shift from Chezy in combination with Bazin towards the application of Strickler-Manning-Gauckler has occurred. Much input for the discussions on design was taken from the German-speaking countries, together with British India. Canal design graphs were an important design tool in the process. Division and measurement structures in the Tjipoenegara area partially shifted from standard Cipoletti weirs in combination with regulated intakes to Venturi structures; the complete shift towards Romijn weirs was not clearly found for the Tjipoenegara system, unlike in the Krawang system.

Figure 6.8
Design rules in
the
Tjipoenegara
case



I started Chapter five stating that the design process can be analyzed as ‘relatively one-dimensional’, as linear. That does not imply that the design process was linear all the time; true, certain logic in the process from larger scale to smaller scale can be detected, but iteration was a key in the design process. Values or choices set or assumed in early design documents, for example on command or irrigated areas or water availability, were changed in later documents. In particular the relations between areas, water availability and structures employed, both in type and location, were reason for change. In the overall design, the location of the weir and main intake influenced the potential command area; a change in measurement structures in Boegis from Chipoletti to Venturis increased the irrigated area and decreased relative water availability. On the level of detailed calculations, a type of iteration can be found as well, for example when the maximum discharges in relation to river behavior had to be determined. Iteration as a key feature of the design process can be traced back directly to the early designs of the 1880s, in particular the Pekalen and Pemali systems. It also reflects modern ideas of design quite well⁷⁹. Has anything changed?

7 Rules in retrospect

Remains of colonial irrigation in Indonesia

Indonesia's independence in the 1940s effectively put a halt to massive Dutch engineering efforts in the archipelago. At the end of the 1940s and beginning of the 1950s it became clear that the high number of engineers working in the East Indies would not be reached anymore; the East Indies as employment option had disappeared¹. The number of active engineers between 1945 and 1949 had already been limited in comparison with the period before World War II, when about 280 engineers were employed by the Department of Public Works. After 1945, some 100 engineers were active in the areas of Indonesia under Dutch control, including 25 engineers which had been sent directly from the Netherlands. Irrigation received relatively little attention; restoring and building transportation infrastructure was of much higher importance. Furthermore, unlike transportation facilities, irrigation works may have been relatively secure from war damage².

'When visiting several areas after the [Dutch military] actions it has struck me particularly, that from the irrigation works not more was destroyed than was judged necessary for certain military actions, e.g. inundation of large complexes, by the republican troops. In my view this clearly demonstrates the great value, which the Indonesian attaches to irrigation works'³

Despite the expectation and hope of the Dutch, including many engineers, who perceived their work as being of great value for Indonesia, as the quote illustrates, relations with the new Republic of Indonesia cooled down considerably in the 1950s. At the end of the 1960s, however, relations did improve. In 1967 the Indonesian Government applied for international assistance to develop an integrated water development plan for the country. Rehabilitation of existing infrastructure was the first priority; a large-scale program including 780,000 hectares in total – with 90% on Java – was formulated, focusing on constructive rehabilitation and/or upgrading and if necessary new irrigation facilities. The Dutch government offered assistance as well⁴, and Dutch engineers started to work on projects like the Tarum canals on West Java and the Djratunseluna area on Central Java⁵. These first cooperation efforts focused on constructional aspects of irrigation. Attention for management, however, soon became an issue, as many irrigation systems, which were not rehabilitated for financial reasons

could still be improved by improvements in management, which could be cheaper too. Furthermore, as the population on Java had grown strongly and land use patterns had changed, irrigation systems had to function in different circumstances. Much non-irrigated land (*tegalan* or *pekarangan*) had been transformed into irrigated land (*sawah*), putting more stress on water distribution and management. New projects were started, like the East Java Irrigation Project of 1981, which aimed at rehabilitation, including management reform, of small to mid-sized⁶ irrigation systems with a total irrigated area of about 320,000 hectares⁷. Besides rehabilitation, another type of projects can be distinguished in the programs to develop multipurpose reservoirs, usually with feeder canals to supplement water to a series of formerly independent irrigation systems. On West Java, the Jatiluhur system with its Tarum feeder canals is the forerunner of this type; others have been developed later, for example the Wadaslintang project of the 1980s and early 1990s in South-Kedu at the south coast of Central-Java.

Colonization efforts in Lampung, Sumatra

The Lampung area in Southern Sumatra⁸ is an area showing considerable irrigation related activities after independence as well. In the area, both Dutch and Japanese engineering firms were active. As colonial influences were strongly influencing irrigation development in this region, like in other areas of Indonesia, Lampung is a fascinating mix of old, new, rehabilitated, planned and abandoned irrigation systems. The Lampung case includes a smaller case study in itself shedding light on (dis)continuities of Dutch irrigation after 1949; we will make a short side-visit to Nigeria to come back to Lampung⁹. The Lampung area represents a number of irrigation schemes outside Java. Dutch irrigation engineers did build irrigation systems on Sumatra, Sulawesi¹⁰ and Kalimantan¹¹, although their efforts were not that successful before 1930. Lampung will also prove to be representative for Javanese irrigation schemes, even given the differences in contexts. The Lampung irrigation systems were developed by the Dutch colonial powers to accommodate settlers in the context of the Netherlands East Indian colonization program (Figure 7.1). Lampung colonial irrigation projects were settlement schemes. Settlement or transmigration was an important policy of the Indonesian state as well; in a way modern irrigation engineers are working on Lampung irrigation systems, which were planned in the 1930s in the context of colonization projects for Javanese settlers. Obviously, these modern engineers do so within a context of international cooperation instead of colonialism.

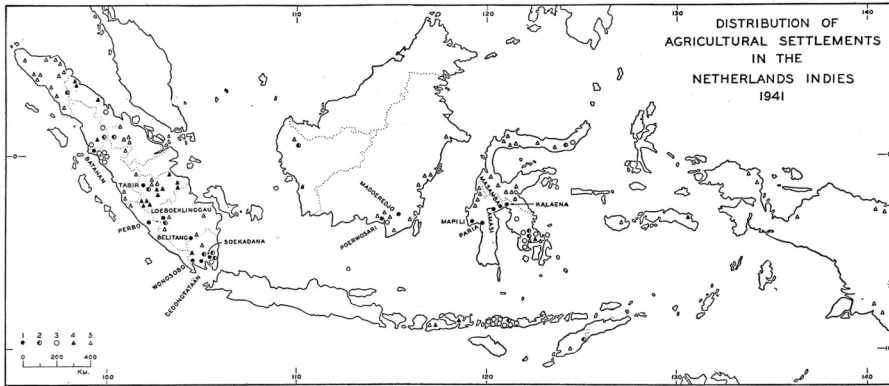


FIG. 164—Agricultural colonies and areas under consideration for settlement in the Netherlands Indies, 1941. The numbered symbols indicate: 1—Agricultural colonies actually existing in 1941; 2—Areas approved by preliminary soil and irrigation surveys; 3—Areas rejected; 4—Areas visited by reconnaissance parties but not yet scheduled for irrigation survey; 5—Areas considered, but not yet surveyed by reconnaissance parties. (Based on data supplied by the Central Commission for the Migration and Colonization of Natives.)

Figure 7.1
Colonization
regions in the
Netherlands East
Indies¹²

The need for attention for irrigation on islands other than Java was stressed as early as 1887, when former resident D.F. van Alphen urged for extending irrigation outside Java.

‘But the speaker admitted that he doubted the ambition of the engineers [...]’¹³

For a part this was due to similar pioneering working circumstances as encountered on Java earlier, but for another part it was caused by the recruitment of the engineers assigned to the works.

‘Generally we experience much difficulty to transfer Public Works servants to the outer possessions. Attempts were made to meet this problem by transferring engineers in temporary service at a high salary; but I have to admit honestly, Mister Chairman, that except for a single favorable exception, this has turned into a fiasco. We have set loose people with little experience at the outer areas, just to name it like that.’¹⁴

When irrigation projects in other areas than Java did finally get momentum, it was late. In 1939, the expenditures on irrigation of the Department of Public Works amounted to 1,725,000 guilders for Java and 2,489,000 guilders for the Outer Islands¹⁵. However, many colonial irrigation projects started in the 1930s could not be finalized before 1942, the year of the Japanese occupation. After 1965, when Dutch engineers re-entered the irrigation development discourse in Indonesia, Dutch rehabilitation activities have also focused on these late-colonial, non-Javanese systems, like the Way Sekampung system in Lampung and the Luwu system at Sulawesi.

Sumatra has been one of the most important islands for irrigation development in the colonial period (Table 6.1). Reasons for irrigation development, however, were not alike for all regions of Sumatra. In northern and eastern Sumatra the potential for irrigation was discussed in the context of food security for the workers on the estates in these

areas, as these workers were usually migrants from other regions without land of their own. Irrigation development in Lampung strongly connects to colonization efforts of the Dutch colonial administration.

‘The rapid start with irrigation in non-exploited areas in the outer regions is closely connected to the colonization of Natives, which, intensively developed since 1935 and primarily intended for Javanese colonists, is only considered possible when irrigable nuclear areas are available.’¹⁶

Table 7.1
Colonization
projects studied
on Sumatra
before 1940¹⁷

Project	Area (approximate thousand hectares)		Impression
	Surveyed	Tentatively approved	
<i>Atjeh</i>			
<i>Alas Pamah</i>	11	11	Favorable
<i>East coast of Sumatra</i>			
<i>Loeboe</i>	56	23	Fairly favorable
<i>Sosa</i>	15	7	Unfavorable: practically non irrigable
<i>Bila</i>	25	25	Favorable as far as irrigation is concerned; rejected because of soil
<i>Natas</i>	22	20	Same as for Bila
<i>Koealoe</i>	25	25	Same as for Bila
<i>Tapanoeli</i>			
<i>Natal</i>	25	20	Same as for Bila
<i>Aek Si Oetam</i>	11	?	Not unfavorable
<i>Palembang</i>			
<i>Moesi-Koengkoe</i>	100	80	Favorable
<i>Lampoeng Districts</i>			
<i>Djapara</i>	17	15	Favorable; reservoir irrigation

The Lampung of early 1900 was a pepper-exporting region, with some growth of rubber export from 1915 onwards. Between 1905 and 1930, the population more than doubled from about 160,000 to just over 350,000 people, with a contribution of several ten thousands of colonists from Java¹⁸. The need for planned colonization was discussed earlier, but the beginning of the 20th century marked the start of official governmental recognition for using the instrument for decreasing population pressures on Java. In the Ethical Policy, irrigation and emigration were two sides of the same coin. Javanese future settlers would not be tempted to start a new life outside Java when irrigation facilities would not be available¹⁹.

In the early 20th century, the colonial government received alarming reports of overpopulation and poverty in the residency of Kedu and authorized Assistant-Resident H.G. Heyting to study possibilities for migration of Javanese to the Outer Islands²⁰. Heyting began his survey in Kedu, took some assistants and villagers from Kedu with him to Sumatra, and travelled in several residencies on Sumatra, including

the Lampung Districts to find suitable colonization terrains. In December 1903 Heyting proposed six colonization projects in Lampung and five in Java. A total of 22,940 families were to migrate within ten years from Kedu to the new colonies, beginning with 500 families for each project. Hopefully, each of these families would attract related families, leading to spontaneous colonization. The government considered the plan too ambitious and decided to experiment in one selected locality. This was to be Gedongtataän in Lampung, south of the Way (river) Sekampung, which apparently had sufficient water available for rice irrigation. Using assistance of amongst others two mantris of the Irrigation Service, Heyting arrived in Gedongtataän in May 1905. A first group of 155 families arrived later that year in the area and founded the desa of Bagelen. A second desa, Gadingredjo, was founded in 1906 with 555 families. Other desas were established too, and in 1911, a total of four desas counted 4,818 Javanese people.²¹

Before 1911, settlers received support in cash and kind directly from the government. In 1911, however, that same government founded the People's Credit Bank of the Lampoeng Districts. Settlers still received some direct support, but development costs for their colonies were provided through loans, which had to be repaid. During periods of great labor demand, however, both on Java and the Outer Islands, the government lost interest in colonization projects and consequently reduced colonization budgets. For example, in 1914 the Ministry of Colonies declared that the necessity for colonization had been eliminated for this reason of labor availability. Between 1918 and 1923, the government increased the funds again, whereas from 1924 until the depression little was done. One of the problems with colonization was a certain optimism concerning the development of irrigation, which importance had been stressed by Heyting. He had planned that the Javanese themselves would build the irrigation infrastructure, as they were familiar with the methods of irrigation. Thus, no engineers had been involved, but mantris of the Irrigation Service. Irrigating crops in existing systems, however, appeared to differ from building irrigation in a new environment.

'In 1927, Schalkwijk, manager of Gedongtataän, reported that many fields had too much, others, too little water.'²²

As a clear example of problems with the settlement schemes, the People's Credit Bank of the Lampoeng Districts was closed in 1928.

'Fraud, embezzlement, and faulty bookkeeping'²³,

discovered in 1926, was certainly one of the problems, but generally the colonization had not brought the results in numbers of migrants hoped for by the colonial government. Engineer Wehlburg, who became involved in the Lampung program in 1933, blamed the bad planning of the schemes. Flat, badly drained areas had been

reserved for houses causing malaria, which either killed settlers or made them leave the scheme. He adds that

‘[t]his was masked by machinations by the colonization leader, a former planter who registered premiums and advance payments on the names of dead and runaway colonists and used the money for his own benefit.’²⁴

Nevertheless, in 1927 the colonized population in Lampung had increased to approximately 21,800 persons. Within this group, 914 persons had migrated on their own to southern Sumatra, a number, which would reach a total of 3,500 Javanese in 1931. These settlers had paid themselves, selling their possessions in Java to test their luck in the Outer Islands. Apparently this growing number of settlers stimulated the government to think big. After 1931 the efforts for agricultural colonization were expanded. Most of the settlers in 1932 were still absorbed by the *desas* of Gedongtataän, but that colony was filling up so rapidly that new areas had to be found. These should be close to Gedongtataän, which was supposed to serve

‘as a nucleus or, rather, as a bridge’²⁵

The Soekadana district, northeast of Gedongtataän, was selected. Already in 1932 the first colonists arrived. In the next few years, plans were made for large-scale settlement, which started in 1935 with 5,500 persons moving to the Soekadana district. The numbers increased per year, with 8,784 new persons in 1936, 6,715 in 1937, 13,882 in 1938 and approximately 18,000 in 1939. Soekadana had a population of 47,000 in 1940, 2,000 more than Gedongtataän.²⁶

Irrigation and colonization

Plans for the Soekadana colony included the development of irrigation systems. Although the Dutch had constructed irrigation works in the Lampung area from the early 20th century, the Soekadana colonization project was the first major irrigation system designed and constructed in Lampung. Similar to the process on Java, first Dutch irrigation efforts mainly focused on main structures, in the Lampung case small weirs and intake structures. Many of these weirs are still functioning in modern Lampung (Figure 7.2). As early as 1910, the Government started a general reconnaissance study to define the potential for irrigation development in Sumatra, and the Lampung Districts in particular²⁷. As it had to be cheap, young engineers with temporary employment did the study; apparently the results of their work were not satisfactory enough, as in 1912, the experienced engineer Van Tubergen traveled to the Lampung Districts to study irrigation possibilities. In 1913 his report was published, sketching in general terms several issues and ideas concerning irrigation. A lack of data, river flow measurements were not and rainfall measurements only scarcely available, a lack of detailed maps and the time needed to travel through the Districts did not prevent Van Tubergen to be very positive about the potential for irrigation. That this potential had not been exploited yet had to do with the circumstance that

‘in general irrigation affairs have only attracted little attention from local civil servants so far’²⁸,

as land to grow pepper and practice ladang was still readily available and wet rice cultivation scarce. The pockets of irrigated rice cultivation that existed in the area did show, however, that larger-scale irrigation would be possible, especially

‘when it is possible to deliver living, fertile, sediment-rich water’²⁹

Irrigation would result in higher production. Furthermore, as ladang was practiced at

‘places difficult to reach’³⁰,

constructing irrigation would strengthen the control of the Government over the population³¹. Planning irrigation schemes would have to be the responsibility of the Department of Public Works, not of the Civil Service. The Service would take into account too much the existing scattered pattern of villages and try to bring irrigation to all these small desas. Such irrigation would become more expensive, because it would be

‘highly artificial.’³²



Figure 7.2 Way Tebur weir in Lampung, originating from 1916

Van Tubergen considered the Way Sekampung the most important river in the Lampung Districts for the development of irrigation schemes in the empty landscape³³. Some twenty years later, however, the first plans for irrigation in the Soekadana area using Way Sekampung water did not include developing the large-scale, engineering-based systems of Van Tubergen. In 1918, the Government had decided to allow construction of an intake weir in the Semah river to irrigate almost 1500 bouw³⁴, but

the general opinion until the first years of the 1930s was that irrigation could be realized by the colonists themselves, as they would erect simple desa weirs without the assistance of engineers in four small rivers³⁵. This opinion changed, as the smaller rivers appeared to be not much more than trenches with very low slopes, flowing with sufficient capacity only directly after rainfall. To reach sufficient irrigable areas, weirs had to be constructed far upstream, with the double disadvantage that dependable flow would become even less and long canals would be needed. As promises to settlers were made to provide them with irrigation water³⁶, other plans were to be made. In 1934 plans for the construction of irrigation works to supply about 10,000 bouw with water were approved, with an extra potential of some 60,000 bouw under irrigation. In 1940, options to expand up to a total of 90,000 bouw of irrigated land were studied. As a family typically would receive 1 bouw of irrigated land³⁷, about the same number of families could eventually migrate to the Soekadana area. These plans were rather optimistic, as in 1940/41 actually some 5,000 to 6,000 bouw of the planned 7,000 bouw received water³⁸.

Design of Lampung irrigation

But let us keep the optimistic spirit of the early 1930s alive for the moment. In November 1933, Chief engineer Van Haefte drafted a report on the possibilities for irrigation in the Lampung area. According to a design report of 1934, however, already in March 1933 studies were so far advanced that a decision on irrigation could be made; even a decision in an official note of the sub-director of Unit E of Public Works of March 25th 1933. A first plan included an irrigated area of some 30,000 bouw, with the main intake planned close to the desa of Negarasaka, about seven kilometers upstream of Tegineneng. The main feeder canal would have a length of some 16 kilometer with a capacity of 25 m³/s and would include crossings with the Way Sekampung Anak, the railway line and the main road in its course. Further study showed that the main intake could be much closer to Tegineneng, saving a long main canal with three crossings³⁹... The colonization plans for Soekadana were discussed at a meeting on the 14th of November 1933 at the Department of Agriculture, Industry and Trade in Buitenzorg, Java. Present at the meeting were the Inspector for Agricultural Affairs of the Civil Service, the Heads of the Units of Crisis Affairs and Agricultural Affairs of the Department of Agriculture, the Director of the Experimental Station for Agriculture, the Head of the Soil Institute and the Head of the Irrigation Unit of the Department of Public Works⁴⁰. As irrigation was regarded as a prerequisite for the success of the Soekadana project, the general plan for irrigation requiring an investment of 1,700,000 guilders was discussed. As the suitability of the soils for irrigation was not clear, the meeting could not sanction the plans yet; further soil studies were regarded necessary. These extra studies showed that the soils, although not superior in their fertility, were suitable for sawahs. At a second meeting, taking place on May 16th 1934 at the Department of Economic Affairs in Batavia, it was decided to supply some 10,000

bouw of the best soils with irrigation. The existing colony close to Gedong Dalem was left out of this area; including it as was originally planned would be too expensive.

One of the major issues to be solved was the water demand. Two reports, unfortunately without reference to a date, are mentioned in the Explanatory Note of 1934, both giving a water demand of 1.5 l/s per bouw⁴¹. This figure was considered to be higher than would normally have been needed, but was considered necessary to improve the soils in the area. Four months of irrigation with this 1.5 l/s per bouw would result in suitable soils; the total available area was set at 20,000 hectares gross, 16,000 hectares net. The water from the Way Sekampung was not very fertile and contained few sediments. Therefore, the water could not be used ‘excessively’⁴², reason to restrict irrigation to the West Monsoon. A first design for the 10,000 bouw was made, dated October 12th 1934⁴³. In a letter of the Director of Economic Affairs from May 25th 1939 rice water requirements figures were confirmed (Table 7.2)⁴⁴. Wehlburg remarks that these were the figures in a stable agricultural situation.

‘As long as the forest soil is still crumbly and a plough-shoe has not shaped yet, much more water per hectare is needed and leaking losses on the field will be much higher in the beginning too. Everything, – galangans, – canals, fills especially, – everything leaks like a basket in the beginning, especially because of the holes left by rotting wood and roots and this will take several years.’⁴⁵

<i>Purpose</i>	<i>Period in days</i>	<i>Amount in l/s per ha</i>
For seed beds and soil preparation	0 – 45	1.70
	45 – 54	0,85
For root and plant development / blossoming	54 – 63	0,85
	63 – 85	1,10
	85 – 99	1,10
	99 – 132	1,60
	132 – 138	1,60
For fructification and ripening	138 – 150	0,80
	150 – 165	Nihil

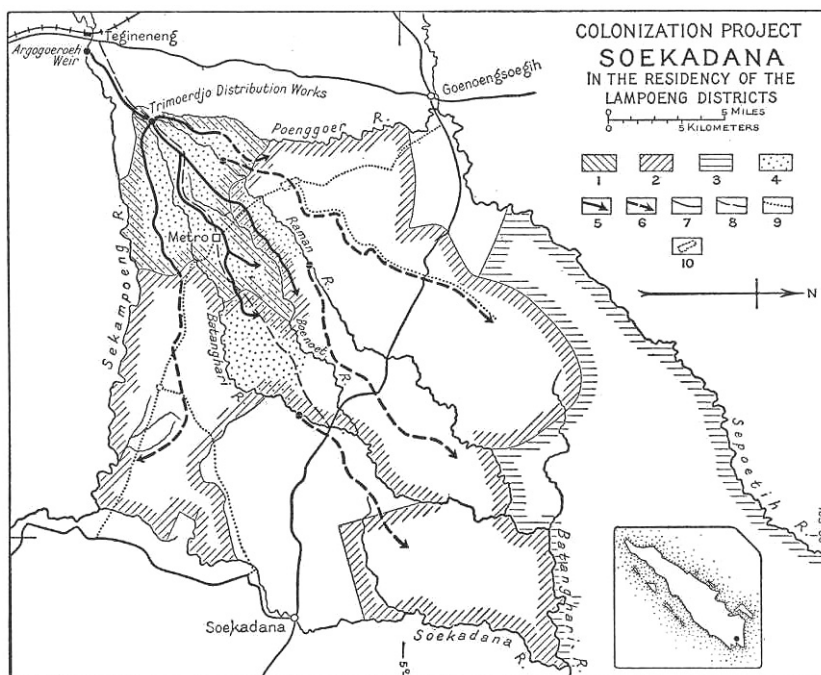
Table 7.2 Rice water requirements in Lampung⁴⁶

The Way Sekampung had plenty of water for irrigation available. With a catchment of more than 2150 km², the river had a regular flow pattern without severe bandjirs, reasonable discharges in the East Monsoon and low sediment content. The Service for Hydropower and Electricity had employed self-registering flow measurement equipment since October 1928, which data were happily used for irrigation designs. The data showed that 25 m³/s would be available as a rule during the six months of the West Monsoon. The lowest measured flow during the East Monsoon was 8.3 m³/s, with a mean East Monsoon flow of some 15 m³/s. Peak flood calculations with the method of Melchior resulted in a maximum design flow of 495 m³/s. As measurements were only available for a few years and were considered only accurate up to 5% below

flows of 50 m³/s, this value was not considered to be the maximum actually possible. A duration line constructed with the available data suggested that the 25 year maximum flow would be 485 m³/s; the yearly maximum flow would be 340 m³/s. A design maximum flow of 500 m³/s was selected as sufficiently safe, also because the embankments along the river had to be constructed higher anyway to protect them against tree trunks and other floating material during peak flows.

Figure 7.3 Map of the Way Sekampung irrigation system

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The weir and main intake structure were positioned at Argogeroeh, the first of five rapids⁴⁸ (Figure 7.3). As the river was rather broad and maximum flow not extremely high, a standard fixed weir was applied. Furthermore, higher flows of the Way Sekampung developed slowly, which meant that the gates of the flushing sluice could be manually regulated. Altogether, the weir was 76 meters across, with a flushing sluice of six meters. In the design report of 1934, the intake was designed for a capacity of 12 m³/s for 10,000 bouw. Within a year, the design for the main intake was enlarged to the planned maximum capacity of 25 m³/s; enlarging the intake after construction would be expensive and impossible without disturbing irrigation. Expansion of Soekadana colony was expected at a more rapid pace than originally planned, requiring the extra capacity sooner. In 1939, the potential command area was set at about 70,000 bouw, which would need a canal capacity of 54 m³/s (!), or the mean flow in the Way Sekampung in November⁴⁹. Argogeroeh weir was completed in 1935. The main canal, designed for 12 m³/s, was to be enlarged later when needed. As enlargement for foreseen anyway, the designer(s) of the canal used a mean water velocity slightly higher than in the preliminary design. The cross section of canal thus would be smaller,

reducing costs. Some scouring of the canal bed was anticipated upon, but was not regarded a problem. The canal had to be enlarged anyway, and by that time the right velocity for the local circumstances would have been found by experience.

With the relation between the width of the canal bottom b and water height h set at 2.40, canal side slopes of 1:1.5, and a roughness factor k of 50, the feeder canal dimensions were defined as bed width $b = 5$ meters, water level $h = 2.10$ meters, and bed slope $i = 0.000128$. Calculations were done according to procedures given by Verwoerd in the early 1930s discussed in Chapter 6. A check whether enlarging the canal to 25 m³/s was possible, taking into account the energy head needed at the intake, was done too. With a mean velocity of 0.80 m/s, same side slope, a bed width of 8 meters and a water level h of 2.62, bed slope i would become 0.00011, leaving more than sufficient head at the main intake. In 1939, a section of 2,400 meters of the feeder canal section between Argogeroeh and Pantjoer was enlarged from 12 m³/s to 54 m³/s. To save on canal excavation, the section was completely lined, allowing a design water velocity of 2 m/s. The section between Pandjoer and Trimurdjo with a length of 6,800 meters would remain in earth. As the maximum capacity of 54 m³/s was not to be reached yet, this section was enlarged up to 20 m³/s in 1940⁵⁰.

The feeder canal ended at the main distribution point at Trimurdjo, which was opened in September 1938⁵¹. Three secondary canals diverted the water further, the Poenggoer canal (2,245 bouw gross, 1,530 net), the Batanghari canal (5,114 bouw gross, 3,650 net), the Boenoet canal (4,755 bouw gross, 2,715 net), and one unit directly irrigating from the distribution structure Raman (699 bouw gross, 500 net). Furthermore, an area of 2,527 bouw gross (1,735 net) could be irrigated directly from the main canal. As water levels in the secondary canals were much lower than in the feeder canal, three overflow weirs to be regulated with stop logs were considered sufficient. Tertiary units were given a maximum surface of 500 bouw, considerably larger than usual on Java. On Java, however, the presence of sugar cane and irrigation in the East Monsoon, elements not to be expected in Lampung soon, were supposed to require intensive exploitation and refinement of water management, and thus smaller end units⁵². As the water demand was set at a relatively high 1.5 l/s/b for reasons explained above, water availability would be high, requiring less sophisticated water management. Wehlburg remarks that water distribution in the early years of the system was not that precise.

‘In the beginning one does not allocate and measure the water exactly. One simply gives as much as is reasonably possible [...]’⁵³

The tertiary units were implemented in such a way, that they could be subdivided relatively easily and at minimal costs into smaller units⁵⁴. Wehlburg stressed the importance of planning the tertiary unit though.

‘On Java this [the unit plan; MWE] is the foundation for water management. Only important for the Irrigation service, – nothing more! Here the unit distribution is

incomparably much more important. It is the basis for planning and organization of the area and through this of the entire clearing: for all the work in the area, all agriculture of the colonists and the building of their own agrarian community.’⁵⁵

The capacity curve – referred to as ‘reduction curve’ – was based on the earlier defined 1.5 l/s/b, which would have to be available for a mean tertiary unit of 300 bouw⁵⁶. The Resident of the Lampung Districts had decided that the borders of the *desas* to be developed would coincide with the borders of the tertiary units. This would stimulate better interaction between farmers, and thus would help to avoid

‘the difficulties with water distribution so often encountered on Java.’⁵⁷

All in all, the Way Sekampoeng irrigation design reflected the standard irrigation regime approach developed on Java pretty well; decisions on water allowances and unit size were adapted for these specific circumstances, but in the future the values for these respective categories were expected to become comparable to the values on Java.

Figure 7.4
Impressions
from the Way
Sekampung area
⁵⁸ Top: Left:
Irrigated sawahs;
Right:
Trimurdjo
distribution
structure.
Bottom: Left:
Argogoeroeh
weir; Right:
Construction of
main canal



Transmigration in Indonesia

Colonization of Javanese on the other islands remained an important policy for independent Indonesia. Re-labeled ‘transmigration’, resettlement programs were resumed and between 1950 and 1974, in total about 500,000 people were resettled in the Outer Islands. In 1980, about one million people had been resettled, where the third five-year development plan (Repelita III, planning period 1979 – 1984) achieved to resettle almost 1.5 million people⁵⁹. Developing irrigation was nearly always included

in transmigration projects, as in colonial times. Lampung remained an important target area for transmigration. In 1953, construction of irrigation systems was taken up again, and new schemes were realized, Batanghari Utara (7,100 has, 1953), Raman Utara (6,300 has, 1959) and Punggur Utara (31,200 has, 1963) (Figure 7.5)⁶⁰. A second feeder canal from Argogeroeh was constructed, with an apparent capacity of more than 70 m³/s⁶¹ and a length of eight kilometers⁶². In the 1970s, several studies were conducted on irrigation development, like the Sumatra Regional Planning Study of 1972 and the Lampung Water Resources Development Project, which included a 15-month feasibility study of the Way Seputih and Sekampung basins, in 1975⁶³.

‘The feasibility study revealed the weakness of the run-of-river type irrigation project, namely, unstable supply of irrigation water and water shortage for dry season crops.’⁶⁴

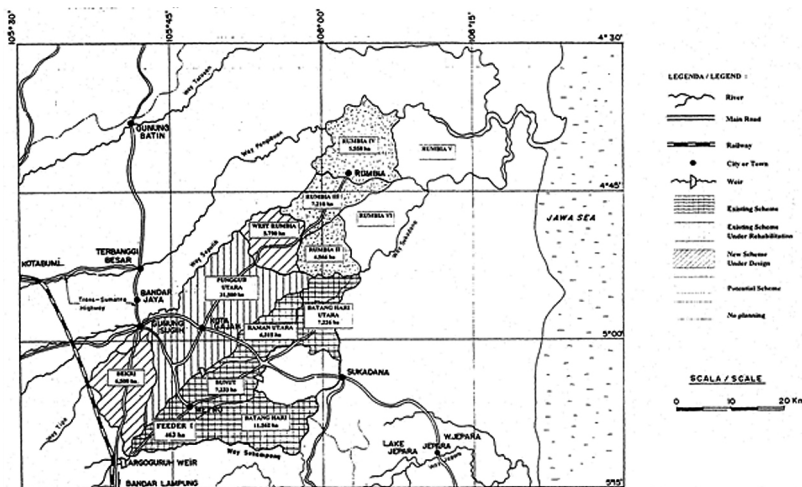


Figure 7.5
Overview of the
Way Sekampung
area⁶⁵

As an answer, the reservoir Waduk Batutegi was planned in the upper catchment of the Way Sekampung; its construction was completed only recently in the early 21st century. The recommendations of the feasibility study also included rehabilitation and re-modeling of existing irrigation systems. Between 1979 and 1986, the original Way Sekampung system, which was now called Feeder I system, was rehabilitated. In 1983, a Draft Final Report summarizing the major findings, recommendations and designs for new construction and rehabilitation work was submitted to the Government of Indonesia⁶⁶. Apparently, no actual construction activities were undertaken based on this report, as in 1992, a new contract for rehabilitation and developing the Way Sekampung irrigation area, in particular the Punggur Utara scheme, was signed. This time a Dutch consultant in cooperation with firms from Indonesia was involved. In the same period, design activities for the Bekri and West Rumbia systems started. The consulting firm for this works came from Japan. Construction efforts for the Bekri area were completed in 2003. To make the picture complete, in 2002 a new program started on river basin management in the Sekampung – Seputih basin. The ‘Good Governance in

Water Resource Management Project' functioned under the responsibility of the Ministry of Settlement and Regional Infrastructure and was financed by the European Union. The GGP worked in three basins, two on Java and one in Lampung, aiming to establish a working institutional infrastructure for basin management. The Japanese consultant active in Lampung also worked on river basin geared activities for this basin, although

'the scope of the works indicates that much of the work is geared towards feasibility studies for irrigation schemes and dams, besides evaluating strategic options for optimal water utilization and reconnaissance of possibilities for River Basin Public Cooperation.'⁶⁷

This short overview shows that irrigation developments in Lampung have a similar trend as on Java: from constructing new schemes, occasionally based on colonial plans, in the 1950s and 1960s via rehabilitation and remodeling of schemes in the 1970s and 1980s to river basin scale developments, both regarding infrastructure – the reservoir Waduk Batugegi – and management. As on Java, participants from many different countries contributed to these projects, each with their respective ideas and approaches on how to 'do it properly'. Below we will discuss how engineers from the Netherlands and Japan have interacted in the irrigation design process.

Irrigation in transmigration projects in Lampung

One of the major problems (re-)encountered in the transmigration settlement schemes in Lampung⁶⁸ was the high initial water demand of the irrigated lands.

'Land preparation in virgin land requires excessive initial water use due to the high percolation rates of new and porous soils. Experience in Indonesia indicates that it takes several years before the excessive water consumption for flooded paddy fields reduces to stabilized operation levels.'⁶⁹

Stabilization of (lower) water demands occurred due to the process of seepage of fine soil particles in the soil layer below the root zone, causing the formation of a nearly impervious layer. Building up such a layer can take ten years, but the typical formation period was five years⁷⁰. This phenomenon had been recognized already in the 1930s.

'The normal water requirement at the stable condition was recorded by Whelburg in the Tataän Colonization Area, South Lampung at about 0.9 l/s/b or about 1.26 l/s/ha. This figure is much lower than the maximum requirement at the early phases which was as high as 5 l/s/b or 7 l/s/ha.'⁷¹

In the 1934 design report for the Way Sekampung area standard water demand was set at 1.5 l/s per bouw, to improve the soils in the area. The capacity curve assigned this 1.5 l/s per bouw to a mean tertiary unit of 300 bouw, or 2.1 l/s per hectare for a unit of 210 hectares. So, although still far below the maximum water requirements of the initial

stages of 5 l/s/b^{72} , the design canal capacity in the first design for the Sekampung area was considerably higher than stabilized water demands would finally need. In the designs made from the 1950s onwards, standard design capacities apparently have been set at 1 l/s/b or 1.41 l/s/ha , which are the values of the Tegal capacity curve⁷³; this may prove influence of the Tegal curve in post-independence irrigation efforts in Indonesia. The values of the Tegal curve have been set aside in the Draft Final Report of 1983, as this set peak requirements at 1.65 l/s/ha for the dry season and 1.24 l/s/ha for the wet season. In 1992 capacities were set at 1.65 l/s/ha (wet season) and 1.89 l/s/ha (dry season). This general figure was translated into capacities for tertiary system design for the Punggur Utara system (Table 7.3). On its turn, the capacity curve approach was abandoned in the designs for two other sub-systems in the Way Sekampung area, the Bekri and West Rumbia system. Canal capacity requirements were defined at tertiary levels and main system levels, using standard 80 hectare sized tertiary units (Figure 7.6).⁷⁴ This shift from a typical Tegal capacity curve to another expression of canal capacities coincides with a shift in nationality of the engineering consulting firm in the area from Dutch to Japanese.

Area (ha)	Area factor (-)	Capacity (l/s/ha)	Area (ha)	Area factor (-)	Capacity (l/s/ha)
10	2.14	3.53	110	1.09	1.80
20	1.76	2.90	120	1.07	1.77
30	1.57	2.59	130	1.04	1.72
40	1.45	2.39	140	1.02	1.68
50	1.36	2.24	150	1.00	1.65
60	1.30	2.15	160	1.00	1.65
70	1.24	2.05	170	1.00	1.65
80	1.19	1.96	180	1.00	1.65
90	1.16	1.85	190	1.00	1.65
100	1.12	1.80	200	1.00	1.65

Table 7.3
Tertiary system
capacities in
Punggur Utara ⁷⁵

Note: Basic Water Requirement set at 1.65 l/s/ha , to be multiplied by Area Factor.

For the Bekri and West Rumbia extension of the Way Sekampung irrigation area, the canal capacities have determined using the next two formulas.

$$\text{TDR} = (\text{NFR} \times \text{F}_c) / \text{E}_t \quad \text{and} \quad \text{DR} = \text{NFR}_{\text{ave}} / \text{E}$$

In which:

TDR = Tertiary Delivery Requirement

NFR = Net Field Requirement

F_c = Flexibility Factor (1.04)

E_t = Tertiary canal Efficiency

DR = Delivery Requirement (project level)

NFR_{ave} = Average Net Field Requirement

E = Project Efficiency

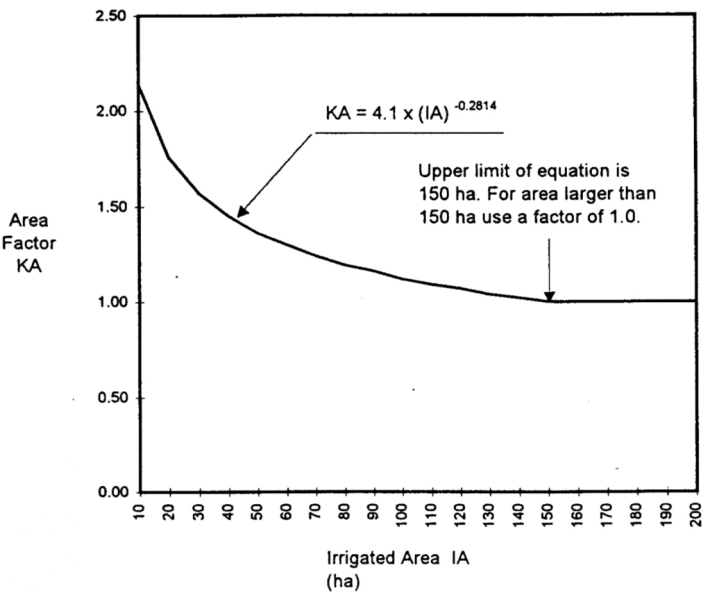
With these formulas, the respective capacities became

TDR = 2.0 l/s/ha

DR = 1.65 l/s/ha

Which are similar values as resulting from the approach given in Table 6.

Figure 7.6
Capacities for
Bekri and West
Rumbia⁷⁶



Water management structures in Punggur Utara

Water in canals needs to be manipulated in order to flow to fields. The original Punggur Utara scheme was equipped with cross-regulators operated by stop logs in the main system for water level control. Water measurement was done by velocity measurements. In 1983, it was proposed to continue with stop logs in the secondary canals, but use vertical lift screw operated gates in the main canal⁷⁷. Tertiary off-takes would be sliding gates. Within the 1992 rehabilitation project, some amendments were made to this original setup; it was proposed to install automatic cross-regulators of the Vlugter and/or Begemann type and use constant discharge orifice gates as off-takes. The Indonesian Directorate General of Water Resources Development agreed to use the automatic gates, but proposed to replace the off-takes proposed with Crump-De Gruyter gates⁷⁸. This configuration was selected as the design standard (Figure 7.7).



Figure 7.7
Begemann gate
in the Punggur
Utara system

The Begemann gate was named after the Dutch engineer S.H.A. Begemann, who also introduced the Venturi in the Netherlands East Indies. In 1926, Begemann published an article in which he discussed the usability of automatic gates in irrigation practice. His publication is a follow-up of two other publications on the issue.⁷⁹ Automatic gates were introduced to replace the stop log gates often used in the East Indies for water level control. Figure 7.8 illustrates the bewildering amount of gates tested in the Indies. Stop logs required manual labor of the Javanese irrigation personnel, reason to consider the option of an automatic gate

‘to become independent of the alertness of the operating personnel’⁸⁰

Begemann defined the goal of an automatic gate

‘to ensure, that in a canal the water level does not decrease below a certain level [...], and that at the highest expected discharge in that canal a given level (= highest allowable water level) is not exceeded.’⁸¹

Begemann described several types of gates, but the one his name has become attached too was a simple hook-type gate with a counterweight on top; the first exemplar of this type (Figure 7.9) was

‘made after a sketch made by me with meccano by my little sons. [...] The little wholes in the meccano bars make it easy to replace weights, and enlarge the lever arm.’⁸²

Figure 7.8
Automatic gates
everywhere...⁸³

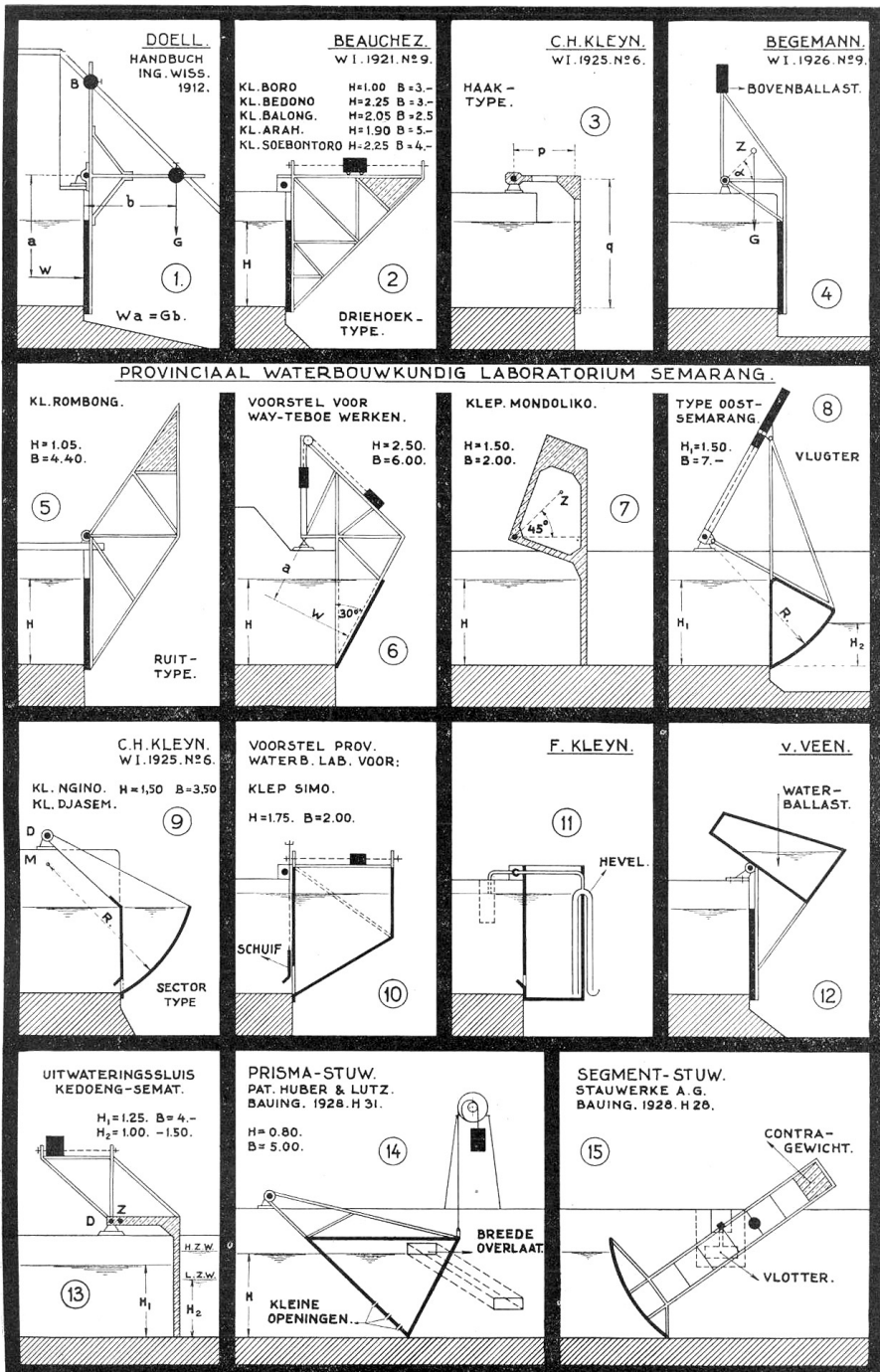




Figure 7.9
Begemann gate
made of
meccano ⁸⁴

Foto 3.

Stuwklep haaktype (Meccanomodel).

This counterweight gate and other types were tested in the Hydraulic Laboratory of Semarang⁸⁵. One of the other structures of the same counterweight type developed in the Netherlands East Indies and in the Way Sekampung area is the Vlugter gate. This gate was developed for the East Semarang area, in which the Demak irrigation system is situated. In this flat coastal plain, the Prauwvaart canal had to both maintain water levels for irrigation and occasionally discharge excess water. Automatic gates were preferred, as this would lower the costs for personnel considerably and make the functioning of the gates more dependable in case of sudden bandjirs. Because of low gradient and head loss available, downstream water levels could influence the functioning of the gates. For this specific circumstance a circle-shaped downstream side of the gate to counteract the downstream water influence was tested, which became the Vlugter gate⁸⁶.

Some ten years before their involvement in Lampung, the Dutch consultant gained experience with Begemann gates in the Kano River Project in Nigeria in the 1970s. Under NEDECO-umbrella, Dutch engineers were involved in this project to irrigate some 24,000 hectares from a reservoir in the Kano River in northern Nigeria. How to arrange water distribution was one of the key questions. The area showed quite some variability in soils and crops, also within tertiary units, resulting in a variable water demand in time and place. The irrigation system needed to be able to deal with the variability, a demand comparable with the Netherlands East Indies, without being able to count on a reliable organizational infrastructure, which was not comparable with the Indies. Night irrigation was to be avoided, requiring storage facilities in which the night water could be kept to be used during the day. This storage would also become a key in

adapting to variability. Dutch team member C.L. Begemann, the son of S.H.A. Begemann, and probably one of the builders of the meccano gate in Figure 7.9 proposed to apply broad crested weirs as tertiary discharge structures in combination with a Begemann gate as water level controller. The Begemann gate had to ensure that the water level upstream of the weir would not fluctuate too much. Referring to the French orifice type baffle distributors, another Dutch team member proposed to change the weir into an orifice; the advantage of an orifice is that its discharge is less sensitive for water level changes than a weir. With a Begemann gate keeping the water level almost constant whatever the discharge changes are⁸⁷, this combination would combine two main advantages of the two types of structure⁸⁸. The Begemann combination was finally selected and applied in the Kano system (Figure 7.10). A publication of the World Bank on successful approaches and examples in irrigation water management refers to Kano as

‘particularly interesting. Using only simple hydraulic principles and control structures, good control of water levels and flows throughout the system has been achieved and inefficient night irrigation has been avoided.’⁸⁹

Figure 7.10
Begemann
automatic gate
in the Kano
River system,
Nigeria⁹⁰



Furthermore, the installation of automatic water control devices, the Begemann gates, would have contributed to lower levels of conflicts among water users. The Dutch engineer who proposed the orifice in combination with the Begemann was the link between Nigeria and Lampung; he was involved in both systems on behalf of the Dutch consultant. This way, a structure originally developed in the Netherlands East Indies found its way back to Indonesia, although through a slight detour over Nigeria. For new system designs in the Lampung area, however, other configurations of structures were selected by the Japanese consulting designer. The intake structures for

the Bekri and West-Rumbia extensions, taking water from the Argogoeroeh feeder canal, used a similar configuration as applied in the Punggur Utara rehabilitation project of 1991: a Crump-De Gruyter gate as off-take and Vlugter automatic gates as cross-regulator (Figures 7.11 and 7.12). Within the extensions themselves, however, the Japanese consultant proposed to use sliding gates combined with fixed crest weirs as cross-regulators, in combination with Crump-De Gruyter off-takes. Sliding gates would require a relative small head loss and experience with operating this type of gates was extensive in the Way Sekampung area⁹¹.

The already quoted World Bank report refers to the sliding gate as follows, in the paragraph on 'Specific structures to avoid'!

'Vertical slide gates as check structures. Slide gates have three disadvantages: (a) they are underflow gates, therefore the upstream water level tends to fluctuate widely with small adjustments; (b) they require considerable force for operation; (c) they tend to stick in place easily.'⁹²

It is not unlikely that the designers of the Bekri extension had this severe criticism in mind. The fixed crest weir had to secure that excess water upstream can spill to downstream canal sections. The Crump-De Gruyters were selected, as this type was the best known application in the entire system and was less susceptible for upstream fluctuations in water level. Tertiary off-takes were provided with Crump-De Gruyters as well. As the capacities of these off-takes were in the range from 10 l/s up to 200 l/s, however, tertiary units less than 15 hectare with associated capacities of 30 l/s or less, were equipped with pipe off-takes in combination with sharp crested weirs. For these small flows, Crump-De Gruyters would not measure accurately⁹³. Each tertiary off-take was to be equipped with a sliding gate as cross-regulator, unless the next downstream gate was close enough.



Figure 7.11
Vlugter gates in
Lampung

Figure 7.12
Crump-De
Gruyter gate in
Lampung



Indonesian Irrigation Design Standards

Although not everybody might agree with the choices made by the designers of the Bekri and West-Rumbia extensions, their choices were accepted. This is logical, as the work of the designers was based on design standards in Indonesia. In the Japanese design documents explicit reference is made to the Irrigation Design Standards (IDS) published in 1986 by the Indonesian government in a rather successful attempt to standardize irrigation design in Indonesia and effectively limit the number of different types of structures applied in Indonesia. The IDS series includes thirteen volumes (Table 7.4) and was produced with the assistance of a Dutch consulting firm. The series presents an overview of the irrigation design process, available options for different

elements of an irrigation system in a ‘how-to-do-it’-approach. The first Volume stresses that only the

‘[i]rrigation systems and methods as commonly used in Indonesia’⁹⁴

are discussed. This is reflected in Volume I, which describes the regime differentiation between three levels of irrigation systems (wild, semi-technical and technical), with a slight modification of terminology: instead of non-regulated, ‘wild’ systems are referred to as ‘simple’ systems. The definitions/descriptions of the levels, however, are similar to those given in colonial publications (Table 7.5).

	Code
Design criteria	
Irrigation system design	KP-01
Headworks	KP-02
Canals	KP-03
Structures	KP-04
Tertiary units	KP-05
Structural parameters	KP-06
Drawing standards	KP-07
<i>Technical specification</i>	
Irrigation system design	PT-01
Topographic survey	PT-02
Geotechnical investigations	PT-03
Hydraulic model testing	PT-04
<i>Drawing</i>	
Typical irrigation structures	BI-01
Standardized irrigation structures	BI-02

Tabel 7.4
Irrigation
Design
Standards
(1986)

Table 7.5
Irrigation system
classification ⁹⁵

Classification of irrigation system				
		Technical	Semi-technical	Simple
1.	Headworks	Permanent structure	Permanent or semi-permanent structure	Temporary structure
2.	Capacity of structures to measure and regulate discharge	Good	Fair	Poor
3.	Canal system	Irrigation and drainage separated	Irrigation and drainage not completely separated	Irrigation and drainage combined
4.	Tertiary system	Fully developed	Not developed or with low tertiary structure density	No tertiary system developed
5.	Overall efficiency	50 – 60 %	40 – 50 %	< 40 %
6.	Sizes	No limit	Up to 2,000 ha	Not more than 500 ha

Each of the Design Criteria volumes, apart from Volume VII (Drawing Standards) contains a list of references. Most of the documents referred to in the IDS86 were not available to me to study in detail, therefore my analysis is limited. Nevertheless, some issues concerning the history of the IDS86 can be raised based on reference analysis (Table 7.6). First, original material from the Netherlands East Indies is quoted in three volumes. Volume I on general design issues refers to Van Maanen (1931), and although no direct references are used in the text of the Volume, it is likely that this book has been used when the general approach to irrigation is discussed. In the IDS-paragraph on standard nomenclatura, the similarity with the remarks of Van Maanen (1931) is noticeable. Volume III on canals refers to Vlugter (1941 and 1962) and De Vos (1925), both discussing sedimentation and erosion in canals, and Der Weduwen (1937), known for his peak flow discussion, whereas Volume IV on structures uses [Dimensioneering] (1937) on side spillways, and De Gruyter (1926 and 1927), Romijn (1932 and 1938) and Vlugter (1940a and 1940b) on control structures in canal systems. In other words, the IDS86 uses original material from the Netherlands East Indian period when the general approach of irrigation design, canal sedimentation and control structures are discussed.

In Volume I and IV, structures to be employed for water control are discussed. The measuring and regulating structures receive most attention. Seven types of structures are included in the standards: the broad crested weir, the Parshall flume, the Cipoletti weir, the Romijn weir, the Crump-de Gruyter orifice, the gated pipe off-take and the Constant-Head Orifice. The IDS recommends in primary canals,

‘[f]or large flows a broad crested weir for measuring and flat sliding gates or radial gates for regulating’ ⁹⁶

	IDS I	IDS II	IDS III	IDS IV	IDS V	IDS VI	All
TYPE							
Dutch ¹	1	-	4	6	-	-	11
Indonesian ²	6	1	2	4	10	19	42
Consultant ³							
<i>Dutch</i>	2				5		7
<i>Other</i>	3				2		5
Other ⁴							
<i>Dutch</i>	1	2	3	5			11
<i>US Gov</i>	3		3	4			10
<i>Other</i>	4	8	8	14	1	1	36
Total	20	11	20	33	18	20	122
YEAR							
– 1945	1	-	3	7	-	-	11
1945-1954	-	3	-	3	-	-	6
1955-1964	2	3	2	6	-	2	15
1965-1974	5	1	11	7	5	4	33
1975-1984	10	4	4	9	9	9	45
1985 –	2	-	-	1	3	-	6
Total	20	11	20	33	17	15	116

Table 7.6
References in
the IDS 1986

¹ Documents published in Dutch journals, in Dutch (with English in one exception)

² Documents (mainly standards) published by the Indonesian Government, in Bahasa Indonesia (with English in exceptions)

³ Documents published by consultants or in the context of an irrigation project, in English

⁴ Books, reports and other documents for an international audience, in English

Secondary outlets are to be equipped with

‘Romijn movable weir or Crump-de Gruyter orifice for measuring and regulating. If flow rates are too large a broad crested weir in combination with a sliding or radial gate is applied as for the primary canal.’⁹⁷

Tertiary outlets would need a

‘Romijn movable weir for measuring and regulating or Crump-de Gruyter orifice if fluctuations in the canal discharge are large. Gated pipe off-takes may be considered for small tertiary units along a primary canal with large water level variations.’⁹⁸

Recommended structures are included in the main text of the IDS; non-recommended structures are discussed in annexes. The main reason to disapprove of the Cipoletti weir, the Parshall flume and the Constant-Head Orifice, these last two being of USA-origin, is their complicated operation and reading. Romijn gates are standardized at widths of 0.50 to 1.50 m, with 0.25 steps in-between. For both Romijn and Crump-de Gruyters rating tables are provided for quick calculations⁹⁹. It is not all continuity though; not every Dutch-colonial standard was copied or recommended¹⁰⁰. A major

change has occurred in the determination of design capacities for the canal system, a major subject for colonial irrigation engineers. IDS Volume III discusses canal capacity determination. Capacity curves are no longer applied in the IDS, as modern calculation methods give

‘more accurate tertiary off-take capacities’¹⁰¹

and

‘reductions on capacity allowed for canals supplying areas larger than 142 ha are now incorporated in conveyance efficiencies.’¹⁰²

It might be worthwhile to note that the figure of 142 ha has been maintained! The extra water needs in newly developed areas are taken into account too. These higher demands are not to be used as design values, which remain the ultimate water requirements. The irrigated area in new lands is to be expanded gradually, allowing the water needs to decrease¹⁰³. In the IDS, calculation of design discharges is proposed using the formula similar to the formula used in the Bekri extension design

$$Q = c \cdot N \cdot F \cdot R \cdot A / e$$

With Q = design discharge in l/s; c = rotation (golongan) reduction coefficient; NFR = peak net field water requirement in l/s.ha; A = irrigated area; e = overall irrigation efficiency. When conveyance canals are designed, the capacity should be raised taking into account the efficiencies of these conveyance canals. As rotation reduces peak demands, a reduction coefficient would have to be included. The IDS do not favor introducing reduction coefficients for

‘typical irrigation schemes with irrigable areas up to 10,000 ha and taking water directly from a river.’¹⁰⁴

For such systems, factor c equals 1. In larger systems, reduction factors

‘may be used based on O&M experience’¹⁰⁵

Advantages of reducing peak demands are recognized in the IDS, but disadvantages are considered to be too high. In a way, the authors of the IDS leave the approach developed in the Netherlands East Indies when they state that reduction through a golongan arrangement

‘leads automatically to a rather complicated operation of the irrigation scheme.’¹⁰⁶

Furthermore,

‘reduction of the design discharge makes rotation a permanent feature for the operation of the scheme’¹⁰⁷,

which would create a permanent need for considerable operational capacities in terms of available manpower. The labor intensive water control and distribution system of the Netherlands East Indies was no longer the option to go for in Indonesia. Despite these adaptations, one cannot but notice influences of Netherlands East Indies irrigation experiences and approaches when studying both the activities of irrigation engineers in Lampung and guidelines like the Irrigation Design Standards. Although changing context-related operational realities are recognized in the IDS, leading for example to an adapted canal capacity approach, several pillars of the Dutch-colonial irrigation regime are maintained. Measuring and regulating flows remains a top-priority. As a consequence, a designer can either select a Romijn gate¹⁰⁸, which have been standardized, or a Crump-De Gruyter, as in the Bekri-extension in Lampung. The influence of the standards is considerable, not only because irrigation designers (need to) apply them; the standards are also used in educating Indonesian civil engineers as lecture material, providing the design rules for future Indonesian irrigation engineers. The Dutch consultants who co-authored the Irrigation Design Standards probably will have recognized (used?) their own lecture notes from Delft in the writing process. The design standards are obviously an attempt of the Indonesian Government to structure the design space of irrigation engineers. In that sense the guidelines may be a response to the bewildering amount of different artifacts and approaches entering Indonesia through engineering firms from many countries in the context of development cooperation¹⁰⁹. Many of these projects were rehabilitating or building originally colonial schemes and plans; the responsible engineers imported their technological regimes and selected their preferred artifacts from these. The IDS can be interpreted as an attempt to (re-)establish an Indonesian approach.

Such irrigation approaches or technical regimes did not only structure irrigation activities in Indonesia. In other countries, Dutch engineers brought their knowledge base with them too. The combination of an overflow weir and a Begemann gate, originally proposed in the Kano project in Nigeria, can be defined as an East Indian configuration of artifacts; after all, irrigation practice in the East Indies developed a preference for overflow discharge structures. With the change in context, however, a change in design routines became an option. The Kano project itself was an arena for debate between engineers from different background, at least Nigerian, Egyptian, Pakistani and Dutch; with the world opening up for international engineering firms the chance to meet several technological regimes outside its original context increased. Dutch engineers have designed downstream controlled systems of the French type in Bangladesh and Tunisia. The final Kano configuration can be defined as a hybrid: combining a French idea with East Indian hardware¹¹⁰. If Kano is representative for other Dutch international irrigation efforts, it would be possible to state that the East Indian technological regime did have influence on the design results, but not to the extent that deviations were impossible. Many of these Dutch engineers were trained at the Department of Civil Engineering of the Delft Polytechnic¹¹¹. After World War II,

irrigation engineers graduated with a professional perspective totally different from the graduates in colonial times. Nevertheless, experiences and approaches from the Netherlands East Indies have shaped the irrigation courses in Delft until at least the 1980s, as I will discuss in the next chapter.

8 I want to become an engineer

Irrigation education in Delft

The informative booklet produced by Delft Polytechnic in the early 1920s to attract prospective students breathes a spirit of optimism; the number of students increased every year, new large technological projects like the Zuiderzee works were at the point to be realized and profits of the industry were sky-high.

‘No wonder, that the youth allows itself being carried away in admiring enthusiasm when beholding the modern Works and proclaims with great fervor: “I want to become an engineer!”’²¹

The post-World War I optimism on the number of prospective students was lowered considerably some years later; the number of students remained behind expectations. The period nevertheless marks significant changes in the way civil engineers were educated and trained in irrigation: first, the Polytechnic had employed engineer Haringhuizen as full professor in irrigation in 1919²; second, in Bandoeng, Java, the Polytechnic School for the Netherlands East Indies was opened in 1920, with civil engineering and irrigation as major subjects. Irrigation had thus become a regular element in the training of Dutch civil engineers, both in the Netherlands as in the East Indies. This normalization of irrigation education was the result of the same process in which civil engineers strived for political recognition, with their emphasis on their own department and overall responsibilities for irrigation affairs in the Netherlands East Indies. The irrigation engineers also emphasized the need to recognize irrigation engineering as a proper area within the general field of civil engineering. This proper area had to be rewarded with its own, clear position in the main educational institution of Dutch civil engineering at that time: Delft Polytechnic. In 1906 irrigation gained ground in Delft. In this chapter it will become clear that this recognition had to be re-established again after Indonesian independence in the 1940s in Delft. Without the perspective of a career in the colony for newly trained engineers, the irrigation engineers had to find a new position within a basically Dutch oriented study program.

Education and working environment in the East

The link between irrigation education in Delft and the prospective working environment in the East Indian colony was tight. In the early 1920s the Dutch government even tried to attract Delft students for working in the Indian colony: selected students could receive financial support for their last years of study in return

for signing a five-year contract for work in the colonies. A similar arrangement had existed between 1874 and 1878.

‘During these four years, the Indian Public Works Department was supplied with a group of young men, who already foresaw in their study time their special technical goal and which included some, who belonged to the most talented of their contemporaries.’³

Lamminga and Weijs were among these young men, as was engineer Grinwis Plaat, famous for his report of his visits to Spain and Italy⁴. Grinwis Plaat became the first engineer to teach irrigation in Delft; he started lecturing in 1906 during his leave from Indian office and received an extraordinary professorship in 1908. Bright and motivated as the generation of Grinwis Plaat, Lamminga and Weijs may have been, their education in Delft at the Polytechnic did not include dedicated attention for irrigation. The Irrigation Commission of 1879 already made a plea for a separate irrigation course, as it was clear that

‘until now, the Government does not seem to recognize how important it is, that the engineers destined for **the Indies** take a course in irrigation.’⁵

Establishing such a course, to be taught by an experienced engineer from the Indies, was seen as an absolute necessity. The report acknowledged that some irrigation design guidebooks were available, most of them in French, but these were not aimed at Java, although the ‘Cours d’agriculture et d’hydraulique agricole’⁶ included some discussions on rice. Whereas engineers did not receive specific training for working in the colony until the early 20th century, dedicated educational programs for colonial civil servants had been available from the early 19th century⁷. After the restoration of Dutch supremacy over the East Indian archipelago in 1815 and the related centralization and extension of colonial rule, the immediate need for civil servants increased. Knowledge of local circumstances, including languages – minimally Javanese – was considered important. In 1818, six civil servants were sent to the military school at Semarang to receive training in the Javanese language⁸. Establishing a proper educational program took a bit longer, because of the Java War and a general lack of money; the program was established, however, in 1832. It was not Leiden, although this city with its famous university was mentioned often, but Soerakarta which hosted the ‘Institute for the Javanese Language’; twelve students started their education in Javanese, History, Law and Popular Institutions⁹. Soon the program received criticism: student results were worse than expected and the education would be too theoretical. At the same time, the idea that the motherland should be in control over training and education of its colonial civil servants gained momentum. In 1842, Minister for Colonial Affairs Baud decreed that all higher positions within the colonial service were reserved for candidates who had been educated in the Netherlands. Baud

‘considered the control on the Cultivation System only guaranteed in white [that is: Dutch] hands’¹⁰

The monopoly for educating civil servants was handed to a new institution; only a diploma of this institution opened the higher ranks in the colonial civil service. By Royal decision of January 8th 1842 the Royal Academy in Delft was formally established¹¹. The East Indian elite wanted to maintain its position within the colonial government ranks and sent a large number of (male) students to the Netherlands. From the 305 students at the Academy between 1842 tot 1857, 195 persons came from the East Indies¹². Next to colonial civil servants, the Academy educated a different population too, engineers¹³; five different programs of four years were offered: civil engineering, mining engineering for the colonies, building engineering, mechanical engineering and commercial engineering¹⁴. In the first two years of the study program, the prospective engineers and civil servants partially received similar technical courses. In the context of the Cultivation System, the colonial civil servant was as much a governor as a production manager¹⁵; technical works were executed under his responsibility too, reason enough to bring technical courses in the civil service curriculum in Delft.

The Royal Academy was criticized too, in particular on the military discipline and the (lack of) quality of the teachers¹⁶. Lack of money was a persistent problem; as early as 1848 the Academy escaped an early closure, when financial support from the Dutch government was not sufficient. Despite empty pockets and external critique, the Academy did attract students. In its first year the Academy counted 46 students; ten students were studying to enter the civil service, 36 received their training within the Department of General Studies which hosted the engineering programs. In 1843 the Academy hosted already 117 students, in 1844 142 and in 1845 170¹⁷. Within the engineering programs the civil engineering study was the most popular program by far: figures from 1864 showed that from 207 graduates in the Department of General Studies an overwhelming majority of 183 students had chosen civil engineering¹⁸. With the application of the new Dutch educational law on June 30th 1864 the Academy was abolished, but the new Polytechnic School was established. The Department of General Studies became the Polytechnic. The monopoly of Delft on educating civil servants disappeared, as programs were established in Leiden and Batavia as well; furthermore, the civil service program in Delft was no longer part of the Polytechnic¹⁹. Until 1905, the Polytechnic School was formally registered as secondary professional education, but in that year the School gained academic status and a program of five years.²⁰

The Netherlands East Indian Department of Public Works connected itself clearly with the Delft engineering school. In 1874 it decreed that for employment with the Department the civil engineering degree from Delft was obligatory²¹. Between 1874 and 1878, the Ministry for Colonial Affairs even stimulated new engineers to seek employment in the colonial service with a grant program for students who would sign a

contract for five years within the colonial department. This program was a success²². All in all, some 25 to 30 percent of Delft graduates went to the Indies²³. The engineers that started their career in the colony did so with a strong Dutch-oriented background. The Delft engineering program did not include much attention for the colony; although one could doubt whether this was because

‘the increasing scientific basis of technology strongly pressed the element of professional preparation to the background’²⁴,

as some argued, as the earlier, more profession-oriented programs did not include any East Indian elements either. Furthermore, empirical approaches may have supposedly been replaced with applications based on physics and mathematics²⁵, but

‘[i]n the Educational Report of 1934 [...] a long argumentation is still inserted including the remark that in civil engineering and architecture one should not just give presentations based on own experiences [...], but more based on scientific research.’²⁶

Specific attention for the East Indian engineering reality

Although the engineers from Delft did not perform too badly in irrigation development from a technical point of view before the establishment of an irrigation course²⁷, the call for dedicated attention in the Delft curriculum for hydraulic engineering issues from the East Indies, particularly

‘irrigation and other Works in non-flat and tropical regions’²⁸

was strong from the beginning.

‘Even when one wants to state, that for Indian engineers knowledge about Dutch circumstances for the aspects mentioned is desirable too, this can never be a reason to leave the Indian terrain, on which they will have to act exclusively, completely fallow.’²⁹

The pleas for dedicated attention basically emphasized differences in technical – like soils, climate, building materials – and social – like laws and regulations, language, administration – issues between the motherland and the colony. An added argument was that a civil engineer in the East Indies had to work on his own. He was not participating in a larger team or guided by senior colleagues; he was often the single authority in a large region and responsible for many more tasks than his fellow engineer would be in the Netherlands. The Dutch engineers were no particular admirers of the quality of education for colonial engineers in Britain³⁰, but British attention for dedicated preparations for service in the colony of their engineers was considered an example to follow³¹. In 1906, negotiations between the Ministry for Colonial Affairs and Delft Polytechnic resulted in nominating a civil engineer on leave from the colony to give the required dedicated course on hydraulic engineering on Java; the course was

not obligatory for all civil engineering students. Engineer Grinwis Plaat, who had worked on several locations in the colony on a variety of issues, was the first lecturer. In 1908 his temporary nomination was changed into a permanent position as extraordinary professor in hydraulic engineering; unfortunately problems with his health made it impossible to fulfill this position long. On January 1st 1910 Grinwis Plaat retired as professor. Before that date, engineer Heijning – from Demak – had already taken over his class. In 1911, rector magnificus Cardinaal remembered Grinwis Plaat as the right man on the right place.

‘His education covered a small place in the program and roster; but it meant much for many. Given the labor demand of our East Indian Possessions, where complete regions wait for reclamation, it is certainly important to, next to the general courses on civil engineering, give the opportunity to become acquainted with the topics of interest for the Indian engineer, like irrigation, improvement of mountain streams, construction of works in mountainous areas, etcetera.’³²

In his inaugural speech as successor of Grinwis Plaat, Lamminga stressed that he and Grinwis Plaat considered irrigation a subject not just important for engineers who would go to the colony.

‘On the contrary, I argue that the civil engineer needs to know as much about this topic as part of hydraulic engineering as for example reclaimed areas, polders and such.’³³

Attention for irrigation did not imply ignoring drainage; drainage was also important in the colony, although not so much in the context of polders like in the Netherlands. Lamminga considered irrigation important in many regions, including those without water shortage; irrigation was a good instrument to increase production intensities in general. Lamminga and Grinwis Plaat would not be the only irrigation professors in Delft stressing the broader meaning of irrigation; their successors, up to the last ‘real’ irrigation professor (R. Brouwer), would make similar remarks (Table 8.1). Most of them, however, including Lamminga and Grinwis Plaat, mainly referred to the Netherlands East Indies in their courses for new engineers.

After the academic year of 1910-1911, Lamminga already left his professorship. It had already been

‘after much insistence’³⁴

that he had accepted the position in the first place, but he resigned because of a

‘lack of appreciation’³⁵

expressed in

‘too low a salary connected to the position and the remarkably less important position, which is taken by an extraordinary professor in Delft, in comparison with the other, regular professors.’³⁶

Table 8.1
Overview of
irrigation
professors in
Delft

	Name	Remarks
1906 – 1910	P.T.L. Grinwis Plaat	Extraordinary professor from 1908
1910 – 1911	A.G. Lamminga	
1912 – 1913	W. Elenbaas	
1913 – 1919	C.W. Weijs	Full professor from 1917
1919 – 1938	J. Haringhuizen	First newly appointed full professor
1938 – 1954	S.H.A. Begemann	Combined irrigation with hydropower
1954 – 1966	F.M.C. Berkhout	
1966 – 1984	H.J. Schoemaker	
1985 –	R. Brouwer	Started as part-timer, full-time since 1993
2004 –	N.C. van de Giesen	Successor of Brouwer, subject is river basin management

After a short intermediate professorship of Elenbaas, it was the other grand seigneur of early colonial irrigation Weijs, who fulfilled the professorship. Weijs received a regular professorship in 1917; in 1919 his successor Haringhuizen, who had just started in 1917 as professor in hydraulic engineering at the Agricultural School in Wageningen, was the first regular professor to be appointed anew. In 1938, almost 20 years later(!), Haringhuizen was succeeded by Begemann, the engineer who introduced the Venturi and statistics in hydrology in the Netherlands East Indies. With a full professorship irrigation engineering had become a regular subject within the Delft curriculum. Just a few years before, the need for this regularization had been subject of discussions among engineers themselves. In a meeting of the ‘Union of Delft Engineers’ on September 13th 1913, engineer Cramer had complained about the current professorship in irrigation. Cramer wanted to realize a full, regular professorship, if necessary by adding theoretical and experimental hydraulics to its subject area. In a reply engineer Kloppenburg disagreed with this idea, not only because it would interfere with the tasks of De Vries Broekman, who did cover hydraulics and hydropower in Delft, but also because

‘[m]ister Cramer does not consider the irrigation subject in itself important enough to create a permanent professorship for it’³⁷

To Kloppenburg, it was basically a matter how the professorship would be defined: in case it had to include newest developments worldwide and not just the East Indies, a full professorship would be a suitable option. In case, however, the lectures would be restricted to what the irrigation engineers needed for working in the colony, Kloppenburg could imagine very well that the Government would not want to spend money on a full professorship. The reply of the Minister of Internal Affairs during the 1914 budgetary discussions in parliament made clear that the Government considered

an extraordinary professorship fulfilled by engineers on temporary leave in the Netherlands the best option.

‘Particularly the temporariness of the position guarantees that someone directly from East Indian practice will be entrusted with this education.’³⁸

But the Minister was prepared to consider a full professorship and discuss the issue with Delft Polytechnic. Apparently this discussion resulted in the appointment of Weijs as full regular professor in 1917; the nomination of his successor Haringhuizen confirmed the recognition of the irrigation specialization³⁹ for the Delft civil engineering curriculum (Table 8.2). From this moment onwards, a prospective civil engineer could make a choice for a program oriented at the Dutch context or at the East Indian colony, although the differences were mainly found in the subjects for design and drawing tasks. A short variant of the irrigation course was compulsory for all civil engineering students; those students interested in an East Indian career were encouraged to take the extended irrigation course.

Study. The program is mainly mathematical. Furthermore the development of the ability to prepare extensive designs (drawings) comes to the front. The first year exam includes a large mathematical course and much drawing:

Mathematics; architecture (40 drawings); physics; hydraulic engineering.

The engineering exam includes the proper professional study, main courses are:

Theoretical and *applied mechanics; land surveying* (theory and practice); *architecture* (drawings, utility and esthetic buildings); mechanical engineering; electrotechnical engineering.

For the final exam are requested:

Hydraulic engineering; bridges and roads; concrete.

Some subjects can differ for future Indian hydraulic engineers.

Employment. A graduate has many options, and within each option there is room for many. This explains that the civil department in Delft is always the largest.

Foreign employment is exceptional. In the Netherlands national, provincial and municipal governments demand many engineers for Public Works (Zuiderzee), as director of municipal works, etcetera. In private employment many work for rail roads, concrete producers etcetera.

With the Netherlands offering employment to about 60%, the East Indies take 40%, which are mainly attached to the Department of Public Works ¹⁾ and the Department of Governmental Buildings. They are charged with construction and maintenance of bridges, roads and other Works, construction and supervision of rail roads, fulfill technical service of mail and telegraph, or exploit the many unexploited sources for hydropower. The Topographical Service, charged with making maps, can offer an adventurous career.

Prospects. Chances for appointment and promotion are very favorable, the demand cannot be met. In the Indies many foreigners are employed. Prof. Haringhuizen in Delft, for years working as c.e., mentions in his inaugural speech (4th of April 1919) a.o. the following on employment and prospects: “characteristic for executing public works is that in general this is done by the Governmental. Putting out under contract is rare. Everything which is done here by contractors needs to be done by the engineer himself and his personnel in the Indies... therefore the engineer in the Indies is not just responsible for sound work, but also for economic execution.

Thus it can be understood why, particularly in municipal service, nowadays grateful use is made of engineers returned from the Indies. ²⁾

And further to the students: “Gentlemen who are privileged to look for employment as c.e. in the Indies, I have had the honor to work there for over 20 years and I declare in full sincerity that, if I would have the choice as fresh graduate, I would not doubt a single moment to choose that career again.”

¹⁾ The largest number is charged with construction and exploitation of irrigation works. Red. W.I.

²⁾ The Indian Government should get this into its head. Red. W.I.

Table 8.2 Civil engineering in Delft around 1920 ⁴⁰

In a way, the recognition and position of Netherlands East Indian hydraulic engineering is reflected in something as down to earth as the lecture rooms: lecture room 114 was reserved for Indian hydraulic engineering, although shared with the subject of bridges and steel constructions. Other specializations – including general and Dutch hydraulic engineering – had their lecture rooms too, but lecture room 114 was the one best suited for showing slides.

In room no. 114 the window covers can be closed and opened by electrical force in a very short time, and the light in the projection lantern can be lightened from the desk of the professor; showing a single slide by the professor from his place without external assistance is therefore very easy.⁴¹

The distance between the lecture room in the Netherlands and practice overseas may have encouraged the usage of slides in the lectures in Delft on irrigation and other hydraulic engineering subjects in the East Indies; after all, practice had to be brought to education as much as possible.

Bringing education to practice

East Indian attempts to bring civil engineering education much closer to practice gained importance too over the years. The possibilities and necessity to establish technical education in broad sense, not particularly on university level, in the East Indies had been discussed as early as in 1912, when the 'East-Indian University Union' proposed to the Governor-General to establish a Polytechnic in the East Indies⁴². The Director of Public Works, Homan van der Heide, advised against the Polytechnic, with a similar argument as the one mentioned in 1913 by a Commission of Advice, which concluded that technical education for the colony was still not something to strive for⁴³. Just before 1920, the changing relation between the Netherlands and the East Indies created circumstances in which the call for higher engineering education in the colony became stronger. During the First World War, connections between the Netherlands and the East Indies were difficult; those in the colony eager to take up a study in Delft saw their possibilities vanish. The Royal Institute of Engineers in the Indies started emergency courses for them in 1917; ten students participated, six for civil engineering and four for mechanical engineering⁴⁴. Apart from showing that

‘good teachers for courses in Mathematics and Physics can be found very well in the Indies’⁴⁵,

these courses also made clear that

‘the legitimate Indian wishes cannot be met with full justice, when the claims are ignored of those, who achieve more in this area too than suspected in Holland.’⁴⁶

In his position as chairman of the Committee for Technical Education for the colony, established in 1918, Damme strongly opposed interference with Indian educational

affairs from the Netherlands, in particular regarding establishing a Polytechnic on Java. He was not against such an institute as such, but he strongly opposed to the route selected in promoting the institute. Damme's remarks were a direct reply to a presentation of Klopper, professor of mathematics in Delft, who presented plans made by private stakeholders to establish a Polytechnic in Bandoeng. In 1917 the 'Indië Weerbaar' ('Defend Indies') group visited the Netherlands; the group managed to collect the considerable sum of more than three million guilders from Dutch industry to stimulate the

'recovery of pre-war relations and creating strong new ones' ⁴⁷

between colony and mother country. The money was dedicated to the establishment of a Polytechnic in the East Indies. The new 'Koninklijk Instituut voor Hooger Technisch Onderwijs in Ned.-Indië'⁴⁸ (KIHTONI) had to develop plans for it; the initiative was successful as on July 3rd 1920, the Polytechnic, the first institution for scientific education in the East Indies, was officially opened in Bandoeng. Bandoeng Polytechnic offered one program, civil engineering. The new school was a success: after two years the number of first year students amounted to 37 ⁴⁹; for the second year exams 19 students passed, 16 Europeans and 3 Chinese; from 22. The Bandoeng diploma was set at equal level with the Delft diploma, although this had not been self-evident from the beginning⁵⁰. The option for 'higher technical' education, which would be on secondary level, instead of 'technical higher' education, which would be on academic level, had been an option. The choice for Bandoeng as location had not been uncontested either, as both Batavia and Bandoeng were candidates. Governor-General Van Limburg Stirum and the Director of Education Creuzberg supported Batavia, whereas IJzerman, one of the most important members of the KIHTONI as he represented the Institute in the Indies, and Klopper, who would become the first rector of the Polytechnic, preferred Bandoeng.

'In the end, however, IJzerman stated furiously that the gentlemen could choose between a Polytechnic in Bandoeng or no Polytechnic, in concurrence with the wish of the donors. Indeed the argument became so strong, that the Governor-General left the meeting in anger. But equal to the wish of initiators and donors, for whatever reason, Bandoeng became the place.'⁵¹

One of the main reasons to prefer Bandoeng was its climate, which was (and is) considerably cooler than Batavia's; with the heavy tasks awaiting staff and students, Bandoeng would provide a better working climate for intensive studies⁵². Bandoeng Polytechnic was a private gift to the East Indies; per October 18th 1924 the colonial Government took over the responsibility for the institution⁵³. Especially in the beginning, many were positive about the Polytechnic. In his speech of January 8th 1919, the Rector of Delft Polytechnic declared that Delft was glad with the birth of its younger sister; it would release the pressure of the Delft programs, which had seen a dramatic increase in new students after the end of the War. With the perceived shortage

of engineers in the colony and the consequent expectations that high numbers of engineers were needed, an extra engineering institution would not be a competitor, but enrich the engineering profession. Some years later, it became clear that the need for engineers in the Indies was considerably lower than anticipated upon; competition with Delft graduates became apparent soon and job opportunities in the colony for Delft engineers were seriously reduced⁵⁴. Bandoeng had become a competitor for Delft graduates, reason for at least one civil engineer from Delft to plea for dramatic action: he proposed to change the status of Bandoeng from an academic school to a secondary school. This would not just decrease competition, but also justify the level offered in Bandoeng; to the (anonymous) engineer it was clear that the educational program in Bandoeng could not meet the Delft standards by far⁵⁵.

The editors of the 'Waterstaatsingenieur' wrote in a comment on this letter that it raised a continuous issue. Indeed, the desired level and aim for technical education in the East Indies had been subject of discussion before. These discussions dealt with the level – academic or not, at level with Delft or not –, the development strategy – starting with the higher level or on secondary level – and program organization – the Dutch model, other examples? Center of the discussions was the Committee for Technical Education mentioned before; established on March 12th 1918 by the colonial Government, its task was to study needs and possibilities for technical education on all levels in the colony. Its members represented the principal colonial technical fields: civil engineering, sugar production, railway and mining. Applying the metaphor of a building, Commission chairman De Voogt stressed the need for a firm foundation, lower technical education, before the upper parts, higher education could be constructed⁵⁶. His successor Damme emphasized the different needs of the Indies in comparison with the Netherlands, which to him was reason not to copy the Delft example too easily. Indeed, the Commission studied systems of technical education in other countries than the Netherlands, the American model in particular, as it would represent the need of typically 'new' countries, including for example Australia.

'Are we allowed to say: That is all well for America, Australia and such, but here [that is: in the Indies] Dutch solidity and science need to **keep** wielding the scepter.'⁵⁷

The Commission continuously stressed the need for careful study and discussion on the relation between Indian needs and educational systems; by doing so, however, it seems to have missed momentum. When it delivered its final report in 1920, the decision to establish the Bandoeng Polytechnic was already made by others.

Technical education at Bandoeng Polytechnic

Although the engineering school in Bandoeng was a gift from the Netherlands, the founding committee and its members did focus on the institution as one that should suite East Indian needs. The engineers trained in Bandoeng were supposed to find

employment in the colony. The East Indian needs and technical issues set the context for content and setup of the educational program. A sub-committee of the Committee for Educational Advise of the KIHTONI, consisting of Hoogewerff, professor in chemistry and former rector of Delft polytechnic, Weijs and engineer Van Sandick as reporter defined the study program; Klopper played an important role in setting up the program too, particularly concerning the mathematical courses. The educational system and program of Delft were taken as the models to follow, but adaptations were made. In Bandoeng the whole program was obligatory, which was only a small contrast to Delft with its few optional courses. The sub-committee thought that the drawing courses would offer some choice to students in Bandoeng; they could draw those subjects they were most interested in.

‘Such freedom would typically be more beneficial than damaging to the program.’⁵⁸

The Bandoeng program took four years, Delft had one year extra; nevertheless, the program in Bandoeng should be at the same level as Delft. The room was found to make an exception for mathematics. As the number of lecture hours for different engineering subjects should not be lower than in Delft, but squeezing the program in four years was needed, the sub-commission proposed to cut down attention for mathematics. Candidates would only require mathematics as supporting science to be able to function as a professional engineer⁵⁹, and

‘quite generally the feeling is that at Delft Polytechnic demands for these courses go beyond the absolutely necessary to allow the engineer to qualify for the practical execution of his profession.’⁶⁰

The sub-commission asked Klopper whether and, if so, how the limitations for mathematics could be realized. Not only did Klopper agree with the idea of minimizing mathematical content, but he took a different position on fundamental, theoretical courses in the Bandoeng curriculum altogether. He proposed to schedule the majority of these courses in the last year instead of the first. With such a setup, theoretically less capable students could leave the program after three years as technicians on middle level; those capable enough could continue their fourth year to reach the engineering level. Klopper used two arguments for this proposal. First, he knew how many students in Delft struggled with the theoretical courses.

‘they trudge along, each time subjecting themselves anew to an exam, without showing any real progress – and in the end graduating. Finally, the examiners do not see other solutions and give the diploma against their will.’⁶¹

Second, he thought that such developments, including students not finalizing their studies, could not be afforded in the East Indies, as non-successful students

‘will be a larger burden for society.’⁶²

Table 8.3
The study
programs in
Bandoeng and
Delft⁶³

		<i>Bandoeng Polytechnic</i>		<i>Delft Polytechnic</i>		
		L	A	L	A	E
1	Pure and applied mathematics	360	120	476	112	-
2	Theoretical and applied physics	160	160	168	168	-
3	Chemistry for engineers	80	-	-	-	56
4	Architecture	300	720	296	720	-
5	Hydraulic engineering	400	660	338	582	34
6	Construction and exploitation of roads and bridges	420	540	349	492	17
7	Mechanical technology	80	-	-	-	70
8	Knowledge and research of building materials	200	-	120	-	-
9	Technical drawing	-	120	-	84	-
10	Theoretical and applied mechanics	300	120	288	144	34
11	Theoretical and experimental hydraulics	60	-	48	-	-
12	Mechanical engineering	80	120	96	96	-
13	Electrotechnical engineering	60	-	64	-	34
14	Technical hygiene	80	-	-	-	64
15	Surveying and leveling	160	160	128	128	-
16	Administrative law	80	-	112	-	-
17	Metallography	-	-	-	-	68
18	Urban development	20	-	-	-	17
19	Trade law	80	-	-	-	68
20	Business administration and accountancy	80	40	-	-	136
21	Economics	60	-	-	-	68
Total		3040	2760	2483	2526	666

C = Compulsory; E = Elective; L = Lecture; A = Assignment

The potential escape after three years should prevent that students would leave the Polytechnic without any diploma⁶⁴. As in Delft the Bandoeng curriculum was divided in 21 courses, each with a dedicated number of contact hours, either through lectures or assignments (Table 8.3). The total amount of hours offered to the students in Bandoeng, with 3040 hours of lectures and 2760 hours of assignments, was not less than in Delft with 2483 + 666 hours of lectures and 2526 hours of assignments. We will not discuss how the Bandoeng curriculum must have felt for a student, with such an amount of hours in four years; the course program, however, was similar to the Delft curriculum. Taking a closer look on the course descriptions sheds light on differences and similarities of the content of the courses; such a comparison shows to what extent East Indian civil engineering differed from Dutch civil engineering in the late colonial period⁶⁵. A diverse picture emerges: courses like road construction and geodetics included attention for the difference in geographical circumstances; courses

like business administration and again geodetics emphasized that East Indian engineers were involved much more than their Dutch colleagues in actual measurement, construction and administration of the designs they made. Attention for hygiene and construction materials was needed, as these areas were still relatively new and undefined in the colony; the same argument applied to administrative law was reason to minimize attention for that subject. Hydraulic engineering in the Netherlands East Indies, with the longest description, had become a discipline of its own compared to the hydraulic engineering profession in the Netherlands.

Post-colonial Dutch irrigation education

Thus, attention for irrigation engineering was firmly settled within both the Delft and Bandoeng engineering schools after 1920, the last two decades of Dutch colonial rule in Indonesia. Indonesia's independence effectively put a halt to Dutch engineering intervention in this territory; the East Indies as employment option had disappeared. When the direct connection between education and employment disappears one can expect discussions about the usefulness of that specific educational program, particularly in engineering. In this context, engineer Eijsvogel, designer of the Sadang irrigation works on Sulawesi and irrigation professor at the other supplier of colonial engineers, Wageningen Agricultural Engineering School, pointed out that quite a few people argued that the study programs directed at the East Indies could be erased⁶⁶. Nevertheless, Wageningen kept offering specializations directed at non-Dutch regions; these specializations were referred to as 'tropical', not 'colonial'⁶⁷. Within Delft, similar discussions could not be avoided; the focus of the discussions was on its own graduates, Bandoeng was ignored⁶⁸. Despite or because of discussions on continuities, the possibility to graduate in irrigation was maintained in Delft too after 1945. In the 1930 civil engineering program of Delft students could choose between two main graduation specializations: 'Dutch' civil engineering and 'East-Indian' civil engineering, with just a few courses difference between them. In 1955, a prospective engineer could select one of seven specializations: 1) general hydraulic engineering, 2) polders, 3) irrigation and hydropower, 4) bridges and roads, 5) utility buildings, 6) sanitary engineering and 7) theoretical subjects⁶⁹. From these options, the specialization for irrigation and hydropower,

'non-native branches of civil engineering practice'⁷⁰

was the successor of the East-Indian program. It was the 'Dutch' branch, however, which was really transformed; instead of one general program, six different graduation subjects were defined. One of them was 'polders', which had been a subject in the educational program long before, but had remained somewhat hidden. With the appointment of Klein as extra-ordinary professor for polder development in 1953 – even though his official position, which he held until 1972 still was referred to as 'hydraulic engineering' – this specific field within hydraulic engineering became recognized in Delft. In his inaugural speech, the fresh professor discussed several issues

related to polders, but paid most attention to the issue of water deliverance to polders. He argued that one used to focus on

‘keeping our polder land dry as good or bad as possible’⁷¹,

but that a new, additional task had come to the front: water level control, which he defined as

‘maintaining ground water levels almost constant – and thereby the levels of ditches and other water courses [...]. Next to improved water discharge this brings water delivery under attention.’⁷²

For Klein the conclusion was clear.

‘Irrigation is not just important for tropical or dry regions anymore, but, although in a different shape, for our country, which is not typically known for its tropical or dry climate, as well.’⁷³

Despite this recognition of irrigation as a relevant subject for the Netherlands, I have no indications that Klein worked closely together with his Delft irrigation colleagues; especially Berkhout, who was appointed professor in 1954⁷⁴ and held his position roughly in the same period as Klein, would be a candidate to cooperate with. The branches of polders, focusing at the Netherlands, and irrigation/drainage, focusing on tropical countries, remained two separate specializations⁷⁵. The irrigation professors in the Netherlands emphasized the need to broaden the perspective of irrigation engineering from the East Indies to all tropical regions, and even to the Netherlands. In a presentation to members of the Royal Institute of Engineers in 1950, Eijssvoogel discussed the development of modern irrigation technology in the Netherlands East Indies; after descriptions of the constructive and hydraulic issues encountered and solved, he stressed the attention of the Dutch engineers for lay-out, organization and management of irrigation systems. He distinguished between two main models how these connected issues were approached: an organizational model based on water distribution to individual farmers and an organizational model based on water distribution to groups of farmers. Leaving aside communist countries and some notable exceptions to the rule, Eijssvoogel distinguished between

‘distribution to the individual farmer where properties have a reasonable size (thus e.g. in the U.S.A., South Africa, Australia) and distribution to a group of farmers where small land holding prevails (that is in the tropics).’⁷⁶

In just a few pages, ‘tropics’ became equal to ‘Javanese’, when Eijssvoogel stated that Lamminga had thoroughly studied and defined the principles which had to be applied when designing and constructing irrigation systems in ‘tropical regions’.

‘It must be noted how the founder of irrigation on Java, ir Lamminga, sorted this subject out very quickly 50 years ago and defined the principles, which need to be followed when developing irrigation facilities in the tropics. These principles are:

- a. An irrigation area has to be divided in distribution groups, which are separated by topographical borders. On Java these sawah complexes were called: end units.
- b. Water distribution to these end units needs to be executed with division structures, which are constructed in such a way that one can control water division completely. Each unit receives water at only one location.
- c. Discharging excess water from the end units needs to be considered as much as bringing water to the units.

As mean unit size 150 ha was selected; that this was a good choice is proven by the fact that, despite proposals for changes, this size has been kept over the years. To these principles one other very important principle was added in the first years of the 20th century by ir Numans, namely that both water distribution as maintenance within the unit is the task of all landholders, a principle comparable to our water board regulation. Therefore they elect one of their own, whose salary is provided by them together. In Tegal, where this regulation was introduced in 1909, one refers to this representative of the landholders as *oeloe oeloe pembagian*.’⁷⁷

In this way, the East Indian irrigation concept was narrowed down to distributing water to smallholders. Sugar cane, a crop which played such an important role in Javanese irrigation and influenced the need to control water division is left out by Eijssvoogel. In his own inaugural lecture, Berkhout referred to the importance of irrigation worldwide, the need for increased food production and the expertise available in the Netherlands because of its East Indian past. Berkhout emphasized the strategic aspect related to attention for irrigation in the Netherlands; allowing the irrigation domain to disappear from the Delft curriculum would mean that the Netherlands would not be able to maintain its leading position in the international aid programs applied worldwide. Apart from its colonies at that time, Surinam and New Guinea, and the UN-guided development programs, Berkhout saw possibilities for cooperation within the context of the Benelux⁷⁸; Dutch engineers could assist Belgium to develop irrigation in its African colony Congo. Involving Dutch irrigation engineers in the British and French territories would be an option too, as was a return to Indonesia somewhere in the future. All in all, Berkhout was very pleased that irrigation had not only maintained a professorship, but also that a condensed course in irrigation was obligatory for all civil engineering students. Berkhout re-introduced an argument already mentioned by Grinwis Plaat and Lamminga: providing water to agriculture was an issue in the Netherlands too. Although the shape of irrigation systems in the Netherlands were different, mainly sprinkler systems, some knowledge of water distribution systems was necessary for Dutch drainage-oriented engineers. Berkhout emphasized that knowledge on technical issues was not enough: water management was at least as important, if not

more important. This management aspect of Dutch colonial irrigation was not only restricted to principles of water distribution as such; it was also necessary to consider

‘that [in the Indies] close cooperation existed between civil servants, agricultural experts and irrigation engineers.’⁷⁹

The successor of Berkhout, engineer Schoemaker was professor between 1967 and 1984; he did not see any need to defend attention in the Delft civil engineering curriculum for ‘exotic hydraulic engineering’, as he called it⁸⁰. For him it was clear that his own appointment already showed that the need was recognized by the university. Schoemaker stressed discontinuities between the Delft educational program and the engineering practice abroad. Discussing available knowledge and applications for several fields, like hydrology, soil mechanics and hydraulic engineering, Schoemaker tried to show that

‘a large gap exists between availability of this body of knowledge and its proper use.’⁸¹

Although at first sight available knowledge for prospective engineers looked promising for working abroad, the well-established East Indian knowledge had not become redundant at all, even when it had partially been

‘reduced to a set of antiques’⁸²

In his remarks to his future students, Schoemaker acknowledged that the content of his lectures would be one-dimensional and incomplete, given the complexities they would be confronted with in their professional work abroad. Confrontations with these limitations during the study program were extremely useful, however, as it would increase student’s capabilities to apply their

‘scientifically responsible ingenuity.’⁸³

When it was his turn to shed light on the irrigation fields, engineer Brouwer, who succeeded Schoemaker in 1985, did not make a fundamental difference anymore between water management in the Netherlands and abroad.

‘In this speech I will argue tht the similarities in engineering knowledge for Dutch and foreign water management are much bigger than the differences, and that a stronger exchange between water management in the Netherlands and water management as applied abroad will be beneficial to all involved.’⁸⁴

The string of inaugural speeches of Delft’s irrigation professors suggest an increasing normalization of the position of irrigation within the civil engineering program; the need to defend the subject within the curriculum seems to decrease. The increasing importance of international development aid provided a welcome new working environment for Dutch irrigation engineers and a new perspective for educating these

engineers. In the late 1960s, working abroad was well-established; the need to defend working abroad and/or attention for irrigation had disappeared. The speeches also suggest that Delft irrigation attention had come loose from its East Indian roots; the issues to be discussed, trained and solved by irrigation engineers were formulated in general ways, without specific reference to its colonial past. The study material applied in the irrigation courses, however, shows that the Netherlands East Indies technological regime was of considerable influence in the educational process of Dutch irrigation engineers after 1950.

Study material in civil engineering irrigation education

The lecture notes of De Vos, irrigation professor in Bandoeng are the most extensive notes of all Dutch irrigation professors I studied. When De Vos became professor in the 1920s, it was already common procedure that professors would write lecture notes for their students. His lecture notes consist of more than 450 (!) densely printed pages; to follow the lectures of De Vos must have been challenging at times, but at least the lecture notes included detailed discussions of many irrigation issues related to design and management in general. The notes are not restricted to the Netherlands East Indies per se, as they include much information on other areas, like the USA, British India and Europe. The design approaches discussed in the notes, however, are restricted to East-Indian practice; De Vos does occasionally include a critical remark on typical East-Indian methods. After discussing three capacity curves (Tegal, Pategoean and Solo), he continues that

[o]f course all three capacity curves are more or less arbitrary; the Tegal curve is usually applied and has always given good results, that is no cause for miscalculations, in practice, even in regions without sugar cane when it is actually not applicable. However, as this curve is based on the assumption that 1/5 of the cultivable surface is used for sugar cane, it would actually be logical for regions with much less or no sugar cane to set the reduction for surfaces of 1000 bouws not at 20%, but smaller, for example 5% a 10%.⁸⁵

In Delft, lecture notes seem to have become available since 1905; this year is at least mentioned in an article in 'De Ingenieur' from 1920, which discusses a meeting of representatives of professors and students of the Delft engineering school. The subject of this meeting of March 25th 1920 was the 'lecture book'; the students argued that existing experience since 1905 had shown that lecture notes were extremely useful for students, as they made it easier to listen to the professors, included references and more details than could be told during a lecture. Already in 1891, Van Sandick had remarked that lectures in Delft were

‘a kind of stenographic exercise’⁸⁶

The students of those days could study existing Dutch handbooks⁸⁷; some may have used the older French handbook of Nadault de Buffon (1858), but it is likely that most

students had to rely on their lecture notes, and probably those from their colleagues as well. The first lecture notes available for my research are those prepared by professor Weijs; these notes include a long list of available books for students, only one of which is written by a Dutch engineer (Table 8.4).

Table 8.4 Study material mentioned in lecture notes of Weijs⁸⁸

Year	Author	Title
1891	J.E. de Meijer	Bevloeïngen
1883	Dünkelberg	Enzyklopädie und Methodologie der Kulturtechnik
1903-1908	Vogler	Grundlehren der Kulturtechnik
1909	Risler & Wery	Irrigations et drainages
1907-1908	Friedrich	Kulturtechnischer Wasserbau
1911	Spöttle	Landwirtschaftliche Bodenvernesserungen
1913	Newell & Murphy	Principles of irrigation engineering
1910	Bligh	The practical design of irrigation works
1912	Brown	Irrigation. Its principles and practice as a branch of engineering
1919	Davis & Wilson	Irrigation-engineering
1915-1916	Escheverry	Irrigation practice and engineering

The successor of Weijs, Haringhuizen expanded the study material available for students considerably⁸⁹. Haringhuizen became a major actor in establishing the link between East Indian irrigation practice and Delft irrigation education; he was a professor between 1919 and 1938, a period which enabled him to develop much study material and educate many engineers. If Lamminga was the founding father of the East Indian irrigation regime, Haringhuizen must be considered the founding father of Delft irrigation education. One of the products of Haringhuizen used in his teaching were the design graphs he developed (Figure 8.1); I have also encountered a note on capacity curves which most likely has been used in class⁹⁰. If the meeting of 1920 between students and staff was representative for civil engineering too, irrigation students would have been in favor of such lecture notes, as it saved them much effort during lectures. Another argument was that with the notes students could prepare themselves for lectures; furthermore, the students argued that the clarity offered by lecture notes would stimulate students to really learn the course contents and not just strive for a capacity of repetition. The professors were not convinced, although they acknowledged the value of good study material. The professors argued that availability of lecture notes would allow students to stay away from the lectures. They argued too, that repetition by students had actually increased instead of decreased after lecture notes were introduced. Notes which only included the study material needed to pass the exam were not considered academic; on the other hand, handbooks were too expensive for most students⁹¹.

The successor of Haringhuizen, Begemann continued with lecture notes; he included some new elements, including the subject which had made him famous in the East

Indies: statistical analysis in hydrology⁹². The notes of Begemann are largely based on the Netherlands East Indies, other regions are scarcely mentioned. On his turn, Berkhout was responsible for three courses related to irrigation: F17, a short course on irrigation, F18, the regular, extensive irrigation course and F19, a course on major structures and reservoirs; F19 included the majority of the statistics from Begemann. Course F17 included most standard elements already encountered in this book: the design rules for tertiary units, discharge measurement structures, canal design graphs of Haringhuizen and capacity curves. In comparison with Begemann's lecture notes, the F17 notes are more or less the same, with some minor changes, for example in the section on discharge measurement. Berkhout includes much more on Cipolettis and Thomson weirs and minimizes attention for Venturis and Crump de Gruyter gates. One new type of discharge measurement and regulation structure is recognized.

'In some countries completely different measuring devices or measuring methods are applied. In Northern Africa and other French or formerly French regions (and elsewhere too, like recently in Eastern Pakistan) automatic distribution sluices and diversion structures are applied, of which Neyrpic possesses patents.'⁹³

Including French types did not mean approving of it, however.

'The judgment on these is not undividedly favorable: some experts consider the constructions not sufficiently robust: too much clock maker's work.'⁹⁴

The lecture notes for the extended irrigation course F18, which was the regular course for those who wanted to graduate as irrigation engineer, come close to the lecture notes of De Vos, although his second chapter, which is missing in F17, discussed irrigation in other regions. Other extensions in comparison with F17 are in the paragraphs on goals for irrigation, irrigation methods, and capacity curves and canal design. The chapter dealing with canal design recommends the construction of design graphs when designing an irrigation system, as it would save much work doing calculations.

'For developing such a design graph one can take as a starting point the Tegal capacity curve, for which between 18 and 142 ha the formula $y = 5,22 B^{-1/3}$ can be applied. For units with a surface between 142 en 300 ha the exponential formula $y = 1,415 B^{-0,07}$ and $Q = 1,415 B^{0,93}$ can be applied.'⁹⁵

Schoemaker continued to use the lecture notes of Berkhout, as he considered them good notes. Although he kept the lecture notes, Schoemaker did develop new study material; he produced a number of (extensive) monographs on several subjects, including canal design, in which he included sediment analysis made by De Vos, which had been absent in the standard Delft lecture notes. These documents were not part of the final examination, however, but were made available to students in case they would need them later in their professional practice. The number of students actually studying the extra material was probably low; Schoemaker himself declared that

‘most engineers have a deadly fear of mathematics’⁹⁶

Each civil engineering student in Delft who wanted to specialize in irrigation engineering had to make a final design of an irrigation system; usually a student had to make several designs, for example of an irrigation system, a bridge and a road network, or conduct a small research project instead, hydraulic behavior of a weir, a structure or comparable structures. I have traced a range of the irrigation graduation designs from the period 1937-1980, with the majority later than 1954, when Berkhout became professor. Design situations from Indonesia form about two third of the total number of designs (96 out of 149); most of these tasks are taken directly from systems from the colonial period. Design tasks from two African countries, Ethiopia and Tanzania, form more than half of the total number of design situations from other countries than Indonesia (34 out of 53); it is probably not a coincidence that the systems to be designed for these tasks had to irrigate sugar cane, although the category Ethiopia includes some other cropping patterns. All design tasks asked similar activities of students: (1) the main layout of the irrigation system, including planning of units, (2) calculating a number of canals, including drawings of length profiles, and (3) detailed design of one or two hydraulic structures, usually the intake structure and the sand trap. The actual formulation of these tasks differs considerably between the Indonesian and non-Indonesian subjects; non-Indonesian descriptions are all quite general and occasionally include East Indian terms like ‘bandjir’ or ‘wadoek), but the Indonesian descriptions are very detailed⁹⁷:

‘To be designed:

1. the water intake structure (floor-plan and cross sections at scale 1:100);
2. the main canal, its flushing and diverting sluice and the connected flushing canal (horizontal scale 1:1000, vertical scale 1:100, structure at scale 1:100);
3. the position of the components under 1. and 2. on the map handed out;
4. the division in units for the entire command area, in which all secondary units are given a specific basic color and all tertiary units are given an extra color of the secondary unit at the margins, but in a darker shade; irrigation canals are drawn blue, drainage canals red; main canals are drawn with a thick continuous line, secondary canals with a thinner continuous line, tertiary canals with a striped line and population canals with a dotted line; division structures are indicated with a small circle, with a small horizontal line when a level regulator is included, without line in case no regulator is present; a systematic labeling system for canal sections and structures needs to be applied;
5. capacities of several sections of the main and secondary canals and longitudinal and characteristic cross sections of these canal sections; longitudinal sections at a horizontal scale of 1:20.000 and a vertical scale of 1:100, cross sections at 1:100.’

The designs made by students show that they include a set of East Indian elements, such as the Pemali water use graph, the Tegal capacity curve, a golongan arrangement, a tertiary unit size of about 140 hectares (200 bouw), the Romijn weir as discharge measurement structure, the Haringhuizen canal design graph and the standard Indian system of indicating systems elements⁹⁸. The design task based upon the Tjipoenegara system, for example, includes many of these elements (Table 8.5), and prescribes irrigation for sugar cane and rice, an interesting detail, as sugar cane never prospered in the area.

	1940	1959	1968	1972	??	??
Pemali water use graph	-	-	*	*	*	-
Tegal capacity curve	*	-	*	*	*	-
Golongan	-	-	* ³	*	*	-
Tertiary unit size 140 hectares			*	*	*	-
Romijn	* ¹	*	*	*	- ⁴	Drawing ⁵
Naming system Van Rosse	-	-	*	*	-	-
Haringhuizen design graph	-	* ²	*	-	*	-

Table 8.5 East Indian design elements in Tjipoenegara design tasks

¹ Includes analysis of venturi, Crump-de Gruyter and Romijn structures

² Backwater curve with Van Maanen / Stilling basin with Vlugter

³ Golongan paragraph refers to a remark of Lamminga / Stilling basin with Vlugter

⁴ Includes reference to a ‘measuring device’ in the system / Literature includes Van Maanen

⁵ Only one drawing available

What may have been self-evident for Indonesian design subjects, and probably not even surprising for the modern researcher, appears to be self-evident for the non-Indonesian subjects too: Delft students made irrigation designs based on the East Indian model. Of course, the student designs for Tanzania, Ethiopia, Syria and Nigeria were showing not East Indian systems, that would be too simple an interpretation, but in general the designs include most of the East Indian elements already mentioned. The large majority of student reports include a remark, that the East Indian system to label canals and structures was used. There is one student who used the system because it is

‘the best system ever developed’⁹⁹

He had probably taken the extended irrigation course F18, as the lecture notes of this course similarly state that

‘[a] better system has never been found and is not known either abroad’¹⁰⁰

Another student seems to apologize for not completely following the system.

‘Naming the different components of the concession can be kept simple because of the highly regular division of 4 x 16 tertiary units, although it slightly differs from the nomenclature normally applied in Indonesia.’¹⁰¹

Most students used the system just like that, sometimes without referring to it, but always without discussing it. Students selected the discharge and/or measurement structures for their designs in similar ways. I have been able to find three designs in which it is explicitly made clear that a Romijn weir was not selected just like that. Again, a large majority selects a Romijn weir without any discussion; the structures are usually not detailed, they are only included in the design reports because their head losses influence the water level needed at the intake. In the three cases where the students have discussed the appropriateness of the Romijn weir, the reasoning is different. One student had selected Romijn weirs for most off-takes in his Syrian system; for one off-take with considerable available head loss he recognized the possibility to select another structure. For reasons of standardization he decided to select the Romijn weir after all. For a design in East Pakistan (Bangladesh) a student applied Romijn weirs for small off-takes and Venturis for larger ones. Student Visser, however, who designed an irrigation system in Ethiopia, studied the selection of discharge measurement in detail. He concluded that the circumstances for water regulation in his system differed from the Indonesian context; as his system was owned by one company to grow sugar cane, there were no different water users to interfere with distribution. Furthermore,

‘simplicity and constructional robustness are highly important, given the industrial set-up.’¹⁰²

After considering the Romijn, Visser decided to apply a Parshall flume,

‘which does have the inconvenience of separated measuring and operation functions, but is robust and invulnerable.’¹⁰³

There was another reason: his selection was also influenced by the consideration

‘that it is useful to gain some experience in designing measuring devices of American origin.’¹⁰⁴

Apparently, applying a non-East Indian structure needed more defense than applying the usual Romijn weir. The same student Visser also concluded that a capacity curve was not necessary for his system, as units were similar in size and sugar cane the only crop¹⁰⁵. Most of his fellow students seemed to agree with him; there are only six students within the group of non-Indonesian designs who apply a capacity curve as such¹⁰⁶. For a Syrian case, one student constructed his own curve, another one simply applied the Tegal capacity curve. A third student applied the Tegal curve in his Ethiopian design because

‘unit sizes differ considerably’¹⁰⁷

In the Kano case, one student again simply applied the Tegal curve; his colleague applied the curve too, but he realized that

‘this formula is based on rice as the main crop’¹⁰⁸

A similar remark is made by student Meijer, but he applied the Tegal curve in his Ethiopian case as

‘data from practice for this area are not known and furthermore one has to take into account cropping of secondary crops by the population during six months’¹⁰⁹

He assumed that

‘in any case application of the curve is safe.’¹¹⁰

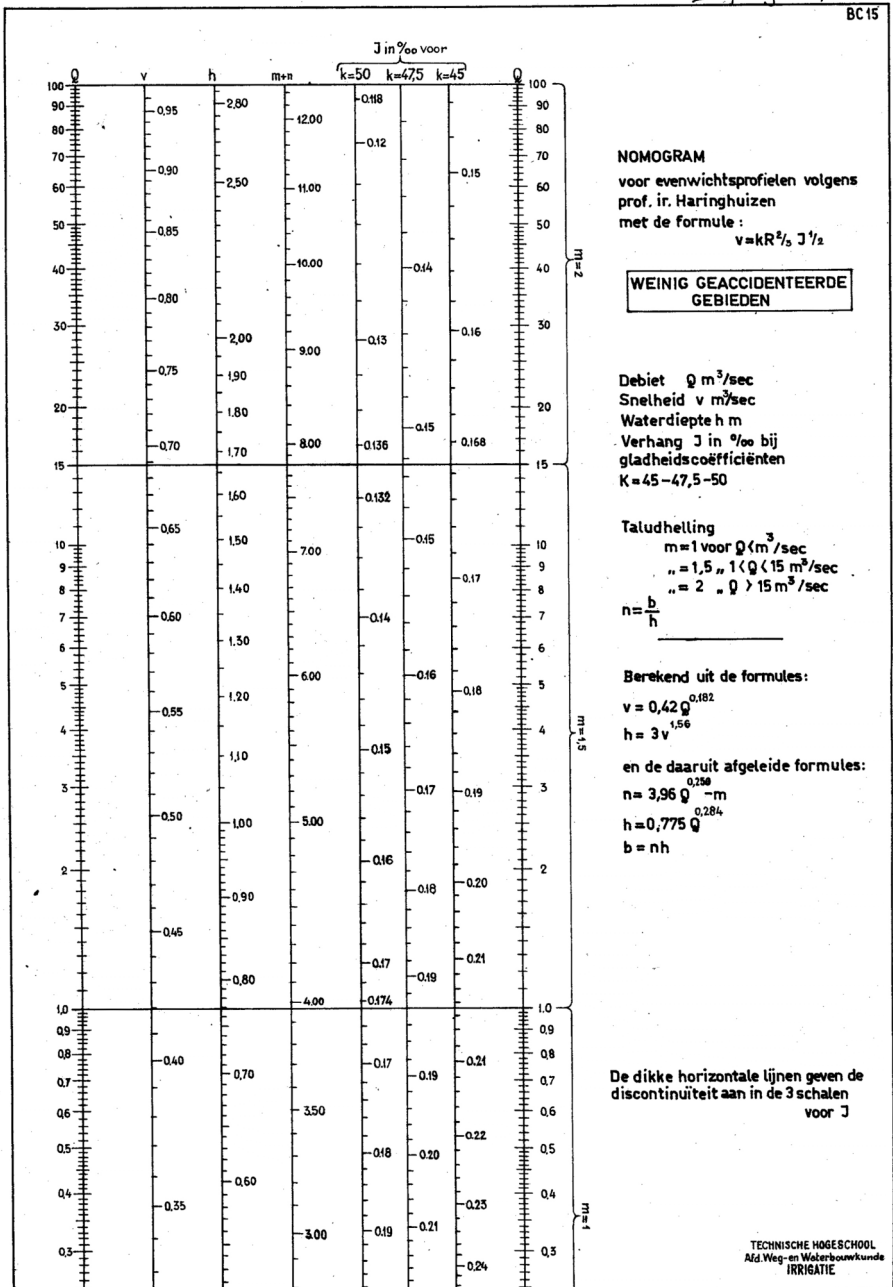
All students had to design the basic layout of the irrigation system, with canal routes and sizes and shapes of secondary and tertiary units. The standard tertiary unit size in the Netherlands East Indies of about 140 hectares was never applied just like that; in case the unit sizes are discussed, however, the East Indies was mentioned as reference. Two students defended their selection of relatively smaller tertiary units for their sugar cane plantations with a reference to the different water distribution context compared to Indonesia. Two other students included the rules for shaping tertiary units developed in the East Indies; single intakes were recommended, parallel canals were to be avoided to limit water theft and community borders were to be respected as much as possible. Most students managed to select relevant considerations, but some simply copied the whole list. In a handwritten comment, probably by the supervisor, in a design report from 1973 for the Tanzania case the remark is made that the consideration for water theft, a topic included in the lecture notes,

‘does not apply for this design’¹¹¹

After all, the system was owned by one company, who would only steal water from itself... As one could expect for a civil engineering program, the focus of the designs was on the main works; all designs included calculations for the main intake structure, flushing sluice, stilling basin and sand trap. The large majority of students followed a similar procedure for these designs; the calculations applied were generally the same. An approach to determine the depth of the stilling basin developed by Vlugter was applied in all cases except just a few; student De Jong informed the reader that he had applied the Vlugter method

‘as described in an annex of lecture notes F18.’¹¹²

Figure 8.1
Canal design
graph of
Haringhuizen



Another calculation method applied very often by students was the canal design graph developed by Haringhuizen. Based on the discussions on canal calculations professor Haringhuizen developed these graphs, with which canal profiles could be determined easily. The two graphs represented two different topographical situations: relatively flat

areas and mountainous areas (Figure 8.1). Many students applied one of these graphs, usually the one for flat areas; some students applied the graph, but slightly adapted it. Only very few students applied other calculations methods; those who did either applied the Strickler formula or the sediment formulas of De Vos¹¹³.

Prescriptions

In the 1920 discussion on the lecture notes, one of the fears of the professors was that lecture notes would be nothing more than

‘just prescriptions without background derivations’¹¹⁴

I would argue that between the 1920s and the 1980s the study material which was used to train the new civil engineering irrigation engineers did not change substantially and was mainly prescriptive in nature. The respective professors added their own personal interests, but did not change the basics of the irrigation approach the students had to follow. For example, the remark that the East Indian labeling system was the best ever continued to be included in the lecture notes. Although the lecture notes for the short course F17 and the regular course F18 differ in detailing issues within irrigation systems, they do not differ on the issues on the main level we have already encountered in the graduation design reports. The similarities in the irrigation graduation designs suggest some application of recipes. One of the other major dangers of lecture notes according to the professors was

‘the danger of insufficient revisions of the lecture book’¹¹⁵

The last new old F18 lecture notes published by Schoemaker in 1981 were the same notes as those developed by Berkhout in 1967, which on their turn came pretty close to the notes of Begemann and De Vos, which on their turn... etcetera. In 1980, however, Schoemaker published the first part of new lectures notes; in 1982 he published a second part of these notes. He included several parts of his extra monographs in these lecture notes; for example, the paragraphs on canal capacities included much more theoretical and statistical discussions than ever before. Schoemaker continued to apply East Indian knowledge and material: the paragraphs on layout and topography were clearly closely related to the East Indies and the work of De Vos. Even the labeling system was included, but this time

‘the systematics given here for nomenclature and connected indications on maps are only meant as an example’¹¹⁶

Discharge measurement structures were not dealt with in detail, but were mentioned occasionally as they cause head losses in the system; the Cipoletti weir was mentioned as a case of higher head loss, for discharge measurement structures Romijn and Butcher¹¹⁷ (!) weirs were included as examples of structures with lower head losses. The first Dutch civil irrigation engineers were trained in Dutch hydraulic engineering. In the

early 1900s, with the appointment of Grinwis Plaat as lecturer, specific irrigation education started in Delft preparing for irrigation practice in the Netherlands East Indies. Dutch and East Indian hydraulic engineering became two separate specializations, even though the difference in number of courses was not that big. Before World War II, irrigation education in Bandoeng and Delft had a clear professional practice to train students for: the colony. In discussions on technical education in the Indies occasionally the option popped up that Bandoeng engineers could work in the 'new countries' as well, in contrast to the old mother country. However, this professional outlook for Dutch irrigation engineers was actually realized for Delft-trained engineers when Indonesia became independent. The new irrigation engineers had to find their way to other regions; instead of one irrigation practice there were numerous ones. Thus, after World War II irrigation practice moved away from irrigation education. Nevertheless, those Delft graduates who would start to work overseas in irrigation did so with a training based on East Indian irrigation design conceptualizations up to the early 1980s; only a few graduation design exercises touched upon the other irrigation world.

9 Technical construction of society

Conclusions

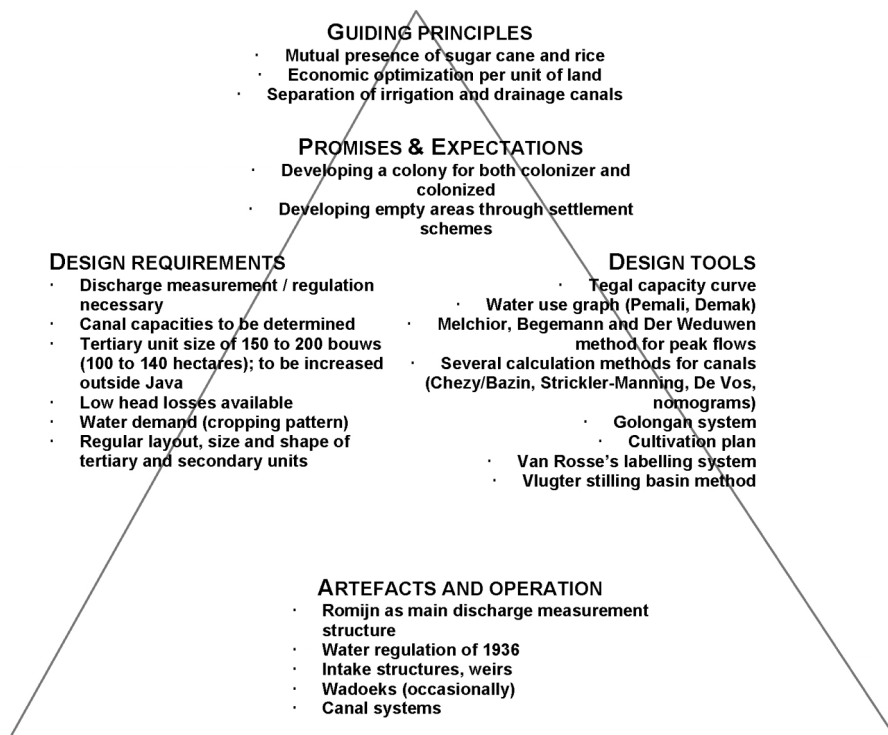
We started tracing our river of continuity with discussing how the juggling act¹ of colonial rule between available labor from colonizers and colonized, available financial resources and political goals influenced colonial irrigation development in British India, colonial Africa and the Netherlands East India. Irrigation development in the colonies did not only serve the colonial powers, but also had to serve the colony itself; it should not be exploitation, but become an element of productive imperialism. Differences in agrarian policies of the colonial powers appeared as vital in explaining differences in irrigation approaches between colonies. Furthermore, debates in different colonial circles – engineers, politicians, general public – did not necessarily coincide; debates within one community did not always influence debates in another one. Different types of rules and/or guidelines were employed in East Indies irrigation design; an important guiding principle was – anticipating on – the presence of sugar cane next to rice in the same irrigated area. This required control over flows varying in time and space. This guiding principle was translated by civil engineers into a design approach. Artifacts and methods developed by Dutch engineers in colonial times still shaped to a large extent irrigation design practice in independent Indonesia and Dutch civil engineering irrigation education.

The irrigation regime of the Netherlands East Indies

All this resulted in a Netherlands East Indian irrigation regime. To start at the end: in 1940, the Dutch irrigation regime with its main features looked like Figure 8.1. Guiding principles were threefold. 1) Sugar cane and rice were mutually present in irrigated areas, and 2) economic optimization of irrigation water was to be achieved. Between 1920 and 1940, another main focus of irrigation policy was added in 3) developing empty areas through irrigation, including the coastal plains of Java – including Tjipoenegara, Krawang and Tangerang. On other islands such areas included Lampung and Sadang. Although the presence of sugar cane was to be doubted, the standard Tegal capacity curve was applied in these systems. The tertiary unit size was preferably 200 bouw or a bit smaller. The original size of units could be bigger, but it was expected that increasing irrigation intensities would require subsequent subdivision of these larger tertiary units in the smaller units of 200 bouw. Water management in the systems was facilitated by the Pemali approach, culminating in the 1936 water

regulation and Venturis and later Romijn discharge measurement structures, with the occasional wadoek or Crump-De Gruyter.

Figure 9.1 The Dutch irrigation regime triangle in 1940



The regime of Figure 9.1 did not grow out of a single, linear regime development process between 1830 and 1940. The set of design rules was shaped by human actors; they did so in a social construction process in different natural and social environments. In and through their activities the human actors reproduced the conditions that made these activities possible and created a regime. The relation between sugar cane and rice remained on the agenda up to the 1930s; many problems with the mutual presence, like the day and night regulation, and some solutions, like wadoeks, were debated upon and tested, although the mutual presence of the crops itself was not discussed. Innovations in irrigation design were plentiful, for example on discharge measurement structures; the introduction of the new Venturi type resulted in a vivid and intense debate. De Gruyter proposed another structure, but finally Romijn could present the Dutch answer to the question how to discharge and measure without large head losses. How to calculate canal profiles is another technical question heavily debated upon in this period. The political debate changed as well, with new social groups as agricultural engineers entering the arena. Nevertheless, the agrarian-political context of Dutch colonial irrigation set from the Cultivation System onwards did not really change. Commercial and food crops needed to be irrigated with the same irrigation infrastructure; sugar cane and rice had to share the same irrigation facilities. Agricultural

engineers were not really visible in irrigation design, even though a single element like the standard tertiary unit size was lowered to 150 bouw for agricultural reasons. Later this standard unit size was enlarged again for economic reasons, and we have seen that in many designs the 200 bouw unit was applied anyway.

Understanding regime shifts

Between 1830, with no irrigation regime whatsoever, and 1940, with a well established irrigation regime, a clear transformation has occurred. I now turn to the question whether this transformation process did include subsequent regime changes before the final 1940 regime or not. How gradual was the transformation? It has been argued that

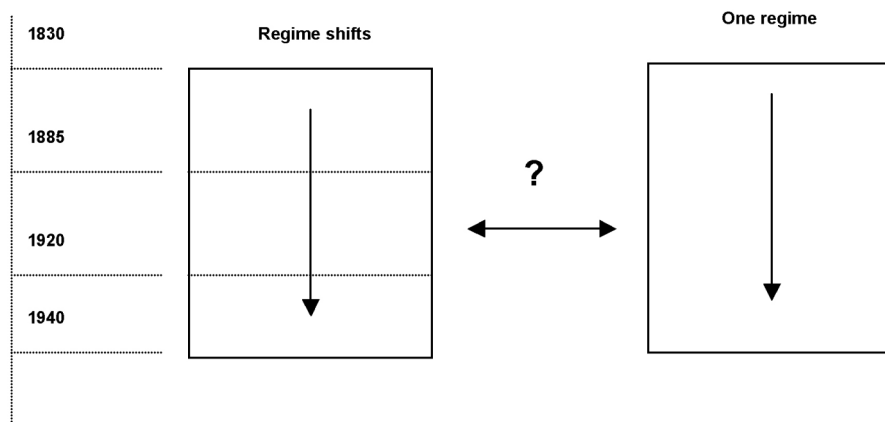
‘[...] in the irrigation development in colonial Java various technological regimes can be distinguished.’²

According to this view, when colonial irrigation activities recommenced with full swing after World War I,

‘[...] a new generation of irrigation projects that differed in main outline from what had gone before [...]’³

started. These new systems would be different regarding irrigation management, agricultural aspects of projects, reservoir construction technology, the step-wise approach to the creation of irrigation works and the development of laboratory facilities⁴. I disagree with this view and argue that differences, if any, between the generations of irrigation projects before and after World War I are not significant and can be explained much better within a framework of regime continuity than in terms of regime change. Approaches and methods developed between 1885 and 1914, mainly in the context of the first General Irrigation Plan, were a stable foundation on which a new generation of irrigation projects could be developed in the 1920s and 1930s. Guiding principles and the design requirements were formulated in the early period, whereas the design tools and artifacts showed a more continuous development over time, with relatively many new tools and artifacts being developed in the second period. When working on the second generation systems, civil engineers could discuss and select design tools and artifacts to further shape the Dutch irrigation regime. ‘Closure’ of the principles and requirements occurred much earlier than ‘closure’ of tools and artifacts. Thus, I argue that the new generation of irrigation projects on Java of the 1920s did not differ fundamentally from the generation before; the new systems were designed with the same reasoning and procedures as their ancestors. Changes in elements, particularly artifacts and design formula applied, did not change the design reasoning and procedures already established around 1900. Actually, the second generation projects realized the basic principles of colonial water management through application of new hydraulic insights and artifacts. In other words, the irrigation regime development process in the Netherlands East Indies did not include a regime shift. I am on the right in Figure 9.2.

Figure 9.2
Two regime
development
positions for
the Netherlands
East Indies



What would change mean? I think it is reasonable to accept a shift from one technological regime to another only in case a major part of the guiding principles and promises/expectations, together with part of the design requirements, would change. A technological regime is transformed if one or more of its core or constitutive rules changes⁵. The guiding principles for Dutch colonial irrigation, the core rules vital for the continued existence of a technological regime, were defined in the early phase, before many of the more peripheral rules of tools and artifacts were defined in the second phase; the core rules have not profoundly changed over time. The peripheral rules are important enough; after all they do give shape to the regime in design practice, as we have seen for the post World War II period. However, they are not constitutive for a technological regime as such⁶. Figure 9.3 shows the Dutch irrigation regime around 1900; I have ‘frozen’ the development process as it were. Comparing Figures 9.1 and 9.3 shows that between 1900 and 1940 no major changes have occurred on the higher levels of the regime rules, with one exception. A new constitutive element was added in the focus of the late colonial state on empty areas. This change in focus from the early, smaller systems of East and Central Java to the larger settlement schemes may have changed the working context for regime elaboration, but it did not influence existing guiding principles.

Understanding regime continuity: phases

Not being able to distinguish different regimes over time does not imply whatsoever that one could not distinguish phases in the regime development process in the Netherlands East Indies. Although I would argue that it is not possible to define these phases as representing shifts or changes in direction of the regime, I do think that it is possible to recognize a certain pattern in the regime development process. Earlier I already argued that the ‘higher level rules’ were developed earlier than ‘lower level rules’; in this paragraph I will specify this general idea. Before presenting the phases I distinguish, we may take a look at the periods proposed by others. Four phases are quite often distinguished⁷:

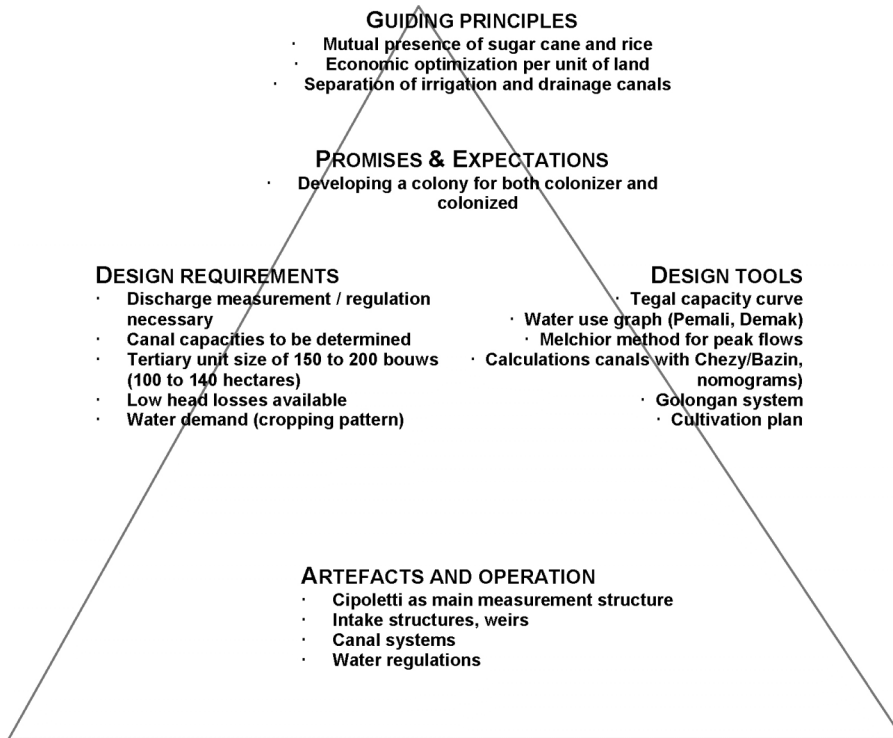


Figure 9.3 The (imaginary) Dutch irrigation regime triangle around 1900

1. Before 1872: indigenous irrigation, with engineering interference from 1832
2. Between 1872-1888: technical measurements and construction of systems
3. Between 1888-1912: technical water management
4. From 1912: onwards agricultural water management

Another distinction, focusing on the engineering aspects, applies three phases⁸:

1. Before 1900: a pioneering phase
2. Between 1900-1925: increasing construction activities
3. Between 1925-1950: liberation of fixed shapes and perfectionism

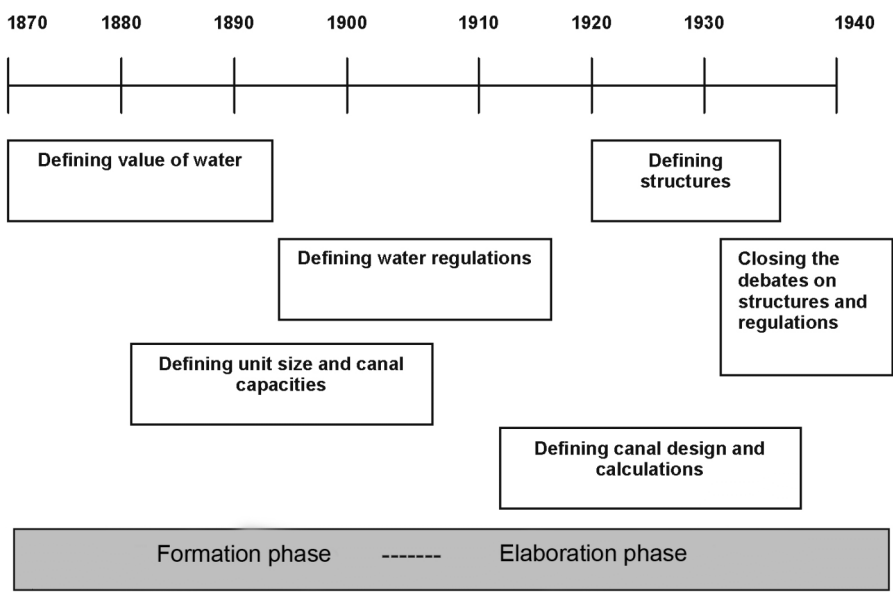
A distinction in regimes, related to the formation process of the colonial state, would be⁹:

1. Between 1832-1885: semi-technical regime, traditional colonial state
2. Between 1885-1920: technical regime, transformations in the colonial state
3. Between 1920-1942: technical-agricultural regime, modern colonial state

It is clear that defining phases is a function of the present: those looking further back define longer pioneering phases and apply more general distinctions between phases¹⁰. Not escaping this law of the distant observer, I propose a distinction in two phases in the development process of the Netherlands East Indian irrigation regime. In Figures 9.4 and 9.5, these two periods are shown graphically on a time scale between 1870¹¹ and 1940.

Figure 9.4 shows main topics for debate and rule development in irrigation design, whereas Figure 9.5 clearly shows two phases in expenses on irrigation development in the same period. The phase between 1870 and 1910 can be best understood as the formative phase of the regime: the phase in which the guiding principles, promises/expectations and the majority of the design criteria took their shape. The focus in this phase was on developing prescriptions for irrigation design. The phase between 1910 and 1940 can best be understood as the elaboration phase of the regime: the phase in which the tools and artifacts to translate the general rules into physical infrastructure were defined. The focus in this phase was on perfecting the tools and artifacts applied in irrigation design.

Figure 9.4
Regime phases
in the
Netherlands East
Indies



It is probably not necessary to remark that it is rather difficult to pin these two phases on exact years. The different distinctions in phases suggest that there are more than enough years which qualify as borders between phases anyway: 1832, 1872, 1885, 1888, 1900, 1912, 1920, and 1925. If we should vote for one year representing the phase change in my two-phase model, several candidates can be found. A major candidate is the year 1900, when the Solo Commission published its report; the report probably symbolized the end of the (short) political freedom of the civil engineer, but probably confirmed the technical approach developed by the engineers so far. Another possible turning point would be the year 1908, when the Demak Commission published its report, which symbolized the dominant position of the Pemali system. Although it took to 1920 before all elements were finalized, 1910 represents the practical realization of the first General Irrigation Plan for Java, at least in financial terms. The whole period between 1900 and 1910 can be viewed as turning period. Whatever the exact years, it is clear that in the early period the higher level rules and the most important design criteria were defined, whereas the later phase focused on the tools and artifacts. For

practical reasons, and also because this event did influence the relations between colonizers and colonized significantly, I would propose using 1914-1918, World War I, as the phase change.

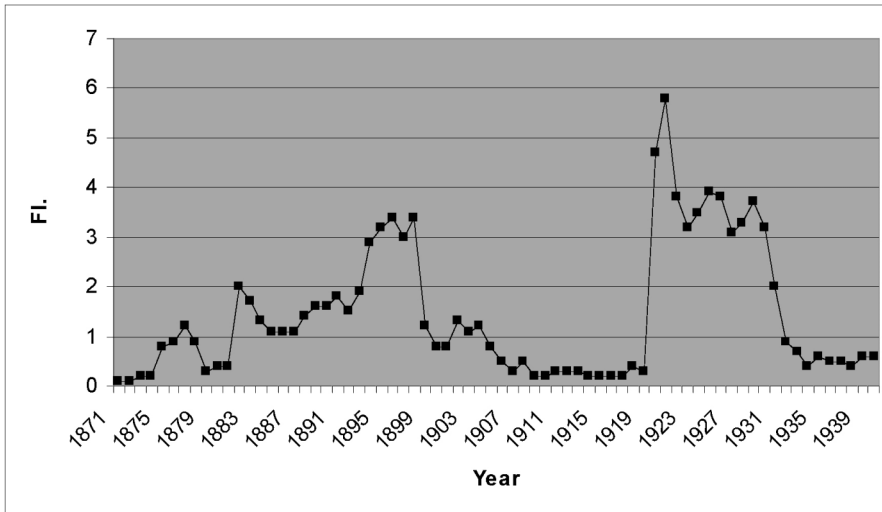


Figure 9.5
Irrigation
expenditures in
the Netherlands
East Indies

(in millions of guilders, corrected for inflation (data from Ravesteijn 1997; Annex H; 360))

A colonial mission: the type of regime

The irrigation regime development process described and discussed in this book, or the innovation pattern of the Netherlands East Indian irrigation regime, can be understood as a mission-oriented innovation pattern, defined as a pattern in which

‘innovations derive from a mission formulated by a powerful actor acting as principal for the artefacts designed. Such missions define a framework within which innovations are accomplished.’¹²

In such a mission-oriented innovation pattern, main carriers of innovation/transformation are governmental agencies; typical areas in which such a pattern is to be expected are defense, energy, communications and transport. In the Netherlands East Indies, our powerful actor acting as principal is found in the colonial state; several times in this book we have seen that the colonial state itself needs to be understood as a result of a process of social construction, at least when it comes to its irrigation related policies. Several social groups, including civil engineers, civil servants and agricultural engineers as insiders of the state and sugar cane industries as important outsiders, debated on desirable irrigation developments. Civil engineers became a dominant group quite early, around 1890, in this discourse. Earlier, civil servants were the dominant group. They were involved in some important regime elements, for example in establishing water regulations, but their importance decreased steadily over time.

Agricultural engineers entered the discourse to some extent after 1900, when the guiding principles were already defined by the other two groups. The agricultural experts were active enough in Javanese agriculture; influence of agricultural engineers on regime elements focusing on irrigation design, however, is hard to find.

For aspects of irrigation development like defining layout of systems and applying design calculations, one would indeed expect civil engineers as the social group to determine regime development; concerning the 'non-technical' regime aspects, however, their influence has been pretty strong too. The final General Water Regulation for Java of 1936, basically the Pemali regulation, is a case in point. Of course the Pemali regulation and the many others discussed were not exclusively civil engineering products. Furthermore, within the engineering community itself the opinions on the best water regulation were divided. Civil servants were usually involved in formulating regulations. Nevertheless, it was the responsibility of irrigation engineers to shape water distribution practices in the irrigation systems with these regulations. The key position of engineers within colonial regime development is partly explained by the mission innovation pattern; if in such patterns the relation between the main actor and the innovators is close, also today.

Such a situation, for example, existed at least until recently in the Dutch infrastructure section. In this sector, governmental agencies – pre-eminently the **Rijkswaterstaat** – act as client/principal, designer, researcher and regulator [...]. R&D and design activities, to an important extent, take place within the same organization that formulates missions for technical projects.¹³

Another factor explaining the relative important role of the engineers is found in the phasing of the regime development process. The core regime rules were developed in a period when the engineers were one of the most influential social groups within the colonial state; this period between 1870 and 1900 could very well be the most successful period for colonial engineers in terms of power, influence and independence. The most important founding element, the mutual presence of sugar cane and rice in the same irrigated area, was a direct consequence of the colonial economic optimization approach based on productivity per unit of land. Such an approach should ensure that the benefits of irrigation development would be benefits for the colony as a whole and not just a small group within colonial society. Based on the guiding principles they helped setting, the engineers continuously looked for and proposed applications to regulate and measure discharge within the entire irrigation system; another issue was how to take into account all different water uses in the whole area when canal capacities had to be determined. Closely connected to capacity discussions were the desired management arrangements, like the golongan system, the position of the 'oeloe oeloe', and cultivation plans.

Regime components: decisions and guidelines

After a pause between 1910 and 1920, with World War I as a clear demarcation, the last two decades of colonial rule were the scene of renewed irrigation activities. The Tjipoenegara case dates from this period. In the design process, most design related decisions were the responsibility of civil engineers; either Public Works or the Head of the Krawang works formally confirmed, regularly adapted and proposed decisions made by the engineers of the Maatschap. In the Tjipoenegara design process the internal decision making process of the Department of Public Works and its representatives checked the design process; proposals made by the designers had to meet the standards, unless there were good reasons to do otherwise¹⁴. Internal documents, often formulated as design guidelines, produced within the engineering community played a very important role in building a framework and maintaining continuity. The guidelines were the intermediates which stored the information available to the design engineering network; the continuous relevance of colonial design rules in Indonesian irrigation practice and Delft irrigation education shows the essential role of storage in networks representing technological regimes, as it permits time-space distantiation: older design guidelines structure later designers. Guidelines could change fast; a letter in December 1896 still recommended application of the Pategoean capacity curve, but this recommendation was withdrawn in a letter in January 1897.

Before guidelines could be changed or even produced, however, the design steps and tools needed to be well known, tested and accepted; in the East Indies the proof of the pudding was in the eating. Applications that had shown to work in a real-life irrigation system were potential candidates for a guideline from the Department of Public Works. The irrigation engineering community was a thriving community in the sense that all types of discussions were stimulated; many subjects were included in journals, books and presentations. At the same time the engineers preferred design tools and methods which were secure, which had shown their value even if they were not perfect. Irrigation practice was the determining factor in the selection of discharge measurement structures: De Gruyter, for example, could not show results from irrigation practice on Java with his modified Crump flume, he proposed the structure based on theoretical considerations. Theoretical proof, however, was not enough foundation to select design tools or artifacts in the practice oriented network of civil irrigation engineers. Begemann proposed the Venturi structure based on own experiences in a Javanese irrigation system; it became a success. The Romijn weir was originally proposed as an improvement for a practical problem of the Venturi structure; when the broad-crested weir proposed by Verwoerd was judged by the regime requirements – adjustability, measurement, low head loss – it immediately became the new solution for these requirements. Another demand from practice was the simplification of calculations, for example through developing canal design graphs. Results of calculations had to be trustworthy and based on theories and experiments that were as sound as possible, but new theories and results which required considerable extra work, even if they promised

to be better, did not easily replace existing calculation methods. The niche of the irrigation engineers was the practice of their irrigation systems; new approaches proven in or based on practice were selected.¹⁵

From regime to frame: continuity after 1942

Unlike World War I, which only set a temporarily halt to expenditures and did not change the irrigation regime, World War II forms a demarcation for the Netherlands East Indian irrigation regime. After World War II, the new political realities caused a major shift in context for Dutch irrigation activities; Indonesia disappeared as secure field of practice. This disruption of colonial realities after 1945 was not unique for Indonesia and the Netherlands; within 20 years most colonies gained their independence and were redefined as 'developing countries'.¹⁶ In this new reality Dutch irrigation engineers started to work in countries worldwide; the first generation did so with their experience in the Indies embodied in their persons, the second generation did so based on their education and training in Delft. Dutch engineers started working in other tropical regions, engineers from different countries started to work in independent Indonesia. Although the new working realities for Dutch irrigation engineers were recognized and explicitly taken into account to defend continuation of the Delft irrigation program, the study material suggests that irrigation engineering in Delft maintained being approached as application of design prescriptions developed in the Netherlands East Indies. Most graduation designs include the same East Indian regime elements, with most of them applied without further discussion. The fact that until the 1980s, all irrigation professors in Delft gained their working experience in the Netherlands East Indies is probably part of the explanation.

The Delft design approach can be regarded as the extreme version of the colonial irrigation regime. At the end of Dutch colonial rule, the design approach of the irrigation engineers had already come loose from its original guiding principles. These original principles were not ignored, but were well integrated, or even hidden, in the irrigation design approach defined in rules on the lower of the regime triangle. Delft went a step further: until the 1980s the Delft irrigation approach reads like a collection of design tools and artifacts stripped from their original political, economical, and even natural context (Figure 9.6). Only in 1980s Delft irrigation education allowed several new, post-War experiences from outside the East Indian regime into the courses. For Indonesia, the Irrigation Design Standards from 1986 symbolize the end of a period in which Indonesian irrigation practice served as one of the arenas in which different irrigation frames were competing. With the Standards, the Netherlands East Indian design rules, similar to those taught in Delft, were re-established, with some changes. The Tegal capacity curve, for example, is not prescribed anymore.

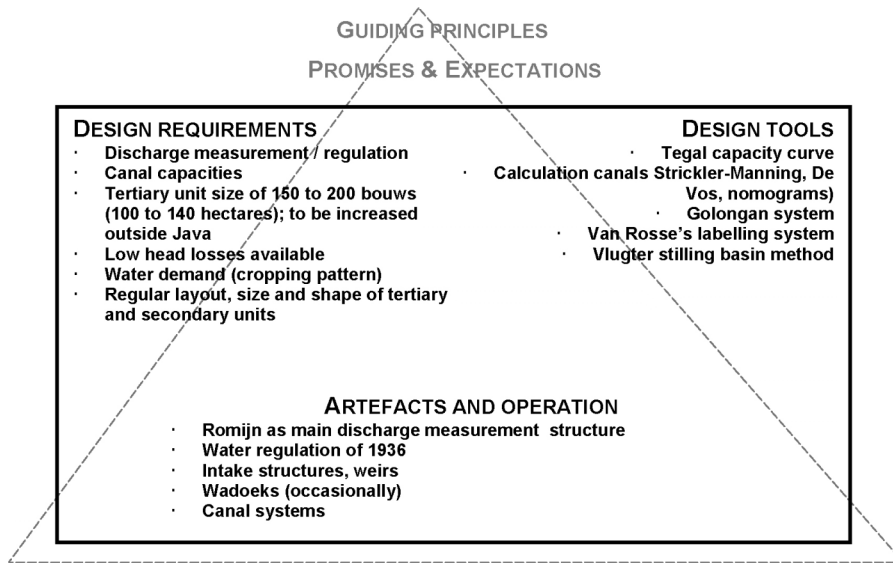


Figure 9.6
Regime elements
of Delft
engineering
education

Final remarks: understanding regimes and design

In 1906, Grinwis Plaat was appointed as the first irrigation lecturer in Delft. This book, published more than a century after this appointment, is an attempt to explain how the irrigation approach that Grinwis Plaat and his successors taught, was shaped, continued and changed. In this analysis, I applied a rather restricted concept of technological regime, focusing on the activities and discussions within the network of civil engineers. Although I did include other social groups, my main body of material was produced within the civil engineering community of practice. I did look for material to include other potential elements and discussions on irrigation development, in particular agricultural issues like crop water requirements, but when I found that such discussions did not really influence the regime design rules of irrigation systems I decided to leave these issues out of this book. Thus I stayed close to the civil engineering profession, writing a history with an emphasis on tools, artifacts and design practice.

Within these limitations, I believe I managed to show how the irrigation regime developed over time, with different types of rules showing different timings of closure and stabilization. The Dutch irrigation regime did develop over a period of 110 years; the general rules, guiding principles and promises/expectations, were translated into design requirements in the second half of the 19th century, whereas a standardized realization of these requirements emerged in the first half of the 20th century. Restricting my regime conceptualization to the repetitive actions of irrigation engineers has allowed me to emphasize the importance of daily practice and routines as structuring factors in technological development. Political discussions on technological development remain important, as they were in the Netherlands East Indies, but one should question to what extent the results of these debates directly influence design

processes. This book has made clear that there is indeed a relation between politics and design; next to artifacts and systems useful for the fulfillment of needs, engineers (designers) bring along a new societal reality. Engineers change society with their designs, sometimes without deliberate purpose, often on purpose.

The Dutch irrigation engineers in the Netherlands East Indies knew that they were changing society. They wanted to change society, improve the colony and improve the lives of the Javanese. Engineers were busy creating locales of happiness, or so they thought¹⁷. Nevertheless, the influence of the political context, perhaps better formulated as 'broader social circles than engineering alone' on daily practices of engineers may be limited. I do not argue that engineers are isolated from the outside world; again, engineers are performing many roles in society and do engage in many political debates. Daily engineering practice, however, may be much more influenced than we recognize¹⁸ by what their engineering predecessors defined as 'good practice' and not by societal debates. Recognizing this would include recognizing the need to further clarify relations between communities of engineering practice on the one hand and relations between societal discourse and technological design on the other.

'Even if political and social factors play key roles, they are indeed intertwined with technological determinations. Despite what its name suggests, the so-called "Social Construction of Technology" has shown that, while technology is socially constructed, technological organizations and objects often shape society and sociability. What may appear as purely political and social factors is often linked to technological determinations.'¹⁹

Finally, I hope that my book contributes to acknowledgement within the engineering profession that a concept like technological regime helps to understand engineering design practice. As other networks of interaction, engineering communities show a certain degree of relative stability enabling as well as constraining engineers in their actions. Recognizing such stability may not immediately lead to improvements in irrigation system design, but I would say that understanding processes which bring about designs, including societal influences on decisions, is a first step to take anyway if anyone ever would like to improve them.

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Notes

Chapter 1

- ¹ For example Ravesteijn (1997; 2002); Schrevel (1993, 1997); Booth (1977, 1985, 1988); Van Schaik (1986)
- ² Van Halsema (2002), Mollinga (1998) and Bolding et al (1995)
- ³ Horst (1996) Dahmen (1997); see for example Glick (1972) for Spanish influence on the USA.
- ⁴ Constant II (1980; 10). See also Downey and Lucena (2004), Picon (1996, 2000, 2004).
- ⁵ Dahmen (1997; 100)
- ⁶ Like in Plusquellec H., Burt C. and Wolter W. (1994)
- ⁷ A debate which has been pointed out by Reynolds (2001)
- ⁸ Compare with Franssen (2002)
- ⁹ Van de Poel (2003; 49).
- ¹⁰ Picon (2004; 424).
- ¹¹ Two terms are applied: 'technological tradition' (Constant II 1980) or 'technological regime' (Van der Poel 1998; Van de Poel 2003). A practical reason to study rule-sets with the concept of irrigation traditions instead of regimes would be that irrigation engineers could associate the term 'regime' with the regime-theory of Kennedy (a British engineer), formulated in the early 1900s on stability of earthen canals. Although it is a side step, it is not uninteresting to note that this theory is 'imported' from British India in the Netherlands East Indies. Nevertheless, I have chosen to apply the regime concept as it is much wider used in discussions on technology development than the tradition concept.
- ¹² Inspired by Giddens' propositions (Giddens 1979, 1984) and guided by Van de Poel (1998; 2002)
- ¹³ Van de Poel (1998; 16)
- ¹⁴ From Van de Poel (1998; 17)
- ¹⁵ From Van de Poel (1998; 17)
- ¹⁶ Franssen (2002; 468)
- ¹⁷ See Sewell (2005) for a very nice elaboration of Giddens' theories. As I only apply some restricted ideas of Giddens, basically the idea of rules having a social history and future, I do not include a detailed discussion of Sewell's improvements of Giddens.
- ¹⁸ Giddens (1979; 64).
- ¹⁹ Giddens (1979; 64).
- ²⁰ Giddens (1984; 2).
- ²¹ Giddens (1984; 17). See Franssen (2002) for a critique on Giddens, especially his 'rule' concept. See Sewell.
- ²² Van de Poel (1998)
- ²³ Many researchers have studied technological regimes to account for technological change or transitions. In such work changes in technological development, or shifts from a particular technology to another one, are explained with reference to the structuring environment a regime would offer. Obviously, there is no 'change' without 'persistence'; change would be measured against a background of non-change or persistence. A key term in my view is

'gradually'; studying technological change looking for shifts in terms of a few years is not very fruitful; one has to look on longer time scale in the order of 70 to 100 years. Change and persistence not only become difficult concepts on short time scales, but may not even be applicable anymore. Studying longer periods is like studying social change. See Sewell (2005) for an excellent discussion on the issue of event and structure, or short and long time scales. See Van de Poel (1998); Van de Poel (2002); Geels (2002)

Chapter 2

¹ Van Halsema (2002; 35)

² Mollinga (1998), Stone (1984)

³ Jurriens et al (1996)

⁴ Mollinga (1998)

⁵ Mollinga (1998)

⁶ Stone (1984; 35)

⁷ Van Halsema (2002; 39)

⁸ Van Halsema (2002; 40)

⁹ French and Dutch colonial authorities engaged local rulers too, but a little different. 'Whereas the British system of indirect rule maintained traditional forms of authority as much as possible, the French chiefs were in practice not more than instruments of the colonial dominator.' (Wesseling 2003; 64)

¹⁰ Bolding et al (1995; 810)

¹¹ Van Halsema (2002; 36)

¹² Headrick (1988)

¹³ Jurriens et al (1996)

¹⁴ Jurriens et al (1996), Mollinga (1998)

¹⁵ Headrick (1988)

¹⁶ Quoted in Stone (1984; p34)

¹⁷ Headrick (1988)

¹⁸ Headrick (1988), Stone (1984)

¹⁹ Headrick (1988), Stone (1984)

²⁰ Headrick (1988)

²¹ Stone (1984)

²² Bolding et al (1995). This change in policy is reflected in other colonies too. 'In the late nineteenth century, exploitation of the colonial world was taken up more systematically and on a larger scale through the development of mining and plantations. In this period new ideas on colonization emerged as well. In France these are known as the policy of 'mise en valeur', a enlightened version of colonialism, not directed at simple sweating, but at longer term exploitation by applying new rational and scientific methods and governmental investments. In the Netherlands one refers in this context to the 'ethical policy', which stressed the responsibility of the colonizer for the colonized and governmental tasks in the areas of economic infrastructure, health care, education and such-like.' (Wesseling 2003; 49)

²³ Jurriens et al (1996)

²⁴ Bolding et al (1995)

²⁵ Van Halsema (2002)

²⁶ Bolding et al (1995; 810)

²⁷ Stone (1984)

²⁸ Headrick (1988)

²⁹ Stone (1984)

- ³⁰ Stone (1984)
- ³¹ Bolding et al (1995)
- ³² Bolding et al (1995; 811)
- ³³ Jurriens et al (1996)
- ³⁴ Jurriens et al (1996), Stone (1984)
- ³⁵ Jurriens et al (1996; 6)
- ³⁶ Van Halsema (2002), Stone (1984)
- ³⁷ Stone (1984)
- ³⁸ Bolding et al (1995), Jurriens et al (1996)
- ³⁹ Jurriens et al (1996)
- ⁴⁰ Jurriens et al (1996)
- ⁴¹ Jurriens et al (1996)
- ⁴² Mollinga (1998)
- ⁴³ Mollinga (1998)
- ⁴⁴ Jurriens et al (1996)
- ⁴⁵ Jurriens et al (1996)
- ⁴⁶ Jurriens et al (1996)
- ⁴⁷ Stone (1984)
- ⁴⁸ Jurriens et al (1996)
- ⁴⁹ Van Halsema (2002; 38)
- ⁵⁰ A 'guestimate' by Jurriens et al (1996).
- ⁵¹ Jurriens et al (1996); Van Halsema (2002)
- ⁵² Mollinga (1998)
- ⁵³ Jurriens et al (1996)
- ⁵⁴ This paragraph is based on Ertsen and Ravesteijn (2008).
- ⁵⁵ Ertsen (2002), Ertsen (1998)
- ⁵⁶ Weijs (1913; 8)
- ⁵⁷ Ravesteijn (1997)
- ⁵⁸ Melchior (1895/1896)
- ⁵⁹ Lamminga (1910; 5)
- ⁶⁰ See Moon (2007); Fasseur (1993); De Jong (1998); Jonkers (1948)
- ⁶¹ NA 2.22.07 Invr 64 (Telders et al 1900; Annex E) Telders J.M., W.F. Leemans, J. Kraus en J.E. de Meyier 1900 Verslag van de commissie van advies nopens de werken in de Solovallei. Waltman, Delft
- ⁶² Wesseling (2003); Tvedt (2004)
- ⁶³ Barnett (1977); Wesseling (2003)
- ⁶⁴ Gaitskell (1959); Holt & Daly 2000)
- ⁶⁵ Quoted in 'The Gezira Scheme from within', (1959, p. 3)
- ⁶⁶ Gaitskell (1959, p. 26)
- ⁶⁷ Barnett (1977, p. 1)
- ⁶⁸ Barnett (1977)
- ⁶⁹ Gaitskell (1959, pp. 48 – 49)
- ⁷⁰ Barnett (1977); Gaitskell (1959)
- ⁷¹ Watt (1954, p. 6)
- ⁷² Gaitskell (1959)
- ⁷³ Holt & Daly (2000)
- ⁷⁴ Gaitskell (1959, p. 123)
- ⁷⁵ Gaitskell (1959, p. 99)
- ⁷⁶ Gaitskell (1959, pp. 84 – 85)

- 77 Gaitskell (1959)
- 78 Van Beusekom (1989)
- 79 Van Beusekom (1989, p. 24)
- 80 Van Beusekom (1989)
- 81 Spitz (1949)
- 82 De Wilde (1967); Van Beusekom (1989)
- 83 Van Beusekom (1989)
- 84 Schreyger (1984, pp. 28 – 29)
- 85 Spitz (1949)
- 86 Schreyger (1984)
- 87 Schreyger (1984, p. 37)
- 88 Spitz (1949); Van Beusekom (1989)
- 89 Schreyger (1984); Spitz (1949)
- 90 Spitz (1949, p. 53)
- 91 Van Beusekom (1989)
- 92 Schreyger (1984); Spitz (1949); Van Beusekom (1989)
- 93 De Wilde (1967, p. 252)
- 94 Van Beusekom (1989, p. 12)
- 95 De Wilde (1967)
- 96 Schreyger (1984)
- 97 De Wilde (1967)
- 98 Schreyger (1984)
- 99 Van Beusekom (1989)
- 100 De Wilde (1967)
- 101 Swearingen (1984)
- 102 Swearingen (1984)
- 103 Wesseling (2003, p. 419)
- 104 Swearingen (1984, pp. 53 – 54)
- 105 Swearingen (1984)
- 106 Marić (1984); Swearingen (1984)
- 107 Swearingen (1984)
- 108 Quoted in Swearingen (1984, p. 87)
- 109 Duval (1933), quoted in Swearingen (1984, p. 110)
- 110 Swearingen (1984)
- 111 Swearingen (1984)
- 112 Swearingen (1984)
- 113 Préfol (1986, p. 78)
- 114 Swearingen (1984, p. 167)
- 115 Poncet (1961); Préfol (1986); Swearingen (1984)
- 116 Préfol (1986)
- 117 Préfol (1986, p. 175)
- 118 Préfol (1986, p. 175)
- 119 Stone (1984, p. 8)
- 120 Quoted in Wesseling (2003, p. 17)
- 121 Wesseling (2003, p. 77)

Chapter 3

- ¹ Sengupta (1987)

- ² Van Doorn (1994)
- ³ Van Doorn (1994)
- ⁴ Chailley-Bert (1900; in Van Doorn (1994; 41))
- ⁵ Metz (1932; 64)
- ⁶ Bijker (1995; 6)
- ⁷ Bijker (1995; 85)
- ⁸ See Bosma et al (2007)
- ⁹ The cropping cycle of sugar cane was three years: first year planting, second and third year maturing and several times harvesting.
- ¹⁰ Haringhuizen and Nijman (1914)
- ¹¹ Although the termination of the arrangements of the Cultivation System differed per crop type and could last up to 1915.
- ¹² Onderzoek OMWI (1910; 87)
- ¹³ Onderzoek OMWI (1910; 87)
- ¹⁴ NA 2.22.07 Invnr 137 (Algemeen 1936; 1) Algemeen 1936 Het Algemeen Waterreglement. Tekst met officiële toelichting door mr. H.D. van Werkum, 4^e druk, G. Kolff & Co., Cheribon
- ¹⁵ Rapport (1879)
- ¹⁶ De Bruyn (1863)
- ¹⁷ Rapport (1879; 2; emphasis in original)
- ¹⁸ Stigter (1914) remarks that it was too easily expected that Java should be one singular entity. He refers to the number of inhabitants and land surface of Java and to the Netherlands, where almost every water board or polder had its own regulations and laws.
- ¹⁹ Rapport (1879; 23; emphasis in original)
- ²⁰ See Chapter 4; see Bolding et al (1995)
- ²¹ Rapport (1879; 59)
- ²² Rapport (1879; 30)
- ²³ Rapport (1879; 30)
- ²⁴ Weijs (1898)
- ²⁵ Volkswelvaart (1914; 32)
- ²⁶ Stigter (1914)
- ²⁷ NA 2.22.07 Invnr 137 (quoted in Algemeen 1936; 2)
- ²⁸ NA 2.22.07 Invnr 137 (Algemeen 1936; 2)
- ²⁹ Onderzoek OMWI (1910)
- ³⁰ Weijs (1898; 170). Homan van der Heide (1900) discussed in detail the interest of sugar estates in water distribution by irrigation engineers.
- ³¹ Onderzoek OMWL (1908; 178)
- ³² Onderzoek OMWI (1910; 93). In discussions on these experiments, other irrigation systems are regularly discussed too (like the Kening and Madioen systems). Available detailed information, however, on these other systems is at best fragmented.
- ³³ Weijs (1898)
- ³⁴ Lamminga (1895, 1905)
- ³⁵ Onderzoek OMWI (1910)
- ³⁶ NA 2.22.07 Invnr 58 includes a design report (Weijs 1900) Weijs C.W. 1900 Aanleg en exploitatie der Pategoewanwerken. Een blik op de werkzaamheid van de ingenieur op irrigatiegebied in Nederlandsch-Indië. Overgedrukt uit de Notulen der vergadering van het Koninklijk Instituut van Ingenieurs van 14/11/1899 pp 41-57, Gebr. J&H van Langenhuijsen, Den Haag

- ³⁷ NA 2.22.07 Invnr 137 (Ter Meulen 1918) Ter Meulen J.H.F. 1918 De geschiedenis van eene Regeling tot Exploitatie van Irrigatiewerken op Java. Overgedrukt uit “De Indische Mercur” van 13 September 1918
- ³⁸ The district is since $\pm$ 1900 part of Pasoeroean.
- ³⁹ NA 2.22.07 Invnr 96 (BOW 1894; 207) Verslagen over de Burgerlijke Openbare Werken in Nederlandsch-Indië. 1892 – 1928; compare with Lamminga (1905) on page 59)
- ⁴⁰ Bernard (1903)
- ⁴¹ NA 2.22.07 Invnr 96 BOW (1894; 207)
- ⁴² The Javanese word *golon* means ‘switch’ or ‘exchange’ (*wisselen*) (Lamminga 1910; 19)
- ⁴³ As we shall discuss below, in the Pemali area 5 *golongans* were defined, in other areas 3 or 4 *golongans* could be found too. The figure depended on water availability in ratio to command area (Lamminga 1905).
- ⁴⁴ Lamminga (1905; 765)
- ⁴⁵ Lamminga (1905; 766)
- ⁴⁶
- ⁴⁷ NA 2.22.07 Invnr 137 (Ter Meulen 1918)
- ⁴⁸ Weijs (1898; 185)
- ⁴⁹ NA 2.22.07 Invnr 96 (BOW 1895)
- ⁵⁰ Weijs (1898; 186)
- ⁵¹ NA 2.22.07 Invnr 67 has a handwritten concept regulation (Concept Reglement; art. 9), probably written by Weijs and/or Ter Meulen. Weijs refers to the regulation in a letter dated January 13th 1909 (OMWI 1910; 113-115). Concept Reglement op de water-verdeeling in het gebied der Pategoewan-werken
- ⁵² Onderzoek OMWI (1910; 99). The Welvaartsverslag Irrigatie mentions that experiments would be expanded to the Bekatjak-area, but timing and results of this is not clear.
- ⁵³ Onderzoek OMWI (1910; 100); Weijs (1898)
- ⁵⁴ Onderzoek OMWI (1910; 100)
- ⁵⁵ Onderzoek OMWI (1910; 100)
- ⁵⁶ NA 2.22.07 Invnr 40 (Polderman 1936) Polderman L.J. 1936 5 jaren crisisarbeid in de Pemali-Tjomal. Notitie Jan. 1936, omgewerkt augustus 1936
- ⁵⁷ Lamminga (1905; 746-747)
- ⁵⁸ Who was a strong supporter of the Balinese *subak* and involvement of both Javanese and the Civil Service in water distribution in general (Onderzoek OMWI 1910; Lamminga 1905).
- ⁵⁹ Lamminga (1905; 765)
- ⁶⁰ Lamminga (1905; 765)
- ⁶¹ Letter of January 13th 1909, in OMWI (1910; 114)
- ⁶² Letter of January 13th 1909, in OMWI (1910; 114)
- ⁶³ NA 2.22.07 Invnr 137 (Ter Meulen 1918). The contradiction between Pekalen and Pategoean regulations was not as big as suggested in discussions; the Pekalen approach left room for Javanese influence, for example when cultivation plans were made; the Pategoean approach maintained strong control for engineers and did not give all the checks to Javanese or water boards at all. The Irrigation Welfare Report (Onderzoek OMWI 1910) includes four letters from the period 1908-1909, in which four persons involved give their opinion on how and why the Pategoean method was not implemented on larger scale. These persons are the chief engineer of Brantas Irrigation Division, Karsten; the resident of Pasoeroean in 1908; engineer Steup and Weijs. The main topics debated between the four are the status of the method, the struggles within the colonial state, the balance of power within the *desa* and technical arguments. These four letters serve as a mini-case of social construction, in this case of judging results and relevance of the water regulation experiment. The discussions show that both in

formulating and debating the different distribution methods, opinions of opponents and defenders of the two different approaches cannot be understood by just looking at their professional position and departmental context

⁶⁴ Although colonial control had its limits, as Roessel (1927; 511) points to irrigated areas with thousands of bouws largely outside the control of authorities. This illegal extension was a slow process and difficult to monitor due to frequent changes in personnel [].

⁶⁵ Van Doorn (1994)

⁶⁶ The main system was still controlled by the irrigation service: negotiations between water courses or with sugar estates could not take place. Sugar estates received water separately.

⁶⁷ NA 2.22.07 Invnr 56 (Weijs 1893) Weijs C.W. 1893 Nota over organiseren van waterschappen op Java (afschrift)

⁶⁸ Compare with modern attempts to create water boards in irrigation systems.

⁶⁹ NA 2.22.07 Invnr 56 (Weijs 1893)

⁷⁰ NA 2.22.07 invnr 137 (Doel 1918) Doel en regeling van waterschappen in Ned. Oost-Indië. Indisch Genootschap. Vergadering van 12 maart 1918, 91-121, Martinus Nijhoff, Den Haag

⁷¹ NA 2.22.07 invnr 137 (Doel 1918; 1090). Despite this particular attention to Public Works, there is no reason to assume that other professional categories did consider water boards attractive.

⁷² NA 2.22.07 Invnr 61 (Cramer 1920; 28) Cramer Ch.G.1920 Het beheer van bevoeiingswerken. Prae-advies. Algemeen Ingenieurscongres Batavia 8 – 15 mei 1920, 2^e Sectie Irrigatie en Assainering, NV Drukkerij De Unie, Batavia-Weltevreden

⁷³ This may be attributable to the influence of certain persons at the moment (like Liefcrinck), but I did not study these mechanisms in detail.

⁷⁴ Bernard (1903)

⁷⁵ Not on his own: many years later, engineers congratulated themselves that they did have the opportunity to work for Lamminga. Haringhuizen, professor of irrigation in Delft in the 1920's and 1930's made some canal designs under guidance of Lamminga.

⁷⁶ NA 2.22.07 Invnr 40 (Polderman 1936; 1)

⁷⁷ NA 2.22.07 Invnr 83 (Rapport 1913; 5) Rapport der Commissie tot het instellen van een onderzoek naar de werking van de ordonnantie in Staatsblad 1903 No. 269 betreffende de waterverdeeling in de afdeeling Demak (residentie Semarang), Landsdrukkerij, Batavia (Advice dated at June 1908).

⁷⁸ Numans (1916; 339)

⁷⁹ Numans (1916; 342); Graadt van Roggen (1932; 123) refers to the same person as 'oeloe-oeloe pembagian'

⁸⁰ NA 2.22.07 Invnr 83 (Rapport 1913; 7)

⁸¹ Graadt van Roggen (1932; 123)

⁸² The first one was No. 9724/34 dated 14th October 1907 (Numans 1916; 342), Graadt van Roggen refers to Residential Decision No. 804/7 of January 10th 1924 (adapted by Residential Decision No. 2747/34/SI of August 17th 1927 (Graadt van Roggen 1932; 123).

⁸³ Numans (1916; 42); Graadt van Roggen (1932; 123)

⁸⁴ Numans (1916; 342). Numans adds that the Municipality Act grew out off existing water regulations. Is this another example of the pioneering role irrigation played in state formation (Ravesteijn 1997)?

⁸⁵ NA 2.22.07 Invnr 83 (Rapport 1913; 26)

⁸⁶ Although in practice the six golongans were brought back to four or even three (six paired in three groups) with phase differences of 14 days, as this decreased the total growing season.

⁸⁷ Bernard (1903)

⁸⁸ Haringhuizen and Nijman (1914)

- ⁸⁹ NA 2.22.07 Invnr 83 (Rapport 1913; 29)
- ⁹⁰ The report of the Demak Commission gives a dazzling overview of all the discussions, decisions and changes, including the people involved.
- ⁹¹ NA 2.22.07 Invnr 96 (Weijs 1904; 265). Weijs C.W. 1904 Voorloopige mededeelingen over de getroffen regelingen op de waterverdeeling in het gebied der Demaksche waterwerken. In: Verslag der Burgerlijke Openbare Werken 1910, NA 2.22.07 Invnr 96
- ⁹² NA 2.22.07 Invnr 83 (Rapport 1913; 44)
- ⁹³ NA 2.22.07 Invnr 96 (Weijs 1904; 265)
- ⁹⁴ Document of 23rd of December 1903, No. 20666/E; OMWI (1910; 117)
- ⁹⁵ NA 2.22.07 Invnr 96 (Weijs 1904; 268)
- ⁹⁶ NA 2.22.07 Invnr 83 (Rapport 1913). The document number 10840/E suggests that this was done by the Director of Public Works, as the irrigation unit was labeled with 'E'
- ⁹⁷ NA 2.22.07 Invnr 83 (Rapport 1913)
- ⁹⁸ NA 2.22.07 Invnr 83 (Rapport 1913; 1)
- ⁹⁹ NA 2.22.07 Invnr 83 (Rapport 1913; 33)
- ¹⁰⁰ For the golongan system, Lamminga refers to the Pemali system, not to the source area of Pekalen.
- ¹⁰¹ Lamminga (1910; 20)
- ¹⁰² Lamminga (1910; 20)
- ¹⁰³ Lamminga (1910; 20). I argue that Lamminga means that no particular water management regulation was perceived for new systems. Adjustability of structures for daily changes was a shaping factor, but not the exact regulation.
- ¹⁰⁴ Like Stigter (1914; 12). See also NA 2.22.07 Invnr 61 (Cramer 1920; 14/15)
- ¹⁰⁵ NA 2.22.07 Invnr 74 (Trenité 1923; 8) Trenité G.J.N. 1923 Indisch Waterrecht, overgedrukt uit het Tijdschrift Vragen des Tijds, H.D. Tjeenk Willink, Haarlem
- ¹⁰⁶ Volkswelvaart (1914; 356)
- ¹⁰⁷ Onderzoek OMWI (1910)
- ¹⁰⁸ Onderzoek OMWI (1910; 76-79)
- ¹⁰⁹ Institutional struggles are not a main theme in my thesis; the study of Ravesteijn (1997) deals with it in detail. Based on my limited coverage of the literature on the subject, I would argue that as in the discussions on water regulation, the debate cannot be understood by just taking into account the institutional positions of actors. A considerable number of well-known engineers seem to have supported a stronger role of the Department of Agriculture in irrigation affairs, with as ultimate consequence a change in responsibilities.
- ¹¹⁰ Lamminga (1912; 63)
- ¹¹¹ Lamminga (1912; 62; capitals and emphasis in original)
- ¹¹² NA 2.22.07 Invnr 137 (Algemeen 1936); 4; see also Invnr 61 (Cramer 1920)
- ¹¹³ NA 2.22.07 Invnr 137 (Algemeen 1936); 4; see also Invnr 61 (Cramer 1920)
- ¹¹⁴ I only touch upon main topics. A related discussion was on water boards; in a region on Java, the 'Vorstenlanden', such water boards had been established in 1907 (Meijll 1922).
- ¹¹⁵ Onderzoek OMWB (1914; 38)
- ¹¹⁶ NA 2.22.07 Invnr 67 (Homan van der Heide 1902; 3) Homan van der Heide J. 1902 Aantekeningen omtrent de verstrekking van irrigatiewater in de sectie Mojokerto der irrigatieafdeling Brantas. H. van Ingen, Soerabaia
- ¹¹⁷ Van der Marel et al (1919)
- ¹¹⁸ NA 2.22.07 Invnr 74 (Ontwerp; 5) Ontwerp Algemeen Waterreglement
- ¹¹⁹ Ravesteijn (1997)
- ¹²⁰ Ravesteijn (1997; 274) mentions a decrease of sugar cane with 83%!

- ¹²¹ Graadt van Roggen (1935) indicates for example slight changes in the Pemali-Tjomal golongan arrangements.
- ¹²² NA 2.22.07 Invr 40 (Polderman 1936; 9)
- ¹²³ NA 2.22.07 Invr 137 (Algemeen 1936)
- ¹²⁴ NA 2.22.07 Invr 137 (Algemeen 1936)
- ¹²⁵ NA 2.22.07 Invr 137 (Algemeen 1936)
- ¹²⁶ NA 2.22.07 Invr 137 (Algemeen 1936)
- ¹²⁷ NA 2.22.07 Invr 40 (Polderman 1936; 9)

Chapter 4

- ¹ Crump (1922; Van Halsema (2002)
- ² Romijn was not the person who was the first to suggest the application of the adjustable broad-crested weir in water discharge regulation and measurement on Java; he remains the person, however, who tested the structure and published the first results.
- ³ Bijker (1995)
- ⁴ See Van Oosterhout (2008)
- ⁵ Van der Marel et al (1919; 7)
- ⁶ Van der Marel et al (1919; 11)
- ⁷ Cramer (1921; 35), see Cramer (1919)
- ⁸ Van der Marel (1919; 23). Compare with Lamminga (1905) quoted at page 59: engineers are seen as providing infrastructure, which enables all kinds of management and regulation.
- ⁹ Cramer (1921; 22)
- ¹⁰ Van der Marel (1919; 21)
- ¹¹ Begrooting (1925)
- ¹² Begrooting (1925; 253)
- ¹³ Haringhuizen (1931)
- ¹⁴ Metzelaar (1932)
- ¹⁵ Van Dissel (1919; 123)
- ¹⁶ De Gruyter (1925, 1926, 1927); Bos (1990)
- ¹⁷ De Gruyter (1925; 70)
- ¹⁸ Bolding et al. (1995); Van Maanen (1931)
- ¹⁹ Buckley (1920)
- ²⁰ MacKenzie (1910; 106)
- ²¹ Buckley (1920; 253)
- ²² Buckley (1920; 248)
- ²³ MacKenzie (1910; 107; emphasis in original)
- ²⁴ Bolding et al (1995)
- ²⁵ Van Halsema (2002)
- ²⁶ Van Halsema (2002; 47)
- ²⁷ Van Halsema (2002)
- ²⁸ Van Halsema (2002; 49)
- ²⁹ Van Halsema (2002; 49)
- ³⁰ De Gruyter (1925; 70)
- ³¹ De Gruyter (1925; 70)
- ³² De Gruyter (1926; 392)
- ³³ De Gruyter (1926; 392)
- ³⁴ Romijn (1938; 39)

- ³⁵ All losses in the canals before the measuring point were not taken into account. The losses, however, could be considerable and constrained water availability for peasant crops.
- ³⁶ Baggelaar (1916; 156)
- ³⁷ Romijn (1938; 5)
- ³⁸ NA 2.22.07 Invnr 53 (Romijn 1931) Romijn 1931 Verslag 1931 over de ervaring, opgedaan bij de exploitatie van meetinrichtingen in de Sectie Demak der Provinciale Irrigatieafdeeling “Serang”
- ³⁹ NA 2.22.07 Invnr 53 (Romijn 1931; 1)
- ⁴⁰ Or as my irrigation design teacher used to say: ‘constant headache orifice’; the device is somewhat difficult to manage with its two gates.
- ⁴¹ Lamminga (1905; 760)
- ⁴² Lamminga (1905; 760)
- ⁴³ According to Lamminga such structures had been applied in the Brantas Irrigation Department with good results.
- ⁴⁴ Voorduyn (1914)
- ⁴⁵ NA 2.22.07 Invnr 53 (Meetinrichtingen) Meetinrichtingen in de Irrigatie-afdeling Pemali-Tjomal (probably around 1930)
- ⁴⁶ Numans (1916)
- ⁴⁷ NA 2.22.07 Invnr 53 (Meetinrichtingen)
- ⁴⁸ Lamminga (1905)
- ⁴⁹ For example Baggelaar (1916); Brandenburg (1920, 1921a, 1921b, 1922)
- ⁵⁰ Van Maanen (1931; Begemann (1924)
- ⁵¹ Begemann (1924)
- ⁵² Begemann (1924; 329)
- ⁵³ Van Maanen (1931)
- ⁵⁴ NA 2.22.07 Invnr 99 (Jaarverslag 1930; 158). The 1931 edition of the design handbook written by Van Maanen includes an extensive paragraph on Venturi structures, whereas the 1924 edition does not even mention them, showing the development of Venturi use in the 1920’s. Verslagen van openbare werken op Midden-Java. 1930 – 1937
- ⁵⁵ NA 2.22.07 Invnr 53 (in important irrigation areas, Pemali (Meetinrichtingen); Demak (Romijn 1931)!)
- ⁵⁶ Vlugter (1931)
- ⁵⁷ NA 2.22.07 Invnr 53 (Verwey) Verwey Bezwaren tegen de Venturimeter
- ⁵⁸ NA 2.22.07 Invnr 53 (Verwey)
- ⁵⁹ Verwoerd (1930)
- ⁶⁰ Vlugter (1931; p264) gives as costs for different structures: (1) gated pipe intake with Cipoletti 600 guilders, (2) gated pipe intake with broad crested weir 650 gld, (3) Venturi 500 gld, (4) Crump de Gruyter 400 gld and (5) his own proposed device 500 gld. In a comment on Vlugter, Verschoor (1931) sets the costs at (1) 450 gld, (2) 500 gld, (3) 750 gld, (4) 650 gld and (5) 650 gld. Verschoor had included a 10 meter long crossing with a road. Costs are not an issue for me, but the difference triggers my curiosity.
- ⁶¹ Van Maanen (1931; 251)
- ⁶² Van Maanen (1931; 256; emphasis in original); the same quote is found in Verwoerd (1930; 105; without emphasis)
- ⁶³ NA 2.22.07 Invnr 53 (Meetinrichtingen; 6)
- ⁶⁴ NA 2.22.07 Invnr 53 (Meetinrichtingen)
- ⁶⁵ NA 2.22.07 Invnr 53 (Romijn 1931; 10)
- ⁶⁶ NA 2.22.07 Invnr 53 (Romijn 1931; 10). The irrigation development discourse really has not changed much...

- ⁶⁷ Van Maanen (1931); Verwoerd (1930)
- ⁶⁸ This will prove to be an understatement.
- ⁶⁹ Verwoerd (1930)
- ⁷⁰ NA 2.22.07 Invnr 53 (Romijn 1931)
- ⁷¹ NA 2.22.07 Invnr 53 (Romijn 1931; 14/15)
- ⁷² NA 2.22.07 Invnr 53 in Romijn (1931)
- ⁷³ NA 2.22.07 Invnr 53 (Handwritten comment in (Romijn 1931); opposite 15)
- ⁷⁴ Vlugter (1931)
- ⁷⁵ Verschoor (1931)
- ⁷⁶ Romijn (1938; 19)
- ⁷⁷ Verschoor (1931; 361)
- ⁷⁸ Romijn (1932; 287)
- ⁷⁹ Romijn (1932; 287)
- ⁸⁰ Romijn (1938)
- ⁸¹ Strictly speaking, H in a flow formula is not the water level, but the energy level (which is the sum of water level (potential energy) and the water velocity component (kinetic energy)). In practice (old and new) the water level is used; this does not result in too large inaccuracies, as the velocity component is pretty low (velocities in irrigation are low).
- ⁸² Romijn referred to the formula of Bundschau.
- ⁸³ Romijn (1932; 290)
- ⁸⁴ How to interpret the way Romijn presented his results remains unclear for me; it might be a way to promote himself, it might be just a bit 'clumsy' or it might be just a coincidence.
- ⁸⁵ Romijn (1932; 291)
- ⁸⁶ Romijn (1932; 291). Romijn refers here to the issue of sensitivity of gates and combinations of gates. Romijn weirs typically have been applied with stop logs; research into level regulation gates (with the famous Begemann and Vlugter types included) also has been conducted in the East Indies. See Horst (1996) for a discussion on sensitivity and the worst possible combination of discharge regulation structures.
- ⁸⁷ See for example Hens (1934)
- ⁸⁸ Steneker (1935; VI.85)
- ⁸⁹ Which Romijn did not relate to Verwoerd in his 1938 publication either! His overview of potential discharge measurement structures did not include the Vlugter sluice proposed in Vlugter (1931): 'The size of the Manual did not allow treatment of the special measuring sluice designed by ir. Vlugter' (Romijn 1938; 1). Apparently, the Vlugter sluice was not important enough. In 1940 Vlugter published new laboratory research on the Romijn weir; he proposed to give the weir a slight upward angle in the downstream direction. (Vlugter 1940a, 1940b)
- ⁹⁰ Romijn (1938; 37/38)
- ⁹¹ Which is not surprising, when we take into account the original British Indian design context of the device. However, De Gruyter did design his structure for changing water flows!
- ⁹² Hens (1934; VI-131)
- ⁹³ Compare with Geels (2002)

Chapter 5

- ¹ NA 2.22.07 Invnr 1 Tjipoenegarawerken (Salamdarma stuw) 1924/25. Het maken van een watervang in de Tjipoenegara en het onverdeelde hoofdkanaal met bijkomende werken.
- ² NA 2.22.07 Invnr 96 (BOW 1928) Verslagen over de Burgerlijke Openbare Werken in Nederlandsch-Indië. 1892 – 1928
- ³ Antwoorden (1918; 351)

- ⁴ Ravesteijn (2001). After the Japanese occupation Van Blommestein became head of the Irrigation and Drainage Department and extraordinary professor in irrigation at the Agricultural School in Bogor (Buitenzorg). Van Blommestein published in 1948 the so-called 'Welvaartsplan voor West-Java', which aimed at stimulating rice production and strengthening the economy. The plan consisted of civil engineering works to connect several river basins and for different uses (including irrigation, drainage, flood control, drinking water, hydropower, shipping and industry). Three reservoirs in the Citarum River formed the core of the plan: Jatiluhur, Tji Rata en Sangguling. From these reservoirs, feeder canals were to supply water to existing irrigation areas as far as the Kali Ramboet in the Pemali-Tjomal area! In modern Indonesia, one of these feeders, the East Tarum canal ends at Salamderma weir in the Tjipoenegara River.
- ⁵ The availability of a large amount of design documents in the Dutch National Archives made this possible. Main reason for this is that, luckily, engineer Haringhuizen, then professor of irrigation at Delft Polytechnic and member of the Maatschap, received the design documents, probably for educational purposes. The Tjipoenegara system was used as design case in the Delft irrigation program several times. Maps of the area are still available in Delft!
- ⁶ Redrawn from part of original map 'Peta Divisi Usaha III' by Sandra Junier
- ⁷ Van Oort (1919; 12/13)
- ⁸ N.V. (1917; 350)
- ⁹ NA 3.13.17.03 Dossier 61 NV Maatschap Eigen Beheer
- ¹⁰ N.V. (1917; 350)
- ¹¹ The Maatschap was established in a period with ample discussions in the Indies on the role of contractors in colonial development programs, in particular the system of tendering. Homan van der Heide (main shareholder of the 'Maatschap Eigen Beheer') (NA 3.13.17.03 Dossier 61) was heavily involved in this debate.
- ¹² N.V. (1917; 350)
- ¹³ N.V. (1917; 350-352)
- ¹⁴ On July 1st 1926, engineer A.W. de Groot replaced Elenbaas.
- ¹⁵ NA 3.13.17.03 Dossier 61
- ¹⁶ NA 2.22.07 Invnr 96 (BOW 1926; 102)
- ¹⁷ Proceedings (1980)
- ¹⁸ Originally, the lands were two properties, but they were brought together in an intriguing process of ownership changes roughly between 1816 and 1900.
- ¹⁹ Broersma
- ²⁰ Broersma (28)
- ²¹ The sell was heavily debated upon. Compare the company with those of the Sudan.
- ²² Daukes (1943)
- ²³ Daukes (1943; 104). This description comes quite close to a description of the Gezira scheme! Of course a main difference between the two areas is that the P&T Lands were privately owned.
- ²⁴ The history of irrigation in the Krawang area already starts in the late 19th century with plans to develop smaller-scale irrigation works (Bakhoven 1936).
- ²⁵ Ravesteijn (1997)
- ²⁶ NA 2.22.07 Invnr 68. This is the most likely title (obviously translated from Dutch); the Dutch original cannot be read completely. 1928 (Grond?) slagen voor het ontwerp van (leidi?) ngen en kunstwerken
- ²⁷ These are discussed in Bakhoven (1936) too
- ²⁸ NA 2.22.07 Invnr 68
- ²⁹ Weijs (1921); Ravesteijn (1997)

- ³⁰ Weijs (1921); Ravesteijn (1997) and many others! Lamminga's works have been regarded as examples for irrigation design. Although Van Houten is credited for his design approach, Demak is not very often mentioned as a success system.
- ³¹ Weijs (1921; 374). Van Bosse (1893) refers to Kening (3800 bouw, Kali Kening, tributary of the Solo, designed by Pierson) as the first system designed according to the principles of the Irrigation Brigade.
- ³² Lamminga (1910; 5)
- ³³ NA 2.22.07 Invnr 96 (BOW 1894)
- ³⁴ Van Bosse (1893)
- ³⁵ The history of these and other future dams in the Pekalen reads like the history of the Sampean works in Ravesteijn (1997). The two drawings given in NA 2.22.07 Invnr 96 (BOW 1894) with the river situations in 1850 and 1885 show how much the situation had changed.
- ³⁶ NA 2.22.07 Invnr 96 (BOW 1894; 191)
- ³⁷ NA 2.22.07 Invnr 96 (BOW 1894)
- ³⁸ NA 2.22.07 Invnr 96 (BOW 1894; 192-193)
- ³⁹ Meijll (1922)
- ⁴⁰ Lamminga (1905)
- ⁴¹ Lamminga (1905 and 1911)
- ⁴² The design process of the Pemali system will be discussed relatively superficially here; it is discussed extensively in Ravesteijn (1997).
- ⁴³ Van Marle (1894). According to Van Bosse (1893), the attempt to construct a weir and main canal failed due to lack of technical knowledge; Van Marle (1894) mentions that a heavy bandjir stopped the work.
- ⁴⁴ Van Bosse (1893)
- ⁴⁵ Van Marle (1894)
- ⁴⁶ In a document dated April 17th 1882, no 295/13 (Van Marle 1894)
- ⁴⁷ Ravesteijn (1997)
- ⁴⁸ Ravesteijn (1997); Van Marle (1894) and Van Bosse (1893) mention 1892.
- ⁴⁹ Van Marle (1894)
- ⁵⁰ Ravesteijn (1997). Haringhuizen, chair of irrigation at Delft Polytechnic between 1919 and 1938, member of the Maatschap and the provider of the Tjipoenegara case material, has worked in the Pemali area; he co-designed the main canals and the division of tertiary units.
- ⁵¹ As he would have done in the Pekalen area. The claim is made by Ravesteijn (1997; 163)
- ⁵² NA 2.22.07 Invnr 62 (Lamminga) Lamminga Voorloopig ontwerp van de verbetering van de bevloeiing en den waterafvoer tusschen Tjomal en Tjatjaban (Afdeling Pamalang en district Waridaja). Notas van Toelichting, Tegal
- ⁵³ For the Tjipoenegara system, a set of design documents has been produced; the exact number is not known, but 36 were available for my research.
- ⁵⁴ It most likely also relates to the general problem with historical documents, as they tend to disappear.
- ⁵⁵ NA 2.22.07 Invnr 3 (De Groot 1929) Groot de A.M. 1929 Nota van toelichting tot het ontwerp: Het als onderdeel der Tjipoenegarawerken maken van een bandjirdijk op de linkeroever van de Tjipoenegara, het eerste pand van de Djatiredja-leiding en de werken tot bevloeiing en afwatering van het secundaire vak Bodjong Keding
- ⁵⁶ The change was proposed by the N.V. Ing. Maatschap 'Eigen Beheer' in a letter of August 24th 1924 to the Director of Public Works.
- ⁵⁷ NA 2.22.07 Invnr 1 (Elenbaas 1922). In the Krawang area similar discussions have occurred, see Bakhoven (1936). Elenbaas W. 1922 Nota bij het ontwerp der werken tot aftapping van de Tjipoenegara

- ⁵⁸ Although the intake location downstream of the railway bridge made it necessary to check the backwater influences, which was discussed in a separate document. First, the water level at Salamderma was determined using an iterative calculation. With a maximum flow of 1,000 m³/s, the backwater curve was estimated at 6,000 m. As the bridge was located some 5300 meters upstream, the weir would influence the water level under the bridge. With the lowest part of the bridge at + 25.49 meter and high water without backwater curve at + 24.23 meter, the margin was 1.26 meter. This was considered to be sufficient. The exact water level under the bridge was not calculated!
- ⁵⁹ The extra cubic meter per second allocated to the irrigation system (total of 41 instead of 40) is partly caused by rounding off upwards and partly because it was considered unlikely that both maximum discharges would be needed at the same time.
- ⁶⁰ The design calculations for the Venturis were made by the Kent Company in London, not by the Dutch designers. As discussed in chapter four, De Gruyter would have liked to see his gate being applied.
- ⁶¹ NA 2.22.07 Invnr 14 (De Groot 1926; 3) Groot A.W. de 1926 Nota van toelichting tot het ontwerp: Het maken van het 1^e gedeelte der werken voor de bevoeiing en afwatering van het bevoeiingsgebied der Tjipoenegara-rivier, zijnde het eerste gedeelte van het Andjatankanaal met bijbehorende kunstwerken enz.
- ⁶² NA 2.22.07 Invnr 14 (De Groot 1926; 2)
- ⁶³ Not just doubled, as wadoeks would probably increase water losses somewhat.
- ⁶⁴ NA 2.22.07 Invnr 14 (De Groot 1926; p6)
- ⁶⁵ This is in contrast with the normal rule, that sugar cane and rice were supplied through the same canal system. In the Tjipoenegara area, however, the sugar cane growing private party involved owned land in the system and had a right for 30% of the total water available.
- ⁶⁶ Dated November 11th 1929, made by the Maatschap and sent to the Department by the Head of Krawang.
- ⁶⁷ NA 2.22.07 Invnr 8 (Nota 1930; 2) 1930 Nota van toelichting tot het ontwerp: Het als onderdeel der Tjipoenegarawerken maken van het tweede gedeelte van het Kandanghaoerkanaal en de voortzetting der werken voor de detailbevoeiing van het Kandanghaoergebied
- ⁶⁸ Van Maanen (1931; 72)
- ⁶⁹ As discussed in Van Rosse (1913), who defined such a uniform methodology, applying combinations of numbers, letters and names. The exact type of labeling as such may be not that important, but it does reflect the regularity strived for in colonial irrigation design.
- ⁷⁰ NA 2.22.07 Invnr 96 (BOW 1895)
- ⁷¹ NA 2.22.07 Invnr 64 (Telders et al 1900; Annex E) Telders J.M., W.F. Leemans, J. Kraus en J.E. de Meyier 1900 Verslag van de commissie van advies nopens de werken in de Solovallei. Waltman, Delft
- ⁷² NA 2.22.07 Invnr 107 (Rapport) Rapport over de mogelijk- en wenschelijkheid van de invoering op Java van een irrigatie-beheer in den geest van het soebakwezen op Bali
- ⁷³ Like in the Krawang system (Bakhoven 1936)
- ⁷⁴ These views were probably written down in a letter from August 19th 1929, No 3571/T.Q, directed at the Director of Public Works and the answer to this letter from September 14th 1929, No E/12/9/9, which are later than the Krawang guidelines.
- ⁷⁵ NA 2.22.07 Invnr 14 (De Groot 1926)
- ⁷⁶ NA 2.22.07 Invnr 53 (Romijn 1931) Romijn 1931 Verslag 1931 over de ervaring, opgedaan bij de exploitatie van meetinrichtingen in de Sectie Demak der Provinciale Irrigatieafdeeling "Serang"
- ⁷⁷ Bakhoven (1936; VI.122)

Chapter 6

- ¹ NA 2.22.07 Invnr 87-96 Verslagen over de Burgerlijke Openbare Werken in Nederlands-Indië. 1892-1928 (BOW 1895)
- ² Ankum (1989); NA 2.22.07 Invnr 157 Haringhuizen J. 1939 Waterbehoefte voor de rijstcultuur op Java. Vereischte capaciteit der aanvoerwerken; NA 2.22.07 Invnr 64 (Telders et al 1900) Telders J.M., W.F. Leemans, J. Kraus en J.E. de Meyier 1900 Verslag van de commissie van advies nopens de werken in de Solovallei. Waltman, Delft
- ³ NA 2.22.07 Invnr 64 (Telders et al 1900; Annexes C and D)
- ⁴ Van Maanen (1931)
- ⁵ NA 2.22.07 Invnr 157 (Haringhuizen 1939)
- ⁶ NA 2.22.07 Invnr 157 (Haringhuizen 1939; 7)
- ⁷ Van Maanen (1931)
- ⁸ NA 2.22.07 Invnr. 45 (Nota; 77) Nota op het algemeen plan tot verbetering der bevoeiing en afwatering in de vlakten van Sawitto, Rappong en Sidenreng (“Het Sadang-bevoeiingsplan”)
- ⁹ Dumas (1929)
- ¹⁰ A FAO study discussed in Van Schaik (1986) sets suitability for sugar cane based on soils in the area at ‘moderately suitable’ for the Tjipoenegara region. The map given in Van Schaik (1986) on page 46 clearly shows the difference in suitability for cane between East and West Java.
- ¹¹ Bakhoven (1936; pVI.118)
- ¹² Bakhoven (1936; pVI.118)
- ¹³ Compare with Alexander and Alexander (1978)
- ¹⁴ This assumption was similar as made for the Solo Valley. NA 2.22.07 Invnr 64 (Telders et al 1900)
- ¹⁵ NA 2.22.07 Invnr 1 (Gravestein 1926; 3) Gravestein J.H. 1926 Nota betreffende de capaciteitskromme voor de aanvoerleidingen der detailbevoeiing
- ¹⁶ NA 2.22.07 Invnr 2 (Nota 1922; 3) 1922 Nota betreffende de inrichting van het Hoofdverdeelwerk Boegis
- ¹⁷ The same document mentions that drainage canals were designed using ‘nomogram B.II.4’ (‘graph B.II.4’) of engineer Steevensz.
- ¹⁸ NA 2.22.07 Invnr 7 (De Groot 1927 Nota betreffende ... 1) Groot A.W. de 1927 Nota betreffende de bij het opmaken der ontwerpen voor de detailbevoeiing der Tjipoenegarawerken gebruikte hydraulische formules
- ¹⁹ Verwoerd (1931)
- ²⁰ Bakhoven (1936)
- ²¹ I only discuss Steevensz and Verwoerd, as these are the two known to have been employed in the Tjipoenegara case. The graphs of Steevensz were very popular by irrigation engineers in the Netherlands East Indies. Their development can be retraced quite well too, making the discussions a nice example for knowledge development and sharing.
- ²² And is still debated. Similar discussions occur for the Strickler-Manning formula.
- ²³ Van Maanen (1924, 1931)
- ²⁴ Van Maanen (1931; 89)
- ²⁵ Van Maanen (1924, 1931)
- ²⁶ Van Maanen (1924; p85)
- ²⁷ Van Maanen (1931; 90)
- ²⁸ Who had published these in the ‘Zeitschrift des österr; Ingenieur- und Architekten-Vereins’ in 1913 and 1914
- ²⁹ Nijman (1915)

- ³⁰ Van Maanen (1931; 91)
- ³¹ Nijman (1915; p23)
- ³² Nijman (1915; 24)
- ³³ As early as 1905, Homan van der Heide had published an extensive contribution on the subject of sediments in British India in 'De Ingenieur'; the Dutch engineers did know what their British colleagues were doing.
- ³⁴ Steevensz (1916a; 79)
- ³⁵ Steevensz (1916a; 79)
- ³⁶ Steevensz (1916a; 79)
- ³⁷ Steevensz (1916a; 79)
- ³⁸ Steevensz (1916a)
- ³⁹ Steevensz (1916a)
- ⁴⁰ Steevensz (1916a)
- ⁴¹ Steevensz (1916a; 79). The coefficient of Gangguillet and Kutter $C = (1/n + 23 + 0.00155/i) / ((1 + (23 + 0.00155/i) n/R^{1/2}))$
- ⁴² Steevensz (1916a; 81)
- ⁴³ In a contribution of June 1916, very soon after the article of Steevensz, Hansen argued that a formula of the type developed by Steevensz could be developed, which was valid for practically all canals (Hansen 1916; 237). Hansen came with the formula $v = 7.7 i^{0.369} Q^{0.270}$, which is virtually the same formula as the one developed by Steevensz. The graphs developed by Hansen, however, were very complicated, and he himself refers to the graphs of Steevensz as much easier in daily use. Afterwards, no sign of Hansen can be found anymore in the literature.
- ⁴⁴ Steevensz (1916b; 272)
- ⁴⁵ Steevensz (1916b; 272)
- ⁴⁶ Steevensz (1918; 218)
- ⁴⁷ Steevensz (1918; 181)
- ⁴⁸ These monographs also included design graphs for pipes and structures.
- ⁴⁹ The question why the Maatschap engineers developed their own graph for irrigation canals could not be answered in this research; developing a specific graph is in line with the suggestion made by Steevensz himself in his contribution of February 1916, but seems to be out of place with design approaches in the Krawang area, Tjipoenegara's main reference, which included the graphs of Steevensz right away.
- ⁵⁰ Bakhoven (1936; VI.122)
- ⁵¹ Vreedenburgh (1924)
- ⁵² Published in 'Die Wasserkraft' of April 5 1922 (entitled 'Scobey's Untersuchung über den Durchfluss durch Betongerinne')
- ⁵³ 'Beiträge zur Frage des Geschwindigkeitsformel und der Rauheitskoeffizienten für Ströme, Kanäle und geschlossene Leitungen' (part 6 of the 'Mitteilungen des Amtes für Wasserrwirtschaft' in Switzerland)
- ⁵⁴ Vreedenburgh (1924; 254)
- ⁵⁵ Vreedenburgh (1924; 254)
- ⁵⁶ Meesters (1934). In his response, Vreedenburgh explicitly refers to his earlier work, which apparently had been missed by Meesters: 'I hope to diminish nothing of the merits of the author when I point out that this subject had my attention already many years ago and that a study on the matter appeared in de Waterstaatsingenieurs No. 9 – 1924 [...]' (Vreedenburgh 1934; VI.67)
- ⁵⁷ The engineer who had proposed the extra broad-crested weir downstream of the Venturi, which has become known as the Romijn weir (chapter 3).

- ⁵⁸ The Strickler formula is also known as Gauckler-Manning.
- ⁵⁹ Verwoerd (1931)
- ⁶⁰ Verwoerd (1931)
- ⁶¹ Der Weduwen (1936; VI.220)
- ⁶² Breeman (1936 7)
- ⁶³ For details on these calculations see chapter 4 of Ertsen (2005).
- ⁶⁴ NA 2.22.07 Invnr 5 (De Groot 1928) Groot A.W. de 1928 Nota van toelichting tot het ontwerp: Het als onderdeel der Tjipoenegarawerken maken van het eerste gedeelte van den bandjirdijk op den rechteroever der Tjipoenegara met het eerste pand van de Pengarenganleiding
- ⁶⁵ NA 2.22.07 Invnr 5 (De Groot 1928; 9)
- ⁶⁶ Bakhoven (1936)
- ⁶⁷ Bakhoven (1936; VI.122)
- ⁶⁸ Bakhoven (1936; VI.122).
- ⁶⁹ For details on these calculations see chapter 4 of Ertsen (2005). Criticism came from the Dutch engineers Van Kooten (1927) and Begemann (1931), for example. The method presented by engineer Der Weduwen (1937) became an attachment to the Melchior standard in the last years of Dutch colonial power, but did not change the foundation laid by Melchior. In independent Indonesia, the approach developed by Melchior continues to be applied. In *Irrigation Design Standards* (1986), an irrigation design handbook of the Indonesian Department of Public Works, the basic irrigation system design process is covered. One of the issues is how to determine the expected peak flow in the river, important for a safe design of river structures. The book mentions the Melchior and Der Weduwen formula's as possible methods to estimate river discharges.
- ⁷⁰ Bakhoven (1936)
- ⁷¹ June 2nd 1927, No. E 12/3/24
- ⁷² Bakhoven (1936; pVI.135)
- ⁷³ NA 2.22.07 Invnr 45 (Nota)
- ⁷⁴ Anthonijs Feher (1932)
- ⁷⁵ NA 2.22.07 Invnr 45 (Nota; 89-91)
- ⁷⁶ Excluding the formal design documents as decisions themselves.
- ⁷⁷ In terms of the simplified regime triangle applied in this thesis, the presence of sugar cane could not only be labelled as a general guideline, but in the Tjipoenegara case (and Krawang too) as part of the 'promises and expectations' category too.
- ⁷⁸ Compare with the discussion in Alexander and Alexander (1987), who argue that the canal capacities in Javanese systems are still too small because of this. The Sadang report quoted earlier suggests that at least in colonial times this problem was not detected (NA 2.22.07 Invnr. 45; Nota).
- ⁷⁹ For example discussed by De Ridder (1998)

Chapter 7

- ¹ The post World War II development aid programs have brought with them a flow of technical activities for European and American engineers in Africa, Asia and Latin America, including former colonial areas. International development organizations under the wings of the United Nations, like the Food and Agricultural Organization, the World Bank and the Asian Development Bank, were in need for engineering expertise. Irrigation development was one of the key fields, to increase global food production. Dutch engineering firms united themselves in the umbrella-organization NEDECO in 1951. Geographically, the employment

- opportunities for Dutch irrigation engineers increased; instead of going to the East Indies, their horizon expanded to countries like Bangladesh, India, Pakistan, Nigeria and Colombia.
- ² Eijssvoogel (1950); Berkhout (1950)
- ³ Berkhout (1950; 330)
- ⁴ Although one can imagine that the return of the former colonial power may have given some tension, especially in case Dutch engineers would tell others, including Indonesian engineers, how to do things. Engineer Wehlburg (who we will meet again when we are discussing Lampung) may have referred to such feelings when he wrote in his letter of April 25th 1972 to Schoemaker (professor in irrigation at Delft Polytechnic): 'I can vividly imagine that they are heartily sick of it – to a certain extent even allergic. Nevertheless, over-sensitivity on this point is very much a pity, because particularly us old gentlemen, who were born and raised there, – who know and sense nature there, as a civil engineer, a hydraulic engineer must be able to do, – the mountains and landslides, – the rivers and bandjirs, – the woods and erosion through deforestation, we can offer so much more than the pure technologies of Americans and Germans .. and totoks!' Wehlburg is not just judging Indonesian efforts and feelings here... (NA 2.22.07 Invnr 174). Brieven van A.F. Wehlburg aan H.J. Schoemaker over de ervaringen van Wehlburg bij verkenning van kolonisatiemogelijkheden op Sumatra en Borneo, met kaarten. 1972 – 1974
- ⁵ The activities in this last region, east and southeast of Semarang, are an excellent example of the continuous involvement of Dutch engineers in water affairs. Irrigation and flood protection infrastructure dates from around 1850. In 1968 a project mission consisting of Indonesian and Dutch experts formulated a general plan. The three Dutch members were representatives of the link between the Netherlands, the Netherlands East-Indies and Indonesia. One was born in Indonesia and at that time professor of irrigation at the Delft Polytechnic. Another member was a former professor of the Institute of Technology at Bandoeng, than technical advisor of Grontmij N.V., and a third was former employee of the Algemeen Landbouwkundig Proefstation Bogor, later professor at the Agricultural Department of the Universitas Indonesia Bogor and the Gadjah Mada Universiteit Jogjakarta, and finally working at the International Institute for Land Reclamation and Improvement Wageningen (Reconnaissance 1968).
- ⁶ Phase I included 58 schemes with a total area of 70,000 hectares, the second phase 41 schemes with 50,000 hectares; one could conclude that small to medium-size schemes are about 1200 hectares.
- ⁷ Vivekananthanan (1987; 154)
- ⁸ Lampung is not to be confused with South Sumatra, which is a province to the north of Lampung. Lampung thus is further south than South Sumatra!
- ⁹ Selecting Lampung has partly been for practical reasons. In general, detailed material available on systems shaped by both colonial and Indonesian actions is limited for many systems, for Lampung the material available allowed detailed analysis.
- ¹⁰ Eijssvoogel (1941); Van Beukering (1936)
- ¹¹ Indonesian project engineer Bandung, Pers.Comm.
- ¹² Pelzer (1945; 190)
- ¹³ Irrigatie (1888; 11)
- ¹⁴ Ott de Vries in Van Oort (1920; 424)
- ¹⁵ NA 2.22.07 Invnr 96 (BOW 1940; 236) Verslagen over de Burgerlijke Openbare Werken in Nederlandsch-Indië. 1892 – 1928
- ¹⁶ NA 2.22.07 Invnr 96 (BOW 1940; 236)
- ¹⁷ Pelzer (1940; 262)

- ¹⁸ NA 2.22.07 Invnr 57 (Van Tubergen 1913) Van Tubergen 1913 Rapport nopens een ingesteld irrigatie-onderzoek in de residentie Lampongsche districten, Medan
- ¹⁹ Clason (1936)
- ²⁰ Pelzer (1945)
- ²¹ Pelzer (1945)
- ²² Pelzer (1945; 194)
- ²³ Pelzer (1945; 198)
- ²⁴ NA 2.22.07 Invnr 174
- ²⁵ Pelzer (1945; 204)
- ²⁶ Pelzer (1945)
- ²⁷ NA 2.22.07 Invnr 57 (Van Tubergen 1913)
- ²⁸ NA 2.22.07 Invnr 57 (Van Tubergen 1913; 10)
- ²⁹ NA 2.22.07 Invnr 57 (Van Tubergen 1913; 48)
- ³⁰ NA 2.22.07 Invnr 57 (Van Tubergen 1913; 66)
- ³¹ This aspect of control is mentioned by Clason (1936) as well: 'The big, all-determining advantage of irrigation in colonization areas is therefore, that one stimulates a regulated society.'
- ³² NA 2.22.07 Invnr 57 (Van Tubergen 1913; 68)
- ³³ Compare with activities of British and French engineers in Africa and of British engineers in Pakistan and Sri Lanka: when an area is considered 'empty' colonial powers started to plan a new social reality. Please note, that in the Lampung case settlers were treated as people with a history, and were made owners of their land, not tenants! Compare with Pfaffenberger (1990) on Sri Lanka and Ertsen (2006).
- ³⁴ Bevloeiing (1918)
- ³⁵ NA 2.22.07 Invnr 57 (Nota van Toelichting 1934) Nota 1934 Nota van Toelichting bij het voorontwerp van het kolonisatie-terrein Soekadana in de Residentie Lamoengsche Districten; Pelzer (1945)
- ³⁶ In a way, such promises still are a major leading factor in irrigation activities in modern Lampung.
- ³⁷ Together with 0.25 bouw of not-irrigated 'erfgrond' (garden area near the farm house)(NA 2.22.07 Nota van Toelichting 1934).
- ³⁸ Pelzer (1945)
- ³⁹ NA 2.22.07 Invnr 57 (Nota van Toelichting 1934)
- ⁴⁰ NA 2.22.07 Invnr 57 (Nota van Toelichting 1934)
- ⁴¹ One report is from Dr. H. Loos, another is from the Agricultural Adviser (Landbouwconsulent).
- ⁴² NA 2.22.07 Invnr 57 (Nota van Toelichting 1934; 20)
- ⁴³ NA 2.22.07 Invnr 57 (Nota van Toelichting 1934) The report was sent by the Director of Public Works to the Government at November 8th 1934 (No. E 15/6/12) and approved by that Government at January 9th 1935 (No. 631)
- ⁴⁴ NA 2.22.07 Invnr 174; No. 2240/L
- ⁴⁵ NA 2.22.07 Invnr 174
- ⁴⁶ NA 2.22.07 Invnr 174
- ⁴⁷ Pelzer (1945; 205)
- ⁴⁸ 'Goeroeh' translates as 'rapids'.
- ⁴⁹ NA 2.22.07 Invnr 96 (BOW 1940)
- ⁵⁰ NA 2.22.07 Invnr 96 (BOW 1940)
- ⁵¹ NA 2.22.07 Invnr 108 (Kolonisatiebulletin 3) Exemplaren van Kolonisatie bulletins, uitgave van de Centrale Commissie van Emigratie en Kolonisatie van Inheemschen. 1938 – 1940

- ⁵² A similar reasoning was followed in the design of the Sadang works on Celebes (Sulawesi), where the combined absence of a large population and 'European cultivation' was reason to select larger tertiary units. Within these larger units 'the irrigation situation can have a more irregular character, until – in the far future – the population has reached such a density that it will be necessary to perfect irrigation in the tertiary units too.' NA 2.22.07 Invnr 45) Nota op het algemeen plan tot verbetering der bevoeiing en afwatering in de vlakten van Sawitto, Rappong en Sidenreng ("Het Sadang-bevoeiingsplan")
- ⁵³ NA 2.22.07 Invnr 174
- ⁵⁴ Wehlburg emphasizes the need for careful designs, with not too many sawahs available in the beginning, as the early settlers were simply not able to cultivate larger amounts of sawahs; they were busy settling themselves. Wehlburg (1972; 16); NA 2.22.07 Invnr. 174.
- ⁵⁵ NA 2.22.07 Invnr 174. Therefore, Wehlburg made detailed plans himself; '[...] naturally I did this with the help of a very detailed unit division. Detailed in so far, that on the basis of the demands which have to be made in practice it came down to the planning frame for the colonists. And that went well. Very well!' (Wehlburg 1972; 15; NA 2.22.07 Invnr. 174).
- ⁵⁶ Memory support: the Tegal curve has a unit of 200 bouw as reference, with an assigned capacity of about 1 l/s/b. In another major irrigation scheme outside Java, the Sadang works, the Pemali curve was used (NA 2.22.07 Invnr 45).
- ⁵⁷ NA 2.22.07 Invnr 57 (Nota van Toelichting 1934)
- ⁵⁸ Pelzer (1945; 180-181)
- ⁵⁹ Gany (1993)
- ⁶⁰ Nippon Koei (1996)
- ⁶¹ The exact chronology of and changes made in the different irrigation schemes in the Lampung area is hard to define. Most schemes are connected, and reports give different values for (actual and potential) command areas and flows.
- ⁶² Haskoning (2000)
- ⁶³ Haskoning (2000). The Nippon Koei 1996 report on the extensions mentions 1978 as the year for the feasibility study. This might be the year of completion.
- ⁶⁴ Nippon Koei (1996; 2)
- ⁶⁵ Nippon Koei (1996)
- ⁶⁶ Haskoning (2000)
- ⁶⁷ Good Governance Project (2002). These two strategies (the 'building concrete' versus the 'building institutions' approach) may be considered as symptomatic for the different directions that can be found in river basin management worldwide.
- ⁶⁸ But for example on Sulawesi as well.
- ⁶⁹ Gany (1993; 65)
- ⁷⁰ Gany (1993)
- ⁷¹ Gany (1993; 143). The Tataän Colonization area may be the Gedongtataän area. I have been unable to trace the Wehlburg document; I have consulted his letters to Schoemaker in the NA.
- ⁷² Gany (1993), who defines water requirements in similar terms as the relative canal capacity. He does not give the water use diagram which expresses crop water requirements per unit area. It is possible that Gany actually refers to the canal capacity and not to water requirements; in the Lampung area canal losses would typically be high, resulting in high relative canal capacities.
- ⁷³ The 2000 Haskoning report mentions, that in Puggur Utara the Tegal curve has been used as well, and that the curve is based on '1 l/s/ha voor 200 bouw = 142 hectare'.
- ⁷⁴ Nippon Koei (1996)
- ⁷⁵ Nippon Koei (1996)
- ⁷⁶ Nippon Koei (1996)
- ⁷⁷ Haskoning (2000)

- ⁷⁸ Haskoning (2000)
- ⁷⁹ Begemann (1926); Beauchez (1921); Kleyn (1925)
- ⁸⁰ Beauchez (1921; 286)
- ⁸¹ Begemann (1926; 303)
- ⁸² Begemann (1926; 309).
- ⁸³ Vlugter (1940)
- ⁸⁴ Begemann (1926)
- ⁸⁵ Vlugter (1940)
- ⁸⁶ Vlugter (1940). One disadvantage of the Vlugter gate is its relative instability when the gate is opened above a certain angle, an issue studied by Delft University of Technology. To overcome this, simple damping devices have proven their applicability in practice.
- ⁸⁷ Obviously within certain limits.
- ⁸⁸ In a similar way a combination of baffles and hydraulic gate of Neyrpic (French origin) would do. Brouwer (1987)
- ⁸⁹ Plusquellec et al (1994; 81). Begemann-type structures have been applied in Californian Irrigation Districts too (Burt et al 2001).
- ⁹⁰ Ertsen (2008; 397); photo by R. Brouwer
- ⁹¹ Nippon Koei (1996). The main canals were equipped with broad-crested weirs to measure flows. CdeG's apparently remained popular with all parties. The 1996 report refers to a report (which I do not have) 'Technical note on water distribution system for Bekri and West Rumbia Main Irrigation Systems', which is the result of a technical meeting on 'Automatic Regulation Gate and definition of regulation and division structure' in Jakarta on June 30, 1995.
- ⁹² Plusquellec et al (1994; 46)
- ⁹³ Nippon Koei (1996)
- ⁹⁴ IDS (1986, KP-01; 3)
- ⁹⁵ IDS (1986; Vol I; 6)
- ⁹⁶ IDS (1986; Vol. I; 21)
- ⁹⁷ IDS (1986; Vol. I; 22)
- ⁹⁸ IDS (1986; Vol. I; 22)
- ⁹⁹ Concerning check structures the situation is slightly different. 'The standards appear to be ambiguous with regard to check structures. After finding both the stop-log gates and the flat sliding gate suitable for water level regulations, their pros and cons are discussed (ibid. p.p 43, 44). Rightly the disadvantage of sliding gates in terms of their sensitivity to changes in flows (large fluctuations in water level) are pointed out. The standards note (ibid, p. 44) that when used in combination with the Romijn weir (recommended as offtake structure!), frequent adjustments will be required. This discussion ends with the surprising statement that 'Ease of operation and durability make that it is recommended to use undershot gates as regulating gates in spite of the mentioned shortcomings'. In other words, the standards recommend 'the worst possible combination' (World Bank, 1990) of water division structures.' (Horst 1996; 15). (Cited: World Bank (1990) Discussion paper on operational issues at the scheme level. Irrigation Sub-Sector Project in Indonesia.) It has been mentioned above, that the Japanese designer of the Bekri extension did not select the sliding gate. The option to select Begemann-type gates as check structures is not mentioned in the IDS, radial gates are mentioned briefly.
- ¹⁰⁰ In Volume II on head works the Vlugter stilling basin is discussed and found to be 'unreliable with tailwater levels above and below the laboratory tested levels. [...] For these reasons the use of the Vlugter basin is no longer recommended with fluctuating discharges, as with weirs in rivers.' (IDS 1986; Vol. III; 63). In irrigation canals, however, the Vlugter basin can be applied, as it 'was developped [sic] especially for drops in irrigation canals.' (IDS 1986; Vol. IV; 101).

¹⁰¹ IDS (1986; Vol. III; 5)

¹⁰² IDS (1986; Vol. III; 5)

¹⁰³ In accordance with the approach discussed by Gany (1993).

¹⁰⁴ IDS (1986; Vol. III; 9)

¹⁰⁵ IDS (1986; Vol. III; 9). O&M stand for Operation and Maintenance.

¹⁰⁶ IDS (1986; Vol. III; 9)

¹⁰⁷ IDS (1986; Vol. III; 9)

¹⁰⁸ The Horizontal Broad Adjustable Weir (Hobrad) is a modified Romijn weir; its history starts in the 1970's, when drinking water supply activities in a Dutch province created a need for a structure which could measure and regulate discharges with little head losses (not over a few decimetres) (Boiten 1981). The original Romijn structure has been applied in the Linge water system in the Netherlands by engineer Binkhorst of Haskoning; a Romijn weir was applied in hydraulic laboratory research with Delft Hydraulics to measure flows to the scale models for the Delta Storm Barriers. (Brouwer PC 2004)

¹⁰⁹ Horst (1996)

¹¹⁰ The case of the Begemann gate has one other intriguing element; the gate found its way back to Indonesia via a detour to Nigeria. Nevertheless, the gate has not been included in the IDS. The fact that the Dutch firm applying the gates and another Dutch firm assisted in preparing the IDS may be an explaining factor here.

¹¹¹ Nowadays Delft University of Technology. Dutch irrigation engineers were trained at Wageningen Agricultural University too (the author of this book is one of them), but the influence of the Indies on the irrigation program in the late 1980's was (to my taste at least) less and not a subject in my book anyway.

Chapter 8

¹ Studie (1921; 243)

² Engineer Weijs became the first full professor in irrigation in Delft when his special professorship had been changed in 1917, but Haringhuizen was the first full professor to start.

³ Van Sandick (1911; 200)

⁴ Grinwis Plaat (1895)

⁵ Rapport (1879; 15; emphasis in original)

⁶ 'Course in agriculture and agricultural hydraulics' from Nadault de Buffon (1858, 1865)

⁷ Although late compared to England. In 1806, the big rival and example colonial power England had already established the East Indian College to organize the education of its future civil servants in the British Indies (Van Leur and Ammerlaan 1990). In 1794, the Engineering College at Madras had already started to train surveyors; in 1859 this college was transformed into a civil engineering school (Ambirajan 1995). In 1847 an engineering college had been started at Roorkee (India) (Derbyshire 1995; Kumar 1995); later colleges included Calcutta (1856), Bombay (1888), Sibpur (1880) and Poona (1854) (Derbyshire 1995).

⁸ Van Leur and Ammerlaan (1990); see Fasseur (1993) for a full account of the East Indian civil servants education history.

⁹ Van Leur and Ammerlaan (1990)

¹⁰ De Jong (1998; 250)

¹¹ Van Leur and Ammerlaan (1990). This date is relatively late in comparison with similar institutes established in Germany, including Karlsruhe (1825), München (1827), Dresden (1828), Stuttgart (1829), Hannover (1831) and Darmstadt (1836) (Groen 1988).

¹² De Jong (1998; 251)

- ¹³ Originally the title ‘engineer’ referred to military designers/constructors trained since 1600 in fortification in Leiden (Van Leur and Ammerlaan 1990). The influence of this program on Leiden University has been remarkable; in 1814 the La won Higher Education still mentioned that mathematics applied to hydraulic engineering as part of the department of mathematics and physics (Kamp 1955). In 1789 the government decided to establish gunnery-schools; in 1805 one was founded in Amersfoort, in 1814 in Delft. This last one moved to the Royal Military Academy in Breda in 1829. The Delft military school had to supply officers for artillery and military engineering and for public Works; the school thus included both military and technical education (Van Leur and Ammerlaan 1990).
- ¹⁴ Groen (1988). With the establishment of the Academy, a separation between military and civil technical education was realized in the Netherlands (Van Leur and Ammerlaan 1990; Van Doorn 1994).
- ¹⁵ Van Doorn (1994; 113)
- ¹⁶ Van Leur and Ammerlaan (1990); Van Doorn (1994)
- ¹⁷ Van Leur and Ammerlaan (1990)
- ¹⁸ Schippers (1989)
- ¹⁹ De Jong (1998); Van Leur and Ammerlaan (1990)
- ²⁰ Higher technical education came on equal level with university education; engineering had become an academic profession in 1905 (Van Doorn 1994)
- ²¹ Van Doorn (1994)
- ²² At least according to Van Sandick (1911; 200).
- ²³ Van Doorn (1994); some of them returned to Delft to become professor.
- ²⁴ Van Doorn (1994; 117)
- ²⁵ The irrigation component of the curriculum stayed close to the empirical level for a long time. In general, discussions on practical versus theoretical approaches, and the validity of the Delft diploma in either one or both of these terms have been present within the engineering community throughout the history of the engineering school.
- ²⁶ Groen (1988; 208)
- ²⁷ After all, hydraulic engineering was firmly rooted in engineering education.
- ²⁸ Van Sandick (1911; 202)
- ²⁹ Snethlage (1890; 427)
- ³⁰ Compare with Snethlage (1890; 433); Openbare (1892; 25)
- ³¹ Compare with Fasseur (1993)
- ³² Quoted in Van Sandick (1911; 202)
- ³³ Lamminga (1910; 4)
- ³⁴ Wenschen (1913; 78)
- ³⁵ Wenschen (1913; 78)
- ³⁶ Hoofdstuk (1914; 194)
- ³⁷ Kloppenburg (1914; 200)
- ³⁸ Hoofdstuk (1914; 194)
- ³⁹ And not just of the permanent residence of Weijs in the Netherlands, as was used as an argument for a full professorship by some (according to the Minister) (Hoofdstuk 1914; 193).
- ⁴⁰ Based on Studie (1921; 245-246)
- ⁴¹ Westendorp et al (1930; 32)
- ⁴² Homan van der Heide (1913); Hooger (1918; 88)
- ⁴³ Homan van der Heide remarked that ‘one can hardly do a developing Eastern nation a bigger disservice than giving it a mock-university or polytechnic-in-name, as the British did in British India.’ Homan van der Heide (1913). Not everything the British did was to be copied...
- ⁴⁴ Van Oordt (1918; 381)

⁴⁵ Damme (1919; 270)

⁴⁶ Damme (1919; 270)

⁴⁷ Baudet (1992; 389)

⁴⁸ 'Royal Institute for Higher Technical Education in the Neth. East Indies'

⁴⁹ 21 passed the exams (15 Europeans, 4 Indonesians and 2 Chinese).

⁵⁰ Just before World War II Delft and Bandoeng were set at the same level in terms of academic affairs (grades and PhD rights) (Baudet 1992).

⁵¹ Baudet (1992; 390)

⁵² Klopper (1919; 263). 'Stressing first that in Batavia hard and good work is done, everyone has to admit that on this issue Bandoeng has a lead, not just for Europeans, but according to declarations of inspectors and other servants of Indian education for Indians too.'

⁵³ Van der Wal (1963; 423 (note 1))

⁵⁴ Van Doorn (1994)

⁵⁵ For this engineer experience in the Netherlands as part of general personal development was vital for engineers (Bandoengsche 1922; 446); 'in the highest ranks [one] still generally [encounters] a number of true-born Dutchmen, and always only people who know Holland as good as the Indies. Fortunately this is still the case and I have enough faith in our Governmental policy to assume that it will stay that way for the time being too'. Compare with Fasseur (1993) on similar debates concerning the education of civil servants.

⁵⁶ Hooger (1918; 89/90)

⁵⁷ (Damme 1919; 267; emphasis in original). He applied another metaphor too (Hooger 1918; 90) 'We want to have certain fruits; we know at what trees these grow, but what we do not know is whether these same trees, transported to our soil and influenced by our climate, will bear similar, or at least comparable fruits.' A similar reference to 'new' countries was made at the opening of the General Engineering Conference in Batavia (8 – 15 May 1920) by Damme. When referring to the societal context of engineering work, he continues (Van Sandick 1920; 491) 'Therefore we turned to the "newer countries", which, despite many national and local differences, show considerable points of similarity between themselves concerning the stage of technical and economic development and the relation of these with available resources as well as the direction in which it moves, in contrast with the more developed cultural states.' Another lecturer at the opening, Van Sandick opposed to the idea of 'newness' as such, as (Van Sandick 1920; p492) 'these colonies are not new countries. The islands of Java, Sumatra, Bali for example are countries with an old civilization, on such high level and so old, that when they were constructing the temples of Borobodor, Mendoeet and Brambanan, the Netherlands had to go through the transition to the middle ages and the Dutch were still barbarians.' Van Sandick did agree, however, with the term 'new' from a development perspective (Van Sandick 1920; 492) 'Your chairman is nevertheless right in the sense that the technical development dates from recent times.'

⁵⁸ Hoogewerff et al (21)

⁵⁹ Apparently the commission did not regard the program in Bandoeng as academic; being academic was reason for Delft to include much mathematics. Compare with Van Doorn (1994), who states that the colony did not have an academic climate.

⁶⁰ Hoogewerff et al (17)

⁶¹ Klopper (1918; 3). How modern these words sound...

⁶² Klopper (1918; 3)

⁶³ Based on Klopper (1918)

⁶⁴ Interesting enough, with such an approach the Bandoeng curriculum could be labeled as an Indian version of the Anglo-Saxon Bachelor-Master structure.

- ⁶⁵ Full descriptions of the courses in Bandoeng are included in Ertsen (2005) and in Ravesteijn and Kop (2008)
- ⁶⁶ Groen (1988)
- ⁶⁷ Tropical rural engineering ('tropische cultuurtechniek', the MSc program I did myself between 1986 and 1993) was a mixture of a new program on rural engineering and old irrigation-based courses. Other elements of the old program survived as tropical crop science ('tropische plantenteelt').
- ⁶⁸ Baudet (1992)
- ⁶⁹ Groen (1988; 263)
- ⁷⁰ Brouwer (1955; 18)
- ⁷¹ Klein (1954; 4)
- ⁷² Klein (1954; 4/5)
- ⁷³ Klein (1954; 5). Several publications in 'De Ingenieur' on irrigation in the Netherlands (mainly on meadow irrigation) illustrate this statement.
- ⁷⁴ Although Berkhout himself was of the opinion that Eijssvoogel should have been appointed. Eijssvoogel had just been appointed in Wageningen, and unlike Haringhuizen in 1919, did not want to leave this post so soon. Berkhout had been the last engineer-head with the water boards in the Vorstenlanden; he may have been much more of a manager than a designer. In 1955 professor (A.R.H.) Brouwer, not to be confused with the other, much later, professor (R.) Brouwer (irrigation), became the successor for the hydropower part of professor Begemann's combined hydropower and irrigation professorship.
- ⁷⁵ A similar remark could be made of rural engineering in Wageningen; there were (are for that matter) two distinctive branches, one Dutch (European) and one tropical. In Wageningen, however, it has not been only a matter of region defining the difference, but also in including social, economic and political issues in the program. In Delft this last difference is less prominent.
- ⁷⁶ Eijssvoogel (1950; 341); see also Eijssvoogel (1946)
- ⁷⁷ Eijssvoogel (1950; 342). What Eijssvoogel defines as these principles are indeed foundations of the Dutch irrigation tradition, as we have encountered throughout this book.
- ⁷⁸ The partnership between Belgium, the Netherlands and Luxemburg.
- ⁷⁹ Berkhout (1954; 16)
- ⁸⁰ Schoemaker (1967)
- ⁸¹ Schoemaker (1967; 17)
- ⁸² Schoemaker (1967; 12)
- ⁸³ Schoemaker (1967; 21).
- ⁸⁴ Brouwer (1)
- ⁸⁵ National Archives 2.22.07 Invnr 144 (De Vos 1925; 120; underlining in original). Obviously, professor De Vos, who started his irrigation professorship in Bandoeng just before the course of 1921-1922 (Tweede 1922; 303) included his energy criterion in his (extensive) lecture notes. Collegesyllabi van prof. ir. H.C.P. de Vos, hoogleraar aan de Technische Hogeschool te Bandoeng. Irrigatie I en II, met aantekeningen van de student Tan Hwat Tang.
- ⁸⁶ Van Sandick (1891; 45)
- ⁸⁷ Like the work of De Meyier ('Deel I. Afdeeling VII. Bevlociingen'; 1888 and 1891), which was part of a larger series on hydraulic engineering entitled 'Waterbouwkunde'. This work included considerable attention to agricultural aspects (including sediment and nutrients for crops) and hydrology (the Lauterburg and Iszkowski formulas); it would not have been readily available for all students, however.
- ⁸⁸ NA 2.22.07 Invnr 107 (Lecture notes) Collegedictaten van prof. ir. C.W. Weijs over bevlociingen op Java. Z.j. (ca. 1915)

- ⁸⁹ It is this material which has been moved to the National Archives; in a way part of my work is based on the study material collected by Haringhuizen. See also Haringhuizen (1919)
- ⁹⁰ In 1924 the famous handbook of Van Maanen (1924, 1931) was published in *Weltevreden*; apparently De Vos did not use the book, which was directed at the 'technician at mid level' and 'has to and will find its way to secondary technical schools', but also to 'the polytechnics; 'the irrigation engineer would want to miss it on his book shelf' (all quotes by De Vogel in the foreword by the book, pXIV).
- ⁹¹ Those familiar with teaching at universities would have recognized the discussions by now, I suppose.
- ⁹² According to Schoemaker, the field of statistics in irrigation was a new phenomenon in the Netherlands; the East Indies would have been at least 10 years ahead on the Netherlands in this subject (Schoemaker, Personal Comment 2004).
- ⁹³ Lecture Notes Berkhout (1965; 47)
- ⁹⁴ Lecture Notes Berkhout (1965; 47). A student who designed a Parshall flume (with Berkhout as responsible professor) used the argument of robustness in favour of the structure! See below.
- ⁹⁵ Lecture Notes Berkhout (1967; 47-48; underlining in original)
- ⁹⁶ Schoemaker (Personal Comment 2004)
- ⁹⁷ With the only exception to this general rule the design description for the Tjipoenegara task, which does not include the detailed demands for drawings, scales and names/codes attached to elements of the system.
- ⁹⁸ As discussed by Van Rosse (1913) and Van Maanen (1924, 1931). The system proposed by Van Rosse (1913) gives rules how to indicate main, secondary and tertiary canals and structures; Van Maanen (1924, 1931) mentions two slightly different variants of the system. I will not discuss the rules themselves; what matters now is that whatever they were, students applied them.
- ⁹⁹ Graduation design Hasselt
- ¹⁰⁰ Lecture Notes Berkhout 1967; 15 (HV). The lecture notes of the short course only stated that the Van Rosse system 'was very satisfactory'. Lecture notes Berkhout (1965; p28)
- ¹⁰¹ Graduation design Hissink (1957; 17)
- ¹⁰² Graduation design Visser (1959; 31)
- ¹⁰³ Graduation design Visser (1959; 32)
- ¹⁰⁴ Graduation design Visser (1959; p33)
- ¹⁰⁵ Although Visser statement that (Graduation designs; Visser 1959; 23) '[c]apacity curves are applied in areas, in which sugar cane and rice are intermingled cropped' shows that coming loose from the Indian context was not always easy.
- ¹⁰⁶ Basically all students consider how to define capacities for canals, but most do not construct or apply a capacity curve. Most do construct a rotation schedule to minimize the peak flows in the system.
- ¹⁰⁷ Graduation design Ergus
- ¹⁰⁸ Graduation design Collard (1980; 12).
- ¹⁰⁹ Graduation design Meijer (1968; 15)
- ¹¹⁰ Graduation design Meijer (1968; 15).
- ¹¹¹ Graduation design (1973; 16)
- ¹¹² Graduation design De Jong (51)
- ¹¹³ The theory of De Vos deals with ways to determine sedimentation capacities of canal profiles.
- ¹¹⁴ Georganiseerd (1920; 399)
- ¹¹⁵ Georganiseerd (1920; 399)
- ¹¹⁶ Lecture notes Schoemaker (1982; 29)

¹¹⁷ Developed in the Gezira system in Sudan.

Chapter 9

¹ Stone (1984; p8)

² Ravesteijn (2002; 363)

³ Ravesteijn (2002; 383)

⁴ Ravesteijn (2002; 382)

⁵ Van de Poel (2003; 52)

⁶ Van de Poel (2003; 52; see for a much more detailed analysis Van de Poel 1998))

⁷ The general description of irrigation development by Van Sandick (1912) has been brought back by Ravesteijn (1997; 363-364) to this short version, although the distinction between the last two phases was much more an expression of the wishes of Van Sandick than reality, as he wrote his history in 1912...

⁸ Vlugter (1949)

⁹ Ravesteijn (1997), Ravesteijn (2002)

¹⁰ Ravesteijn (1997; 364)

¹¹ I did not start in 1830, as I did not point out specific events in this period. Just after 1870, De Bruyn and his Commission presented the report which can be regarded as the first expression of an attempt to formulate guiding principles to shape colonial irrigation.

¹² Van de Poel (2003; 55)

¹³ Van de Poel (2003; 55; note 11; emphasis in original).

¹⁴ This principle still works in modern times, it was literally explained to me by the Japanese head of the design team responsible for the Bekri and West Rumbia extensions when I visited Lampung in June 2003; his room for manoeuvre was determined by the Indonesian Irrigation Design Standards of 1986. When he had good reasons, expressed in design reports with the necessary argumentation, the designs made could differ from the Standards. In a way, Delft civil engineering students had their own design standards in the shape of lecture notes and design tasks.

¹⁵ These findings are in line with Geels (2002), who concludes that 'novelties first in [sic] emerge in technological niches [...]. The novelties often contribute to solving problems in the existing regime. The interpretation of the functionality of novelties often occurs with categories from the existing regimes.' (Geels 2002; 322).

¹⁶ One element of the new political realities after World War II was the growing role of the USA in international policies in general and in water development in particular. The example model of the Tennessee Valley Authority (T.V.A.) became popular; many of the reasons for the success of the T.V.A. seemed applicable to the economic situation of developing countries. Many larger scale water resources development plans saw the light in the context of development cooperation; the Welfare Plan developed by Van Blommestein acts as the (early!) East Indian (or Indonesian) version of this new development perspective. The regime development process I reconstructed in this book cannot include the Welfare proposal very convincingly; it is almost like Van Blommestein attached a new level to the activities of civil engineers and water resources planners. The issues raised by Van Blommestein, including the differences in water availability in the West and East Monsoons and reservoirs to partly deal with these differences, were not new in the debates on irrigation in the East Indies; I think, however, that the solutions he proposed connect very closely to a post-War USA-based water resources development model and no longer to an irrigation development model.

¹⁷ See Mrázek (2002)

¹⁸ Or like for that matter.

¹⁹ Picon (2004; 423; compare with Bijker 1995)

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