6 FROM PROJECTS TO SYSTEMS: THE EMERGENCE OF A NATIONAL HYDRAULIC TECHNOCRACY, 1900–1970

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Between 1900 and 1970 Dutch water management became a "hydraulic technocracy." This does not mean that civil engineers literally exercised political power as leaders, ministers, or parliamentarians—though they did all of these. "Technocracy" in this case was a situation in which engineers tackled problems in the sphere of water management and road transport—*according to their own perspective*. This "technocracy" rested on a power to identify problems and imagine solutions without really having to take into account the opinions of non-experts. It rested in part on the ascendance of what Monte Calvert famously called "school culture" over traditional "shop culture": the replacement of empirical knowledge by authoritative "engineering science."

The laws on the two largest coastal engineering projects of the twentieth century—the closing and reclamation of the Zuiderzee (passed in 1918) and the so-called Delta Works to dam off the estuaries in the southwest part of the country (passed in 1957)—were symptomatic of this technocratic spirit. They were inspired by exhaustive studies and recommendations by leading civil engineers who themselves had defined the problem and the therapy. Moreover, the texts of the laws themselves were extremely succinct—taking no more than a few pages in the parliamentary record to sketch the basic features of the project. All the details regarding the kinds of infrastructure, the timing, the method of construction, and so on were not dictated and were regarded as the prerogative of the engineers. Hence, within a flexible mandate and an elastic budget, civil engineers, and the Rijkswaterstaat in particular, came to enjoy enormous latitude in defining and solving their own problems. During this period large parts of the Netherlands became their hydraulic playground and the organizations they led and staffed became among the most powerful in the country.

This new hydraulic technocracy was not only a shift in power from lawyers and bureaucrats to engineers, it also involved a new scale of planning and building. Although the idea of "hydraulic systems" was by no means novel—as in the river management in the nineteenth century—after the turn of the century it gradually became a cornerstone of Dutch hydraulic engineering. Whereas "projects" had been the basic unit of engineering imagination in the nineteenth century, now regional and even national "systems" became the dominant mode. This approach was coupled to new kinds of systematic knowledge and, eventually, more centralized hydraulic administrations. Both were fostered in turn by the promotion of engineering education from the sphere of secondary education to that of higher education in 1905. In that year, the Delft Engineering School, which had a monopoly on the education of state engineers, became the Delft Technical High School, equivalent to the classical universities in everything but the name. Its professors were granted the *Ius Promovendi,* which not only increased the prestige of the engineering sciences but proved to be an important stimulus for fundamental applied science research—including research in civil engineering.

There had been few indications during the last quarter of the nineteenth century that this kind of technocratic future was in the offing. On the contrary, many signs pointed to the dawning of a new populist era in Dutch politics and, by the same token, water management. This had to do with the gradual erosion of liberal hegemony by new political movements. Although the liberal revolution of 1848 had given an immense impetus to the consolidation of national water management and to the implementation of a great number of water management and infrastructural projects, by the 1880s the liberal engine had begun sputtering. By then the liberal example had created space, institutions, and resources for new social movements that were challenging the old liberal monopoly and making politics more complex and contentious. After 1870, Catholics and socialists also began an assault on state power, and by the end of that decade a progressive liberal movement was taking shape that challenged both the old liberals' unconcern with the social injustice generated by unbridled industrialization as well as their horror of a state that intervened in the free market system.

It may have seemed that in this new era everything—including water management—would be utterly politicized. The ideological mobilization of the public, especially in new "populist" Catholic and socialist political movements, promised an active, alert citizenry that would impress its will on the state and make its own demands in the fields of infrastructure and water management. As the poet Albert Verwey, co-founder of the influential literary and political journal *De Nieuwe Gids* (1885), put it: "This is a time of passion, rather than of introspection." People "have things to say that brook no delay and their movements are the movements of people that suddenly take action."[1] This cultural climate stood in sharp contrast to the era of classical liberalism in which the spokesmen of commerce, industry, and liberal ideology were the moving forces, using the state as a tool to ease the way of economic progress and to secure the physical integrity of the land.

Water management became embedded in this politicized and "pillarized" world. It was now potentially a bone of contention among the political pillars. The rise of religious pillars with strong constituencies in the countryside or a specific regional focus on the Catholic south, threatened to make water management once again a contentious business. Protestant agrarian interests pursued improved drainage and water management of small rivers and the reclamation of "wild lands" in the eastern part of the country. The Catholic pillar clamored for similar measures in the Catholic provinces of North Brabant and Limburg, with the Limburg bourgeoisie also advocating the canalization of the Dutch Meuse.

Nonetheless, there were many regional projects that represented a generic (that is, non-pillarized) interest in safety, economic progress, and competitiveness. This applied to reclamations, flood control, and especially to waterways. In the second half of the nineteenth century the classical liberals had enlarged and upgraded the waterways in the core western provinces; there was now an ever-increasing clamor to extend this core network into the peripheries. The Zuiderzee closure, the Meuse canalization, and a project for a canal system between the Twente textile cities and the

Weir at Grave, one of the weir construction projects in the Meuse canalization program, aimed at facilitating navigation for bulk transport, completed in 1929

Rhine were all examples of this new regionalism, as well as the improvement of the peripheral harbors of Vlissingen, Delfzijl, and Harlingen. Because until 1918 parliamentarians were elected on a regional basis, water management was handled in Parliament on the basis of local and regional interests. Successive governments had to maintain at least the appearance of equitable distribution of resources among the regions. While this did not absolutely paralyze progress, it did demand long and tedious negotiations that considerably slowed the pace of water management projects during the first two or three decades of the twentieth century. This phenomenon might be viewed as a Dutch version of American "pork barrel" politics.

The new pillarized and regionalized politics of water management also had negative effects on the Rijkswaterstaat during this period. While the organization had flourished under the liberal "project," it seemed to flounder in the new and much more complex world of political water management. This may have been due in part to its own basically regional organization—with the provincial directorates identifying first and foremost with their own provincial water management interests. Up to and through World War I (in which the Netherlands remained neutral) the Rijkswaterstaat proved incapable of exercising leadership in the domain of water management. Matters were not helped by the fact that the organization was also

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Normalization of the Meuse River, ca. 1935

struggling to master a number of new civil engineering technologies, including electrical power, reinforced concrete, and steel construction.

However, in the 1920s a new spirit seized hold of the Rijkswaterstaat and the new *Dienst der Zuiderzee-werken* (Zuiderzee Service). Hydraulic imagination began to transcend local and regional projects and to conceive of national systems of flood control, navigation, and fresh water supply. New technologies were applied and their impact carefully studied. The new élan was confirmed by the reorganization of the Rijkswaterstaat in 1930, which shifted power from the provincial peripheries to a national command center and provided new organizational niches for specialization and research. Although the Zuiderzee Works were carried out by a formally independent organization, several of its leading engineers were former Rijkswaterstaat employees, and the new style of planning and construction was rapidly adopted by the Rijkswaterstaat as well. During the 1930s, for example, the theoretical groundwork was laid for the Delta Works that were carried out in the wake of the massive 1953 flood.

The long period of reconstruction after World War II provided ideal conditions for reinforcing the new interventionist state and developing a strong central planning dynamic. Doing so was mainly a reaction to the economic recession of the 1930s and the chaos and devastation of the war. But the example of the German

Rijkswaterstaat

Johannes Aleidis Ringers (1885–1965), director-general of the Rijkswaterstaat (1930–1935) and Commissioner for Reconstruction (1940–1943)

occupation had ironically fostered a new appreciation of a strong central administration's planning role, symbolized by the appointment of Rijkswaterstaat boss Johannes Ringers to the post of commissioner for reconstruction during the occupation. The experiences of the period 1930–1945 left their mark on the postwar social and political climate. There was a widespread call for more government coordination. There were also inspiring foreign examples: Roosevelt's New Deal was admired by many; and the 1942 report, *Social Insurance and Allied Services*, by the British economist and politician W. H. Beveridge, containing proposals to set up a social security system and a national health system, was also influential in the Netherlands. In the 1950s and 1960s, consecutive Dutch governments increased state intervention in many fields. Until 1960, the government determined wage levels in every economic branch; it designed ambitious industrial development plans; it planned huge housing production schemes; and it invested heavily in the national infrastructure. In this period of frenzied modernization, nature was sacrificed to industrial zones and traditional landscapes were transformed into large-scale agricultural plots in the interest of improving agricultural productivity.

After 1960 the Dutch welfare state came into being and with it a variety of new allocations and benefits. Though there was a basic consensus among the political parties about these kinds of government re-allocation, they disagreed about the extent and the scope. The Social-Democrats were strongly committed to the planned economy; the Christian-Democrats, on the other hand, were rather reluctant to support big government. Instead, they set out to create tripartite consultative institutions, where government, business representatives, and labor unions held discussions and gave advice about social-economic issues. These institutions, the Social-Economic Council (*Sociaal-Economische Raad*) and the Labor Foundation (*Stichting van de Arbeid*), were successful instruments for reaching compromises on a wide range of issues. Between 1948 and 1958 the Christian-Democrats and Social-Democrats formed government coalitions. After that, the Liberals replaced the Social-Democrats. Nonetheless, by international standards, government intervention remained strong. In 1946 the Liberal leader, Pieter Oud, made a cautious, but revealing remark: he was not against government planning, he said, provided its scope did not exceed certain limits. Oud's flexibility mirrored not only contemporary liberalism's underdog role, but also its conceptual pallor.[2]

The era between 1940 and 1970 was also shaped by great confidence in technology and its problem-solving capacities, an attitude that was already discernible in the

1920s and 1930s. Engineers had an exalted professional status and their unchallenged social position certainly helped to legitimize government policies, to a considerable extent shaped by top-down planning, research and, in general, expert opinion. Technical education was expanded further with the establishment of two new technical universities, at Eindhoven (1956) and Twente (1961). Technical vocational training also attracted more students as more special technical schools were created.

A rational, confident, forward-looking orientation was widespread in Dutch society, fostered by the economic boom, full employment, and rising prosperity.[3] Besides, until the late sixties, the leaders of the main ideological pillars—Social-Democrats, Protestants, and Catholics—cooperated on critical social issues, while simultaneously keeping their adherents under control. In this climate of political stability, respect for authority, general confidence in technical solutions, and a growing government budget, the Rijkswaterstaat's power grew to unprecedented heights.

Repairing the immense war damage (under the Rijkswaterstaat's supervision) had been the first item on the agenda in 1945. Numerous bridges were rebuilt and waterways were swept clear of wrecks and mines. Once this emergency work was done, a huge infrastructure construction program shifted into gear. A freeway network, outlined in national schemes published from 1927 onwards, was built; new canals were constructed and existing ones enlarged; sluices, bridges, and tunnels were built. In 1952 the Amsterdam-Rhine Canal was finished: upon completion, the huge locks at Tiel were the largest in Europe. In 1953 the Twente Canal was opened for shipping. It also served regional drainage. Canals in Noord-Brabant and Friesland followed. In 1957, after much delay, the Rijkswaterstaat completed its first tunnel at Velsen, under the North Sea canal.[4] The opening attracted so many car drivers that a traffic jam ensued—still a rare phenomenon for that time. A spectacular project, carried out in a partnership with the city of Rotterdam, was the seaward expansion of the Rotterdam Harbor. The Rijkswaterstaat built a new harbor entrance on the coast and created a huge harbor development zone (Europoort), where not only shipping quays but also petrochemical plants were set up. In response to a request by American shipping companies, the quays and industrial parks were designed

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Beatrix Lock in the Amsterdam-Rhine Canal; see map in chapter 1

Bart Hofmeester

Shell's oil refinery at the huge petrochemical complex in Europoort, symbolizing the expansion of the Rotterdam harbor after 1945

at a height of 5 meters (16.4 feet) above mean sea level. These projects were supported by the Rijkswaterstaat's new research departments, built up since the late 1920s, and epitomizing the Rijkswaterstaat's dominance *vis-à-vis* the provinces and the water boards. The provinces, swept along with the current, likewise expanded and improved their provincial canal and road networks.

OLD IMPULSES, NEW CONCERNS, AND NEW TOOLS

During this long period between the turn of the century and the turn of the political tide in 1970, the two traditional pillars of Dutch national water management—floods and waterways—were joined by a third, water quality. The threats of floods, from swollen rivers and storm-swept seas, continued to be the main prod to national activity in the field of water management. Three floods in particular had a big impact: the Zuiderzee flood of 1916, the Meuse River floods in Gelderland, Brabant, and Limburg in 1926, and finally the disaster of February 1953, which inundated a good part of the southwestern delta. As in the past, these disasters were powerful catalysts for initiating costly engineering plans.

The record flooding on the Meuse in 1926 was a call to arms. The responsible engineer, Cornelis Willem Lely, immediately drew up a plan to improve the river's discharge capacity so that it could handle high river stages without flooding and without the infamous Beers floodway as a relief valve. Lely was the son of Cornelis Lely, the spiritual father of the Zuiderzee works, as discussed below.[5] Lely's plan was basically to normalize the river between Blauwe Kamer and Grave (the site of the most downstream weir complex of the existing canalization project completed between 1919 and 1929). The plan proposed rectification—that is, elimination of meanders—and normalization—that is, achieving uniform channel breadth and depth. In order to ensure sufficient draught for navigation in the streamlined river at low stages, Lely also proposed extending the existing canalization downstream by building a final weir at Lith. The ten-year project was started in 1932, at the height of the Great Depression, and was financed in part under a public works scheme that enabled Rijkswaterstaat to conscript unemployed laborers.[6] Both of the other major hydraulic projects of this period—the enclosure of the Zuiderzee and the Delta Works—were also initiated in response to extensive floods. These tragedies converged with the emergence of the more proactive engineering culture, at least among Rijkswaterstaat engineers. Plans to prevent catastrophes were now being made ahead of their actual occurrence, even though it often still took the disaster itself to get the plans through Parliament.

The second traditional driver in the field of water management was nautical transport, extending as far back as the reign of King William I, the "canal-king." This driver did not apply only to the "core" waterways system centered on the harbors of Rotterdam and Amsterdam, with their artificial seaways and the large-scale rivers and canals connecting them to distant hinterlands. After the turn of the century, industrial and mining centers in the peripheries also demanded competitive modern connections to the core waterways system. These pressures kept Rijkswaterstaat at work. Not only the Twente canal was built in this period, but in the 1920s several Meuse sections were canalized and in the 1930s the Meuse section bordering on Belgium was bypassed by constructing the Juliana Canal.

Canalization of the Meuse in Dutch Limburg had been contemplated since the 1860s, inspired partly by the example of Belgium, where large sections of the Meuse were being canalized at that time. A joint Dutch-Belgian Commission (1906–1912) presented an ambitious canalization report, including the canalization of the common "Border Meuse," but World War I intervened. After the war the Dutch developed these plans into their own canalization scheme for the Dutch Meuse downstream of the Border Meuse, spurred by a pressing demand for cheap coal transport from the highly productive Limburg coal mines. To enable navigation at different river stages, Rijkswaterstaat designed five huge movable weir complexes between the towns of Linne and Grave, adapting British, Swiss, and German technology to the situation of the Meuse. The canalization scheme, carried out between 1919 and 1929, thus became an open-air school for Rijkswaterstaat engineers in which they learned how to integrate technologies of reinforced concrete, steel construction, and electrical power into complex weir and lock designs.[7]

However, in contrast to the previous period, the rivers and waterways were no longer the main act, although major river management and navigation projects continued to be executed. The most spectacular projects were the two "flood-management" systems mentioned above, involving a drastic reduction of the length of coastline that could be exposed to the ravages of storms and storm surges at sea.

As early as the 1930s, the old impulses of navigation improvement and flood management were joined by concerns about the very *quality* of fresh water. "Pure" water—or at least water that could be used for macro-hydraulic, agricultural, and domestic purposes—gradually became scarce. This shortage was due in part to increased demand, as a result of population increase, the growth of greenhouse farming, and industrialization; in part to increasingly stringent quality demands made possible by improved analytic techniques; and in part to the increasing pollution of fresh water by both urban and industrial polluters and by saline intrusions from the sea. Surface water salinity was considerably increased by the large new seaways connecting Rotterdam and Amsterdam to the sea. These were not only highways for world trade, but also conduits for salt water from the sea. Another source of salinity was the Rhine, which was burdened by increasing amounts of salt waste from German coal mines and industries and later from the Alsatian potash mines. This situation was a double-bind because it was only thanks to the Rhine's copious supplies of fresh water that Dutch water managers were able to keep the maritime salt intrusions at bay and to flush the polders—at least in times of moderate to high river stages. This new set of issues began to shape the water management agenda on its own, ultimately to become integrated into the more traditional flood control projects and transportation infrastructure.

The scope and scale of the new water management agenda had its counterpart in a new range of basic technologies that had emerged by the turn of the century. New tools, theories, methods, materials, and energy sources held the promise of a revolution in civil engineering practice. Reinforced concrete and steel construction made it possible to build large and strong monolithic structures at previously unimagined scales. Electricity was a flexible conveyor of energy and a subtle medium of control. Sheet-piling and deep-well pumping created a way of realizing ever deeper foundation pits. New hydrodynamic theories and experimental methods provided safe guides to increasingly daring and cost-effective designs. All these innovations promised dramatic increases in both the scale and subtlety of civil engineering projects. The major challenge for the Dutch civil engineering community in general, and Rijkswaterstaat in particular, was how to appropriate these new technological promises into an effective and efficient management structure. There was a thin line between caution and conservatism that was not always appreciated by outsiders and politicians, and on several occasions—especially in the first three decades of the twentieth century—it proved difficult for the Rijkswaterstaat to justify its claim to being the most competent and technologically advanced actor in Dutch water management.

Lack of trust influenced the 1918 decision not to charge the Rijkswaterstaat with the enclosure and reclamation of the Zuiderzee. The government's decision to entrust this mammoth project to a new agency directly responsible to the minister was a serious blow to the Rijkswaterstaat's self-esteem. The general dissatisfaction with the performance of the Rijkswaterstaat since the 1890s in fact prompted the minister to appoint a commission (the so-called Rosenwald Commission) to prepare plans for a thorough reorganization. The decision to exclude Rijkswaterstaat from the Zuiderzee

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Cornelis Lely (1854–1929)

works was taken by a minister of waterstaat, commerce, and industry who was himself a civil engineer, Cornelis Lely. As a young engineer in the service of the Zuiderzee Association, a private lobby group promoting closure and reclamation of the Zuiderzee, Lely had in 1891 himself proposed the scheme that would ultimately be carried out. The lethargy, conservatism, and outright skepticism of the Rijkswaterstaat at the time had apparently made such an impression that, years later, Lely still had a very negative image of the agency and judged it unfit to undertake the project.[8] Lely's immediate successor as minister, the Catholic electrical engineer and former professor at Delft, G. J. Van Swaay, had similar problems with the Rijkswaterstaat in connection with the canalization of the Meuse. In response to a dispute about an appropriate design for the weir at Grave, he lectured his two inspectors-general as follows:

> *It has given me very little satisfaction to be forced to conclude that the study of the requested information has been carried out with such a lack of initiative, that so little independent judgement has been manifested and that, out of the conflict of opinions among those whom I have asked for advice, no clearly circumscribed proposals have been forthcoming.*[9]

All this changed for the better after 1930 when, partly in response to the 1926 report of the Rosenwald Commission, the Rijkswaterstaat was reorganized. Although the outmoded regionally based structure was not abolished, it was encapsulated in a much more hierarchically organized command structure which considerably shortened the interminable internal debates that had previously paralyzed action. The organization was now headed by a single director-general who not only had very strong powers within the agency but who also was directly responsible to the minister, thus shortening the chain of command by bypassing a separate hydraulic bureaucracy in the ministry itself. The first incumbent of this post—perhaps fortunately for the Rijkswaterstaat—was the brilliant civil engineer Johannes Aleidis Ringers.[10]

Ringers had been a student of the prolific Jacob Kraus who, as professor of civil engineering and rector at Delft in the first decade of the new century—and later as minister of waterstaat—had propagated the modernization of Dutch civil engineering as a scientifically innovative and economically oriented discipline.[11] As a Rijkswaterstaat engineer, Ringers carried this concept of civil engineering to new heights. As early as 1912 he had designed and supervised the highly innovative construction of a large lock at Hansweert in the canal through South Beveland on the waterway between Rotterdam and Antwerp. At Hansweert, Ringers created what was arguably the Netherlands' first economically rational construction site, utilizing a number of innovative technologies. He applied electrically powered deep-well pumping to keep the deep construction pit dry; he used reinforced concrete for the piling, floors, sills, and walls of the lock; and he employed the first of many floatable riveted-steel horizontal rolling lock-doors to be used in Dutch locks.[12] In the mid-1920s he applied these early lessons to the world-class North Lock at IJmuiden at the entrance to the North Sea Canal. This lock, which for many years after its completion in 1930 remained the largest in the world, also pushed the envelope on numerous points of design and construction. Among other things, the innovative use of scale-model experiments (at Prof. H. Krey's *Preussische Versuchsanstalt für Wasser- und Schiffsbau* in Berlin) enabled Ringers to save a million guilders—a huge sum in 1921—by replacing the cumbersome longitudinal filling manifolds in the lock walls with short tunnels circumventing the doors.[13] Doing so made it possible to construct the walls much thinner, lighter, and higher, and hence more

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The IJmuiden North Lock construction site, ca. 1925

cheaply. Upon the completion of the lock, he served as president-director of the contractors' conglomerate charged with building the dam to close off the Zuiderzee. Two years later he was appointed the first chief of the new Directorate of the Waterstaat, with the title of director-general and directly responsible to the minister. The new directorate included both the Rijkswaterstaat and the Zuiderzee Service.

Ringers applied his considerable technical and organizational experience to restoring a sense of purpose and dignity to the Rijkswaterstaat. He set about his task with patience, taking two years to produce his master plan for reorganization. Meanwhile he recruited a number of like-minded engineers to fill vacancies in leadership positions and he created several new specialist agencies that could begin to function as the innovative "brains" of the organization. Contrary to what some expected, Ringers' plan left the old regional organizational structure more or less intact. Though there were good reasons to do so, this aspect of the plan has also been interpreted as a smokescreen serving to quash potential dissent by hiding Ringer's real objective of relocating the Rijkswaterstaat's dynamism to specialist departments partly outside the regional structure.[14] He himself set the precedent by arranging for the construction of the North Lock at IJmuiden to be organized as an independent project directly under the minister's supervision and independent of the Rijkswaterstaat's regional structure.

Ringers also made crucial decisions that finally put the plans for a national hydraulic experimental station on a firm footing. In view of the Rijkswaterstaat's increasing use of hydraulic scale models, it would have been convenient for it to have had its own in-house hydraulic laboratory, but Ringers recognized the value of an independent academic standing in cases where scale-model experiments were necessary to resolve disputes about hydraulic projects.[15] The new laboratory was therefore organized as a foundation in which the Rijkswaterstaat participated, but it was organizationally integrated into and physically located at the Technical High School at Delft and used partly as a teaching laboratory by Delft's Civil Engineering Department.

The creation, in 1930, of the Research Service for the Tidal Rivers within a Directorate for Tidal Rivers was particularly consequential. This agency, headed by the extremely bright, ambitious, and headstrong engineer Dr. Johan van Veen, was charged with mapping, measuring, and producing plans for what Ringers described as the "general improvement" of the tidal rivers and estuaries in the southwest part of the country. Over the course of the 1930s, Van Veen and his staff would transform this mandate into a research project to calculate the propagation of marine storm surges into the Dutch estuaries and further upstream, including the construction of a huge electromechanical analog tidal computer. They also advanced a number of schemes for radical reconstruction of the estuary system which, after World War II, would provide the basis for the Delta Plan. Its backdrop was the Delta Plan's predecessor: the first major coastal reconstruction and reclamation project of the twentieth century, the Zuiderzee Works.

THE IJSSELMEER AND THE DELTA: A NATIONAL SYSTEM FOR FLOOD PROTECTION, FARMLAND AND FRESH WATER

THE ZUIDERZEE WORKS

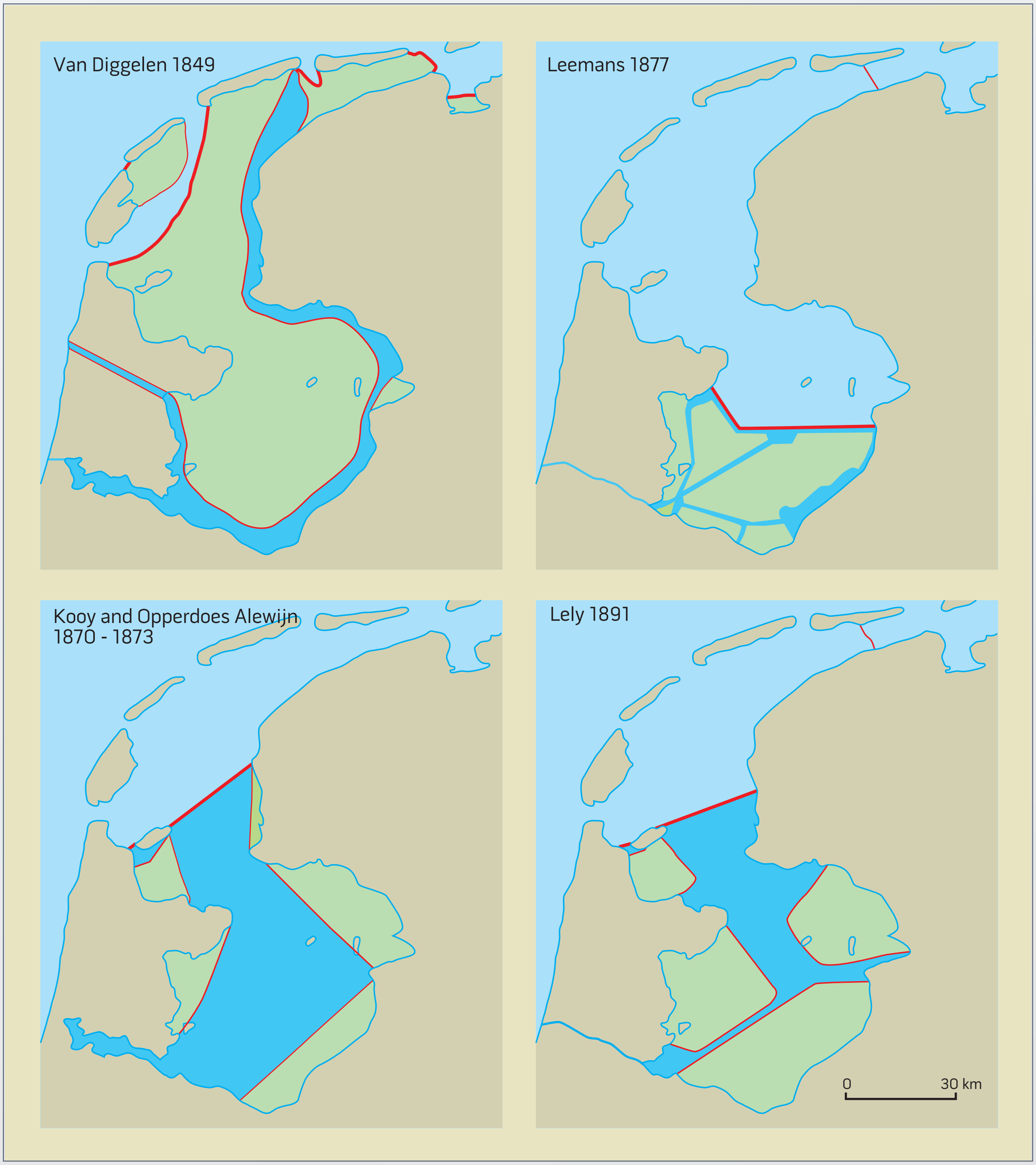
The Zuiderzee project, the largest twentieth-century Dutch reclamation project and an icon of modernist planning and engineering, has a long history. The first nineteenth century plans for this huge undertaking had a dual motivation. They focused on an agricultural enterprise economically justified by prospects of being able to sell the reclaimed land to farmers for a profit. However, like many of its predecessors, the Zuiderzee project proposals were equally motivated by concerns over flooding, as storm surges in the Zuiderzee repeatedly caused havoc along its coasts. Nearly every generation witnessed a major flood disaster. There were particularly heavy storm surges in the years 1717, 1775, 1776, 1808, and 1825.[16]

Subsequent to the Haarlemmermeer's successful drainage, a great number of more-or-less visionary plans were put forth for reclaiming what many seemed to think was only its somewhat bigger brother, the Zuiderzee. However, the fact that the Zuiderzee was a maritime bay filled with salt water, subject to tides and currents, made the purported "family resemblance" rather specious. In fact, the Zuiderzee was in another league entirely.

The first plans that were developed in 1848–49 were chiefly advanced by Frisian agricultural interests and were designed to drain and reclaim almost the entire Zuiderzee (and part of what is now the Waddenzee) by extending the reclamation not only along the east coast of North Holland but also to the coast of Friesland and even a part of the Groningen coast. In 1875, however, the Rijkswaterstaat engineer Leemans proposed a more modest plan to enclose and reclaim only the southern part of the Zuiderzee. This would leave the sea dikes in Friesland, North Holland, and Groningen still facing open tidal salt water, which would be difficult for drainage and virtually useless for irrigation. Worse yet, common sense suggested that the enclosing dam would raise water levels on its seaward side and place these sea-dikes in even greater jeopardy from storm surges. In any event, the government fell and the bill pending in Parliament was withdrawn. But it was clear, at least to

Four Zuiderzee Reclamation Plans, 1849–1891

Top left: Van Diggelen's 1849 plan; top right: Leemans' 1877 plan; bottom left: Kooy's and Opperdoes Alewijn's 1870–1873 plan; bottom right: Lely's 1891 plan. Lely's plan encompassed the basics of the later Zuiderzee Works. Lely designated four polders: (clockwise) Noordoostpolder, Flevoland, Markerwaard, and Wieringermeer.



Matrijs, Utrecht

some, that the interests of the northern provinces would be served only by a plan in which the enclosing dam was positioned well to the north—hence, the founding of the Zuiderzee Association in 1886.

Initiators of the Zuiderzee Association were Age Buma (agricultural consultant, member of the Frisian Agricultural Society, member of Parliament) and P. J. G. van Diggelen (lawyer in Zwolle and son of civil engineer B. P. G. van Diggelen, author of another very ambitious 1849 plan to enclose the entire Zuiderzee).[17] Membership in the association was open to provinces, municipalities, water boards, and private citizens. It was financed by membership dues and donations. Formally, the association aimed at the publication of a well-wrought plan, based on its own research, for the enclosure and reclamation of what they called the "entire" Zuiderzee.

Neither the civil engineering establishment enthroned in the Royal Institute of Engineers nor the Rijkswaterstaat were convinced; official opinion held that such an ambitious reclamation would be foolhardy. The technical feasibility was doubtful and, even if it could be done, there would hardly be profit in it. So around 1890 the curious situation arose of a private association framing an assault on the civil engineering establishment (and the Rijkswaterstaat in particular) with the aim of advancing a regionally-inspired plan for a Zuiderzee reclamation. The assault was facilitated by a Parliament based on regional representation, and the weapons were hydrological science, meticulous data gathering, and economic reasoning—all larded with visionary utopianism.

The founding of the Zuiderzee Association and its dedication to science and data was basically a response to Parliament's rejection of a plan put forth by Buma in 1882—using his right of initiative as parliamentarian. Buma's plan was a minor reworking of the already discredited "total" approach favored during the early years of the liberal revolution, with as its major virtue the inclusion of the Frisian and Groningen coast in the enclosure scheme. Frustrated by the rejection of the plan and the refusal of Parliament and the government to subject the question to a proper scientific investigation, Buma and Van Diggelen considered it time to take matters into their own hands by founding the Zuiderzee Association and hiring a young Delft-trained engineer to undertake the necessary research to produce a robust plan based on their particular view of the matter.

By 1891 the young engineer, Cornelis Lely, had produced a new plan for the closure and partial reclamation of the Zuiderzee, based on four years of intensive research, both in the literature and on board a survey vessel in the Zuiderzee itself.[18] Thanks to this work, Lely had been able to produce a detailed map of the sea bottom and he could therefore situate his reclamations where the seabed promised to be most fertile. The reclamation of the four, later five, individual polders was to be preceded (with the exception of the first, the Wieringermeer) by construction of the main closure dam. The dam would eliminate tides in the now-enclosed sea and, because of the influx of fresh water from the IJssel river coupled with drainage through sluices in the dam at low tide, rapidly turn the sea into a freshwater lake. Once this had been accomplished, the four remaining ring-dikes could be constructed, the water pumped out to form polders, and the land prepared for occupation. Lely's inclusion of the mouth of the IJssel River behind the closure dam required not only large tidal sluices in the dam but also a large buffer lake to store the river's discharge in the event of protracted high river stages or storm surges at sea. The large lake was not only hydraulically advantageous, it also promised to be an important resource for water management (drainage, irrigation, and flood control) in the provinces surrounding the proposed reclamation. It was, in short, a *system* for water management—with multipurpose management features—but also a plan that still had too few supporters to be taken up in Parliament or to be of interest to the Rijkswaterstaat or the ruling government. However, inasmuch as Lely had been asked in the summer of 1891 to assume the post of minister of waterstaat, trade, and industry in the left-liberal cabinet headed by Gijsbert van Tienhoven, this state of affairs was about to change. His new position enabled him to further the Zuiderzee reclamation as a national project. Although as minister Lely had many irons in the fire (for example, he devoted much energy to progressive labor legislation), he did not lose sight of his Zuiderzee plans and in 1892 appointed a broad-based government commission to make recommendations on how to proceed. The commission's report of April 1894 was overwhelmingly in favor of reclamation along the lines of Lely's 1891 plan; but before matters could be put to a vote the government collapsed, and the project was shelved. Nonetheless, it was clear there was now consensus on a practical plan for partial reclamation of the Zuiderzee, though numerous questions remained about the economic justification and the technical feasibility.

By the turn of the century, the plan was firmly fixed in the national consciousness and had acquired an importance far beyond the regional northern interests initially pursued by Buma and the Zuiderzee Association. In addition to the "agrarian" improvement of the surrounding territories—improved drainage, flood protection, and fresh water for irrigation—it had also acquired significance as a new framework for safer inland navigation as well as providing a route for a much shorter railway link to the north via the enclosure dam. In 1901, Lely, during a second term as minister, again submitted a Zuiderzee bill to Parliament, but again the collapse of the government halted progress.

A third attempt was made in 1907 by a new minister of waterstaat, trade, and industry, the dynamic Delft civil engineering professor Jacob Kraus. Though this government was also short-lived, the bill stayed on the books until 1913. Meanwhile, details of the project, such as the proposed method of building the enclosing dam using traditional materials like sand and basalt-ballasted willow mattresses came under attack in the popular and the engineering press. A number of commentators—several from outside the engineering establishment—proposed revolutionary new designs using reinforced concrete caissons, claiming that construction on the basis of the existing plans was hopelessly outdated and would be needlessly risky and expensive. However, reinforced concrete was far from a proven technology for hydraulic works, and in order to settle the matter and save the project from public deconstruction of its technical feasibility, the Zuiderzee Association appointed a Reinforced Concrete Commission in 1909. Two years later, this commission returned a split decision, with the majority underscoring the advantages of using reinforced concrete caissons to effect the closure, but an important minority stressing the great risks involved. It seemed that parliamentary ratification of the pending bill was farther away than ever.

Half a decade later, however, events had conspired to change the odds again. In 1913 Lely had accepted a third term as minister on condition that he be given free rein to see a new Zuiderzee bill through Parliament. He started his campaign by retracting the pending bill and appointing a commission to reassess the economic underpinnings of the project—assuming that Parliament would want to see a profit before it consented to invest the money. However, this time nature intervened. In January 1916 a severe storm surge caused dikes to be breached at several places around the Zuiderzee. The entire countryside north of Amsterdam flooded and, standing on the city quays along the southern shore of the IJ, the inhabitants of the capital were able to see with their own eyes the danger of an open Zuiderzee. Lely took advantage of the flood to underscore the importance of the Zuiderzee project for flood control and submitted a new bill to Parliament.

But the 1891 plan on which the bill was based had situated the closure dam such that the northern coasts of Friesland and Groningen remained unprotected. There were concerns in the north that the new dam would, in fact, increase the average height of tides along these coasts, and in that way also raise the height of storm surges—thus actually *increasing* the threat of flooding. Opinions differed regarding this claim and there was no consensus about an appropriate method for determining the new dam's effects on water levels. To alleviate the uncertainty and the associated resistance in Parliament, Lely appointed a commission in 1918, headed by the Leiden University physicist and Nobel Laureate Hendrik Lorentz, to solve the controversy on the basis of a mathematical analysis. In the course of the next eight years Lorentz and his associates took many measurements and devised an entirely new method of calculating the propagation of tides through systems of estuarial tidal channels, an approach that would prove extremely fruitful in years to come.[19] The commission's report appeared in 1926 and predicted a rise of nearly a meter near the point where the dam joined the Frisian coast. This prediction corresponded within just a few centimeters to actual measurements after the dam was built—an outcome that did much to bolster trust in mathematical modeling.[20] The Lorentz report also indicated that the closure dam alignment had to be modified. The seafloor in the vicinity of the Frisian coast offered no solid foundation for the two complexes of five drainage sluices that were projected there, complementing the three complexes of five drainage sluices that had been designed at the southern tip of the dam. A bend in the alignment near the Frisian coast solved this problem. This bend also reduced high water levels at this spot.

Fortunately, Lely did not have to wait for Lorentz's results to proceed with his project. By 1918 critical food shortages during the closing months of World War I convinced many parliamentarians that food self-sufficiency was an important national goal and that the 200,000 hectares of agricultural land promised by the Zuiderzee project would go a long way toward meeting the country's needs in this regard. Hence in June 1918, even before the end of the war, a concise three-page law was passed committing the government to constructing a dam across the Zuiderzee between Den Oever and Piaam and to reclaiming five polders according to the outlines of the plan of 1891. In June 1920 the construction of the first section of the dam between the mainland of North Holland and the island of Wieringen was undertaken.

As noted above, Lely's doubts about the flexibility and zeal of the Rijkswaterstaat led to his creation of a new dedicated organization—the Zuiderzee Service—to carry out the works. At the time, the Rijkswaterstaat, as Tessel Pollmann puts it, was "bureaucratic, hesitant, lethargic, a closed structure of civil-servants, with sluggish promotions on the basis of years of service—all this made the Rijkswaterstaat unsuited to lead a large, new project."[21] Only a few senior Rijkswaterstaat engineers made the switch to the Zuiderzee Service; for the rest, the Zuiderzee Service had to make do with new recruits. It would take until the mid-1930s before the Rijkswaterstaat, under Ringer's inspired leadership, began to recover from this blow to its prestige.

Meanwhile, the fledgling Zuiderzee Service, headed by the former Rijkswaterstaat chief engineer Hendrik Wortman, shouldered the heavy burden with its distant promise of glory. The work of the Zuiderzee Service was embedded in a broad-based cross-pillar coalition organized in the so-called Zuiderzee Council. Lely acted as chairman; co-chairmen were Gerard Vissering, president of the Dutch State Bank, and the prominent politician Hendrik Colijn, active in the Zuiderzee Association and later to become minister of finance and finally prime minister. The council also included high-placed civil servants from agriculture, fisheries, public health, water management, defense, economics, and finance. The council's formal task was to review the work of the Zuiderzee Service and to offer advice where necessary. It also served to anchor the project in the various policy domains on which it touched. The Zuiderzee Works had become a truly national project.

No sooner had construction started than the postwar recession occasioned renewed doubts about the project's economic viability. Fearing vast cost overruns and doubtful of the profit to be had, the minister of finance appointed a state commission in 1921 to assess the economic feasibility of the proposed works. Though the project was never completely halted, it was considerably delayed before the commission finally gave the go-ahead again in 1924, citing in particular the value of new land for the "healthy development" of agriculture and the importance of a new supply of fresh water.[22] It is curious that flood defense was no longer the major issue, or at least not one that could be evaluated in economic terms.

In 1925, during his first tour of duty as prime minister, Hendrik Colijn submitted a bill to Parliament stipulating that the Zuiderzee Works should thenceforth be carried out with all possible speed. It was passed by acclamation. The Zuiderzee Service could now proceed rapidly with the difficult task of building the main dam. It was materially aided in this endeavor by a new form of cooperation among several large hydraulic contractors united in the so-called Company for the Execution of the Zuiderzee Works. Under the effective leadership of Johannes Ringers (who in 1928 had just completed the North Lock at IJmuiden and would return to the Rijkswaterstaat as its director-general only two years later), this well-equipped engineering conglomerate devised new procedures and specialized equipment for depositing what is estimated

Rijkswaterstaat

Closure dam works: fascine mattresses made of willow branches were used extensively in the Zuiderzee closure dam to resist bottom erosion caused by fierce currents, 1929

Rijkswaterstaat

The Closure Dam nears completion, 1932

to be some 36.5 million cubic meters of sand and till (boulder clay) to create the massive body of the dam.[23] The fortuitous discovery of deposits of boulder clay in the Zuiderzee itself proved crucial in closing the final gaps. Doing so was a race against time, because with every change of the tide the fierce currents in the breach threatened to wash away what the workers and the cranes had just as feverishly deposited in the preceding hours. But the boulder clay proved sufficiently resistant and the cranes sufficiently fast to make even this part of the task almost routine in the end. The great fear was that a sudden storm would wash away months of tedious work. Though there were some close calls, the project proceeded apace and, on May 28, 1932, in an impressive ceremony, the final buckets of till closed the dam. While dividing the new IJsselmeer from the North Sea, at the same time the dam provided a means for connecting the provinces of North Holland and Friesland via a 32-kilometer-long highway.

While the dam was still under construction, work was also started on the first of five planned polders, the so-called Wieringermeerpolder. Because the main closure dam was not yet completed, the polder dikes themselves had to be built in what was effectively open sea, and the builders consequently faced the same issues as on the main dam. This was not the case with subsequent polders, because their enclosing dikes could be built in tideless fresh water already cut off from the open sea by the main enclosure dam. With its 207 square kilometers of new land, the Wieringermeerpolder was in itself a serious agrarian enterprise, but it was also seen as a laboratory in which to develop techniques and protocols for making and populating the much bigger subsequent polders. To start with, the Wieringmeer was drained by two pumping

Rijkswaterstaat

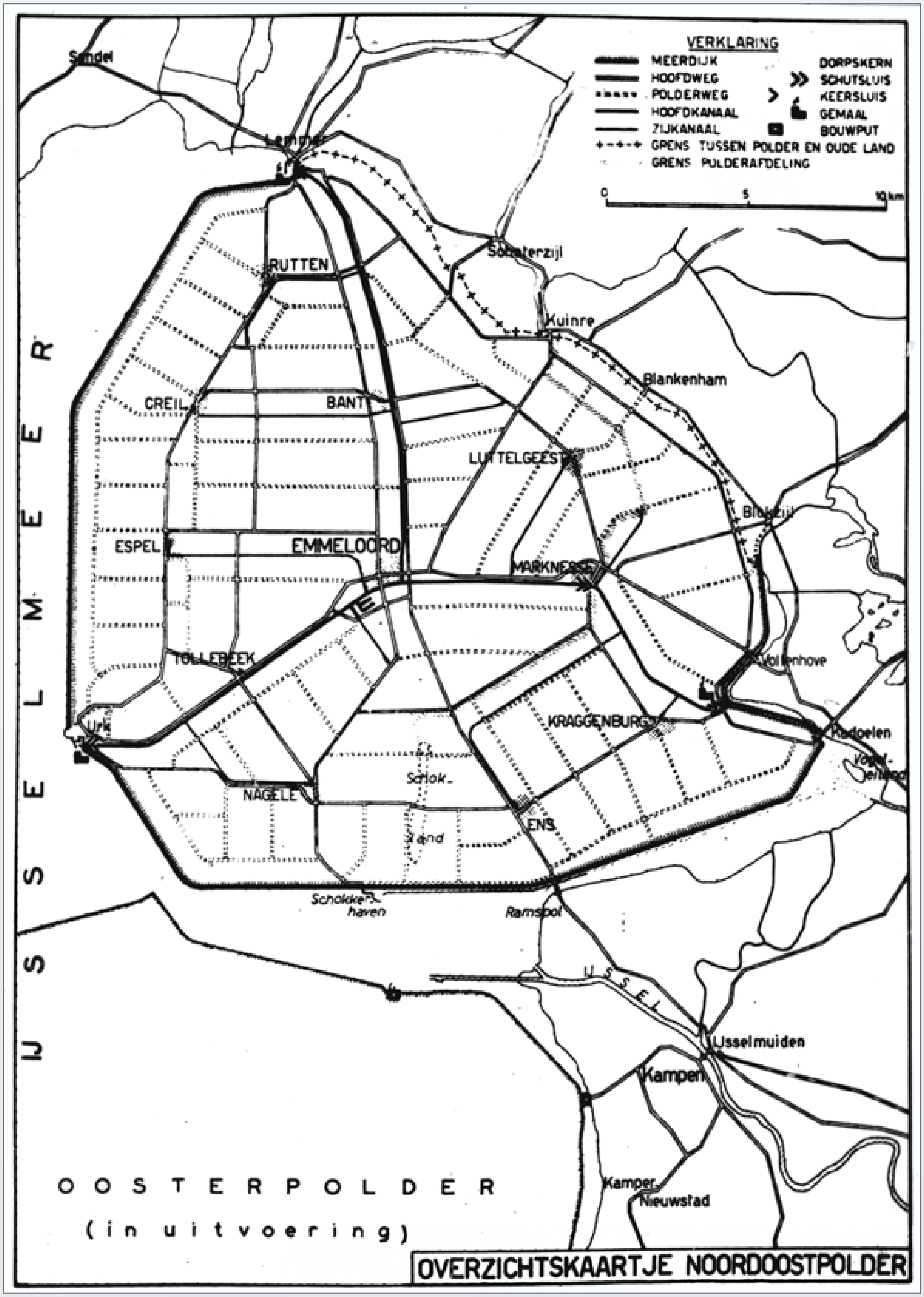
The final gap in the Closure Dam is being closed, May 28, 1932

stations, one powered by diesel engines and the other by electric motors, as a purposeful experiment to allow a comparison of reliability and operating costs of the different techniques under similar conditions. Moreover, it was insurance in case one or the other sources of energy became scarce or suddenly unavailable.

In the summer of 1930 the Wieringermeer had been pumped out and the land fell dry. Desalinating the old seabed and preparing the endless expanse of raw clay for human occupation and farming was the first order of business, to be accomplished by a separate Wieringermeer Directorate that was established alongside the Zuiderzee Service in 1930.[24] This powerful and highly technocratic agency was responsible not only for preparing the land in a material sense—planning and constructing villages and towns, creating micro-drainage systems, deep-plowing the soil, and building roads, canals, bridges, and locks—but also for parceling the land out and distributing it to farmers. In an effort to avoid repeating the dismal history of the haphazard settling of the Haarlemmermeerpolder in the mid-nineteenth century, the new population of the Wieringermeerpolder was meticulously selected, not only in an effort to achieve a religious balance and to ward off potential troublemakers, but also to maximize the chances of success by selecting only ambitious and vigorous colonists who had already proved themselves on the old land. To screen and select the candidates according to what could at least be argued were professional scientific standards, the Wieringermeer Directorate, very much in the spirit of the times, employed sociologists and psychologists. In all respects, the Wier-

Map of the Noordoostpolder

Rijkswaterstaat



ingermeer set the tone for the reclamation and population of the subsequent IJsselmeerpolders.

These polders followed after the closure of the Zuiderzee in 1932 and by 1936 its transformation into the freshwater IJsselmeer. In 1937 work was started on the so-called Noordoostpolder (Northeast Polder). The ring of dikes was closed by December 1940. In the meantime, German forces had invaded the Netherlands and established a Nazi regime. However, initially at least, the invaders supported the improvement of their new province and no attempt was made to interfere with the completion of the polder, for example, by rationing fuel supplies or building materials. At the beginning of 1941 the three pumping stations began their work, and by September 1942 the 480 square kilometers (185 square miles) of polder were pronounced dry, though far from habitable or tillable. By this time rationing of fuel and material made progress extremely difficult, but the construction of micro-drainage and transportation infrastructure continued throughout the war. By 1947 the Wieringermeer Directorate, following the same strict selection process as in the Wieringermeerpolder, was able to start the process of allocating land to farmers. Requirements were relaxed somewhat when priority was given to farmers dispossessed as a result of the catastrophic 1953 floods in Zeeland.

The Noordoostpolder was a unique enterprise. Unlike the Wieringermeerpolder, which was, in some sense, a large-scale proof of principle and a laboratory for testing out different approaches, the Noordoostpolder was the real thing, a feeling that was expressed by designing it as a kind of celebration of a modernist idea of new land. The pattern of settlements was inspired by the "central places" approach developed in the 1930s by the German geographer Walter Christaller. The original plan was to build a central city, Emmeloord, surrounded by a ring of smaller towns at distances of one hour by bicycle from Emmeloord. After the war the plan was modified due to the increased use of automobiles. Modernity was also evident in the fact that Emmeloord's several churches, built to serve the various denominations selected into the polder's new population, were utterly dominated by a single huge tower at the city's center whose secular carillon sounded far and wide over the polder. One of the small towns, Nagele, was itself an experiment in modern town planning, being designed by a collective of modernist architects and town planners, including famous names like Aldo van Eyck, Gerrit Rietveld, and Mien Ruys. Another odd feature of the new polder was the partial inclusion of two former islands, Urk and Schokland. The former, which housed a thriving fishing village of the same name, remained so aloof from its new agrarian setting that in a cultural and economic sense it long continued to be an island even though firmly connected to the new mainland.

One other feature of the Noordoostpolder that deserves mention is its hydraulic relationship to the contiguous "old land." Like the Wieringermeer, the Noordoostpolder was directly "tacked on" to the old land, effectively using the old sea-dikes as part of the ring-dike around the new polder. The surface of the new polders was some three to four meters below the level of the contiguous old land and, as a result, groundwater percolated from the old land into the drainage ditches of the new polder. In the case of the Noordoostpolder, this phenomenon resulted in progressive desiccation and subsidence of the old land between the towns of Lemmer and Blokzijl—and a lot of extra pumping in the new polder. This design flaw was avoided in subsequent polders, all of which were separated from the contiguous old land by narrow "peripheral lakes" that conserved existing water levels—and hydraulic counterpressure—on the outer flanks of the old sea-dikes. To this day, proposals are regularly put forth to repair the past and construct a similar peripheral lake at the boundary of the Noordoostpolder and the old land.

Persfotodienst

Stone-pitching in the dike surrounding Eastern Flevoland

While the Noordoostpolder was still being finished and populated, in 1950, work had already started on the next polder, Eastern Flevoland. By 1957 it was pronounced dry and ready for further development. Slightly larger than the Noordoostpolder, its design was, in many ways, the product of a new age. It was dominated by a new city, Lelystad, on its westernmost corner. Lelystad's placement near the geographical center of the new IJsselmeer polders clinched its destiny as both economic hub and capital city. However, because the last of the planned polders has not (yet) been built, the economic promise of Lelystad has not been fully realized. Lelystad was the first Dutch city to be designed in full consciousness of the impact of automobiles on urban space, following the principles of the famous Buchanan report (*Traffic in Towns*) published in 1963. The basic message was that in order to maintain a livable urban environment, car traffic should be isolated as much as possible from other transport systems and urban functions in general. In Lelystad this was realized by designing the city at two levels, one for automobiles and one for other functions. Opinion is divided whether this has in fact produced a more "livable" city. The advent of the automobile also legitimized reducing the number of peripheral towns. It also subtly redefined Eastern Flevoland as a road transport hub, inasmuch as it lay at the crossroads of new east-west and north-south road links—the latter across the dike built from Lelystad to Enkhuizen in anticipation of the fifth unbuilt polder, the Markerwaard. However, besides its usefulness as roadbed, this dike also had an important hydraulic function, connected with the appropriation of the new IJsselmeer into a national fresh water system.

TOWARD A NATIONAL FRESHWATER SYSTEM

In addition to creating new land, the closure of the Zuiderzee also created an enormous new freshwater basin in the heart of the country. The Zuiderzee was, strictly speaking, an estuary of the IJssel river, itself a distributary of the Rhine. Hence, the Zuiderzee had always been the recipient of generous amounts of fresh Rhine water. Precipitation, runoff, and a number of smaller rivers also contributed to the inflow of fresh water and reduced the Zuiderzee's intrinsic salinity. After closure, the huge sluices in the new dam released excess water at every low tide and hence the IJssel Lake's salinity was progressively reduced. It was only a matter of time before it would be fresh enough to be incorporated into the hydraulic systems of the surrounding countryside (as drainage buffer and source of water for irrigation and flushing) and even possibly as a source of potable water.

By 1936 the IJsselmeer was declared nominally fresh. The declaration occurred at a moment in time when issues of water quality, and particularly the increasing scarcity of non-polluted (and non-saline) sources for public water supplies, were being hotly debated. Basically there were two issues: first, increasing salinity and, second, increasing pollution due to municipal sewerage and industrial wastes. Both were byproducts of population increase and industrialization.

Salt intrusions occurred via groundwater as deeper layers of salt water replaced the potable fresh water pumped up from aquifers, especially the coastal dunes. This effect had been known since the turn of the century.[25] Increasing salinity of surface water was mostly due to the continual enlargement of seaways, particularly the New Waterway in Rotterdam. Every high tide conveyed tons of marine salts up the rivers; every increase in waterway dimensions exacerbated this problem. The increasing salinity was most critical for the greenhouse industry along the northern shore of the New Waterway, inasmuch as these farmers were dependent on its waters for irrigation of their greenhouse crops (which, of course, did not get rinsed from time to time by natural precipitation). Predictions indicated that it

Rijkswaterstaat

Eastern Flevoland

would only be a matter of time before the so-called "salt tongue" would also threaten the intakes of public water supplies farther upstream. These were, in fact, already threatened by a second front in the "salt war"—the increasing salinity of Rhine water caused by effluents primarily from Alsatian potash mines and coal mines and steel plants in the Ruhr.[26]

Pollution of ground and surface water by sewage and industrial effluents was also an issue that had been around since the turn of the century. But whereas at the outset water pollution had been a local and incidental affair, by the 1930s it was taking on systemic proportions. Sewage from the larger cities was increasingly compromising the water supplies of neighboring municipalities. Rotterdam and other cities on tidal rivers were even threatening their riverine water intakes with their own pollution. Add to this the increasing burden of a wide range of industrial pollutants, both of Dutch origin and imported by the Rhine and Meuse rivers from industries in the Ruhr and the Liège basin, and it becomes clear why a mood of crisis and gloom dominated Dutch discussions on fresh water in the 1930s and why the creation of the IJsselmeer was greeted with such enthusiasm.

In 1933, even before the lake had formally been pronounced fresh, Johan M. K. Pennink, eminent hydrologist and the first director of Amsterdam's waterworks after it became a public utility, warned: "Let us now finally and unreservedly acknowledge that we have gotten ourselves into a difficult pass, from which we can escape only by creating a preferably large and truly freshwater lake. That is not as easy as many may think."[27] Pennink's "difficult pass" was the dire prospect of insufficient fresh water for Dutch public waterworks, particularly in the highly urbanized west.[28] Though the large freshwater lake might solve the problem, making it fresh and, especially, keeping it so depended on holding the lake's salinity to extremely low levels. A major source of salts, as Pennink argued in his article, would certainly be the new polders. The soil was still saturated with chlorides which would slowly leach out and be pumped into the lake in the process of routine drainage.

Pennink's polemic against further land reclamation put the Zuiderzee Service in a tight spot, the more so as it not only pursued reclamation but also subscribed to the idea of an IJsselmeer as a source of potable water. As soon as the dam was closed in 1932, the Zuiderzee Service began to study the behavior of its new charge, paying attention not only to the inflow and outflow of water, but also keeping track of various contributors to the lake's salt burden. It soon became clear that, although great quantities of salt were leached from the new polders (and indeed the entire salt-impregnated former sea bottom), the inflow of fresh water from the IJssel (along with the expulsion of water through the sluices in the dam) would just suffice to reduce salinity to tolerable levels within a span of several years—even though the IJssel itself was burdened with Rhine salt. In other words, the most favorable outcome depended on maximizing IJssel River input into the IJsselmeer.

At this juncture the Rijkswaterstaat, in pursuit of its responsibility to maintain and improve the nation's navigable waterways, came up with a plan that threatened to wreck the delicate win-win solution that the Zuiderzee Service had in mind. The crux was ensuring the nautical accessibility of the new Twente Canal system. The original plan prescribed a direct link from Twente to the Waal (the main Dutch Rhine branch), but the canal as built connected to the Rhine only via the upper reaches of the IJssel, between Zutphen and Arnhem. The upper IJssel was, however, poorly navigable, and in order to realize the full potential of the new Twente Canals, the Rijkswaterstaat proposed to canalize this stretch of the river. This plan, though it would hardly affect the IJssel's flow at high river stages, would certainly cause stagnation at low summer stages—precisely when maximum inflow to the IJsselmeer was most needed to combat salinity. Rijkswaterstaat also favored the IJssel canalization because it could contribute to the desalinization of the western part of the country. Canalizing the IJssel would produce higher average river stages at Arnhem, which would force more fresh water through the Nether-Rhine-Lek-New Waterway system and help to keep the New Waterway's encroaching salt-tongue at bay.

It was obvious at this stage (the late 1930s) that the broad coalition of interests in keeping the IJsselmeer as fresh as possible was on a direct collision course with the equally valid interest in keeping salt water out of the urbanized west. This might well have led to much acrimony and fatal delay had it not been for a rejuvenated

Rijkswaterstaat that was prepared to assume the role of national system builder by effectively integrating the IJsselmeer into a national system for distributing the Rhine's supply of fresh water throughout the nation.

The key to this national hydraulic system were the plans that Johan van Veen and his colleagues at the Research Service for the Tidal Rivers had been framing since 1936 in response to complaints about salinization. Based on new insights into the propagation of tidal flows, Van Veen had devised a scheme to conjoin a number of large islands and close off the seaward ends of a major estuary (the Brielse Maas) just south of the New Waterway. This scheme, which after World War II was developed into the "Five Island Plan" and ultimately the Delta Works, would reduce the amount of salt water entering the river system at each high tide—and especially at storm surges. Not only was high water deflected at the seaward entrance to the Brielse Maas, it was also kept at bay via the "back door" thanks to a reduction in the surface area of the basin that had to be "filled." A second advantage was that more fresh river water from the Lek would be forced northward through the New Waterway, precisely where it was most needed.

But it took the keen vision of the new director-general of the Rijkswaterstaat, Ludolf Reinier Wentholt, to fuse these disparate projects—the IJsselmeer and Van Veen's "island plan"—into the backbone of what he was soon calling the "national water household."[29] In November 1940 Wentholt wrote a memo describing twenty different features of this "water household," which in its emphasis on the interlocked nature of quantitative and qualitative aspects of water management actually foreshadowed what would become "integral water management" a half century later. In one breath Wentholt named such previously separate aspects as "the feeding of canals, the pollution of public waters, the salinization of the western and northern Netherlands, and the public water supplies of various large cities."[30]

During World War II, the German occupiers allowed routine water management to go on largely undisturbed. It seems there was even an opportunity to plan for the future, because in the course of 1940–41 Wentholt succeeded in forging a new consensus between the freshwater demands of the west and those of the north (the IJsselmeer). Consultations with key advisors like Jo Thijsse, director of the Hydraulic Lab at Delft, chief engineer Victor Jean Pierre de Blocq van Kuffeler of the Zuiderzee Service, and (of course) Johan van Veen revealed that the latter's "island plan" would be so effective in resisting the salt-intrusions in the estuaries that it would be possible to canalize the Nether-Rhine rather than the IJssel. Canalizing the Nether-Rhine would have the effect of driving more water up the IJssel even at low Rhine stages, because the first weir in the Nether-Rhine (at Driel) could be set to raise water levels at the upstream junction of the two rivers. This would provide enough draught in the IJssel for navigation as well as keeping fresh water flowing into the IJsselmeer. Although the Nether-Rhine would convey almost no water at low Rhine stages, it would remain navigable thanks to the closed weirs and locks. Thus, in addition to the weir complex at Driel, similar complexes along the Nether-Rhine were designed at Amerongen and Hagestein. The designs were developed by L. van Bendegom, who created a so-called visor weir, named after the visor of a medieval helmet. The purely tensile water forces on the two semi-circular visors were transferred to hinges in the land abutment and the central pier. The construction elements were deemed indispensable in order to resist wind forces when the visor was opened. The circular shape induces the underflowing water to spread over a larger width than the navigation opening, thus reducing the necessary amount of bottom protection. In addition, the visor shape produces a variable underflow opening, damping vibrations produced by the undercurrents.

Rijkswaterstaat

Nether-Rhine canalization system: at low Rhine stages, the Driel weir is closed to ensure fresh water flow to the IJsselmeer through the IJssel (upward arrow)

The Nether-Rhine canalization was carried out between 1954 and 1970. With the completion of the Haringvliet Sluices in 1971 as part of the Delta Plan, Wentholt's vision of a national water household was finally realized. However, while concerns about salinization were incorporated into the design of the Delta Plan, the broader issues of pollution and ecological sustainability that Wentholt had started to address were drowned out by the call for secure flood defenses in the aftermath of the catastrophic flood of February 1953. It would take many years—until the cultural revolution of the 1960s and 1970s—before water quality in the broad sense would become a prominent issue again.

THE HIGH TIDE OF COASTAL ENGINEERING

COASTAL ZONE MANAGEMENT

In the 1930s and 1940s, the Research Service for the Tidal Rivers, under the energetic leadership of Johan van Veen, made pioneering contributions to the rather unexplored field of coastal engineering. The main topics were tidal modeling—inspired by the Lorentz Committee—wave research, morphology, sediment transport, and estuary research. Van Veen himself did extensive research into tidal currents, the coastal morphology, and sediment transport in the English Channel and the North Sea. The Research Service thus gave a major impetus to the emergence of science-based coastal

Spaarnestad Photo

Weir at Hagestein, regulating the water level in the Nether Rhine during low stages to facilitate navigation, completed in 1958 engineering, a multidisciplinary field integrating fluid mechanics, hydrodynamics, tidal and wave research, morphology, and meteorology. It was the Dutch version of similar American, British, German, and Norwegian research programs. In 1939 the first international coastal engineering congress took place.[31]

Between 1938 and 1953 Van Veen proposed bold projects to close off several estuaries in order to address both the vulnerability of flood-prone Zeeland and the problem of salt intrusion. A closed and therefore shortened coastline would decrease the chance of dike failure and create new freshwater reservoirs. He also set up a dike monitoring program in southwestern Holland, because he was worried about rising sea levels in the future. The results were alarming, showing that the dikes were grossly inadequate to provide a sufficient level of safety.

The government responded by appointing a Storm Surge Committee in 1939, which expanded the monitoring program, made predictions about future storm surge levels and developed new sea dike design standards.[32] Van Veen's colleague, Pieter Wemelsfelder, proposed a new flood management philosophy in 1939 based on a probabilistic rather than experiential assessment of storm surge heights and frequencies. Prior to this, the design heights for dikes were based on the highest recorded water level, plus some margin of safety. Wemelsfelder refused to take experience for granted, in particular the notion that the highest *recorded* water level was also the highest *possible* water level. On the basis of a very long time frame, spanning 10,000 years, he was able to estimate the statistical probability of various extreme high water levels. He concluded that there was a reasonable chance that the highest recorded water level would be surpassed within a century. Wemelsfelder's storm surge frequency distribution method was adopted by the Storm Surge Committee to predict future storm surge heights as a baseline for design standards for coastal and estuarial dikes.

WALCHEREN

In the immediate postwar years, the exciting advances in coastal knowledge, the emerging flood risk philosophy, and the development of new coastal strategies and designs, went hand in hand with the mastery of new technical skills. These skills were first honed during the recovery of the Island of Walcheren in the province of Zeeland in 1945, the final year of the war. Walcheren had been intentionally flooded by Allied Forces the previous year in order to drive out the German garrison guarding access to the strategically important harbor of Antwerp. The flooding had been accomplished by bombing the dikes at three widely separated locations. After initial hesitation whether it would actually be possible—or worth it—to reclaim the island, Queen Wilhelmina's insistence that no territory must be lost to the sea forced the issue. The Rijkswaterstaat, in cooperation with the MUZ (the contractors' combination for the Zuiderzee Works) rose to the challenge by executing a spectacular closure and drainage scheme. The main obstacles were the immense depth that the dike breaches had attained due to the year-long scouring of tidal currents through the gaps—the continuing twice-daily filling and emptying of the island through the gaps as a result of the five-meter tidal range. The Rijkswaterstaat took a gamble by opting to close the breaches with caissons left over from the Allied landing operation in Normandy. It turned out that sinking caissons in the deep breaches was a very effective closing technique, which was perfected in the following years. Between 1950 and 1952 two complex closure projects were performed, the Brielse Maas and the Braakman Inlet on the Westerschelde. In planning these operations, the critical timing and positioning of the caissons was crucial, and on this point the assistance of the Delft Hydraulics Laboratory proved invaluable, as it had earlier in connection with the Walcheren closures. A fruitful and long-lasting relationship was built up between hydraulic experts and the Rijkswaterstaat engineers.[33]

Rijkswaterstaat

A caisson is being placed to close the last major gap on Walcheren, 1945

THE 1953 FLOOD DISASTER AND ITS AFTERMATH

In hindsight, these complicated closure projects, executed between 1945 and 1952, proved to be rehearsals for the reconstruction work after the 1953 flood and ultimately for the Delta Works. On February 1, 1953, a mammoth storm surge proved too much for the weak dikes in the southwestern delta region, breaching them at hundreds of places. A total of 1,836 people lost their lives; countless cattle drowned in the icy water; 500 kilometers of dikes were destroyed; 47,000 houses, schools, churches, farms, and other buildings were damaged. The physical damage was enormous, amounting to 1.5 billion guilders (1953 value). And the number of casualties could have been much larger: On the night of the storm surge, near the village of Nieuwerkerk aan de IJssel, a bargeman maneuvered his ship in front of an impending dike breach in the Hoge Schielandse Zeedijk, a levee protecting Holland's heartland—including the cities of Rotterdam, The Hague, and Amsterdam. This action may well have prevented the inundation of central Holland, and thus saved thousands of lives, as well as the huge economic assets of the nation's economic core region.

A detailed analysis demonstrated that the catastrophe was attributable to a complex of factors. The southwestern region had a long coastline, lacking the natural protection of dunes, except at the western coast of Goeree, Schouwen-Duiveland, and Walcheren. As noted above, poor

Aviodrome Luchtfotografie, Lelystad

The flooded village of Nieuwerkerk, Zeeland, February 1953

maintenance had seriously weakened the sea dikes. The storm surge had struck with exceptional power, because of a combination of high winds (11 Beaufort, or 56–63 knots), blowing across a 1,000-kilometer-long wind-field from a north-northwestern direction, stretching from Scotland to the Dutch coast. To make matters worse, this all coincided with a spring tide. The water level rose to three meters above average high tide, a level that according to Wemelsfelder's probabilistic method would be expected only once in 300 years. In fact, three consecutive storm surges occurred, and the third one, on the afternoon of February 1, dealt the fatal blow. Wind speeds were actually not that exceptional, but the gale lasted, at least in Zeeland, an extraordinarily long time.[34]

As the scope of the disaster became clearer, one overriding conclusion was drawn: the existing flood defense strategy was bankrupt. Investments in sea dike maintenance by the small and poorly funded water boards had been utterly inadequate. The storm surge warning system, built up since 1921 and managed by the Dutch weather institute, the *Koninklijk Nederlands Meteorologisch Instituut* (KNMI), and the Rijkswaterstaat, had failed, as had lines of communication (telephone lines, telegrams) and local government. The failure of communications was especially serious, inasmuch as the mobilization of emergency dike monitoring teams depended on functioning communications. Weather forecasts had been broadcast by radio, but they had underestimated the gravity of the approaching storm surge. Thus, the Rijkswaterstaat and other authorities in the region were caught utterly by surprise as the dikes broke and the water flowed in.

A long and heated discussion ensued between the Rijkswaterstaat and the KNMI about these communication failures and the measures to be taken in the future. In 1954 the dialogue resulted in a new set of rules. Storm surge warning messages were to be issued by the responsible Rijkswaterstaat manager instead of the KNMI top executive manager. The Rijkswaterstaat issued warning messages if a high-water level was expected that occurred on average one or two times a year. This was the signal for restricted dike monitoring. Once the water had risen to a level with a statistical probability of once in ten years, then the regional Rijkswaterstaat managers were instructed to call up teams for dike monitoring, covering complete dike stretches. Moreover, hospitals and other emergency services were called into standby mode. Provincial authorities retained their own authority in regard to activating their staff. This storm surge warning system was soon extended to cover nearly the entire Dutch coast.[35]

In hindsight, it seems amazing that there was almost no discussion about the question of whether the disaster could have been prevented. Dutch Parliament exhibited little interest in initiating official investigations into this painful question. The lack of political will to reflect critically on the multiple failures involved in the flood illustrates the widespread tendency to absolve and protect the responsible authorities. This was also discernible in the weeks after the flood within the provincial administrations of Zuid-Holland and Zeeland and at meetings of the managers of local water boards. A parliamentary investigation would raise too much criticism, encroach on the authority of the water management actors and, by implication, the government, and thus hamper the reconstruction of Dutch society—which had top priority.

There are rational arguments against the view that the 1953 catastrophe could have been prevented. Clearly, postwar dike strengthening schemes had been hampered by inadequate funding. Though some projects, like a major dike through Rotterdam (the Maasboulevard) had been completed, the overwhelming majority of the dikes remained much too weak. Van Veen's and Wemelsfelder's new analyses clearly pointed out the very serious safety gap in the southwestern parts of the country. But although this diagnosis seemed convincing to the innovative vanguard, and had an unambiguous impact on the Storm Surge Committee's recommendations, the latter—which eventually proved to be correct—were also viewed with skepticism, even suspicion, by mainstream engineers both in the Rijkswaterstaat and on the water boards. A second objection related to the time scale: planning and implementing the huge Delta Works would have required a time span of at least twenty years (actually, the Delta Works took more than thirty years). Finally, the war would have made implementation of such ambitious projects impossible, and during the post-war reconstruction, as already noted, flood management had to compete in the political arena with numerous other urgent matters.[36]

RECOVERY OPERATIONS

The recovery operations in the wake of the flood disaster, beginning with closing the breaches and draining the land, were conducted entirely in the spirit of the postwar era. It was a time of doing and alertness, rather than reflecting—phrases like "can do," forward-looking, hands-on typified the mood. This was manifest, first, in the immediate recovery operations. The Rijkswaterstaat erected an emergency service (*Dienst Dijkherstel Zeeland, DDZ*) to coordinate the workflow. The water boards were completely outmaneuvered—an unambiguous indication of their weakened position. Until then, their prerogatives and obligations had been carefully respected. No fewer than four hundred breaches had to be closed, and the pace of work was feverish. The experience gained in the Walcheren drainage was invaluable in closing the numerous dike breaches, each of which presented a unique challenge. Helped by the Hydraulic Laboratory to achieve the optimal positioning for sinking, workers sunk numerous caissons to close the major breaches. Around midnight on November 6 and 7, 1953, at the turn of the tide, the last gap, at Ouwerkerk, was closed. The entire operation had taken less than a year.

DELTA COMMITTEE

Meanwhile, the government had assembled a Delta Committee to develop a strategic vision aimed at preventing future floods. The committee was headed by the Rijkswaterstaat's top manager, A. G. Maris, and was filled with experts from Rijkswaterstaat, The Delft Polytechnical University, the Delft Hydraulics Laboratory, the Rotterdam Economic University, provinces, water boards, consultants, and contractors. Van Veen functioned as secretary. The Delta Committee developed a Delta Works scheme, publishing five draft reports and a final report in six volumes.[37]

In the second report, the committee provided a detailed analysis of the situation along the Hollandse IJssel, which had narrowly escaped disaster. A Rijkswaterstaat report emphasized the imminent danger: if levees broke here, the lives of 1.5 million citizens were jeopardized. In the same vein, the committee was very concerned about the low safety level in this region. However, instead of a levee-strengthening scheme, it proposed to build a storm surge barrier in the Hollandse IJssel. The latter option would be less expensive, require a shorter construction schedule, occasion less damage to the landscape, and simultaneously provide a new river bridge. To minimize obstacles to navigation, the barrier would be movable.[38]

The Delta Committee, meanwhile, issued its third draft report on February 27, 1954, outlining the key elements of the proposed Delta plan. Its main components were a seaward closure of the estuaries Haringvliet, Brouwershavense Gat, Eastern Scheldt, and Veerse Gat, with secondary closure dams behind these primary closure dams further inland in the Volkerak, Grevelingen, and Zandkreek. The purpose of the secondary dams, which would be built first in relatively sheltered waters, was to attenuate the tidal currents in the estuaries, thus easing the construction of the primary seaward dams. They also created new lakes between the dams, which were intended as freshwater reservoirs.

The committee argued that the alternative, a comprehensive coastal dike strengthening scheme aiming at dike crests at least 1.5 to 2 meters higher, would meet with insurmountable problems. Closure dams, by contrast, would reduce the length of the coastal dikes from 700 kilometers to only 20 to 30 kilometers. The current dikes would lose their primary protective function, but they would still have a useful function as secondary flood protection lines. Coastal maintenance management would be much less fragmented, because this task was to be transferred from the water boards to the Rijkswaterstaat. Obviously, this meant that the water boards in the region would suffer a loss of responsibilities, but they would remain in charge of the interior dikes as well as polder level (and much later, water quality) management. This was not a situation without precedent. The closure of the Zuiderzee had effected much the same transfer of power and responsibilities from water boards to the Rijkswaterstaat.

The committee estimated that the Delta Works scheme would cost between 1.5 to 2 billion guilders and take some twenty-five years to complete. It further devoted much attention to the economic position of fisheries and the shellfish industry in the Eastern Scheldt. Closure of this estuary meant an annihilation of the oyster cultivation, and the mussel cultivation would be reduced considerably; consequently, 900 jobs were

The Delta Works Program

Matrijs, Utrecht

at stake. Rescue or compensation plans, the committee concluded, would certainly be appropriate.

On January 5, 1955, the fourth draft report was made public. It contained more detailed proposals to close off the Zandkreek and the Veerse Gat, the so-called Three Islands Plan, thus linking Noord-Beveland with Walcheren and Zuid-Beveland. To facilitate navigation, the inland Zandkreekdam was to be provided with a lock. The fifth and last draft report developed a new flood-safety strategy. The design of sea dikes would have to be based on Wemelsfelder's probabilistic approach. The committee proposed three safety levels. Central-Holland's sea defense should be able to withstand a storm surge level associated with a probability of once in 10,000 years, the southwestern flood defense structures had to meet a safety level of 1:4,000 and most Wadden Island dunes and dikes had to maintain a safety level of 1:2,000. The corresponding water levels are called "basic levels," from which "design levels" are derived, resulting in a set of differentiated safety standards, dependent on differences in values to be protected, differences in evacuation opportunities, and so on. For central Holland, the design levels are equal to the basic level (annual exceedance frequency of 1:10,000). These safety levels were the result of an econometric cost-benefit analysis, balancing the investments in flood projects and the flood damage costs. The econometric optimal safety level for central Holland was determined at 8×10^6 or 1/125,000 per year; a major flood in this core economic region would cause unprecedented damage. However, this cost-benefit analysis had a number of uncertainties, and the committee decided that designing for a maximum sea level at Hoek van Holland (at the entrance of the New Waterway) of 5 meters above mean sea level would give sufficient protection against flooding. This was 1.5 meters higher than the highest water level during the extreme conditions in 1953. Finally, the committee indicated an execution sequence: first the moveable storm surge barrier in the Hollandse IJssel, then the execution of the Three Islands Plan, followed by the closure of the Grevelingen, Volkerak, Haringvliet, Brouwerhavense Gat, and Eastern Scheldt.[39]

The committee's high productivity and the speed with which it finished its job was remarkable given the complexity of its task. Dutch historians have explained this amazing efficiency and effectiveness by reference to the prior pioneering designs made by Van Veen between 1938 and 1953 and to his fundamental tidal, geomorphologic, and dike monitoring research. There is little doubt that Van Veen's investigations and plans were indeed an important contribution to the final Delta Works scheme. However, credit is also due to a later generation that made a number of modifications to his proposals and added important new elements. Only Van Veen's Hollandse IJssel barrier plan and his Three Islands plan were adopted without major adaptations. In the end, the Delta Committee's alacrity seems to have owed as much to its own sense of urgency and dedication to preventing a recurrence of the terrible events of 1953 as it did to Van Veen's rich legacy.

The government agreed to the proposals and codified them in a Delta Act to submit to Parliament. The safety standards enshrined in the Delta Act not only implied heavy and long-term national investments in dike strengthening, they also had a clear impact on the balance of power among actors in the field of water management, as these norms were also imposed on the water boards, thus encroaching on their autonomy.

After the 1953 flood, the new safety standards 1:10,000 for the sea dikes in central Holland and 1:4,000 at the Zeeland coast required massive dike strengthening schemes in which the water boards were compelled to play their part. A total dike length of thousands of kilometers thus had to be made much more robust. Sea dike strengthening projects took several decades but made steady progress. It was not long before similar probabilistic demands were being applied to the levees along the large rivers. In 1956 Minister of Waterstaat Jacob Algera advised the Provincial Estates of Gelderland to specify the maximum river discharge of the Rhine at Lobith at 18,000 cubic meters per second with a probability of 1:3,000 years. This decision was taken.[40] The water levels along these related rivers were defined as the "design high water levels" (*maatgevende hoogwaterstanden* or MHW).

EXECUTION OF THE DELTA WORKS SCHEME

The Rijkswaterstaat set up a new department, the Delta Service (*Deltadienst*), to oversee the realization of the Delta Works, beginning with the building of the storm surge barrier in the Hollandse IJssel between 1954 and 1958. The closure projects in the estuaries were carried out in order of increasing complexity. Each project was an object lesson for the subsequent projects. To gather experience with the risky and difficult closure technique, the smallest seaways were closed first. In accordance with the Delta Committee's recommendations, secondary dams were constructed inland of the seaward closure dams to attenuate the strong currents invoked by the closure operations. A number of closure techniques were applied. Caissons, already successfully used to close dike gaps after the war and after the 1953 flood, were now further developed. Various caisson types were custom made to suit conditions in the different estuaries. The Delft Hydraulics Laboratory again assisted with detailed closure schemes.

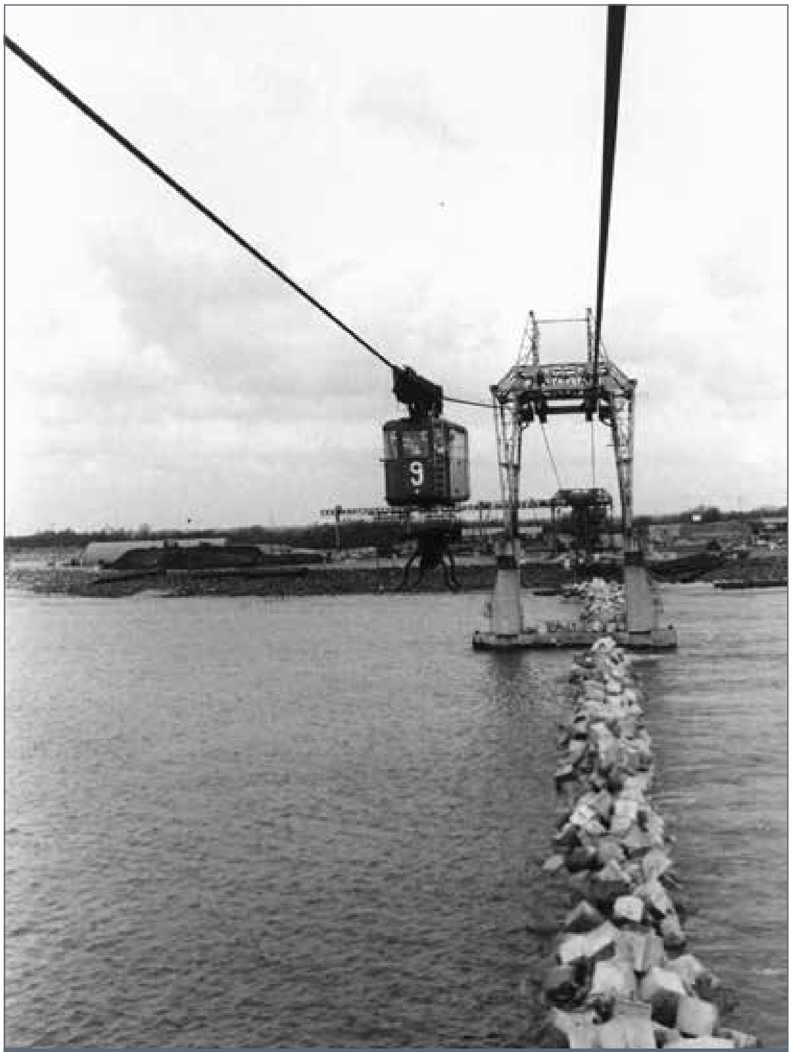
Rijkswaterstaat

Delft Hydraulics Laboratory model of the southwestern delta, 1948–1956. This model has been used to simulate and predict tidal effects and water level changes during the construction of the Delta works. The Delft model was inspired by the lower Mississippi River model by WES in Vicksburg.

The Delta Service was worried that at several locations, such as the Brouwershavense Gat, the estuary bed was too unstable to bear the weight of caissons without the risk of uncontrolled settling. As an alternative, the engineers appropriated an alpine technology and used a cable-car system spanning the estuary equipped with special gondolas that enabled them to dump boulders along the entire length of the cable. The Rijkswaterstaat had studied this technique in Grenoble at the French enterprise Neyrpic, which had ample experience with this technology. The Haringvliet, the Grevelingen, and the southern part of the Brouwershavense Gat were closed with rock fill, dumped by means of such cable lines, which were progressively improved.[41]

Between 1954 and 1971, the Delta Works advanced on schedule with no significant delays or interruptions. Sometimes consultants and contractors co-designed elements of the hydraulic structures. For the Haringvliet Dam, the Rijkswaterstaat established a public-private project team to maximize the number of options and carefully select the best one. Two of the risk factors that designers had to consider were the possible damage to the discharge sluices caused by ice jams and the wave pressure the dam had to withstand. To deal with these issues, a hydraulic contractor, an engineering consultancy firm, the Delft Hydraulics Laboratory, and three Rijkswaterstaat services were involved in the design of the dam construction. After long discussions, the Rijkswaterstaat decided to construct seventeen discharge sluices in the dam, the segment (Tainter) gates of which were hinged to a single monolithic prestressed concrete beam of triangular cross-section. These discharge sluices were big enough to discharge Meuse and Rhine river water into the sea, even at extraordinarily high river stages.

In other Delta projects, however, the Delta Service had the leading role in design, aided by other technical Rijkswaterstaat services. Despite chronic friction between the Rijkswaterstaat services, the projects advanced on schedule and the Rijkswaterstaat's prestige rose to an all-time high. The Delta Works were hailed as icons of modern engineering.[42] Each successive closure drew broad media attention and was an occasion for widespread flag-waving.



Rijkswaterstaat

Gondola dumps rock-fill to build the Grevelingen dam, 1963

But there was a hidden subplot within this glittering success story. Environmentalism was emerging as a popular movement and would soon challenge the primacy of flood protection, which was the principle focus of the Delta Works. The Rijkswaterstaat itself experienced serious harmful environmental effects after the Brouwersdam had been completed in 1971. The healthy and rich ecosystem in the closed-off Grevelingen was destroyed at an incredible pace. Alarmed by this ecological disaster, the minister of water management, Tjerk Westerterp, decided in 1974 to have a sluice constructed in the Brouwersdam, which became functional in 1978. Since then, the salt-water ecosystem of the Grevelingen lake has recovered.

Meanwhile, environmentalism was having a huge impact on the last closure project. In 1967 the Delta Service began to pump sand for three work islands in preparation for the extremely difficult estuary closure of the Eastern Scheldt. This mighty estuary had, by far, the largest tidal volumes—ten times that of the Veerse Gat,

Rijkswaterstaat

One of the segment gates in the Haringvliet Dam, completed in 1971 one of the earliest closures. Thus, closure of this estuary was the final *pièce de résistance*. To reduce the closure risks, the Delta Service again opted for a cable trolley with boulder-carrying gondolas. By 1970 the cable trolley was in place and the Rijkswaterstaat was poised to display its mastery of the estuaries in yet another complicated closure operation.

However, the Eastern Scheldt closure ran into heavy opposition in Parliament. Critics of the closure pointed to the damage that would be done to the estuary's extremely rich aquatic biodiversity and its unique variety of bird species. Excellent conditions for mussels and oysters supported a flourishing shellfish industry of considerable economic importance, which also was threatened by the closure plans. The Delta Committee had pointed this out in its third concept report. In Parliament, within the nascent environmentalist movement, and among the oystermen, there was growing criticism of Rijkswaterstaat's closure schemes. They proposed an alternative approach: massive dike strengthening around the estuary.[43] The critics were not completely ignored. In 1969 the Delta Service added an environmental department to investigate the biological richness in the area. Its researchers explored the estuary, the shores and mudflats of its tidal creeks, and its wetlands, aiming at the development of a management scheme for protecting threatened bird populations.[44] But the closure scheme itself did not change one bit, as alternatives put forth by critics were ignored. Thus, the seeds of conflict were sown, and this conflict escalated in the early seventies to an unexpected and massive confrontation that would ultimately have a huge impact on the Rijkswaterstaat.

THE TURN OF THE TIDE

GROWING ENVIRONMENTAL CONCERN

In the 1950s and 1960s Dutch water management was strongly oriented towards safety and economic interests—fresh water supply, transport, and agriculture. The emergence of large-scale agriculture not only destroyed idyllic landscapes, but also demanded strict water level management. Waterlogged fields were anathema to an efficient agricultural enterprise whose only aim was to maximize production. To this end, water levels had to be stabilized, that is, kept under tight control. This was no boon to biodiversity.

The emphasis on social-economic issues in politics and in public opinion seems, for many years, to have suppressed widespread environmental criticism. Until the mid-sixties, there were few protests against the destructive aspects of economic modernization. After all, the social benefits were obvious: rapid economic growth, full employment, low inflation. The growing environmental side effects thus remained largely unnoticed and beyond the political horizon.

At least until the early 1960s public opinion was equally indifferent. Critical reflections on environmental issues were rare. This was due not only to the social-economic bias of the media but also to ignorance of environmental effects. Little research had been done on pollution, biodiversity, or other ecological issues. Although after 1957 institutes for fundamental environmental research were established, applied research remained restricted to analyses of toxicological effects of chemicals on human safety and health. Conservation organizations retained their traditional focus on preserving natural zones and promoting environmental education, but refrained from widening their scope of action.

However, this reticent attitude met with growing criticism as environmental awareness grew during the 1960s. Initially, this mental shift was mainly the result of negative publicity about pesticides. One pesticide, DDT, became notorious after the publication of Rachel Carson's *Silent Spring* (1962). DDT, she argued, had very detrimental effects on birds. Moreover, she argued, the chemical industry manipulated information about the side effects of pesticides. Carson's bleak picture shocked public opinion, not only in the U.S. but internationally. In 1965 the Dutch government established an advisory committee on pesticides, composed of biologists, toxicologists, civil servants, and representatives from private industry. It advised on the side effects of pesticides and developed educational programs. Thus, Carson's views, enriched with Dutch contributions, stimulated an environmentalist spirit that was congruent with the emerging trend of fundamental social critique that characterized the 1960s.

CULTURAL REVOLUTION OF THE SIXTIES

In the counter-cultural slipstream, new environmentalist groups began to flourish. Two of them criticized growing air pollution in the New Waterway area. A Waddenzee Association was set up to defend the natural values in this shallow sea. Finally, a protest group for an open Eastern Scheldt began to knock loudly on the Rijkswaterstaat's door. But a group that agitated against the proposed establishment of a carbon disulfide plant by the chemical firm Progil in Amsterdam's harbor had the most success. The anti-Progil group had a more radical strategy than the other environmentalist pressure groups, which had a preference for engaging in dialog with the authorities. This moderate attitude bore a strong resemblance to that of the traditional conservationist organizations. But the Progil protestors created a media-strategy, broadcast environmental warning messages, and collected signatures. At the same time, they developed alternative options based on scientific research. But gradually, even the Progil group's pragmatic localism was overshadowed by more fundamental alternative views. The British economist E. J. Mishan, who took a stand against unbridled economic growth in his book *The Costs of Economic Growth* (1967), inspired the new environmentalists. In the 1970s anti-capitalist and anti-consumerist perspectives were much more vehemently articulated. Concomitantly, a systems approach emerged that questioned the dominant anthropocentrism inherent in economic growth policy and proposed instead a symbiotic relationship between humans and nature. This ecological paradigm was to have a profound impact on water management.[45]

ENVIRONMENTALISM AND WATER MANAGEMENT

Deteriorating water quality was one of the main environmentalist themes. This was hardly surprising, as research on this subject was more advanced than on other environmental topics. In the 1930s a comprehensive water quality monitoring program had started, and in 1949 the environmentalist association *Nederlandse Vereniging tegen Water-, Bodem-, en Luchtverontreiniging* (NVWBL) presented the results in a multi-volume report. The latter inspired the NVWBL to plead again for adequate legislation. The drinking water enterprises started a Rhine water quality monitoring program, run by a joint committee. The freshwater fishing lobby also became committed to the campaign for cleaner water.[46]

In 1950 the water board of the Dommel (a small river in the south of the country) introduced a levy on pollutants and set up a purification board, funded by the levies, that pioneered riverine water quality management in the Netherlands. A few other purification boards (De Donge, De Geul) were also established at this time. The government supported these activities and drew up a preliminary bill that sought to incorporate the Dommel Board's polluter-pays principle into legislation. But this proposal languished because of resistance by the provinces. A revised bill that empowered the provinces was submitted in 1958, but now the water boards were disgruntled. The stalemate was a thorn in the side of a number of organizations that were pursuing improved water quality.[47] They successfully exerted pressure on the government to create effective legislation. In 1964 the government presented a Surface Water Pollution Bill to Parliament. Water had to be suitable for the manufacture of drinking water and to be useful for industrial and agricultural purposes. Two principles were dominant: the polluter pays and pollution will be tackled at its source (rather than at the point of consumption). Wastewater discharge required a permit, and the discharge of specific polluting substances would be taxed. The bill created a more or less coherent legal framework, but it lacked an implementation strategy. No emissions standards were introduced. No central monitoring coordination was outlined. The government was inclined to support bottom-up purification processes without clearly defining the role or nature of the inspection authorities.[48]

The snail's pace of legislation revealed a lack of environmental commitment in political circles and within the Rijkswaterstaat. Infrastructure works and water quantity management still had a much higher priority. Generally speaking, environmental values were subordinated to the dominant technocratic and economic orientation. Consequently, water pollution was not high on the political agenda. Similarly, most water boards were inclined to stick to their core business: water level management, irrigation, and drainage.[49] This conservative attitude also had a cultural component, as most water board managers were farmers and thus inclined to give priority to agricultural interests.

Nevertheless, deteriorating water quality had become a major practical problem as a result of emissions from petrochemical and chemical industries, the use of fertilizers and pesticides in agriculture, and the introduction of detergents into households. In 1959 tons of dead fish clogged the Hollandse IJssel and Rijnland waterways following poisonous waste disposals.[50] In 1961 a leftist weekly, *Vrij Nederland*, published a story about the pollution scandals in many waterways : a litany of poisoned fish, repugnant smells, and sulfuric acid drifting in a canal.[51] Pollution could no longer be ignored: car emissions, smelly rivers, oil emissions in harbors—one could see, hear, and smell the deteriorating environment. "Environment" had ceased to be an abstract scientific formula; it had entered the realm of the senses. Sensory data were corroborated by an increasing mass of scientific data, as the national wastewater research service *Rijksdienst voor Zuivering van Afvalwater* (RIZA) in 1964 standardized and expanded its river water quality measurements.

This took place against the background of increasing international concern over environmental degradation. Water quality in the Rhine and Meuse deteriorated further because of chemical emissions and salt emissions from French potash mines, German coal mines, and the soda industry. Not only did Dutch greenhouse enterprises suffer; the quality of fresh water supplies in central Holland deteriorated as well. In 1949 a gulf of poisonous effluents had finished off the already-ailing salmon population. In 1969 one of Hoechst's chemical plants near Griesheim discharged the very poisonous effluent Endosulfan. Numerous Dutch weirs and water inlets had to be hastily closed to prevent a disaster. Concerned by this catastrophe, an international network of Rhine river municipal waterworks was set up, which

Spaarnestad Photo

Environmentalists protest against water pollution after a chemical plant discharged Endosulfan into the Rhine, 1969 lobbied for adequate measures. By 1970 the Rhine had become a biological graveyard: oxygen had vanished from the water, and aquatic life had all but disappeared.[52] In response to the rapidly deteriorating water quality, international cooperation among the Rhine states intensified. This internationalization process is discussed in detail in Chapter 8.

CONCLUSION

The period between 1900 and 1970 can justly be labeled as a technocratic era. Engineers increasingly acquired a mandate and were granted budgets to establish a policy agenda and to design solutions for a wide range of water resource issues. The gradual unfolding of a hydraulic technocracy took place against the background of the rise of an interventionist state starting in the 1890s and coming to full flower after World War I. The Zuiderzee project was the first major technocratic project. It was a long-term technological and social laboratory, in which engineers, agronomists, social scientists, and architects were mandated to create a new polder society on the reclaimed Zuiderzee soil. Top down-planning was strengthened during the German occupation (1940–1945), and it is no coincidence that a national freshwater system emerged in these years, with the IJsselmeer freshwater reservoir and measures against salinization in the southwestern estuaries as elements of a comprehensive water resource system approach.

The period 1940–1970 was the heyday of the interventionist state. After the economic depression of the 1930s and the chaos and misery of World War II, a consensus emerged that the market could only guarantee economic progress if it was controlled and limited by the state. The fusion of Social-Democratic planning ideology with the Christian-Democratic zeal for social-economic cooperation gave rise to an expanding state, more or less counterbalanced by ongoing negotiations over wages and prices on the basis of consensus and compromise. Rapid and sustained economic growth, stimulated by liberalization of international trade, industrialization, and agricultural modernization bolstered an image of the state as modern, efficient, and rather successful. Politics and technology seemed increasingly intertwined, which was clearly demonstrated in a large number of major water resource management projects.

How did the 1953 flood fit into this pattern? Ultimately, the disaster demonstrated the failure of the traditional flood management system. Neither the water boards in the flooded regions nor the Rijkswaterstaat had been able to establish a sufficient level of safety. Strikingly, the 1953 crisis did not shake the belief in the government's problem-solving capabilities. On the contrary, water management authorities were granted time and facilities to design new and better solutions. Though trust in authority was generally strong until the late 1960s, this is not the only explanation. There was, for instance, deep-seated discontent about other urgent problems, notably the housing shortage due to a rapidly growing population and war damage.[53] But the water management engineers were able to demonstrate very efficient tools that quickly restored confidence in their expertise. In the period 1890–1930 they had cultivated their collective knowledge, especially studying practical problems from the viewpoint of scientific and engineering theory, resulting in a growing mastery of complex water management problems. This new know-how was demonstrated not only in technological innovations but also in the organization of new complex networks among different stakeholders and between the Rijkswaterstaat and its contractors. The Rijkswaterstaat had invested in its capability for innovation by setting up new research services and by developing its conceptual capabilities—a multifunctional water system approach (Wentholt), estuary closure concepts (Van Veen), and a new safety risk philosophy (Wemelsfelder). The intellectual and organizational capital accumulated in the previous decades now paid off as a large variety of technical and organizational solutions could be developed in a rather short time.[54] The long-lasting postwar economic boom, ending in 1973, enabled rising levels of expenditure in water management and so created even more favorable circumstances in which engineers could demonstrate their skills.

In the late 1960s the Rijkswaterstaat's power reached its zenith. But then, in a matter of a few short years, its image became tarnished almost beyond recognition. The cultural revolt of the sixties, with its fundamental critique of established institutions—including the market system and the state—struck the Rijkswaterstaat in the heart. Environmentalism offered an alternative to the narrow economic and safety orientation of the engineers. The growing concern over the Eastern Scheldt closure was another and even more alarming signal of the changing attitude towards the Rijkswaterstaat's modernist engineering, its technocratic values, and its top-down decision-making procedures. For decades, these characteristics had underpinned the Rijkswaterstaat's shining reputation, but now they were becoming the stakes of political struggle and social conflict. Similarly, the water boards had to adjust to environmentalism and growing public participation. A long and challenging process of adaptation began.

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