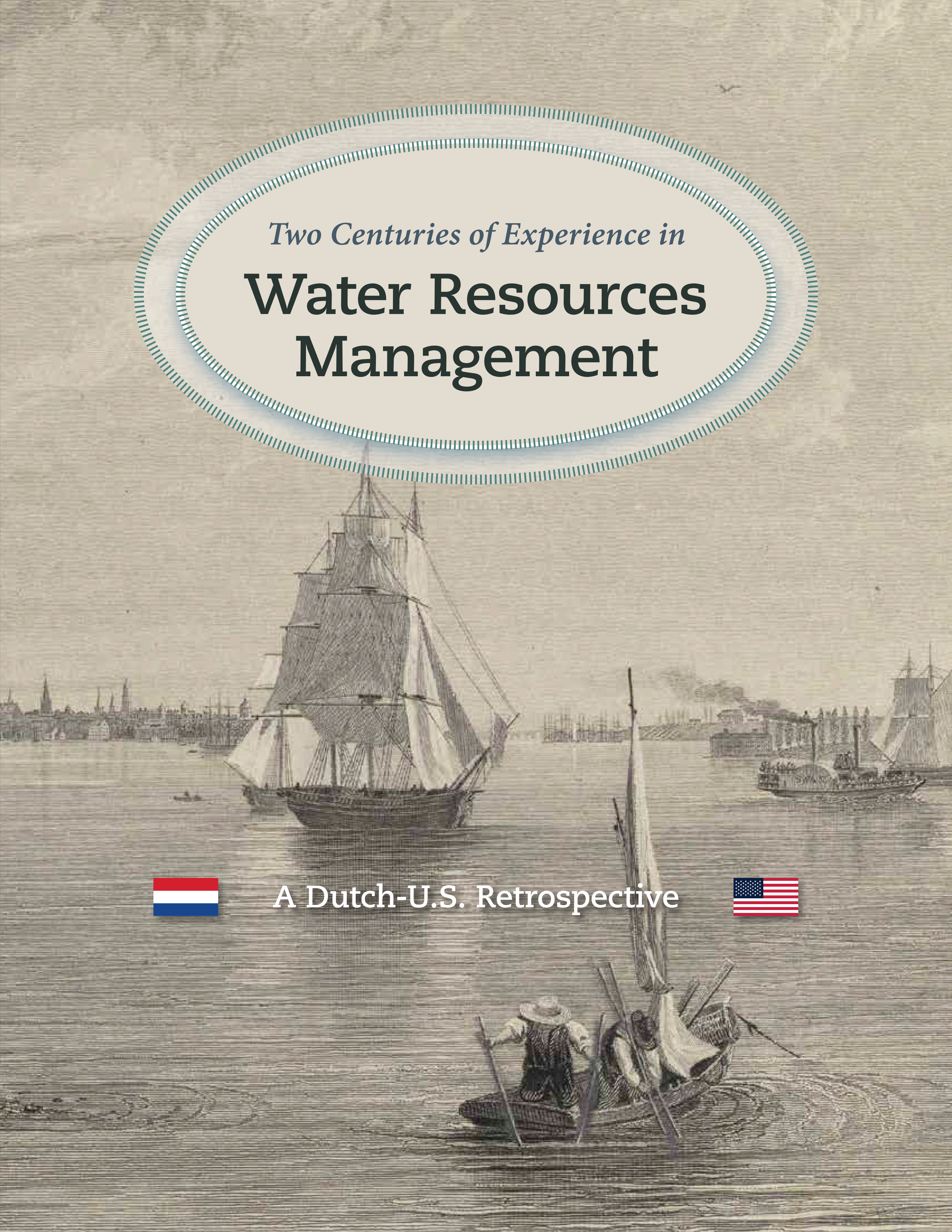
Two Centuries of Experience in

Water Resources Management



A Dutch-U.S. Retrospective

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Editors

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On the cover:
"Bay and Harbour of New York, From Bedlon's [Bedloe's] Island," ca. 1840, painted by John G. Chapman, engraved by James Smillie, and published by John Disturnell. Two centuries earlier, in the early 1600s, the harbor and the lower end of the nearby island of Manhattan were under Dutch control as part of the colony of New Netherland, with New Amsterdam (present-day New York City) as the settlement's capital. The lands were ceded by the Dutch to the English in 1664, and the English renamed the village New York the following year.
Credit: J. G. Chapman - James Smillie- John Disturnell / Museum of the City of New York

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Foreword

For over two centuries the Netherlands and the United States followed markedly different paths for managing their periodic floods and droughts, navigable waterways, coastal zones, and environments. That accumulated experience represents an extraordinarily rich record of technological achievement and innovation, and it was against that backdrop that representatives from each nation's responsible public works organization — the Dutch Rijkswaterstaat (RWS) and the U.S. Army Corps of Engineers (USACE) — recognized the need for close collaboration on a wide range of water management topics. As the partnership evolved it became clear that understanding the similarities and differences in backgrounds, institutional organization, and development of water management development would facilitate the exchanges of ideas and expertise between the two nations. The RWS and USACE reached a formal agreement in 2004, and this study is one result.

At first blush, a comparative history of these particular two countries might seem puzzling given the vast difference in geographic scale, with the Netherlands' entire area approximating half the size of the U.S. state of Maine. What the Dutch lack in space, however, they make up for in water management expertise. One quarter of the Netherlands lies below sea level, and over the centuries the Dutch have devised an intricate network of measures to protect against inland flooding and coastal storms. In fact, their first water board (*waterschappen*) was established as far back as 1255 in Leiden as a means to oversee levee development and maintenance.

The double blow to the Gulf Coast dealt by Hurricanes Katrina and Rita in August and September of 2005 opened up opportunities for further collaboration between the Rijkswaterstaat and Army Corps of Engineers. Coastal zone protection and management became the immediate focus of the relationship. Once the affected Gulf Coast area stabilized, however, the partnership deliberations shifted to a variety of additional topics including asset management, risk-informed decision making, project management, levee safety, integrated water resources management, operations and maintenance, organizational change, flood policy standards, and the public-private interface. Since 2004, scientists, engineers, and policy makers from a variety of Dutch and U.S. organizations have met on numerous occasions to compare notes on these critical matters and to suggest needed improvements to related policies and procedures. Challenges persist in the growing threat of sea level rise, salt water intrusion, and land subsidence.

Along the way, it has proven helpful to pause and reflect on the various forces that have helped guide our organizations since their formations in the early nineteenth century. This comparative history explores how the evolution of Dutch and American experiences shaped their respective approaches to fields as diverse as hydraulic engineering, flood management, navigation, building with nature, and urban development.

We look forward to a long and fruitful partnership between our two respective organizations, and now invite you to enjoy this journey back in time.

Hon. Jo-Ellen Darcy
Assistant Secretary of the Army (Civil Works)
United States

Mr. Jan-Hendrik Dronkers
Director General
Rijkswaterstaat, The Netherlands

Contributors

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Antoon Bosch studied at Radboud University Nijmegen and earned his PhD at the Delft University of Technology in 2000. Since 1988 he has been working at the Department of Humanities and Law of the Dutch Open University as an Associate Professor in Cultural History. He has published several articles and books, including *Om de macht over het water. De nationale waterstaatsdienst tussen staat en samenleving (1798–1850)* (2000); “Changing Societies Produce Changing Rivers. Managing the Rhine in Germany and Holland in a Changing Environment, 1770–1850” in T. Tvedt, R. Cooper (eds.), *A History of Water, Series 2, Volume 2: Rivers and Society: From Early Civilizations to Modern Times* (2010); and L. H. M. Wessels, A. Bosch (eds.), *Naties, staten en Nationalisme in Europa sinds circa 1750* (2012).

Nil Disco is a senior researcher at the Department of Science, Technology, and Policy Studies at the University of Twente. Trained as a sociologist, he has published in recent years on urban technologies, transnational water management, and Dutch water history. He recently co-edited a volume with Eda Kranakis titled *Cosmopolitan Commons. Sharing Resources and Risks across Borders* (2013).

Maurits Ertsen is a member of the Water Resources Management group of Delft University of Technology. He studies water history in a broad perspective. He is currently collaborating with archaeologists in order to increase our understanding of human-environmental interactions within water systems in the past. Furthermore, he is interested in colonial irrigation in the twentieth century, with a focus on Indonesia and Sudan. He is treasurer of the International Water History Association (IWHA), secretary of the Dutch Association of Water History, and one of the two main editors of *Water History*, the official journal of the IWHA.

Leland Johnson, who passed away in late February 2014, held degrees from Murray State University and St. Louis University and a PhD from Vanderbilt University. Specializing in the history of engineering technology, he completed dozens of studies and publications during more than five decades of research and writing. Many of these chronicled the work of the Army Corps of Engineers and include *Situation Desperate: U.S. Army Engineer Disaster Relief Operations, Origins to 1950* (2011) and *Triumph at the Falls: The Louisville and Portland Canal* (2007). Three times the Society of American Military Engineers awarded him the Toulmin Medal for outstanding article of the year published in *The Military Engineer*.

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John Lonnquest is the Chief of the Office of History, Headquarters, U.S. Army Corps of Engineers. As a staff historian he served as director of the Corps of Engineers' oral history program, directed its wide-ranging field history program, and led the Corps' Iraq and Afghanistan history teams. He has also written and edited histories on missile development and the Korean War. He received his PhD in history from Duke University in 1996.

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Matt Pearcy has been a historian with the Office of History, Headquarters, U.S. Army Corps of Engineers since 2006. He previously worked as the district historian in the St. Paul District of the Corps of Engineers in Minnesota. While there, he coauthored (with Charles Camillo) *Upon Their Shoulders: A History of the Mississippi River Commission* (2004). He has published related articles in *Louisiana History, Journal of the Illinois State Historical Society, Florida Historical Quarterly, Military History of the West, and Army History*. He holds a PhD in history from the University of North Texas and is currently writing a biography of army engineer Andrew A. Humphreys (1810–1883).

Bert Toussaint is employed as a corporate historian in the Ministry of Infrastructure and the Environment. His main tasks are management of research projects on the history of water management, infrastructure, and transport, and education on these topics. His publications include *In een Japanse stroomversnelling* (edited with Louis van Gasteren) (2000) and *Polder Pioneers. The Influence of Dutch Engineers on Water Management in Europe, 1600–2000* (edited with H. S. Danner) (2005).

William F. Willingham has long experience in the fields of American history, historic preservation, architectural history, water resources development, and community history. He has taught at the college level, served as a district and division historian for the Corps of Engineers, and worked as a consulting historian. He has authored numerous scholarly books, articles, reviews, consultant reports, and professional papers. He received his PhD in American History in 1972 from Northwestern University and a BA from Willamette University in 1966.

Preface

In the spring of 2004, the U.S. Army Corps of Engineers and the Dutch Rijkswaterstaat agreed to participate in a joint effort that promotes mutual cooperation and information exchange to improve water resources management in both countries. As a result of that initiative, a 2005 workshop in The Hague brought together Dutch and U.S. historians and water resources professionals to develop the framework of a comparative history to explore the social, political, economic, and technological factors that shaped the development of water resources in the Netherlands and in the United States.

After the meeting in the Netherlands, a team of nine historians—six Dutch and three from the United States—spent the next several years examining the myriad factors that shaped the evolution of water resources development in their respective countries. The history they produced is both collaborative and comparative. The introduction was co-written by a Dutch and an American historian. Each of the following eight chapters, built around a common chronology and investigating many of the same historical themes, was written by Dutch or U.S. historians. The conclusion, which also was co-written by a Dutch and an American historian, provides the comparative synthesis of the material provided by the authors in the previous chapters.

This collaborative history required more than insightful research and graceful prose. Working diligently to weave together the two parallel narratives, the editors sought to provide balanced historical coverage, giving Dutch and American readers sufficient information to explain key geographic, social, and political background without distracting from the narrative. Deciding on a common, or a least consistent, terminology was a challenge.

Many people on both sides of the Atlantic deserve special mention for their support of this project. Dr. Marty Reuss of the Office of History, U.S. Army Corps of Engineers was instrumental in starting the comparative history but retired before it was completed. Mr. Bert Keijts, former Director General of the Rijkswaterstaat, and Mr. Steven Stockton, Director of Civil Works for the Corps of Engineers, provided valuable support for this project. Mr. Hans Pietersen, Mr. LuitzenBijlsma, and Dr. Jean-Marie Stam of the Rijkswaterstaat, as well as Mr. Robert Pietrowsky and Mr. Paul Bourget of the U.S. Army Corps of Engineers' Institute for Water Resources, provided critical insight along the way. We also extend special recognition to our reviewers: Dr. Joe Manous, Dr. Maurits Ertsen, Mr. Pieter Huisman, Dr. Gerry Galloway, Dr. Leonard Shabman, and Dr. Robert Brumbaugh. Mr. James Garber and Mr. Doug Wilson, both of the Office of History, were instrumental in designing and producing the U.S. maps and editing the manuscript. Mr. John Mitrione of the U.S. Government Printing Office was responsible for the layout and design of this publication, and Dr. Jeff Brideau and Ms. Barbara Chastel de Boinville provided invaluable copyediting reviews.

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1 Introduction

Bert Toussaint and William F. Willingham

This volume tells a trans-Atlantic story. Its chief protagonists are two established and respected federal water resources organizations—the United States Army Corps of Engineers (USACE) and the Dutch Rijkswaterstaat. Founded more than 200 years ago, both organizations have a complex institutional history. These histories are geographically and culturally specific, but overlap in substantively important ways. Although the United States and the Netherlands maintain a long tradition of political, economic, and technical cooperation, only recently have these institutions formally engaged one another in meaningful forms of direct and collaborative interaction. These exchanges, which explored the organizations' experiences in managing national water resources, led to this comparative study of their histories, values, and practices.[1]

In May 2004, the Corps and the Rijkswaterstaat signed a Memorandum of Agreement (MOA) that formally initiated a program designed to facilitate bilateral collaboration in research, development, testing, and evaluation—all directed toward improving the management of water resources in both countries. These formal exchanges underscored a need to explore the fundamental similarities and differences between the two organizations and instilled a desire to construct a better understanding of the historical context that shaped their respective water management practices.

In November 2005, a two-day workshop with ten participants from each country was held at The Hague, Netherlands. This small group of Dutch and American water resources historians and others interested in the historical context of water resource management identified significant decisions and activities that shaped water resources programs and policies in the Netherlands and the United States. The MOA and the workshop were given heightened significance by Hurricane Katrina, which struck the Gulf Coast of the United States on August 23, 2005. This storm, which resulted in 1,800 fatalities and ranked as the fifth deadliest in U.S. history, provided an immediate, tangible incentive for both nations to share their extensive institutional knowledge about coping with storm surge and other water-related disasters.

A central question discussed during the workshop was: "Is a comparative water management history a good idea?" At a glance, the countries' relative size and physical-geographical features seem prohibitively dissimilar, and devising comparative metrics presented a serious intellectual challenge. The workshop participants agreed to investigate this question by developing a comparative framework. They began by identifying, comparing, and contrasting significant events and programs in Dutch and U.S. water history. They then proceeded to contextualize these historical markers with key political, socio-economic, technological, demographic, and environmental factors that helped shape the water resources infrastructure over time. Constructing this historical and comparative framework, they hoped, would provide an answer to their preliminary question and offer insight for Dutch and American policy makers, planners, and other decision makers as they implemented water management and infrastructure projects in their respective countries.

TIMELINE FOR COMPARATIVE ANALYSIS

After identifying the main features and events of each country's national water resources development, the workshop established historical timelines to chronologically focus a comparative analysis of the identified programs and projects. The timeline used in this book was a refinement of the historical phases of water resources development that emerged from the workshop discussions. The workshop participants identified broad phases of development: two for each century and bridging time segment. Condensed from five to four phases for this volume, the chronology employed reflects the changing role of national governments in water infrastructure development and management, as well as technological changes and socio-economic and demographic factors.

During the first phase, between 1800 and the 1860s, national governments played a limited participatory role in infrastructure undertakings. In the United States, the national government's constitutional authority to build a transportation infrastructure was debated, inhibiting action until mid-century, although Congress did fund a limited number of surveys as well as modest river and harbor improvements. In the Netherlands, political revolution and the consolidation of state power, scarce financial and personnel resources, and the turmoil surrounding the advent of the liberal state, limited the national government from making major commitments to river improvement projects until near the end of the first phase, although major canal, reclamation, and infrastructure projects were accomplished.

During the first half of the nineteenth century, both countries evinced a form of *laissez-faire* economic and political liberalism that actively discouraged federal expenditure on public works. However, in the latter half of the nineteenth century, both national governments became increasingly activist and willing to deploy public funds and resources for infrastructure projects in their respective "national interests," inaugurating a second phase. The outcome of the Civil War in the United States largely settled the constitutional debate in favor of expansive federal power, and provided the appropriate political conditions for extensive federal navigation improvements in rivers and harbors, as well as extensive land-grant subsidies for private railroad construction and natural resource exploitation. In the Netherlands, the liberal state undertook flood control work on the nation's rivers. In addition, it constructed new entrances for the Amsterdam and Rotterdam harbors and launched new canal projects.

The third phase, 1900 to 1970, encompassed for both nations the modern industrial state, two global wars, economic depression, and the advent of the Cold War. The beginning of the period is marked by the transition to scientific water resources management in both countries. In the United States, this era is characterized by the proliferation and up-scaling of major federal water control works, such as multiple-purpose dams and large-scale flood control works constructed by several federal agencies, including the Army Corps of Engineers and the Bureau of Reclamation. In the Netherlands, the national government planned and developed the technologies required for flood control along its coastal zone and for an effective use of its freshwater capacity. Major examples of these efforts are the Zuiderzee Works, which included a closure dam that closed-off the Zuiderzee and construction of polders in the created freshwater lake; development of a national freshwater system; and the Delta Plan, a major flood protection scheme in the southwestern delta region, implemented between 1954 and 1986.

The final, fourth phase covers the last third of the twentieth and the beginning of the twenty-first century. In both nations, environmental and budgetary concerns limited or altered the development of new, large-scale water resources projects. An emphasis on the operation and maintenance of existing infrastructure marked the era. In the United States, the federal government insisted that local interests share the cost of developing any new water resources projects, and a proliferation of federal legislation and directives institutionalized environmental considerations. In the Netherlands, by then functioning within the European Union, there emerged a commitment to internationalizing water resources development and new plans for flood control on the river deltas and the coastal zone were implemented.

This framework, divided into four distinct and historically coherent eras, provides the structure for this book, which can be regarded as the first U.S.-Dutch comparative account of water management history. It focuses on the federal (U.S.) and national (Dutch) levels of government.

GEOGRAPHICAL DIFFERENCES

Clearly, there are striking and significant geographical differences between the two countries: The United States covers 9,629,090 square kilometers (3,717,813 square miles); and the Netherlands only 41,526 square kilometers (16,163 square miles), slightly smaller than half the state of Maine. The contiguous U.S. is geographically diverse, containing eight distinct physiographic divisions. The most conspicuous divisions are the Atlantic Plain, along the coastal regions of the eastern and southern continental shelf; the Appalachian Highlands, lying on the eastern side of the continent; interior lands called the Great Plains; the Rocky Mountain System traversing the inland western states; the Intermontane Plateaus that lie between the Rocky Mountains and the Pacific Mountains; and the Pacific Mountain System that includes the Pacific mountain ranges. The Netherlands, except for a few hilly regions in the southeast and the coastal dunes in the west, is mostly plains composed of river-borne alluvial deposits, depositions from the sea, peat bog areas, and cover sands. In terms of climate, the U.S. includes examples of nearly every global climatic zone, from sub-tropical to polar. The Netherlands, on the other hand, is situated in a marine climate—cool and humid, with strong prevailing westerly winds and ocean storms depositing an average annual rainfall of 833 millimeters (32.8 inches).

WATER RESOURCES AND INFRASTRUCTURE

Water is an important feature of both countries. One-sixth of the Netherlands' surface area is covered by water in rivers, lakes, ponds, and canals, while less than 5 percent of the United States is covered by water (470,131 square kilometers; 181,519 square miles). The Great Lakes alone account for 244,106 square kilometers (94,250 square miles) of water surface, though this resource is shared with Canada. A striking feature of the Netherlands is that one-quarter of the country lies below sea level, with the lowest point registering -6.7 meters (-22 feet) below Dutch Ordnance Datum. The plains in the west of the country are low-lying, while the highest point lies in the southeast at 322 meters (1,053 feet) above Dutch Ordnance Datum. In contrast, the United States contains great extremes of elevation. Its highest point is Mount McKinley at 6,194 meters (20,320 feet) and its lowest spot resides in Death Valley, California, at -86 meters (-282 feet) below sea level.

Rivers have exerted profound influence on the historical development of both countries. The two major rivers of the Netherlands are the Rhine (1,230 kilometers; 763 miles) and the Maas (950 kilometers; 589 miles). When the Rhine enters the Netherlands, it changes its name to the Upper Rhine, and once the Waal River splits off the Upper Rhine, the latter becomes the Pannerdensch Kanaal. Downstream, the Pannerdensch Kanaal splits into the IJssel and Nether Rhine. The Nether Rhine becomes the Lek, then the Nieuwe Maas before it enters the Nieuwe Waterweg. Finally, the Maas flows as Bergse Maas into the Hollands Diep. The Dutch coastline is protected by a series of dunes, dikes, and dams, and dikes also reinforce the rivers' banks. The delta is susceptible to destruction by strong surge tides, and for centuries, storm surges wreaked havoc along the Dutch

Major Rivers and Hydraulic Structures in the Netherlands

coast until the Delta Plan was initiated in the 1950s. By comparison, the much longer ocean coastline and series of river banks in the United States have protective structures only in areas of high potential storm damage.

The U.S. has several major river systems. These include the Mississippi/Missouri rivers and their major tributaries (Ohio, Illinois, Arkansas, and Red rivers); the Columbia River and its chief tributaries (Snake and Willamette rivers); and the Colorado River and its tributaries. The Mississippi River system (3,730 kilometers; 2,320 miles) is the largest, draining all or part of thirty-one states with a basin of 2,981,076 square kilometers (1,151,000 square miles). The Columbia River (2,000 kilometers; 1,214 miles) drains 352,446 square kilometers (219,000 square miles) in seven western states and an additional 63,569 square kilometers (39,500 square miles) in British Columbia, Canada (total drainage: 668,000 square kilometers; 415,076 square miles). The Colorado River (2,330 kilometers; 1,450 miles) and its tributaries form a watershed of 629,000 square kilometers (242,900 square miles) in seven U.S. states and the two Mexican states of Baja California and Sonora.

Major Rivers of the United States of America

In their natural state, these rivers could not be safely navigated on a year-round basis. Their depths fluctuate based on flows affected by seasonal snowmelt, precipitation from storms, and drought. Under natural conditions, many of these river channels are prone to meandering within their flood plains, and large quantities of silt and debris could clog channels. During the nineteenth century, the Corps met these hydrologic challenges with a variety of engineering responses including wing dams, dredging, snagging, levees, and revetments. These engineered interventions culminated in the construction of multiple-purpose dams (flood control, hydroelectric power generation, navigation, etc.) and levees on main stem rivers and major tributaries, during the first half of the twentieth century.

A major feature of Dutch water management has been the effort to create land by draining lakes and marshes. Between the years 800 and 1250, the Dutch reclaimed the main part of the peat marshes and turned them into arable land or land suitable for animal husbandry and livestock. Laborers carried out the drainage of peat areas by digging parallel ditches, usually starting from a natural watercourse. If a natural watercourse was not nearby, workers dug a drainage canal that flowed into a river or brook before reclamation began. The reclaimed land was protected from the inflow of water from higher-situated peat areas by digging demarcation ditches, located perpendicular to the drainage canals. These ditches drained the water from upstream areas. If drainage proved insufficient, laborers broadened drainage canals and demarcation ditches or dug new canals. In this way, the typical Dutch polder landscape developed.

Unfortunately, nearly all of the drained polders eventually subsided because of compaction and oxidation of the top soil layer. Hence, the polders' soil level dropped continuously, which increased their vulnerability to flooding. This increased susceptibility made structural flood protection measures, like dike and levee building, a necessity.

Dutch engineers used a more complex process when draining a lake to create a polder. First, workers surrounded the lake with a dike and a ring canal. Then, they pumped the water out of the lake into the ring canal, which conveyed the pumped water into a peripheral storage canal for temporary holding. From the storage canal, the water was discharged into rivers that ultimately carried it to sea. Initially, windmills powered the pumping process, but they were successively replaced by steam and diesel engines, then by electrically operated pumps. The newly reclaimed land was subsequently intersected with drainage canals and parceled out into agricultural units.

In the U.S., land reclamation also occurred, but most of the land was reclaimed from freshwater rather than the sea. Individual farmers undertook the majority of these reclamation efforts, especially in the "prairie and pothole" regions of the Midwest.[2] Significant reclamation efforts also occurred through polder-like techniques in the deltas of the San Joaquin and Sacramento rivers of California. In the east, one of the most extensive U.S. land reclamation projects was the Central and Southern Florida Flood Control Project (C&SF Project), which sought to control the waters of the meandering Kissimmee River as it flowed southward down the Florida peninsula. Authorized by Congress in 1948, this project was extremely successful in reclaiming wetlands for pasture, agriculture, and urban development, but the project's negative environmental impacts proved so significant that forty years later, the Corps, in partnership with local, state, and other federal agencies, initiated an even more ambitious project – the Comprehensive Everglades Restoration Plan (CERP), to restore some of the natural hydrologic functions of Florida's wetlands.

THE COMPARATIVE STUDY

Recognizing the two countries' similar needs to develop and manage water infrastructure, while keeping in mind their fundamental geographical and socio-political differences, this comparative study is organized into chronological, narrative chapters alternating between Dutch and American authors. The narrative is broken into four time periods (chapters) for each nation. This narrative is followed by a concluding chapter highlighting the similarities and differences between the water management styles and efforts of the Rijkswaterstaat and the U.S. Army Corps of Engineers. Throughout the text, illustrations, maps, photographs, and other graphics are included to clarify and illuminate the discussion.

In this book, historians, policy makers, and the general reader will find stimulating insights into the evolution of water resources management from the perspective of two of the world's preeminent water resources agencies. Both journeys have proven exciting, economically successful, and essential to the growth of their respective nations, while showcasing adaptability to changing economic, political, and cultural contexts. Alongside the many successes, challenges evolved that required innovation, technical expertise, and political determination. This book chronicles both the successes and the failures of each agency, and celebrates champions in water resources management and their achievements. It is a scholarly, comparative history of both academic and practical merit. The insights from this book are intended to help water resources managers as they address present and future challenges on both sides of the Atlantic.

ENDNOTES

1 For a recent overview of Dutch-American relations, see Hans Krabbendam, Cornelis A. van Minnen, and Giles Scott-Smith (ed.), *Four Centuries of Dutch-American Relations*, 1609–2009 (Amsterdam: Boom, 2009).

2 Regions of North America whose land surface was modified by glacial activity and is characterized by low permeability glacial till soils and a lack of surface drainage.

2 Dutch Water Management In an Era of Revolution, Restoration and the Advance of Liberalism, 1795–1850

Toon Bosch

Managing water in the Dutch delta has always been governed by the interaction of climatological and geological factors with the population and its relations with water—water as an adversary and an ally—and shaped under changing societal conditions. These water management efforts not only made the existence of a good part of the country physically possible, but also contributed to the emergence of a unique hydraulic society. The Netherlands is a country in which managing water has a fundamental influence on individual and collective behavior and on the environment itself—such that it can justifiably be called, in the words of the French historian Fernand Braudel (1902–1985), a *civilisation de l'eau*, or water-civilization. The water-civilization of the Low Countries acquired specific characteristics from the eleventh century on. There was, first of all, a dynamic development of hydraulic and craft knowledge. Concurrently, changing political arrangements influenced the organization of water management and gave rise to a decentralized structure of water governance during the Dutch *Ancien Regime*. In this political arrangement, local levels of government and private bodies in the form of water boards took the lead. These institutions succeeded in raising safety levels and constructing impressive water works. They also contributed in cooperation with scientist and engineers—among them the famous Andreas Vierlingh (1507–1579) who wrote one of the first theoretical essays on constructing sea dikes—to the development of hydraulic expertise. While these bodies were, as a rule, adequate to the task, new hydraulic and political developments at the end of the eighteenth century caused this system of water governance to enter a period of serious crisis.

This chapter briefly reviews water management and the development of the decentralized system of water governance during the *Ancien Regime*. It then concentrates on the causes and forces that put an end to the decentralized political framework of the Republic of the Seven United Provinces at the end of the eighteenth century, which laid the foundations for a new centrally governed national unitarian state. In the domain of water management, as in other fields, this political regime transformation was accompanied by a conscious effort at upgrading centralization, and a dominant role for the state. This chapter also discusses the politically and administratively troublesome emergence of centralized water management in the period 1795–1813, the so-called Batavian-French Time, and its continuation under the new political covenant of the (United) Kingdom of the Netherlands, up to the liberal constitutional reforms that were effected at the end of the 1840s. The second part of this chapter covers the founding and consolidation of the national corps of hydraulic engineers and its new role as representative of the nation-state. This national corps of engineers was a new actor in a tension-ridden water-management regime already populated by old and established actors together with whom it sought a new national style of water management with clearly delineated rights and responsibilities for the different parties active in this domain. The outcomes of these efforts by the state engineers is covered in the last section of this chapter, specifically for the domains of coastal defenses and river management.

POLITICS, CULTURE AND GENERAL WATER MANAGEMENT IN THE ANCIEN REGIME

The historical development of the Dutch water civilization can be viewed as “the story of a continuing dialogue of people and society with the shaping forces of water”; and shows how hydraulic and cultural coping strategies altered decisively several times over the course of several hundred years.[1] From the eleventh century onwards, in the context of economic progress and a growth of population and changes in the behavior of the sea and the rivers, the population of the Dutch delta adopted an increasingly defensive posture in the struggle against water. Starting in the sixteenth century this was supplemented by an offensive strategy that had adopted a manipulative attitude toward water and the environment by the early nineteenth century. The driving force of Dutch water management in general was the need for safety against floods—particularly because flood-proneness was aggravated by soil subsidence in peat and clay areas resulting from the systematic lowering of the ground water table intended to make and keep these areas suitable for agriculture.

The first large-scale collective arrangements in the defensive phase consisted of the construction of continuous levees along the rivers around the beginning of the eleventh century.[2] Subsequent centuries witnessed the development of an increasingly interlocking system of water management with specific local and regional characteristics. Its backbone consisted of the water boards, sometimes created by the authorities, but in many cases by the inhabitants themselves with the approval of local and regional secular or ecclesiastical rulers. These bottom-up corporations—an estimated three thousand—are the oldest civil water management and democratic institutions in the Netherlands. There were enormous differences in the scale at which these water boards operated and in the responsibilities they bore. Regional water boards managed extensive tracts of countryside, others only a single polder or a dike. The way they went to work was

Rijkswaterstaat

Three mills on a polder dike near Leidschendam determined by the specific geographical and hydraulic characteristics of the terrain they governed, which in turn sometimes required the application of complex hydraulic knowledge and methods. In addition to the water boards, local and regional powers also had an interest in water management. This interest was generally limited to adjudicating conflicts, granting concessions for peat-digging, and regulating the use of the large rivers and the founding of new water boards. Higher levels of government at the district or provincial level rarely intervened in the daily practice of water management. This was almost exclusively the prerogative of the autonomously operating water boards. This water management arrangement also remained intact during the federally governed Republic of the Seven United Provinces (1588–1795) under which the highest state authority had nothing to do with water management—in line with contemporary ideals of political freedom and administrative autonomy. However, the provincial estates did play a more active role than previously. Aside from supervisory and regulatory tasks, they also sometimes subsidized impoverished water boards and, in some cases, even carried out hydraulic works for the benefit of provincial trade and security.

For centuries, this decentralized system of water management functioned more or less to everyone's satisfaction. It stimulated taking an offensive approach toward water management, and encouraged perseverance in the struggle against water. Together with internationally recognized hydraulic engineering know-how, this contributed in no small part to the cultural and economic flowering of the Dutch Republic in the seventeenth century. In this famous *Golden Age*, water management was boosted by the investments of huge profits, made in all kinds of trade, agriculture, and craftsmanship, and they included reclamations of larges lakes into fertile soil. But at the same time the Dutch water civilization was and remained a vulnerable society. Much of the nation was surrounded by seas, a large part of it lay below sea level and it formed the delta of three large European rivers. The physical survival of this country was and is, therefore, continually dependent on the exertions of organizations and individuals who—inevitably under changing societal, ecological, and climatological conditions—dynamically manage and adapt the necessary hydraulic institutions and arrangements in the domains of dike-building, drainage, river management, and coastal defenses.

In the second half of the eighteenth century, meeting this challenge became gradually more difficult. The fragmented water management system with its numerous autonomous actors proved to be progressively less equal to the task of adequate management of certain aspects of the water management problem. Coastal defenses demanded a continuous, heavy, and expensive effort and from time to time heavy storms painfully revealed the weak spots in the line of defense. With the progressive soil subsidence, it became ever more difficult to regulate the drainage of low-lying polders using existing pumping technology. But the biggest worry concerned the management of the flows of the large rivers and the associated flood catastrophes. From the 1780s on, these disasters not only became more frequent, but also caused more damage to the lands along the large rivers. In this way, the already beleaguered nation saw itself confronted with a hydraulic crisis of such proportions that many feared for the country's very survival. Inspired by the ideals of the French Enlightenment, knowledgeable contemporaries and progressive citizens looked first to scientific and hydraulic solutions for salvation. Gradually, however, they also came to recognize the pernicious effects of their stagnant federal system of governance which, lacking powerful institutions at the national level, was especially ill-equipped to tackle the complex and large-scale problem of the rivers.

Haags Historisch Museum

A session in the National Convention, the parliament, at The Hague, 1796

THE RISE OF CENTRAL STATE MANAGEMENT IN A REVOLUTIONARY PERIOD (1795–1806)

In 1793, the French National Convention decided to liberate the Republic of the Seven United Provinces from their "tyrannical" ruler and declared war on the Dutch Stadtholder (or sovereign) William V. Two years later a French Army, accompanied by Dutch Patriots who had lived as political refugees in French exile since the failed purge of 1787, crossed the frozen rivers, occupied the nation, overthrew the stadtholder and his regime, and so "liberated" the oppressed people of the Republic by granting them the crown jewels of their own revolution: freedom, fraternity, and equality.[3]

The demise of the Dutch *Ancien Regime* was confirmed by French acclamation and recognition of the "one and indivisible" Batavian Republic, a French satellite state. In sharp contrast to the loosely federated Republic of the Seven United Provinces that it replaced, this new republic was to be a unified state with a strong central government, a democratically chosen parliament, and a constitution. Yet these ideals were met with forceful resistance by the protagonists of the "old" republic, who preferred strong and autonomous provinces (or departments) and a weak central government. The debate on the future constitution in Parliament resulted in a stalemate between the two opposing parties of Unitarians and Federalists. The impatient French interfered in January 1798. They supported a purge carried out by radical Unitarians, which resulted in imprisonment and intimidation of the Federalist opposition and they enjoined Parliament to vote for a constitution based on the principles of strong unified government and the subordination of the provinces.

The constitution also laid the foundation for centralized water management. One of the tasks of the newly appointed minister of internal affairs, A. J. La Pierre, was the management of "roads, waters and dikes" on a national scale—an idealistic, revolutionary approach but hazardous as well.[4] For centuries, responsibility for coastal and river water management and the control of the water economy in cities and in polders had been entrusted to provincial estates, but was in practice carried out by autonomous water boards, formerly private associations of local and regional stakeholders.

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Christiaan Brunings (1736–1805), the first chief executive officer of the national water management service

Even if full-scale state interference had been politically feasible, the state lacked the knowledge, financial, and legal instruments, and a board of state engineers to assume responsibility for these numerous and often complicated collective arrangements. How then should central state water management be organized and performed? At La Pierre's request, prominent hydraulics experts answered these questions in a master plan for future state water management. Among these experts were Christiaan Brunings (1736–1805), the German son of a vicar and former head of water management in the province of Holland, and the *uomo universalis* Cornelis Krayenhoff (1758–1840), a medical doctor, political activist, hydraulic expert, and high-ranking army officer and counselor, who had a great interest in hydraulic problems. They delegated the overall supervision and control of national water management to the minister of internal affairs and proposed substantially reducing the role of provincial estates and the water boards in favor of more state influence. To facilitate this, national water management was divided into three separate domains: coastal water management, river management, and the management of "internal" water. Responsibility for these tasks was assigned to a newly founded national water board, of which Brunings was appointed chief executive officer. The approval of this scheme by Parliament in May 1798 can be considered the birth of central water management in the Netherlands.

Nevertheless, resistance to centralized water management was far from extinct. In addition to a fundamental political rejection of the idea of a strong central state, opponents argued that central water management would be both expensive and impotent—simply because it would be incapable in dealing with complex local and regional water management problems. In this polarized political atmosphere a parliamentary commission was appointed to define the tasks and the span of control of the minister of the interior in the area of water management. Repeatedly, the Federalist members rejected state encroachment on the prerogatives of the provincial estates and the water boards. Additionally, the representatives of the inland provinces complained of the dominance of the province of Holland in the proposed structure for national water arrangements. A new commission eventually broke the stalemate at the expense of the rigid centralization model. From now on the minister had to abstain from direct involvement in the internal affairs of the water boards and the provinces. The direct influence of the minister was also restricted by a system that allocated three kinds of water works, according to the actors who were legally and financially responsible for their supervision and maintenance. Only for the first category of works—large rivers and a number of well-circumscribed levees along the shores and the rivers that were considered of national importance—was the nation-state held fully responsible for the necessary financial and hydraulic arrangements. In the other categories, the existing hydraulic actors—provinces, water boards and private stakeholders—were assigned this role. Yet one major important infringement on this system allowed the minister to continue the oversight of water works of the water boards. In spite of new protests, Parliament approved this arrangement in 1800. Given the vehement opposition to any infringement of the former republican autonomy, this was a surprising outcome. In the literature this remarkable turn is ascribed to the changing political tide in which economic decline and the loss of overseas colonies to England eroded the "Batavian" revolutionary spirit and stimulated the longing for stability.

In any case, out of the revolutionary turbulence emerged a new model for water management. This included old collective arrangements and practices but also new revolutionary elements. The upshot was a new nationwide arrangement in which the old actors—the provinces and the water boards—now also had to take account of the nation-state and its national water service in carrying out their tasks. This was certainly a widely contested arrangement that "did not match with the character of the nation," but, given the serious problems that threatened the physical survival of the Dutch Delta, it was apparently the lesser of two evils. The extreme centralization of 1798 obviously did not harmonize with Dutch political culture, but in spite of the ongoing opposition and the gradual restoration of the political influence of the provinces, the essential revolutionary core of the new polity—state intervention—remained intact. When considered in detail this was quite a remarkable course of events because the national government and the provinces disagreed fundamentally about their legitimate spheres of influence—giving rise to interminable and laborious negotiations. Eventually they agreed to decentralize the power of the state by instituting cooperation between state and provincial officials in two national commissions for coastal and river management. Though this was a new infringement on the principle of central state water management, it was rather short-lived. In 1805, the discontented French dismissed the Batavian government because of its inability to meet French fiscal and military demands. They bestowed absolute power on the head of the Amsterdam lawyer R. J. Schimmelpenninck, a prelude to a new period of centralization of state power. The first fruit of this policy was the passage of a national river law in 1806 that for the first time enabled the implementation of a truly national policy for river management.

THE FRENCH VERSUS THE DUTCH STYLE OF CENTRAL WATER MANAGEMENT (1806–1813)

When Louis Bonaparte arrived as king of the newly created Kingdom of Holland in 1806 he was astonished by the way Dutch water management was organized and performed. In his memoirs he characterized Dutch hydraulic culture as an almost complete anarchy in which extreme individualism, traditionalism, and absolute

Rijkswaterstaat

Louis Napoleon, king of the Netherlands, 1806–1810

exclusion of state engineering expertise characterized the water management of villages, cities, and provinces. He immediately took firm measures to reinforce the role of the national state in managing coastal and river areas, a policy already initiated by the previous head of state, R. J. Schimmelpenninck.[5] His ideal was the implementation of the French absolutist model of national agency in hydraulic and infrastructural matters, but this model, as a committee of experts wisely advised, was not congenial to specific Dutch conditions and needs.[6]

Nevertheless, the king reinforced the position of the corps of state engineers and, together with elite members of that corps, designed a grand scheme for improving and (re)constructing rivers, canals, dikes, and water works. This monarch fully understood the strategic position of his kingdom, which he described as a floating island, a country under permanent siege by its seemingly invincible water enemies. His water management policy, "the first concern of the nation," in his own words, was characterized by a sense of urgency and the promotion of science as an instrument for developing hydraulic know-how by savants, expert craftsman, and engineers organized in the Royal Academy of Sciences and *ad hoc* advisory boards. When a catastrophic flood ravaged a great part of the Dutch delta in 1809, the king instantly visited the stricken area, established a national disaster relief fund based on charitable donations, and sent his corps of engineers to repair the broken dikes and to assist the stricken population. In addition to inventing traditions of royal concern for water management and of supporting charitable campaigns for victims, King Louis ordered his ministers to draft a law detailing a uniform national system of dike maintenance. The execution of his truly modern Dike Law, which subsumed the countless idiosyncratic polders into a mere seventeen hydraulically inspired "dike rings," floundered when it was introduced in 1810. It fell victim to administrative difficulties and to resistance from the water boards and provincial estates who still objected to any infringement of their hydraulic autonomy.[7] As a result, neither the royal government nor the Napoleonic French government, which annexed the Dutch kingdom to its empire in the summer of 1810, were ultimately able to administer this law in an effective manner. Beside this short-lived Dike Law, these years witnessed the development of laws and regulations about the free course of navigable rivers and canals, and about improvement of non-navigable water courses and the maintenance levees. These regulations became part of the legal basis of the national water management and the activities of the Rijkswaterstaat since 1813.

As had been proven often in the years before the fall of Napoleon in 1813, the French model of rigid centralization was incompatible with the specific local and regional hydraulic conditions of the nation and with the associated centuries-old culture of autonomous local and regional-based water management—including its experience and informal know-how—as it had developed since the early Middle Ages. The nascent central state had neither the capacity nor the expertise to replace the local hydraulic actors without damaging the nation's safety and welfare. Yet in the Batavian-French period in a relatively short time—despite resistance—this system of water management lost its exclusive nature. Despite the fact that during these years continuity prevailed in the routine practice of water management, it was nonetheless clear that the foundations had been laid for the political, legal, and hydraulic establishment of a new regime in water management and infrastructure wherein the national state, as a new actor next to the provincial estates and the water boards, would soon be demanding a decisive role.

RKD, The Hague

King William I, who reigned over the Netherlands until 1840 under the constitution of 1815

CENTRALIZED WATER MANAGEMENT IN THE (UNITED) KINGDOM OF THE NETHERLANDS (1815–1840)

The institutions of national water management survived the collapse of the French Empire, the retirement of the French troops and the proclamation of the Kingdom of the Netherlands in 1815. The constitutions of 1814 and 1815 reasserted the supervision of the national state over water management which, in the political culture of the time, meant that the sovereign could command a central role in the water polity.[8] The king's minister was formally placed at the head of the water management system and functioned according to constitutionally sanctioned instructions. In addition to these political achievements of the Batavian-French period, many of the water management laws of the period were also retained. Policy making and implementation were once again delegated to the Ministry of Internal Affairs where, apart from a few brief episodes, they would remain until the establishment of a separate Ministry of Water Management in 1877. Initially, the provinces played a subservient role, despite the fact that in principle the Constitution of 1815 granted them a more prominent role in the scheme of things. The water boards were, to be sure, subject to provincial supervision, but in practice they stuck to their independent and autonomous tradition. They were supported by King William I, who, in 1814, partly repealed the extremely unpopular Dike Law of 1810. Moreover, in 1817 he restored to the water boards their "ancestral" rights by renewing the judiciary powers they had lost during the annexation by France. Two years later, the provinces were also charged with the direct supervision and management of a large number of hydraulic works, the upkeep of which had proven to be too great a financial burden for the central state to bear. These were remarkable decisions, in view of the brief history of centralized water management, in which the national state had attempted to achieve a powerful position. This is even more remarkable because of what is commonly viewed as the "autocratic" style of governance of the "canal-king" William I and his intensive involvement in the financing, policy making, and execution of hydraulic works and other infrastructure. These characteristics have encouraged history's image of an egocentric monarch whose word was law, but a closer look reveals that this is too extreme a view. This monarch recognized that it would be utterly impossible to realize a successful system of water management based on a dominant central state without widespread societal acceptance and the cooperation of the water boards and provinces. Evidence of this recognition can be found in the broad-based composition of the Royal River Commissions of 1820 and 1825, in the employment of external technical advisors, and in the king's dealings with the water boards and provinces. Beyond the domestic water issues, the king had to deal with the German states who put pressure on the Central Commission for the Rhine Navigation (1815) to improve the Rhine as a transport chain to the North Sea.

From a strict constitutional perspective, the influence of the central government and of King William I on the institutions of water management was greatest during the first six years of his reign. The administrative partition between national and provincial hydraulic infrastructure marked the end of this period, but it can also be seen as a search for a new policy, in which, to a greater degree than previously, the state searched for a form of "co-governance" with the other actors in order to assure the physical integrity of the nation.[9]

This necessary balance could profit from the further development of workable political arrangements. But since the advent of centralization the political framework—along with financing—had proven to be the Achilles heel of a national system of water management. The biggest problem was and remained the division of labor among the national state, the provinces, and the water boards. The partition into national and provincial hydraulic works did stabilize relations, but despite *ad hoc* repairs and corrections, the achievement of a practical balance in the precise delineation of state and provincial spheres remained unrealized. A similar situation prevailed in relations with the water boards. The government tried, to no avail, to get a new dike law passed. In 1835 they proclaimed null and void the remaining portions of the old law. The curbing of the judicial power of the water boards met with more success. This power was abrogated in 1841. But at a number of places local government and water management continued to be *de facto* intertwined for several more decades.

Compared to the Batavian-French period, the reign of William I exhibited little initiative in regard to constructing and modifying the basic legal framework of water management. Nonetheless, under this king the legal and administrative underpinnings of water management rapidly expanded. This had to do with a number of factors: the expansion of state intervention; the enlargement of state responsibilities; the division of labor among the state, provinces, and water boards in the system of water management; the execution of a series of large public works; and the efficient functioning of the national water management agency. Until the 1840s, the usual form in which this legal instrument was cast was the Royal Decree. These were "general administrative measures," independent acts of material legislation in which the king simply circumvented the Estates-General. The framing and formulation of such measures was usually entrusted to the Water Management Department of the Ministry of Internal Affairs, but even here the king kept a sharp eye on his civil servants and did not hesitate to intervene when he thought it expedient.

The constitutional reforms of 1848 marked the close of a period of more than five decades in which the state and society cast about for a workable model of national water management. Over the course of this period, extremely centralistic variants relinquished the field to a decentralized model of water management in which the state (with the king as most powerful player), the provinces, and the water boards each searched for the limits of their own specific responsibilities and their roles *vis-à-vis* one another. However, the development of an adequate legal-administrative instrument, essential to establishing this division of labor and defining spheres of influence appropriate to the national state, the provinces, and the water boards, remained a weak point.

Despite the criticism of His Majesty's Water Policies, aimed first and foremost at the rather opaque financing of infrastructural works, his regime formed a crucial link in sustaining and anchoring centralist water management in Dutch society between the Batavian-French time and the water management regime of the liberal period—considering the problematic financial-economic and political conditions that plagued his reign. In the new democratic phase of water management, the king formally retained ultimate supervisory powers, though in practice these were exercised by his minister under the watchful eye of Parliament. The constitutional reforms also reaffirmed the public legal status of the water boards. From then on, the executives of the water boards were bound to generic legal regulations governing their charters and procedures. The appointment of the Dike Count (chief officer of a water board) became the responsibility of the king and his ministers.

BUIDLING A NATIONAL CORPS OF STATE ENGINEERS (1798-1849)

Shortly after the introduction of the Constitution in 1798, Parliament decided that the Minister for Internal Affairs would be supported by a corps of technical civil servants called the Bureau of the Waterstaat. (Waterstaat refers to the hydraulic condition of the nation and the related water management activities.)[10] This first national water management agency (which acquired the full name Rijkswaterstaat after 1848) was staffed by several administrators and fifteen hydraulic "engineers" who as "commissars-inspector over the nation's waterways and *waterstaat*" were stationed at various posts across the country from which they exercised managerial authority over public works in a specific region. Aside from being responsible for the large rivers and the sea defenses, they also supervised drainage projects, public roads, canals, locks, and the business of the water boards. The bureau was led by Christiaan Brunings, one of the most authoritative Dutch and European civil engineers with an impressive record as former inspector of water management in the province of Holland and as hydraulic engineer in the service of the large and prestigious Rijnland Water Board. Brunings' new bureau was organized according to strict hierarchical principles, based on the professional organization of the technical services of large water boards like Delfland and Rijnland, in which the position and tasks of every functionary were spelled out in detailed instructions.

The composition of the bureau showed that it was steeped in craft practices, rather than in science and scholarship. The majority of the "engineers" can be classified as practically-schooled hydraulic "tinkerers"—self-made men, generally from the lower bourgeoisie. With very few exceptions, they had been practically trained, lacked formal technical/hydraulic education and had, prior to their employment by the state, been in the service of provincial estates and water boards. A few of these early engineers were men of culture, enlightened intellectuals who were well-acquainted with each other's work and knew one another through common employers, through memberships in learned societies, or both. Another shared characteristic was the impressive empirical knowledge and know-how that these experts had accumulated in practice. This knowledge was not only fundamental for sustaining routine water management, but also served as the foundation of a broad, *national* knowledge system and was the future basis of the professionalization of centralized water management. Thus, from its very inception the new Bureau of the Waterstaat carried out systematic soundings, measurements, and inspections that were recorded and centrally archived.

The first phase of the existence of the national water management service was heavily influenced by the political and financial climate of the newly emergent nation-state. Central water management, and hence also a national agency for water management, was by no means uncontested. As a result, the new bureau served as a pawn in the struggle between proponents and critics of a centralized state in interaction with the

Rijksmuseum, Amsterdam

Jan Blanken (1755–1838), chief executive officer of the national water management service from 1808 until 1827

Maritiem Museum, Rotterdam

Construction of a navy dock at Hellevoetsluis, under the direction of Jan Blanken, 1802 demands that the French were making on the Batavian Republic as a vassal state. These factors shaped the response to the decentralizing reaction of 1801. From that moment on, the increasing influence of the provinces on national water management took the form of internal reorganizations and a reduction in the list of national hydraulic works for which the bureau was responsible. Two years later the bureau was split into two sections, one bearing responsibility for the estuaries and harbors and the other for large rivers. This functional organizational model mimicked the organization of the military fortifications in the Batavian Republic. Some of the engineers in the Bureau of the Waterstaat, including the eminent Jan Blanken, seized on this development to argue for a merger between the (civilian) bureau and the corps of army and navy engineers. This would mean a substantial increase in status for the bureau engineers with their modest bourgeois backgrounds. But in the social hierarchy of the times, the largely aristocratic officers of both services were so far elevated above the craft-based Waterstaat that this proposal could not even be taken seriously. From this example it is apparent that the national Waterstaat service not only wrestled with its ambiguous political setting, but also struggled with its social-cultural acceptance in a society that thought and acted within the mental framework of the *Ancien Regime*, while progressive vanguards were already initiating a thoroughgoing societal modernization. The status and prestige of the Bureau of the Waterstaat as a “revolutionary state institution” were further compromised by internal strife between the civil servants in the ministry and the top officials of the bureau. The two groups held divergent views on the optimal implementation of central water management policy and tried to win the ministers’ favor for their respective plans. This situation turned to the bureau’s disadvantage after the death of the first director-general Christiaan Brunings in May 1805, when the minister, for financial and other reasons, decided not to fill Brunings’ vacancy but instead to divide the position’s responsibilities between two inspectors. This was a major blow to the Waterstaat’s influence on policy making. Falling into a tinderbox of personal frictions, rivalry among a number of prominent engineers and disgruntlement over the low social status, it also ignited new tensions within the Waterstaat service itself. This developed into a latent organizational culture with a tendency for cooptation and, as a consequence, the creation of family networks within the corps of engineers. With changing political circumstances, internal social contradictions, reorganizations, and engineering conflicts, these latent features could sometimes erupt into open conflict—either with civil servants or among the engineers—culminating in progressive segmentation within the corps itself.

UNDER THE FRENCH WING (1806–1813)

From the moment that the French assumed power in 1806—with the demise of the Batavian Republic and the founding of the Kingdom of Holland—the Bureau of the Waterstaat found itself in a more stable situation. King Louis Napoleon called an almost immediate halt to the decentralizing tendencies. For the institutions of centralized water management this meant, among other things, a reinforcement of the authority of the nation-state over the provinces. This authority took the form of the establishment of a separate Ministry of Waterstaat, a novel step in Dutch (water) history. The Bureau of the Waterstaat itself became the object of vigorous reforms. The principle of a single director was restored and the bureau was strengthened in both quantitative and qualitative respects. Besides more personnel in both the higher and lower ranks, the bureau also acquired a so-called “General Service.” This was a specialist department that focused on knowledge-acquisition in general, including geodetic investigations and surveying, and which also assumed responsibility for preparing large infrastructure projects and provided assistance when dike breaches and other hazards threatened. Finally, the king improved the program of formal technical education for junior Waterstaat engineers, instituted in 1805.[11]

Efforts to mimic the French educational system, particularly the model of general education for aspiring state engineers at the *Ecole Polytechnique*, had mixed results. Up to 1813, future cadres of the Dutch Waterstaat were formed according to French political and pedagogical ideals, including semi-military discipline, residential barracks, and compulsory uniforms. However, it soon became clear that the strong emphasis on theoretical (mathematical/physical) schooling was not compatible with the culture of Dutch water management and the specific practical demands of water management itself. An advisory committee of prominent scholars and hydraulic experts managed to change the king's mind, at least in part. Thereafter Dutch water management curriculum afforded an important place to the practical training of aspiring engineers.[12]

Louis Napoleon's reorganizations mark a decisive shift in the development of the fledgling Bureau of the Waterstaat. In the short run, the king's measures enhanced the social status of this civilian, technical state agency—and not just with the introduction of a mandatory uniform. In the long run, these reforms were initial steps in a process whereby the Waterstaat transformed itself (with the usual growing pains) from an association of craft-based hydraulic engineers into a professional technical organization. After Louis Napoleon relinquished the throne, the Waterstaat came under the direct authority of Emperor Napoleon Bonaparte himself. The incorporation of the Kingdom of Holland into the French Empire in 1810 portended a wholesale metamorphosis for the Bureau of the Waterstaat. From then on the bureau functioned as the sixteenth division of the French imperial *Corps des Ponts et Chaussées*. This French technical state agency, founded during the reign of King Louis XIV in 1714, was characterized by a strict militaristic hierarchical mode of organization which now also became the rule for Dutch state hydraulic engineers—including the French functional titles and the mandatory *Corps* uniforms.[13]

From that moment on, Dutch hydraulic experts adopted *ingénieur* as their preferential form of address and aspiring state engineers attended the *Ecole Polytechnique* in Paris. This situation lasted no more than three years. Nonetheless, in a remarkably brief time a further break with the originally craft-based mode of organization of the Bureau of the Waterstaat became evident. Decades after the French departed, this break continued to influence the organization's development.

Atlas van Stolk

Rijkswaterstaat engineer in official uniform around 1820

Collectie Hoogheemraadschap van Rijnland

Digging of a drainage canal to the North Sea coast near Katwijk, 1805

FIGHTING FOR RECOGNITION IN A NEW NATION-STATE (1813–1849)

Despite various political and mental blocks, the Batavian-French period had demonstrated the practical utility and necessity of centralized water management: for example, in completing the digging of a drainage canal to the North Sea at Katwijk.[14] In the same way, the intercession of the state and its hydraulic engineers also facilitated the reclamation of the Zevenhoven and Nieuwkoop Lakes. Both of these works had been initiated before the Batavian revolution, but had stagnated because of administrative complexity and deficient finances. In addition, there were the beginnings of centralized river management, including national dike surveillance and emergency procedures, as well as the first steps toward the construction of a national road system. These accomplishments, together with the resolve that a strong central state should be maintained, contributed to the continuation of the achievements of centralized water management realized during the Batavian-French period.

Nonetheless, in these years the position of the Bureau of the Waterstaat was once again an object of debate. Critics of central water management reiterated their conviction that the status and influence of the Waterstaat had increased disproportionately after 1810 and that uniformed Waterstaat engineers had behaved arrogantly in their dealings with provinces and water boards. The resolve for a strong central state continued following the defeat of Napoleon and the succession of William I as sovereign of the United Netherlands. While not insensitive to these criticisms of the Waterstaat's influence and status, the king also realized the necessity of a national Waterstaat service. This conviction, together with the government's weak financial position, led in 1816 to a reorganization. The king, following the French organizational model, consciously pursued the formation of a broad technical state service which, in addition to water management tasks, could also perform in other domains. The sovereign also retained the formal schooling of aspirant engineers and the administrative-legal instruments developed in the Batavian-French period which (except for the much criticized Dike Law of 1810), formed the legal basis of national water management. The king maintained the existing two-person directorate of the Waterstaat and established a new Council for the Waterstaat, which implied recognition of the expertise of Waterstaat engineers and granted them direct and indirect influence on water management policy. To the great disappointment of the corps of Waterstaat engineers, the introduction of new uniforms was put off and petitions for integration with the army and navy engineers were systematically ignored. The Bureau of the Waterstaat therefore remained a civilian institution.

Hence, despite the Waterstaat's development into one of the largest (if not the largest) state agency and despite the uniforms, which were eventually issued in 1824, the organization could not resolve its ambiguous position. This position was exacerbated by the persistence of a number of quasi-military characteristics: for example, the strict hierarchy and the stiff disciplinary measures and punishments. Prominent Waterstaat engineers were, accordingly, manifestly dissatisfied. This was not only because they were frustrated in their pursuit of social recognition and status, but also because in their eyes the king had too firm a hold over the Bureau of the Waterstaat and even intervened in personnel questions and the delimitation of the Bureau's responsibilities. Relations did not improve when, in 1819, the king, under strong pressure to cut his budget, transferred a good deal of the hydraulic works supervised and managed by the state to the provinces, including part of the corps of Waterstaat engineers, making them subject to the authority of the provincial estates.

In the decades to follow, the Waterstaat was subject to further attrition. In 1828 responsibility for state roads and canals was ceded to the so-called *Amortisatiesyndicaat*, a private institution founded by the king that accumulated capital by selling state property and loans. This—in addition to the permanent financial crisis and new budget cuts, the secession of Belgium in 1831, which halved the personnel and budget of the Waterstaat, and a weak directorate that after 1831 was staffed by no less than four inspectors—dragged the Waterstaat along in the general social malaise. In the 1830s, the organization found itself in a downward spiral, exacerbated by the simultaneous emergence of internal contradictions. The problems derived from the ceaseless staff reductions and budget cuts but also from a generational conflict between older engineers, who had been practically trained and who occupied the key posts in the Waterstaat, and a young scientifically educated generation of ambitious Waterstaat engineers. It appeared to the younger engineers that the non-meritocratic system of promotion, based on years of service, condemned them to stunted careers and burdened them with colleagues who performed their duties ever less adequately and who no longer understood the pulse of their time. A temporary reorganization did not temper the dissatisfaction but did offer new chances for the most brilliant young Waterstaat engineers. It was all the virtually bankrupt government could do, not least because both Parliament and the provincial estates opposed an influential and therefore expensive national Waterstaat. But at this point the king and successive governments did succeed in drawing a line; they resisted all further efforts to undermine the Waterstaat's position.[15]

They met with some success. The government was able to drag the beleaguered agency through a difficult period until, at the end of the 1830s, new opportunities presented themselves. The ratification of the Treaty of London in 1839, which definitively settled independence for Belgium, freed the nation from a costly and seemingly interminable conflict. Doing so made it feasible to think about new large projects, such as the reclamation of the Haarlem Lake and the construction of railway lines. Additionally, the supervision and management of the state roads and canals were restored to the Waterstaat, followed in 1841 by the restoration of supervision of water management in the province of Limburg. These favorable developments coincided with gradual improvements in the political and fiscal-economic climate.

After the abdication of King William I, ever more progressive liberal forces in the government and Parliament exerted influence on the creation of new economic policies and associated infrastructural innovations. During this time new technologies began to emerge. Steam power began to be applied in hydraulic engineering, and the Waterstaat devoted itself increasingly to the construction of railways and electromagnetic telegraph lines. These developments were a source of technological inspiration and exploration for the Waterstaat. For the younger generation of hydraulic engineers it was obvious that these emergent technologies would play a key role in the future political and social-economic development of the nation-state. But to realize this promise, it was imperative that the organization of the Waterstaat be adapted to the spirit of the times. In this connection they demanded an elaborate set of measures from the government which they considered essential in order to realize the professionalization they so adamantly desired. In addition to schooling and the cultivation of knowledge, they also demanded an adequate organizational structure and personnel policy as well as higher salaries and status. Moreover, a number of progressive state engineers, most notably Frederik Willem Conrad and Leopold van der Kun, expressed fears that in a rapidly changing society that placed new demands on technological leaders, the Waterstaat engineers would lose out to private industry.

After years of sometimes heated polemic, Johan Rudolf Thorbecke, the first Liberal Dutch prime minister, finally resolved some of these thorny issues. A year after his epochal constitutional reforms of 1848, in which the power of the king was cut back in favor of Parliament and ministers, he approved a reorganization of what had come to be called the *Rijkswaterstaat* (literally, state water management). This reorganization incorporated some of the demands of the progressive Waterstaat engineers. A new personnel policy made promotions and raises dependent on individual accomplishments, and a new balance between the segment of practically trained engineers and that of the modern, scientifically schooled engineers was realized, thanks to a shockwave of dismissals and promotions. The schooled engineers were now also better represented at the top of the Rijkswaterstaat hierarchy. For the rest, there was little reason to celebrate. The desired increase in salary and status was rejected, the agency was not expanded, no provision was made for a Council of the Waterstaat, leadership was not vested in a single director-general, and the power of the provinces over state engineers was actually augmented, albeit marginally. Under changed governmental and political conditions it was once again made clear to the corps of state engineers that their perception of the role and status of the organization differed materially from that held by the government. The agency was and remained dependent on the political landscape and on the financial position of the government. These were the two constants that determined the prestige, the power, and the societal role of the national Waterstaat agency in an era of revolution, restoration, and the emergence of the liberal democratic state.

NEW SPACE, OLD PROBLEMS, NEW CHALLENGES—NATIONAL WATER MANAGEMENT (1798-1850)

While in principle the founding of the unitary state in 1798 portended a drastic break with the organization of water management under the *Ancien Regime*, at first continuity ruled. The persons and institutions that for centuries had been turning and draining the waters, for the most part blithely carried on. At the same time they were confronted with a new actor—the national state and its Bureau of the Waterstaat. From its very inception this new actor had been charged with the mission of unifying and upgrading the fragmented organization of water management. This mission included the general task of appropriating and systematizing specific technological, hydraulic and geographic knowledge.

In addition, the agency was charged with specific tasks in the areas of coastal defenses, the estuaries and harbors, the large rivers, the development of a national road network, and the reclamation of large lakes. In a later phase this charge would be extended to include the construction of canals, railways, bridges, and telegraph lines, and the construction and maintenance of government buildings. Because the national government directly managed only a small selection of hydraulic works, but was nonetheless charged with ultimate legal responsibility for all water management and hydraulic works in the country, it was inevitable that at many points the interests of the Waterstaat touched on those of the provinces and the water boards. It was thus essential to cooperate, not only to maintain quality, for which local knowledge was often essential, but also in the execution of hydraulic works for which the Waterstaat employed local and regional contractors, workers, and suppliers. The manner in which this complex mission was accomplished in interaction with the provinces and water boards is the central topic of this section. The discussion includes coastal defenses, river management, reclamations and infrastructure, and the construction of state buildings.

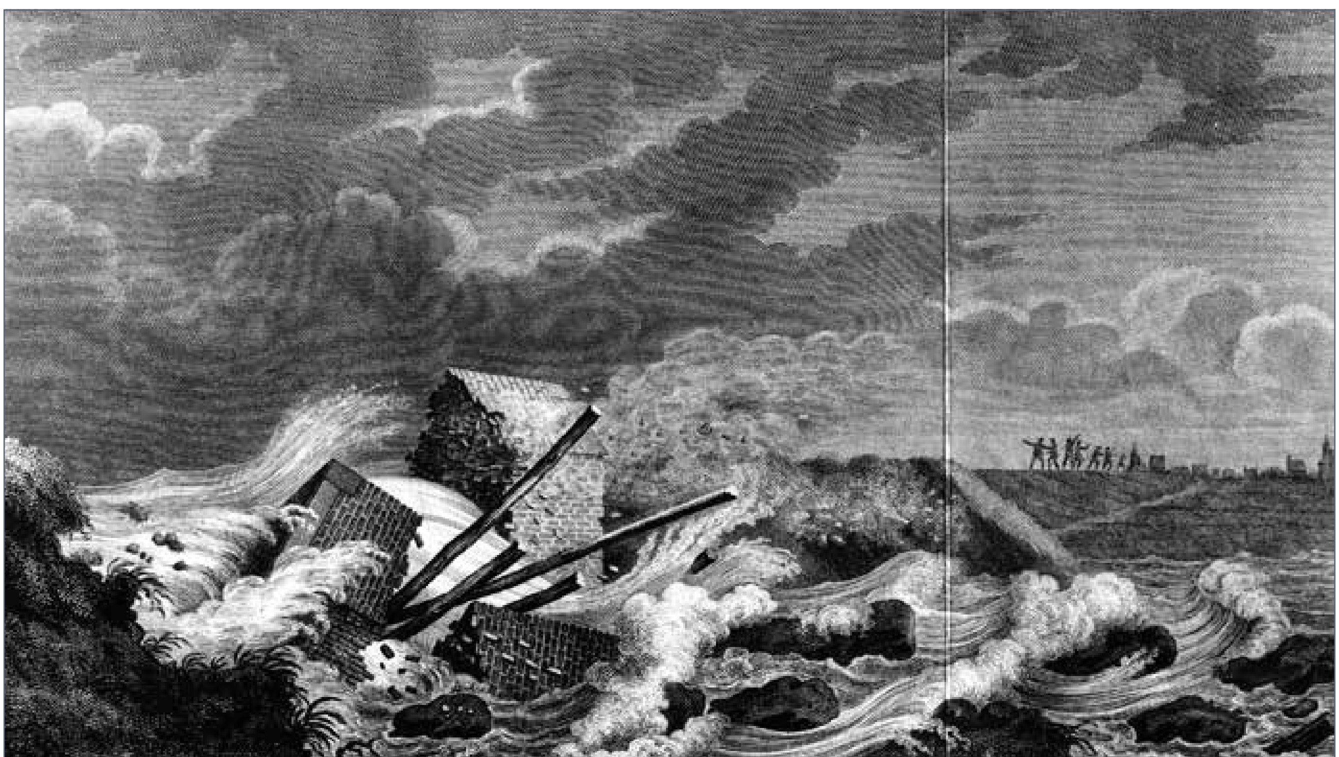
Collectie Gemeentemuseum Het Hannemahuis, Harlingen

Stormy weather approaching the harbor at Harlingen in Frisia, ca. 1815

COASTAL DEFENSES

Defending the coasts along the North Sea and the Zuiderzee had traditionally been the business of water boards. In some cases, where costs of construction, maintenance, and management exceeded the budgets of the water boards, the provincial estates intervened directly in coastal defense.[16] This was the case, for example, in the provinces of Holland, Zeeland, and Groningen, where the provincial estates deployed provincial engineers to several locations and provided subsidies for the protection of the dunes and the reinforcement of dikes. Despite the catastrophic storm surges that ravaged the coasts from time to time, it proved possible in the course of the eighteenth century to defend the coast more efficiently using new techniques, including improved dike-building techniques, progressive armoring of dikes with stone, and the construction of groynes. These long double rows of wooden poles stretching from the beach into the sea direct strong sea currents away from the coasts and prevent beach erosion. The role of the national state in coastal defense focused primarily on inspecting the sea defenses for which the provinces and water boards were responsible. Aside from a measure of quality assurance, this surveillance also produced reports which in turn provided the basis for new insights into coastal defense. While in the normal course of events the national state had only an indirect role to play, this was patently not the case when calamity struck. Under these conditions the national Waterstaat sprung into action and supported provinces and water boards with rescue and salvage operations and the repair of destroyed dikes. Examples include the storm surges that struck the province of Zeeland in 1808 and the north and middle of the country in 1825. The Waterstaat also had an active role in managing coastal defenses for which the national government was directly responsible, or which it subsidized. In

Waterlands Archief, Purmerend



The 1825 storm surge in the Zuiderzee hits a dike near Durgerdam addition to building and reinforcing hydraulic works like groynes, dikes, and defensive dunes, related projects like the construction of piers, ferry slips, and lighthouses were also carried out in the coastal provinces.

The national state played a prominent role in the coastal defenses of the province of Zeeland since 1798. Because of the extremely vulnerable setting of this coastal province, its polders suffered more than elsewhere from storm surges, dike collapse, and erosive currents. Traditionally, the provincial government supported the affected water boards in their struggles with the sea, but after the introduction of national water management, the national government took this task upon itself. During the Batavian-French period the state provided extra support for the most vulnerable polders. Under this arrangement thirty-six polders were denoted as "calamitous," a legal status that assured them of government subsidies for dike maintenance but which also placed the technical and financial supervision of this maintenance firmly in the hands of the national government. The gravity and scope of this problem concentrated the exertions of the national Waterstaat in the domain of coastal defenses for decades on the province of Zeeland. This hydraulic challenge was gradually mastered through the further development, formalization, and theoretical elucidation of practical craft knowledge, which in turn stimulated the search for new techniques. An example was the notion of "mixed dike defenses," a concept introduced by Abraham Caland, a national Waterstaat engineer originally from Zeeland. This approach, universally recognized as a significant innovation, sought to direct strong sea currents away from the coast by means of heavy defenses on projecting dike angles. These efforts led to the reclamation of land that had previously been considered useless and to the modernization of the dikes in Zeeland. The seaward slopes of these dikes were progressively faced with stone using standardized procedures and materials such as prismatically shaped blocks of basalt. By the middle of the nineteenth century the coast was substantially reinforced, the province was safer than ever, and 5,300 hectares of farmland were added to the province.

The Waterstaat proved less successful in discharging its responsibility for the estuaries and harbors. The seaways leading to the harbors of Amsterdam and Rotterdam were permanently threatened by shoaling of the fairways with the ceaseless deposits of sea and river sediments. In view of the fact that the national government now also counted the maintenance of harbors and seaways among its responsibilities, it fell to the engineers of the Waterstaat to devise an efficient solution for this venerable problem. This proved a difficult task because the state of knowledge of marine currents, sedimentation, and dredging was still in its infancy. The recourse was a tried and tested hydraulic solution: digging new canals to improve access to the harbors. This was an efficient remedy, though, as time would tell, only a temporary one.

STAGNATION AND PROGRESS: WRESTLING WITH THE LARGE RIVERS

The biggest hydraulic problem with which the Netherlands had been wrestling since the second half of the eighteenth century was taming the ferocious behavior of the Rhine and its (delta) branches the Nether-Rhine, the Lek, the Waal, and the IJssel.[17]

Floods in the river delta were an almost annual occurrence that sometimes took the form of widespread catastrophes with great loss of life and property. The causes of this flooding problem were complex. The main cause was the subsidence of the clay and peat soil behind the dikes because those areas were continuously being drained. The dikes concentrated the sedimentation in the floodplain, and as a consequence the difference between the polder and the floodplain level increased over the years. In addition to the influence of climate change—a secular long-term decline in average temperatures that brought with it increased precipitation and colder and longer winters, also known as the Little Ice Age—the persistent deterioration of the management of the river system itself was also to blame. Since 1770, for example, the situation at the point where the Waal and the IJssel split had progressively deteriorated and the entire river system suffered from an insufficient number of mouths through which to discharge the waters and ice floes into the sea. But human activities in and around the river were also responsible for the poor state of the shipping channels and riverbanks. Since the early Middle Ages, riparian lords and communities, lacking supervision, had dammed up river branches in order to protect the shores, reclaimed land from the riverbed, and used the floodplains for various kinds of economic activities. This activity seriously hampered not only navigation but also the annual discharge of large quantities of water to the sea in the winter and spring. This situation combined with the discharge of masses of ice floes, which sometimes formed enormous ice dams in narrow meandering stretches of the river. Behind the ice dams the water piled up, leading to dike breaches. Between 1750 and 1850 more than two hundred dike breaches followed this scenario. In the fragmented system of water management of the *Ancien Regime*, the riparian water boards and provincial governments were incapable of tackling this immense problem, despite the fact that on several occasions the provinces productively cooperated in regulating the division of water among the Rhine and its distributaries. Impressive modifications were made, especially after 1770, in the border region where the Rhine enters the Netherlands.[18]

From the moment the Waterstaat was founded, therefore, the core of its societal mission was to improve the rivers so that the country would eventually be spared these calamities. Almost immediately after the introduction of centralized water management, it became clear what the government's intention in this sphere would be and what role the Bureau of the Waterstaat would play.[19] Based on the legal stipulations that the national government bore sole responsibility for the channels, some of the river dikes and the shores, the river problem was attacked from three closely related angles.

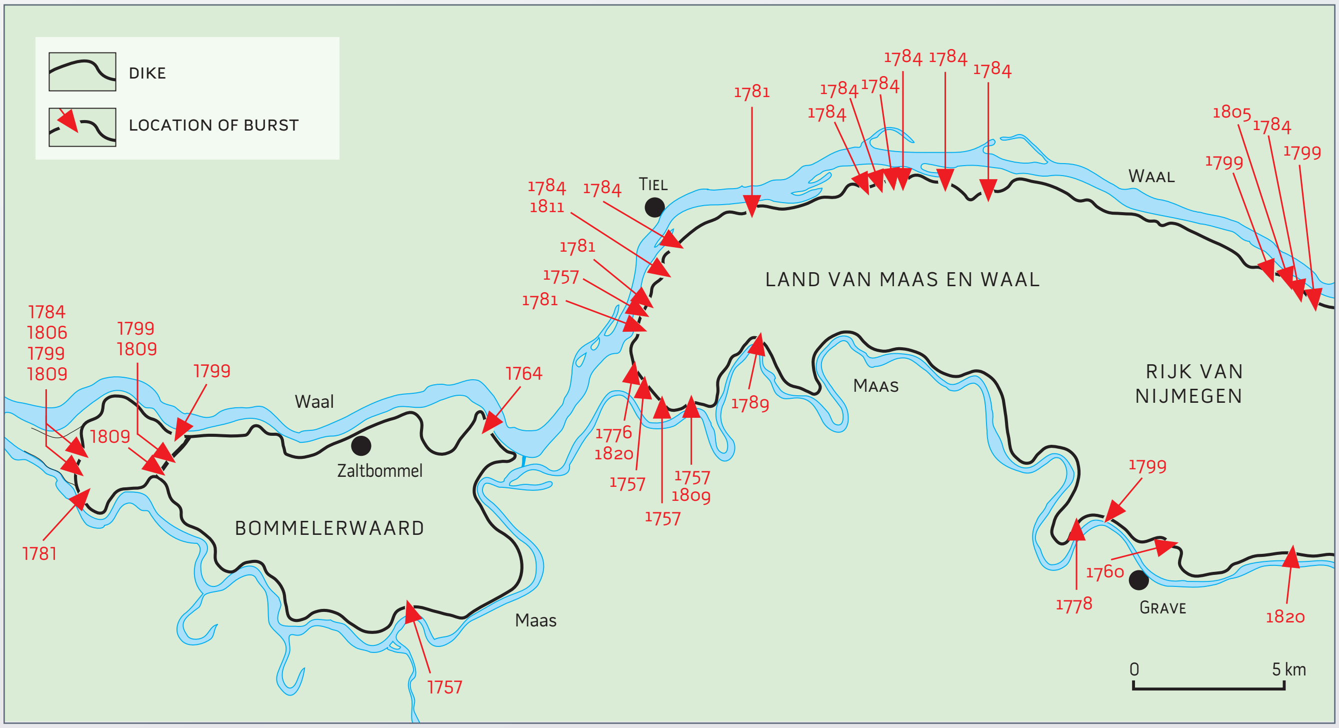
The backbone of the effort was formed by the systematic inspection of the channels, dikes, groynes, and sluices that were directly managed by the central state. The inspections were carried out by engineers of the Waterstaat in their proper districts in the spring and fall. On the basis of these inspections it was possible to make decisions about repairs, improvements, and clearing channels; to enter into negotiations with water

Atlas van Stolk

An ice formation builds up at a levee near Ochten along the Waal River, January 1789

Dike Breaches

Dike failures along the Waal and Meuse in the Betuwe region, between 1750 and 1820



Matrijs, Utrecht

boards whose dikes were substandard; and to grant subsidies to those water boards whose own means were insufficient to cover the costs of maintenance and repair. At the same time, the reports provided the basis for the production of a national system of knowledge concerning the behavior of the large rivers and the conditions of the dikes and shores.

The second approach was the patrolling of the river dikes in times of high water. To this end, a national system of dike surveillance was developed, the so-called "extraordinary correspondence," during which engineers of the Waterstaat—assisted as needed, by local water board personnel, inhabitants of nearby towns and villages, and, in serious situations by army troops—systematically monitored river stages, the behavior of ice masses, and the condition of dikes at twenty-two stations along the rivers. Couriers on horseback continually transmitted data to the Waterstaat directorate situated in emergency quarters in the middle of the river district. The directorate then decided what, if any, measures needed to be taken. In case of emergency the assigned Rijkswaterstaat engineers had the authority to command the local water boards to take necessary measures. In order to facilitate quick responses, water boards were mandated to set up and maintain "dike repositories"—sheds containing tools and emergency materials in case the dike required acute reinforcement or repair. In addition, after 1809, safety measures for the river region were proclaimed at regular intervals. Hence, the government stipulated that a sufficient number of lifeboats be available and defined communications protocols and procedures for evacuation. In case of flooding, the Waterstaat assisted the water boards with emergency measures, provisional dike repair, and struc-

Christie's

A river landscape, ca. 1800

tural improvements in the local system of flood security. This was the case after the flood of 1809 when the Waterstaat orchestrated the execution of flood-prevention works on the Linge River, including large-scale dike reinforcement and the improvement of drainage facilities in the western portion of the Betuwe Polder.[20]

The third point of entry of national water management was the development of new knowledge in civil engineering, geography, and hydrology. The water boards and provinces certainly possessed qualified personnel and empirical knowledge in these areas, but this knowledge could not readily be accessed by the national Waterstaat. Moreover, the expertise was adapted to a local and regional scale of water management and therefore not congruent with the ambition of river management at a national scale. In addition, the critical rationalism of the Enlightenment stimulated the rise of a theoretical-based knowledge type in river hydraulics among prominent hydraulic state engineers. This required a different, universal and theoretically oriented type of knowledge based on standardized methods of research and registration so that data could be exchanged and compared. This knowledge was gathered in different ways.[21] The daily practice of engineers and technicians of the Waterstaat was the basis for the accretion of this kind of knowledge. According to their instructions they were obligated to acquire old and new hydraulic knowledge in their districts on a permanent basis. In addition, a second stream of information concerning the condition of river sections, shores, dikes, river stages, dike breaches, and other particulars got underway via the reports of the spring and fall inspections of the district engineers and the accounts of the "extraordinary river correspondence." This information was centrally registered by the Bureau of the Waterstaat and the ministry and augmented by the research, measurements, and soundings of the General Service, the department of the Waterstaat set up in 1808 for the purpose of performing technological-scientific research and preparing large projects.[22]

During the first half of the nineteenth century these registration systems were steadily enhanced. In 1829 the government authorized the introduction of a national system of river stage gauges and launched a project to compile a general river atlas. The initial objective of this river atlas was the registration of the existing situation between the main river dikes, meant to support the regular inspection. Hence, this tool helped to avoid discussion with users of the river bed and enabled river engineers to control all kinds of illegal practices that could obstruct the discharge of water and ice floes. Later, the river atlas proved to be an excellent instrument in the planning of the large-scale river improvement works, because the atlas was supplemented by registers that described in detail the hydraulic situation for every page of the map. Another route along which the top cadres of the Waterstaat contributed to the expansion of hydraulic and related civil engineering knowledge was realized through the study of domestic and foreign technical literature, publications, experiments, and memberships of the Royal Academy of Sciences, the Royal Advisory Commissions on river improvement, learned societies, and finally, after 1847, of the Royal Institute of Engineers. The outcomes were sometimes remarkable, such as the invention by Waterstaat engineer H. F. Fijnje of the steam-powered double-acting vertical piston pump, which was responsible for a breakthrough in the problematic drainage of the river polders in the early 1840s.

While taming the large rivers was the most urgent water management challenge facing the nation in the first half of the nineteenth century, it proved extremely difficult to develop a firm understanding of the dynamics of the rivers. There were several reasons for this stagnation. Aside from the social and hydraulic complexities, it could be ascribed to insufficient knowledge of riverine hydraulics, technologies, and logistics. Moreover, the experts appointed to the Royal Advisory Commissions in the wake of the 1821 floods in order to find a consensus regarding the best way to tackle the problem could not come to an agreement. Nonetheless, the government charged the Waterstaat with implementing a series of recommendations published in the report of the Commission of 1825. These projects were aimed at dike reinforcement in cooperation with the riparian water boards, facilitating the flow of water and ice by cleaning up the floodplains, improving the organization of dike defense, and several river works in the Nether- Rhine and the Waal which were also aimed at improving navigability. Still, this could by no means be interpreted as wholesale, systematic river improvement, a vision that, thanks to discussions among hydraulic engineers and the Royal Advisory Commissions, was slowly gaining ground at the cost of the alternative—the method of diversions. The proponents of the diversion program believed that the risk of flooding could best be kept at bay by constructing a system of low sills and floodways that would allow the river water to flow away into other beddings. By contrast, in the systematic approach that aimed at improving the hydraulic efficiency of the existing river, every river was to have its own opening to the sea and to have its bedding optimized by structures that constrained and directed the current.[23] It was expected that this would strongly improve the discharge of large quantities of water and ice, the safety of the riparian lands, and the navigability of the rivers. While in the Netherlands debate raged about the most effective method for improving the rivers, in the German Rhine principality of Baden a project had been underway since 1817, based on the plans of the engineer Gottfried Tulla, which aimed at wholesale improvement of the Upper Rhine. Although Tulla encountered considerable resistance, he managed, in the space of a few years, to improve the discharge capacity of the river and the safety of the riparian lands by constraining the channel and eliminating meanders.[24]

In the Netherlands, proponents of such large-scale improvements, including the prestigious hydraulic engineer C. R. T. Krayenhoff, emphasized that this approach would also improve the safety of the Dutch delta and the navigability of the rivers. But the Royal Advisory Commission of 1825 somewhat arrogantly concluded that this approach was unsuited to the Dutch situation. Hence, much remained the same and the Dutch government was confronted in increasing measure with complaints from the German Rhine states. The conclusion of the Royal Advisory Commission poisoned relations with the Central Commission for the Navigation of the Rhine (founded in 1815 in the aftermath of the fall of the Napoleonic Empire to guarantee freedom of and a secure navigation on the Rhine) and with the Prussian government. The Central Commission complained about the poor navigability of the Rhine and its tributaries in the Netherlands. Though not insensitive to the criticism, the Dutch government faced such staggering financial and political problems in the 1830s and 1840s that it simply was unable to satisfy these international demands. Even if it had not been confronted with these problems, presumably no government would have been able to solve the very difficult hydraulic situation in the Dutch delta in this period.

At the end of the 1840s, political and economic reforms provided new impetus for decision making on river improvements. The streamlining of state finances and the laws governing trade by the liberal ministers Van Hall and Van Bosse was a key factor. Thanks to the growing political influence and ambition of the first generation of Dutch liberals the stalemate regarding the best hydraulic approach to river improvement was finally and rather simply resolved. In 1849 Rudolf Thorbecke, the first liberal minister-president of the Netherlands and animating spirit of the constitutional reforms that laid the groundwork for a modern democratic state, charged the authoritative engineers of the Waterstaat, Jean Henri Ferrand and Leopold Joannes Antonius van der Kun, with drawing up a national plan for systematic river improvement. The pragmatic minister-president emphasized that the new proposal should build on the most acceptable insights from the debates and plans of the past half century. Barely a year later the two engineers presented their blueprint, Parliament lent its approval, and Dutch society and its Waterstaat plunged into one of the biggest and riskiest ventures of its existence.

RECLAMATIONS

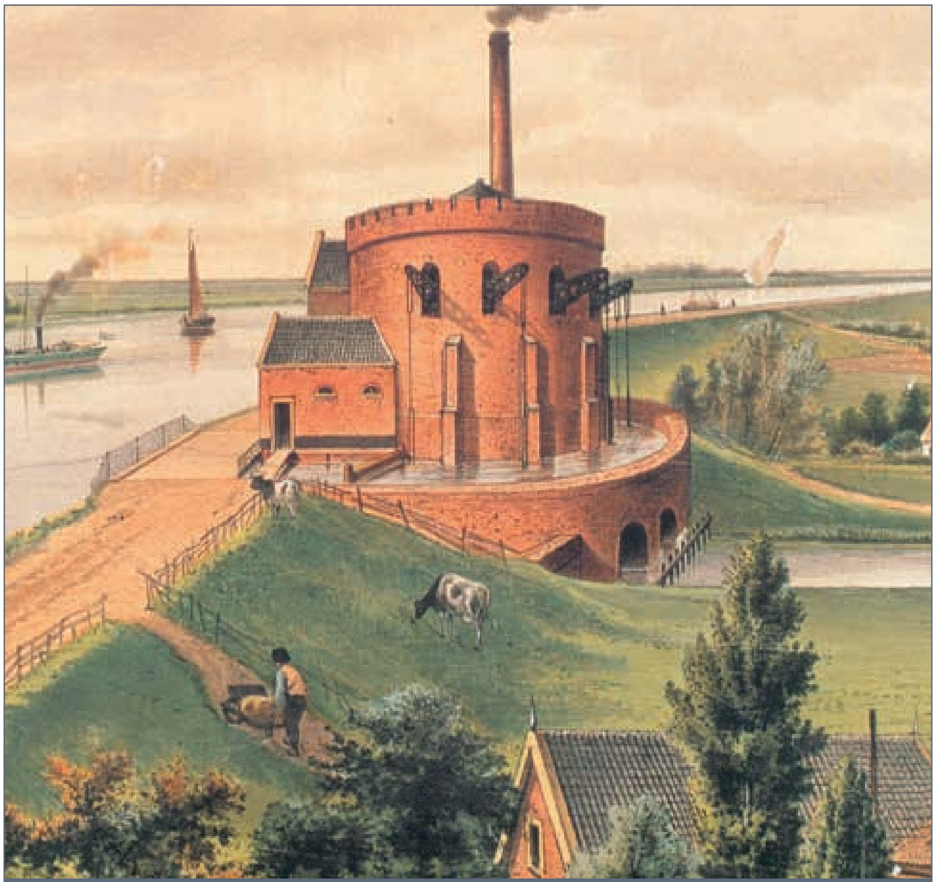
Since the seventeenth century, the reclamation of large lakes had been one of the internationally acclaimed specialties of Dutch hydraulic engineering. The impressive results have since come to be considered as the cornerstone of Dutch water civilization, a judgment seconded by the recent accession of the Beemster Polder, constructed in the years 1608-1612, to UNESCO's World Heritage List. Besides creating fertile soil, an important motive for reclaiming pools and lakes was increasing security against flooding. This was the case in South Holland where centuries-long peat extraction had led to the creation of enormous peat lakes. Besides disturbing the ecological balance, these lakes posed an increasing threat to their surroundings because the progressive erosion of the soft shores occasioned significant loss of land.

From the inception of central water management, the state and its engineering corps were partner to the prepa-


Atlas van Stolk

The world's first steam-powered pumping station, near Rotterdam, draining the polder Blijdorp, opened in 1787 ration and execution of reclamation projects. Formally this was a task for the provincial governments, but important considerations of safety as well as the financial-administrative and technological complexity of these works made the intervention of the central state imperative. This was the case with the reclamation of the Meijdrecht, Zevenhoven, and Nieuwkoop Lakes—all three projects had been initiated prior to 1795 but had stalled due to various causes. Together with the water boards and the provinces, the Waterstaat managed to resurrect them. In the roles of designer, contractor, builder, and coordinator, the Waterstaat successfully saw these projects through to completion and, despite the political turbulence of the Batavian-French period, demonstrated the usefulness of central water management and the hydraulic-technological potential of its own organization. The corps of engineers remained active in this domain, playing a prominent role in the preparations and execution of the reclamation of the Zuidplas Lake near Rotterdam in 1816. While the works were supervised by a Commission of Inspection composed of provincial and local stakeholders, it was clear that the technical leadership was entrusted to the Waterstaat engineers. Their problem-solving ability carried the project through a number of crucial decisions involving deviations from the original plan. In fact, it was partly thanks to the influence of chief engineer J. B. Vifquain that the Zuidplas reclamation adopted a unique approach: the use of a mixed pumping system depending not only on wind power but on steam as well.

But the *pièce de résistance* in this domain was certainly the reclamation of the huge Haarlem Lake.[25] Plans for this project dated back to the eighteenth century, but it was only in 1836, when destructive storms demonstrated that society was growing ever more vulnerable to this sometimes raging mass of wild water with its resemblance to an inner sea, that King William I seized the opportunity and ordered a plan for its reclamation. After parliamentary approval, it transpired that the administrative organization of the project was a direct copy of that of the Zuidplas reclamation, except for the fact that the Waterstaat and the Commission of Inspection now also had to deal with the interests of



Collectie Nationaal Onderwijsmuseum, Dordrecht

"Cruquius," one of the three steam-powered pumping stations that drained the Haarlem Lake, 1849–1852 other ministries, including the Ministry of War. Here too, the big question was whether to use steam power for pumping. Almost all of the Waterstaat's experts pondered this question deeply, including the internationally recognized authority, J. A. Beijerinck, who had also advised the American government on the drainage and reclamation of the swamps near New Orleans.[26]

Despite its authoritative participation, the Waterstaat was not in a position to monopolize the discussion, and the decision on the pumping technology was taken in close consultation with the Commission of Inspection and external experts. After experiments, study trips to England, and consultation with Dr. G. Simons (the government's advisor for mathematical and chemical questions), Beijerinck shoved his own reservations aside and advocated for the exclusive use of steam-powered pumps. In rapid succession, three huge steam-powered pumping stations were built and drained the Haarlem Lake between 1849 and 1852—an unparalleled achievement that brought the Waterstaat international respect and esteem.

INFRASTRUCTURE AND GOVERNMENT BUILDINGS

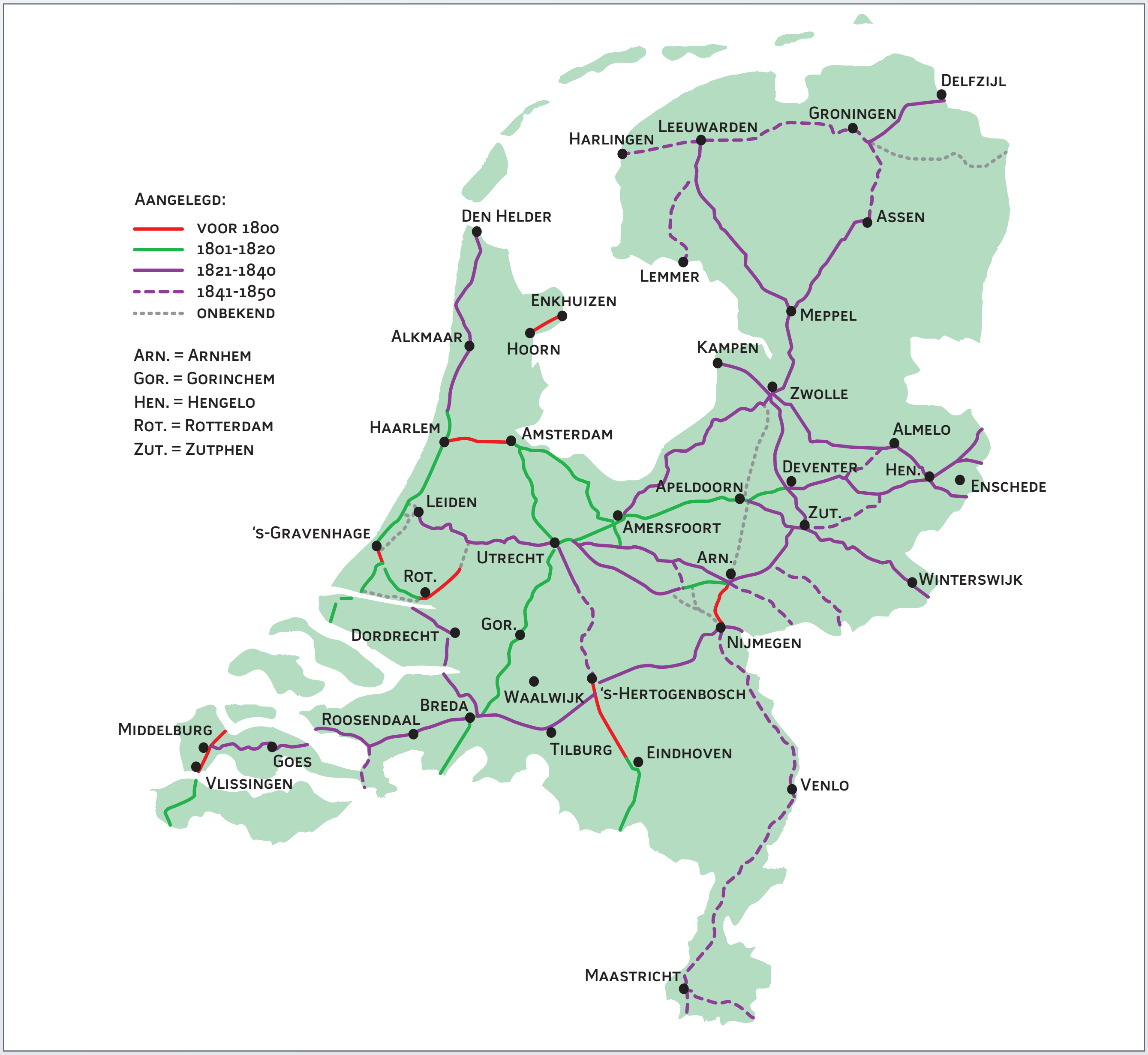
The emergence of a centrally administered unitary state also set the stage for general societal modernization, including the renovation and construction of harbors, roads, and waterways. After the strengthening of French influence on public administration, serious efforts were deployed toward the construction of a system of national highways. After 1813, King William I continued this policy, including the French system of classification, the associated financing, and the division of maintenance responsibility between the national and lower levels of government. These arrangements were modified several times in the following years in the context of a new politics of fiscal restraint and decentralization. Nonetheless, and also in line with the French approach, the national state maintained a firm grip on road construction, both by means of legislation and the active involvement of the Waterstaat. Waterstaat engineers were involved in the design, construction, and management of all the roads for which the state was at least partially responsible. Although Waterstaat engineers based their legitimacy and their professional pride above all on water management, they nonetheless succeeded without great difficulties in constructing the first national highway network between 1820 and 1850.

The national state and its Waterstaat also occupied a pivotal position in the domain of canal construction.[27] On the basis of foreign theories and examples it was clear to King William I that the economic modernization of his kingdom required canals in addition to roads. They would serve not only to incorporate isolated regions into the state but also to improve communications between the northern and southern portions of his newly founded United Kingdom of the Netherlands, formed at the behest of the Congress of Vienna in 1815 uniting the Austrian Netherlands (Belgium) with the Northern Dutch Kingdom. The success of this embryonic state and its forging into a single nation depended crucially on such improved means of transport and communication. High state officials, private institutions, and regional governments were also quite enthusiastic about canal building. From time to time they would submit plans that had already been ripening for years. In this favorable climate the king and other interested parties succeeded in mobilizing the requisite capital, and in the 1820s this expressed itself in a true Dutch "canal mania." In both the southern and the northern Netherlands, existing canals were modernized and new, large-scale canal projects were executed, including the construction of locks, harbors, and feeder systems. In the southern part of the country local entrepreneurs and chambers of commerce generally took the initiative. There, the state played a modest role. In the north, by contrast, the state took the lead in consultation with the provinces and other stakeholders, as in the construction of the South Williams Canal and the Great North Holland Canal.

The Waterstaat had no formal power in deliberations regarding new infrastructure, but in practice the monarch began receiving serious advice from his top engineers at quite an early stage. Once a plan was approved, the minister would formally involve the Waterstaat. The agency subsequently drew up an overall project plan in the context of which it performed geodetic research, surveyed the terrain, took measurements, and

Development of the National Road Network, 1800–1850

Red lines: built prior to 1800; green lines: built in the period 1800–1820; purple lines: built in the period 1821–1840; dotted purple lines: built in the period 1841–1850; gray lines: unknown



Walburg Pers, Zutphen

Canal Projects in the Northern Netherlands in the Era of King William I, between 1814 and 1840

Green lines: built prior to 1815; red lines: new connections; blue lines: improved connections; dotted blue lines: not completed connections

Walburg Pers, Zutphen

North Holland Canal, completed in 1824

prepared appropriation proceedings. While the canal was being built, the agency bore the main responsibility and in that capacity monitored the progress and quality of the work. Upon completion, the canals remained under the management and surveillance of Waterstaat functionaries. The center of state participation in canal building lay in the northern part of the kingdom. But in the south, even though the role of private actors was much larger, the state was also active, certainly when technically interesting problems presented themselves. Hence, when canals were being built in the south between Brussels and Charleroi and from Pommereuil to Antoing, a number of Waterstaat engineers travelled to England to gather knowledge about building canals in elevated terrain and about applying steam power to the feeding of canals. In contrast to the road system, there was no plan for constructing a national canal network. Nonetheless, impressive results were achieved, resolving a number of inter-regional transport problems and markedly improving the problematic access of harbor cities to the sea.

The role of the national Waterstaat agency with respect to infrastructure acquired a new dimension after the opening of the world's first railway line between Manchester and Liverpool in 1830. This example inspired Dutch entrepreneurs, who promptly filed requests for concessions to build similar lines. The king and his government were receptive and in turn requested engineers in the Waterstaat's General Service to report on the technical feasibility. While a heated social debate about the pros and cons of railway construction exploded in the background, the Waterstaat engineers concentrated on crucial aspects of railway technology. Their findings, as well as positive advice from the Royal Advisory Commission, disposed Parliament favorably towards a plan whereby the state would finance an elaborate national railway network. An important motivation behind this decision was the fear that the energetic Belgians with their proposed Iron Rhine—a railway connecting the Belgian port of Antwerp with the Prussian Rhine port of Cologne—would be able to challenge the Dutch trade monopoly with the German and Central European hinterlands.

In a fair imitation of France, the Dutch state now manifested itself as entrepreneur and builder of large nation-spanning railway lines and used its engineering corps for the technical preparation and actual management of the construction process. Given the many lakes, rivers, and canals in the Netherlands and the exceedingly soggy soil, this was no simple task. It was a technologically complex enterprise that demanded superior geodetic knowledge and considerable know-how in the fields of railway technology and bridge-building. Such knowledge was gathered partly through study trips in foreign countries. The construction of the first railway lines between Amsterdam and Haarlem (1839) and between Rotterdam and Amsterdam (1842) proved that, aside from a capacity to learn, the Waterstaat was capable of mastering all the technical problems that came up. For example, the construction of stations,

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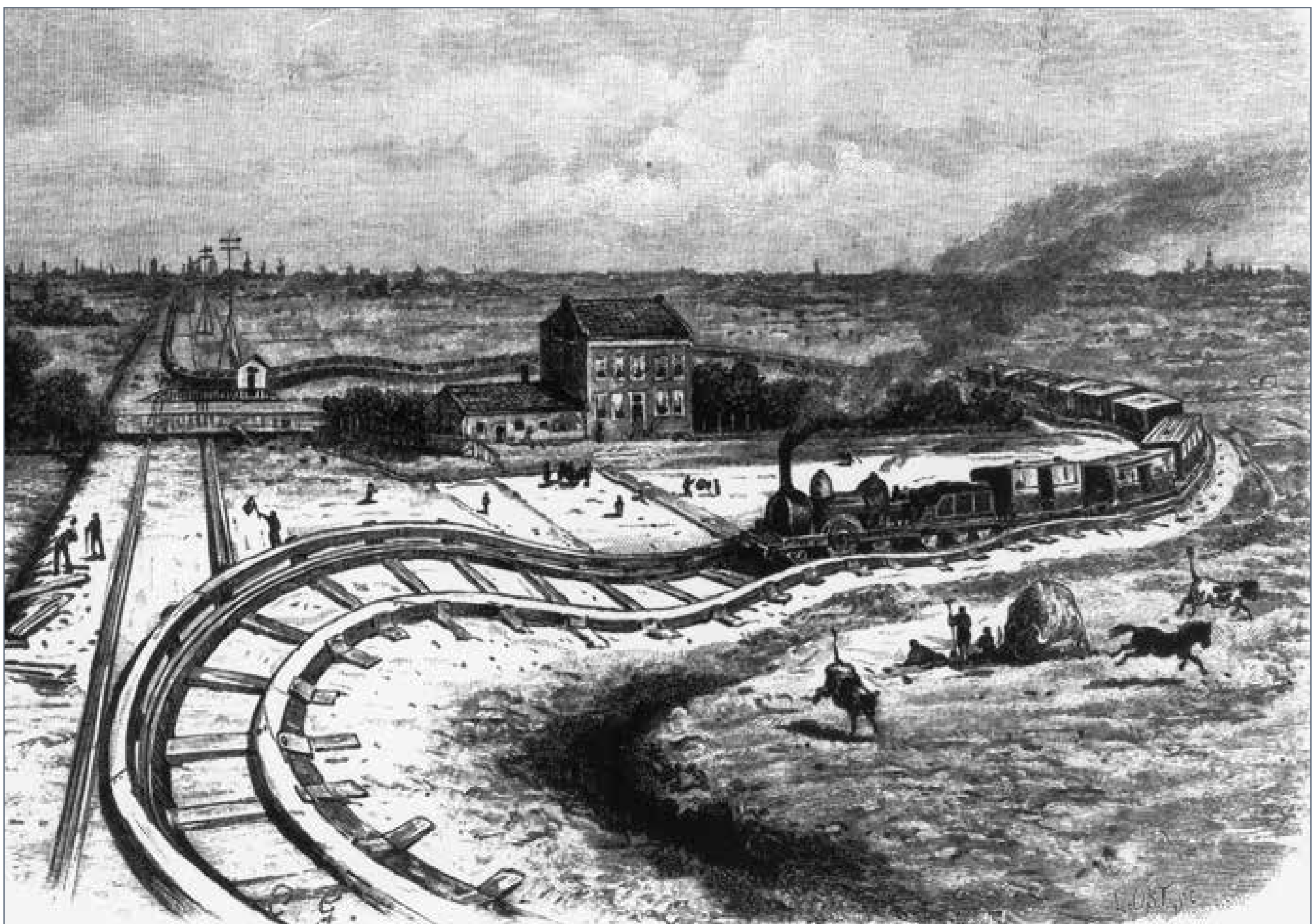
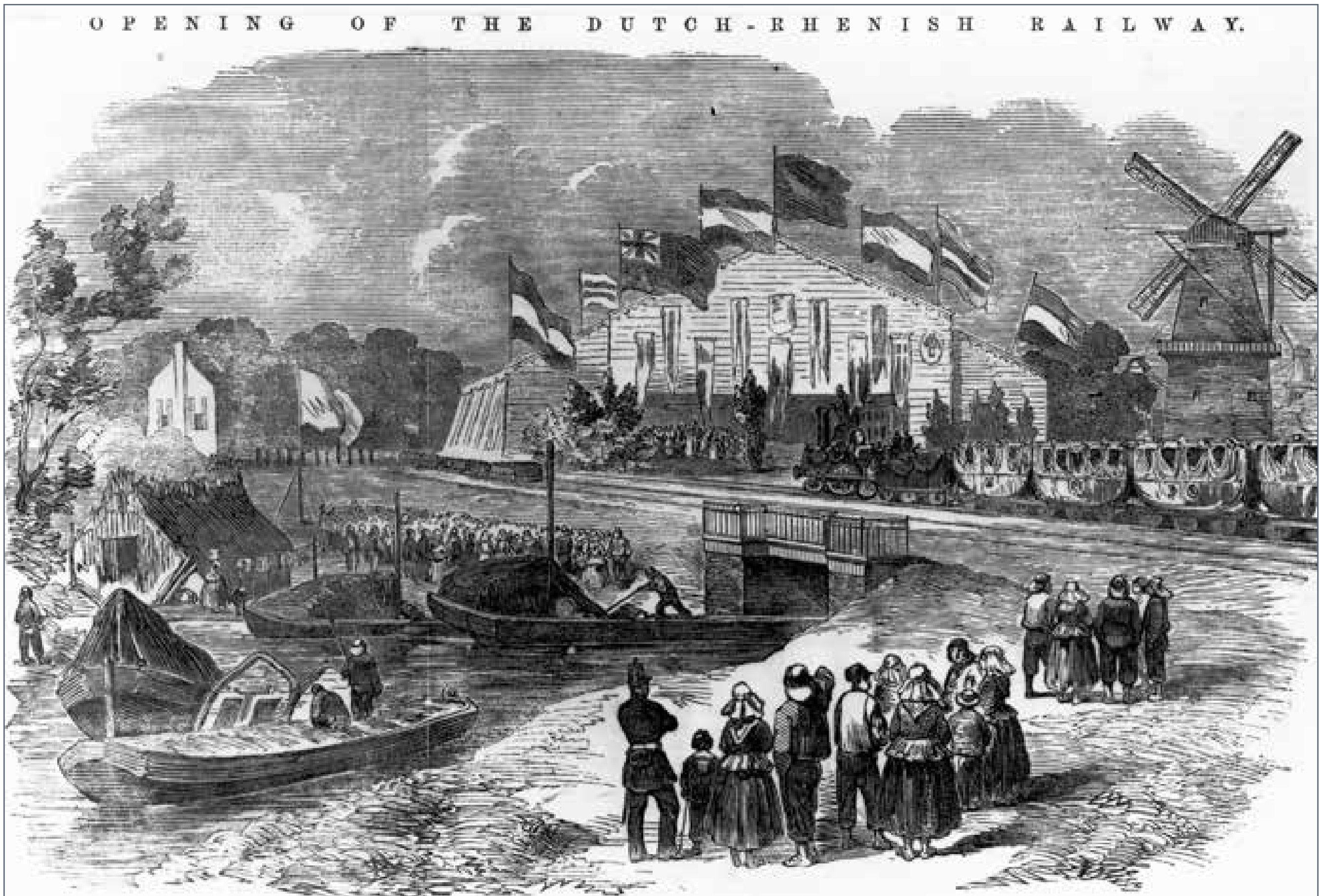


A bend in the railway track near Delft: the land owner refused to sell his land, 1847



Atlas van Stolk

Opening ceremony of the temporary railway station at Rotterdam, 1855

warehouses, and other railway buildings presented no problems, but that was to be expected. As the state's official architect and builder, the national Waterstaat agency had already been actively employed for decades in supplying expertise and management for a wide variety of the state's civil engineering needs. State engineers had been asked to advise on the introduction of gas lighting in The Hague, on the organization of Amsterdam's public water supply, and on the construction of border demarcations with the neighboring countries. The agency was also responsible for the maintenance of government buildings, including palaces, courts, schools, museums, national monuments and memorials, and later churches, prisons, and military barracks.[28] King William underlined the importance of the state engineers for the safety and development of the state by the creation of Royal Academy for education of civil engineers in Delft in 1842. At this academy, apprentices were trained for performing technical service to the nation and industry. The academy became the Polytechnical School in 1864 and the Institute of Technology in 1905. Since 1986 the Institute bears the name Delft University of Technology.

CONCLUSION

The transitions that took place in the structure of Dutch water management at the end of the eighteenth century occurred in a global and especially European context in which, since 1750, critical political and cultural transformations had been taking place, influenced in part by the rationalist ideology of the Enlightenment. These led in turn to the revolutionary disintegration of old regimes and laid the foundation for the rise of centrally governed nation-states in the first half of the nineteenth century. This period, in which the political and mental map of large parts of Europe was utterly transformed, is characterized in the literature as "the age of Atlantic revolutions" (by the American historian J. J. Palmer) and as "Sattelzeit" (by the German historian R. Koseleck). Both authors point to the fundamental rifts in social and cultural science, also labeled as modernization, that emerged across all sectors of society and influenced the way in which humans interacted with nature and their own direct habitats in the period 1750–1850. In those nations where water management was a prerequisite for survival—including the Netherlands and the German Rhine riparian states—this led to upgrading the attention to the political-administrative arrangements for water management, a process in which the central state and its bureaucratic apparatus insisted on a gradually more important role in the planning, management, and construction of hydraulic works.

In the Netherlands, this transition to a system of central water management "Dutch style" was a fitful business.[29] The originally envisioned extreme centralization, in which the central state absorbed virtually the whole of water management, was quickly found to be untenable in the context of Dutch political and hydraulic traditions. The physical maintenance of the nation could simply not do without the routine work of local and regional water managers and their knowledge and skills. However, a return to the old situation was rejected by prominent politicians, scientists, and hydraulic experts, notwithstanding the mounting pressure of opponents of centralized state and hydraulic administration. French intervention prevented a return to decentralization and the premature marginalization of the national corps of Waterstaat engineers. French influence, at its zenith during the incorporation of the Netherlands into the French Empire between 1810 and 1813, also stimulated the professionalization of state water management and the development of hydraulic knowledge, including the schooling of aspiring engineers. Hence, while the Low Countries had an impressive hydraulic past, the French, in less than two decades, had managed to make a deep impression on the future of Dutch water management.

Indeed, after the French had departed, the further development of national water management followed the political and institutional lines set out by the French in the Batavian-French period. At the same time, there was a search for a socially acceptable balance between the rights and responsibilities of the state and those of the provinces and water boards. In this sometimes difficult process of exploration, which was increasingly confounded by political and financial instabilities, central water management increasingly assumed the guise of a form of co-governance with semi-autocratic characteristics. Where decisions on large projects were at issue, or the financing, status, influence, and role of the Waterstaat in the state bureaucracy was at stake, Parliament played a subservient role and the king had a strong position. But the liberal constitution of 1848 curtailed the royal powers, and from that moment on a democratic form of water management began to emerge in which Parliament played a progressively more important role. In the somewhat longer term this change naturally also benefitted the national Bureau of the Waterstaat, now called the Rijkswaterstaat. Nonetheless, the agency had already proved its viability during the first half of the nineteenth century under often-difficult conditions and had developed into a professional civil engineering organization able—in addition to its primary tasks in water management—to make a crucial contribution to the creation of a national space, particularly in the domains of coastal defenses, reclamation, emergency relief, and infrastructure.[30] Pressing societal demands for the wholesale improvement of the Rhine and its tributaries were impossible to satisfy at that time. There was certainly considerable effort put into the nationwide compilation of knowledge about the rivers and their dynamic currents and numerous plans for improvement were advanced, but prominent Waterstaat engineers and other experts could not agree about the preferred hydraulic method by which the river improvements should be carried out. But even had they succeeded in achieving a consensus, the sorry state of the treasury would probably have prevented actual implementation. This stalemate was only resolved with the advent of liberalism at the end of the 1840s. The ambition and resolve of the liberal movement ended stagnation and cleared the way for a comprehensive program of river improvements that in their wake brought fundamental changes in riverine landscapes and their ecological balance. At the same time, this reconstruction of the Dutch river region was of vital importance for flood safety and the economy and therefore a precondition for the modernization of the Dutch nation.

BIBLIOGRAPHIC ESSAY

ENGLISH SOURCES

For a general overview on the Dutch socio-cultural history around 1800, see Joost Kloek and Wijnand Mijnhardt, *1800: Blueprints for a national community* (Assen/Basingstoke, 2004). Jan Luiten van Zanden and Arthur van Riel offer a solid analysis of the nineteenth-century Dutch economy in their *The strictures of inheritance: Dutch economy in the nineteenth century* (Princeton, 2004). Hans Krabbendam, Cornelis A. van Minnen and Giles Scott-Smith (ed.), *Four centuries of Dutch–American relations 1609–2009* (Amsterdam, 2009) is a rich collection of essays covering various aspects of four centuries American–Dutch relations.

A comprehensive survey of Dutch water resource management is provided in G. P. van de Ven (ed.), *Man-made lowlands. History of water management and land reclamation in the Netherlands* (Utrecht, 2004). Pieter Huisman, *Water in the Netherlands, managing checks and balances* (Utrecht, 2004) offers a succinct overview. An older account is Paul Wagret, *Polderlands* (London, 1968), an English translation of a book written in French, *Les polders* (Paris, 1959). The classic account by J. van Veen*, Dredge, drain, reclaim, the art of a nation* (The Hague, 1955) is still valuable. M. Reuss (ed.), special issue on Water Technology in the Netherlands, in *Technology and Culture* 43 (2002) 3, pp. 465–584, focuses on various aspects of Dutch water management from the Middle Ages until the 1980s. F. M. van der Meer, "Water Management in the Netherlands in the 19th and 20th Centuries," in: J. C. N. Raadschelders (ed.), *Cahiers d' histoire de l'administration* 8, special issue on The Institutional Arrangements for Water Management in the 19th and 20th Centuries (Amsterdam, 2005) pp. 45–62, offers a succinct overview on Dutch water management and major projects in this period.

On the development of river management, see the English edition of A. A. S. van Heezik, *Battle over the Rivers: Two Hundred years of River Policy in the Netherlands* (Haarlem and The Hague, 2008), a popular version of this Ph.D. thesis (see below). A true environmental history is M. Cioc, *The Rhine: An eco-biography, 1815–2000* (Seattle and London, 2002), that sketches a vivid picture of ecological degradation of a major European river due to repeated river training projects. W. ten Brinke, *The Dutch Rhine: A restrained river*, (Diemen, 2004), is a richly documented portrait of the river Rhine from a geological, geographical, hydraulic, and historical perspective. P. H. Nienhuis explores the interrelatedness between the developments in river management, its ecological impact on the landscape, flora, and fauna, and the role of climate change in *Environmental History of the Rhine-Meuse Delta. An ecological story on evolving human-environmental relations coping with climatic change and sea-level rise* (Dordrecht/London, 2008). Toon Bosch focuses on the period 1770–1850 in "Changing societies produce changing rivers. Managing the Rhine in Germany and Holland, 1770–1850" in Terje Tvedt and Richard Coopey (eds.), *A History of Water*. Series II, Volume 2: Rivers and Society: From Early Civilizations to Modern Times, (London/New York 2010), pp. 263–86. On the Meuse, see Toon Bosch, "'Canalise the Meuse! Do it. Now or never!' Aspects of the struggle for the improvement of The Meuse in the Dutch province of Limburg (1839–1925)," in *Physics and Chemistry of the Earth* 34/3 (2009), pp. 109–18.

"Knowledge development" in Dutch water management has not often been the subject of a book, but it is the heart of the matter in C. S. Maffioli, *Out of Galileo. The science of waters 1628–1718* (Rotterdam, 1994), a Ph.D. thesis on the theoretical insights of Italian scientists and their impact on Dutch eighteenth-century civil engineering.

DUTCH SOURCES

There are various good and recent general books on Dutch history. R. Aerts et al., *Land van kleine gebaren. Een politieke geschiedenis van Nederland 1780–1990* (Nijmegen, 2013) is a lucid account on Dutch political history. A fascinating portrait of socio-cultural shifts in the era 1780–1810 can be read in Joost Kloek and Wijnhardt Mijnhardt, *1800: Blauwdrukken voor een samenleving* (The Hague, 2001), the Dutch edition of *1800: Blueprints for a national community*. The standard work on economic development in this period is J. L. van Zanden and A. van Riel, *Nederland 1780–1914. Staat, instituties en economische ontwikkeling* (Amsterdam, 2000), the Dutch edition of *The strictures of inheritance: Dutch economy in the nineteenth century*.

A. van der Woud, *Het lege land. De ruimtelijke orde van Nederland 1798–1848* (Amsterdam, 1987) is a stimulating Ph.D. thesis about Dutch spatial management, including water resource management, in the first half of the nineteenth century. H. Knippenberg and B. de Pater, *De eenwording van Nederland, schaalvergroting en integratie sinds 1800* (Nijmegen, 1988) unravels the interplay between societal integration and infrastructural development in the Netherlands since 1800. H. W. Lintsen (ed.), *Geschiedenis van de techniek in Nederland. De wording van een moderne samenleving 1800–1890*, vol. 3 (Zutphen, 1993) provides in a number of chapters stimulating overviews on nineteenth-century civil engineering and water management. R. Filarski, and G. Mom, *Van transport naar mobiliteit* (2 volumes) (Zutphen, 2008) is a standard work on the development of Dutch infrastructure since 1800.

For general books on Dutch water resource management, see in the first place G. P. van de Ven (ed.), *Leefbaar laagland* (Utrecht, 2003), the Dutch edition of *Man-made lowlands*. W. ten Brinke, *Land aan zee* (Diemen, 2007) provides a vivid general overview of Dutch water management, linking geographical, climatological, and historical perspectives. C. Rooijendijk, *Waterwolven* (Amsterdam, 2009) sketches in a colorful account the development of the Dutch water resource management since prehistory, emphasizing the role of a few important and influential water management experts. H. C. Toussaint offers a brief overview on eleven centuries of Dutch water management in Bert Toussaint, "Met subtiliteit en zoetheid. Een overzicht van elf eeuwen Nederlands waterbeheer," in *Jaarboek Central Bureau voor Genealogie* 57 (2003) pp. 5–52. Eelco Beukers (ed.), *Hollanders en het water. Twintig eeuwen strijd en profijt* (2 volumes) (Hilversum, 2007) offers a valuable overview on water management history in central Holland since the prehistoric era, covering governance, flood management, navigation, fishery, fresh water management, military aspects, and recreation. Toon Bosch emphasizes the significant role of Lodewijk Napoleon for the emerging national water resource management in "'t voornaamste onderwerp in Holland.' De betekenis van Koning Lodewijk Napoleon voor de nationale waterstaatszorg (1806–1810)" in *Tijdschrift voor Waterstaatsgeschiedenis* 16/2 (2007), pp.108–19.

Alex van Heezik, *Strijd om de rivieren. 200 jaar rivierenbeleid in Nederlandof de opkomst en ondergang van het streven naar de normale rivier* (Haarlem, 2008), is a Ph.D. thesis covering two centuries of river management. W. ten Brinke, *De beteugelde rivier* (Diemen, 2004) is the Dutch version of *The Dutch Rhine: A restrained river*. A still informative account of Rhine navigation is H. P. H. Nusteling, *De Rijnvaart in het tijdperk van stoom en steenkool (1831–1914)* (Amsterdam, 1974). G. P. van de Ven, *Aan de wieg van Rijkswaterstaat. Wordingsgeschiedenis van het Pannerdens Kanaal* (Zutphen, 1976) provides a very detailed description of a crucial eighteenth-century Rhine training project. Ch. Jeurgens, *De Haarlemmermeer. Een studie in planning en beleid 1836–1858* (Amsterdam, 1991) is a solid Ph.D. thesis on the Haarlemmermeer reclamation. The impact of river floods around 1800 is pointed out in detail in the Ph.D.

thesis from A. M. A. J. Driessen, *Watersnood tussen Maas en Waal. Overstromingsrampen tussen 1780 en 1810* (Zutphen, 1993) and in A. Bosch, "Nijmegen en zijn '*gryze Stroomgod,'* Hoog water, strenge vorst en calamiteuze watersnoden, 1781–1861," *Jaarboek Numaga* 56 (2009), pp. 32–51.

On flood coping strategies, see Petra van Dam's inaugural lecture, Petra J. E. M. van Dam, *De amfibische cultuur. Een visie op watersnoodrampen* (Amsterdam, 2010) and the special issue of the *Tijdschrift voor Waterstaatsgeschiedenis* 21 1/2 (2012), that further explores this theme.

M. L. ten Horn, *Wonderen der techniek, Nederlandse ingenieurs en hun kunstwerken* (Zutphen, 1994) provides valuable essays on a number of major Dutch engineering projects in the nineteenth and twentiety centuries. R. Filarski, *Kanalen van de koopman-koning* (Amsterdam, 1995) is a solid Ph.D. thesis on the development of navigation and the canal building in the first half of the nineteenth century, including thorough cost-benefit analyses. R. G. W. Hisgen and R. W. P. M. Laane, *Geheimen van de kust, van Zwin tot Marsdiep* (Diemen, 2008) is a colorful collection of essays on Dutch coastal engineering in the past and the present.

The first decades of the nineteenth century are reviewed in a recent biography on the brilliant engineer, physician, and topographer Kraijenhoff: Wilfried Uitterhoeve, *Cornelis Kraijenhoff 1758–1840: een loopbaan onder vijf regeervormen* (Nijmegen, 2009), a vividly written Ph.D. thesis. R. M. Harbourdin et al., *De physique existentie dezes lands: Jan Blanken, inspecteur-generaal van de waterstaat (1755–1838)* (Beetsterzwaag, 1987) is a rich collection of essays on Jan Blanken, one of the most prominent Dutch nineteenth-century engineers, issued at the occasion of a 1987 exhibition on Blanken in the Amsterdam Rijksmuseum.

A valuable collection of essays on the institutional development of the Dutch water boards is J. C. N. Raadschelders and A. J. Toonen (eds.), *Waterschappen in Nederland. Een bestuurskundige verkenning van de institutionele ontwikkeling* (Hilversum, 1993). A general corporate history of the Rijkswaterstaat is provided in A. Bosch and W. van der Ham, *Twee eeuwen Rijkswaterstaat, 1798–1998* (Zaltbommel, 1998), an overview that integrates developments in society, technology, and engineering and its impact on the Rijkswaterstaat organization. An organizational analysis of the Rijkswaterstaat organization and the position of its engineers in the nineteenth century is provided by H. W. Lintsen, *Ingenieurs in Nederland in de negentiende eeuw, een streven naar erkenning en macht* (The Hague, 1980). Toon Bosch gives a detailed account of the establishment and formative decades of the Rijkswaterstaat in his Ph.D. thesis A. Bosch, *Om de macht over het water: de nationale waterstaatsdienst tussen staat en samenleving 1798–1849* (Zaltbomel, 2000).

1 M. van Buuren, C. van Drimmelen, W. Iedema (eds.), *Rapport Waterlandschappen. De cultuurhistorie van de toekomst als opgave van waterbeheer* (Lelystad: RIZA, 2002), 54. The periodization that follows is also inspired by this report.

2 G. P. van de Ven, *Man Made Lowlands. History of water management and land reclamation in the Netherlands* (Utrecht: Matrijs, 2004), 38–100; Frits M. van der Meer, "Water Management in the Netherlands in the 19th and 20th Centuries", in: Jos C. N. Raadschelders (ed.), *Cahier d'Histoire de 'l'Administration* no. 8, IIAS. The Institutional Arrangements for Water Management in the 19th and 20th Centuries (Amsterdam: IOS Press, 2005), 45–61; A. Bosch en W. van der Ham, *Twee Eeuwen Rijkswaterstaat, 1798–1998* (Zaltbommel: Europese Bibliotheek, 1998), 19–29; A. Bosch, *Om de macht over het water. De nationale waterstaatsdienst tussen staat en samenleving 1798–1849* (Zaltbommel: Europese Bibliotheek, 2000), 19–40.

3 Laura Cruz, Dutch Revolutions (1780–1848) in: Gregory Fremont-Barnes (ed.), *Encyclopedia of the Age of Political Revolutions and New Ideologies 1760–1815*, Vol. I (Westport, Conn., London: Greenwood, 2007), 205–09; Jonathan Israel, *The Dutch Republic: Its Rise, Greatness and Fall 1477–1806* (Oxford History of Early Modern Europe) (Oxford: Clarendon Press, 1995), 1098–1112 and 1113–1130.

4 Bosch, *Om de macht over het water*, 42–57.

5 Bosch, *Om de macht over het water*, 57–62; 69–89; 91–107; Toon Bosch, "Koning van een dobberend land. De betekenis van Lodewijk Napoleon voor de nationale waterstaatszorg 1806–1810", in: *Tijdschrift voor Waterstaatsgeschiedenis* 16, no. 2 (2007): 108–19; G. P. van de Ven, Lodewijk Napoleon en de Waterstaat in: J.Hallebeek, A.J.B. Sirks (red.), *Nederland in Franse schaduw. Recht en bestuur in het Koninkrijk Holland* (1806–1810) (Hilversum: Verloren, 2006), 125–46.

6 See for a description of the French organization of water management during the *ancien regime:* G. C. Gillespie, *Science and polity in France at the end of the old regime* (Princeton: University Press, 1980), 497–98.

7 Bosch, *Om de macht over het water*, 62.

8 For the political-administrative elaboration of central water management between 1813 and 1849 see: Bosch, *Om de macht over het water*, 109–27.

9 Following: Th. A. J. Toonen, "The unitary state as a system of co-governance: The case of the Netherlands", in: *Public Administration* 1990 (68), 281–96.

10 See for the development of the corps of engineers of the "Waterstaat": Bosch and Van der Ham, *Twee eeuwen*, 33–44; Bosch, *Om de macht over het water*, 87–89.

11 For the French situation see: Gillespie, *Science and polity*, 479–98; briefly for the Netherlands: Bosch, *Om de macht over het water*, 85–86.

12 See for the development of technical education for Waterstaat engineers: G. P. J. Verbong, "De uitgangssituatie"; "Gescheiden paden 1813–1842"; "De spanning tussen aanbod en vraag: ingenieurs en nijverheidstechnici 1842–1863", in: H. W. Lintsen (ed. et. al), *Geschiedenis van de techniek in de negentiende eeuw. De wording van een moderne samenleving 1800–1890*, vol. 5 (Zutphen: Walburg Pers, 1994), 45–49; 53–60; 101–09 and the literature cited there.

13 See for the development of Dutch state engineers in the nineteenth century: H. W. Lintsen, *Ingenieurs in Nederland in de negentiende eeuw. Een streven naar macht en* erkenning ('s Gravenhage: Nijhoff, 1980) ; for the history of the French *Ponts et Chaussées*: J. Petot, *Histoire de l'administration des Ponts et Chaussées 1599–1815* (Paris : Rivière, 1958); A. Brunot, R. Coquand, *Le corps des Ponts et Chaussées* (Paris: Centre national de la Recherche Scientifique, 1982) en: A. Picon, *L'invention de l'ingénieur moderne L'Ecole des Ponts et Chaussées 1747–1851* (Paris: Presses de l'école nationale des ponts et chaussées, 1992).

14 This section based on: Bosch, *Om de macht over het water*, 91–107, 163–97; Bosch, Van der Ham, *Twee eeuwen*, 97–116.

15 See: Bosch, *Om de macht over het water*, 149–50.

16 Based on: G. P. van de Ven, *Man Made Lowlands*, 255–59; Bosch, Van der Ham, *Twee eeuwen*, 58–60; Bosch, *Om de macht over het water*, 175–76.

17 Based on: Toon Bosch, Gerard van de Ven, "Rivierverbetering", in: H. W. Lintsen (ed. et. al), *Geschiedenis van de techniek in de negentiende eeuw. De wording van een moderne samenleving 1800–1890*, vol. 2 (Zutphen: Walburg Pers, 1993), 106–27; Van de Ven, *Man-made Lowlands*, 346–67; Alex van Heezik, *Strijd om de rivieren. 200 jaar rivierenbeleid in Nederland of de opkomst en ondergang van het streven naar de normale rivier* (Haarlem: Van Heezik Beleidsresearch, 2006), 43–52; 53–86.

18 Van de Ven, *Man-made lowlands*, Ch. 4.

19 See: Bosch, *Om de macht over het water*, 94–103; 177–84.

20 See: G. P. van de Ven, "Jan Blanken en de Waterstaat" in: P. C. Jansen (ed. et al.), *De Physique existentie dezes lands. Jan Blanken inspecteur-generaal van de waterstaat (1755–1838)* (Beetsterzwaag: AMA Boeken, 1987), 70–74.

21 See: Bosch, *Om de macht over het water*, 199–201.

22 See for the history of the "General Service": Bert Toussaint, *Uitgemeten en uitgetekend. De geschiedenis van de Algemene Dienst van de Rijkswaterstaat* (Den Haag: Rijkswaterstaat, 1998).

23 See for these discussions: Bosch, Van de Ven, "Rivierverbetering", 106–27.

24 Mark Cioc, *The Rhine. An eco-biography 1815–2000* (Seattle-London: University of Washington Press, 2002), 59–62; Christophe Bernhardt, "The correction of the upper Rhine in the Nineteenth Century: Modernizing Society and state by Large-Scale Water Engineering", in: Susan C. Anderson, Bruce Tabb (eds.) *Water, Culture, Politics in Germany and the American West* (New York: Peter Lang International Academic Publishers, 2001), 183–202; David Blackbourn, *The conquest of Nature, Water, Landscape and the Making of modern Germany* (London: Cape, 2006), 71–111.

25 See: C. Jeurgens, *De Haarlemmermeer. Een studie in planning en beleid 1836–1858* (Amsterdam: NEHA, 1991).

26 J. G. W. Fijnje, "Levensberigt van Frederik Willem Conrad, voorzitter en een der opgrigters van het Koninklijk Instituut van Ingenieurs en eene bijdrage tot de geschiedenis van den waterstaat van zijn tijd", in: *Notulen van het Koninklijk Instituut van ingenieurs* ('s Gravenhage: KIVI, 1870), 187.

27 See: R. Filarski, *Kanalen van de koning-koopman. Goederenvervoer, binnenscheepvaart en kanalenbouw in Nederland en België in de eerste helft van de negentiende eeuw* (Amsterdam: NEHA, 1995).

28 Bosch, *Om de macht over het water*, 193.

29 Harry Lintsen, "Two Centuries of Central Water Management in the Netherlands" in: *Technology and Culture* vol. 43, no. 3 (July 2002): 549–68.

30 For the environmental consequences of these spatial interventions see: Piet H. Nienhuis, *Environmental History of the Rhine-Meuse Delta. An ecological story on evolving human-environmental relations coping with climate change and sea-level rise* (Dordrecht: Springer, 2008), 543–46.

This chapter is dedicated to my beloved friend P. J. W. Elly Wilbers–Berndsen (1951–2014)

3 The U.S. Army Corps of Engineers and The Evolution of Navigation Practice and Policy, 1800–1865

MATTHEW T. PEARCY

The greatest legacy of the early Army Corps of Engineers was its work on rivers, canals, and harbors. America was a vast young nation, and its waterways bound it together. They provided routes from western farms to eastern markets and aided settlers seeking new homes beyond the Appalachian frontier. These vital arteries beckoned and enticed, making progress possible, but they were also quick to destroy the dreams of unwary travelers and shippers whose boats were punctured by snags or stuck on sandbars. Both commercial development and national defense begged for more reliable transportation arteries. Beginning in 1824 with the General Survey Act, Congress turned to the Army Corps of Engineers to carve navigation passages for a growing nation.[1]

The Corps of Engineers was uniquely positioned to assist in the development of a water transportation network. Although its history stretches back to the American Revolution, when Gen. George Washington appointed Col. Richard Gridley as chief engineer of the Continental Army in 1775, the modern Corps dates to 1802. In that year, Congress permanently established the Army Corps of Engineers and founded a military academy at West Point under Corps supervision as the first engineering school in United States. Until the 1850s, West Point served as the main source of academically trained engineers, both military and civilian. Training there was closely modeled on the program taught at the French *Ecole Polytechnique*. Over time, elements of civil engineering became an increasingly important component of the curriculum. In addition to acquiring skills in the construction of fortifications, graduates of West Point gained the knowledge necessary to play a key role in shaping the nation's internal improvements such as mapping, road building, canal construction, improving rivers and harbors, and surveying for railroads.

TOWARD FEDERAL INVOLVEMENT IN INTERNAL IMPROVEMENTS

The authority of the federal government to engage in internal improvements had to overcome serious questions involving the interpretation of the U.S. Constitution. Throughout the antebellum period, the several decades before the Civil War, many American political leaders questioned whether the Constitution authorized the federal government to construct roads and canals,

"Looking Down the River," a view of West Point from above Washington Valley, 1834, by George Cooke

to improve the navigability of rivers and harbors, or to contribute to private efforts to accomplish such work. A line of presidents from Thomas Jefferson to James Buchanan, together with members of Congress of various political parties, expressed support for certain federal internal improvement efforts but interpreted the Constitution to limit the conditions under which federal monies could be expended for such projects. According to this reasoning, the projects had to be tied to one of the enumerated powers granted under the Constitution, such as national defense, mail delivery, or the collection of federal revenues. James Madison, who joined in questioning federal powers in this sphere, could recollect that the Constitutional Convention had approved Elbridge Gerry's proposal to allow Congress to establish post roads but rejected Benjamin Franklin's plan to include among the enumerated powers of Congress the authority "to provide for cutting canals," despite support for the clause in the Virginia delegation. Such debates consumed the first decades of the nineteenth century and stood in the way of direct federal funding for these enterprises.[2]

Among the earliest and most influential advocates of a federal role was Secretary of the Treasury Albert Gallatin. He produced the first comprehensive study of American transportation needs in 1808 recommending an elaborate system of interconnected roads, canals, and improved waterways to bind the young republic together. Gallatin not only balanced the federal budget but also accumulated a surplus that he hoped to use for construction of the transportation system. The Embargo Act of 1808 and the Anglo-American War of 1812 (1812–1815) interrupted revenue collections, eroded the budget surplus, and delayed action on Gallatin's recommendation; but the war also drew attention to the need for a better transportation system.[3]

During the war, transportation and logistical problems severely handicapped the operations of American armies on the frontiers. Field commanders often complained that the lack of material support contributed to their defeats, and the high costs of reinforcement and supply created a new national debt. Among the few bright spots of the war was the last-minute reinforcement and supply of Gen. Andrew Jackson and the American Army at New Orleans via the inland rivers in 1814–15. These events resulted in the direct involvement of the War Department and its Corps of Engineers in postwar transportation planning. A Baltimore newspaper editor commented in 1815 that "the exigencies of the nation, during the late war, has raised all those advantages of roads, bridges, and canals, etc., which our country so happily presents to us."[4]

NATIONAL DEFENSE AND INTERNAL IMPROVEMENTS

A board of officers, composed of Gen. Simon Bernard, Col. Joseph Totten of the Corps of Engineers, and a naval officer, began a study of national defense needs in 1816, in light of the experiences of the war. The board reported that national defense should rest on four pillars: a strong navy, adequate coastal fortifications, a regular army and organized militia, and *improved interior transportation to permit swift concentration of armed forces to meet foreign threats*. The secretary of the board later explained the rationale supporting the fourth pillar, water improvements: "While every improvement in the channels of communications has… a direct relation to national defense, it especially tends to develop the agricultural industry of the country, the fundamental basis of public prosperity, and to consolidate the internal peace of the citizen."[5]

In 1818 John C. Calhoun of South Carolina, secretary of war in the James Monroe administration, initiated an experiment with the use of rivers and steamboats for military logistics. He sent Maj. Stephen H. Long of the Corps of Engineers to Pittsburgh to construct a trial steamboat named the *Western Engineer*, which was specially designed for service on shallow, tortuous, and obstructed inland streams in connection with the western advance of the army into the Missouri basin. Long designed a more mechanically efficient steam engine, placed the paddlewheel in a recess at the stern to protect against damage from snags, and developed an improved hull design to reduce the draft of the boat. His remarkable vessel was the prototype for the inland river steamboats that later played such a significant role in the development of the Mississippi River basin. Its travels evidenced the need for river improvements for both military and commercial purposes. Although the *Western Engineer* could navigate on a mere nineteen inches of water, it spent nearly six months in port at Paducah, Kentucky, because of shallow waters.[6]

OBSTACLES TO RIVER TRANSPORTATION

Fluctuating river depths adversely affected river transportation. Extended low water stages during each year from 1818 to 1820, for example, disrupted regular river traffic for long periods and caused severe seasonal economic recessions in the Midwest. Millions of dollars worth of commodities piled up at river ports each year awaiting navigable stages on the inland streams, bringing commerce to a stop, forcing the closing of mills, and triggering widespread unemployment. Concerned by these conditions, state governments in the Ohio River basin established a joint commission to survey the Ohio from Pittsburgh to Louisville and

American Philosophical Society, Philadelphia

Stephen Long's steamboat, the *Western Engineer*, at Engineer Cantonment, winter quarters on the Missouri River, 1820, by Titian R. Peale

to plan an improvement project. In its reporting, the commission decried the "painful spectacle" of many commercial craft stranded on bars and rotting useless in ports "whilst through a fertile and populous region of 1000 miles in extent, the commerce and interchange of domestic commodities are completely embargoed." The commission recommended that state governments fund improvements on the Ohio River upstream of Louisville and appeal to Congress for assistance.[7]

In the same year, Calhoun called for a federal effort to improve waterways and transportation routes more generally. He argued that such projects would contribute significantly to national defense, not only as a direct benefit to military logistics, but also as a means of enhancing American commercial and economic development on which national defensive capabilities ultimately rested. "It is in a state of war," he explained, "when a nation is compelled to put all of its resources in men, money, skill, and devotion to a country into requisition that its government realizes in its security the beneficial effects from a people made prosperous and happy by a wise direction of its resources in peace."[8]

EXTENSION OF THE OHIO RIVER SURVEY

Congress responded to the petitions from the states and the recommendations of Secretary Calhoun by appropriating $5,000 in 1820 to extend the survey from Louisville and continue with it down the Ohio and Mississippi to the Gulf of Mexico. Calhoun assigned the river survey to General Bernard, Colonel Totten, and their Corps of Engineers staff who were then traveling the country planning seacoast fortifications and the logistic lines to support them. Upon reaching Louisville in 1821 to begin the survey, they were greeted with newspaper editorials emphasizing the dual civil and military benefits of the proposed project. One read:

> *The contemplated improvement of the two principal rivers in the west, so as to render them navigable at all seasons must be an undertaking of the first magnitude to the government and people. It will greatly facilitate the passage of our produce to market at the most important season of the year, while the government will be able at any time, in case of the future invasion of New Orleans, to send men, arms, and ammunition in time to defend it.*[9]

Office of History, Headquarters, U.S. Army Corps of Engineers, H. Abbot Collection

Joseph G. Totten (1788–1864), who became Chief of Engineers in 1838

The engineers finished the survey of the lower Ohio and Mississippi rivers in 1822, submitting their maps to the secretary of war and a report to Congress. They recommended the removal of boulders and snags from the channels of the Ohio and Mississippi and the construction of low dams behind islands and at shoals to concentrate stream flow at low stages to a single well-defined channel.

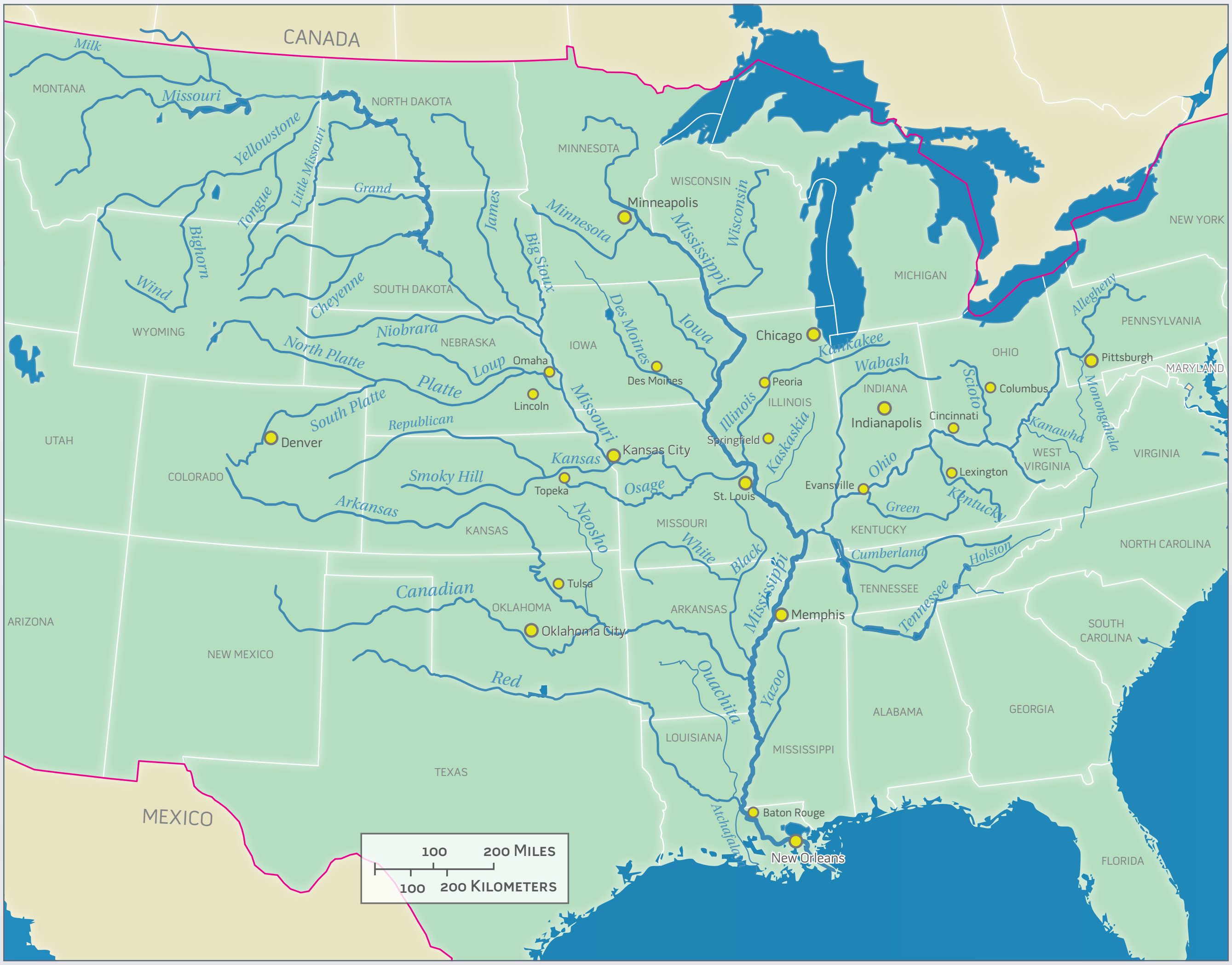
CONGRESSIONAL DEBATE ON FEDERAL AUTHORITY

Armed with the favorable survey report, Speaker of the House Henry Clay of Kentucky and his political supporters from the Mississippi River basin states launched a campaign in Congress to secure an appropriation for federal improvement of the Ohio and Mississippi rivers. Other congressmen, mostly from seaboard states, stood in opposition, asserting that an appropriation for a waterway development project would be an unconstitutional extension of federal powers. The debates over federally funded waterways projects assumed a sectional character, with eastern seaboard states pitted against states in the Mississippi valley that resented the apparent neglect of inland rivers as compared with regular funding for seacoast fortifications and lighthouse construction at seaports.

Speaker Clay believed that the Ohio and Mississippi rivers, forming boundaries of several states and being the common commercial highway of all, were national properties, deserving special consideration from Congress. He argued that the debate on an appropriation to improve their navigation should concern only methods and expediency, not constitutional issues. Congressman Robert P. Henry of Kentucky pointed out that the Ohio valley states had joined in 1819 to survey the river, and predicted that if the federal government did not fund the proposed navigation project, it would be undertaken by a regional compact of state governments. Recalling the threats of secession heard in the Mississippi valley over the issue of free navigation on the inland rivers during the years before the Louisiana Purchase, Henry warned Congress that a confederacy of states united to conduct the navigation project might become a threat to national union. Federal action was required.[10]

The Mississippi River Valley

The Mississippi River watershed is the largest in North America and the fourth largest in the world. Its tributaries, including the Missouri, Ohio, Arkansas, and Red rivers, drain all or parts of 31 U.S. states and two Canadian provinces between the Rocky and Appalachian mountains.



Clay and Calhoun finally won the day. On April 30, 1824, Congress passed the General Survey Act authorizing the president to use Army engineers to survey road and canal routes "of national importance, in a commercial or military point of view." A few weeks later, on May 24, Congress appropriated $75,000 for experiments with dam construction at the shoals of the lower Ohio River and for the prompt removal of all snags from both the Ohio and Mississippi. Henry Clay had beaten back amendments to add such tributary streams as the Monongahela to the authorized project but had allowed extension of the work to include that section of the Mississippi between the mouths of the Ohio and Missouri Rivers or between Cairo and St. Louis. While Clay thought the amount of the appropriation inadequate, he was pleased that a principle had been established by this legislation. The inland rivers thereafter would be regarded, in Clay's words, as "our seas—as our Atlantic Ocean and Mexican gulph."[11]

ARMY ENGINEERS IN DEMAND

The second act also authorized the president to select any engineers in the federal service he thought proper to supervise the project, and some support existed for giving the job to agencies other than the Corps of Engineers. Congressman Alexander Smyth of Virginia, for example, advocated for the Navy. Reflecting the simplistic view of river projects then prevalent, Smyth proposed that the Navy build more gunboats at Pittsburgh and dispatch them downstream with crews ordered to clear river channels on their way to New Orleans and foreign service.

Clay and Calhoun argued persuasively for choosing the Army Corps of Engineers as project supervisors. First, the Corps had performed the project surveys and, because West Point in 1824 was the sole formal engineering school in the nation, the Army engineers had the necessary professional training. Calhoun also argued that Army engineers would produce greater design and construction efficiency. Moreover, supervision of waterways projects during peacetime would furnish the engineers with excellent training for military construction in wartime. Finally, the project had both direct and indirect value for national defense. Apparently persuaded by those arguments, President Monroe directed Gen. Alexander Macomb, the chief of the Corps of Engineers who was personally familiar with river navigation hazards, to undertake the Ohio and Mississippi River project. Macomb sent Major Long to the lower Ohio to begin experiments with dam construction and fluvial hydraulics and, as directed by the authorizing act, contracted for the removal of snags from the Ohio and Mississippi rivers, with Capt. Samuel Babcock of the Corps serving as project engineer and contract administrator.[12]

Early success put Army engineers much in demand. They supervised the construction of the Cumberland Road; they built fortifications and lighthouses along the Atlantic Coast; and they surveyed railroad routes and prepared construction specifications for more than twenty railroads between 1827 and 1838.[13] They also turned their attention to river improvement work.

CANAL CONSTRUCTION

The subject of internal improvements became increasingly divisive during the antebellum period. The Whigs, a new conservative opposition party established in 1834, generally supported federal funds for transportation improvements. Democrats generally did not. While the debate raged, states and local interests pushed ahead with road and canal construction. Numerous canal companies had been chartered in the nation's early history, but of all the canals projected, only three had been completed by the War of 1812. These were the Dismal Swamp Canal in Virginia, the Santee Canal in South Carolina, and the Middlesex Canal in Massachusetts. It remained for New York to usher in a new era in internal communication by authorizing the construction of the Erie Canal in 1817. This bold bid for western trade alarmed the merchants of Philadelphia, particularly since the completion of the national road threatened to divert much of their traffic to Baltimore. In 1825, the legislature of Pennsylvania grappled with the problem by proposing a series of canals to connect the great Philadelphia seaport with Pittsburgh on the west and with Lake Erie and the upper Susquehanna on the north.[14]

Like the turnpikes, the early canals were constructed, owned, and operated by private joint-stock companies but later gave way to larger projects funded by the states. The Erie Canal, proposed by New York Governor De Witt Clinton, was the first canal project undertaken as a public good to be financed at the public risk through the sale of bonds. When completed in 1825, the canal linked Lake

I. N. Phelps Stokes Collection, Miriam and Ira D. Wallach Division of Arts, Prints and Photographs, The New York Public Library, Astor, Lenox and Tilden Foundations

View on the Erie Canal, 1829, by John William Hill

Erie with the Hudson River through 83 separate locks and over a distance of 363 miles. The success of the canal spawned a boom in canal-building around the country, and more than 3,326 miles of artificial waterways were constructed between 1816 and 1840. Small towns that lay along the main canal routs (including Syracuse, Buffalo, and Cleveland) grew into major industrial and trade centers, whereas exuberant canal-building pushed some states such as Pennsylvania, Ohio, and Indiana to the brink of bankruptcy.[15]

The magnitude of the transportation problem was such, however, that neither individual states nor private corporations were able to meet the great demand for internal trade. Treasury Secretary Albert Gallatin had earlier advocated the construction of an ambitious system of internal waterways to connect East and West, at an estimated cost of $20 million. But the only federal contribution to internal improvements during the Jeffersonian era was an appropriation in 1806 of 2 percent of the net proceeds of the sales of public lands in Ohio for the construction of a national road, with the consent of the states through which it should pass. By 1818, the road was open to traffic from Cumberland, Maryland, to Wheeling, West Virginia.[16]

As the country recovered from financial depression following the Panic of 1819, the question of internal improvements again moved to the forefront of public debate. In 1822, President James Monroe vetoed a bill to authorize tolls on the Cumberland Road. In an elaborate essay he set forth his views on the constitutional aspects of a policy of internal improvements. Congress could appropriate money, he admitted, but it could not undertake the actual construction of national works or assume jurisdiction over them. For the moment, the drift toward greater participation by the national government in internal improvements was stayed. Two years later, Congress authorized the president to institute surveys for such roads and canals as he believed to be needed for commerce and military defense. No one pleaded more eloquently for a larger conception of national government than Senator Clay. He called the attention of Congress to provisions made for coast surveys and lighthouses on the Atlantic seaboard and deplored the neglect of the interior of the country. Andrew Jackson also supported a general survey bill, as did John Quincy Adams, contrary to the narrow view of his section on this issue. Of the several presidential candidates in 1824, only Treasury Secretary William Crawford of Virginia felt the constitutional scruples that were everywhere being voiced in the South. He followed the old expedient of advocating a constitutional amendment to sanction national internal improvements.[17]

In his first message to Congress, newly elected President John Quincy Adams advocated not only the construction of roads and canals but also the establishment of observatories and a national university. Although President Jefferson had recommended many of these and called for Congress to consider necessary amendments to the Constitution, Adams seemed oblivious to any legal limitations. In much alarm Jefferson suggested to Madison the desirability of having Virginia adopt a new set of resolutions, patterned on those of 1798 and 1799 (the Kentucky and Virginia Resolutions), and directed against the acts for internal improvements. In March

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Portland (Maine) Head Light, the first federal lighthouse, renovated and maintained by the Light House Board

1826, the Virginia General Assembly declared that all the principles of the earlier resolutions applied "with full force against the powers assumed by Congress" in passing acts to protect manufacturers and to further internal improvements. It was a foregone conclusion that the administration would meet with opposition in Congress.

RIVERS AND HARBORS

Federal assistance for internal improvements evolved slowly and haphazardly, the product of contentious congressional factions and an executive branch generally concerned with avoiding federal intrusions into state affairs. In 1824 the Supreme Court ruled in *Gibbons v. Ogden* that federal authority covered interstate law, a ruling that, together with the General Survey Act, marked the beginning of the Corps' continuous involvement in civil works. This initial legislation authorized the president to have surveys made of routes for roads and canals of national importance, in a commercial or military point of view, or necessary for the transportation of public mail and to improve navigation on the Ohio and Mississippi rivers by removing sandbars, snags, and other obstacles. Such congressional authorizations for the benefit of navigation became known as rivers and harbors acts. After 1824, successive Congresses passed one or more of these acts to provide for maintenance and improvements on America's waterways. Each act contained two principal parts: a section authorizing and directing preliminary examinations and surveys at designated localities, and a section authorizing specific river and harbor works in accordance with reports previously submitted by the Army's chief of engineers.[18]

R. W. Norton Art Gallery, Shreveport, Louisiana

Capt. Henry M. Shreve clearing the raft from the Red River, 1830s, by Lloyd Hawthorne in 1969


St. Paul District, U.S. Army Corps of Engineers

Henry Bosse photograph of wing dams below Nininger, Minnesota, on the upper Mississippi River, 1891

By 1829, U.S. Army engineers were using snagboats developed by the famous steamboat captain, Henry M. Shreve, to remove obstructions in river channels. Appointed by the secretary of war as superintendent of western rivers, Shreve realized that the use of a steam engine and other design techniques would reduce by half the cost of snag removal. His first double-hulled snagboat, the *Heliopolis*, successfully removed extensive obstructions along the lower Mississippi and Red rivers (and later the Missouri, Ohio, and upper Mississippi rivers). An iron beam connecting the two hulls was used as a battering ram to dislodge a snag from the river bed. Lifting capability was provided by machinery instead of by hand, which made the vessel a much more powerful snag remover. These Corps snagboats, which could lift a submerged tree weighing seventy-five tons lodged up to twenty feet deep, became known as "Uncle Sam's Toothpullers." Shreve, who eventually received a patent on his snagboat design, also began clearing riverbanks to prevent falling trees from sinking into the river and becoming navigational hazards.[19]

In the mid-nineteenth century, the Army began constructing wing dams, stone structures that extended downstream from the bank of the river at a forty-five-degree angle. The dams decreased the width of the channel, thereby increasing the current's velocity and directing its force against the riverbed. Theoretically, these structures would cause the river to scour a deeper channel. Major Long experimented with wing dams along the Ohio in the 1840s on a compacted gravel bar near Henderson, Kentucky, just below the mouth of the Green River. At low-river stage, this bar was covered by only fifteen inches of water. After preliminary studies, the major outfitted several flatboats with hand-powered pile drivers and began to build a wing dam. Long experimented with various widths, lengths, and heights, but his final structure was 402 yards long and consisted of twin rows of 1,400 piles joined with stringers and filled with brush. Sediment gathered against the dam and helped anchor it to the riverbed. The project's total cost was less than $3,400. Wing dams were used on the Ohio and other major rivers during most of the nineteenth century, but the stone and brush structures were easily destroyed and only marginally effective.[20]

NAVIGATION ON THE GREAT LAKES

Beginning in the early 1820s, the federal government encouraged the settlement of the Great Lakes region by subsidizing the improvement of transportation routes. Congress appropriated $20,000 in 1824 to deepen the channel leading into the harbor at Erie, Pennsylvania. Over the next sixteen years, a steady stream of federal money flowed to this and other harbor projects in the region. Congressmen favoring strict adherence to the Constitution, however, continued to oppose federal expenditures for internal improvements. By 1840, the opponents of federally subsidized internal improvements prevailed in Congress and such spending was greatly curtailed until after the U.S. Civil War (1861–1865).[21]

Officers of the Army Corps of Engineers had responsibility for overseeing federal lake harbor improvements between 1824 and 1838. In that latter year Congress established an independent Army Corps of Topographical Engineers (topogs) and gave it authority to conduct most internal improvements, especially canal, road, and river and harbor improvements while the Corps of Engineers turned its attention primarily to coastal fortification. Beginning in 1832, the topogs sought to clear the sand bar at the mouth of the Chicago River and to build piers for a harbor at that location. To complement this effort, the state of Illinois, with a federal subsidy, dug the Illinois and Michigan Canal to connect the Great Lakes with the Mississippi River. Constructed between 1836 and 1848, the canal began at the head of navigation on the South Branch of the Chicago River and extended for one hundred miles southwesterly to the Illinois River, which then drained into the Mississippi. The Chicago harbor served as the eastern terminus of this vital commercial waterway. In spite of uncertain funding and environmental and political problems, the Army Engineers built port facilities that eventually saw Chicago dominate the trade of the West. By 1854, commerce through the Great Lakes at Chicago exceeded that at New Orleans.[22]

Early harbor improvements consisted of channel deepening by constructing parallel jetties from just upstream of a river's mouth into the deep water of a lake. The jetties, usually 200 feet apart, trained the river's flow to wash away sand and other debris from the channel. To provide a breakwater so that lake vessels could enter a harbor in rough weather, engineers extended one of the parallel jetties beyond the other. Over the years, they were extended into deeper water to accommodate ever-larger lake vessels and provide greater harbor depth. The extension of the jetties, however, lessened the scouring effects of river freshets.

Engineers used wood in most harbor improvements, but as early as 1835 they employed masonry in pier work at Buffalo. In 1839, the engineers tried concrete instead of timbers as a foundation for a new masonry pier. Concrete construction proved more costly than wood and required special skill not always available. Until the end of the century when large wooden timbers became scarce and more costly to acquire, wood remained the primary material for constructing harbor improvements for navigation. Typically, the wooden piers consisted of a series of timber or log cribs about twenty or thirty feet square. Held together with iron bolts and strengthened with cross beams, the heavy structures were constructed on shore, floated into position in the channel, filled with stones, and sunk to the lake bottom. Once a line of cribs had been placed, workers built a superstructure of sawed timber over them to a height of six or seven feet above the water level and then filled the superstructure with small stones and planked over it to form a deck. Although the underwater timber cribs lasted indefinitely, the superstructure—exposed to rugged weather—required frequent repairs.[23]

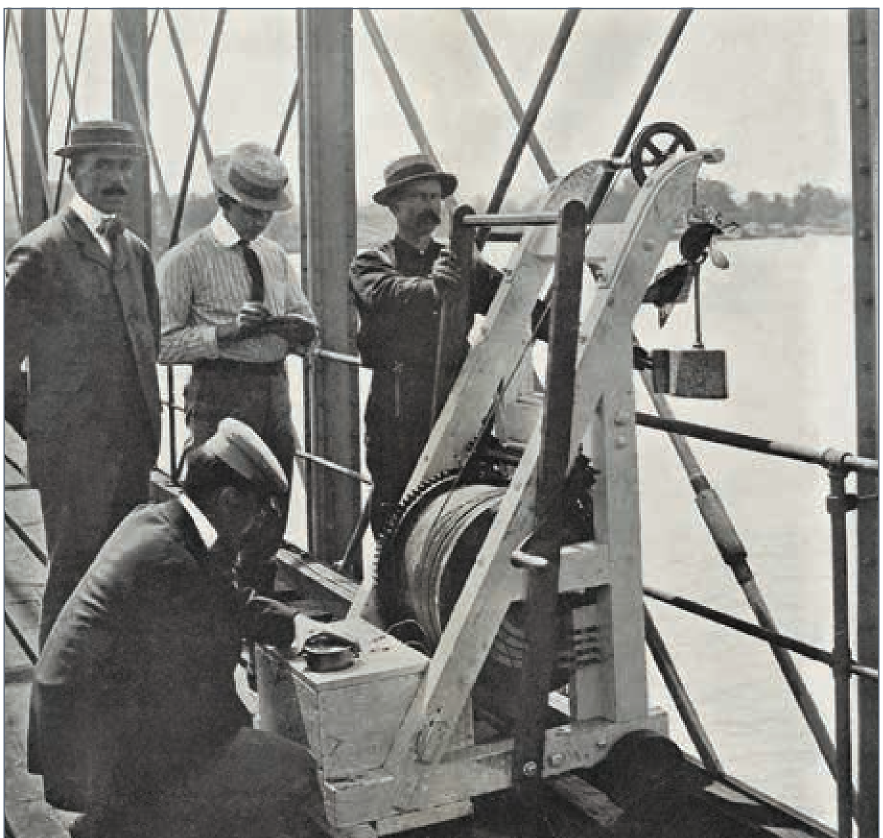
Army Engineers also had responsibility for other navigation improvements on the Great Lakes, including beacons and lighthouses. By 1837, sixteen lake harbors had such structures, then operated by the Treasury Department. The Lake Survey, another congressionally assigned duty of the Corps, began in the pre-Civil War era. Although the Army Engineers had long made surveys on the Great Lakes in order to prepare accurate charts for navigation, the first systematic survey of the lakes began with a $15,000 appropriation from Congress in 1841. It assigned the task to the new Topographic

Corps. When the topogs merged with the Corps of Engineers in 1863, the survey became the responsibility of the latter agency. The mission eventually expanded to include surveying the navigable waters of the New York State canal system, Lake Champlain, and Lake of the Woods. The Corps completed surveys of Lakes Michigan and Superior in 1874, Lake Ontario in 1875, and Lake Erie in 1877. The Lake Survey issued its final report in 1882, but the increased number and size of lake vessels soon required updated charts. The work of the Lake Survey, headquartered first at Buffalo and later Detroit, continued late into the twentieth century.[24]

The number and size of lake vessels increased as did commerce and demands for further improvements. The value of lake trade increased from $4 million in 1835 to over $60 million in 1846. In response to heavy lobbying by commercial interests, Congress again appropriated money for improvements. It voted funds in 1844 to carry out work at twenty different harbors. These monies enabled the Army Engineers to make repairs, complete unfinished work, or modestly extend existing projects, but more ambitious improvements necessary for permanent protection of lake commerce were not possible. Another eight years passed before Congress again funded these projects. The 1852 river and harbor appropriation of $2.25 million—although the largest of its kind in the antebellum period—paid for only the most urgent repairs and maintenance of existing work and a few new undertakings.[25]

Between 1853 and 1861, Democratic presidents, Franklin Pierce and James Buchanan, opposed federally sponsored internal improvements and vetoed river and harbor bills intended to improve conditions for lake navigation. Lacking federal support, local interests did what little they could. In 1856, Congress overrode Pierce's veto to appropriate money to improve St. Clair Flats, which connects Lake Huron and Lake Erie; and St. Marys River, which connects Lake Superior with Lake Huron.

By the Civil War, efforts to survey and improve the nation's rivers and harbors were hampered by politicians with myopic and strict constructionist views. Because of the parochial interests of the legislators, Congress appropriated small amounts of money primarily for scattered projects of local or regional value. Advocates for internal improvements



Office of History, Headquarters, U.S. Army Corps of Engineers, ARCE 1900

Engineers making observations of the current near the International Bridge just north of Lake Erie at Buffalo, New York, 1899, as part of the effort to survey the Great Lakes

Library of Congress, LC-DIG-cwpb-00124

Topographical engineers at Camp Winfield Scott in the vicinity of Yorktown, Virginia, by James F. Gibson, May 1862

secured votes only by pandering to reluctant legislators. Sectional jealousies, constitutional questions, and conflicts between legislative and executive branches further muddied the river-improvement waters, making comprehensive planning impossible.

FEDERAL FLOOD CONTROL

While the federal interests bickered over rivers and harbors legislation, regional interests from the Mississippi valley made headway toward the federalization of flood control. The first step came with the passage of the Swamp Land Grants of 1849 and 1850. Approved in the wake of two devastating floods, these acts provided aid to the people of the Mississippi valley in the form of land grants that transferred unsold swamplands to the states of the alluvial valley with the stipulation that funds from the sale of these lands be used for building levees and drains required for reclamation purposes. However, by transferring federally owned swamplands to the states to finance levee construction, the federal government sought to keep the onus of flood control on local authorities.[26]

At about the same time, Congress affirmed its growing commitment to the Mississippi River problem by appropriating $50,000 for a survey geared toward the preparation of plans for navigation improvements and flood control. Secretary of War Charles M. Conrad split the appropriation between the military and civilian engineering communities. Lt. Col. Stephen H. Long and Andrew Humphreys, then only an Army captain, spearheaded the military effort, although the latter officer performed almost all of the work. Charles Ellet, Jr., a prominent civil engineer educated at *L'Ecole Polytechnique* in Paris, initiated the civilian effort.[27]

Completed in 1852, Ellet's report posited an extraordinary but concise examination without extensive analysis of the river's regimen and lacking the precise observations and measurements necessary to support his conclusions. Despite its brevity, the report evidenced Ellet's advanced understanding of the Mississippi River problem. He concluded that the federal government should assume responsibility for improving the Mississippi River for both navigation and flood-control purposes and identified a comprehensive approach to accomplish just that. His plan, which incorporated various engineering techniques working together to both accommodate and control the river, included the improvement of the existing levee system, with special emphasis on the levees below the mouth of the Red River; the prevention of cutoffs along the excessive bends in the river; the construction of headwater reservoirs on the upper Mississippi River and on its main tributaries; the enlargement of natural river outlets through Bayou Plaquemine and the Atchafalaya River; and the creation of an artificial outlet from the river to Lake Borgne, Louisiana. Both in its recommendation for the federalization of improvements along the Mississippi and its support for a comprehensive flood control plan, Ellet's report represented a valuable contribution to the treatment and understanding of the river. At the same time, though, he openly conceded that his report did not dwell upon "microscopic examination," leaving many of his conclusions open to criticism.[28]

Such criticism materialized later when Humphreys completed the second and far more influential study. Humphreys and his assistant, fellow West Pointer Lt. Henry L. Abbot, completed their investigation in 1861, after nearly a decade of exhaustive research. The 500-page study, titled *Report Upon the Physics and Hydraulics of the Mississippi River*, contained the close field experimentations lacking in Ellet's study and represented the most thorough analysis of the Mississippi River ever completed up to that time. The Humphreys and Abbot report, also known as the Delta Survey, dismissed many of Ellet's unsubstantiated hydraulic theories as flawed and erroneous. Additionally, it rejected several of Ellet's conclusions on flood control as either too expensive or too dangerous to be attempted, particularly with respect to artificial outlets and headwater reservoirs. The report recommended an approach based almost exclusively on levees supported by a few natural outlets to prevent overflow.[29]

LEVEE CONSTRUCTION

In contrast to Ellet's assertion that a plan based extensively on levees was impractical, the Humphreys and Abbot report argued that a general levee system "may be relied upon for protecting the alluvial bottomlands liable to inundation below Cape Girardeau." Because of its unprecedented thoroughness, the report won the respect of engineers around the world. The study influenced the development of river policy well into the twentieth century in terms of both the data gathered and the conclusions rendered. Following the Civil War, Humphreys, bolstered by the international acclaim he received as primary author of the study, became chief of the Army Corps of Engineers, a position he used as a bully pulpit in defense of his conclusions. As the merits of these influential studies were debated among the engineering community, the construction of levees along the Mississippi River advanced at a rapid rate.[30]

The 1850s were a relatively prosperous period for the Mississippi valley. With the fiscal impetus of the Swamp Land Grants, the planters of the lower valley were better prepared than ever to fund levee construction. By mid-

Office of History, Headquarters, U.S. Army Corps of Engineers

Workmen shoring up a levee during high water near Memphis, Tennessee, in 1927 using emergency techniques little evolved from those used the previous century

decade, most of the levees along the lower Mississippi were in place, averaging about four feet in height. But the progress made during this period remained haphazard, uneven, and, according to Humphreys and Abbot, "quite inadequate." As late as 1857 and 1858, sizable gaps existed in the system, and the completed levees were of grossly insufficient size, gauge, and cross section.[31]

THE FLOODS OF 1858 AND 1859

Severe floods in 1858 and 1859 exposed these inadequacies and destroyed much of the progress of the previous decade. In 1858, flood levels in the lower Mississippi valley were, according to Humphreys and Abbot, "second to none of which we have records." High water inundated the city of Cairo, washed away miles of levees along the St. Francis front, and deeply flooded the Yazoo, Tensas, and Atchafalaya basins. Below Red River Landing, two major crevasses at Bell and Lafourche left the fertile country between the Mississippi River and Bayou Lafourche submerged for weeks. Few of the much-needed levee repairs could be made before the spring of 1859, when a second flood struck the valley. Though not as severe as that of the previous year, the flood of 1859 was of unprecedented duration. The river at Memphis remained near the high-water mark for eighty consecutive days. The strain proved too much for the fledgling levee system, and at least thirty-two separate crevasses formed, leaving much of the lower Mississippi valley inundated.[32]

The floods of 1858 and 1859 proved conclusively that the levees had to be built higher and stronger. The people of the lower Mississippi valley had already expended $40 million for the construction of the failed levee line. Nearing the end of their resources, they turned to the federal government with very strong appeals for aid. By 1861, both houses of Congress were considering the problem, but the country soon found itself occupied with more pressing matters. Another deluge arrived in April 1861, but this one did not subside with the passing of the spring rains. On the morning of April 12, 1861, Confederate forces under the command of Gen. P. G. T. Beauregard fired upon Fort Sumter, plunging the nation into Civil War.[33]

The conflict postponed work on civil projects, as Army Engineers devoted their primary attention to the military mission. Because of the naturally corrosive effects of flowing water, levees must be constantly maintained and repaired. Necessarily preoccupied by the war, the people of the lower Mississippi valley abandoned their flood-control efforts altogether, and the levees quickly fell into disrepair. General neglect of the levees throughout the war years resulted in untold damage to the system, as whole sections washed away or collapsed. A major flood in 1862 expedited the deterioration, but the most devastating damage resulted from military operations in 1863 and 1864. To break the Confederate stronghold at Vicksburg and flood rebel supply routes, the Union army destroyed many levees, including the Yazoo and Huspuckena levee—the finest in the delta.[34]

With the destruction of the levee system nearly complete by the summer of 1865, the states of the lower Mississippi valley began to evaluate their predicament. Four years of war had done much to destroy the prosperity of the region. In 1860, the state of Mississippi had been among the wealthiest in the United States; following the war it ranked among the poorest. Louisiana, Arkansas, Tennessee, and Missouri were similarly impoverished. Property values throughout the region tumbled in the years after the war and, as a result, so did tax revenues. In 1860, farm property in Arkansas, Mississippi, and Louisiana was valued at $607,385,474; ten years later that value had fallen to $213,885,602, a loss of almost $400 million. The job of repairing the dilapidated levee system represented a daunting task in the best of times. One Mississippi congressman noted that, with conditions as they were, "the prospect of an enforced abandonment of the whole delta country grew… more certain."[35] The postwar years saw the federal government gradually ramp up its commitment to flood control, and the Mississippi valley would be far and away the greatest beneficiary.

WESTERN EXPLORATION

For much of the antebellum period, the Corps of Engineers shared responsibilities for federal internal improvements with its brother organization, the Corps of Topographical Engineers. In addition to their long association with civil works, the topogs also played a key role as the young nation rapidly expanded during the early nineteenth century. During his first inaugural address in 1801, President Thomas Jefferson said, "However our present interests may restrain us within our own limits, it is impossible not to look forward to distant times, when our rapid multiplication will expand itself beyond those limits and cover the whole… continent." Seizing upon an opportunity to greatly increase the land size of the United States, Jefferson negotiated with Napoleonic France for the Louisiana Purchase. Soon after, the imaginative president sought to have this large expanse explored, with the ultimate goal of finding a Northwest Passage to the Orient. The reconnaissance of the Trans-Mississippi West began with the four-thousand-mile epic journey of Lewis and Clark in 1804–06. They traveled the length of the Missouri, Clearwater, Columbia, and Snake rivers to the Pacific Ocean and back again.[36]

Another ten years would pass before the government began to professionalize official exploration. In 1816, topographical officers—known as Geographers during the American Revolution and Topographical Engineers during the War of 1812 and thereafter—were added to the peacetime Army. Unlike the other officers of the Corps of Engineers, whose primary duties centered on the construction and maintenance of fortifications, topogs performed essentially civil tasks as surveyors, explorers, and cartographers. In 1818, the War Department established the Topographical Bureau under Maj. Isaac Roberdeau to collect and store the maps and reports of topographical operations. Like the topogs, who numbered only six at this early date, the bureau fell under the Engineer Department.

Almost from the outset, there was great demand for the skills of the topographical engineers. The accelerated movement of Americans into the interior of the continent served to emphasize the nation's need for networks of transportation and communication. Congress recognized the compelling nature of the requirement in its passage of the General Survey Act. This law became the basis for topog involvement in the development of canals, roads, and, later, railroads.

Office of History, Headquarters, U.S. Army Corps of Engineers, H. Abbot Collection

John James Abert (1788–1863), who became Chief of the Topographical Bureau in 1829

COLONEL ABERT AND THE TOPOGS

Along with the growing importance of the topogs came increases in their numbers and improvements in the organizational structure. Most of the changes came during the first decade of Col. John J. Abert's tenure as chief of the Topographical Bureau. A strong-willed and ambitious West Pointer who received the appointment after Roberdeau died in 1829, Abert sought independence for both the bureau and the topogs. He realized his goal in 1831 when Congress removed the bureau from the Engineer Department and gave it departmental status under the secretary of war. Seven years later, he attained the second objective and became chief of an independent Corps of Topographical Engineers, a position he held for twenty-three years. Abert sought a great deal more for the topogs than prominence within the bureaucracy. Whereas Roberdeau had been content to manage the office as a depot for maps and instruments and as a clearinghouse for correspondence, Abert saw his role as planner and administrator for national policy regarding internal improvements and western exploration. As a member of the Board of Engineers for Internal Improvements, established to evaluate projects considered under the General Survey Act, Abert had a part in the selection of tasks and their execution. But in western exploration—which for many years took a back seat to internal improvements—Abert's role remained minor. His bureau distributed instruments, collected maps, and forwarded correspondence.[37] Individual members of the Corps of Topographical Engineers, however, achieved great importance in western exploration and surveys.

During the expansionist era of the 1840s, from the first stirrings of Oregon fever in the early years of the decade to the acquisition of the huge southwestern domain after the Mexican War, topogs examined the new country and reported their findings to a populace eager for information about the lands, native peoples, and resources of the West. Best known of all was John C.

Fremont, the dark-eyed and flamboyant pathfinder who led three parties to the Rockies and beyond. The ranks also included William H. Emory, author of a perceptive assessment of the Southwest, and James H. Simpson, discoverer of the ruins of the ancient Pueblo civilization of New Mexico. Howard Stansbury, whose report of an exploration of the Great Salt Lake is still considered a frontier classic, also wore the gold braid of the Corps of Topographical Engineers. In the 1850s, when the emphasis shifted from reconnaissance to more detailed exploration and road building, topogs continued to make their marks: John N. Macomb laid out the basic road network of New Mexico; George H. Derby initiated harbor improvements in California; and Joseph C. Ives became the first Anglo-American to descend the Grand Canyon.[38]

CONSEQUENCES OF GOVERNMENT POLICY MAKING

The disparity between the renown of members of Abert's Corps and the obscurity of his bureau was due to the absence of a government policy regarding exploration. The topographical engineers frequently went into new country on an *ad hoc* basis—at the behest of a politically powerful figure like Missouri Senator Thomas Hart Benton or to accompany a military expedition. Topog exploration often took a secondary position to other purposes, such as Major Long's 1819 journey up the Missouri River as a minor adjunct of Col. Henry Atkinson's Yellowstone Expedition, or Emory's southwestern exploration during the Mexican War and subsequent Mexican boundary surveys.

When exploration and surveys in the Trans-Mississippi West were finally organized and coordinated in the 1850s, Abert no longer wielded the political influence that had brought his ambitions so near fruition in the 1830s. Duties he hoped would devolve to the Corps of Topographical Engineers went instead to the Office of Pacific Railroad Explorations and Surveys, a small organization created by Abert's political foe, Secretary of War Jefferson Davis, and headed by one of Abert's most talented topogs, Capt. Andrew A. Humphreys. It was Humphreys rather than Abert who would manage the surveys for railroad routes linking the Mississippi River to the Pacific Ocean.[39]

Despite the lack of a unified policy and central direction, the history of topog expeditions forms a coherent entity. Topographical officers provided the link between the mountain men—those rude, brawling beaver trappers who first probed far beyond the frontier and were walking storehouses of geographical knowledge—and the civilian scientists who undertook a rigorous study of western natural history and resources after the Civil War. Between the trappers and the specialists of the United States Geological Survey, topogs provided the nation with an overall picture of the Trans-Mississippi region. They explored bits and pieces as opportunity allowed until a general understanding of western topography emerged in the form of topog Lt. Gouverneur K. Warren's map of 1858, completed under Captain Humphreys in the Office of Pacific Railroad Explorations and Surveys. The Warren map was the first accurate overall depiction of the Trans-Mississippi West and a milestone in American cartography that reshaped the American sense of self and ushered in a new era of Western settlement and the exploitation of its water resources.[40]

FUNDING INTERNAL IMPROVEMENTS

The period of rapid territorial expansion in the 1840s saw Congress substantially extend federal jurisdiction over inland waters. An important Supreme Court decision in 1870 effectively codified this expansion by declaring that "those rivers must be regarded as public navigable rivers in law which are navigable in fact. And they are navigable in fact when they are used, or are susceptible of being used, in their ordinary condition as highways of commerce, over which trade and travel are or may be conducted in the customary modes of trade and travel

U.S. Pacific Railroad Survey Reports, Volume 3, 1855

A view of the Bill Williams River valley during Amiel Whipple's Pacific Railroad Survey (1853–54) along the 35th parallel, 1855, by John Tidball and lithographed by Sarony, Major & Knapp

on water." In this decision, the courts merely confirmed what Congress and private interest had long taken for granted: the right to regulate navigable waters includes the right to improve them. [41]

Although federal jurisdiction was expanding, the states and other entities were still responsible for a great deal of construction in the period before the Civil War, and they were often assisted by federal grants. These were generally land grants or funds of money derived from the sale of public land. In 1819, Congress set aside five percent of the monies received from the sale of lands in Alabama to be returned to the state as a fund for internal improvements. Congress continued the practice, though generally at 2 or 3 percent for other new states entering the union. In 1827, Congress initiated the practice of granting rights-of-way through public lands for canal projects in states such as Illinois and Indiana. The following year, Congress granted four hundred thousand acres of public lands to Alabama to finance improvement of the Tennessee River at Muscle Shoals and Colbert's Shoals.[42]

By the 1840s, Congress had given substantial acreage to the states—over a million acres, for example, to Ohio and Indiana alone. In 1841, Congress enacted 500,000-acre land grants for public improvements. Under this measure, eight states and every public-land state thereafter admitted to the union were to receive a grant of public lands for use for specified improvements. By the time the program was terminated in 1889, fifteen states had each received the full 500,000 acres, and two more, Illinois and Alabama, had received 209,086 and 97,469 acres, respectively.

The uses of this land were various—some states used it to finance public education, others for railroad construction or irrigation; some applied a portion to river improvements, canals, or roads; one state, Minnesota, liquidated state bonds previously loaned to railroads. The Swamp Lands Acts of 1849 and 1850 were a logical extension of this practice, with funds applied to the repair and construction of the Mississippi River levees and other flood protection measures and in the drainage and reclamation of the lands. In 1850, Congress extended the act to cover other states, and another extension in 1860 included Minnesota and Oregon. Eventually, fifteen states received a total of 64,853,922 acres of land—or 101,334 square miles, an area slightly smaller than the state of Colorado.[43]

Another form of federal assistance to state, local, or private internal improvement projects was the purchase of stock in canal companies. The first such investment came in 1825 when Congress authorized the purchase of 1,500 shares in the Chesapeake and Delaware Canal Company. This investment was followed by four others, with the total investment approaching $2 million. Gradually, as the role of states in internal improvements projects declined, the role of the federal government increased.

CONCLUSION

The history of federal participation in water resource developments in the nineteenth century is one of increasing activity in terms of both kind and degree—and of increasing calls from states and private interests for ever more federal assistance. The numbers are impressive. Altogether, by 1860, Congress had appropriated about $14.5 million for river and harbor improvements and another $2.5 million for canals. These amounts include the subscriptions to canal companies and the monies from the two- or three-percent funds. Of that $14.5 million spent for rivers and harbors projects, roughly $5 million had been spent on the Atlantic Coast and $1 million on the great inland rivers—the Mississippi, Ohio, Missouri, and Arkansas. A trifling amount had been spent on the Pacific Coast.

The value of the land grants is more difficult to determine, but certainly the federal government transferred a substantial amount of land. Federal land grants for canals, according to figures compiled by the Department of Commerce, totaled 4.5 million acres. Grants for river improvement projects amounted to another 1.7 million acres. The Swamp Land Act grants overshadowed all others and approached 65 million acres of which 51 million seem to have been used at least partly for the purposes of reclamation or flood control. The states eventually turned over approximately 14 million acres to various railroads interests. Of the nearly 8 million acres granted under the 500,000-acre land grants, a considerable part was used to fund river, harbor, and canal work.

These grants and appropriations represent a modest amount of aid compared to the assistance forthcoming after the Civil War. By the 1850s, river interests in the interior were agitating for far more aid than they were receiving. St. Louis rivermen calculated that river obstacles such as snags and sandbars resulted in the loss of boats and cargo in the amount of $3.6 million just for the years between 1822 and 1841. This is more than the total federal appropriations from 1824 to 1860 for the four great inland rivers. By the mid-1840s, the first of the river conventions had met at Memphis to lobby for more federal aid. That convention would be followed by many others. The Civil War brought almost all internal improvement projects to a halt and effectively destroyed commerce on the Mississippi River. When work resumed after the war, it would be on a scale far greater than ever before.[44]

BIBLIOGRAPHIC ESSAY

Several recent studies track the origins of federal involvement in civil works and the ways in which improvement schemes often foundered on questions of political ideology and local interests. The best of these are Daniel Howe, *What God Hath Wrought* (2007), and John Larson, *Internal Improvement: National Public Works and Promise of Popular Government in the Early United States* (2001). Another, Paul Paskoff's *Troubled Waters: Steamboat Disasters, River Improvements, and American Public Policy, 1821–1860*, offers a comprehensive examination of the federal government's river improvements program from its beginnings in the early republic to 1844.

There is still much work to be done on the early history of the Army Corps of Engineers. The best single volume is Todd Shallat's *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers* (1994), a wide treatment of the agency though the post–Civil War period. Martin Reuss's *Designing the Bayous* (2004) is superb as well with a focus on the Mississippi Valley and good coverage of the early years. A number of Corps of Engineers district and division histories tell civil works stories from regional perspectives. William Willingham's histories of the Seattle and Portland districts are groundbreaking and provide a nice balance against the more numerous studies detailing Corps efforts in the eastern United States. Leland Johnson's works on the Pittsburgh, Huntington, and Louisville districts are strong as well. For a textbook level treatment, see *The U.S. Army Corps of Engineers: A History* (2008) and *History of Public Works in the United States, 1776–1976* (1976).

William H. Goetzmann's *Army Exploration in the American West, 1803–1863* (1959) ranks among the best books ever written about the Topographical Corps and western exploration. As useful supplements, see Frank N. Schubert's *Vanguard of Expansio*n (1980) and Garry D. Ryan's dissertation, *War Department Topographical Bureau, 1831–1836: An Administrative History* (1968). For a recent history of the Pacific Railroad Surveys (1853–57), see Matthew T. Pearcy's "Science, Politics, and Bureaucracy: Andrew A. Humphreys and the Office of Pacific Railroad Explorations and Surveys" (*Military History of the West*, 2008). W. Turrentine Jackson's *Wagon Roads West* (1979) and, especially, Forest G. Hill's *Roads, Rails, & Waterways* (1957) stand out on the subject of road and waterway construction. An excellent new addition is Robert G. Angevine's *The Railroad and the State: War, Politics, and Technology in Nineteenth-Century America* (2004).

There are some superb primary sources on the activities of the Army Corps of Engineers in the nineteenth century. Among the best of these are the *Annual Reports of the Chief of Engineers* (ARCE), exhaustive and occasionally illustrated. Most of these reports are available digitally through ProQuest and date as early as 1822. In addition, the National Archives maintains Army Corps of Engineers records in Record Group 77. Though the finding aids have not been updated in many decades, the collection remains an essential resource for information on the agency in the nineteenth century. Outside of the National Archives, the best of the personal paper collections are the Andrew A. Humphreys Papers at the Historical Society of Pennsylvania, the Henry Larcom Abbot Papers at Harvard University, and the Thomas Lincoln Casey Papers at the Casey Farm in Saunderstown, Rhode Island.

ENDNOTES

1 Martin Reuss and Charles Hendricks, "U.S. Army Corps of Engineers: A Brief History," Office of History, Headquarters, U.S. Army Corps of Engineers (CEHO), undated; Todd Shallat, *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers* (Austin, Tex.: University of Texas Press, 1994), 118–20.

2 Charles Hendricks, "A History of Corps of Engineers Civil Works Real Estate Policies," 1995, unpublished manuscript, CEHO.

3 Shallat, 121; Carter Goodrich, "American Development Policy: The Case of Internal Improvements," *Journal of Economic History* XVI (1956): 449–60.

4 Leland Johnson, "The Fourth Pillar of Defense: Waterways," *National Waterways Roundtable Papers: Proceedings on the History and Evolution of U.S. Waterways and Ports*, April 22–24, 1980, Norfolk, Virginia (Ft. Belvoir, Va.: Institute for Water Resources, 1980), 24; Martin Reuss and Paul K. Walker, *Financing Water Resources Development: A Brief History* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History), 19.

5 Ibid.

6 Richard G. Wood, *Stephen Harriman Long, 1784–1864: Army Engineer, Explorer, Inventor* (Glendale, Calif.: The Arthur H. Clark Company, 1966), 63–64; Leland R. Johnson, *The Headwater's District: A History of the Pittsburgh District, U.S. Army Corps of Engineers* (Pittsburgh: U.S. Army Engineer District, 1979), 59–61; John T. Starr, "Long's Expedition to the West," *Military Engineer* LIII (1961): 116–18.

7 *Reconnaissance of the Ohio River above the Falls Made in 1819 by Commissioners Appointed by the States* (1819), in Cartographic Division, National Archives; Leland R. Johnson, *Men, Mountains, and Rivers: An Illustrated History of the Huntington District, U.S. Army Corps of Engineers, 1754–1974* (Washington, D.C.: Government Printing Office, 1977), 22–25.

8 *American State Papers*, Miscellaneous, II, 533–37.

9 Leland R. Johnson, *The Falls City Engineers: A History of the Louisville District, Corps of Engineers, United States Army, 1970–1983* (Louisville, Ky., U.S. Army Engineer District, 1984), 43.

10 *Annals of Congress*, 18th Congress, 1st sess., 2578–83.

11 *History of Public Works in the United States, 1776–1976*, ed. Ellis L. Armstrong (Chicago, Ill.: American Public Works Association, 1976), 134–35; *Niles' Weekly Register* (July 17, 1824), 327.

12 Johnson, "The Fourth Pillar of Defense."

13 Robert G. Angevine, *The Railroad and the State: War, Politics, and Technology in Nineteenth-Century America* (Stanford, Calif.: Stanford University Press, 2004), xiv.

14 Carl L. Becker, *Beginnings of the American People* (Boston: Houghton Mifflin Company, 1915), 255.

15 *History of Public Works*, 25–26.

16 *History of Public Works*, 61–62.

17 W. Turrentine Jackson, *Wagon Roads West: A Study of Federal Road Surveys and Construction in the Trans-Mississippi West, 1846–1869* (Lincoln, Neb.: University of Nebraska Press, 1964), 2–3; Becker, 310.

18 Shallat, 125–26; Edward L. Pross, "A History of Rivers and Harbors Appropriation Bills, 1866–1933" (Ph.D. diss., Ohio State University, 1938).

19 Shallat, 144–48; U.S. Army Corps of Engineers, *The U.S. Army Corps of Engineers: A History* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 2007), 42.

20 John O. Anfinson, *The River We Have Wrought: A History of the Upper Mississippi* (Minneapolis, Minn.: University of Minnesota Press, 2003), 41–45; *The U.S. Army Corps of Engineers: A History*, 47.

21 John W. Larson, "Ante-bellum Channel and Harbor Improvements on the Great Lakes," *National Waterways Roundtable Papers: Proceedings on the History and Evolution of U.S. Waterways and Ports*, April 22–24, 1980, Norfolk, Virginia (Ft. Belvoir, Va.: Institute for Water Resources, 1980), 68.

22 John W. Larson, *Those Army Engineers: A History of the Chicago District, U.S. Army Corps of Engineers* (Chicago, Ill.: U.S. Army Engineer District, 1979), 25–37; Rufus Putnam, "The Port of Chicago," *The Military Engineer* (March-April 1932): 152–54.

23 Nuala Drescher and James Martin-Diaz, *Engineers for the Public Good: A History of the Buffalo District, U.S. Army Corps of Engineers* (Buffalo, N.Y.: U.S. Army Engineer District, 1982).

24 *History of Public Works*, 40.

25 Larson, 76–77.

26 Martin Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering: Politics and Technology in the Army Corps of Engineers, 1850–1950," *Technology and Culture* 26 (January 1985), 5–7.

27 Charles A. Camillo and Matthew T. Pearcy, *Upon Their Shoulders: A History of the Mississippi River Commission from its inception through the advent of the modern Mississippi River and Tributaries Project* (Vicksburg, Miss.: Mississippi River Commission, 2004), 17–21.

28 Senate Executive Document No. 49, 32nd Cong., 1st sess., 1952, 2; Albert E. Cowdrey, *Land's End: A History of the New Orleans District, U.S. Army Corps of Engineers, and Its Lifelong Battle with the Lower Mississippi and Other Rivers Wending Their Way to the Sea*, (New Orleans: U.S. Army Engineer District, 1977), 10; House Committee on Flood Control Hearings, 1922, 180.

29 Arthur D. Frank, *The Development of the Federal Program for Flood Control on the Mississippi River* (New York: AMS Press, 1930), 33; Cowdrey, 10.

30 Reuss, *Designing the Bayous: The Control of Water in the Atchafalaya Basin: 1800–1995* (Washington, D.C.: Government Printing Office, 1998), 50–52.

31 Andrew A. Humphreys and Henry L. Abbot, *Report Upon the Physics and Hydraulics of the Mississippi River* (Washington, D.C.: Government Printing Office, 1861), 153.

32 Ibid., 181, 183, 185.

33 *Congressional Record*, 43rd Cong., 1st sess., 1875, 4654.

34 Frank, *Federal Program for Flood Control*, 30; James M. McPherson, *Ordeal by Fire: The Civil War and Reconstruction* (New York: Knopf, 1982), 312; Robert W. Harrison, *Levee Districts and Levee Building in Mississippi: A Study of State and Local Efforts to Control Mississippi River Floods* (Stoneville, Miss.: Delta Council, 1951), 26–27.

35 Benjamin G. Humphreys, *Floods and Levees of the Mississippi River* (Memphis, Tenn: Mississippi River Levee Association, 1914), 22, 24.

36 *The U.S. Army Corps of Engineers: A History*, 21–27; Frank N. Schubert, *Vanguard of Expansion: Army Engineers in the Trans-Mississippi West, 1819–1879* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 1980), vii–viii.

37 William H. Goetzmann, *Army Exploration in the American West, 1803–1863* (New Haven, Conn.: Yale University Press, 1959); Garry D. Ryan, *War Department Topographical Bureau, 1831–1863: An Administrative History* (Ph.D. diss., American University, 1968).

38 Goetzmann, 380–393; Schubert, 88–90.

39 Matthew T. Pearcy, "Science, Politics, and Bureaucracy: Andrew A. Humphreys and the Office of Pacific Railroad Explorations and Surveys," *Military History of the West* 38 (2008): 84–114.

40 Schubert, 123; Pearcy, "Science, Politics, and Bureaucracy," 96–98.

41 The Daniel Ball, 77 U.S. 557 (*1870*).

42 Reuss and Walker, 8–10.

43 Reuss and Walker, 9; Reuss, *Designing the Bayous*, 45–46; Camillo and Pearcy, 17–18.

44 Reuss and Walker, 8–10.

4 LARGE-SCALE PROJECTS IN A LIBERAL ERA, 1850–1900

Eric Berkers

Half a century after the founding of the Bureau of the Waterstaat in 1798—an occasion that marked the formal centralization of Dutch water management—the actors involved were still enmeshed in a politically sensitive, subtle, and fragile constellation of regulations, competencies, and responsibilities. The nation-state, provinces, and water boards played their roles within a legal framework subject to a variety of interpretations and chronic debate. Tensions persisted between the water management ambitions of the centralized Dutch state and the deeply rooted freedom and expertise of local and regional organizations in this domain. The specific, if often tacit, knowledge of regional actors was vital in an era that lacked profound theoretical insights and, accordingly, authoritative central expertise in water management.[1] So in 1848, the Rijkswaterstaat's regionally-based organization still served primarily to offer national resistance or national legitimization (as the case might be) to what was still fundamentally a regionally dominated water policy. In practice, there were tensions between the actors, but these were muted inasmuch as the routine business of water management gave little reason to change the status quo. The limits of the legally ordained order were explored only when individual characters clashed or major external influences, such as flooding, intervened.

Yet for the chief engineers of the Rijkswaterstaat—especially those who had been educated in civil engineering at the Military Academy at Breda—this situation was far from satisfying. They were frustrated in their collective ambition by a conservative political establishment and a persistent lack of public funds that inhibited the large infrastructural and hydraulic projects that might have improved their position.[2] In the decades to come, things would change in their favor. New kinds of knowledge, technology, and materials revolutionized the theory and practice of civil engineering. Public finances received a major boost from the intensified exploitation of the Dutch colonies. On the horizon loomed new international markets that were now increasingly accessible thanks to the growing liberalization of trade. Large infrastructure projects were undertaken to reconnect the Dutch economy with this promise of commercial prosperity, a seductive course for a nation that was once the world's leading trading power. All these factors reshuffled water management relations in the Netherlands and contributed to improving the status of civil engineers in the service of the nation-state. A new era in Dutch water management was emerging by the third quarter of the nineteenth century, an era that started with a political revolution and with a new form of public decision making.

LIBERAL POLITICS, ECONOMICS, AND EDUCATION

In the first half of the nineteenth century it was not uncommon for monarchs to interfere directly with the hydraulic structure of their kingdoms. That was certainly the case with King William I of the Netherlands, whose interventions in the physical shaping of his country reflected the enlightened despotism that was fashionable at the outset of the nineteenth century. Drawing a pencil line on a map of the Netherlands, the king showed the engineers of *his* Waterstaat the shortest way from Amsterdam to the North Sea. The king viewed the line as a canal cutting straight through the dunes, which would revitalize the capital's flagging trade. Only with the greatest difficulty could the experts "erase" that line because contemporary hydraulic doctrine regarded it as dangerous.

In 1848, the Dutch Liberal politician Johan Rudolf Thorbecke and his sympathizers rearranged matters so that a royal pencil line on a map would never again have the same impact. The last big hydraulic project that had been framed under the old political regime was then nearing completion. In 1848 the first of three gigantic steam pumping stations started to drain the largest lake in the Netherlands. King William I, who had impressed his will on the plans to drain the Haarlem Lake, would not live to see the outcome of this *tour de force* of nineteenth century hydraulic engineering. He died in 1843. His grandson, William III, inspected the drained lands as constitutional monarch in 1852. He was joined by Thorbecke, who, as minister of internal affairs, was responsible for both the Water-

Rijksmuseum, Amsterdam

Johan Rudolf Thorbecke (1798–1872), liberal leader and main author of the 1848 liberal constitution

staat and, as the first premier under the new constitution, for the king.

The coup carried out by Thorbecke and his liberal political friends was nonviolent, but nonetheless revolutionary. It had appeared possible for a small band of liberals, supported by an international revolutionary movement and an economic crisis, to seize state power.[3] United in their criticism of the rule of King William I, they recreated the constitutional framework, reorganized public finances, changed fiscal and trade politics, deregulated economic life, and increased public investments in infrastructure. All this took place in the space of three decades between 1840 and 1870, with 1848 as the watershed year when ratification of a new constitution definitively blocked the way back.[4]

The new constitution circumscribed the powers of the head of state (the monarch) and introduced ministerial responsibility. It signified a new reality for the Waterstaat as well. Now the minister would have to justify his hydraulic policies in Parliament, which meant greater influence for civil servants (that is, the Waterstaat) in the framing of those policies. A group of young, ambitious, and militarily educated engineers, led by Leopold van der Kun, seized this opportunity to get chronic hydraulic problems and long-cherished plans placed high on the political agenda. As one of these engineers expressed it in 1849: The "new political life," the "simplified state administration" made it "a felicitous moment to mobilize everything that can serve to animate the prosperity of the Nation."[5]

Suddenly all seemed possible, and much was certainly required, because many regarded the Netherlands as having entered a state of serious decline. The Belgian secession had been a blow to morale and the policies of the "Merchant King" (William I) had all but bankrupted the treasury. Moreover, the 1851 World Exhibition in London had ranked the nations on a "progress-scale" and the once-so-illustrious Netherlands had come out second rate. Plans were needed, along with the necessary financing. In the coming decades, neither would be in short supply. In the years around 1850 the new élan stimulated a flurry of ambitious, utopian, and sometimes grandiose ideas, elaborated in brochures, discussed at meetings, and debated in Parliament.

A basic legitimation for many of the hydraulic and infrastructure plans was the gradual liberalization of world trade. Around the middle of the nineteenth century, the economic theory and ideology of liberal "free trade" was gaining the upper hand over economic theories and economies based on protectionism. In 1849, for example, the English liberalized their shipping laws and from 1845 on the Dutch, too, reduced their trade tariffs step by step—with as high points the Van Bosse shipping law of 1862 and the general tariff revisions of 1877.[6] But the fiscal-economic modernization could benefit trade and industry only if that modernization was coupled with the modernization of infrastructure. Engineers, too, would have to make their contribution to Dutch welfare. "All the important sea harbors, except those of the Dutch, reach with iron arms into the furthest hinterlands.... Our harbors, rivers, canals and railways ... their improvement and expansion, is the goal for which we should strive."[7]

Not only trade, but also the education of the engineers and supervisors of the Waterstaat underwent a process of liberalization in the third quarter of the nineteenth century. As discussed in Chapter Two, Dutch Waterstaat engineers of the early nineteenth century had had a practical background and, later on, a military tradition. This would gradually change. A turning point was 1842, when the national program of studies in civil engineering was moved from the Royal Military Academy in Breda to the civilian Royal Academy in Delft. King William II (who reigned from 1840 until his death in 1849) wanted to educate civil engineers for broader purposes, including water management, industry, and trade. At first, stiff admissions requirements, a strict curriculum, and intensive surveillance of students continued to characterize the program of studies: "visions of increased freedom had not yet emerged; the number of students was still relatively small," as a commentator on the first years of the Royal Academy would put it in 1862.[8] The former aspect, especially, was soon to change.

When, after a period of relative leniency in the 1850s, a stricter regime was re-imposed at the Royal Academy, a veritable uprising took place among the students who had in the meantime organized themselves in a student corporation (in imitation of university traditions) with the support of several staff members. A large majority of the students, touched by the liberal spirit of the times, refused to sign the stricter statutes, which prompted the minister to close the academy at the end of 1861. The rebellious engineers-in-training won. Not only was the implementation of the new statutes cancelled, but the Law on Secondary Education of 1863, one of the jewels in the crown of political liberalism, now mandated the founding of a Polytechnical School, offering three years of education to would-be industrialists and technologists and four years to future civil engineers and architects.[9] The same law, moreover, created the Higher Burgher School. This school type, which offered secondary education to a somewhat larger portion of the population, granted admission to the Polytechnical School. While this enlarged the pool from which future Waterstaat engineers could be recruited, it also provided a preparatory school for the growing number of supervisors and higher Waterstaat personnel below the rank of engineer.[10] In the subsequent decades the role and status of technology and engineers in Dutch society would change to such a degree that increasingly vehement arguments were put forth, especially by engineers and their associations, to grant the Polytechnical School full academic rights, on a par with the traditional universities.

For an expanding group of laborers and lower Waterstaat personnel, the trade schools, which began to multiply after 1860, provided a new option for gaining knowledge. In this way, during the third quarter of the nineteenth century, the knowledge base in the domain of water management was expanded: from top to bottom; from engineers, supervisors and clerks to laborers. This also had consequences for employment requirements and career opportunities. New technologies and materials made demands on the knowledge

Delft University of Technology

Classroom for technical design classes in the Delft Polytechnical School, 1895 of "higher" and "lower" personnel. Under the liberal regime the acquisition of knowledge was adapted to modern times. All who wished to advance in an organization like the Rijkswaterstaat had to make use of the expanded educational opportunities. The national Waterstaat agency recruited its personnel via competitive examinations for which, to the disappointment of some, theoretical knowledge was steadily growing more important relative to practical knowledge.[11]

For the engineers, the developments of the 1850s and the Education Law of 1863 meant that they were no longer being educated within the hierarchical structures and mentalities in which their nineteenth century predecessors had been confined. In the ambitious liberal state—which had turned its economic gaze outward, taken up the challenge of social revitalization and was forming a class of self-conscious citizens—the Waterstaat engineer traded in his "gold braids and sword tassel" for a more civilian outfit. From then on he could only legitimate his authority on the basis of the knowledge and skills he had gained through education and experience. His hierarchical position in the state apparatus no longer counted for much. In line with this shift, the Royal Institute of Engineers, founded in 1847, provided a new opportunity for the exchange of knowledge. The institute developed into an important forum in which domestic developments in water management were discussed, foreign developments were followed, and the activities of engineers were legitimized within the profession itself. The *Transactions of the KIvI (Verhandelingen van het KIvI)* and the journal *De Ingenieur*, published since 1886 by the Association of Civil Engineers (*Vereeniging van Burgerlijke Engineers*), became important sources of knowledge for the new generations of engineers.[12] The two journals were merged in 1900. But the crowning glory of "the new engineer"—full academic status—would not be attained in the nineteenth century.

RAILS, RESOURCES, AND A NATION REBORN

Liberal spirit and ambition were in plentiful supply around 1850, but the necessary financial arrangements were absent because the treasury was empty. These circumstances contributed to the attractiveness of leaving the construction of a railway network to private initiative. However, despite the success of the country's first railway line, opened in 1839 between Amsterdam and Haarlem, the length of track added in the twenty years that followed was disappointing. For a long time it had appeared likely that private investors could furnish the country with a railway network; until 1860, investors had filed nearly one hundred requests for concessions to build and exploit railway lines. Concessions were actually granted for more than 1,250 kilometers of track, a figure that corresponded with the track length that had already been realized in Belgium—a country which in this respect many regarded with envy. For a number of reasons, however, it had proved difficult to actually realize the concessions. In many cases, the concession-holders were unable to get their projects financed or they felt the government's demands to be too exacting. By the 1850s, the "railroad question" had become a major issue in Dutch politics. National and regional politicians as well as Rijkswaterstaat engineers entered the fray. The debate reached its peak in 1860 when Parliament scuttled the government's plans for a new concession system. The liberal cabinet fell and a few months later the new conservative government passed a law stipulating that the state would take responsibility for the construction of a national railway network. The Service for State Railways was wrested from the Rijkswaterstaat and assigned the task.

The lengthy political infighting about the degree of involvement of the state in railway construction had not prevented the Rijkswaterstaat from studying a number of technical questions connected with the building of a railway network. In particular, the neces-

Railway Network Development, 1839–1890

Green lines built prior to 1875; red lines built in the period 1875–1890

Walburg Pers, Zutphen

Stichting Historie der Techniek, Eindhoven

The construction of a railroad bridge near Weesp, 1889

sary bridging of the large rivers promised to make a number of north-south lines into a technically problematic and expensive undertaking.

Budgets for water management and infrastructure skyrocketed. These allocations made up an increasing part of the national budget, not only in an absolute sense, but also proportionally. While water management and infrastructure accounted for some 4 to 5 percent of the national budget in 1850, that figure had risen to 15 percent by 1860. From then until the mid-1880s, almost 20 percent of the annual budget would be spent on water management and infrastructure. After that the percentage gradually declined to under 5 percent just before World War I. The large increase in the early 1860s was mainly due to railway construction—but not exclusively, because water management also demanded more resources.[13]

In view of the Rijkswaterstaat's increasing share of the budget, it is not surprising that in 1861 a prominent liberal member of Parliament pleaded for the creation of a separate Ministry of Water Management (Waterstaat). How could it be that a man-made nation that had to be maintained artificially, did not have its own Minister of Waterstaat, but had subsumed the domain under Internal Affairs? In such a situation, Van der Kun, a leading official in the ministry with water management as his responsibility, could have more power and authority than many of his colleagues. A valued engineer, he was chief inspector with sole authority over the Rijkswaterstaat as well as being a member of the important Railway Commission. When he died on January 26, 1864, some mourned what they considered to have been the first modern Dutch Minister of Water Management.

Van der Kun's fifteen years as a leading Waterstaat engineer and top official mark a turning point in Dutch water management. Two formidable challenges that had dominated water management policy for decades were decisively tackled in this period. Engineers planned and built a national railway network and steam-powered dredges finally began to make headway against the centuries-old problem of the rivers. Moreover, in the wake of tedious and difficult political debate, a law was passed which, by means of the construction of two new seaways, aimed to restore the cities of Amsterdam and Rotterdam to their places on the world map. Finally, plans were made that would undoubtedly amaze the world with Dutch derring-do and engineering savvy. The Zuiderzee, which penetrated deep into the country and was responsible for some 300 kilometers of coastline, might be closed off and partly reclaimed. This was certainly not a poor showing for an elite corps of engineers that, just prior to Van der Kun's appointment, had been taken to task for its lack of knowledge, skill, and ambition. Apparently in the intervening years much had changed. The Netherlands had been born anew, as a prominent Rijkswaterstaat engineer had expressed it in 1849, and this rebirth had great implications for water management.

L. J. A. van der Kun (1801–1864)

RKD, The Hague

RESHAPING THE RIVER DELTA

The complex hydraulic situation in the river delta was the main topic in national water management debates in the mid-nineteenth century. The rivers were problematic as shipping lanes because of the shifting currents and sand banks. This problem had an international component, as the Dutch were bound by international treaties meant to allow unhampered navigation on the Rhine. Furthermore, the large rivers discharge of water, ice and sediment periodically caused severe problems for a large geographic area. In January 1850, the leading civil engineers, Van der Kun and his colleague J. H. Ferrand, presented a comprehensive river plan whose basic concept was as simple as it was ambitious; it also promised to be very costly and have a great impact on the organization of the Rijkswaterstaat. By subjecting the large rivers to a strict regime that was to be dictated by engineers (see Table 1) the navigability of the rivers could be improved and periodic floods, a scourge that severe winters invariably brought to the riparian population, could be minimized. With this plan, embraced by Parliament, an era ended in which floodways (temporary channels through which excess river water could flow in times of high water) were the engineers' main answer to the flooding problem. The idea of normalizing the rivers was championed by the new generation of progressive civil engineers. In the words of Van Heezik:

> *The unpredictable, natural ("abnormal") had to be transformed into a predictable, manipulated or—as Van der Kun and Ferrand expressed it—"more normal" river. In this way the rivers could be made completely subservient to the stimulation of general welfare and progress so ardently desired by the new generation of Rijkswaterstaat engineers.*[14]

Although the new river plan—in which flood control was replaced by river control—was simple and lucid on paper, its technical realization was hindered by severe obstacles. Although much research had been done in previous decades, the 1850 plan in fact contained no new insights on how normalization could be carried out in practice. Specific knowledge, the necessary technical equipment, and the requisite funding, were utterly lacking.

The normalization of the large rivers was legitimized chiefly by the increasing significance of the main Dutch rivers as transport arteries for expanding German industries. Since the 1820s some German states and the German tariff union (*Zollverein*) had insisted on unhampered and tariff-free access to the sea. The accession of liberals to power in the Netherlands meant a change of policy in this respect and the chance to negotiate a new trade and shipping treaty with their eastern neighbors. The German desire for increased liberalization of navigation was largely satisfied. In addition to eliminating tariffs on through-commodities, the Dutch also committed themselves to improving the navigability of the rivers.[15]

Projects to improve the rivers were commenced as early as 1850, albeit on a modest scale. An important element in the overall strategy was the creation of a new mouth for the Merwede River. This necessitated narrowing the existing Merwede, and by connecting and deepening a number of tidal creeks laying end to end, thereby created a new Merwede. The idea was that the desired depth would be attained largely through natural scouring by the new river's current. However, this assumption proved to be mistaken. The river bottom containing clay and peat layers turned out to be too hard for nature to accomplish the task. Steam-powered dredges might have been able to solve the problem, but the engineers were divided in their opinions. The dredges were extremely expensive, and some of the engineers refused to abandon their faith in natural scouring.

Table 1. Normal Widths of the Dutch Main Rivers at Mid-Summer Levels, according to Inspectors Ferrand and Van der Kun (1850).

River Section	Width in meters
Undivided Upper-Rhine	400 to 450
River *Waal* -Upper part -Lower part	 360 600
Undivided *Merwede* up to *de Oude Wiel*	600
Old *Merwede*	300
New *Merwede* (eventually)	later to decide
Hollandse Maas from Rotterdam up to the Old *Maas*	280
Hollandse Maas from the Old *Maas* up to the *Voornse Kanaal*	320
Undivided Nether-Rhine	170
Nether-Rhine down the *IJsselmond* as well as the river *Lek* up to Wijk bij Duurstede	150
River *Lek* from Wijk bij Duurstede up to Vianen	170
River *Lek* up to Krimpen	200
Upper-*IJssel*	100
Lower-*IJssel*	170
Upper-Meuse up to Maastricht	100
Meuse from Maastricht up to Mook	100 to 120
Meuse from Mook up to Grave	120 to 200
Meuse from Grave up to Loevestein	200

Source: A. van Heezik, *Strijd om de Rivieren*, 93.

The proponents of dredging received unexpected support in 1861. At the outset of that year it became painfully clear that the works had to be undertaken with more dispatch and that halfway measures—for example

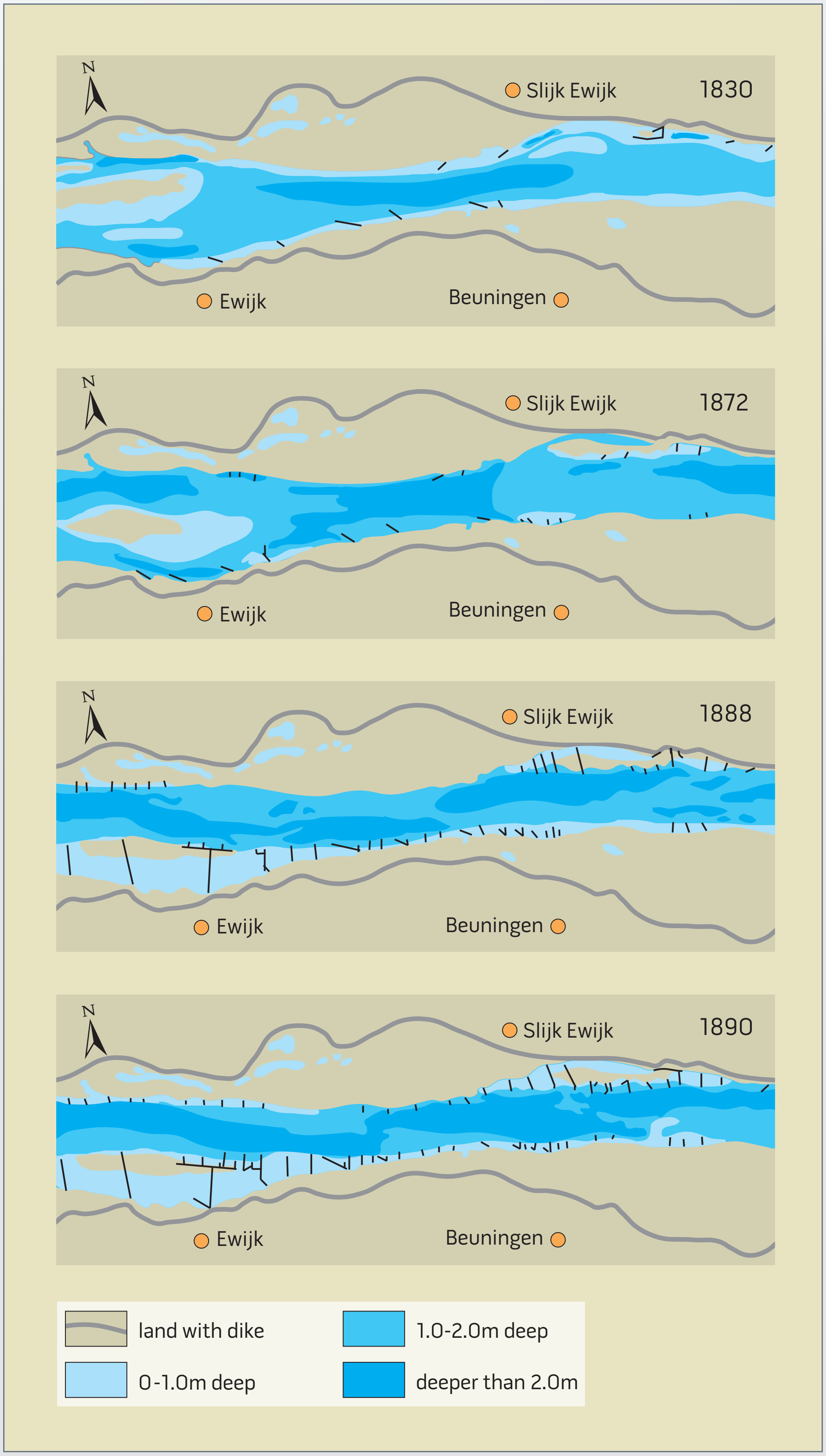
Atlas van Stolk

Prior to the 1861 flood, an 1855 river flood caused much damage. King William III visits victims of a Waal dike breach near Brakel

in separating the rivers Waal and Meuse in the second half of the 1850s—were inadequate. At the beginning of September 1861, thirty-seven people died as a result of dike breaches along the Waal. The Rijkswaterstaat leadership seized upon the catastrophe to convince the government to pursue the river improvements more forcefully. As Van der Kun and his colleagues H. F. Fijnje and F. W. Conrad wrote the minister: "Might the financial condition of the state in 1850 have compelled working on the river improvements with great restraint, this reason currently exists in lesser measure, now the sources of the treasury flow so much more copiously than before."[16]

While the Rijkswaterstaat leadership agitated for the intensification of river improvement works, there were others, especially the officers of local water boards, who held the opinion that the flood catastrophe had been caused precisely by all the man-made modifications to the rivers.[17] It was characteristic of the cultural transformation that had taken place over the past decade that Van der Kun and his associates carried the day in this debate. The river improvements were set forth with renewed vigor, and it was decided to purchase steam dredges. This represented a significant break with the tradition: for ages contractors carried out the public works under the supervision of the public authorities. Until 1878 there were six state-owned steam dredges operating on the New Merwede. After this, the permanent dredging operations were taken over by private contractors.

In the meantime, Prussia kept a sharp eye on Dutch progress in improving the Rhine and its tributaries. In 1861 an international committee of inspection, organized by the Central Rhine Commission, concluded that to that point the Dutch normalization works had resulted in few improvements in the navigability of the main rivers. In that year it was agreed that from Cologne to the sea the Rhine shipping channel should be maintained at a draft of three meters at average low water. The consensus was that to achieve this the Waal, in particular, would have to be improved. Even after the signing of a new treaty among the Rhine riparian states, the Act of Mannheim (1868),



Matrijs, Utrecht

Waal River Channel

Images of normalization works in the Waal, 1830-1890. The creation of a single channel is aided by building groynes

Prussia continued to put pressure on the Netherlands to pursue the improvement works more vigorously. In 1874 a new international inspection committee was again far from positive about the now partly normalized Waal. Shoaling in part of the navigational channel near Rossum in the spring of 1876 drew sharp Prussian criticism. The sandbank was removed. A year later disaster struck again, this time near Brakel and Heerewaarden, with an enormous traffic jam on the river as a consequence. More forceful measures were demanded and forthcoming.

When in 1885 a fourth international inspection committee steamed down the Rhine to ascertain its navigability, it mixed its praise over what had been accomplished with the usual criticisms. The Waal had to be made deeper to sufficiently meet Prussian demands in earlier "agreements" and treaties. After new investigations and negotiations, it was legally stipulated that the Waal would be maintained at a depth of 2.70 meters along its entire length, a figure that could later be increased to 3 meters if possible. Finally, in 1898, the committee of inspection seemed satisfied. Along the entire river they were able to measure a channel depth of at least 3 meters.[18]

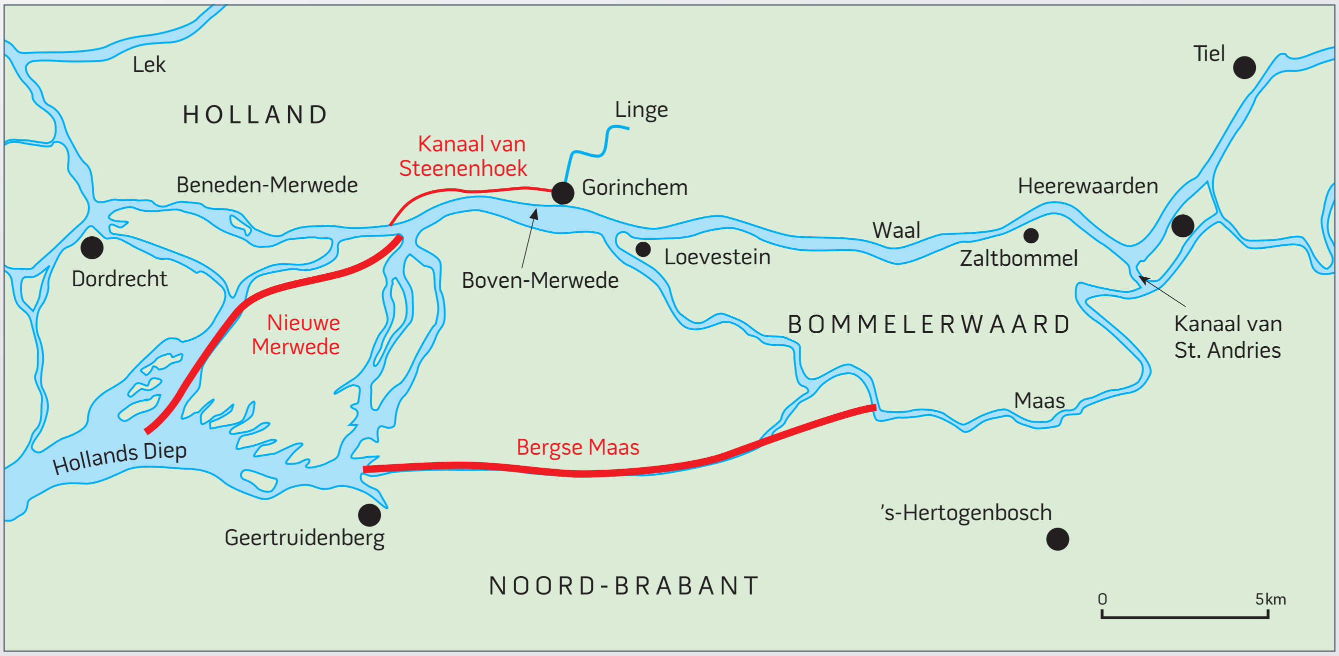
While the principle of the normalization of the rivers was not fundamentally challenged in the second half of the nineteenth century, there were serious debates about how it should be done. Between 1850 and 1870 more than one-fourth of all the articles in the *Verhandeling van het KIvI (Transactions of the Royal Society of Engineers)*, the most important engineering journal in the Netherlands, were about rivers. By comparison, railways only accounted for about 10 percent in the same period. Dutch engineers invested much energy in acquiring knowledge about river improvement. French and German sources were studied and much trial and error experimentation took place, the results of which were duly reported. One of the main issues in the field was the question of natural scouring versus dredging. It was an issue with the New Merwede, and it was even more of an issue in the river improvement project, Rotterdam's "New Waterway" to the sea, which will be discussed further. Oddly enough the most prestigious part of the reconstruction of the river delta in the second half of the nineteenth century was not related to the Rhine and its tributaries but to the second large international river that emptied into the North Sea via the Netherlands—the Meuse.

MOVING THE MOUTH OF THE MEUSE RIVER

At the end of the nineteenth century—after the New Merwede and the Rotterdam New Waterway, the Dutch delta stood to gain another new component. In 1883 it was ordained by law that the Meuse River would be given a new mouth. Like most costly and radical water management projects, this decision had a long history. As early as 1823 the eminent hydraulic engineer Kraijenhoff had argued for separating the Meuse from the Waal.[19] The two rivers were connected by the Canal of St. Andries and at Woudrichem, while at other points they approached each other very closely, which caused severe problems at times of high water or ice drift, especially when floodways were active. Management of the water flows to abet safety and navigability in both rivers would become much easier if a strict separation could be achieved. Because of a shortage of funds, Van der Kun and Ferrand had limited their 1848 plan to closing the Canal of St. Andries, which was accomplished in 1856. Furthermore, the Heerewaardense Dike was built between 1856 and 1859. As a result, the summertime stages of the Meuse decreased. The floods of 1860–61, however, demonstrated that the safety of riparian populations could not be guaranteed by these actions. This occasioned proposals for more rigorous measures, including steam-powered dredging. The Rijkswaterstaat advised reopening the Old Meuse. The terrain was surveyed anew and new cost estimates were made. These efforts led to a new plan by Rijkswaterstaat engineer Leemans that greatly resembled Kraijenhoff's plan

Two New River Mouths

The New Merwede (constructed 1850–1885) and the Bergse Meuse (1885–1904)



Matrijs, Utrecht

of 1823, except that now the New Meuse was projected north of the town of Heusden. It was also kept narrow so that tidal influences would be as weak as possible above Keizersveer. Two drainage canals were planned on either side of the river.[20] The plan was not approved. The wariness was understandable considering the costs, the large projects already under construction, and the fact that the new river mouth had serious hydraulic and infrastructural implications for a considerable portion of the well-populated lands through which the new river would flow.

But the riparian populations were still burdened with the threat presented by the rivers. Catastrophes continued to act as catalysts for action. In March 1876, the Meuse dikes were breached at nineteen places. The entire region east of Den Bosch and south of the road between Grave and Den Bosch (with the exception of Berlicum) was flooded. The Rijkswaterstaat was asked to take another look at Leemans' plans. Later, one of the engineers involved would complain: "Those were days in which the Rijkswaterstaat was put to work everywhere making plans, somewhat in the manner of giving children tasks in order to keep them busy...."[21]

In the summer of 1878, Hendrik Rose, head of the River Department (established in 1875 as part of the Rijkswaterstaat to bring more coherence to Dutch river management), was able to submit the new design to the minister. Contrary to Leemans' plan, it now proposed to promote tidal effects as high up the river as possible. The proposal called for a wide and deep, funnel-shaped mouth. In effect, the proposal was not to bring the Meuse down to the Amer, but to lengthen the Amer upstream to connect it with the Meuse. This plan also entailed the normalization of the Amer. The costs were estimated at 14.5 million guilders.[22] This proposal followed the other plans into the drawer, being considered too expensive.

By the end of the 1870s, the hydraulic situation in northeast Brabant was worse than ever. Although the population was used to floods in winter, now it seemed

Table 2. Several 19th Century Plans for a New Mouth for the River Meuse

Year	Designer	Width (in meters) of the new river at the location: Heleind	Keizersveer	Costs
1823	Kraijenhoff	145	165	unknown
1861	Van der Kun/ Conrad/ Fijnje	145	165	4 million guilders
1865	Leemans	100	150	6.5 million guilders
1878	Rose	167	300	14.5 million guilders
1879	Van der Toorn	150	170	11.7 million guilders

Source: Bongaerts, *Scheiding van Maas en Waal*, passim; *Handelingen der S.-G.* (1881/82), T.K., 1137.

they would have to fear problems in the summer as well. Drainage water from reclamations in the Belgian Kempen and in southeast North Brabant now flowed unimpeded via the Dommel, the Aa, the Dieze, and the South-Williams Canal into the Meuse. This meant that now in late spring high river stages on the Meuse could lead to flooding. In May 1878, 26,000 hectares of land were under water. This situation led parliamentarian Van der Schrieck to conclude that "there is certainly no situation in The Netherlands that is so in need of immediate measures as that of the northeastern part of North Brabant."[23]

In "immediate need" or not, a new catastrophe was necessary to galvanize decision making. In January 1880 the dike at Driehuizen was breached, and as a result most of northeast North Brabant was flooded. Within the month the minister informed the Estates of North Brabant that he intended to take on the separation of the Meuse and Waal rivers, along with the ancillary works. He asked the province for the necessary cooperation and financial support. A new water board was founded and the Rijkswaterstaat set about making a plan. The width of the new river at Keizersveer was set at 250 meters at a minimum. Partly in response to this report, the provincial estates of North Brabant, in their summer meeting of July 15, 1880, voted to subsidize the project to the tune of 1 million guilders.[24] But while the project now seemed to have gained momentum, the sufferings of the riparian communities in the region continued unabated. In December 1880, the dike near Nieuwkuijk gave way, causing the submergence of the Land of Heusden en Altena. In addition, the right mainline levee also succumbed to a big ice-dam, as a result of which the Bommelerwaard flooded.[25]

In April 1881, the new water board promised to furnish two million guilders. The financial commitments of the province and the water board enabled the minister to submit a bill to Parliament in May of that year. Parliamentary deliberations took place the following November. Just at that moment the Upper Rhine in the Netherlands reached the highest stage yet recorded in the nineteenth century.[26]

The decision-making process regarding the new mouth for the Meuse reveals the complexity surrounding interventions in the hydraulic situation in a specific region. In the first place, it was essential to determine whether this was a national problem (part of a national plan to improve the rivers) or a regional problem (improving a provincial hydraulic structure). The answer was consequential for the financing of and the responsibility for the project. By asking for significant financial contributions from the provincial government and the water boards, the national government was making it clear that it regarded the relocation of the mouth of the Meuse as serving important regional interests. Catholic members of Parliament did not fail to point out the disadvantaged position of their fellow believers (largely resident in the southern provinces, like North Brabant) in comparison with Protestant Holland. They argued that the government reserved large sums of money for the hydraulic improvement of the western and northern Netherlands, while leaving the Catholic south to its own devices.[27] Hence, the Rijkswaterstaat, too, experienced the consequences of the emancipation of the Dutch Catholics. But in fact the contradiction between the northwest, low-lying and Protestant Netherlands versus the southeast, higher, and Catholic Netherlands had eaten away at the foundations of the national Waterstaat agency since its founding. As a minister in 1799 complained, speaking of the Waterstaat: "I would wish that for one time there would be a large project on the side of Gelderland or another department than the center; that would let the gentlemen from those quarters see that we do not want to do everything for Holland as they wrongly perceive, but in fact have nothing but the general welfare at heart."[28] More than eighty years later an important part of the Catholic Netherlands still expressed skepticism about the Rijkswaterstaat's conception of the "general welfare."

Aside from this national contradiction, which was by no means limited to the sphere of water management, it was also prudent with respect to large water management projects to take different regional interests into account. For example, landowners in northeast Brabant made demands related to the relocation of the mouth of the Meuse other than those of their fellows in the northwestern part of the province. The separation of the Meuse and Waal implied higher average stages in the Amer, which could lead to drainage problems in

Rijkswaterstaat

Constructing the new Meuse mouth involved many additional works, like a culvert for a drainage canal, 1898

Stichting Historie der Techniek, Eindhoven

Bucket dredges were used during the construction of the new Meuse mouth, 1904

its catchment. Drainage was the responsibility of water boards which, understandably, demanded compensatory measures from the government. Interventions in one place invariably demanded adjustments elsewhere.

In addition to these conflicts of interest, complex technical-logistical questions caused the engineers involved and those bearing the political responsibility serious headaches. Knowledge did not suffice to settle disputes about optimal widths and the influence of tides and meanders on riverine behavior.[29] The largely regionally organized Rijkswaterstaat set up a separate project bureau for the new Meuse-mouth, as it had done for the New Waterway. The final large river improvement project of the nineteenth century could profit from the rapid growth in fixed capital and expertise of the Dutch hydraulic contractors. Thanks to the many large projects, the contractors had been able to invest in new machines and material. Consequently, more than 90 percent of the digging of the almost twenty-five kilometer-long Bergse Meuse between 1887 and 1894 was done by excavating machines. Heavy machinery was also employed for transporting earth, including small-gauge railway dump-cars and pipelines with sand pumps.[30]

After the excavation of the Bergse Meuse, the Amer had to be normalized and various hydraulic and infrastructure adaptations in Brabant had to be realized. Finally in 1904, the Meuse was closed off near Andel and the new river mouth near Heusden could be opened. Not only did the Meuse thus gain a new mouth, but the overall project of improving the Dutch rivers had come to an end.

MAKE WAY FOR THE HARBORS OF ROTTERDAM AND AMSTERDAM

While Rotterdam was the most important Rhine and sea harbor in the Netherlands in the mid-nineteenth century—a status largely resulting from the decline of Amsterdam's harbor—her international position was shaky at best.[31]

Rotterdam's most important seaway, the Voornsche Canal, was undersized for the rapidly growing ocean ships. Moreover, shoaling before the entrance to the canal was eroding Rotterdam's position in the emergent transatlantic steamship trade. Various plans had been advanced since the 1830s to improve the situation. One idea was to improve the New Maas. In order to assess this plan's merits, Van der Kun decided to send the young Rijkswaterstaat engineer Pieter Caland to England and France in the summer of 1856 to study projects to improve the estuaries of the Clyde, the Seine, and the Rhone. These foreign projects made Caland enthusiastic about building jetties into the sea that would concentrate the river's current and induce natural scouring.[32] After Caland's first plan for an improved entrance to the harbor of Rotterdam had been criticized by a specially appointed Council for Water Management, he submitted a second plan in January 1858. He proposed digging through Hoek van Holland so that the Scheur would no longer flow into the estuary of the Maas, but straight into the North Sea. The new river mouth with jetties reaching into the sea would keep itself at the required draft by means of tidal currents, that is, via natural scouring. Later this would be referred to as a "homeopathic" solution.[33] The Council for Waterstaat responded positively to this plan and recommended it with minor modifications to the minister on August 21, 1858.[34]

Around the same time another decision had to be made. Private interests had put forth plans for a canal from Amsterdam through "Holland at its narrowest" to the North Sea, along the lines of the pencil stroke once drawn on the map by King William I. More and more sea ships were having trouble entering not only Rotterdam's harbor, but Amsterdam's as well. The Great North Holland Canal, dating from 1824, not only entailed a detour to Amsterdam of several tens of kilometers, but was also becoming obsolete because of its limited width. After 1848, successive governments were bombarded with plans to put a halt to the economic decline of the capital by constructing a shorter and wider waterway to the North Sea. The most utopian of these—in its way characteristic of the new élan that had infused the Netherlands in 1848—was a plan of that same year by mechanical engineer and inventor P. Faddegon and soap manufacturer J. Kloppenburg. They proposed reclaiming both the Zuiderzee and the IJssel and digging new canals from the IJssel near Arnhem past Amsterdam to the North Sea. This was all to the greater glory of Dutch trade, shipping, and agriculture.[35] This plan got little attention, but the government was getting pressure from Amsterdam's municipal government and Chamber of Commerce. It also had to take account of other interests, such as the industries in the Zaan region and the Ministry of Defense. Therefore, it had to consider new ideas and determine the conditions under which a concession might be granted.

In the summer of 1858, the cabinet asked the Council for Waterstaat for advice on a plan put forth by private parties for the construction of a canal through "Holland at its narrowest." The council, composed exclusively of Rijkswaterstaat engineers, was of the opinion that it would be more prudent with such large and risky projects—in this case the natural coastal defenses in the form of the dunes would be violated—to have the state carry out the projects, rather than a private company.[36] The council also offered its advice on a number of technical questions relating to the design and the execution of such a canal. Using this modified plan as a point of departure, the government decided not to grant a concession to private parties but to submit a bill to Parliament (at the end of 1859) whereby the state would take responsibility for digging a canal "through Holland at its narrowest." Not long after, though, the government collapsed in connection with the railway dispute and the bill for the North Sea Canal was put on hold. The new government finally decided to withdraw it because of the high costs and risks it entailed.

The New Waterway, connecting Rotterdam with the North Sea, 1874

In the meantime, Rotterdam entrepreneurs had expressed their concern to the government about its failure to decide on a scheme for the improvement of access to their harbor. In the harbor city itself, Caland's proposal to cut through the Hoek of Holland had met with a very favorable reception. In 1861, when state execution of the plan seemed unlikely, a number of city councilors requested permission to realize Caland's plan themselves. The project could be profitable inasmuch as the councilors were planning to levy tolls on passing ships.

In the summer of 1862, Thorbecke, who had once again become minister, submitted a bill whereby the digging of a canal through Holland at its narrowest (Amsterdam) would be accomplished by a concession to private investors and the New Waterway by agency of the state. Political decision making on the proposal was difficult and tedious. Minister of Finance Gerardus Henri Betz, who had roots in Rotterdam and was co-signer of the bill, vigorously defended it by pointing out that the Dutch railway network, then energetically being constructed by the state, needed the harbors. He compared the Netherlands to "a funnel, through which world trade can be joined with half of Europe, with all the countries that lie behind and next to us.... The wider one makes the opening of this funnel, the more will pass through it."[37]

In December 1862, the bill was finally ratified into law by a large majority. Unlike Amsterdam, Rotterdam was not obliged to contribute to the costs; nor was shipping in Rotterdam subject to canal duties or hindered by locks. Rotterdam celebrated the new law with a festive display of lights on the occasion of the birthday of William III on February 19, 1863.[38] Caland was assigned direct responsibility for the works the following May. Supervision of the works was delegated to J. A. Beijerinck, then chief engineer of the Rijkswaterstaat in the district of South Holland. Problems with land acquisition would delay the actual start of the project until the end of 1866.

Everything seemed to proceed smoothly. By December 1868, the 4.5 kilometer-long canal between the Scheur and the low-tide line had been completed. It had a depth of two meters below average low water and a width at the bottom of ten meters. The idea was that the channel through the beach would be scoured out by the natural current. Only occasionally would a steam dredge, such as used earlier on the New Merwede, have to remove sand deposited by the river. However, by 1871, it had become apparent that bothersome sandbanks had formed before the harbor entrance. Rijkswaterstaat engineers opted for lengthening the jetties, but admitted that knowledge and experience were lacking to find the optimal solution. The failure to achieve a deep entry to the harbor, the rising costs of the work, and the stubbornness of the responsible engineer, Pieter Caland, who

Joost J. Bakker, IJmuiden

refused to employ dredges or other artifices suggested by interested parties, drove many among Rotterdam's business elite to hovering between despair and outrage.[39]

By 1877 the situation had deteriorated to such an extent that not only transatlantic shipping, but even navigation between Rotterdam and England, was threatened. Reluctantly, Caland now had to accede to dredging to resolve the most pressing problems. But Parliament demanded more energetic measures. First, a law was passed enjoining the state to undertake "extremely forceful measures for artificial enlargement" of the New Waterway. After a change of cabinets, a state commission was appointed to investigate the matter in great depth. Consequently, Caland was dismissed from his post and a plan was adopted that involved great amounts of digging and dredging. The knowledge, experience, and equipment developed and used during the construction of Amsterdam's North Sea Canal could now be put to good use. By the mid-1880s the channel had acquired the requisite depth and Rotterdam could breathe a sigh of relief. By then, Amsterdam had already been reaping profits from its improved access to the sea for an entire decade.[40]

The canal through Holland at its narrowest—called by Thorbecke, at the end of 1862, "an old love, still young as on the first day"—was dug under concession from the state by the Amsterdam Canal Company.[41] This decision was partly motivated by the fact that at the time the government was overwhelmed with public works projects and the participation of private capital and labor was welcome.[42] The Canal Company appointed the Rijkswaterstaat engineer Justus Dirks to lead the project. Because of the complexity of the works and the dearth of sufficiently competent engineers in this era of hydraulic exertions, the company also hired the British contractor McCormick & Son and later also Henry Lee & Son.

Construction commenced in the early spring of 1865, initially along old-fashioned lines, employing hundreds of laborers armed with spades and wheelbarrows. At some locations modern mechanical equipment was also in evidence. Steam dredges were used to dig the channel through the Wijker Lake and the western part of the IJ. These vessels were equipped with novel centrifugal pumps and self-acting dumping arrangements. Innovations such as Freeman's suction-pressure system and Hutton's sand pump were also used. These innovations enabled the dredges to pump the excavated sand into long floating tubes with great force and subsequently, mixed with water, to dump the fluid material behind the dikes. By the time of the completion of the canal and harbor works in 1878, as many as twenty-five steam dredges had been simultaneously employed.[43]

Stadsarchief, Amsterdam

Crane constructing pier blocks at the IJmuiden harbor, the entrance of the North Sea Canal, ca.1865

The construction of the North Sea Canal facilitated a transfer of knowledge and equipment from British contractors to the Dutch. During the course of the project, Dutch contractors had taken over from their British counterparts, acquiring some of their equipment in the process. In future projects it would no longer be necessary for the Rijkswaterstaat and other parties to employ foreign contractors. Thereafter, the Dutch "wet" contracting sector developed rapidly and, thanks to the numerous contracts, exhibited considerable innovative ability. For example, the contractors responsible for digging through the dunes at Hoek of Holland, as part of the New Waterway, decided to experiment with different kinds of excavators. These experiments marked the transition in dry earth removal from manual digging to mechanized excavation.[44] Innovations in steam dredging that had reached the Dutch wet contracting sector from England via the excavation of the North Sea Canal were further developed here and applied in other projects. The 1870s were surely the *Gründerzeit* of what would later become the renowned Dutch wet contracting industry.

One of the first large hydraulic projects able to profit from the experimentation with mechanized earth moving was the Merwede Canal. Between 1886 and 1892 excavators were used for much of the necessary earth moving. The decision to build this canal, which would provide Amsterdam with an improved waterway to the Lek River and the Upper Merwede and thence to the German hinterland (via the Rhine) and Rotterdam harbor, had been taken five years earlier. The amount of time it took before the work could actually begin was due to the structure of Dutch water management, in which water boards were responsible for regional water management. In the case of the Merwede Canal, this meant that the national state had to negotiate with no fewer than forty-three water boards regarding modifications in the form of solid dikes, siphons, extra drainage systems, and various measures (such as ferries and overhauling for small vessels) to compensate for disruptions in the transportation network.

Amsterdam could only profit fully from its new North Sea Canal if the city was also provided with an improved waterway to the large rivers. The capital city itself had favored a route through the so-called Gelderse Valley to the Waal near Tiel, but this option was scrapped because of its high cost. Ultimately, it was decided to improve and normalize the Keulse Vaart (Cologne Waterway) up to the Lek at Vreeswijk and subsequently to dig a new canal from Vianen to the Merwede at Gorinchem. This Merwede Canal was an impressive hydraulic feat, which did not prevent its shortcomings from becoming apparent almost immediately. Amsterdam complained about the "detour" via Gorinchem and agitated for "a second waterway from Amsterdam to the (Dutch) Upper Rhine."[45] Moreover, the locks in the normalized Keulse Vaart soon proved to be too small, a chronic evil in a time when ships were growing at an alarming rate. The same problems occurred in the case of the North Sea Canal and its locks, where engineers were continually designing after the fact. In 1885, a mere seven years after the opening of the canal, the depth of the lock and the canal had already been increased from 5.5 to 7 meters. Only four years after that, it appeared necessary to build a newer and bigger North Sea lock. By the time

Stadsarchief, Amsterdam

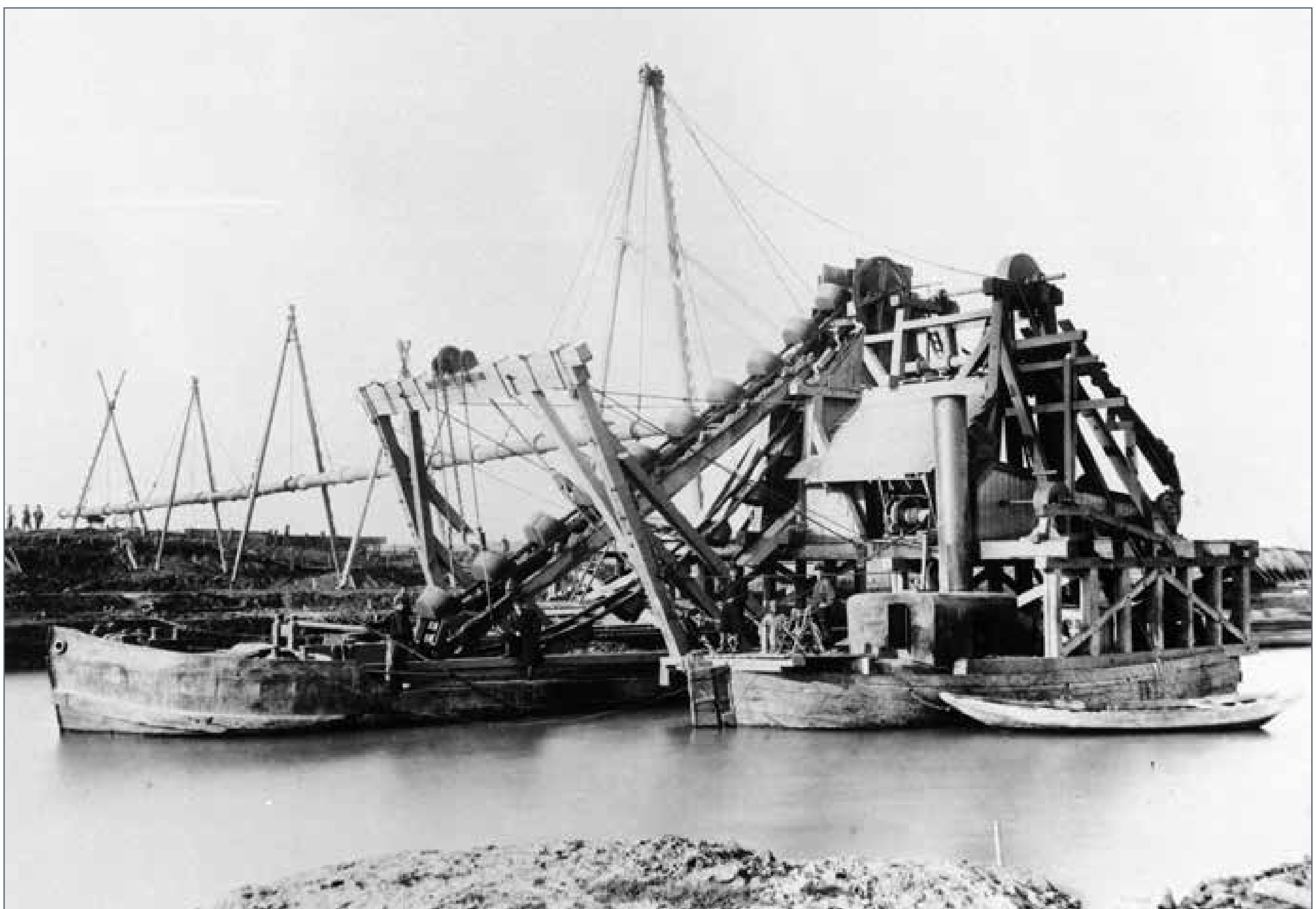
IJmuiden harbor mouth, ca. 1886

this was completed in 1896, allowing ships with a draft of 9 meters to dock at Amsterdam, the bridges spanning the canal had become a new bottleneck, as a consequence of which they had to be rebuilt, and so on.[46] Even so, the new twentieth century would see a slackening of the pace of water resources development work.

DEFINING AND CONNECTING THE PERIPHERY

At the beginning of the 1890s, many large hydraulic projects had been finished or were nearing their completion. The rivers flowed, more or less, in pre-ordained channels and had the requisite depth, the seaways to the harbors of Amsterdam and Rotterdam had been improved, and other (dry) infrastructure like the railways and the telegraph were finished. These completed projects convinced many parliamentarians that "now that a permanent decline in the budget for large hydraulic projects is coming into view, it would be desirable for the state to expend more effort on constructing roads, canals, regional railways and tramways in remote regions, which due to their isolation from the main arteries of traffic, could not without the support of the state achieve that flowering and prosperity which could be their due if they were incorporated into that general traffic."[47] It was not that nothing had been done—in the 1870s and 1880s, many existing waterways had been improved and new canals constructed with state support, primarily in the provinces of Groningen,

Wageningen University



Bucket dredge at work on the Merwede Canal, 1886

Stichting Historie der Techniek, Eindhoven

Lock construction near Amsterdam for the Merwede Canal, 1890

Friesland, Drenthe, and Overijssel. Thanks to such initiatives, these provinces had become connected to the main Dutch waterway network, and thereby also to the German waterways.[48] The northern harbors of Harlingen and Delfzijl had also been improved, but not enough to compete with Amsterdam and Rotterdam. These northern harbors also lacked the large-scale connections to the German hinterland via the Dutch and German Rhine that had been provided for the larger harbor cities. These connections gave Rotterdam and Amsterdam an additional logistical advantage over all the other peripheral harbors like Harlingen and Delfzijl which lacked this direct route to a dawning industrial empire. As Auke van der Woud puts it, the North Sea Canal and the New Waterway "defined future economic relations in the Netherlands."[49] The center and the periphery were in part explicitly, in part tacitly, redefined in the third quarter of the nineteenth century. Once the economic and hydraulic interests of the heart of the country had been secured, the focus could shift somewhat more to the periphery.

One of the hydraulic features that received more attention after 1875 were the so-called "navigable and floatable (small) rivers." In addition to the large international rivers, the Netherlands also contained numerous small streams that were nonetheless of great significance for local and regional economies. Discussions about the improvement and management of these streams had been carried on for decades. The main point of debate was who actually bore the responsibility. Earlier agreements stipulated that if the rivers were indeed navigable and "floatable," the national state would be responsible. But what if a river was navigable only part of the year? Or if only a part of the river was navigable? Because the national government was not particularly enthusiastic about assuming responsibility for a plethora of small rivers, a number of specific riverine water boards were set up in the early 1880s: the water boards of the Linge drainage (1880), of the Dortherbeek and the Schipbeek (1881), of the Berkel (1881), of the Old-IJssel (1882), and of the Regge (1884). Of the so-called "small rivers," only the Zwarte Water near Zwolle was managed by the central state.[50] The establishment of these water boards was not only the consequence of a cautious state, but also of increased concern about agriculture during the economic crisis of the 1880s. In addition, paved roads and railways were increasingly competitive with shipping on the small rivers, and improved drainage in Germany was causing higher stages and increased flooding.

Water boards were entitled to state subsidies only if the improvement of the river served the general interest. The idea of direct state management and supervision was thus abandoned. But through subsidies, the state could still maintain an interest. Even though subsidies had been promised in the early 1880s, the system hardly functioned well. The first subsidy, to the water board of the Old IJssel, was not granted until after 1890. The delaying factor was the condition that the river be maintained as a navigable waterway. The constituency

Foto Aviodrome, Lelystad

Cargo handling in the Rotterdam harbor, 1925

Atlas van Stolk

Panoramic view of the Rotterdam harbors, 1904

of the water board, mostly local farmers, rejected this condition. They reasoned that in the case of a navigable waterway the state itself should shoulder the financial burden. The same thing happened with the Berkel River. Here it was also pointed out that the state levied fishing duties on the river, and those duties disappeared into the national treasury, rather than into the coffers of the water boards or provinces.[51]

This opposition of the agrarian constituencies to the new water boards, the completion of some of the large national projects, and the relative lack of attention paid to the countryside compared to "the west," as was argued by several parliamentarians, compelled the government around 1890 to concern itself more intensively with the small rivers. The floods of 1891 also added urgency. Finally, the existing awkwardness in using subsidies as an instrument of central water management forced the minister to take action. An investigation was launched with the aim of creating more uniformity in subsidy policy. Ultimately the new criteria for extending subsidies were: the river had to be navigable and "floatable" (*vlotbaar*); the river had to serve a general interest (e.g., agrarian or shipping interests); and the river had to process large amounts of transborder runoff.

On the basis of these criteria it was now possible to extend subsidies to the water boards of the Schipbeek, the Berkel, and the Regge. An exception was made for the Overijsselse Vecht. This river served a more universal interest inasmuch as it received the waters of a number of tributaries. Because establishing an equitable division of costs for improving this river would be far from simple, it was decided in 1896 that the national state would assume the burden.[52]

Aside from the navigable and floatable rivers, the local railways and the intraregional tramways were important modes of transport in the countryside. Especially during and after the 1880s, concessions were granted for laying many hundreds of kilometers of track. The state bore responsibility for the legal and regulatory framework and granted the concessions. State subsidies were forthcoming after 1894, in the wake of pressure from Parliament.

By the end of the century, subsidies had become an instrument whereby the state could impress its will on water management and infrastructure in regions that had a "more specific interest." This was in contrast to water management and infrastructure that had a "general interest" for which the state had assumed financial responsibility.[53] A member of Parliament expressed it thusly in 1894: "What may be done for the large agglomerations of population, cannot be accomplished for every single autonomous village or isolated person, without far overreaching the powers of the state."[54] By means of subsidies, the state could invest its bounty proportionally. The periphery belonged, but it was obliged to know its place.

Rijkswaterstaat

Overijsselse Vecht normalization was carried out around 1910. A fascine mattress is being prepared.

REDEFINING POLITICAL AND JUDICIAL WATER MANAGEMENT

Despite the fact that some had been arguing for its establishment for years, for many the creation of a Ministry of Public Works, Trade and Industry (*Waterstaat, Handel en Nijverheid*) in 1877 came as a complete surprise. It seemed logical to grant sole political responsibility to a domain that was so essential for the preservation of the country and that was, moreover, closely associated with core liberal themes such as trade and industry. But the opponents of a more specialized ministry also possessed good arguments. Would not the costs of water management skyrocket even beyond the present exorbitant levels with specialized ministers who wanted to flex their muscles? Also, would a minister with a limited scope of responsibility have enough clout to offer serious resistance to the king? Thorbecke feared this would indeed be the case and therefore opposed a ministry of public works. Finally, some were doubtful of Parliament's competence to monitor a specialist minister.

These fears must have been considerably exacerbated when, only two years after the creation of a separate ministry, a civil engineer was appointed as its helmsman, not for the first time. For a period of six months—from July 1856 to January 1857—the engineer Gerrit Simons, as minister of internal affairs, bore responsibility for public works. Simons was not a civil engineer in the strict sense but a mathematician and physicist. However, he was closely related to or even part of the Waterstaat elite of his time because of his involvement in reclaiming the Haarlemmermeer. He joined several commissions at several stages of these projects. His appointment as director of the Royal Academy in 1846 made him even more a representative of Delft engineers. Furthermore, together with L. van der Kun and F. W. Conrad, he founded in 1847 the Royal Society of Engineers. However, his ministry was anything but a success. He lacked political intuition, was stubborn, and belittled Parliament. In delicate matters, such as the railway question, he had acted unconvincingly. When his budget was rejected he at last tendered his resignation.[55] Would the country witness a similar debacle when, twenty years later, another—or better—real engineer became minister?

Fortunately, this was not the case. As minister, the military engineer Willem Klerck proved himself capable of dealing with a number of knotty issues, not the least of which was the construction of the Merwede Canal and the administrative separation between the national and the provincial public works agencies. It is an expression of the increased status of civil engineers that in the last quarter of the nineteenth century they succeeded in dominating the Ministry of Public Works, Trade, and Industry. As ministers they left their mark on the ongoing modernization of the Netherlands. They set about with a will, not only with respect to the physical existence of the country, but also in societal respects. Minister Cornelis Lely, for example, who would claim a prominent role in the domain of public works at the outset of the twentieth century, twice held sway over this ministry at the end of the nineteenth century and impressed friend and foe alike with the progressive social laws he husbanded through Parliament.

SEPARATING NATIONAL FROM PROVINCIAL WATER MANAGEMENT

At the beginning of this chapter the structure and organization of Dutch water management around 1850 was characterized as a "sensitive, subtle, and fragile constellation." That certainly applied to the division of labor between the state and the provinces. Although the Constitution of 1848 certainly defined the relationships among the different levels of government, it proved very difficult in the customary practice of water management to redefine and strictly separate responsibilities. This is why the constitution stipulated that the general and particular governance arrangements for water management would be organized through additional legislation. Parliament had had little taste for this thorny issue and it would take decades before more clarity was forthcoming.

And clarity was certainly needed—for example, with respect to the position of state engineers vis-à-vis the provinces. The latter had long been able to recruit the assistance of Rijkswaterstaat engineers for tasks delegated to them by the state, which did not contribute to strict separation of responsibilities. In the position of state engineer they were charged with surveillance over the water management activities of the local and provincial governments. Hence, when performing provincial tasks they were de facto supervising themselves. A large number of Rijkswaterstaat engineers, who in any case regarded the low-prestige provincial tasks as an unappealing chore, certainly favored a stricter separation.[56] But liberal politicians, with Thorbecke in the lead, were also proponents.

The provinces were entitled to create their own public works agency—that is, a Provincial Waterstaat. However, doing so had certain consequences. More autonomy in water management cost money. A Provincial Waterstaat was more of a budgetary burden than incidental payments for Rijkswaterstaat engineers. Moreover, it would still have to be demonstrated in practice if it was really possible to separate supervision (the state) of regional public works from their execution and management (provinces and water boards). A general law on water management describing in detail which tasks were whose responsibility did not exist. Many feared that the creation of Provincial Waterstaat agencies would lead to interminable conflicts between governments and engineers in the service of those governments. Provinces which, after 1849, indicated a desire to create their own waterstaat service were refused permission by The

Hague. The usual argument was that first a general water management law would have to be enacted.

In 1862 Thorbecke, who as minister of internal affairs (for the second time) also bore responsibility for water management, informed the provinces that he was considering "separating the central and provincial services to such an extent that the functionaries of the Rijkswaterstaat would be restricted to the required supervision." He continued, "I feel it necessary to be timely in informing you of my opinion, in order to give you the opportunity, in view of my standpoint, to consider the creation of a provincial waterstaat agency."[57] For a few provinces this was a signal to set up their own waterstaat agency, but the majority would wait until 1875 to take this step, when Heemskerk, who was the responsible minister at the time, as opposed to Thorbecke a decade earlier, was willing to compensate the provinces financially. The state reclaimed responsibility for a number of infrastructure works that had been transferred to the provinces in 1819, thus eliminating an important part of the task that the state engineers had to perform for the provinces. There remained the possibility for provinces "where no separate waterstaat agency exists or will be established" to make use of the services of the chief engineers of the Rijkswaterstaat. A complete separation between the Rijkswaterstaat and the provinces was achieved in 1882 when this right was revoked and the rest of the provinces opted for the establishment of their own waterstaat agencies.

THE LONG-AWAITED WATER ADMINISTRATION ACT

The intricate negotiations with a large number of water boards about compensatory measures in relation to the building of the Merwede Canal made it abundantly clear that large water management projects of national scope had to be carried out in a scrupulous fashion and would therefore involve cumbersome procedures. No one contested the need to be scrupulous, but if this was merely used as a cover for local or regional political or even financial gain then it was undesirable for a national government which (in cooperation with lower governments) was impelled by a mission to let state and society grow.[58] It was apparent that without adequate water management legislation, cooperation and confrontation lay close together. In the 1880s, producing such legislation therefore became a priority. The important point was that the idea of defining all the political responsibilities within the framework of a single law had been abandoned. Some had argued that this unified approach was implicit in the constitution of 1848. To remove this obstacle, which had paralyzed legislation in this domain for decades, the modified constitution of 1887 explicitly stated that the administration of water management could be regulated by more than one law. A few years later Minister Lely appointed a state commission "to prepare the implementation of the instructions of the Constitution in regard to water management."[59] The work of the committee provided the point of departure for a number of important laws which, at the end of the nineteenth century, provided a new legal basis for water management in the Netherlands. The *Keurenwet* (Ordinance Law) of 1895 gave the water boards the right to pass and enforce their own ordinances, and the *Bevoegdhedenwet* (Entitlement Law) of 1902 gave them, among other things, the right to levy taxes. The *Belemmeringenwet Verordeningen* (Law on Legal Obstacles) of 1899 was intended to override legal obstacles rooted in water board charters in connection with the execution of works of national interest. But the legal apotheosis was the General Water Administration Act of 1900. In sixty-seven articles the law regulated the various entitlements of the state, the provinces, and the water boards in relation to supervision, acquisition, and management of water management works. That the commission had worked in a useful and fruitful manner can be deduced from the ease with which the legislation passed through both houses of Parliament. The law's great significance was duly touted, not only in Parliament but at great length in the newspapers as well.[60]

The practice of state supervision over the totality of Dutch water management acquired a legal basis around 1900. The provinces supervised the water boards under the minister's "high" supervision. This was no longer based on arbitrary *ad hoc* interpretations, but had been provided with a legal framework and central steering. The result was the regulation and normalization of the water boards. Reorganizations led to a reduction in the number of water boards. Between 1850 and 1900, their number dropped from about 3,500 to about 3,000. This was by no means an indication that they had become marginal actors in the overall system of water management. On the contrary, the *Keurenwet* and the *Bevoegdhedenwet* provided them in many instances with more, rather than fewer, powers.[61] Their numbers were reduced and their role changed, a process that would continue in the twentieth century.

1900: A COUNTRY IN TRANSITION

Despite the completion of the project to improve the rivers, despite the construction and modernization of the core wet and dry infrastructures, despite the connecting of the peripheries to this core, despite the implementation of the General Law on Water Management, at the turn of the twentieth century the Netherlands was not "done" with respect to either infrastructure or water management. It was discovered painfully soon with the experience of the North Sea Canal and the Merwede Canal that the ships desirous of visiting Dutch harbors were continually growing larger. The automobile had appeared, and a visionary like Cornelis Lely already suspected the enormous consequences this would have. New technologies, such as electricity, and materials, such as reinforced concrete, had already been applied in the domain of water management, but it was obvious that more extensive use would be a matter of course. Less visible to the general public was the emergence of a new, more theoretical approach in water management. In the early 1890s the engineer H. Doijer wrote the following about river management in the authoritative *Verhandelingen van het Koninklijk Instituut van Ingenieurs:*

> *A river can be considered as the path of a moving body, the water. Is that path curved, then in addition to a force impinging along the tangent and having its origin in the slope of the river bed, hence in gravity, there is also a second force operative, in the direction of the normal to the tangent… the centrifugal force.… The goal can be approached by making specifications for the shores to which the path of each drop of water should actually conform.*[62]

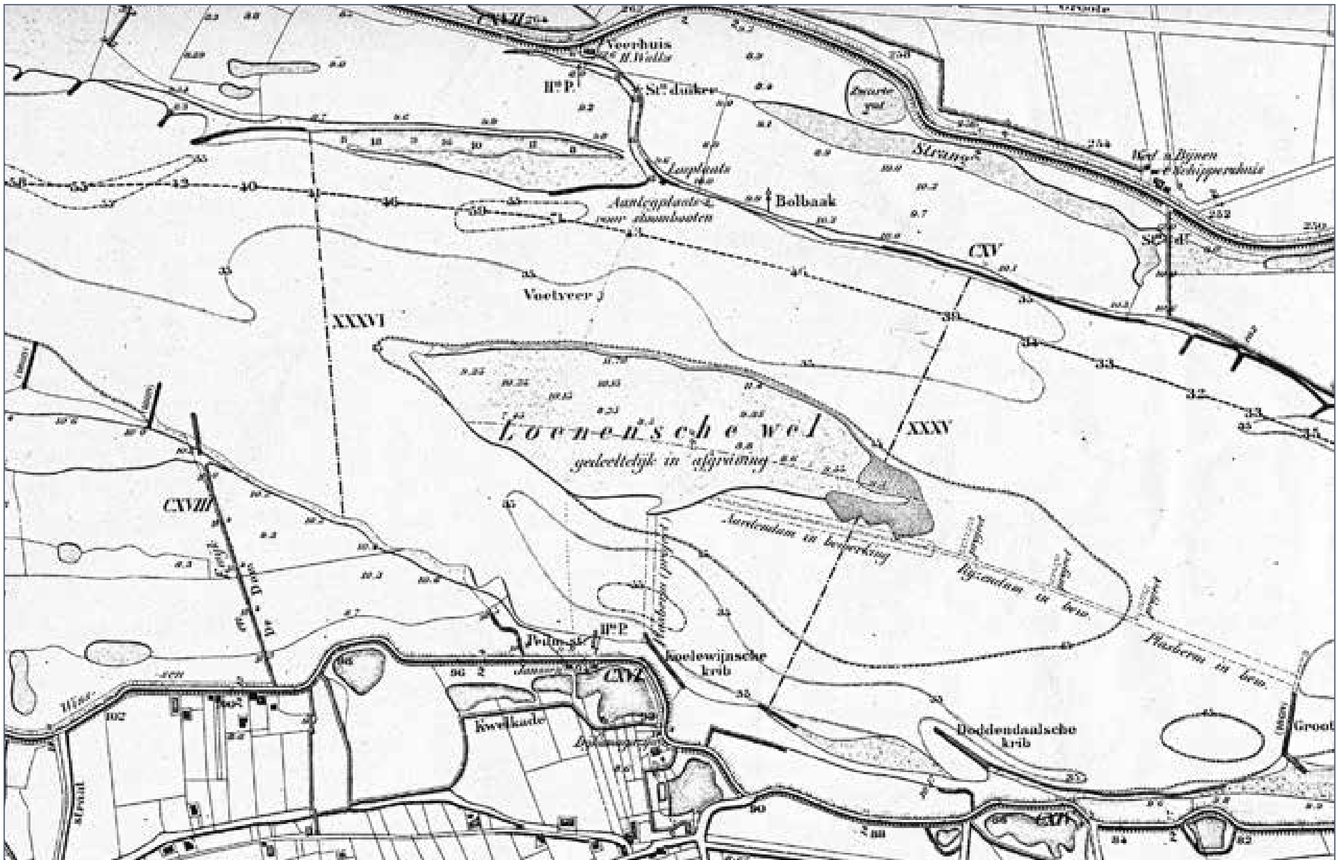
The first hydrodynamic laboratory experiments—performed at a modest scale in the 1870s and 1880s in France, Germany, and England and known to Dutch engineers—foreshadowed new design practices in water management.[63] One of the first hydraulic model experiments in the Netherlands was performed in the early 1890s by Cornelis Lely and the Delft civil engineering professor Jean Marie Telders. They were interested in demonstrating the desalination of an enclosed Zuiderzee.[64]

What an attentive nineteenth century observer must also have seen were the omnipresent functionaries and clerks of the Rijkswaterstaat. The large number of projects under construction had led to an extensive bureaucratic apparatus composed of functionaries responsible for the management and maintenance of the works. State beacon-masters kept their eyes on the sails (and in increasing measure, the smokestacks) on the rivers; lock and bridge keepers operated their facilities on the canals; and road supervisors did their best to get their stretch of road in good condition or keep it that way and, in passing, also served as traffic police and emergency service providers. The number of less-visible Rijkswaterstaat office workers had also grown considerably, partly due to the increasing number of water management laws and regulations. A country that was born of art and maintained by art had not only acquired a minister of Waterstaat (and trade and industry) between 1850 and 1900, but also a water management bureaucracy.[65]

The second half of the nineteenth century had also brought something whose significance could not be underestimated, namely an immense improvement in geographical knowledge of the Netherlands. All the water management and infrastructure plans and projects rested on a firm basis of geographical data and detailed maps. In 1885 a precise national vertical reference network based on the *Normaal Amsterdams Peil* (Normal Amsterdam Level) was the outcome of the First Precision Water Level Survey, started ten years earlier and carried out since 1879 under supervision of the then-established State Commission for Triangulation and Leveling. For man-made lowlands, a vertical reference network was, obviously, of immense importance. For centuries, the main water boards in the low parts of the Netherlands—Rijnland, Delfland, and Schieland—used the Amsterdam datum as a reference to obtain an assessment of the flood risks posed by the Nether-Rhine and Lek. Starting daily tide observations in 1674, Amsterdam has been producing the longest observation series of sea level measurements in the world. The Amsterdam Ordnance Datum has been spread over the world. The precision leveling works of 1879–1885 with "Amsterdam" as a benchmark provided the Netherlands with a highly detailed vertical reference network to build on. In addition, the above-mentioned commission was also charged with supervising the triangulation survey, necessary for a horizontal level reference framework, ultimately published as the National Triangulation Network.

Precise data on levels and triangulation were essential for precise maps. The *Waterstaatskaart van Nederland* (1865–1891) drawn on the foundation of the Topographical and Military Map of the Netherlands (1850–1864) was not only of great importance for the Rijkswaterstaat, it was also unique in the world. That was also the case for the River Map, whose first pages had already appeared in the 1830s and which was completed in 1864. Measuring and drawing the Netherlands involved a large number of organizations. The Rijkswaterstaat had established its General Service, for, among other things, cartographic work. A Topographic Service had been attached to the Ministry of War since 1815, and in 1874 the Ministry of the Navy acquired a Hydrographic Service. The Land Registry Office, a division of the Ministry of Finances, carried out large-scale terrain mapping and throughout the nineteenth century played an important role in legal questions and state dispossessions, thanks to its maps and property registers.[66] The development of a geodetic and cartographic infrastructure went hand-in-hand with the development of the physical infrastructure in the country. Here, too, it was the case that while important strides had been made by the end of the nineteenth century, the end was hardly in sight.

Of the new élan and strong dynamic in water management that had existed in the mid-nineteenth century, little remained fifty years later. Around 1848 political developments had created new opportunities. The ministerial responsibility that had been instituted and the increased significance of Parliament had led to a new kind of decision making that encouraged hope. This was supported by colonial profits, the liberalization of world trade, the application and further development of steam and other technologies, and (partly in consequence) the explosive growth of the hydraulic engineering sector. The engineers of the Rijkswaterstaat, whose self-esteem had been low towards the



Nationaal Archief, The Hague

Detail of a Waal section on an 1870 river map (second edition). Normalization is in progress, showing groyne construction and partial removal of the middle island.

mid-nineteenth century, longed for, and eventually attained "renewal" and higher status.

But the new political relationships also had a dark side: decision making simply took longer. Where projects in the first half of the nineteenth century had an average "process time" of about six years, during the second half of the century decision making was taking more than twice as long.[67] Regional conflicts of interest, often fought out in a Parliament that was chosen by district, sometimes had a complicating or paralyzing effect. A hefty increase in laws and regulations sought to maintain a balance between partisan and general interests and responsibilities. Meanwhile, the Rijkswaterstaat had grown rapidly, especially at the bottom of its organization. It had gained many tasks in control, supervision, operating, and maintenance of waterworks and infrastructure. Its engineers not only had to manage this growing bureaucratic part of the work, they also had to face the new political reality, leading to a increasing indecisiveness towards new, appealing projects.

As water management and infrastructure projects had become subject to parliamentary democracy during the third quarter of the nineteenth century, gradually these topics also became part of the broader public domain. Traditionally notables, property owners, merchants, and manufacturers had submitted petitions to the king, the minister, or their member of Parliament in order to have some particular water management issue resolved according to their specific interest. They enjoyed few rights or legal protection. But things had changed: the constitution of 1848 had guaranteed freedom of association and assembly, Parliament had a greater role, a new middle-class was emerging, the Catholic part of the population no less than the civil engineers were emancipating themselves and acquiring social stature. All these changes facilitated the growth of extra-parliamentary interest groups in the domains of water management and infrastructure. An example is the Zuiderzee Association (1886) and its predecessor, the Zuiderzee Committee. Civil engineers were associated as members or advisors. The association's influence was extensive and it forced parliamentarians and ministers to act. This did not mean that the members' wishes were always satisfied, but they could certainly impose their will on the water management agenda and they forced policy makers to legitimize their choices. In the twentieth century their number and significance for social water management debates would acquire new dimensions.

Those whose role was just about played out around 1900 were the traditional "hands" of the engineers, the enormous number of so-called "polder boys." During the working season they trekked in groups from one water management project to another to offer their services as diggers, bricklayers, weavers of fascine mattresses, and so on. At the big project sites, temporary villages composed of improvised huts and associated facilities sprung up. The "polder boys" had their own customs, and their presence implied a certain disruption in the normal leisurely pace of life in a given region. With increasing mechanization of labor at the worksite, many of the functions of the polder boys became redundant. However, the large number of projects in the second half of the nineteenth century guaranteed sufficient work for them. But when the big projects ended, it became increasingly difficult for the polder boys to maintain their traditional existence.

An additional problem was the increasing dissonance between an ever more regulated and ordered country and their vagabond, nomadic lifestyle. A survey in 1910 revealed that some municipalities resisted the employment of large groups of workers "from outside" within their town limits.

A few of the polder boys were able to adapt to the changed working methods and materials and stayed on in hydraulic construction. For example, a large group of mattress-weavers, who saw their work in Rotterdam's harbor disappear before the onslaught of reinforced concrete, quickly appropriated the skills of steel bender for reinforced concrete constructions. Others sought work in foreign countries. And some of the "hands" of the Dutch engineers accompanied the export of the knowledge and experience of Dutch engineers across the border.[68] The disappearance of the polder boys at the beginning of the twentieth century is symbolic of the transition from a traditional craft-based water management sector and society to its modern industrial incarnation. At the end of the nineteenth century, the taillights of the one were fading, soon to be blotted out by the dazzling headlights of the other.

BIBLIOGRAPHIC ESSAY

ENGLISH SOURCES

For an informative general overview on the era 1880–1910 covering major political, economic, and socio-cultural issues, see Jan Bank and Maarten van Buuren, *1900: the Age of Bourgeois Culture* (Assen, 2004).

For a long-term view on the politics of Dutch water management, see C. Disco and E. van der Vleuten, "The Politics of Wet System Building: Balancing Interests in Dutch Water Management from the Middle Ages to the Present," *Knowledge, Technology & Policy* 14, no. 4 (2002), pp. 21–40, and H. W. Lintsen, "Two Centuries of Central Water Management in the Netherlands," *Technology and Culture* 43, no. 3 (2002), pp. 549–68. C. Disco, *Made in Delft: Professional Engineering in the Netherlands 1880–1940 (*Amsterdam, 1990) describes the professionalization of civil engineering between 1880 and 1940 in a societal context. By doing so, Disco extends the study of H. W. Lintsen, *Ingenieurs in Nederland in de negentiende eeuw. Een streven naar erkenning en macht* ('s-Gravenhage, 1980), that is only available in Dutch. A comparative analysis of Dutch river management and coastal management is offered in B. Toussaint, "Training the rivers and exploring the coasts. Knowledge evolution in the Netherlands in two engineering fields between 1800 and 1940," in *Physics and Chemistry of the Earth* 34/3 (2009), pp. 132–41.

DUTCH SOURCES

Jan Bank and Maarten van Buuren, *1900: hoogtij van burgerlijke cultuur* (The Hague, 2000) is the Dutch edition of *1900: the Age of Bourgeois Culture*. Chapters five to eight of Jan Luiten van Zanden and Arthur van Riel, *Nederland 1780–1914. Staat, instituties en economische ontwikkeling* (Amsterdam, 2000) comprise a broad overview of the socio-political and economic developments in the Netherlands between 1840 and 1913. A sweeping international perspective on the impact of systematic scientific and engineering knowledge development on Dutch infrastructure and river management unfolds in A. van der Woud, *Een nieuwe wereld. Het ontstaan van het moderne Nederland* (Amsterdam, 2007). On spatial planning and infrastructure in the second half of the nineteenth century, see also volume II in the series *Techniek in Nederland. De wording van een moderne samenleving* (Zutphen, 1993), edited by H. W. Lintsen (see also the bibliographic essay in chapter 2).

For a long-term overview of river management, see Alex van Heezik, *Strijd om de rivieren. 200 jaar rivierenbeleid in Nederland of de opkomst en ondergang van het streven naar de normale rivier* (Haarlem, 2008) (see also the bibliographic essay in chapter 2). On one of the major river projects, the Bergse Maas project, see Frans Jansen (ed.), *Honderd jaar Bergsche Maas: de scheiding van Maas en Waal* (Wijk en Aalburg, 2004). Older literature on this topic is still valuable, notably E. van Konijnenburg, *Scheiding van Maas en Waal, beschrijving van den vroegeren waterstaatkundigen toestand in Noordbrabant, alsmede van de werken uitgevoerd voor de verlegging van den Maasmond* (The Hague, 1905), and M. C. E. Bongaerts, *De scheiding van Maas en Waal onder verlegging van de uitmonding der Maas naar den Amer* (z.p., 1909).

On the New Waterway project, see G. van den Burg, *De nieuwe Waterweg: poort van Europa* (Amsterdam, 1989) and A. T. de Groot, *De waterweg langs Rotterdam naar zee 1866–1916* (The Hague, 1916). On the North Sea canal project, see J. Moes (ed.), *Noordzeekanaal: 1876–2001* (Amsterdam, 2001), and H. Wortman and G. J. van den Broek, *Geschiedenis en beschrijving van het Noordzeekanaal* (Amsterdam, 1909).

On the Rijkswaterstaat organization in this period, see Eric Berkers, *Technocraten en bureaucraten: ontwikkeling van organisatie en personeel van de Rijkswaterstaat, 1848–1930* (Zaltbommel, 2002), a Ph.D. thesis about the Rijkswaterstaat, struggling between its inherent bureaucratic and technocratic features, from 1848 to 1930.

1 A. van der Woud, *Een nieuwe wereld. Het ontstaan van het moderne Nederland* (Amsterdam: Bert Bakker, 2006), 173.

2 H. W. Lintsen, *Ingenieurs in Nederland in de negentiende eeuw. Een streven naar erkenning en macht* ('s-Gravenhage: Nijhoff, 1980), m.n. 124–36; A. Bosch, W. van der Ham, *Twee eeuwen Rijkswaterstaat, 1798–1998* (Zaltbommel: Europese Bibliotheek, 1998), 68–73.

3 S. Stuurman, *Wacht op onze daden. Het liberalisme en de vernieuwing van de Nederlandse staat* (Amsterdam: Bert Bakker, 1992), m.n. 161–70; T. J. Boschloo, *De productiemaatschappij. Liberalisme, economische wetenschap en het vraagstuk der armoede in Nederland 1800–1875* (Hilversum: Verloren, 1989), m.n. 179.

4 J. L. van Zanden en A. van Riel, *Nederland 1780–1914. Staat, instituties en economische ontwikkeling* (Amsterdam: Balans, 2000), 209.

5 B. P. G. van Diggelen, *De Zuiderzee, de Friesche Wadden en de Lauwerzee, hare bedijking en droogmaking* (Zwolle: W. E. J. Tjeenk Willink, 1849), vol. 2, 401.

6 J. A. de Jonge, *De industrialisatie in Nederland tussen 1850 en 1914* (Nijmegen: SUN, 1976), 320–24.

7 L. J. A. van der Kun, 'Proeve ter beantwoording der vraag: "Wat kan Nederland op het gebied der openbare werken in het belang van den groothandel doen?"' (nota d.d. 24-4-1856 to the Minister of Internal Affairs), in: National Archives (NA), ministerie van Binnenlandse Zaken, inv. no. 256; Cited in: E. Berkers, *Technocraten en bureaucraten. Ontwikkeling van organisatie en personeel van de Rijkswaterstaat, 1848–1930* (Zaltbommel: Europese Bibliotheek, 2002), 43.

8 Cited in: Lintsen, *Ingenieurs in Nederland*, 155.

9 Lintsen, *Ingenieurs in Nederland*,164–72; G. P. J. Verbong, "Ingenieurs en het technisch onderwijs 1863-1890", in: H. W. Lintsen et al. (eds.), *Geschiedenis van de techniek in Nederland. De wording van een moderne samenleving 1800-1890*, vol. 5 (Zutphen: Walburg Pers, 1994), 117–55.

10 C. Disco, *Made in Delft. Professional engineering in the Netherlands, 1880–1940* (Amsterdam: University of Amsterdam, 1990), 59–62.

11 Berkers, *Technocraten en bureaucraten*, 62–63.

12 Disco, *Made in Delft*, 206–14.

13 Alex van Heezik, *Strijd om de rivieren. 200 jaar rivierenbeleid in Nederland of de opkomst en ondergang van het streven naar de normale rivier* (Haarlem: Van Heezik Beleidsresearch, 2006), 102.

14 A. van Heezik, *Strijd*, 87.

15 A. van Heezik, *Strijd*, 89.

16 Cited in: M. C. E. Bongaerts, *De scheiding van Maas en Waal onder verlegging van de uitmonding der Maas naar den Amer* ('s Gravenhage: Ministerie van Waterstaat, 1909), 15.

17 Van Heezik, *Strijd*, 96.

18 Van Heezik, *Strijd*, 103–04.

19 C. R. T. Krayenhoff, *Proeve van een ontwerp tot scheiding der rivieren de Whaal en de Boven-Maas en het doen afloopen dezer laatste, over hare bedding, op het Bergsche-veld* (Nijmegen: Vieweg, 1823).

20 E. van Konijnenburg, *Scheiding van Maas en Waal* ('s Gravenhage: Mouton en Co, 1905), 28; Bongaerts, De scheiding van Maas en Waal, 25.

21 R. P. J. Tutein Nolthenius, "De drie Maasmond-ontwerpen", in: *De Ingenieur* 19 (1904): 618–19.

22 Bongaerts, *Scheiding van Maas en Waal*, 27 en 30.

23 *Handelingen der S.-G.* (1878/79), T.K., 481.

24 Announced in the *Provinciaal Blad van Noord-Brabant* (1880), no. 17.

25 J. Kasteel, *Geschiedenis van de Maas en de nieuwe Maasmond* (z.p.:V.V.V., 1964), 18–19; Van Konijnenburg, *Scheiding van Maas en Waal*, 22–24. (Here also are a map of the flooded areas and photographs of the flood of 1876).

26 J. C. Ramaer, J. P. Wijtenhorst en E. van Konijnenburg, "De verlegging van de uitmonding der Maas van Woudrichem naar den Amer", in: *De Ingenieur* 19 (1904): 601–04.

27 See for example: *Handelingen der S.-G.* (1882/83), T.K., 405.

28 See 'Blanken to Brunings, d.d. 9-3-1799', in: NA, *Inspecteurs en commissies van de Waterstaat vóór 1850*, inv. no. 139. Cited in: Berkers, *Technocraten en bureaucraten*, 23.

29 Bosch en Van der Ham, *Twee eeuwen*, 120.

30 Ibidem.

31 H. P. H. Nusteling, *De Rijnvaart in het tijdperk van stoom en steenkool, 1831–1914* (Amsterdam: Holland Universiteits Pers, 1974),181 en 201–17.

32 Dirk Maarten Ligtermoet en Harry de Visch Eybergen, *Uitvoering en uitbesteding. Ontwikkelingen in de organisatie van waterbouwkundige werken bij de Rijkswaterstaat* (Den Haag: Rijkswaterstaat, 1990), 13.

33 So called in C. te Lintum, *Een eeuw van vooruitgang 1813–1913* (Zutphen: Thieme, 1912), 219.

34 Cited in: A. T. de Groot en A.B. Marinkelle, *De Waterweg langs Rotterdam naar zee, 1866–1916* ('s Gravenhage: Ministerie van Waterstaat, 1916), 15–16.

35 See: M. G. de Boer, *De haven van Amsterdam en haar verbinding met de zee* (Amsterdam: Gem. Amsterdam, 1926), 38–39.

36 *Handelingen der S.-G.* (1859/60), Bijlage XL (M.v.T.), 157.

37 *Handelingen der S.-G.* (1862/63), E.K., 1746.

38 W. C. Mees, *Man van de daad: Mr. Marten Mees en de opkomst van Rotterdam* (Rotterdam: Nijgh en Van Ditmar, 1946), 151–52.

39 M. L. ten Horn-Van Nispen, "De Nieuwe Waterweg van Rotterdam naar zee", in: *Nederlandse ingenieurs en hun kunstwerken. Tweehonderd jaar civiele techniek* (Zutphen: Walburg Pers, 1994), 63.

40 Ten Horn-Van Nispen, "De Nieuwe Waterweg van Rotterdam naar zee", 64–67.

41 *Handelingen der S.-G.* (1862/63), T.K., 5066.

42 Ibidem.

43 Bosch en Van der Ham, *Twee eeuwen*,107–09.

44 Bosch en Van der Ham, *Twee eeuwen*, 109.

45 Cited in Van der Woud, *Een nieuwe wereld*, 268.

46 Van der Woud, *Een nieuwe wereld*, 259.

47 *Handelingen der S.-G.* (1892/93), Bijlage A, hfdst. IX, no. 10 (v.v. with the budget for 1893), 1.

48 Van der Woud, *Een nieuwe wereld*, 274.

49 Van der Woud, *Een nieuwe wereld*, 281–82; see also Bosch en Van der Ham, *Twee eeuwen*, 132–33.

50 *Handelingen der S.-G.* (1891/92), Bijlage 159 (M.v.T.), 2.

51 J. de Koning, "Over waterschappen en kleine rivieren", in: *Vragen des tijds* (1892), vol.1, 383–84.

52 Wet, d.d. 15-7-1896 (Stbl. no. 131); R. H. van der Voort, *Overheidsbeleid en overheidsfinanciën in Nederland 1850–1913* (Amsterdam: NEHA, 2006),168–69.

53 Van der Woud, *Een nieuwe wereld*, 280.

54 *Handelingen der S.-G.* (1894/95), T.K., 654.

55 *N.N.B.W.*, dl. 5, 742–46.

56 Lintsen, *Ingenieurs in Nederland*, 260–61.

57 Cited in: M. P. de Bruin, *Waken en bewaren. 100 jaar provinciale waterstaat Zeeland 1881–1981* (Middelburg: Provincie Zeeland, 1981), 37.

58 Van der Woud, *Een nieuwe wereld*, 177.

59 K.B. d.d. 21-4-1892 (no.4); H. van der Linden, "Een eeuw Staatscommissie voor de Waterstaatswetgeving", in S.B. Boelens e.a. (eds.), *Waterstaatswetgeving: verleden, heden en toekomst* (Zwolle: W. E. J. Tjeenk Willink, 1992), 10–12.

60 Van der Linden, "Een eeuw Staatscommissie", 26–27, 40; Van der Linden mentions the *Haarlemsche Courant, de Nieuwe Rotterdamsche Courant*, het *Algemeen Handelsblad* en het *Vaderland*.

61 Van der Woud, *Een nieuwe wereld*, 182.

62 H. Doijer in Verhandelingen van het KIvI (1891–1892), cited in: Van der Woud, *Een nieuwe wereld*, 213.

63 Bosch en Van der Ham, *Twee eeuwen*, 119 en 133; Eric Berkers, "Modern ontwerpen", in: J.W. Schot e.a. (eds.), *Techniek in Nederland in de twintigste eeuw*, vol. 1 (Zutphen: Walburg Pers, 1998), 156.

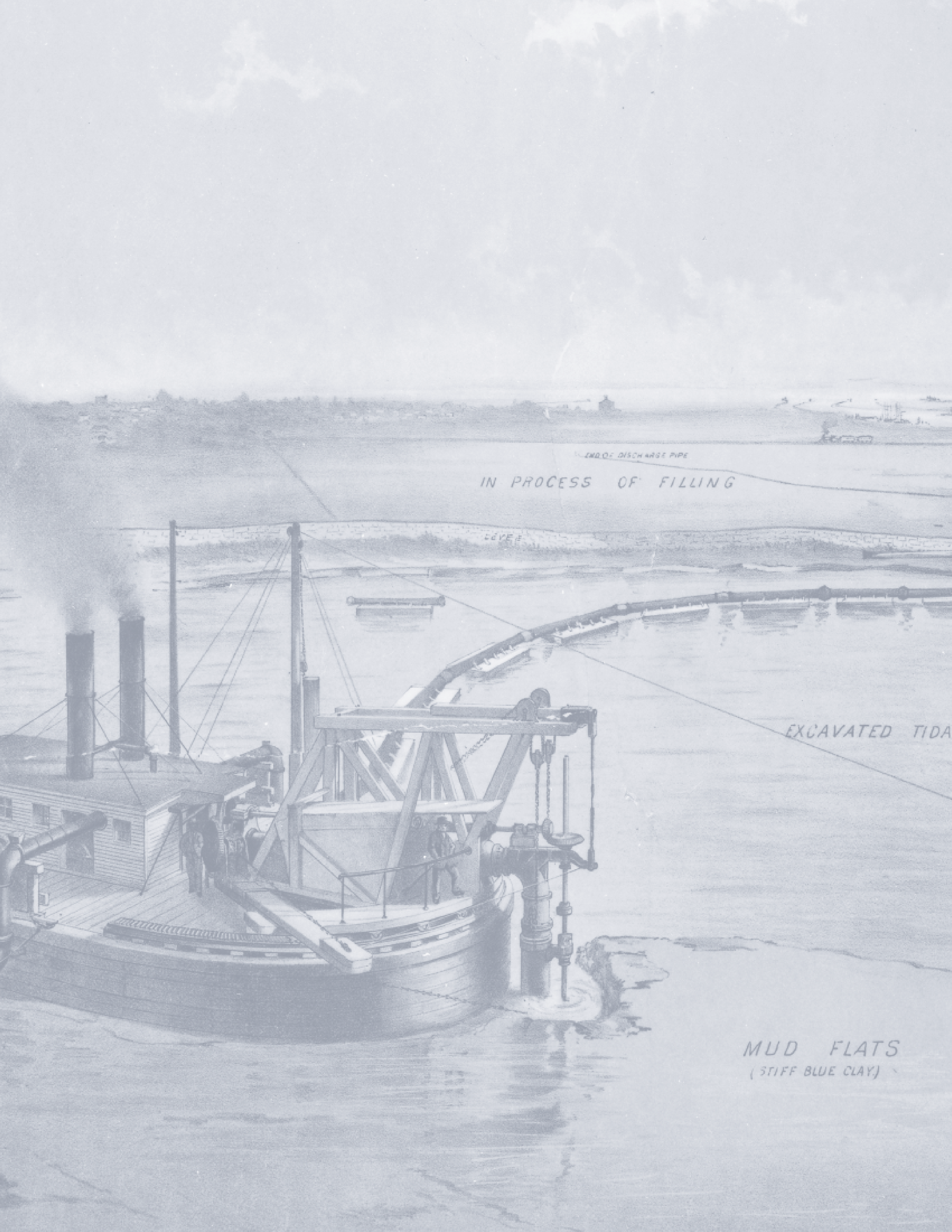
64 Berkers, "Modern ontwerpen", 156.

65 Berkers, *Technocraten en Bureaucraten*, passim.

66 E. Berkers, *Geodesie: de aarde verdeeld en verbeeld, berekend en getekend* (Zutphen: Walburg Pers, 2004), passim ; Van der Woud, *Een nieuwe wereld*, 135–56.

67 H. W. Lintsen, *Made in Holland: een techniekgeschiedenis van Nederland (1800–2000)* (Zutphen: Walburg Pers, 2005), 87; "process time" is measured from the moment that the responsible agency places the project on the agenda up to the moment that construction is actually started.

68 E. Berkers, 'De handen van "het genie". Polderwerkers in de 19e eeuw', in: *Tijdschrift voor Waterstaatsgeschiedenis* 7 (1998): 97–105.


END OF DISCHARGE PIPE
IN PROCESS OF FILLING
LEVEE
EXCAVATED TIDA
MUD FLATS
(STIFF BLUE CLAY)

5 U.S. ARMY ENGINEERS IN THE ERA OF SINGLE-PURPOSE WATERWAY IMPROVEMENTS, 1865–1900

Leland R. Johnson

The Gilded Age, sandwiched between the Civil War and the Progressive era of American history, was a formative epoch: the Reconstruction of the South, the Industrial Revolution, and the settlement of the West were its hallmarks. Composed of thirty peaceful and prosperous years, marred by short depressions and skirmishes with American Indians, the Gilded Age saw a boom in transportation, the rise of great cities, and a revolution in communications—the telegraph and the telephone. Americans of the era became so obsessed with invention, engineering, and industrialization that in 1876 novelist William Dean Howells admonished that engineering, rather than art, had become the "national genius." It was an age of weak presidents, powerful congresses, and ubiquitous public corruption, mocked by Mark Twain when he dubbed it the Gilded Age.[1]

The period after the American Civil War marked the pinnacle of faith that unbridled competition would best regulate the economy and society. It was the age of Darwinism, unfettered hostile corporate takeovers by "robber barons," contention for world markets, and rivalry between railroads and waterways. Politically, the era witnessed disputes between political parties, between presidents and congresses, and among the northeastern, western, and southern states for shares of national budget surpluses generated by high tariffs on burgeoning foreign trade. This competitive tension forced the Corps of Engineers to adapt in an increasingly fluid environment.[2]

Because ships cannot achieve the economies of larger size and capacities without deep rivers and ports, improving waterways seemed key to economic prosperity and to developing foreign trade and the federal taxes it generated. This concept, along with a dramatic change in American politics, brought the Corps to a central position in the national political economy. Along with states' rights, the idea that waterways could best be deepened by state and local governments withered with the Confederacy's defeat in 1865. Americans next turned to the federal government for central direction of national waterways, placing the Corps of Engineers squarely in the midst of the new competitive vortex—economic and political, national and sectional, foreign and domestic, presidential and congressional.[3]

The Corps of Engineers emerged from the Civil War as a leader of American engineering. Civil engineers were just then attaining professional status, reestab-

Office of History, Headquarters, U.S. Army Corps of Engineers, H. Abbot Collection

Capt. Andrew A. Humphreys (1810–1883), ca. 1859, who became Chief of Engineers in 1866

lishing the American Society of Civil Engineers in 1867. From combat officers of the Union army, the Corps inherited abundant talent. Wartime leader Brig. Gen. Andrew Humphreys became the Corps' postwar chief. Although Humphreys and the Corps were disappointed by postwar military construction retrenchments, their expanding civil works mission afforded ample opportunities for national leadership of innovative engineering.[4]

FEDERAL COMMITMENT TO WATERWAY IMPROVEMENTS

The election of Abraham Lincoln and departure of Southern Democrats from Congress had effectively ended the prewar political hostility to federal transportation projects based on constitutional scruples. During the war, the Republican Party encouraged railroad construction with vast land grants and guaranteed loans, and President Lincoln signed waterways bills for building seawalls at Boston and Buffalo, strengthening the Delaware breakwater in the approach to Philadelphia, and repairing timber crib and stone piers at Great Lakes and Northern coastal harbors.[5]

Because combat engineering occupied most officers during the war, the Corps had only two officers available for civil works. One managed Great Lakes projects; the other was responsible for seacoast harbors. The Corps contracted for repairing the prewar projects but saw little progress in further deepening the channels because all Corps dredges had been commandeered for military service. Although in 1866 Congress offered surplus Navy ships to the Corps for rivers and harbors work, the conversion of warships into dredges and snagboats proved uneconomical, and the Corps found it necessary to start anew.[6]

Although once a Democrat and opposed to federal waterways projects, President Andrew Johnson made no effort to suppress postwar federal aid to transportation because he was fighting a losing battle against Congress on other issues. Johnson signed the 1866 rivers and harbors bill, appropriating $3.7 million for forty-nine projects on the Great Lakes and the northern seacoast. The measure also revived the prewar snag-removal program on the Mississippi River system, and mandated special attention to opening the shoal-obstructed mouths of the Mississippi. Southern rivers and harbors in 1866 were clogged with wrecked ships, Confederate obstructions, and snags and sandbars that had accumulated during a decade of neglect, but Congress ignored those obstructions to commercial renewal until political reconstruction was well underway.[7]

POSTWAR CORPS: ORGANIZATION AND MISSION

To cope with the expanding postwar mission, Humphreys reorganized his Washington office into five divisions—fortifications, engineer battalion and depot, rivers and harbors, property and accounts, and maps and surveys—assigning officers to manage each. He made Col. John Parke responsible for the third division, rivers and harbors—receiving and acting on reports and correspondence from Corps field offices then opening throughout the nation. Parke's prewar experience was mostly limited to boundary and railroad surveys, but Humphreys had conducted a landmark study of the Mississippi River and had significant field experience with the engineering and construction of waterways. Together, Humphreys and Parke administered the Corps construction program for thirteen years.[8]

In 1867 Humphreys had an authorized roster of 109 men. He assigned eighteen to field offices managing waterways projects, twenty-one to offices conducting both fortifications and waterways construction, six to the Great Lakes survey, and the remainder to military mapping, fortification, and department posts. Initially known as U.S.

The Great Lakes

Located along the U.S.–Canadian border, Lakes Superior, Michigan, Huron, Erie, and Ontario link to the Atlantic Ocean through the Saint Lawrence Seaway. They form the largest group of freshwater lakes on Earth and contain 21% of the world's surface fresh water. The Corps of Engineers maintains a continuous 27-foot-deep draft waterway that extends from the western end of Lake Superior at Duluth, Minnesota, to the Gulf of St. Lawrence on the Atlantic Ocean, a distance of over 2,400 miles.

Engineer Offices, the field offices, which were responsible for several projects by 1884, were eventually called district offices, and their military leaders became known as district engineers. Because Congress mandated that the Corps issue contracts for construction to the maximum extent possible, and the contractors furnished most of the labor, district offices initially consisted simply of the commander, a civilian assistant engineer or two, a chief clerk, and perhaps also a draftsman and a messenger. This typical field office organization, however, did not apply to the much larger offices of Western River Improvement or the Great Lakes survey.[9]

Reestablished at Cincinnati after the war and moved to St. Louis in 1871, the Office of Western River Improvement designed and operated the great snagboats built to clear the Ohio, Missouri, Arkansas, and Mississippi rivers of snags. Typically these were submerged trees held fast to the bottom of the river and posing a threat to wooden-hulled steamboats. To clear these hazards, the Western Rivers office improved on Henry Shreve's prewar design by building much larger dual-hulled snagboats equipped with six steam engines for propulsion and snag removal, compared to Shreve's two-engine snags. When contractors completed the new designs, the Western Rivers office employed crews and sent them into the field each spring, steaming up and down the waterways, pulling nests of snags.[10]

The Great Lakes survey office at Detroit mapped the lakes to guide and improve shipping safety. Begun in 1841, the lakes survey had continued its work through the war with a single officer and twenty-four civilian engineers supplying maps to foster lakes commerce. Of all Corps offices, the Great Lakes survey office was the most scientific, applying advanced surveying technology, experimental hydrographic measurements, and astronomical studies to its mission. Indeed, near

Office of History, Headquarters, U.S. Army Corps of Engineers

U.S. snagboat *Wateree*, ca. 1896

the end of the war the office applied telegraphy to its surveys, constructing telegraph lines linking harbors and using synchronous azimuth observations to determine comparative longitudes. The office also used the telegraph to warn mariners of storms blowing east from Lake Superior, an initiative that encouraged the 1871 formation of the National Weather Service within the Army Signal Corps. These scientific studies and mapping exercises offered excellent training, and brief assignments with the Lakes Survey launched the careers of many Corps officers.[11]

Humphreys paid special attention to the renewed project at the mouths of the Mississippi, where his prewar survey had made his reputation. In 1867, the Corps resumed its earlier efforts to dredge a deeper channel through one of the passes, building the experimental dredge *Essayons* to stir the bottom. Towboat pilots guiding ships through the passes blocked and delayed the work, storms refilled the dredged channels, and the experimental vessel needed constant repairs, stymieing Corps efforts to attain a deeper channel for years, exasperating Congress, and blockading a principal outlet for inland river commerce. Some leaders began to question whether the Corps' experimental dredging would ever open a deepwater channel to New Orleans.[12]

CONGRESSIONAL ACTION: RIVERS, HARBORS, AND CANALS

As project work resumed after the Civil War, Congress enacted expansive rivers and harbors bills drafted by the House Committee on Commerce. Created in 1865 to handle waterways project authorization and funding for the House Committee on Appropriations, the fifteen-member Commerce Committee initiated postwar rivers and harbors bills, relying on survey reports by the Corps. They reviewed project reports submitted by the field engineers as well as funding estimates. When aggregate cost estimates grew too large, the committee slashed the estimates by a selected percentage. As a result, the field offices seldom received as much as half the amount they requested, with unfortunate consequences. This tendency to grossly underfund projects resulted in delays and higher costs and, in time, earned derision as the "driblet" appropriation system.[13]

Before the war, Congress had fostered state and private canal and navigation lock projects with supplemental funding and land grants, but it had never approved a federal canal project. Hence, the proposal in 1867 to build a canal and navigation locks bypassing Des Moines Rapids on the Upper Mississippi River was novel. The following year Congress initiated efforts to take control of two important older canals: the St. Marys Canal built by Michigan at Sault Ste. Marie, and the Louisville and Portland Canal built by a corporation to bypass the Falls of the Ohio. By the end of the decade, the Corps had not only resumed work at its prewar rivers and harbors projects, but it had also begun efforts to master the technology of navigation locks, dams, and canals.[14]

NEW HARBOR PROJECTS SPUR TECHNICAL INNOVATIONS

President Ulysses S. Grant generally approved federal transportation projects, and during his two terms Congress enacted *annual* rivers and harbors appropriations, gradually expanding the number of projects and increasing yearly funding to $6.5 million. The bulk of this funding went to northern seacoast and Great Lakes harbors, but rapid settlement of the West brought the first funding for Pacific harbors, while projects to remove sunken warships and obstructions from southern harbors began to restore commerce there, supplementing political reconstruction. Throughout this expansion, President Grant maintained relatively tight rein over rivers and harbors funding, sending his adjutant, Maj. Orville Babcock of the Corps to Congress with messages conveying the president's goal of holding annual appropriations within specific limits.[15]

Great Lakes commerce had suffered little wartime disruption. Merchandise flowed west from the Erie Canal terminal at Buffalo to railroad terminals at Cleveland, Chicago, and other lakes ports, while lumber, grain, and ores were shipped east. By 1870, a third of all iron ore and three-quarters of all copper mined in the nation moved from harbors on the western lakes to two hundred blast furnaces, rolling mills, and ironworks at harbors on the eastern lakes. Lake harbors generally were located where rivers flowed into the lakes, and the Corps had improved them before the war by building parallel piers or jetties confining river flows to a straight channel, thereby accelerating river velocity to scour away shoals blocking harbor entrances. The Corps usually built these jetties of timber cribs, rectangular pens, or cribs set side-by-side and filled with stone. After the war, the Corps replaced the deteriorated timber in the prewar cribs, and then lengthened the jetties to extend them farther into the lakes. Where hydraulic action of the rivers proved inadequate, the Corps also contracted for dredging to maintain deeper channels and to open anchorage basins.[16]

To facilitate thriving lakes commerce, shipbuilders constructed larger vessels, and by 1870 the draft of typical lake vessels had increased from the prewar ten feet to fourteen feet or more, making the crowded inner harbors in the river mouths obsolete. The Corps, therefore, initiated projects to construct "outer" harbors at the busiest ports—the cities mushrooming around docks where lake shipping transferred cargo to or from railroads.[17]

During the 1870s, the Corps built stone breakwaters extending around the inner harbors into the lakes, offering protected anchorage for ships waiting to discharge or take on cargo at such major railroad terminals as Buffalo, Cleveland, and Chicago. The Corps also dredged the inner harbors to depths suited to increasing ship draft, thereby fostering a burgeoning rail-to-ship-and-back-to-rail traffic. Indeed, Chicago's commerce grew to the extent that a second harbor became necessary on the city's south side at Calumet River.[18]

The situation was different at Duluth, Minnesota, and Superior, Wisconsin, at the western tip of Lake Superior. These ports lacked a natural inner harbor and were not heavily used before the war. Here, the Northern Pacific Railroad first developed the harbor, building a pier for ships taking on grain, lumber, and commodities brought to the harbor by rail. When Congress, in 1870, funded improvements here, the Corps extended the crib work pier begun by the railroad and dredged a deeper approach to the railroad docks. Located in different states, Duluth and Superior initially competed for harbor improvement funding, but the Corps resolved this by combining the adjacent harbors into a single comprehensive project. And when oil magnate John D. Rockefeller developed Mesabi Range iron ore later in the century, shipping immense tonnages in deep-draft vessels to eastern furnaces and mills, the Corps dredged the Duluth-Superior harbor to sixteen feet, then twenty, and eventually deeper.[19]

IMPROVEMENTS TO GREAT LAKES CHANNELS

Along with expanding the lake harbors, the Corps paid special attention to the channels linking the Great Lakes. Although the lakes afforded ample width and depth for the largest ships, the narrow, shallow, and rocky straits leading from one lake to the next limited ship dimensions. Through projects at the St. Marys River, a 65-mile-long strait between Lakes Superior and Huron, and the 80-mile-long St. Clair and Detroit River strait between Lakes Huron and Erie, the Corps sought to open a deeper channel for commerce moving from Duluth-Superior at the head of Lake Superior to Buffalo at the foot of Lake Erie, a 985-mile sailing distance.[20]

Detroit's docks on the strait between Lakes Huron and Erie had natural protection from storms, not requiring the jetties and breakwaters built at ports along the lakeshores. The Corps' postwar project there involved deepening the connecting channel through the St. Clair River, Lake St. Clair, and the Detroit River, where the initial limiting depth was six feet. To define the dredged channel leading from the St. Clair River into Lake St. Clair and prevent storms from refilling the excavation, the Corps drove double walls of sheet-piling on both sides of the channel, filling spaces between the piling to form straight dikes. The result was the St. Clair Flats Canal. Continual dredging was required to maintain an eighteen-foot depth through the canal, and its walls also required regular maintenance.[21]

At the outlet from Lake Superior into Lake Huron, the Sault Ste. Marie Canal had begun as a state project in 1855 when Michigan completed a canal with navigation locks passing ships around rapids in the strait. The 350-foot-long tandem locks, designed with assistance from Capt. August Canfield of the Corps, could handle three lake ships in a single lockage when they opened in 1855; by 1869 they could pass only one of the larger ships designed to carry Lake Superior's bulky commerce. When Congress accepted the canal locks as a gift from Michigan, the Corps began building a 515-foot-long lock adjacent to the older locks. Yet by the time this new lock was completed in 1881, the ever-increasing size of Great Lakes ships had already made it obsolete, and the Corps started the 800-foot-long Poe Lock, then the largest lock in the world, and also dredged Hay Lake channel to a 20-foot depth through the strait to the lock.[22]

Office of History, Headquarters, U.S. Army Corps of Engineers

Scraper for a dredge boat at Davis Island Dam near Pittsburgh, December 1881

RAILROADS AND COMMERCE

The key to commercial prosperity on the Great Lakes was the railroad connections that hauled western grain and products to Duluth and Chicago, from which ships transported the commodities to ports on the eastern lakes where they transshipped again to railroads for transport to domestic manufacturers or seacoast harbors for export. Lake harbors with railroad terminals prospered, receiving the majority of federal funding for harbor improvements; lake ports lacking rail connections seldom received major harbor improvements unless they offered convenient refuge for storm-tossed shipping. Railway and waterway transportation interests mutually benefited from Great Lakes shipping.[23]

Railroad connections with the interior also proved important for postwar seacoast harbor development. Only at New York, where the Erie Canal and Hudson River afforded a waterway connection to western trade, was competition between railways and waterways a significant consideration in harbor improvements. There, New Yorkers often observed that railroad rates increased during the winter when the canal and waterways froze.[24]

With both canal and railroad connections to the West, New York led the competition with Boston, Philadelphia, Baltimore, and other northern Atlantic ports for shares of foreign trade. The nation's busiest seaport, New York had a better natural harbor than other Atlantic ports, yet the approach to its East River docks was obstructed at Hell Gate by irregular rocky shores threatening safe passage. Here, Col. John Newton of the Corps initiated a project in the 1860s to remove the rocks, first with contractors who manually drilled holes and filled them with gunpowder to demolish the obstructions. This approach progressed so slowly that Newton converted the job into a test site for experiments with explosives, electrical detonating systems, rock-drilling machines, and rock-removal equipment.[25]

Acquiring steam-powered drills, Newton doubled the rock-drilling speed and began sinking vertical shafts into the rocks. As drilling progressed, Newton tested various machine drills, different steels for drill rods, and even diamond-drills, finding the latter especially effective. Once the vertical shaft into Hell Gate rock reached thirty-six feet, Newton had horizontal headings drilled out from the shaft, forming galleries to be filled with explosives to remove the rock with a single blast.[26]

While drilling continued, Newton and his staff experimented with various patented explosives—rend-rock powder, vulcan powder, nitroglycerin, nitrate of soda, and the explosive dynamite, invented in 1867 by Alfred Nobel. Because buildings lined the banks near the excavation, an explosive system that would demolish the rock without damaging nearby property was vital. After determining the properties of the explosives, Newton selected the best for use at various points, ordering them packed in tin cartridges to protect against moisture.[27]

To test electrical firing systems, Newton obtained assistance from Humphreys' longtime protégé, Maj. Henry L. Abbot, who commanded the nearby Willets Point Engineer School. After Congress approved submarine mines for harbor defenses, Abbot inspected European harbor defenses, returning with electrical cables, firing sets, and batteries for tests at the Engineer School. Prior to Abbot's studies, the Corps had used magneto-friction batteries, turning cranks to generate the electric sparks needed for detonating explosives, but when Abbot recommended the dry cell battery—invented in 1868 by Frenchman Georges Leclanché—Newton adopted it for use at Hell Gate. Also advising Newton on the electrical wiring needed to link the batteries with explosives, Abbot served as the project's chief electrician.[28]

With the new batteries wired into cable circuits leading to the tons of explosives, Newton, in a final innovation, wired a Morse telegraph key into the firing circuit, providing a more positive contact than

Office of History, Headquarters, U.S. Army Corps of Engineers, H. Abbot Collection

Topographical Engineer Henry Larcom Abbot (1831–1927), ca. 1863

touching a wire to a battery post. In September 1876, when the key was pressed it closed the circuit, causing an enormous underwater blast and sending a geyser skyward. The explosion generated a ground shock felt in New York and Brooklyn, but not a window was broken. To remove the rock rubble from the channel, Newton contracted with a firm that was using a new type of dredge, called a clamshell, invented by Morris & Cumings Dredging Company. The channel was soon open. In his post-blast report, Newton declared that his experiments proved that an unlimited tonnage of explosives might be safely fired without causing structural damage and that multiple mines for harbor defense could be fired simultaneously. These experiments made Newton famous, and together with his other distinctions saw him elevated to chief of engineers in 1884.[29]

By the time the Corps had opened the East River to vessels drawing twenty-one feet of water, marine engineers had designed still larger ships with drafts of thirty feet. To support a burgeoning American trade, the Corps began dredging Gedney Channel thirty feet deep and one thousand feet wide from deep water into the East River channel. This deeper channel kept New York ranked as the nation's top seaport, but its foreign trade suffered inroads from the competing ports at Boston, Philadelphia, and Baltimore.[30]

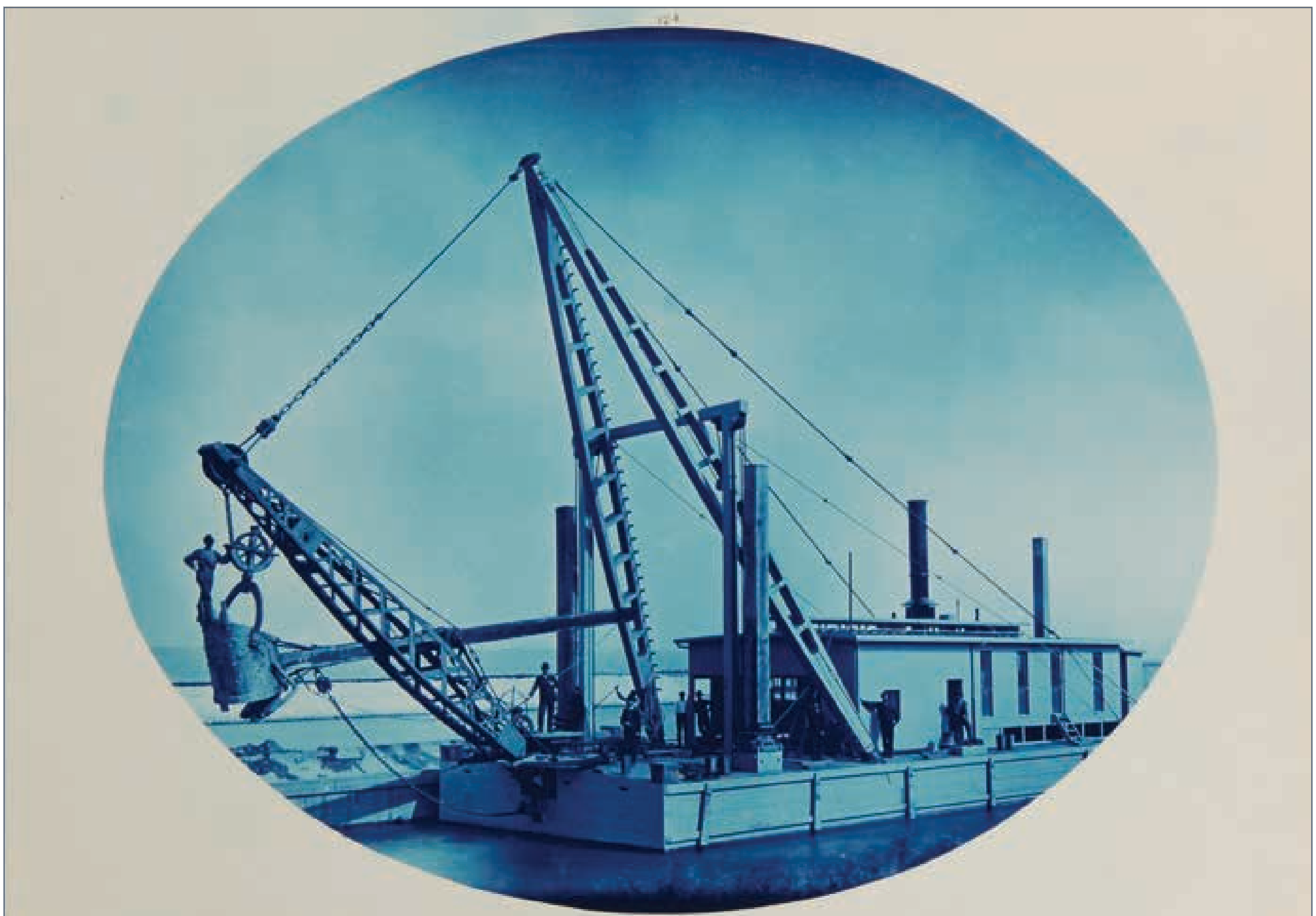
Much of the Corps' work in New England involved harbor preservation. At Boston, the Corps built granite seawalls along islands and headlands to hold on to the old landmarks protecting the anchorage. They also cleared the harbor of obstructive rocks and dredged a 23-foot ship channel through the rocky hardpan. At nearby Plymouth, the small historic harbor's existence depended on saving a three-mile-long sandy spit that sheltered ships from easterly gales. When winds washed gaps through this beach, the Corps first closed the gaps with timber frames filled with stone and brush. After an 1867 storm carried away this beach protection, Capt. Thomas Lincoln Casey of the Corps proposed using *beton-coignet*. He had learned in France of this concrete-like building material of hydraulic lime mixed with sand and water and packed in cribs to harden. This material, together with planted beach grass, could hold the sands protecting Plymouth's local commerce and its storm-driven merchantmen seeking safe harbor. Casey's study presaged the first applications of concrete to waterways projects.[31]

Linked to interior commerce by a state canal system and the Pennsylvania Railroad, Philadelphia hoped to compete with New York in foreign trade, and Congress approved several projects to foster this ambition. The Corps dredged the Delaware River and completed the immense Cape Henlopen breakwater, which was designed before the war to protect shipping from ice and storms, while also allowing the passage of tidal currents to scour shoals in the harbor. Some 900,000 tons of huge stones went into this breakwater to shelter thousands of ships that awaited high tides to ascend the river to Philadelphia.[32]

When a railroad line was completed to Lewes at the Cape Henlopen breakwater, Congress, in 1870, approved the construction of a pier there to transfer coal from the railroad to fuel waiting steamships. Here, the Corps experimented with a pier founded on the wrought-iron screw piles invented by Irishman Alexander Mitchell in 1847 and used earlier in lighthouse construction. Lt. Micah Brown managed the Lewes pier job, auguring the first iron screw pile down in April 1872. When he saw the shafts break after penetrating only eight feet of hard sand, Brown redesigned the screw piles to strengthen them and experimented with new methods of turning them down. Finding that men were not strong enough, he tried steam engines and found them so jerky that they snapped the piling. Thereupon he purchased seven heavy mules and hitched them with six-inch ropes around a drum to nineteen-foot white oak levers attached to the piling. Although the seven-mule hitch sometimes broke the six-inch ropes, they slowly turned the screw piles down into the sand. When completed, the pier served merchantmen and warships awaiting tides in the breakwater's lee, and a telegraph station was built on it to notify Philadelphia of ship arrivals and departures.[33]

Baltimore, at the head of Chesapeake Bay, had a channel excavated before the war in the fifteen-mile approach to its docks, and with matching funding from

St. Paul District, U.S. Army Corps of Engineers



Henry Bosse photo of the U.S. engineer dredge *Phoenix* in 1885. The now famous photographer was an engineer and draughtsman for the Corps and took hundreds of photos of the efforts to reshape the Mississippi River for modern transportation.

the city and Congress after the war, Col. William P. Craighill of the Corps laid out a new channel that was five miles shorter and began dredging it to a 24-foot depth. Finding that clamshell dredges, with two jaws that opened and shut, could excavate three times faster than the older dipper dredges with scoops, Craighill adopted the relatively new technology, putting as many as thirteen to work at once on the channel. Completed in 1874 and named Craighill Channel in his honor, the channel, together with the wharves, elevators, and warehouses built by the railroads, transformed Baltimore into the second busiest port on the Atlantic coast.[34]

Except for a minor project at San Diego, the Corps had made no prewar improvements at West Coast harbors. Congress turned its attention to opening the Pacific coast harbors in 1869, the year the transcontinental railroad was completed to California. Among the Corps' first West Coast projects were efforts to improve access to Portland, Oregon, by dredging an eighteen-foot channel through the bars blocking the Columbia River, and efforts to remove obstructive rocks from San Francisco Bay. During the 1890s, the Corps struggled to increase the lower Columbia River ship channel to twenty-five feet.[35]

San Francisco had an excellent natural harbor through the Golden Gate except for the 190-foot-long Blossom Rock lurking between Alcatraz and Yerba Buena Island. When Congress funded the removal of this rock in 1869, Capt. William Heuer of the Corps tested the use of explosives by placing watertight casks packed with gunpowder on the rock's surface, running wires from the casks to batteries aboard a scow, and detonating the charges. When soundings revealed the

Office of History, Headquarters, U.S. Army Corps of Engineers

Cutterhead dredge at work in Oakland Harbor, 1884 charges accomplished little, Heuer reported it would be necessary to drill deeply into the rock and fill the holes with more powerful explosives, perhaps nitroglycerin—a costly procedure that ultimately proved successful.[36]

A contractor for the Corps also designed a revolutionary dredge used to open Oakland's harbor across San Francisco Bay. The Gilded Age was the heyday of dredge design when engineers invented many new dredge types: clamshell, orange peel, double dippers, and improved hopper dredges that used giant steam-powered pumps to jet or pump sand shoals from harbors. The Corps successfully applied the newly designed cutterhead suction dredge to the improvement of Oakland harbor.[37]

Southern California harbors at Los Angeles and San Diego were also obstructed by shallow shoals. Noting in 1869 that Los Angeles, with eight thousand residents, afforded an outlet for California wine, and that troops bound for the Arizona Indian wars landed there, the Corps surveyor thought Los Angeles had potential, although its harbor entrance was only two-feet-deep at low tide, and ships stopped at San Pedro outside the harbor, hiring lighters to discharge or take on cargo. With meager funding available, the Corps planned a cheap jetty of driven piling filled with brush and stone, thereby confining ebb tides to scour away sand shoals blocking the entrance. The Corps awarded contracts for building it in 1871. Contractor failures, storm damage, and driblet funding delayed completion until 1881, but the jetty opened a ten-foot-deep channel.[38]

However, when the Corps planned a second jetty to further deepen the harbor entrance, its plans became enmeshed in the competition between the Southern Pacific and Union Pacific railroads for the Los Angeles market. When the Union Pacific gained control of the railroad to the harbor, the Southern Pacific built its own pier at Santa Monica and named it Port Los Angeles. Both railroads then lobbied Congress to build breakwaters protecting their respective docks. Congress appointed a series of engineer boards to study the sites, and these investigations continued into the 1890s before the San Pedro site was at last selected. Here, unlike the situation at the Great Lakes, railroad competition had stymied waterways progress.[39]

Farther down the coast, in 1869, San Diego harbor was blocked by shoals and sediment deposited by the San Diego River. The harbor handled only 40,000 tons of commerce annually. An 1854 Corps effort to divert the San Diego River to reduce sediment in the harbor had failed, but in 1875 Congress funded renewal of the diversion dam project and subsequently approved a 7,500-foot-long jetty built of brush mattresses weighted with stone to confine tidal action. The successful works opened a 24-foot-deep harbor entrance, and by the 1890s San Diego's commerce had climbed to 150,000 tons a year.[40]

CHALLENGES TO THE CORPS

In 1867, the Corps had begun experimental dredging to remove shoals that were blocking passes at the Mississippi's mouth, but this program suffered so many delays and disasters that by 1873 Congress had become impatient. Reviewing other means of opening a reliable approach to the Crescent City and providing an outlet for the surplus grain and produce of the Midwest, the Corps recommended the construction of a ship canal with a navigation lock to circumvent the passes.[41]

As a result of the Homestead Act, which granted low-cost federal land in the West to farmers, and also because of the application of mechanized equipment to agriculture, Midwestern grain production had so increased by the 1870s that an immense surplus had developed. Farmers exported their grain surpluses to foreign markets, and by 1872 nearly half of Great Britain's wheat and flour came from American farms—much of it shipped via the Erie Canal and by railroads to New York harbor. Claiming that railroads charged exorbitant rates for carrying produce to markets, farmers organized the Grange and formed political alliances to lobby for lower rates, contending that improved waterways could offer competition for the railroads.[42]

A congressional committee prepared an elaborate report arguing that improved waterways might regulate railroad rates in two ways: waterways could offer a cheap transportation alternative to railroads, and improved waterways might force railroads to reduce their charges to meet the competition. The committee reported favorably on building three west-to-east waterways from the Midwest to the Atlantic: a Northern Route consisting of a canal from the Mississippi to Lake Michigan and improvements in Great Lakes channels to the Erie Canal; a Southern Route extending up the Tennessee river and via a canal over the mountains to the rivers of Georgia; and a Central Route including improved navigation on the Ohio and Kanawha rivers and a canal across the Appalachians to the James River. All these plans revived old concepts that had been studied before the Civil War.[43]

These three proposed routes to the seaboard garnered additional political support for several waterways projects. In 1875, for example, Congress approved the construction of locks and dams on the Kanawha and Ohio rivers—sections of a Central Route that would be useful even if the canal to the seaboard were never built, which turned out to be the case. Congress also authorized building Muscle Shoals Canal, an integral section of the proposed Southern Route, because this canal could be used immediately by steamboats plying the Tennessee River. For the Northern Route, which linked the upper Mississippi River with the Great Lakes, Congress approved two canals: the Wisconsin and Fox River route to Green Bay on Lake Michigan, and the Hennepin Canal from Rock Island to the Illinois River and Chicago. Except for the Ohio and Kanawha River locks and dams, however, the Corps designed these projects for use by steamboats, but it completed none of them in time to save the dying steamboat trade. Only the Ohio and Kanawha locks and dams, designed for towboat-barge commerce, developed benefits commensurate with their costs.[44]

The congressional committee also maintained that the Mississippi River offered an attractive alternate waterway outlet for Midwestern farm produce, and it supported efforts to deepen the passes below New Orleans. After studies of shoals blocking the Mississippi's entrance, the committee was about to recommend the Corps' plan to construct a ship canal to New Orleans at a cost of millions when James Eads, renowned for bridging the Mississippi at St. Louis, offered to deepen the entrance to the Mississippi by building parallel jetties through a pass, thereby increasing flow velocity to scour away the obstructive shoals. He proposed to accomplish it at his own risk: no results, no pay.[45]

The congressional committee withdrew its support from the Corps' ship canal and urged consideration of Eads' jetties. A board of civilian and military engineers went to Europe to inspect jetty systems used there, and when they returned, most supported Eads' plan. They were impressed by British engineer Charles Hartley's jetties that improved a mouth of the Danube River, and by the Dutch jetties built at the Maas mouth of the Rhine. The board recommended that Eads' jetties be constructed of brush mattresses and stone, like those at the Maas, in one of the Mississippi River passes. Humphreys and other Corps officers vehemently disagreed, arguing that the hydraulics of the Danube and Maas, flowing into the nearly tideless Black and North seas, did not correlate with conditions on the Mississippi and that the Mississippi's outlets more closely resembled those of the Rhone River where French jetties had failed. An alluvial river like the Mississippi, they contended, offered challenges far greater than those overcome with jetties by European engineers or by the Corps' own jetties at Great Lake harbors; moreover, a prewar Corps effort to build jetties at a Mississippi pass had failed.[46]

Humphreys and fellow officers strenuously urged that Congress approve building a ship canal to New Orleans, while Eads, supported by Col. John Gross Barnard, a Corps officer and rival of his chief, Andrew Humphreys, campaigned for the jetties. Some senators framed a contract with Eads, offering him $5.25 million for constructing jetties at a Mississippi pass, provided the jetties deepened the channel to specific depths. Eads' offer of contracting on a "no results, no pay" basis earned him sufficient congressional support in 1875 to secure approval of his scheme.[47]

Eads and his company built the South Pass jetties of willow rafts floated into place along lines of driven piling and then compressed by placing heavy stones atop them. By 1877, the two parallel jetties formed a walled shipping channel more than two miles long through

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James B. Eads (1820–1887), ca. 1875

the pass and, as Eads predicted, when the jetties were completed, the river's flow washed the obstructive shoals into deep water, increasing channel depth to twenty-six feet and eventually thirty feet. Eads, already renowned for his St. Louis bridge, became famous as a waterways expert because of his success at the South Pass. His fame stimulated national demand for his services, especially at Galveston, Jacksonville, and Sacramento.[48]

Interest in Eads' jetties at Galveston harbor was also inspired by a Corps failure to achieve an adequate channel across shoals that limited ship draft there to nine feet. Opening a channel at Galveston was especially important because no deepwater harbors then existed on the Texas Gulf coast, and the railroad built to Galveston served as a main outlet for Texas and southwestern products. The Corps had begun efforts to attain an eighteen-foot channel in 1870, first trying to remove the obstructions with dredges. When dredging proved unsatisfactory, the local officer in 1873 proposed building parallel jetties to concentrate tidal flow over the shoals, but because stone was too expensive, he recommended building them of experimental "cement pots" called gabions. These six-foot diameter cylinders, made of woven trees coated with cement, set in place in the jetties and filled with sand, were to serve as an economical substitute for stone. This experiment began in 1874, but hurricanes demolished the working plant, drowned workers, and destroyed the gabion jetties. The Corps then aborted this experiment and began reconstructing the jetties with wooden mattresses and stone like those built by Dutch engineers at the mouth of the Maas. This system also faltered when shipworms devoured the wooden mattresses.[49]

Losing patience with the Corps, Galveston recruited Eads, who agreed to build jetties similar to those on the Mississippi and promised to attain a thirty-foot depth, but only if he could design and construct the project without interference from the Corps. Declaring that the Corps had frittered away funding for Galveston harbor, Texans introduced a bill offering Eads terms like those he enjoyed on the Mississippi. When Congress instead offered to make Eads a consulting engineer at the Galveston project, Eads declined, and the Corps resumed building its jetties. Constructed of massive stones capped with concrete like those built by British engineers on the Danube, the Corps jetties eventually succeeded, making Galveston a thriving deepwater port by the 1890s.[50]

At Jacksonville in 1870, the Corps built a hopper dredge to deepen the nine-foot channel of the St. Johns River to the city wharf. Like the first hopper dredge used at Charleston in 1855, this dredge had a steam-powered pump that sucked up sand from the bottom through pipes into timber bins on deck. When the bins filled with sand, the dredge steamed to a disposal area and used the pump to wash the sand overboard. Storms soon refilled the dredged channel, however, and in 1878 Jacksonville paid James Eads to plan jetties for deepening the entrance of the St. Johns River. He recommended building two converging jetties into the sea, estimating they could provide a twenty-foot channel for $1.7 million. Floridians pressed Congress to fund the Eads proposal, and Col. Quincy Gillmore of the Corps felt the pressure, preparing his own plans for jetties built of brush mattresses covered with stone. Congress approved Gillmore's jetties in 1879, and when completed, they deepened the St. Johns entrance to fifteen feet. Jacksonville itself then funded dredging to attain an eighteen-foot depth.[51]

California requested Eads' assistance with a different sort of problem. Sacramento River navigation from San Francisco to the state capital and above was threatened by debris washing down from gold mines in the Sierras. Using high-pressure water, hydraulic miners excavated the hills to find precious gold, and, borne downstream into the rivers, mining debris filled their channels, interfering with navigation, spilling floods onto farmlands, and spawning an epic competitive struggle between California's farmers and miners. Both sought federal action. Farmers pressed the Corps to stop

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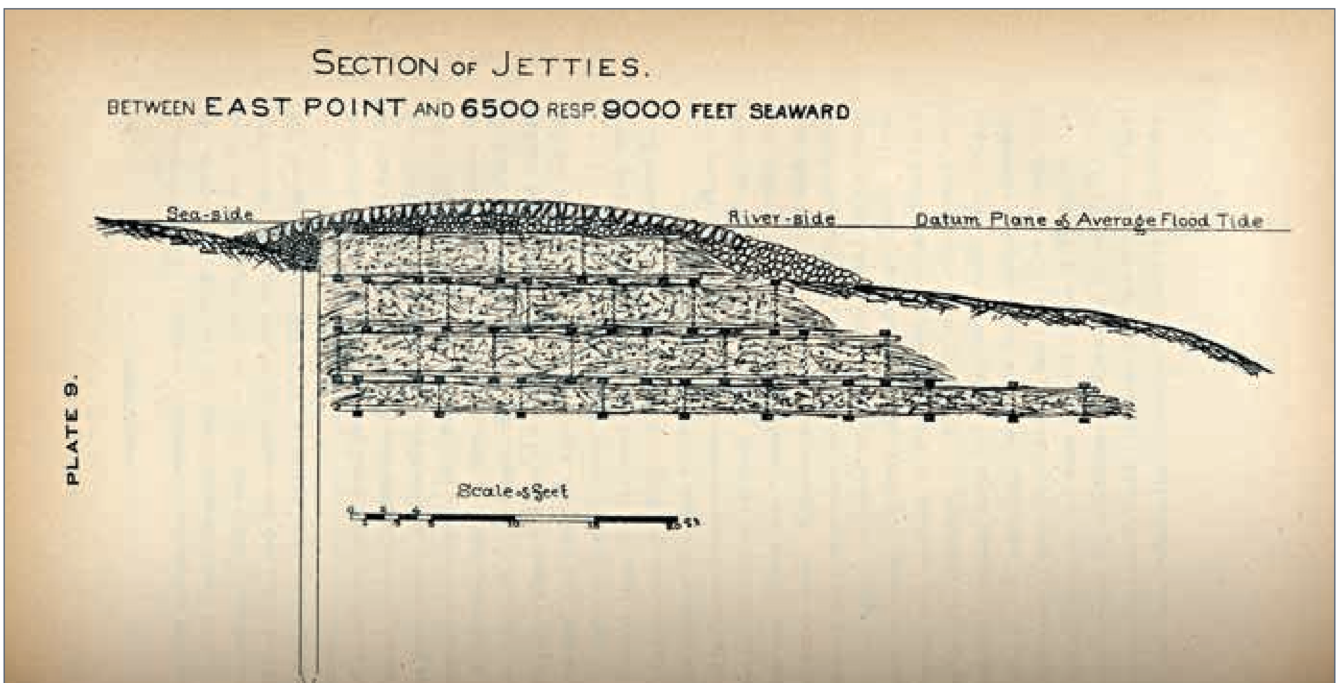

Section of Eads Jetties at South Pass on the Mississippi, 1876 the mining. Miners urged the construction of retaining dams to hold the debris, thereby allowing the miners to continue their prospecting. To encourage federal action, in 1881 California employed Eads as a consulting engineer on the Sacramento.[52]

When Eads reported that mining debris would soon destroy river navigation and begin filling San Francisco Bay, the Corps recommended building stone barrier dams across streams in the Sierras to retain the debris. This enraged farmers who declared the Corps to be a pawn of the miners. Although Congress approved barrier dam construction in 1882, California farmers obtained court injunctions against further hydraulic mining. After more studies by boards of engineers, in 1893 Congress created a California Debris Commission, partly funded by taxes on mining, which built barrier dams and regulated hydraulic mining until the industry faded in the twentieth century.[53]

Although Eads never obtained another contract like that for his South Pass jetties, his studies at Galveston, Jacksonville, and Sacramento focused congressional and Corps attention on jetty and harbor projects nationally. At Great Lakes and West Coast harbors, the Corps relied principally on jetties to deepen the entrances. Many of these jetties, however, predated Eads and resembled his design only in principle. At northern and mid-Atlantic harbors, the Corps used dredges rather than jetties to deepen the channels. It applied a combination of jetties with dredging at most southern harbors, including the South Pass. Although jetties were never entirely supplanted by dredging, the development of powerful seaworthy hopper dredges late in the Gilded Age provided tools that made jetties less significant to harbor engineering.[54]

WATERWAYS FUNDING

Many harbor improvement projects, especially in the West and South, had their origins during President Ulysses S. Grant's administration. While Grant generally approved of harbor projects, he also sought control of waterways funding. In some years, Congress accepted Grant's requests and provided lump-sum waterways appropriations to be allocated to projects by the secretary of war. This arrangement collapsed, however, during Grant's second term, when the House and Senate began earmarking rivers and harbors funding for specific projects, rather than permitting allocations by the secretary of war.[55]

This competition between the executive and legislative branches for management of waterways appropriations climaxed in 1876, Grant's last full year in office. When Congress enacted the annual rivers and harbors bill totaling $5 million, Grant signed the bill but returned it to Congress with a critical message. He asserted that it earmarked far too much for private or local projects lacking national importance, declared that he would have vetoed it if the executive had to spend all the money the act provided, and proclaimed that he would see to it that no funds were spent on projects with merely local benefits.[56]

The chairman of the House Commerce Committee retorted that Grant's funding impoundment was unconstitutional, and if Grant disapproved of the bill he should have vetoed it—the law directed the secretary of war to expend the funds; where they were expended was not discretionary. When Grant ordered his secretary of war to spend no more than $2 million of the $5 million and that only on works of national importance, the angry commerce committee chairman responded by introducing a resolution requiring President Grant to furnish Congress with copies of his orders to the secretary of war limiting expenditures and to clearly state what law had justified his actions. This resolution died as Grant left office in early 1877 amid national uproar over the disputed presidential election of 1876.[57]

Like his predecessor, President Rutherford Hayes sought to limit waterways appropriations, invariably recommending an annual appropriation of exactly $5,015,000. But Congress insisted it was a better judge of what the nation needed than the secretary of the treasury. Congress nearly doubled the annual appropriations in Hayes' four years, earmarking funds for many new projects, large and small.[58]

During this period, Congress mandated that the Corps of Engineers turn increasingly to outside contractors rather than hired labor, but not everyone agreed with the practice. Humphreys had once proclaimed "the system of contracts prescribed in the appropriation acts to be the worst possible mode of carrying on the improvement of rivers and harbors." The officers had ample reason for their concerns—many contractors failed, a few fled the country leaving their labor and creditors at a loss, and others colluded to rig bids and defraud the government. Yet by the 1880s the Corps had worked with Congress to stem these abuses, requiring penal bonds for contract performance and obtaining authority to reject unreasonable bids that grossly exceeded project estimates. By late in the century, nine-tenths of all waterways construction was done by contractors, and no officer could perform construction with hired labor without specific authority from the chief of engineers.[59]

Congratulating contractor James Eads on his success at the Mississippi's mouth, President Hayes called for major projects to improve navigation on "the two great rivers of the North American continent"—the Mississippi and the Columbia. Touring the Northwest, he urged improvement of the Columbia's mouth to provide at least a twenty-foot entrance to the river. Here the Corps paid Eads the compliment of emulation by building a jetty system based largely on Eads' jetties design. Between 1885 and 1895, the Corps constructed the south jetty at the mouth of the Columbia River, attaining a channel that was thirty feet deep across the treacherous bar, at a cost of almost $2 million. The Corps also began canal and locks projects on the Columbia to bypass the falls that obstructed steamboats at the Cascades and The Dalles. These projects opened river navigation as far as Lewiston, Idaho, to compete with a railroad monopoly dominating trade in the Columbia Basin.[60]

President Hayes' reconciliatory policy toward the South abetted efforts there to obtain increased federal waterways funding. By 1877, the South strove to encourage industrial development of a "New South" to compete with northern manufacturing. Recognizing better waterways transport as key to commercial prosperity, Southern congressmen sought federal projects for their rivers and harbors.[61]

To secure their share of the "pork," as opponents in the 1870s labeled waterways appropriations, even Kentucky's Bourbon Democrats welcomed the Republican President Hayes to the Bluegrass State in 1878, urging him to approve a federal project on the Kentucky River. Flowing entirely within Kentucky through the state capital, the Kentucky River had been improved with locks and dams as a state project before the war, but these lay in ruins after the conflict. By adroit lobbying, Kentucky congressmen, in 1878, secured funding to restore the state's locks and dams and to build more. With limited appropriations and difficult construction conditions, it took the Corps thirty-seven years to complete the Kentucky River's fourteen locks and dams.[62] After accepting control of the Kentucky River, Congress could hardly refuse to accept similar state and private projects—even though they flowed entirely within a single state—and the Corps soon became responsible for Kentucky's Green River, Ohio's Muskingum River, West Virginia's Little Kanawha River, and other old lock and dam river projects. These, like canals, required permanent personnel to operate locks and maintain the structures; hence, the district offices responsible for operations as well as engineering and construction assumed an aura of permanence. Operations and maintenance also required regular funding for payrolls and costs, which Congress

Lower Mississippi River and Tributaries

The most heavily-travelled portion of the system, the lower Mississippi River has no locks or dams like its upper segments and northern tributaries. However, the lower Mississippi is constrained by levees and dikes to control flooding and to secure navigation channels.

initially provided for the St. Clair, Louisville, and Soo canals in the annual rivers and harbors bills. When the 1883 rivers and harbors bill failed, however, Congress recognized that resulting funding shortages might force curtailment of services to commercial traffic. In 1884, therefore, Congress decided that operations and maintenance costs for canal and river locks would be funded directly by the Treasury, drawing on the annual sundry civil appropriations for the expenses of government, not the rivers and harbors appropriations.[63]

In the late 1870s, Congress initiated several projects to build locks and dams on streams that previously flowed unfettered to the sea. On the Ohio and Kanawha rivers, Congress approved lock and dam projects that involved challenging engineering that could be solved through technology transfer. Towboats and barges then were supplanting steamboats on the Ohio and Kanawha rivers, and the small locks and fixed timber crib dams used on smaller streams were not suited to towboat-barge commerce. The Corps reviewed European river engineering for useful technology and translated German and French engineering studies. The chief of engineers, Brig. Gen. Horatio G. Wright, subsequently published and distributed these translations to the Corps, explaining: "It is important, in order to avoid costly experiments, that we should avail ourselves of the knowledge and experience of other countries where it has become possible, at great expense, to reach definite conclusions as to the ultimate results of certain methods."[64]

Responsible for completing the largest navigation lock in the world at the Louisville Canal on the Ohio, Col. Godfrey Weitzel translated German reports on lock construction for study by Corps officers. For the Ohio and Kanawha rivers, Colonels Craighill and William Merrill wanted movable dams that could hold deep pools for boating at low-flow stages, yet could be collapsed against the bottom at high flows, allowing towboats and barges to pass the dams without entering the locks. In France, Merrill and Craighill found movable dams designed by Jacques Chanoine and Auguste Boule operating on the Seine near Paris. They translated the French engineering studies and adopted Chanoine's design for dams on the Kanawha and Ohio, while Weitzel used both the Chanoine and Boule designs in a movable dam built at the Falls of the Ohio.[65]

When planning the first lock and movable dam at Davis Island on the Ohio at Pittsburgh, Merrill met with complaints from the marine industry that even the widest existing locks were too narrow to handle the towboat-barge fleets that transported coal as far as New Orleans. After a worldwide review of lock designs, Merrill found in British drydock engineering a lock gate design that allowed him to design and build the widest lock in the world. At 110-feet wide, Merrill's design for the Davis Island lock (Ohio River Lock No. 1), completed at Pittsburgh in 1885, set a standard used at all of the Ohio River's fifty-one original locks and which still prevailed on many rivers more than a century later.[66]

One of the most challenging waterways projects of the late nineteenth century remained the Mississippi River. While Eads' jetties had alleviated problems at the river's mouth, improving navigation above New Orleans required far more than the Corps' snag-removal project could deliver. Continuing its studies of the river's regimen throughout the 1870s, the Corps implemented several advances. To secure reliable data on river stages and flows Colonel Merrill installed the first federal stream-discharge gauges along the Mississippi and its tributaries. Through the telegraph, daily stage reports went to river ports for publication. These reports warned pilots and shippers of hazards or shoals hampering passage along the rivers to New Orleans. At Merrill's recommendation also, Congress, in 1875, approved placing buoys and markers on inland rivers to guide pilots and contribute to navigation safety.[67]

In addition to the shoals blocking the Mississippi's low-water navigation, disastrous flooding in the valley often caused great public distress. Floods overwhelmed local and state levees time and again, and following yet another disastrous flood in 1874, Congress established several boards of engineers to study various levee improvement plans. Increasingly sensitive to river engineering controversies and no longer willing to rely solely on Army engineers, Congress—over strong objection from Humphreys—established the Mississippi River Commission (MRC) in 1879. Composed of three Corps officers, three civilians, and a Coast and Geodetic Survey officer, this mixed commission would manage the Mississippi's navigation and flood control project.[68]

With James Eads as a charter member, the MRC made its plans for improving navigation below St.

A wicket dam, part of Lock and Dam No. 8 on the Ouachita River in Arkansas, 1983

Louis. To deepen the channel at shoals blocking low-water navigation, the commission planned to confine the river's channel within a 3,000-foot width, thereby augmenting flow velocity and eroding away the obstructive shoals through hydraulic action. To reduce the channel to that width, the commission would construct permeable dikes of piling with waling and interwoven willows stretching from the existing river bank toward the channel. Where the dikes slowed the river's current, the river would drop its sediment around the dikes, eventually forming a new bank to narrow the river. Where river erosion cut into the banks, tending to expand the channel width, the commission expected to revet the banks with willow mattresses weighted with stone, thereby covering the banks and stopping the erosion.[69]

The origins of these permeable dike and willow mattress techniques lay chiefly in Europe where engineers had used them as early as the seventeenth century to contract channels, protect banks, and improve river navigation. British engineers had also used these techniques on streams in India. Well-read engineer officers such as Maj. James Simpson and Maj. Charles Suter were familiar with these European applications, and they tested the technology during the 1870s—Simpson at Sawyer Bend near St. Louis and Suter on the Missouri River. In 1878, Suter recommended these methods be used on the Mississippi, fabricating the revetment mattresses of willows, a widely available and economical material that would take root in river banks to help anchor the mattresses.[70]

Supplementing its plans to confine low-water flows to a 3,000-foot width, the Mississippi River Commission also expected to confine the river's high-water flows by repairing and strengthening the levees built by state and local governments for flood protection. By confining both the low and high flows, the commission expected to gradually establish a channel within a channel, applying the hydraulic principles made famous by Eads to the entire river below St. Louis. It promised to be an extremely costly project, and debate soon arose over whether the levee work could improve navigation at all. Eads said it would; others disagreed, describing the levee project as merely an excuse for improving flood protection.[71]

To expedite the project, the commission voted in 1882 to turn field construction over to the Corps and to organize the work in four MRC district offices, each headed by a Corps officer. The commission thereafter provided executive management and planning, and the districts conducted field operations. Because these districts reported to the commission, the chief of engineers could veto the projects but not initiate them. The construction of permeable dikes to decrease channel width and train the river's low flow began on the river section between St. Louis and Cairo, demonstrating promising results within a few years. As a result, the commission expanded its experiments with low-water confinement to reaches of the lower Mississippi.[72]

The commission's plans for confining high-water flows with levees met powerful opposition in Congress, however, especially from New York, which recognized the improved Mississippi navigation as competition for the Midwestern commerce transported east via the Erie Canal and the railroads. To remain competitive in Midwestern markets, New York freed its Erie Canal of tolls, while its congressmen, led by Samuel Cox, bitterly denounced federal funding for Mississippi levees and for waterways projects generally. Through ridicule of projects on streams with odd names such as Cheesequake Creek, French Broad, or Kiskiminetas River, Cox and his allies derided rivers and harbors bills as wrong, wasteful, and wicked. Cox's eloquent, annual tirades against waterways bills became a highlight of every session. Spectators filled the galleries, greeting his attacks on rivers and harbors bills with gales of laughter. His remarks received full publicity in the influential New York newspapers, which waterways proponents contended were the pawns of New York's railroad interests.[73]

James Garfield, who succeeded Hayes as president in 1881, was cut down by an assassin just five months after his inauguration. Although troubled by congressional funding for projects on smaller waterways, his successor, President Chester Arthur, supported the MRC's plans generally and saw a chance to implement them when a record flood drowned the Mississippi valley in 1882.[74]

The 1882 flood overwhelmed local levees, causing 284 breaks aggregating fifty-six miles in length and leaving thousands of refugees stranded on hills. For subsistence of these hungry refugees, Congress made an emergency $100,000 appropriation to supply them with Army quartermaster rations. Learning that hiring steamboats for deliveries might entirely consume the funding, Senator George Vest of Missouri met with the secretary of war and with Wright personally to ask if Corps workboats on the Mississippi might supply the refugees. Once an agreement was reached, the Senator sponsored a joint congressional resolution to reimburse Corps expenses in the emergency, and Corps snagboats and workboats then plied the river, distributing rations until the flood subsided. This first official disaster assistance mission assigned to the Corps set a precedent, and

Congress subsequently relied on Corps floating plant and on-site expertise to conduct emergency operations during flooding and other major disasters.[75]

As the 1882 flood peaked, President Arthur sent a special message to Congress asking for a $1 million appropriation for the MRC to close the breaks in the levees. Moreover, he urged congressional support for the commission's plans to permanently improve navigation and increase the security of the valley, even if it cost as much as $30 million. The valley's cotton crop not only brought in $70 million in taxes, Arthur reported, but it was also vital to the nation's international markets and its favorable balance of trade. Congress approved the levee repairs in 1882 but specifically for navigation improvement and not for flood protection.[76]

With this initial funding, the commission directed its four Corps districts to contract for repairing the broken levees and for bridging between the uncompleted levees with new levees of compacted earth. This first federal levee work was accomplished manually, using wheelbarrows and mule-drawn slip scrapers, but soon the construction methods improved. Wheeled scrapers replaced slip scrapers and experiments began with various types of elevating graders, dump wagons, and engine-powered earth-moving equipment. By 1889, the commission had completed a continuous line of levees along the river's main stem, although with low grades and weak sections inadequate to withstand another record flood in 1890. In each of its appropriations for this work, Congress directed that none of

Office of History, Headquarters, U.S. Army Corps of Engineers

Refugees and livestock on the levee near Hickman, Kentucky, during the flood of 1912 the funding should be used to build levees to prevent overflows or for any other purpose except as a means of deepening and improving the navigation channel.[77]

Although the Mississippi River Commission had investigated the prospect of building storage reservoirs on the upper Mississippi River and concluded they were too costly as a flood control method, construction of the Corps' first storage dams and reservoirs began upstream of the Falls of St. Anthony at Minneapolis. The Corps had saved the Falls of St. Anthony during the 1870s by stopping destructive erosion—a preservation effort that had aroused opposition on grounds that it chiefly benefited the water-powered lumber and flour mills at the Falls. When opponents argued that building storage reservoirs on tributaries upstream of Minneapolis would again chiefly benefit the lumber and flour milling industry, advocates of the storage reservoirs countered that by containing spring rains for release during summer droughts the reservoirs could supply increased depths for river navigation to Minneapolis, and what harm was there if millers also benefited from augmented flows?[78]

To increase the upper Mississippi's low-water flow, Congress, in 1880, appropriated $75,000 to build the first storage dam at Lake Winnibigoshish, and in 1882 it funded dams at Pokegama Falls and Leech Lake. These timber crib dams began operating in 1883 and two more were added in 1885. Together, they increased drought flows of the river at Minneapolis by 50 percent, aiding navigation and also water-power production at the Falls of St. Anthony, where the nation's first commercial hydroelectric plant began operation in 1882. At these pioneering storage reservoirs, the Corps first encountered the challenges of real estate acquisition for inundated lands, a legal battle that continued into the twentieth century. Some of the lands lay on reservations of the Chippewa, whose fierce resistance to the reservoirs ended in a disastrous 1898 battle described as the "last Indian uprising in the United States." At these storage dams also, the Corps employed its first "dam tenders" and began to learn the intricacies of reservoir management. Like the Corps' lockmasters, the dam tenders were paid by requisitions to the Treasury and from annual sundry civil bills rather than from rivers and harbors appropriations.[79]

Both the Mississippi River levees and the storage reservoirs received major funding in the rivers and harbors bill of 1882, which totaled $18.7 million, double the annual appropriations of 1880 and 1881. The 1882 bill, moreover, shocked northeasterners because it funded $10 million worth of projects on the Mississippi River system while providing only $8 million for northeastern harbors. President Arthur vetoed this bill in August 1882, claiming that it funded local projects contributing little to national defense, general welfare, or commerce. He urged Congress to enact a substitute bill that would provide only half the $18.7 million total for the coming fiscal year and requested that the funds not be earmarked but rather allocated to projects selected by the secretary of war with the president's concurrence.[80]

When Congress ignored Arthur's protests and enacted the bill over his veto, newspapers throughout the nation raised a hue and cry against the act and the congressmen who had voted to enact it. Three months later, in the November congressional election, the Republican Party lost its majority in the House, and as one congressman vividly phrased it, "The destroying angel came. He struck down the first-born of the river and harbor statesmen throughout the country."[81]

When Congress convened its lame duck session in December 1882, President Arthur requested that it not enact another waterways bill in 1883 and rely instead on the 1882 act's abundance to carry projects into 1884. In addition, he suggested a means of permitting the president to reject some projects while keeping others, equivalent to a line-item veto. Ignoring this, Congress directed the secretary of war to prepare and submit to it a list of the projects funded in the 1882 bill that he and

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Construction of the original timber dam on the Deer River at Lake Winnibigoshish in Minnesota, 1884

the president thought lacked national importance.[82] Conferring with the president, the secretary learned that Arthur, in his veto message, had referred to projects with little or no foreign or interstate commerce as lacking national significance. The secretary, therefore, compiled a list of the projects so defined. Arthur's "hit list" included ninety-two small projects with appropriations aggregating $1 million, about 5 percent of the $18.7 million in the 1882 act. Congress proved unwilling to surrender its appropriations that were earmarked for small projects, and, when pressed by Congress, the chief of engineers admitted that the improvements that were authorized for small harbors and streams often generated significant commercial benefits.[83]

While denying Arthur's policy, the House reacted by reorganizing its oversight of water projects, transferring river and harbor appropriations from its commerce committee to a newly formed Committee on Rivers and Harbors. Pending formation of the new committee, however, the commerce committee drafted an $8 million waterways appropriation for 1883, sparking its opponents to an extended debate. The opposition to the bill succeeded in delaying a House vote until too late in the session for enactment. This defeat set a precedent that eventually converted rivers and harbors bills from annual into biennial appropriations.[84]

Grover Cleveland's presidential veto of the annual rivers and harbors bill in 1887 was a major setback for the Corps, not only in lost funding but also in statutory authority because the bill had contained a vital section on real estate policy. Because the Corps had acquired the lands needed to build a growing number of navigation projects, Congress first addressed individually the property-acquisition issues raised at each project, mandating that the Corps use state courts for condemnation proceedings. Field experience in the postwar years demonstrated that purchasing project lands and condemning them in state courts often delayed project construction while high real estate prices and court awards drove up costs. The bill Cleveland vetoed in 1887 included general authority for the Corps to purchase project lands without seeking specific individual authority from Congress and, if need be, to condemn the property in federal courts. When Congress convened again in 1888, however, the chief of engineers attended committee meetings with a draft of the general real estate policy in hand. Congress then enacted the revised real estate legislation desired by the Corps but specifically exempted the Mississippi River levee project from this authority. For that project, Congress directed that federal funds be applied only to construction after the local levee districts had supplied the rights-of way.[85]

CASEY REORGANIZES AND REGROUPS THE CORPS

Eads' successful battle with the Corps and the formation of the Mississippi River Commission including civilian engineers in 1879 encouraged the idea that rivers and harbors projects might be better managed by civilian engineers than by the Corps alone. In 1884 Congress established the Missouri River Commission in emulation of the Mississippi River Commission. Composed of three Corps officers and two civilians to plan systematic improvements, the Missouri River Commission sought to focus on turning the truculent river into a viable transportation route rather than expending funds piecemeal on local improvements, chiefly projects that protected riverside property from erosion. Congress even considered forming a Southwestern River Commission to manage projects on the Red, Arkansas, and other western streams, further eroding Corps dominance of national waterways management, but this proposal was not enacted.[86]

At the same time, Congress reviewed bills that proposed the creation of civilian Departments of Rivers and Harbors or a U.S. Civil Engineer Corps to supplant military management of civil works. The proposed organization of these civilian agencies typically included plans to assign department or division engineers permanently to regional offices throughout the U.S. for local supervision of federal projects. In addition, the Army, as part of the old struggle between line and technical officers, expressed its support for divisional management of military construction. Gen. John Schofield argued that Army division commanders in the field should provide immediate supervision of fortification construction where the chief of engineers could not. This was especially true at Pacific coast forts, which were "under the immediate eye of the division commander, but which the chief of engineers may never see." The chief of engineers retorted by asking who was more competent to manage fortification construction: the commander of an Army division or the chief of engineers. Competence aside, the Corps, in the 1880s, waded in deep water, threatening to drown both its civil and military missions.[87]

With these challenges in mind, the chief of engineers, Brig. Gen. John Newton, decided in 1884 to experiment with regional management of projects along the Middle Atlantic coast near Washington, where, because so many junior officers were trained in engineer district management, the area had become known as the "kindergarten." Newton appointed Colonel Craighill as the supervising engineer for the district offices, which were "contiguous and convenient to these Headquarters" at Washington. Craighill had great experience, having successfully completed projects ranging from the Susquehanna River to Cape Fear and from the Craighill Channel at Baltimore to locks and dams on West Virginia's Kanawha River. Receiving instruction on his duties as supervising engineer in June 1884, Craighill replied that he had taken due notice and would govern himself accordingly. He then notified district engineers at Philadelphia, Norfolk, and Washington that they should submit their monthly reports through him to the chief and forward their funding requests to him for review.[88]

Newton found Craighill's service as supervising engineer so useful that in 1885 he made Col. George Mendell at San Francisco the supervising engineer for the Pacific coast, and in 1887 he named Col. Walter McFarland supervising engineer for the Gulf coast. Brig. Gen. Thomas Lincoln Casey, chief of engineers in 1888, determined that the experiment with supervisory engineers was so beneficial to public service that he drafted a revision of Army regulations and with approval from the secretary of war published it in December of that year. It established division engineers as the senior officers who would regularly inspect projects within their region and through whom the district engineers would submit their plans, progress reports, and funding estimates. Each division engineer was allowed an office, a clerk, and reimbursement for travel to the projects they supervised.[89]

Office of History, Headquarters, U.S. Army Corps of Engineers, H. Abbot Collection

John Newton (1822–1895), who became Chief of Engineers in 1884

Casey divided the nation into five parts, placing the region west of the Rockies in the Pacific Division and quartering the remainder into four divisions listed by the compass points they occupied. Col. George Mendell at San Francisco, Col. William P. Craighill at Baltimore, Col. Henry Abbot at New York, Col. Cyrus Comstock at Galveston, and Col. Orlando Poe at Detroit became respectively the Pacific, Southeast, Northeast, Southwest, and Northwest division engineers. These were the most experienced senior officers of the Corps, and they performed such yeoman service that their responsibilities were gradually increased. These five served until 1895, when Craighill became chief and the rest retired.[90]

Casey's second major contribution to the Corps program came in response to the biennial appropriations policy instituted during the 1880s by the president and Congress. When the Rivers and Harbors Committee drafted a $22 million waterways appropriation in 1888, President Cleveland had threatened to veto it until Casey reassured him that the bill contained few worthless projects. The president then let it become law without his signature. The Rivers and Harbors Committee again tried to pass an annual bill in 1889, drafting a $10 million appropriation that was debated in the House but not enacted, once more forcing the Corps to suspend construction on many projects late in the fiscal year. Complaining that this "driblet" appropriations policy was poor business, leaving projects exposed to the weather and substantially increasing their costs, members of the House committee asked Casey what should be done.[91]

Casey had managed construction of the elaborate Library of Congress building started during the 1880s. For this project the supervising architect of the treasury had secured congressional approval for a continuing contract, that is, a contract for the entire estimated cost of the building, with an understanding that Congress would guarantee funding for the work in the annual sundry civil appropriations for the expenses of government. This arrangement had produced savings, and Congress approved a similar continuing contract for building the huge District of Columbia post office. Casey suggested applying this continuing-contract system to a few large waterways projects as an experiment. With specific authority from Congress, the Corps would contract for the entire construction cost of a project, and then produce yearly estimates of work the contractor could accomplish in a fiscal year. The work would be funded in the annual sundry civil bills. By assuring bidders that construction would not be suspended for lack of funding, Casey insisted the system would result in reduced bid prices and significant savings to government; moreover, projects could be completed on schedule, making them available for service at earlier dates than under the "driblet" system of irregular rivers and harbors appropriations.[92]

The House Rivers and Harbors Committee presented Casey's proposal during consideration of the 1890 rivers and harbors bill, and Congress authorized five projects in that bill as concept tests. These were the Baltimore, Galveston, and Philadelphia harbors, and the Sault Ste. Marie and Hay Lake channel projects on the Great Lakes. When Casey reported savings in contract bid prices on these five, averaging 33 percent and totaling $4 million, Congress added thirteen additional projects to the test group in 1892. With regular funding provided in annual sundry civil acts, rather than in biennial rivers and harbors acts, firm construction schedules fostered on-time completion of these projects at reduced costs. Hailing continuing contracts as "the true solution of river and harbor improvement," the Rivers and Harbors Committee for the first time in 1891 did not draft an annual waterways bill. Thereafter the committee submitted only biennial appropriations. In Congress during the 1890s, the political battles over rivers and harbors bills shifted emphasis from obtaining new project authorizations to adding existing projects to the continuing-contract system.[93]

President Benjamin Harrison, personally familiar with Corps capabilities from his earlier service in Congress and his brief tenure on the Mississippi River Commission, turned to Army Engineers for help in 1889 when a flood breached a private dam and destroyed Johnstown, Pennsylvania, drowning more than two thousand residents. The flood wave destroyed all bridges in Johnstown except a stone bridge below town that debris made impassable. The president ordered the Corps to dispatch engineer troops with temporary bridges to Johnstown forthwith.[94]

The Corps had ponton bridges at Willets Point Engineer School and at West Point where they were used for cadet training. Col. John Parke, West Point's superintendent, sent the academy's detachment with its bridge, while Casey dispatched troops from the Engineer School with bridge equipage. Capt. Clinton Sears at Johnstown directed the installation of the ponton bridges, and, at the governor's request, he also planned and managed the removal of flood debris blocking the stone bridge. The Corps' swift action at Johnstown earned resolutions of thanks from the city and a personal commendation from President Harrison.[95]

Years before, while still serving on the Mississippi River Commission, Harrison had voted with Cyrus Comstock of the Corps in the minority that had opposed repairing and strengthening the levees confining high-water flows to deepen the navigation channel. During his presidency, the commission came to a decision on its original plan for a channel within a channel. Rather than abandoning its levees for high-water confinement as Harrison had recommended, however, the commission ended its campaign to confine the low-water channel to a 3,000-foot width through contraction works.[96]

The commission's experimental confinement work on the 200-mile Mississippi section between St. Louis and Cairo, which used bank revetment to stop erosion and permeable spur dikes to slow the current and cause

Accumulated debris at the Pennsylvania Railroad Bridge, Johnstown Flood, June 1889

siltation, had successfully narrowed and trained the channel to greater depths. On this upper river stretch, however, the low-water channel was less than half the width prevailing below Cairo; moreover, the muddy Missouri pouring in at St. Louis supplied abundant sediment, which soon filled spaces between the permeable spur dikes to form new banks thereby narrowing the channel. The commission's experiments with confining the low-water channel at Plum Point and other reaches of the lower Mississippi were less successful. Mattress revetments often failed, and the supply of silt was so uncertain and its deposition so slow that permeable spur dikes made of wood often decayed before new banks had formed around them. It became evident that deepening the low-water channel through contraction would be very costly, perhaps more than $30 per lineal foot the entire length of the river. In 1890, the commission took heed of advancing dredging technology to test another method for deepening the low-water channel.[97]

In 1891, the Mississippi River Commission contracted for building its first cutterhead pipeline dredge as an experiment. Designed by Henry Flad, formerly assistant engineer to Eads on the St. Louis bridge, the *Alpha* was completed in 1893. Tests showed it could excavate hundreds of cubic yards of material per hour from the river bottom to deepen the low-water channel. The commission soon built a small fleet of dredges, and by 1896 it had concluded that dredging could provide a nine-foot depth below Cairo at far less cost than attempting to deepen the channel with contraction works. Thereafter, the commission continued building levees to contain high-water flows within the channel while also offering flood protection, but it relied chiefly on dredging to deepen and maintain the low-water channel and on bank revetment to prevent cutoffs and to protect harbors and levees against erosion.[98]

Pipeline dredges, so useful on inland waterways, were unsuited for work at sea to deepen ship channel entrances to harbors. For this task, the Corps turned to vastly improved and more powerful hopper dredges. These also used pumps and suction lines to excavate channels, sucking up materials into hoppers for storage, and then pumping it overboard after steaming to a disposal area. After the war, the Corps built hopper dredges to work at the Charleston, Savannah, and Jacksonville harbors. At New York in 1885, after efforts with dipper and clamshell dredges failed to achieve the required channel depth, the Corps awarded a contract to build and operate hopper dredges to Joseph Edwards, who made many design improvements and successfully completed New York's thirty-foot Gedney Channel in 1891. Learning from Edwards' designs, the Corps contracted for its own hopper dredges, employing crews and dispatching them to Gulf and West Coast harbors where they excavated channels even deeper than were achieved through jetty construction.[99]

Opening deeper waterways was the Corps' primary mission, but keeping them open proved just as challenging. For decades, state governments and Congress had authorized railroads to build bridges over navigable waters, often without considering how bridges might obstruct commercial navigation. For decades, neither state nor federal government had regulated the dumping of refuse into waterways although its removal drove up the costs of waterways project construction and maintenance. And for decades, steady encroachments by bank filling and pier construction had narrowed navigation channels. The Corps, as the principal federal waterways agency, complained bitterly of these practices without results.[100]

Expanding railroads bridged many waterways after the Civil War. Approval was obtained from state governments or from Congress, if at all. For rivers flowing within single states, state legislatures approved bridge construction with little consideration of the effects on waterborne commerce. As a result, improperly designed bridges ruined commercial navigation on such streams as the Wabash and Wisconsin rivers. On larger waterways, Congress exercised its authority and granted bridge permits individually, sometimes asking for Corps review of the bridge plans, sometimes not.[101]

By the 1870s, Corps field offices warned that the growing number of poorly designed bridges presented obstacles that might destroy river commerce. They recommended a national policy to extend congressional authority over all navigable streams and mandate Corps review of bridge plans and construction to assure unimpaired navigation. The chief of engineers presented these recommendations to Congress, and during the 1880s Congress steadily refined its control over bridge construction. Railroads sometimes ignored the bridge laws, however, and Casey advised the Rivers and Harbors Committee that stronger laws, enforced by imprisonment for violators, appeared necessary. The 1890 Rivers and Harbors Act included an anti-obstructionist package of legislation that reflected Casey's recommendations, providing for Corps review and inspection of all bridges over navigable waterways and stiff penalties for its enforcement.[102]

The 1890 act also addressed the obstruction of navigation by encroaching structures and the dumping of refuse into channels. It was a nationwide problem, but public attention was focused on New York, where for decades state and federal authorities had sought to stop dumping and encroachments into the harbor. There, a multi-agency board chaired by a Navy officer was authorized to draw harbor lines beyond which encroachments and dumping were forbidden. Similar harbor lines were to be delineated by the Corps at other ports. The 1890 act also imposed penalties for dumping refuse into water-

National Archives, 77-HQ-456-1

Bank revetment work using fascine willow mats along the Arkansas River near Pine Bluff, Arkansas, 1881

ways that caused obstruction, but the wording of the act proved unenforceable. In response, Congress revised the act in 1894 and in 1896 further authorized the Corps to draft a compilation of regulations forbidding the obstruction of waterways by any means. This effort resulted in the creation of a nationwide permit program and provided for the arrest of violators. For the first time, the Corps had the tools it needed to prevent the impairment of national waterways, and with few modifications these tools served into the modern era.[103]

TECHNOLOGICAL ADVANCES OF THE 1890S

Before 1890, the Corps principally used stone and wood in waterways structures—locks and dams, piers, and jetties. These easily available, economical materials had been used by builders since ancient times. Stone structures served for centuries if carefully constructed; wooden structures might last for decades when the wood remained submerged. About 1890, however, the Corps began its transition to twentieth century technology, building with concrete instead of stone, and steel instead of wood. While this change increased construction costs, the longer design life of concrete and steel offered long-term savings in maintenance costs that could not be ignored; moreover, concrete could be shaped in forms hardly possible with stone, and steel's great strength provided far more design flexibility than wood.[104]

In the period after the Civil War, the Corps built piers, breakwaters, or jetties in two basic forms. One form involved driving parallel lines of wooden piling and then filling the space between with layers of rubble stone atop brush or willows, perhaps with a wooden superstructure. Another form consisted of building wooden pens, floating them into line side by side, filling the pens with rubble stone, and again constructing a wooden superstructure, perhaps with stone paving. Where storms threatened structural integrity, huge stone blocks weighing many tons could be placed alongside piers and jetties to break storm waves and erosive action. However, the wooden superstructures, especially where exposed to weathering, deteriorated and needed constant maintenance. In addition, it sometimes proved difficult to obtain satisfactory stone except by costly transport from distant quarries. At some harbors during the 1890s, notably Galveston, the Corps began substituting concrete blocks for more expensive quarried stone, a technique developed by French and British engineers. The Corps began replacing wooden superstructures by building forms atop piers or jetties and filling the forms with concrete, another advance pioneered in Europe.[105]

English manufacturers had developed improved Portland cement before the Civil War, but transportation costs prohibited its use for construction in the United States until commercial production began late in the century. American engineers began using the cement in the 1890s. They placed the first concrete paved road at Bellefontaine, Ohio, in 1893, and the first steel reinforced-concrete bridge at Philadelphia in 1895. The Corps recognized this new building material's potential, first using it in fortification and dam foundations. Maj. William Marshall, who directed the Illinois and Mississippi Canal construction in 1891, obtained permission to experiment with Portland cement in waterways structures. Marshall became the Corps expert on concrete design and placement, building concrete locks and dams for the canal. Marshall also adopted the steel sector gates, invented by civil engineer Jeremiah Tainter. These gates eventually became the standard for spillway control. The Corps also used high-quality, foreign Portland cement in constructing the lock walls for the Cascades Canal and Locks on the Columbia River in the early 1890s. On river projects during the 1890s, the Corps capped its old timber

National Archives, 77-H-10581-206F

An excavator pulled by a tractor along the Illinois and Mississippi Canal, August 1904 crib dams with concrete. In 1895, it completed its first concrete river navigation lock on Kentucky's Rough River. Soon the Corps used concrete for harbor pier and jetty superstructures, began experiments with concrete-slab bank revetment, and devised the national standards for concrete quality testing.[106]

By the 1890s, conversion of the American iron industry to steel production offered opportunities to substitute structural steel for wood and iron in lock gates, dam crests, and other movable components of waterways projects. After studying the metal lock gates used in Europe, Capt. Harry Hodges of the Corps published the pioneering study of mitering lock gates fabricated of steel in 1892. Because steel offered much greater structural strength than wood and also promised reduced maintenance costs, the Corps quickly switched to steel for lock gates. This technological advance permitted the design and fabrication of much larger lock gates like the five sets of lock gates fabricated of 2.5 million pounds of steel for the great Poe Lock, which was completed 1896 at Sault Ste. Marie. To maintain navigation between the Mississippi and the Atchafalaya rivers, in the 1890s the Corps also designed the Plaquemine Lock with a 55-foot lock lift, then the highest in the world. When completed in 1896, the upper guard gates of the Cascades Canal and Locks were the largest pair of steel lock gates built to that time. They stood 55 feet tall and reached 52.6 feet in length, with each leaf weighing 325,000 pounds.[107]

Technological innovations extended even into the chief of engineers' office in Washington under Craighill. When he received the chief's appointment in 1895, the other senior officers retired. Maj. Henry Adams, who had managed the third division for rivers and harbors since 1885, also transferred from the chief's office in 1895. Thus the Corps acquired fresh leadership that was open to change and technological advances—a transition apparent even in handling paperwork. In Craighill's headquarters office, telephones replaced telegraph for quick communications, typewriters replaced penmanship, and the Corps purchased its first copier—a mimeograph machine.[108]

While Craighill and the Corps moved to the forefront of technology, funding for waterways projects remained a challenge. Responding to the 1893 economic depression, Congress slashed waterways funding from its $25 million apex of 1892 to only $11.6 million in 1894, but President Cleveland still disapproved and let the bill become law without his signature. Two years later, he vetoed the $14.5 million rivers and harbors bill of 1896. In his veto message, Cleveland contended the bill included far too many projects of questionable merit, and that the thirty additional continuing contracts authorized by the bill created a mortgage on future appropriations totaling $60 million. The bill was not only extravagant; it was, he insisted, insidious.[109]

New support for reviving waterways competition was developing by 1896, however, including powerful business and industrial leaders who supported a waterborne transport renaissance and also urged the management of water resources for multiple purposes. Cleveland's 1896 veto, therefore, did not receive the thunderous applause from the press that had seconded his earlier vetoes. Congress responded by declaring the number of local projects in the 1896 bill insignificant, thereby expressing its support for the continuing-contract system, and promptly overriding Cleveland's veto, with only five senators voting to sustain the president. At the end of the nineteenth century, the historic competition between the executive and legislative branches for control of waterways appropriations thus ended with congressional victory.[110]

CONCLUSION

In the years after the Civil War, the United States was transformed by engineering and commerce from the agrarian republic of Jefferson and Lincoln into the

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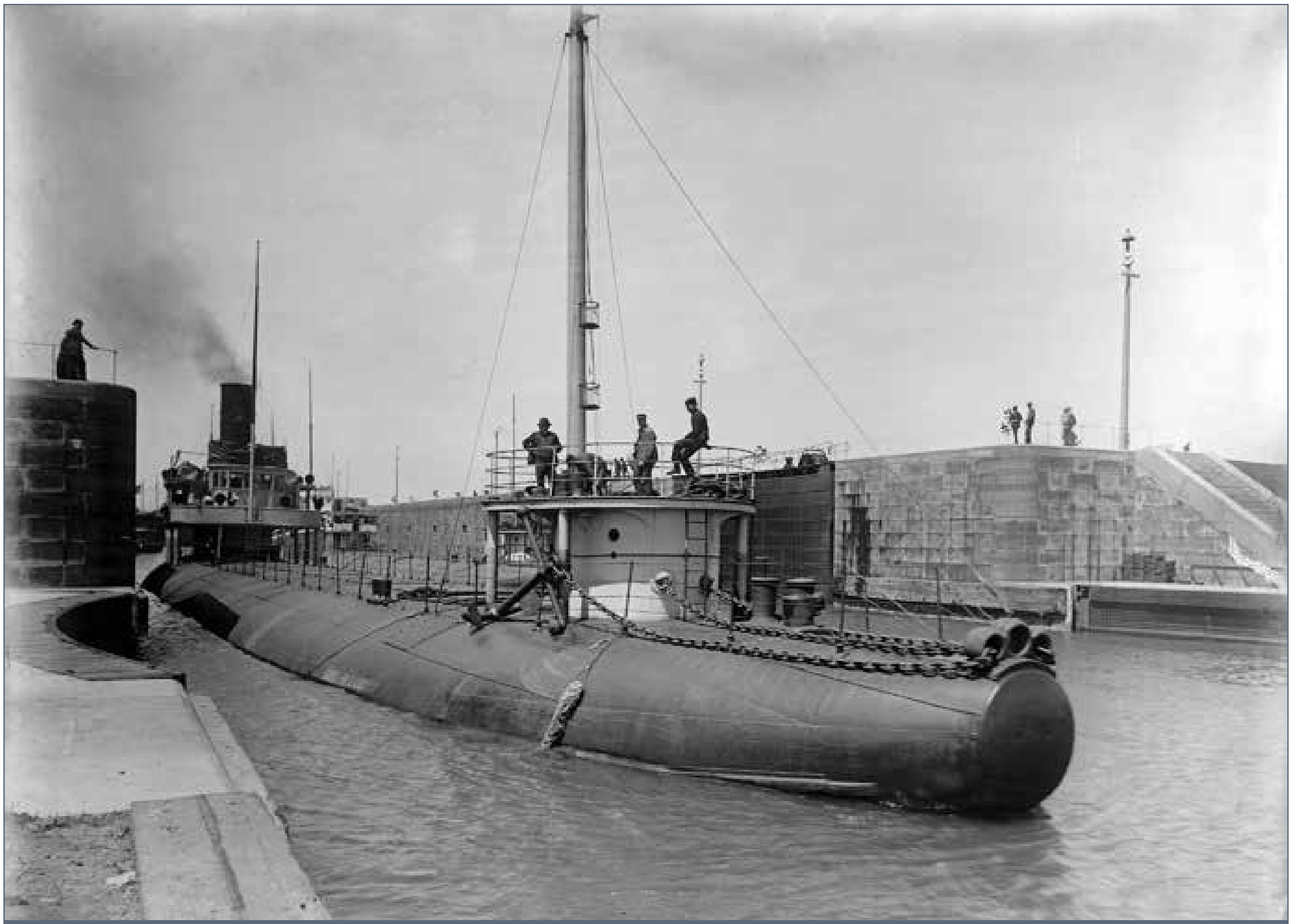

A “whaleback” transport ship—commonly used in the late 19th century on the Great Lakes and notable for carrying grain or ore—on its way through the Poe Locks, the largest in the world when completed in 1896

industrial world power of McKinley and Roosevelt. The Corps of Engineers played a significant role in this metamorphosis, applying engineering advances from every source to waterways technology—opening, deepening, and developing rivers and harbors, and fostering American economic prosperity and success in competitive world markets.

During this period, American presidents substantially affected the Corps' waterways programs. Presidents Grant, Arthur, and Cleveland enjoyed some success in their efforts to limit and direct waterways appropriations. Presidential opposition to exorbitant bills converted Congress from annual to biennial appropriations and from driblet funding to the continuing-contract system. Congress used this continuing-contract system until the formation of the Budget Bureau and a return to annual waterways appropriations in 1921.

The shady politics of the era tainted rivers and harbors bills, which were often pictured as pork barrel—an unfortunate result of political log-rolling—and as wasteful expenditures. Missing the impact of the congressional shift in 1883 from annual to biennial appropriations, some historians have emphasized the growth of appropriations from $3.7 million in 1866 for 49 projects to $14 million in 1896 for 433 projects. The 1896 bill intended to cover construction costs for two years, however, allowing $7 million per year, an annual amount just double that of 1866. In the same years, from 1866 to 1896, the population of the U.S. also doubled from 36.5 million to 70.8 million citizens. Moreover, the 1896 appropriation funded construction of nearly ten times as many projects as in 1866. The continuing-contract system pioneered in 1890 did shift some costs to the sundry civil acts, but these constituted obligations for major rivers and harbors that few congressmen or citizens opposed.[111]

The Gilded Age has been portrayed as the pinnacle of the free market economy and widespread corporate abuse—the "robber baron" era. Federal waterways projects often were justified as competition for railroad conglomerates, and in specific local situations, improved waterways did encourage reduced railroad charges, but nationally declining rail rates resulted largely from increased railroad efficiency rather than competitive waterways. Indeed, the Corps' most notable missteps came when constructing canals that link the Mississippi River with the Great Lakes and on the Columbia River, chiefly as competition for railroads. These canals saw little traffic after their completion, and as regulators of railroad charges, the improved waterways had little success. On the contrary, the Corps' most successful projects were those that complemented railroad services—deeper harbors on the Great Lakes and seacoasts where railroads served as feeders, or on rivers where rail terminals loaded commodities into barges for continued movement to export markets.

The end of the nineteenth century marked the heyday of the Corps' commitment to single-purpose water resources projects. In the early twentieth century, the Corps would have to make a difficult transition to multiple-purpose water projects. In one respect, however, the Corps' development of regulatory legislation, adopted by Congress beginning in the 1880s, presaged its role as part of Progressive-Era government committed to making dispassionate use of professional expertise for the benefit of the national community as a whole. This effort sought to protect waterways by regulating the construction of bridges, by establishing restrictive harbor lines, and by preventing corporate dumping into waterways, recognizing that the community had overriding interests in waterways.

BIBLIOGRAPHIC ESSAY

There are a number of excellent sources on the Reconstruction period. Among the best are books by James McPherson, *Ordeal by Fire: The Civil War and Reconstruction* (1982), and Heather Cox Richardson, *West from Appomattox: The Reconstruction of America after the Civil War* (2007). For the period after Reconstruction, Robert Wiebe, *The Search for Order, 1877–1920*, provides an excellent overview of American political, economic, and social history of the period and details the struggle of American society to shake off the anxious uncertainty of the years immediately after Reconstruction and move toward the "bureaucratic thought" that would prevail after the First World War.

For the story of the Army Corps of Engineers during this period, researchers may find helpful an unpublished history by Janet McDonnell, "An Administrative and Organizational History of the U.S. Army Corps of Engineers, 1865–1902." District and division histories are again a very useful resource for this period, and virtually all of these are now available digitally and online. These published histories exist for all of the modern civil works districts except the Norfolk District.

There are a number of good dissertations related to the Corps of Engineers. The most recent, "Science, military style: Fortifications, science, and the United States Army Corps of Engineers, 1802–1861" (dissertation, University of Minnesota, 2003), was authored by Mary Margaret Thomas and deals primarily with the careers of army engineers Jonathan Williams and Joseph Gilbert Totten and the development of defense works along the eastern seaboard of the United States. Two are primarily biographical. These are Thomas E. Griess, "Dennis Hart Mahan: West Point Professor and Advocate of Military Professionalism, 1830–1871" (Ph.D. dissertation, Duke University, 1968) and James W. Kershner, "Sylvanus Thayer, A Biography" (Ph.D. dissertation, West Virginia University, 1976). Another valuable resource detailing the legislative history of the rivers and harbors bills that funded most of the Army's civil works program is Edward L. Pross, "A History of Rivers and Harbors Appropriation Bills" (Ph.D. dissertation, Ohio State University, 1968). Also useful is John P. Wall, "The Civil Works of the United States Army Corps of Engineers: Program Modernization" (Ph.D. dissertation, Cornell University, 1973).

The Corps of Engineers also produced *Professional Papers*, *Occasional Papers*, and *Professional Memoirs* during this period, and these are excellent resources for biographies of key Army engineers and for original scientific research conducted by the agency. Related biographies are hard to find and are mostly unsatisfactory, at least for key engineers in the era before the Civil War. The best are probably David W. Miller's *Second Only to Grant: Quartermaster General Montgomery C. Meigs, A Biography* (2000); Richard G. Wood's *Stephen Harriman Long, 1784–1864* (1966); and Gene D. Lewis's *Charles Ellet, Jr.: The Engineer as Individualist, 1810–1862* (1968). Available biographies of George Meade and Gouverneur Warren focus overwhelmingly on their Civil War experiences at the expense of long careers in civil works. Those engineers missing biographies altogether are Andrew A. Humphreys, Joseph G. Totten, and John J. Abert.

1 Sean D. Cashman, *America in the Gilded Age*, 2nd ed. (New York: New York University Press, 1988), 1–15; John A. Garraty, ed., *The Transformation of American Society, 1870–1890* (Columbia, S.C.: University of South Carolina Press, 1968), 1–12; Edward C. Kirkland, *Business in the Gilded Age* (Madison: University of Wisconsin Press, 1952), 3–7; Carl N. Degler, *The Age of the Economic Revolution*, 1876–1900 (New York: Scott, Foresman and Company, 1975), 1–15.

2 Cashman, *America in the Gilded Age*, 44–51; John F. Stover, *The Life and Decline of the American Railroad* (New York: Oxford University Press, 1970), 79.

3 Wayne Cutler, "Jackson, Polk, and Johnson: Defenders of the Moral Economy," in Carroll Van West, ed., *Tennessee History: The Land, the People, and the Culture* (Knoxville: University of Tennessee Press, 1998), 113–27; Robert Kelley, "Ideology and Political Culture from Jefferson to Nixon," *American Historical Review* 82 (June 1977): 547–48.

4 Martin Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering: Politics and Technology in the Army Corps of Engineers, 1850–1950," *Technology and Culture* 26 (January 1985): 1–33; Robert S. Browning III, *Two If By Sea: The Development of American Coastal Defense Policy* (Westport, Conn.: Greenwood Press, 1893), chap. 5.

5 U.S. Army Corps of Engineers, *Laws of the United States Relating to the Improvement of Rivers and Harbors*, 3 vols. (Washington, D.C.: U.S. Army Corps of Engineers, 1913 and 1940), 1:144–49.

6 *Annual Report of the Chief of Engineers, U.S. Army, for 1864* (Serial 1230), 30; *Annual Report of the Chief of Engineers, U.S. Army, for 1865* (Serial 1250), 919–23. (This serial set cited hereafter as *ARCE*, followed by year of the report.)

7 *Laws of the United States Relating to the Improvement of Rivers and Harbors*, 1:151–76; *Congressional Globe*, 39th Cong., 1st Sess., 1866, 2287–93, quotes Thomas Eliot of Massachusetts who said at the war's end "from every loyal section of the land petitions have come up demanding the action of Congress in behalf of works where the highest industrial interests of the country are involved."

8 John G. Parke biographical file, Research Collection, Office of History, Headquarters, U.S. Army Corps of Engineers, Alexandria, Va. (cited hereafter as CEHO); Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering," 1–33; *ARCE*, 1867, 16; *ARCE*, 1869, 69; Janet A. McDonnell, "An Administrative and Organizational History of the U.S. Army Corps of Engineers, 1865–1902," (1989) draft manuscript, CEHO, 3–5. Humphreys reduced his office divisions to four by 1870. John Barnard of the Corps opposed Humphreys' appointment as chief because Humphreys lacked experience in fortifications construction; see Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering," 17.

9 McDonnell, "An Administrative and Organizational History of the U.S. Army Corps of Engineers," 11; *ARCE*, 1869, 3–4.

10 Leland R. Johnson, *The Falls City Engineers: A History of the Louisville District, Corps of Engineers, United States Army* (Louisville: U.S. Army Engineer District, 1975), 115–18; *ARCE*, 1870, 395–98.

11 Frank S. Blust, "The U.S. Lake Survey, 1841–1974," *Inland Seas* 32 (Summer 1976): 91–104; *ARCE*, 1870, 537–38; Arthur M. Woodford, *Charting the Inland Seas: A History of the U.S. Lake Survey* (Detroit, Mich.: U.S. Army Engineer District, 1991).

12 *ARCE*, 1870, 324–47. Walter M. Lowrey, "Navigational Problems at the Mouth of the Mississippi River, 1698–1880," (Ph.D. diss., Vanderbilt University, 1956) details developments at the passes.

13 Albert B. Hart, "Biography of a River and Harbor Bill," *Papers of the American Historical Association* 3 (1887): 180–97; *Congressional Record*, 49th Cong., 2d Sess., 1887, 1992–2002; *ARCE*, 1871, 377.

14 *Congressional Record*, 39th Cong., 2d Sess., 1867, 1822–27; Johnson, *The Falls City Engineers*, 121–31; Brian S. Osborne and Donald Swainson, *The Sault Ste. Marie Canal, A Chapter in the History of Great Lakes Transport* (Ontario, Canada: Parks Canada, 1986), 25–28; John W. Larson, *History of Great Lakes Navigation* (Fort Belvoir, Va.: Institute for Water Resources, 1983), 19–23. James Wilson was one of the five U.S. Civil Engineers whose employment Congress authorized in 1867.

15 Carlton Jackson, *Presidential Vetos, 1792–1945* (Athens, Ga.: University of Georgia Press, 1967), 128–48; Orville F. Babcock biographical file, CEHO; *Congressional Record*, 44th Cong., 1st Sess., 1876, 5631; Edward L. Pross, "A History of Rivers and Harbors Appropriation Bills, 1866–1033" (Ph.D. diss., Ohio State University, 1938), 61–63.

16 Alexander Mackenzie, *Notes on Harbors of the Great Lakes* (Willets Point, N.Y.: Battalion Press, 1869), 1–8; John W. Larson, "Ante-bellum Channel and Harbor Improvements on the Great Lakes," *National Waterways Roundtable Papers: Proceedings on the History and Evolution of U.S. Waterways and Ports*, April 22–24, 1980, Norfolk, Virginia (Ft. Belvoir, Va.: Institute for Water Resources, 1980), 41–59.

17 Raymond H. Merritt, *Creativity, Conflict & Controversy: A History of the St. Paul District, U.S. Army Corps of Engineers* (St. Paul, Minn.: U.S. Army Engineer District, 1979), 302–35; Larson, *History of Great Lakes Navigation*, 29–50.

18 *ARCE*, 1876, 433–38; *ARCE*, 1896, 324–25, 363–64, 371–72.

19 *ARCE*, 1896, 301–02; Merritt, *Creativity, Conflict and Controversy*, 302–05; *Congressional Globe*, 41st Cong., 3d Sess., 1871, 1881–83.

20 Larson, *History of Great Lakes Navigation*, 17–23; *ARCE*, 1870, 163–68.

21 John W. Larson, *Essayons: A History of the Detroit District, U.S. Army Corps of Engineers* (Detroit, Mich.: U.S. Army Engineer District, 1981), 75–78; *ARCE*, 1896, 35–57.

22 *ARCE*, 1871, 168–70; Merritt, *Creativity, Conflict and Controversy*, 298–300; *ARCE*, 1896, 351–52.

23 *ARCE*, 1871, 168–70; Merritt, *Creativity, Conflict and Controversy*, 298–300; Larson, *History of Great Lakes Navigation*, 50–56.

24 *ARCE*, 1871, 280; Congressional Record, 47th Cong., 2d Sess., 1883, 3359–62.

25 John W. Chambers II, *The North Atlantic Engineers: A History of the North Atlantic Division and its Predecessors in the U.S. Army Corps of Engineers, 1775–1975* (New York: U.S. Army Engineer Division, 1980), 23; *ARCE*, 1870, 433–40.

26 *ARCE*, 1871, 724–25.

27 *ARCE*, 1876, 238–39.

28 *ARCE*, 1877, 227–42.

29 Ibid.

30 *ARCE*, 1896, 106–09; Chambers, *North Atlantic Engineers*, 29; Marion J. Klawonn, *Cradle of the Corps: A History of the New York District, U.S. Army Corps of Engineers, 1775–1975* (New York: U.S. Army Engineer District, 1977), 107–09.

31 *ARCE*, 1870, 455–56; *ARCE*, 1871, 886–94; Aubrey Parkman, *Engineers in New England: The Military and Civil Works of the Corps of Engineers in New England, 1775–1975* (Waltham, Mass.: U.S. Army Engineer Division, 1978), 26; *ARCE*, 1896, 603–11.

32 Chambers, *North Atlantic Engineers*, 32; *ARCE*, 1896, 10–11; Todd Shallat, *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers* (Austin, Tex.: University of Texas Press, 1994), 163–66.

33 *ARCE*, 1871, 665–86; *ARCE*, 1872, 758–72; *ARCE*, 1896, 115.

34 *ARCE*, 1870, 416–18; *ARCE*, 1896, 137–38; Harold K. Kanarek, *The Mid-Atlantic Engineers: A History of the Baltimore District of the U.S. Army Corps of Engineers, 1794–1974* (Baltimore: U.S. Army Engineer District, 1974), 41–56.

35 Anthony F. Turhollow, Benjamin F. Gilbert, and K. Jack Bauer, *History of Navigation and Navigation Improvements on the Pacific Coast* (Fort Belvoir, Va.: Institute for Water Resources, 1983), 32–34; William F. Willingham, *Army Engineers and the Development of Oregon: A History of the Portland District, U.S. Army Corps of Engineers* (Portland, Ore.: U.S. Army Engineer District, 1983), 10–26, 70–71; *ARCE*, 1870, 515–16.

36 *ARCE*, 1869, 471–93.

37 *ARCE*, 1869, 460–61, prints a dredge study by Lt. Col. George Thom.

38 *ARCE*, 1869, 479–84; *ARCE*, 1871, 939–45.

39 Anthony F. Turhollow, *A History of the Los Angeles District, U.S. Army Corps of Engineers, 1898–1965* (Los Angeles, Calif.: U.S. Army Engineer District, 1975), 24–37.

40 Ibid. 66–68; *ARCE*, 1870, 511–15; *ARCE*, 1896, 387–88.

41 Charles A. Camillo and Matthew T. Pearcy, *Upon Their Shoulders: A History of the Mississippi River Commission from its inception through the advent of the modern Mississippi River and Tributaries Project* (Vicksburg, Miss.: Mississippi River Commission, 2004), 26–27; Albert Cowdrey, *Land's End: A History of the New Orleans District, U.S. Army Corps of Engineers, and its Lifelong Battle with the Lower Mississippi and Other Rivers Wending their Way to the Sea* (New Orleans: U.S. Army Engineer District, 1977), 12; Shallat, *Structures in the Stream*, 195–99.

42 Congressional Record, 48th Cong., 1st Sess., 1884, 4929. Howard B. Schonberger, *Transportation to the Seaboard: The "Communication Revolution" and American Foreign Policy, 1860–1900* (Westport, Conn.: Greenwood Press, 1971) analyzes the Senate committee's activities.

43 U.S. Congress, Senate, *Report of the Select Committee on Transportation Routes to the Seaboard*, Sen. Rept. 307, 43rd Cong., 1st Sess., 1874; *Congressional Record*, 43rd Cong., 2nd Sess., 1875, 2156–77.

44 *Congressional Record*, 43rd Cong., 2nd Sess., 1875, 2156–77; Leland R. Johnson, *The Headwaters District: A History of the Pittsburgh District, U.S. Army Corps of Engineers* (Pittsburgh: U.S. Army Engineer District, 1979), 136–37; Leland R. Johnson, *Men, Mountains and Rivers: An Illustrated History of the Huntington District, U.S. Army Corps of Engineers, 1754–1974* (Washington, D.C.: Government Printing Office, 1977), 78–79; Leland R. Johnson, *Engineers on the Twin Rivers: A History of the Nashville District, Corps of Engineers, United States Army, 1769–1978* (Nashville: U.S. Army Engineer District, 1978), 121–25.

45 Congressional Record, 45th Cong., 3rd Sess., 1879, 207–11.

46 Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering," 19–20; *ARCE*, 1875, 35–36, 952–65. The board members were Horatio Wright, Cyrus Comstock, and Barton Alexander of the Corps, Henry Mitchel of the Coast Survey, and civil engineers T. E. Sickles, Milnor Roberts, and H. D. Whitcomb.

47 Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering," 19–20.

48 Shallat, *Structures in the Stream*, 195–99; Martin Reuss, *Designing the Bayous: The Control of Water in the Atchafalaya Basin, 1800–1995* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 1998), 63; see also John M. Barry, *Rising Tide: The Great Mississippi River Flood of 1927 and How It Changed America* (New York: Simon & Schuster, 1997).

49 Lynn M. Alperin, *Custodians of the Coast: History of the United States Army Engineers at Galveston* (Galveston, Tex.: U.S. Army Engineer District, 1977), 23–91.

50 Ibid.; *Congressional Record*, 48th Cong., 1st Sess., 1884, 4962; *Congressional Record*, 48th Cong., 2nd Sess., 1885, 1068; *Congressional Record*, 50th Cong., 1st Sess., 1888, 487, 3256–57.

51 *ARCE*, 1872, 65–66; *ARCE*, 1896, 186–88; George E. Buker, *Sun, Sand and Water: A History of the Jacksonville District, U.S. Army Corps of Engineers, 1821–1975* (Jacksonville, Fla.: U.S. Army Engineer District, 1980), 76–87.

52 Joseph J. Hagwood, *The California Debris Commission: A History* (Sacramento: U.S. Army Engineer District, 1981), 1–30.

53 *Congressional Record*, 46th Cong., 3rd Sess., 1881, 1678–79; *ARCE*, 1896, 421; Robert Kelley, *Battling the Inland Sea: American Political Culture, Public Policy, and the Sacramento Valley, 1850–1986* (Berkeley, Calif.: University of California Press, 1989).

54 Shallat, *Structures in the Stream*, 195–99; "Discussion on the South Pass Jetties-Ten Years of Practical Teachings in River and Harbor Hydraulics," *Transactions of the American Society of Civil Engineers* 15 (April 1886): 223–256; Frederick C. Scheffauer, ed., *The Hopper Dredge: Its History, Development, and Operations* (Washington, D.C.: Government Printing Office, 1954).

55 *Congressional Record*, 44th Cong., 1st Sess., 1876, 5631; Orville F. Babcock biographical file, CEHO; Cashman, *America in the Gilded Age*, 178–79; Trial of W. W. Belknap, *Congressional Record*, 44th Cong, 2nd Sess., 1877, 268.

56 *Congressional Record*, 44th Cong., 1st Sess., 1876, 5628–33.

57 *Congressional Record*, 44th Cong., 2nd Sess., 1877, 23, 374, 2120–21.

58 *Congressional Record*, 46th Cong., 2nd Sess., 1880, 4059–65.

59 *ARCE*, 1868, 24; *ARCE*, 1886, 1531; McDonnell, "An Administrative and Organizational History of the U.S. Army Corps of Engineers," 30–31.

60 *Congressional Record*, 48th Cong., 1st Sess., 1884, 5829; Willingham, *Army Engineers and the Development of Oregon*, 10–36, 60–63.

61 Pross, "A History of Rivers and Harbors Appropriation Bills," 53, 76. *Congressional Record*, 46th Cong., 2nd Sess., 1880, 4016, quotes Sen. Joseph Brown of Georgia: "We are going to put our money into factories and other improvements, and we intend to become rivals with you after a while in that business."

62 Leland R. Johnson and Charles E. Parrish, *Engineering the Kentucky River: The Commonwealth's Waterway* (Louisville, Ky.: U.S. Army Engineer District, 1999).

63 *Laws of the United States Relating to the Improvement of Rivers and Harbors*, 1:415; Johnson, *The Falls City Engineers*, 143–44; Johnson, *Men, Mountains and Rivers*, 99–105. Congress accepted Kentucky River in 1878, Muskingum in 1886, Green in 1888, and Little Kanawha in 1905; in 1897 Congress seized the privately owned Monongahela locks and dams through court condemnation, over objections from the owners.

64 William E. Merrill, "Movable Dams," *Engineering News* 5 (28 March 1878): 100–01; Johnson, *Men, Mountains and Rivers*, 82–84; Brig. Gen. Horatio G. Wright to Secretary of War Alexander Ramsey, 28 Jan. 1881, Entry 66, Letters Sent, 1871–1886, Records of the Chief of Engineers, Record Group 77, National Archives, Washington, D.C.

65 Johnson, *The Falls City Engineers*, 123–25; Godfrey Weitzel, Lock-Gates. Translation of Notes Accompanying Drawings Concerning Construction of Iron Lock-Gates for Harbor of Weser River, Germany (Washington, D.C.: Engineer Department General Publication, 1873).

66 Leland R. Johnson, *The Davis Island Lock and Dam, 1870–1922* (Pittsburgh: U.S. Army Engineer District, 1985), 20–57.

67 *ARCE*, 1870, 415; *ARCE*, 1872, 404, 426–39.

68 Mary B. McBride and Ann M. McLaurin, "The Origins of the Mississippi River Commission," *Louisiana History* 36 (Fall 1995): 389–411; Reuss, *Designing the Bayous*, 63–64.

69 Camillo and Pearcy, *Upon Their Shoulders*, 26–27; Reuss, *Designing the Bayous*, 65–66; Cowdrey, *Land's End: A History of the New Orleans District*, 29.

70 *ARCE*, 1872, 426–39; Floyd M. Clay, *A Century on the Mississippi: A History of the Memphis District, U.S. Army Corps of Engineers, 1876–1976* (Memphis, Tenn.: U.S. Army Engineer District, 1976), 24–25; Michael C. Robinson, "History of Bank Protection through the Use of Revetments," in *Centenaire de l'Association Internationale Permanente des Congres de Navigation, 1885–1985* (Paris: Permanent International Association of Navigation Congresses, 1985).

71 *Congressional Record*, 47th Cong., 2nd Sess., 1883, 3525; *Congressional Record*, 51st Cong., 1st Sess., 1890, 5148–49; Cowdrey, *Land's End: A History of the New Orleans District*, 29.

72 Shallat, *Structures in the Stream*, 193; Reuss, *Designing the Bayous*, 65–66; Cowdrey, *Land's End: A History of the New Orleans District*, 24–26.

73 *Congressional Record*, 47th Cong., 2nd Sess., 1883, 3359–62, 3443; Pross, "A History of Rivers and Harbors Appropriation Bills," 58.

74 *Congressional Globe*, 42nd Cong., 2nd Sess., 1872, 2443, 4317; *Congressional Record*, 48th Cong., 1st Sess., 1884, 4921; Pross, "A History of Rivers and Harbors Appropriation Bills," 64.

75 Leland R. Johnson, *Situation Desperate: U.S. Army Engineer Disaster Relief Operations, Origins to 1950* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 2011), 22–25; Clay, *A Century on the Mississippi,* 28–31; Roald Tweet, *A History of the Rock Island District, U.S. Army Corps of Engineers, 1866–1983* (Rock Island, Ill.: U.S. Army Engineer District, 1984), 289–90; *Laws of the United States Relating to the Improvement of Rivers and Harbors*, 1:541.

76 Johnson, *Situation Desperate*, 22–25; James D. Richardson, *A Compilation of the Messages and Papers of the Presidents*, 9 vols. (Washington, D.C.: Government Printing Office, 1898), 6:4682–83.

77 Reuss, Designing the Bayous, 65–66; Clay, *A Century on the Mississippi*, 28–29; U.S. Army Corps of Engineers, Lower Mississippi Valley Division, *Activities of the Army Engineers in Arkansas* (Vicksburg, Miss.: U.S. Army Engineer Division, 1935), 36–41.

78 Congressional Globe, 41st Cong., 3rd Sess., 1871, 1545–46; Jane Lamm Carroll, *Engineering the Falls: The Corps of Engineers' Role at St. Anthony Falls* (St. Paul, Minn.: U.S. Army Engineer District, n.d.).

79 John O. Anfinson, *The River We Have Wrought: A History of the Upper Mississippi* (Minneapolis, Minn.: University of Minnesota Press, 2003), 81–82; Merritt, *Creativity, Conflict and Controversy*, 69–112.

80 Richardson, *A Compilation of Messages*, 6:4619, 4707–09, 4724–25; Hart, "Biography of a River and Harbor Bill," 182; *Congressional Record*, 48th Cong., 1st Sess., 1884, 5851.

81 *Congressional Record*, 48th Cong., 1st Sess., 1884, 5851; *Congressional Record*, 51st Cong., 1st Sess., 1889, 366, 404; Hart, "Biography of a River and Harbor Bill," 182.

82 *Congressional Record*, 47th Cong., 2nd Sess., 1883, 3353–65, 3409–53; *Congressional Record*, 48th Cong., 1st Sess., 1884, 5851.

83 *Congressional Record*, 48th Cong., 1st Sess., 1884, 5851.

84 *Congressional Record*, 47th Cong., 2nd Sess., 1882, 702; *Congressional Record*, 48th Cong., 1st Sess., 1883, 192–96; William E. Nelson, *The Roots of American Bureaucracy, 1830–1900* (Cambridge, Mass.: Harvard University Press, 1982), 115; *Congressional Record*, 47th Cong., 2nd Sess., 1883, 3540–46.

85 Charles Hendricks, "A History of Corps of Engineers Civil Works Real Estate Policies," 1995, unpublished manuscript, CEHO, 66–80.

86 Emory R. Johnson, "River and Harbor Bills," *Annals of the American Academy of Political and Social Science*, vol. 2 (May 1892): 805–06; *Congressional Record*, 48th Cong., 1st Sess., 1884, 4917; Lawrence Allin, et al., *The Federal Engineer, Damsites to Missile Sites: A History of the Omaha District, U.S. Army Corps of Engineers* (Omaha, Neb.: U.S. Army Engineer District, 1985), 1–13.

87 Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering," 25; U.S. Congress, Senate, Bureau of Harbors and Waterways: Hearing before the Committee on Commerce of the United States Senate, Sen. Rept. No. 1848, 50th Cong., 1st Sess., 1888.

88 *ARCE*, 1885, 4 and 917; Leland R. Johnson, *The Ohio River Division, U.S. Army Corps of Engineers: The History of a Central Command* (Cincinnati: U.S. Army Engineer Division, 1992), 32–37.

89 General File 31-7, CEHO.

90 Johnson, *The Ohio River Division*, 37–39.

91 Pross, "A History of Rivers and Harbors Appropriation Bills," 100–01; *Congressional Record*, 51st Cong., 1st Sess., 1890, 365, 9559; *Congressional Record*, 52nd Cong., 1st Sess., 1892, 3940.

92 *Congressional Record*, 52nd Cong., 1st Sess., 1892, 3937, 3972, 3980–89; *Congressional Record*, 53nd Cong., 2nd Sess., 1894, 4377; Thomas Lincoln Casey biographical file, CEHO.

93 *Congressional Record*, 52nd Cong., 1st Sess., 1892, 3937, 3972, 3980–89; Pross, "A History of Rivers and Harbors Appropriation Bills," 101–02. Congress used continuing-contracts until the Budget Bureau's formation in 1921.

94 Johnson, *Situation Desperate*, 37–40; Leland R. Johnson, "The Johnstown Flood Disaster," *Military Engineer* 66 (Jan. 1974): 42–45.

95 *ARCE*, 1889, 475–76; Johnson, *Situation Desperate*, 37–40.

96 *Congressional Record*, 46th Cong., 3rd Sess., 1881, 1438; *Congressional Record*, 54th Cong. 1st Sess., 1896, 3640.

97 Frederick J. Dobney, *River Engineers on the Middle Mississippi: A History of the St. Louis District, U.S. Army Corps of Engineers* (Washington, D.C.: Government Printing Office, 1978), 52–60; *ARCE*, 1896, 418–20.

98 *Activities of the Army Engineers in Arkansas*, 29–30; Reuss, *Designing the Bayous*, 86; Herbert S. Gladfelter, *Fifty-Five Years of Dredges and Dredging on the Mississippi River* (Memphis, Tenn.: U.S. Army Engineer District, 1952).

99 Scheffauer, ed., *The Hopper Dredge*, 4–7; Ronald B. Hartzer, *To Great and Useful Purpose: A History of the Wilmington District, U.S. Army Corps of Engineers*, (Wilmington, N.C.: U.S. Army Engineer District, 1984), 95–96; Buker, *Sun, Sand, and Water*, 73–75.

100 Albert E. Cowdrey, "Pioneering Environmental Law: The Army Corps of Engineers and the Refuse Act," *Pacific Historical Review* 44 (August 1975): 331–49.

101 Ibid.; *ARCE*, 1872, 303.

102 *ARCE*, 1872, 303; *Congressional Record*, 51st Cong., 1st Sess., 1890, 8602.

103 Klawonn, *Cradle of the Corps*, 129–33; Cowdrey, "Pioneering Environmental Law," 331–49.

104 Johnson and Parrish, *Kentucky River Navigation*, 119–30; Benjamin Thomas and D. A. Watt, *The Improvement of Rivers* (New York: John Wiley and Sons, 1913), 489–96.

105 Smith S. Leach, "Inland Navigation in the United States," *Minutes of Proceedings of the Institution of Civil Engineers* 129 (London, 1897), 247–77; C. W. S. Hartley, *A Biography of Sir Charles Hartley, Civil Engineer: The Father of the Danube*, 2 vols. (Lewiston, N.Y.: Edwin Mellon Press, 1989), 1:262.

106 Hartley, *A Biography of Sir Charles Hartley*, 1:262; Johnson, *The Falls City Engineers: A History of the Louisville District*, 144–45; Tweet, *A History of the Rock Island District*, 143, 149–53, 158–59; Quincy A. Gillmore, *Practical Treatise on Limes, Hydraulic Cements and Mortars* (New York: D. Van Nostrand Publisher, 1872); William L. Marshall, Smith S. Leach, Spencer Cosby, *Report of Board of Engineer Officers on Testing Hydraulic Cements* (Washington, D.C.: Government Printing Office, 1902); Samuel B. Settle, "William McLaurine Hall," *Transactions of the American Society of Civil Engineers* 117 (1952): 1301–02; William Willingham, "Engineering the Cascades Canal and Locks, 1876–1896," *Oregon Historical Quarterly* (Fall 1987): 229–57.

107 John G. Barnard and Horatio G. Wright, *Report on the Fabrication of Iron for Defensive Purposes* (Washington, D.C.: Government Printing Office, 1871); Harry F. Hodges, *Notes on Mitering Lock Gates* (Washington, D.C.: Government Printing Office, 1892); Larson, *Essayons: A History of the Detroit District*, 97; Reuss, *Designing the Bayous*, 89; Willingham, "Engineering the Cascades Canal and locks," 243–44.

108 *ARCE*, 1896, 3–6, 444; Johnson, *Ohio River Division*, 39–45.

109 Jackson, *Presidential Vetoes*, 162–64; Richardson, *A Compilation of Messages*, 9:677–79.

110 Jackson, *Presidential Vetoes*, 162–64; Pross, "A History of Rivers and Harbors Appropriation Bills," 115–17.

111 Hart, "Biography of a River and Harbor Bill," 180–197; Johnson, "River and Harbor Bills," 782–812; U.S. Department of Commerce, Historical Statistics of the United States, 2 vols. (Washington, D.C.: Bureau of the Census, 1975), 1:8.

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

Nil Disco and Bert Toussaint

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

Articapress

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

Aviodrome Luchtfotografie, Lelystad

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

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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

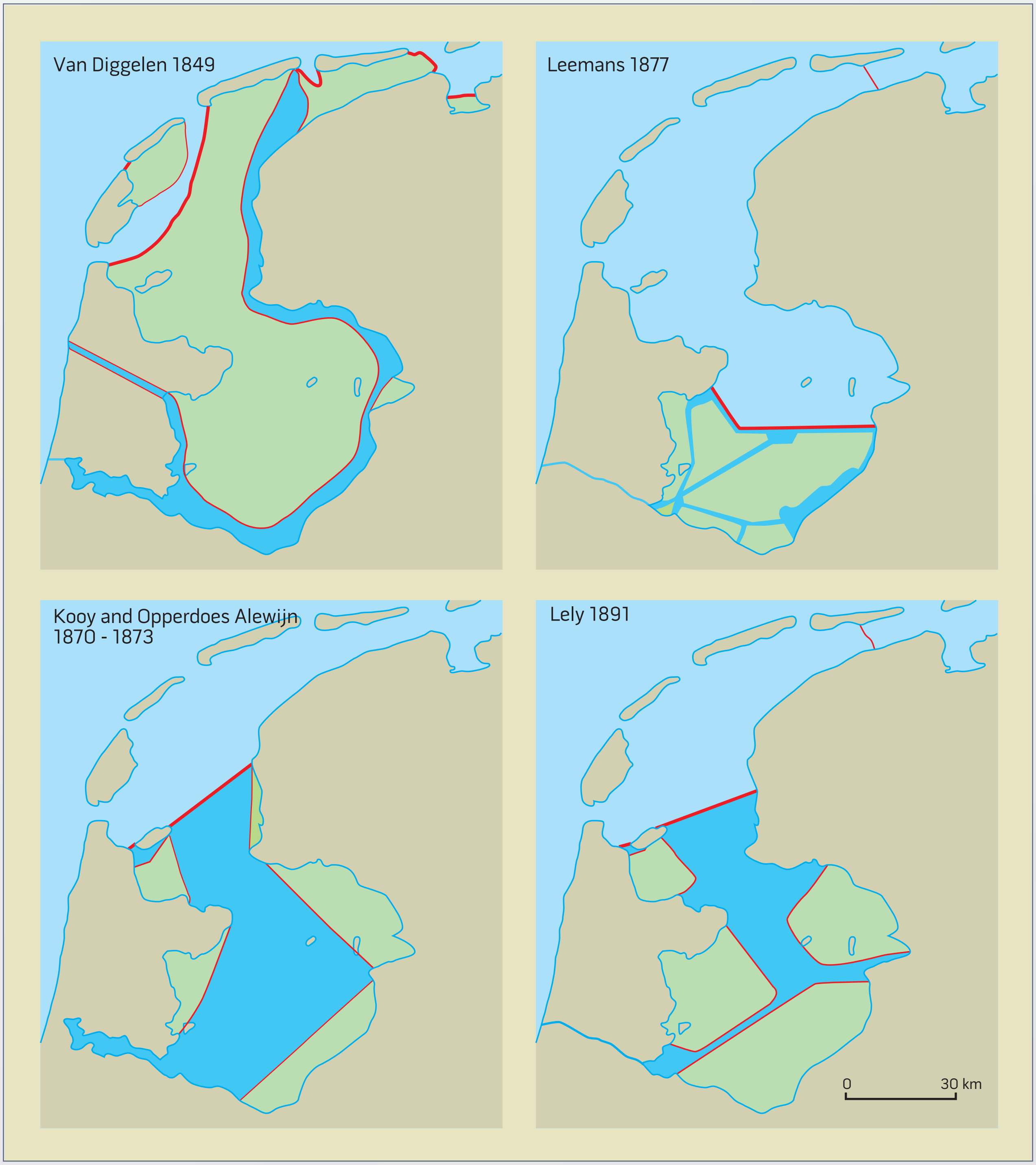
The Zuiderzee project, the largest twentieth-century Dutch reclamation project and an icon of modernist planning and engineering, has a long history. The first nineteenth century plans for this huge undertaking had a dual motivation. They focused on an agricultural enterprise economically justified by 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.



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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

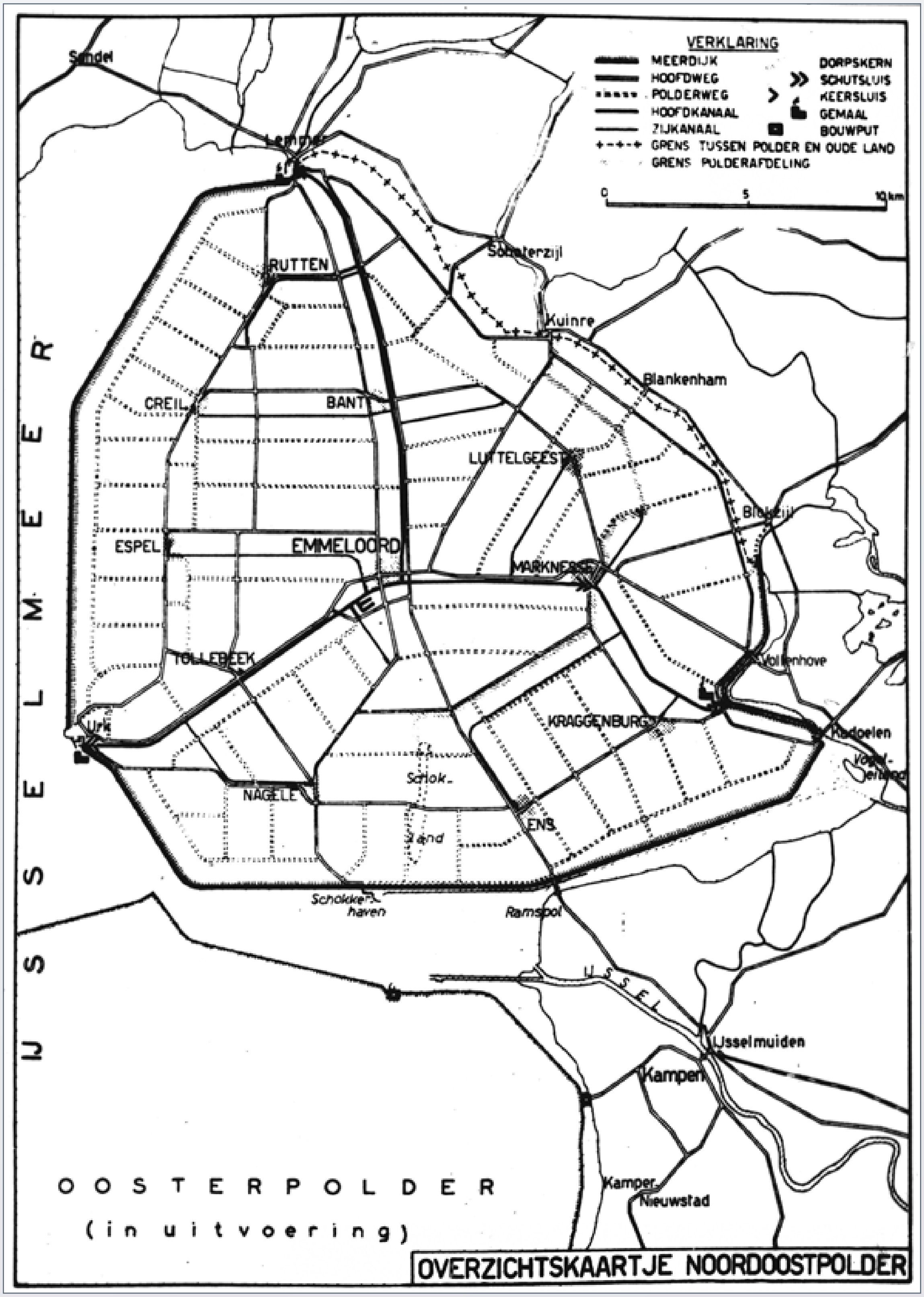
The final gap in the Closure Dam is being closed, May 28, 1932

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.

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)

Rijkswaterstaat

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 x 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.

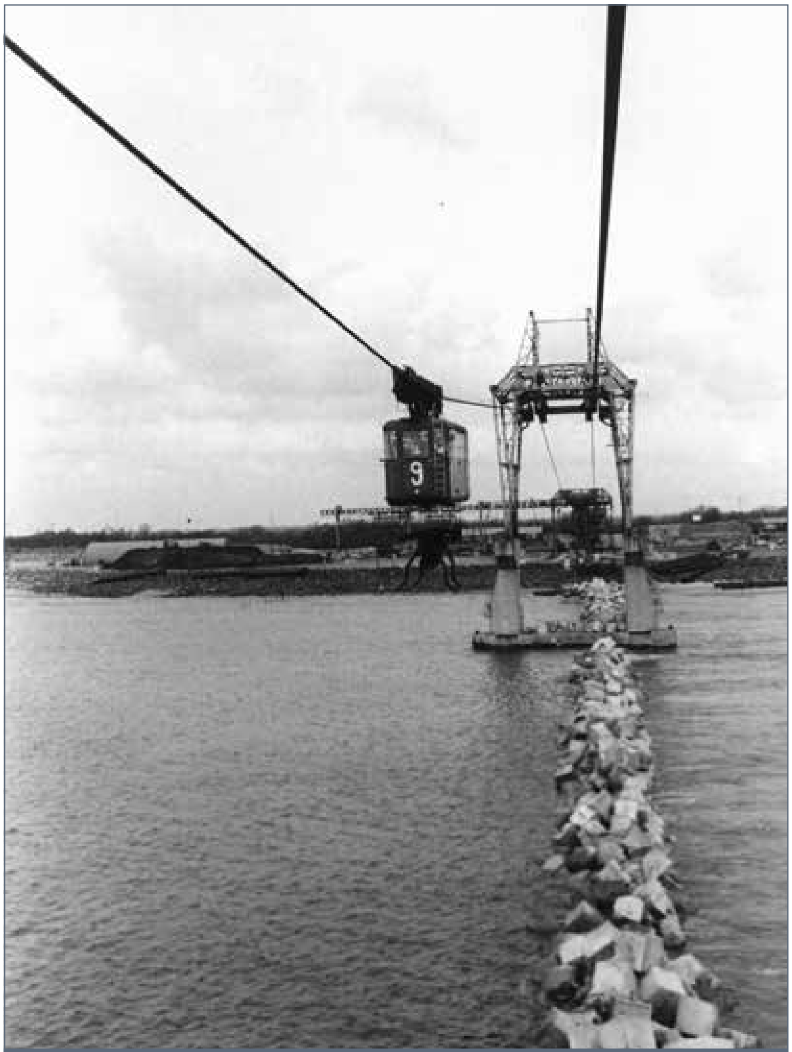
Rijkswaterstaat

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.

BIBLIOGRAPHIC ESSAY

ENGLISH SOURCES

A lucid panoramic overview of Dutch society in the era 1945–1970 is provided by Kees Schuyt and Ed Taverne, *1950: Prosperity and Welfare* (Assen, 2004). Jan L. van Zanden sketches a picture of the twentieth-century Dutch economy in *The economic history of the Netherlands, 1914–1995: a small open economy in the "long" twentieth century* (London, 1998).

For a comprehensive overview of the impact of technology and engineers on the modernization of the Netherlands between 1890 and 1970, see Johan Schot, Arie Rip, and Harry Lintsen (eds.), *Technology and the making of the Netherlands. The age of contested modernization, 1890–1970* (Zutphen/Cambridge, Mass., 2010). Especially relevant are chapters 2 "Networked Nation: Infrastructure Integration of the Netherlands" by E. van der Vleuten and 7 "Technology as Politics: Engineers and the Design of Dutch Society" by D. van Lente and J. Schot.

N. C. Kraus (ed.), *History and Heritage of coastal engineering* (New York, 1996) contains a chapter on Dutch coastal management: E. W. Bijker, "History and heritage in coastal engineering in the Netherlands," pp. 390–412. Also relevant for readers interested in a long-term view of Dutch water management is Johan van Veen, *Dredge, Drain, Reclaim. The Art of a Nation*, (The Hague, 1955) (see also the bibliographic essay in chapter 2).

DUTCH SOURCES

Kees Schuyt and Ed Taverne, *1950: Welvaart in zwart-wit* (The Hague, 2000) is the Dutch edition of *Prosperity and Welfare* (see above). The first volume of the comprehensive Dutch history of technology of the period 1900–1970, J. W. Schot (ed.), *Techniek in Nederland in de twintigste eeuw: Techniek in ontwikkeling*, vol. I, (Zutphen, 1998) is the Dutch edition of Johan Schot, Arie Rip, and Harry Lintsen (eds.), *Technology and the making of the Netherlands. The age of contested modernization, 1890–1970*. This volume contains a number of chapters on Dutch civil engineering development in its international context, water management legal frameworks, and mega-projects in water resource management.

There are numerous books on major water management projects in this period. Regarding the Zuiderzee works, J. Th. Thijsse, *Een halve eeuw Zuiderzeewerken* (Groningen, 1972) is a rich source on applied engineering concepts. A recent overview is offered in Willem van der Ham, V*erover mij dat land. Lely en de Zuiderzeewerken* (Amsterdam, 2007). Two Ph.D. theses offer detailed descriptions of two key Zuiderzee project organizations: A. M. C. van Dissel, *59 jaar eigengereide doeners in Flevoland, Noordoostpolder en Wieringermeer: Rijksdienst voor de IJsselmeerpolders 1930–1989* (Zutphen, 1991) and D. J. Wolffram, *70 jaar Ingenieurskunst: Dienst der Zuiderzeewerken 1919–1989* (Lelystad, 1997). The 1953 flood is brought to life in K. Slager, *De ramp. Een reconstructie* (Amsterdam, 2003) and in S. Leydesdorff, *Het water en de herinnering: de Zeeuwse watersnoodramp 1953–1993* (Amsterdam, 1993). Both are oral history studies based on survivor accounts. *50 jaar na de Stormvloed 1953. Terugblik en toekomst* (Gouda, 2003) is a stimulating collection of essays on the flood. H. de Haan and I. Haagsma provide a useful account of the Delta Project in their *De Deltawerken. Techniek, politiek, achtergronden* (Delft, 1984). Also relevant for the big picture is H. A. Ferguson, *Dialoog met de Noordzee. Tweeduizend jaar Deltawerken* (Hippolytushoef, 1991). Technical features of the project are detailed in E. Stamhuis, *Deltaontwikkeling; de betekenis van de weg- en waterbouwkunde voor de ontwikkeling van de Deltagebieden* (Wageningen, 1987) and in Eize Stamhuis, *Afsluitingstechnieken in de Nederlandse Delta* (Zutphen, 2002). On the Amsterdam-Rhine Canal and its predecessor, the Merwede Canal, see K. E. Baars, *Varend vervoeren: van Amsterdam tot de Rijn. 100 jaar Merwedekanaal* (Utrecht, 1991) and G. M. Greup, *De Rijnverbinding van Amsterdam en haar geschiedenis* (Amsterdam, 1952).

Biographies of two outstanding Dutch civil engineers have been published. In *Meester van de Zee: Johan van Veen (1893–1959), waterstaatsingenieur*, (Amsterdam, 2003) Willem van der Ham provides a well-written portrait of this brilliant pioneer in coastal engineering and designer of early concepts of the Delta Plan. Tessel Pollmann, *Van Waterstaat tot wederopbouw: het leven van dr.ir. J.A. Ringers (1885–1965)* (Amsterdam, 2006) describes in her Ph.D. thesis the life and career of J. A. Ringers, the first director-general of the Rijkswaterstaat and Minister for Public Works and Reconstruction during and after World War II.

There are a number of valuable books on the organization of the Rijkswaterstaat. W. van der Ham's dissertation, *Heersen en Beheersen: Rijkswaterstaat in de twintigste eeuw* (Zaltbommel, 1999), describes in detail the complex interrelationship between Dutch society, civil engineering, and the role and performance of the Rijkswaterstaat. The fate of the Rijkswaterstaat during the period of the German occupation is described in a dissertation by A. Waalewijn, *Achter de bres. De Rijkswaterstaat in oorlogstijd* (The Hague, 1990). Roel de Neve, V*ijfenzeventig jaar deskundig in weg en water 1927–2002* (Delft, 2002) and R. G. de Neve and A. A. S. van Heezik, *Om het zuivere water. Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA), 1920–2005* (Leystad, 2006) are valuable sources of information about two of the Rijkswaterstaat's specialist agencies.

1 Albert Verwey, “Toen de Gids werd opgericht…” *De Nieuwe Gids* I, ii (1886) 190. Cited in Kossman, E. H., *De lage landen 1780–1980. Twee Eeuwen Nederland en België*, vol. 1, 1780–1914 (Amsterdam : Elsevier, 1987), 260.

2 Ido de Haan, “De maakbaarheid van de samenleving en het einde van de ideologie, 1945–1965,” in: Jan Willem Duyvendak, Ido de Haan (eds.) *Maakbaarheid: liberale wortels en hedendaagse kritiek van de maakbare samenleving* (Amsterdam: Amsterdam University Press, 1997), 94.

3 K. Schuyt en E. Taverne, *1950: Welvaart in zwart-wit*. (Den Haag: SDU, 2000); H. W. Lintsen, *Made in Holland, een techniekgeschiedenis van Nederland (1800–2000)* (Zutphen: Walburg Pers, 2005).

4 The first road tunnel in the Netherlands had already been completed by the city of Rotterdam in 1942 (started in 1937).

5 Willem van der Ham, *Heersen beheersen. Rijkswaterstaat in de twintgiste eeuw* (Zaltbommel: Europese Bibliotheek,1999), 110.

6 Ibid.

7 J. W. Schot (ed.), *Techniek in Nederland in de twintigste eeuw*, vol. 1 (Zutphen: Walburg pers, 1998), 89–109.

8 A. Bosch and W. van der Ham, *Twee Eeuwen Rijkswaterstaat, 1798–1998* (Zaltbommel: Europese Bibliotheek, 1998) 146–51; Van der Ham, *Heersen en beheersen*, 62–65.

9 Letter of the Minister of Waterstaat to the Inspectors General of the Rijkswaterstaat, May 27, 1925, in Dutch National Archives, Archive of the Inspectors of the Waterstaat 1849–1930, inventory no. 156.

10 For Ringers' biography see Tessel Pollmann, *Van Waterstaat tot Wederopbouw. Het leven van dr. ir. J.A. Ringers (1885–1965)* (Amsterdam: Boom, 2006).

11 Kraus had also pioneered the use of reinforced concrete in floatable caissons which he used to build breakwaters in his integral plan for the harbor of Talcahuano in Chile. A similar strategy was later adopted by Rotterdam to build harbor quays. See Cornelis Disco, *Made in Delft. Professional Engineering in the Netherlands 1880–1940* (Amsterdam: Universiteit van Amsterdam, 1990).

12 J. A. Ringers, *Beschrijving van den bouw van de derde schutsluis in het Kanaal door Zuid Beveland te Hansweert* (z.p., 1917).

13 By comparison, the entire Rijkswaterstaat budget in 1921 amounted to 37,300,000 guilders. See Van der Ham, *Heersen en beheersen*, table 1, 364.

14 Bosch and van der Ham, *Twee Eeuwen*, 152.

15 J. M. Dirkzwager, *Water - Van natuurgebeuren tot dienstbaarheid* ('s-Gravenhage: Martinus Nijhoff, 1977).

16 W. van der Ham, *Verover mij dat land. Lely en de Zuiderzeewerken* (Amsterdam: Boom, 2007), 212–15.

17 G. L. Cleintuar, *Wisselend getij. Geschiedenis van de Zuiderzeevereeniging* (Zutphen: Walburg Pers, 1982).

18 K. Jansma, *Lely, bedwinger der Zuiderzee* (Amsterdam: H. J. Paris, 1954).

19 J. M. Fuchs and W. J. Simons, *De Afsluitdijk: recht door zee* (Haren: Knoop en Nijmeijer, 1972); Eric Berkers, “Kustlijnverkorting en afsluittechniek”, in: *Techniek in Nederland in de twintigste eeuw*, J. W. Schot et al. (ed.), vol. 1 (Zutphen: Walburg Pers, 1998), 71–88. Secretary of the Lorentz Commission was the civil engineer Jo Thijsse, who would later become the first director of the Hydraulic Laboratory at Delft.

20 The flood of 1916 also caused unusually high stages in the New Waterway between Rotterdam and the sea. Lely appointed a commission headed by the Leiden mathematician H. G. van de Sande Backhuyzen in 1916 to study the causes. This commission, like the Lorentz commission, also proved to be a nursery for mathematical modeling approaches (and mathematically sophisticated hydraulic engineers) that would be integrated into new strategies for hydraulic design in the context of Ringers' and Van Veen's *Study Service for the Tidal Rivers*. Cornelis Disco and Jan van den Ende, “Strong, Invincible Arguments? Tidal Models as Management Instruments in Twentieth-Century Dutch Coastal Engineering,” *Technology and Culture* 44, no. 3 (2003): 502–35.

21 Tessel Pollmann, *Van Waterstaat tot Wederopbouw. Het leven van dr. ir*. J. A. Ringers (1885–1965) (Amsterdam: Boom, 2006), 100.

22 Berkers, “Kustlijnverkorting en afsluittechniek,” 77.

23 This is the equivalent of covering the entire surface of the island of Manhattan (approx. 22 square miles) with a two-foot deep layer of sand and till.

24 In 1962 the Wieringermeer Directorate was renamed the State Service for the IJsselmeerpolders.

25 Terje Tvedt and Terje Oestigaard, *A History of Water*, vol. 3: *The World of Water* (London: I.B. Tauris, 2006), 191–97.

26 After World War II, the contribution of German industry to Rhine salinity would pale in comparison with that of the French (Alsatian) potash mines.

27 J. M. K. Pennink, "Over den Noord-Oost-polder en de drinkwatertoekomst," *De Ingenieur* 48 nr. 9 (1933): A. 87.

28 In 1930 a state commission had been appointed to study public water supplies in the western part of the country. Although the official report did not appear until 1940, by the mid-1930s its somber prognosis and its perception of the IJsselmeer as the ultimate solution were widely known. See P. J. M. Aalberse, *Rapport van de Commissie drinkwater-voorziening westen des lands* (Den Haag: Algemeene Lands-drukkerij, 1940). In the same year, the director of Amsterdam's waterworks also published an exhaustive study in which he expressed a pessimistic view of the utility of the IJsselmeer as a source of potable water—because of its dubious salinity and possibly because the city also wanted to continue to use it as a sewage sink—and opted for infiltration of the existing munic-ipal dune water supply by water pumped from the Lek River. See C. Biemond, *Rapport 1940 inzake de watervoorziening van Amsterdam* (Amsterdam: Gemeentewaterleidingen, 1940).

29 For a fuller account of the national water household see Cornelis Disco, "De verdeling van zoetwater over heel Nederland 1940–1970," in: J. W. Schot, H. W. Lintsen, and Arie Rip (eds.), *Techniek in Nederland in de twintigste eeuw*, vol. 1 (Zutphen: Walburg Pers, 1998), 110–21; Cornelis Disco and Erik van der Vleuten, "The Politics of Wet System Building: Balancing Interests in Dutch Water Management from the Middle Ages to the Present," *Knowledge, Technology and Policy* 14, no. 4 (2002): 21–40.

30 Adolf Waalewijn, *Achter de bres: De Rijkswaterstaat in oorlogstijd* ('s-Gravenhage: SDU, 1990), 81.

31 W. van der Ham, *Meester van de zee, Johan van Veen Waterstaatsingenieur 1893–1959* (Amsterdam: Balans, 2003), 71–96; J. van Veen, *Onderzoekingen in de Hoofden in verband met de gesteldheid der Nederlandsche kust* (Den Haag:Algemeene Landsdrukkerij, 1936).

32 Van der Ham, Meester, 87–95; H. C. Toussaint, *Uitgemeten en uitgerekend. De geschiedenis van de Algemene Dienst van de Rijkswaterstaat* (Den Haag: Rijkswaterstaat, 1998), 70–72.

33 H. Ferguson, *Delta-visie*. (Den Haag: Rijkswaterstaat, 1988).

34 Toussaint, *Uitgemeten*, 91.

35 Toussaint, *Uitgemeten*, 99–100.

36 H. W. Lintsen, "Was de ramp te voorkomen?", in: CUR-Publicatie 212, (Gouda: CUR, 2003), *Waterbouwdag 2003. 50 jaar na de Stormvloed* , 7–19.

37 Deltacommissie, *Rapport Deltacommissie*, 6 vol. (Den Haag, Staatsdrukkerij, 1960–1961).

38 Van der Ham, *Heersen en beheersen*, 229–30.

39 Alex van Heezik, *De Kering: over de bouwers van de stormvloedkering Oosterschelde* (Diemen: Uitgeverij Veen Magazines, 2011), 7–9; R. Antonisse, *De kroon op het Deltaplan. Stormvloedkering Oosterschelde, Het grootste waterbouwproject aller tijden* (Amsterdam/Brussel: Elsevier, 1986), 44–49; R. E. Jorissen, "Kan het morgen weer gebeuren?," *Waterbouwdag 2003*, 127–30.

40 RIVM and MNP, *Risico's in bedijkte termen. Een thematische evaluatie van het Nederlandse veiligheidsbeleid tegen overstromingen* (Bilthoven 2004) 40; Extended English Summary: *Dutch Dikes, and Risk Hikes*. A thematic policy evaluation of risks of flooding in the Netherlands (Bilthoven 2004); Letter of Ministry of Transport, Public Works and Water Management to the Province of Gelderland. *Hoogte bandijken langs de grote rivieren* (October 2, 1956; cited in RIVM, *Risico's in bedijkte termen*).

41 E. Stamhuis, *Afsluitingstechnieken in de Nederlandse Delta* (Zutphen: Walburg Pers, 2002), 63–86.

42 K. Slager, *De ramp, een reconstructie van de waters-nood* (Amsterdam/Antwerpen: Atlas, 2003), passim; Bosch en Van der Ham, *Twee eeuwen*, 176–78; 240–44; Van der Ham, *Heersen en beheersen*, 216–43.

43 P. de Schipper, *De slag om de Oosterschelde* (Amsterdam/Antwerpen: Atlas, 2008), 17–22, 69–83, 109–76.

44 H. Ferguson, *Delta-visie. Een terugblik op 40 jaar natte waterbouw in zuidwest-Nederland* (Rijkswaterstaat: Den Haag 1988), 71–72.

45 J. Cramer, *De groene golf. Geschiedenis en toekomst van de milieubeweging* (Utrecht: Uitgeverij Jan van Arkel, 1989), 17–36.

46 Alex van Heezik, *Strijd om de rivieren: 200 jaar rivierenbeleid in Nederland of de opkomst en ondergang van het streven naar de normale rivier* (Haarlem/Den Haag: Van Heezik Beleidsresearch, 2008), 161.

47 The VWBL, RIZA, the Dutch tourist and mobility organization ANWB, a national conservationist committee (Contact-Commissie voor Natuur- en Landschapsbescherming) and the Dutch angler union.

48 Van der Ham, *Heersen en beheersen*, 255; Bosch en Van der Ham, *Twee eeuwen*, 187; Van Heezik, *Strijd*, 156–79.

49 C. Disco and M. L. ten Horn-van Nispen, "Op weg naar een integraal waterbeheer," in: J. W. Schot, H. W. Lintsen and Arie Rip (eds.), *Techniek in Nederland in de twintigste eeuw*, vol. 1 (Zutphen: Walburg Pers, 1998), 185.

50 Van der Ham. *Heersen en beheersen*, 255.

51 Van Heezik, *Strijd*, 176.

52 P. Huisman, "Waarvan akte. Internationale verdragen nopens de Rijn", in: A. Bosch e.a. (ed.) *Zoals ook zee zich terugtrekt en leegte achterlaat. Vriendenbundel Pieter de Wilde* (Den Haag: HNT Historische producties, 2001), 49–52; Van Heezik, *Strijd*, 179–80.

53 J. Goudsblom, *De nieuwe volwassenen. Een enquête onder jongeren van 18 tot 30 jaar* (Amsterdam: Querido, 1959), 96–102, 183.

54 C. Disco, F. W. Geels, H. W. Lintsen, "Hoe innovatief is Rijkswaterstaat?" *Tijdschrift voor Waterstaatsgeschiedenis* 13, no. 1 (2004): 13–28.

7 U.S. ERA OF PROGRESSIVISM AND LARGE PUBLIC WORKS, 1900–1970

William F. Willingham

The first half of the twentieth century witnessed a dynamic period of growth in water resources development for the U.S. Army Corps of Engineers and other federal water resources agencies. An expanding and modernizing economy placed increasing demands on the nation's system of inland waterways and coastal ports to transport goods and services. New technology was required to upgrade the navigation channels to serve this need. Even economic downturns and world wars during this period spurred increased investment in the nation's water transportation system. The congressional response to natural disasters, such as flooding, and to the growing energy requirements calling for the development of hydroelectricity led to new missions for the Corps, which then built dams to address those needs. Recognizing the need to conserve water and make it available for agricultural purposes in the arid American West, Congress created the Bureau of Reclamation in 1902 to plan and construct massive reclamation projects. Throughout the last century, the Corps and other federal agencies responded to issues of change and continuity in the nation's water resources needs by building, operating, and maintaining appropriate infrastructure. In the process of creating new water control projects, the Corps had to develop objective methods to determine the economic justification or national interest of those undertakings.

MODERNISM REMAKES THE UNITED STATES

By the turn of the twentieth century, the forces of industrialism, urbanism, and large-scale immigration—loosely labeled "modernism"—were remaking the United States. These changes rapidly transformed the lives of ordinary Americans. The growth of cities dramatically reflected the transformation underway in the American society and economy. Population trends mark the transition. In 1880, 72 percent of the nation's population lived in rural areas; by 1900, that number had declined to 60 percent. Urban dwellers finally outnumbered rural inhabitants for the first time in 1920: 51 percent urban to 49 percent rural. The pace only accelerated over the next 20 years. In 1940, the urban-rural split registered 56 to 44 percent.[1]

Cities grew dramatically in the first two decades of the twentieth century. In 1900, the number of urban places with more than one hundred thousand inhabitants stood at thirty-eight, whereas by 1920, sixty-eight cities had reached that level of population. In fact, by the latter year, over one-half the nation's population lived in cities of one hundred thousand or more. Cities faced difficult infrastructure problems as they coped with population expansion. The need for a clean water supply, sewage systems, public transportation facilities, parks, garbage removal, and public safety challenged local government officials. To meet these challenges, a new class of professionals arose which included engineers, architects, scientists, and other experts who proposed solutions to the social and economic costs of growth. The attempt at urban improvement, known as the "City Beautiful" movement, sought to ameliorate urban crowding, disorder, and unsanitary conditions with public green space, better streets and public transport, clean water and sewer systems, attractive civic centers, and other amenities through the application of expert planning and the use of modern technology. In short, expert reformers and planners sought to bring order out of disorder in the urban scene.[2]

Whether focused on urban or rural issues, the amorphous reform movement in the late nineteenth and early twentieth centuries held a strong belief in the power of scientific expertise to solve social and political problems. Those among the reformers who had a strong conservationist bent embraced the notion that so-called impartial scientific experts could infuse government bureaucracy with the knowledge and skills to ensure the proper use and development of the nation's natural resources to benefit all citizens. That promise extended to all water, timber, mineral, and land resources in the public domain. Teams of experts would create the administrative apparatus to carry out appropriate management of those resources. This set of beliefs became the core of what has become labeled as the Progressive movement, and it defined the period from 1890 to 1920.

Library of Congress, LC-USZ62-67323

High-rise buildings in lower New York City along the waterfront, 1908

At the advent of the Progressive Era, about forty thousand engineers practiced their profession. These engineers saw themselves as key exponents of the belief in progress through scientific or technological improvement and the increasing control of nature. Increasingly, they received their education from colleges or institutes rather than through apprenticeship, and they answered to standards set by professional associations. This growing cadre of modern engineers in the private sector of the economy claimed a high degree of professionalism and challenged the dominance of the Corps of Engineers in carrying out federal public works. Civilian engineers asserted that Army engineers trained at West Point lacked the skills for public engineering work and the incentive to produce timely and cost efficient projects. Internally, the Corps' changing engineering force reflected these larger trends in the engineering profession.[3]

GROWTH OF THE CORPS DURING THE PROGRESSIVE ERA

As the Corps' traditional rivers and harbors work expanded during the early twentieth century, its number of civilian engineers grew along with the number of military engineers traditionally trained at West Point. The Corps' expanding civil works program was apparent in the growth of its congressional appropriations. During the 1890s, appropriations totaled $166.7 million; in the next ten years, they reached $254.7 million. During the 1920s, Corps appropriations stood at $674.2 million. The growth in the Corps' budget mirrored the increase in the Corps' projects over time. In 1880, the Corps had thirty-four authorized projects. In 1896, the number expanded to five hundred. By 1910, they had ballooned to 1,208.[4]

In spite of the Corps' growing workload during the last third of the nineteenth century, the number of engineer officers failed to keep pace. During most of that time, the Corps had 109 engineer officers, but by 1910, Congress had expanded the number to 200. In addition, by 1918, the Corps had hired 367 civilian engineers to carry out its work; in 1883 it had only 183. The Corps also hired thousands of laborers, clerks, draftsmen, inspectors, lock operators, and other civilian employees, depending on work load. By congressional edict, most project work was carried out under contract. Contractors, rather than hired labor, executed the Corps' construction work.

The growth in navigation improvement projects assigned by Congress led the Corps to change its organizational structure. It became increasingly difficult for the chief of engineers and his small headquarters staff to properly manage far-flung engineer offices, which increased from thirty-four in 1888 to forty-one by 1906. In 1888, the Corps established five division offices to directly supervise the engineer officers who were carrying out project improvements at various river and harbor locations. At that time, the engineer offices lacked geographic descriptions or boundaries; the projects assigned to an office defined the area of responsibility for the officer in charge. As projects became more complex and required years to complete and then had to be operated and maintained, the focus shifted away from the engineer officer in charge to the geographic area encompassing the projects. The term "district" as a designation for a group of projects in a given geographic area gradually came into informal use to reflect this shift in emphasis. Formal recognition of this distinction took place in 1908 when the Corps' annual reports began to list civil works projects under district headings. Finally, starting with the *Annual Report of 1913*, the Corps described districts in terms of geographic boundaries, rather than by just a list of projects.[5]

The Corps' mission to enhance streamflow for navigation on the nation's major rivers expanded steadily during the first half of the twentieth century. The drive for improved navigation came from local interests who thought that it would bring economic growth to their river port communities. These interests hoped that a better system of inland waterways would bring a resurgence of waterborne transportation through cheaper bulk freight rates and the ability to better compete with the railroads. Having laid a firm foundation for navigation in the nineteenth century on such rivers as the Ohio, Illinois, Mississippi, Missouri, and Columbia, the Corps concentrated on modernizing the navigation system by deepening the shipping channels and upgrading the in-water structures responsible for impounding the navigation pools. On the Ohio, for example, the Corps replaced the initial wicket dams with rolling crest dams and carried out a project to increase the navigation channel to a depth of nine feet (1910–29). The Corps used the roller crest dam exclusively for upgrading the navigation system on the upper Mississippi (1930–48) and for several installations in the Illinois Waterway (1930–39). In 1930, Congress authorized the Corps' nine-foot navigation channel on the upper Mississippi River. Advances in hydraulic engineering brought improved dredging and better placement of river control devices such as revetments, pile dikes, and cut-off dams. On the Columbia River, the Corps drowned out the single-purpose Cascade Canal and Locks (built 1876–96) and The Dalles-Celilo Canal and Locks (built 1905–15) that were originally designed to pass shallow draft steamboats, and in their place installed massive, single-lift locks for modern barge tows in the four multiple-purpose dams it built between 1933 and 1970. In the late 1950s, the Corps constructed the St. Lawrence Seaway, completing the deep-water transportation system on the Great Lakes.[6]

Just as river channels needed upgrading to accommodate larger barge tows, the coastal ports of the U.S. required improvements to keep up with the ever-expanding size of ocean-going ships. On the East Coast, the Corps carried out dredging projects to deepen and widen ship channels in ports including Boston, New York, Philadelphia, Baltimore, Charleston, and Savannah. On the West Coast, the Corps did the same for the harbors of Los Angeles and Portland, while building massive jetties at the mouth of the Columbia River and then dredging a deeper channel so ever-larger ships could navigate 110 miles upriver to Portland. Over the course of a century, the Corps deepened the Portland to the Sea ship channel from seventeen to forty feet. At Seattle, the Corps constructed a canal (1911–1916) to connect the Puget Sound with Lake Washington to add to the city's port facilities. The Corps also dredged harbors and built jetties or breakwaters for numerous small ports along the coasts of Oregon and Washington.

As cities grew and port activities increased, the uncontrolled dumping of refuse and debris created a navigation hazard. Congress responded by giving the Corps authority to restrict the dumping of refuse that threatened safe navigation, beginning in 1886 in New York harbor. In 1888, Congress authorized the Corps to establish harbor lines to protect navigation by limiting construction and deposition of refuse within the lines. Finally, in 1890, the Rivers and Harbors Act authorized the Corps to issue permits for dumping or constructing any structure in navigable waters. Congress further clarified the law in 1899, strengthening the Corps' regulatory control over construction, dredging, dumping, or discharging activities in navigable waterways. In the first half of the twentieth century, however, the Corps interpreted its regulatory authority narrowly—withholding permits for in-water undertakings only if the activity interfered with navigation.[7]

Initially, the Corps placed most of its enforcement efforts on Section 10 of the Rivers and Harbors Act of 1899, as it was considered the most important part of the law. The Corps quickly established a nationwide permit program, which Congress began funding in 1905. Anyone wanting to build, dredge, or make any change in a navigable waterway had to submit a permit application with plans and specifications to the local Corps district. After review, the district engineer either issued or denied a permit and also had authority to turn over violators to the Justice Department for prosecution.

Although Section 13 of the law granted broad powers to prohibit dumping of anything into any navigable stream without a permit, the Corps chose to interpret the law narrowly. The Corps, backed by court decisions, enforced Section 13 provisions only if the dumping of refuse would have an effect on navigation. The Corps did not set up a regular permit program to enforce Section 13, but instead issued permits on an *ad hoc* basis. The Corps did, on occasion, turn violators over for prosecution, but only if the discharge created a hazard for navigation.

The growing economy in the early twentieth century placed great demands on the waterway transportation system of the United States. The response involved both local and national governments. Ports built wharfs and terminals and dredged some harbors, but the federal government responded with a massive program of rivers and harbor work to make the local efforts effective. The Corps dredged harbors, improved river channels, built canals and jetties, constructed breakwaters, dikes, levees, and revetments to protect shorelines and preserve navigation channels. Between 1900 and 1914, New York harbor, for example, was expanded from a depth of thirty to forty feet. At the same time, the Corps increased the depth of Boston's harbor from twenty-seven to thirty-five feet, and both Philadelphia and Baltimore had their harbors increased to a depth of thirty-five feet. The Corps, at the direction of Congress, also made great strides in achieving the long-sought goal of an Atlantic Intracoastal Canal, combining and upgrading canals previously constructed by private companies with naturally sheltered inland passages along the Atlantic coast.[8]

Unfortunately, various obstacles prevented the creation of a nationwide, integrated navigation system. As the federal commissioner of corporations noted in 1909, the United States had not enjoyed "that cooperation between central and local authority that appears in

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View of Boston Harbor in 1906

the best of the European systems." Localities competed with each other in Congress for federal water resources projects, and "pork barrel" politics often determined which projects got funded rather than rational, coordinated planning. The commissioner of corporations argued that the haphazard development of the nation's waterways produced "waste, lack of uniformity, lack of comprehensive plan, and especially a lack of any proportionate contribution from localities peculiarly benefited."[9]

To impose some coherence on a rapidly growing waterborne infrastructure, in 1902 Congress created the Board of Engineers for Rivers and Harbors to approve or reject river development projects. The measure was largely the work of Representative Theodore E. Burton, the powerful chair of the House Rivers and Harbors Committee, who questioned the quality of the Corps' reports for proposed water improvement projects. The legislation, passed over the opposition of the chief of engineers, called for five (later seven) engineer officers to review the proposals from the Corps' district engineers to determine the accuracy of promised benefits and cost estimates and the contribution to the national interest. Although the board improved the quality of federal projects over time, it did not prevent continued congressional approval of local projects of questionable value.[10]

The charge that the Corps engaged in building water projects that benefited only local interests continued to haunt the Corps throughout the first half of the twentieth century. In fact, only once during those years did the Corps request that Congress take a more systematic approach to waterways projects. In 1911, the chief of engineers proposed that the Corps prepare plans for a national water transportation system, but the Congress declined to approve this recommendation. Between 1900 and 1930, the Corps and Congress also experimented with requiring local cost-sharing on some water projects; but no systematic procedure was developed to determine when to apply this requirement. In addition, critics of the Corps complained that its planning failed to include considerations other than engineering, especially in the case of single-purpose projects. After World War II, such criticism of the Corps' lack of comprehensive planning and over-reliance on engineering feasibility to establish benefits and costs for water resources projects reached a crescendo. The Bureau of Reclamation also faced similar criticism that it placed too much emphasis on purely engineering justifications for its water projects.[11]

THE RISE OF MULTIPLE-PURPOSE WATER RESOURCES PROJECTS

The issue of natural resource depletion received much attention during the administration of President Theodore Roosevelt. The rising population and advancing standard of living produced visions of depleted timber and mineral resources and over-grazed grasslands. Concern arose that insufficient water supplies would limit crop production. In addition, inefficient waterways, demands for hydropower, and calls for western irrigation projects highlighted the demands being placed on the nation's water resources. Proponents of the wise use of natural resources for long-term public benefit challenged the unfettered private exploitation of such resources. For example, conservationists and forestry experts sought to apply scientific forestry practices, such as the creation of forest preserves, grazing regulations, and selective timber harvesting, to publicly owned forest lands. To carry out these policies, Congress established the U.S. Forest Service in 1906.[12]

Because many aspects of forest management directly concerned other resources, such as water, a focus on watersheds emerged. By 1908, the concept of multiple-purpose river development had gained prominence. According to this notion, river basins should be efficiently developed and managed to support related needs, including irrigation, flood control, hydropower, navigation, and urban water supply. This new approach often meant reconciling conflicts in priority as well as trade-offs in assigning benefits and costs. Clearly, the new multiple-purpose approach represented a move away from the traditional single-purpose water development projects of the Corps. But before this idea gained traction, other federal natural resources agencies—besides the Corps and the Forest Service—arrived on the national scene. The Corps would now have to work in concert with the other federal agencies that had roles to play in water resources development.

Just before the Forest Service got underway, Congress created the U.S. Reclamation Service (later, the Bureau of Reclamation) in 1902 to scientifically develop the irrigation potential of western watersheds and bring irrigated communities to arid lands. The Corps of Engineers already had charge of navigation development on the nation's rivers. These single-purpose federal water activities reinforced the notion that efficient resource use required the national government to take the lead on multiple-purpose river development. The sheer complexity and cost of resource development, coupled with the problem of overlapping local and state jurisdictions, made federal multiple-purpose planning attractive to those interested in the wise use of natural resources. At this early stage of considering multiple-purpose resource development, the Corps took a conservative stance on the approach. The Corps interpreted its navigation mission narrowly and doubted, for example, that the science of hydrology and the technical requirements of building large dams had advanced to the point of feasibility. Chief of Engineers Brig. Gen. Alexander Mackenzie went so far as to argue that all other river purposes should be subordinate to the federal interest in navigation. Another senior Corps officer argued, "Experience in the practical operation of the Upper Mississippi system has unquestionably demonstrated that the need of navigation and water-power generation

Office of History, Headquarters, U.S. Army Corps of Engineers, H. Abbot Collection

Alexander Mackenzie (1844–1921), who became Chief of Engineers in 1904

are more or less conflicting and that the idea of satisfying both by a single system of reservoirs is visionary." The Corps' opposition to multiple-purpose development put it at odds with President Theodore Roosevelt and other federal resource agency heads.[13]

The Corps' position on multiple-purpose federal public works placed it in an awkward position in the debate over federal authority under the United States Constitution. The multiple-purpose approach relied on a broad interpretation of federal powers based on the commerce clause of the Constitution; states' rights proponents denied any federal responsibility to control the nation's rivers, even for navigation. The Corps thus found itself attacked by both sides. The Corps' assertion of its navigation interest angered states' rights advocates, while its opposition to multiple-purpose development received criticism from those seeking a broader federal involvement on the nation's rivers. In spite of their resistance to multiple-purpose development, the Corps generally retained the respect of Congress and senior policy makers during both Republican and Democratic administrations. This respect kept the Corps in control of traditional federal civil works, despite continuing criticism by private sector engineers.[14]

To circumvent the Corps and congressional opponents of multiple-purpose development, President Roosevelt convened the Inland Waterways Commission (IWC) in 1907 to investigate the options for integrated river basin development. At the time, Roosevelt stated that it was necessary to merge "local projects and uses of inland waters in a comprehensive plan designed for the benefit of the entire country." The IWC reported favorably on future plans that called for multiple-purpose water resources development, but the Corps continued to be highly skeptical of its feasibility. In an era that placed great emphasis on progress through the application of scientific expertise to natural resource development, the Corps, with its narrow approach, seemed slightly out of step. This conservative stance limited the Corps' influence on broader federal water policy, but it did not prevent some engineers within the Corps from calling for greater federal involvement in flood control and regulation of hydropower development, especially on navigable streams. In the short term, questions of financing, technological capability, and constitutional authority led the Corps to resist the multiple-purpose approach. Over time, however, answers to these concerns were forthcoming, and the easiest to resolve seemed to be the technological ones.[15]

LARGE DAM DESIGN

The emerging technology of concrete dam design played a major role in the debate over multiple-purpose river basin development. Only when engineers found it possible to design and build large-scale concrete dams could multiple-purpose manipulation of major rivers be undertaken. At the beginning of the twentieth century, two different engineering visions for concrete dam design competed: the massive tradition, which relied on a dam's weight to hold it in place, and the structural approach, which depended on a dam's shape to transfer the weight of the water to the dam abutments. Massive dams simply used the force of gravity acting on the mass of material in the structure to resist the horizontal pressure of the stored water. A structural dam, on the other hand, employed its shape, such as an arch or buttress element, to resist hydrostatic pressure. If designed and built properly, either design would work. During the first third of the twentieth century, American engineers refined the engineering theory and practice behind both types of dams. These advancements permitted American dam builders to base their design decisions on site conditions, available construction materials and labor, financial constraints, and the professional preference of the designer.[16]

Another technology essential to the construction of water control structures such as dams, locks, canals, and jetties involved the use of concrete as a building material. Although invented by the Romans for a variety of structural purposes, the modern development and application of concrete occurred in the late nineteenth century. Following European experiments in the early 1800s with the various ingredients necessary to make concrete, American builders carried out further investigations and began the systematic application of concrete to structures in the last half of the nineteenth century. The most important advance involved adding iron or steel reinforcement to concrete. Reinforced concrete, unlike regular concrete, could resist tension and thus made the product useful for columns, beams, and floor slabs, as well as for walls and footings. Advances in reinforced concrete design continued in the twentieth century and provided dam builders with an alternative to earth-fill embankment and masonry structures. Roosevelt Dam (1906–11), built by the Reclamation Service, was the last of the large-scale masonry dams.[17]

Innovations in the design of cofferdams by the Corps and its civilian contractors in the early twentieth century also played an important role in the construction of large-scale dams and other in-water structures. Engineers began replacing the traditional timber crib or sheet-pile-founded cofferdams used in building navigation projects in the nineteenth century with interlocking steel sheet pile cofferdams. The steel structures had an important advantage in that they could be built taller than wooden ones and thus allowed work at greater water depths. Economical steel sheet piles became available by 1910, when steel companies developed the means to fabricate sheet piling with interlocks rolled into the beam during manufacturing, rather than having the attachment occur afterwards by riveting. By the 1930s, the Corps' use of steel sheet pile cofferdams in river improvements on the Ohio, Kanawha, and Allegheny rivers led to further innovations. Instead of merely substituting steel sheet piling for wooden sheet piling in conventional box cofferdams, the engineers started using circular cell and diaphragm cell steel sheet pile cofferdams. Other water resources agencies, such as the Bureau of Reclamation and the Tennessee Valley Authority (TVA), also advanced the design and performance of cofferdams in the construction of their dams.[18]

The development and use of electricity, the internal combustion engine, and giant steam shovels in the late nineteenth and early twentieth centuries also enhanced the engineers' ability to economically accomplish large-scale, multiple-purpose water projects. Moreover, being able to generate electrical power from water stored behind dams provided a means to finance other

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Steel sheet pile cofferdam under construction at the Bonneville Dam site on the Columbia River, ca. 1930s water uses and another way to power equipment used in constructing the dams themselves. Federal agencies even shared heavy equipment. After the Panama Canal Commission completed the Panama Canal, it transferred some of the heavy machinery, such as steam shovels, to the Bureau of Reclamation for use in its dam and irrigation projects.

FLOOD CONTROL

While concern for natural resource depletion stimulated a federal response that led to the creation of agencies to better manage the public domain, it took natural disasters to bring a stronger federal involvement in flood control. A series of damaging floods in the nation's heartland in 1912, 1913, and again in 1916 focused attention on the issue. The question of how to prevent devastating flooding in the Ohio and Mississippi River basins fed into the existing argument over whether single- or multiple-purpose flood prevention measures were the best solution. The single-purpose approach relied on extending and improving the existing system of levees and bank protection, whereas the multiple-purpose solutions proposed upstream forest reserves and reservoirs, and construction of artificial outlets in the lower Mississippi basin to send floodwaters to the Gulf.[19]

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Flood victims on a Mississippi River levee at Arkansas City, Arkansas, 1927

In the 1917 Flood Control Act, Congress recognized, for the first time, an obligation to assist flood-prone areas of the Mississippi and Sacramento basins, and it instituted cost-share requirements on local interests: for every two dollars of federal expenditures, local interests had to commit one dollar. The localities also had to provide rights-of-way for levee construction and maintain the structures after construction. Most importantly for the future, the act ordered the Corps to investigate the relationship of flood control to navigation and hydropower, setting a precedent for multiple-purpose planning. While debate continued over the issue of multiple-purpose water resources development, the Corps' response to repeated flooding on the nation's major rivers directly enhanced the Corps' flood control mission.[20]

The federal commitment to flood control established by the 1917 measure was further strengthened in the wake of the catastrophic Mississippi River flood of 1927. The large loss of life and devastating economic impact led Congress to support federal flood control efforts on the entire Mississippi River. The massive flood also pushed the Corps away from its single-minded embrace of "levees only" as the best way to prevent floods on the river. Based on a report authored by Chief of Engineers Maj. Gen. Edgar Jadwin, Congress passed the Flood Control Act of 1928, firmly committing the federal government to flood control on the Mississippi River. General Jadwin's recommendations, although still relying to a large extent on levees, also proposed a mix of floodways and spillways, including a controversial plan to send half of the Mississippi's floodwaters down the Atchafalaya River into the Gulf of Mexico. The Mississippi River Commission (MRC) also presented a competing flood control plan to Congress, but its greater expense caused Congress to reject it in favor of the Corps' approach. Neither proposal recommended a large-scale use of reservoirs to control the Mississippi River floodwaters.[21]

A costly element of both plans was the expense of acquiring land and rights-of-way for enlarged levees and flowage easements and damage to lands in the proposed floodways. General Jadwin's plan, which cost $296.4 million, emphasized that the states and localities should be responsible for real estate costs and property damage. The MRC's plan, on the other hand, recommended federal assumption of the bulk of the real estate costs of the project. After fierce debate, Congress adopted a flood control measure that limited the federal government's responsibility for real estate costs to only those lands affected by "additional" floodwaters diverted from the Mississippi River by new flood control works.[22]

The actual condemnation process for flowage easements or fee-simple rights-of-way and for levee construction proved complex and expensive. Questions over property rights and compensation for land damage in 1929 ultimately led to new concerns about the Corps' floodway plans. It took nearly six years to resolve these issues in the courts and Congress. For its part, the Corps, under a new chief of engineers, Maj. Gen. Lytle Brown, sought to refine its engineering plan for flood control on the Mississippi. After much study, General Brown's approach differed little from General Jadwin's plan. It retained most of the engineering aspects and required nonfederal interests to provide all rights-of-way and flowage rights, except when the federal government specifically agreed to pay such costs. Also, the Corps' long-standing resistance to flood control reservoirs as not cost-effective finally gave way to economic necessity when growing unemployment during the Great Depression made large-scale public works, such as flood control dams, an attractive way to create employment.

The Flood Control Act of 1928 was also notable for creating the Mississippi River and Tributaries Project (MR&T) to be operated under the direction of the MRC. The MR&T sought to provide flood protection for a 36,000 square-mile area in the lower Mississippi River basin stretching from Cape Girardeau, Missouri, south to the Head of Passes, which is the point where the Mississippi River divides into three south-flowing branches. The project was a massive undertaking that included a 3,500-mile levee system; floodways to pass excess flows in critical reaches of the river; channel improvements and bank stabilization to sustain a navigable channel; and tributary basin improvements, such as dams and reservoirs, pumping stations, and auxiliary channels, to better manage flood waters. The MR&T work—which continues into the twenty-first century—is overseen by the MRC but has been constructed and some sections operated and maintained by the Corps of Engineers.

The complete federal acceptance of responsibility for flood control on the nation's rivers occurred in 1936. A series of devastating floods in New England and the Ohio River valley during economic hard times pushed Congress to action. The desire to protect human life and provide public-works relief projects led Congress to enact the 1936 Flood Control Act. This measure recognized that flood control was a federal responsibility in cooperation with the states and local governments and directed the Corps of Engineers to carry out the federal flood control mission. A key provision of the 1936 Flood Control Act mandated that each federal project had to have economic benefits that exceeded costs before it could go forward. The law also set in place requirements for local contributions to the flood control projects. For instance, the law stipulated that before construction could begin the non-federal interest had to provide land,

Pittsburgh District, U.S. Army Corps of Engineers

The intersection of Stanwix St. and Fort Duquesne Blvd. in Pittsburgh, Pennsylvania, covered with floodwaters on 18 March 1936 easements, and rights-of-way; the non-federal entity also had to agree to hold the federal government safe from damage claims and to operate and maintain the completed flood control works according to regulations established by the Corps.

The shared arrangement proved effective in many ways but did not stem the tide of rising flood losses. In the thirty-four years before the Corps received its flood control mission in 1936, flood losses approximated $4.1 billion, but in the subsequent twenty-two years (1936–58) damages amounted to $6.6 billion. The continued human encroachment on floodplains for housing, commercial applications, and industrial uses contributed significantly to mounting losses. Over time, Congress altered the precise requirements imposed on local interests benefitting from federal flood control projects.

Many of the approximately four hundred flood control reservoirs eventually built by the Corps also provided other benefits, such as navigation, hydropower, irrigation, and water storage. The multiple-purpose nature of many flood control projects pushed the Corps and the Bureau of Reclamation to develop a cooperative approach that led the Corps to construct flood control dams on navigable rivers, whereas the Bureau of Reclamation built flood control dams in combination with irrigation needs.[23]

To carry out its expanded flood control mission and develop new methods for dealing with the Mississippi River's flow—beyond simply building higher levees—the Corps needed to develop better scientific knowledge of the river and its tributaries. To that end, Congress authorized the Corps in 1927 to establish a hydraulics

U.S. Army Engineer Waterways Experiment Station

A portion of the Mississippi River Flood Control Model, one of the oldest existing models at the Waterways Experiment Station, showing the Old River Control Structures laboratory, known as the Waterways Experiment Station (WES), at Vicksburg, Mississippi. Over time, the laboratory carried out systematic studies using models of the river and sophisticated mathematics. The engineers then used this knowledge of the river's workings to design improved flood control structures. What distinguished the WES from other hydraulics laboratories, though, was its emphasis on river mechanics rather than just tests on structures such as dams, spillways, and locks. Research at WES advanced both theory and practical application in river control.[24]

CONTROL OF FEDERAL PUBLIC WORKS

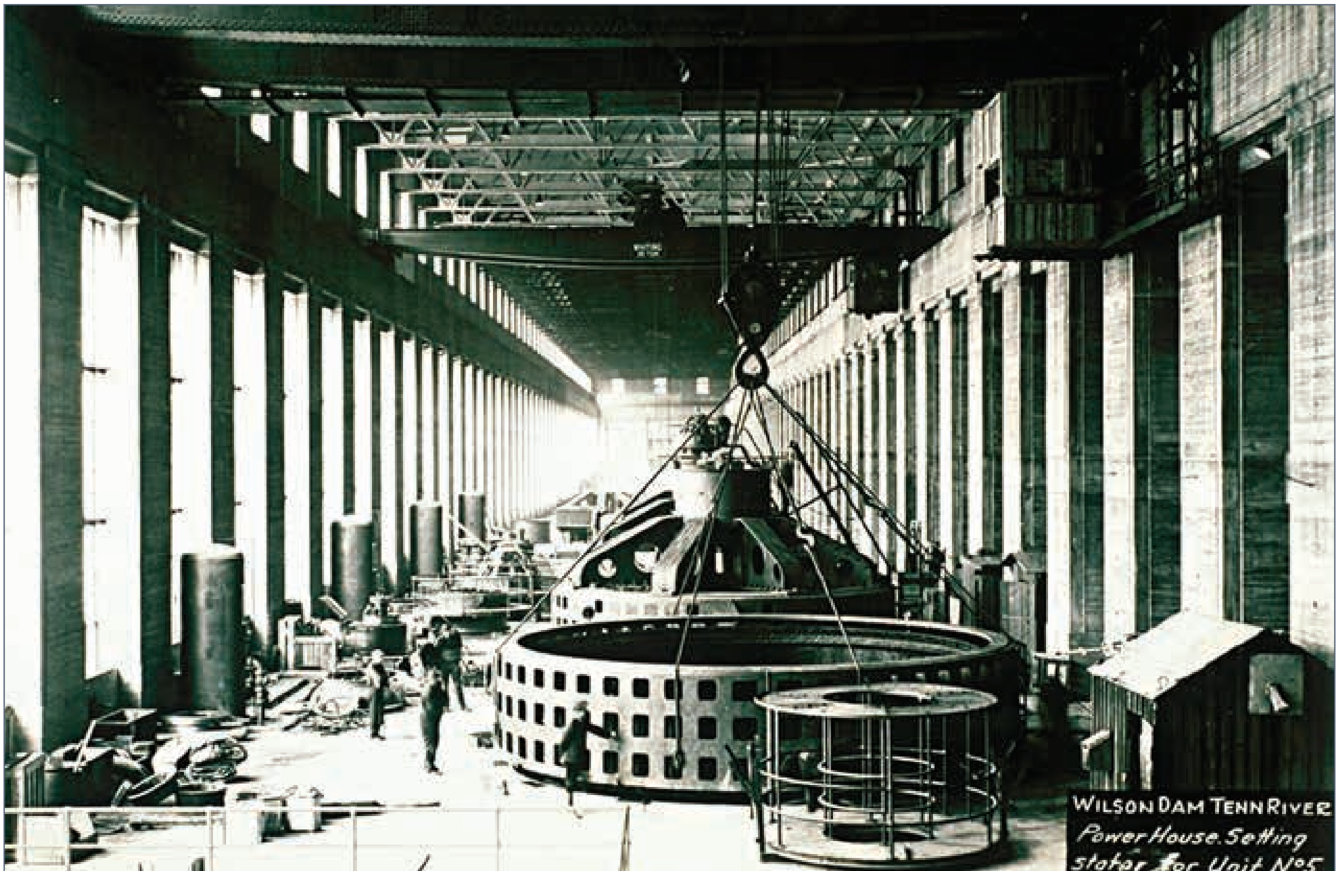
While the Corps began an expanding flood control mission in the 1920s and 1930s, two other developments influenced the methods and direction used to carry out its expanding water resources role. One situation involved the Corps' position in public works construction, while the other determined the scope of its mission. The former issue pitted the Corps against the private construction industry in a struggle over who would direct the building of federal public works, and the latter situation involved the impact of multiple-purpose projects on shaping federal public works.[25]

During the 1920s, the Corps continued to encounter a stiff challenge to its dominance of federal public works from the private construction industry. Private contractors resented the Corps' traditional role in river and harbors work because they believed that the private sector could do such work better and more cheaply than the Corps. Although resistance from nongovernmental engineers and contractors to the Corps' civil works mission had a history stretching back to the 1870s, it took on added intensity in the 1920s as the Corps' activities expanded. The rivers and harbors program during that decade included about two hundred harbor and three hundred river projects, and up to eighty-five canal projects. Private contractors decried in particular the Corps' increasing use of hired labor and government-owned equipment to carry out its navigation and flood control projects. In 1900, for example, the Corps conducted 12 percent of its project work with hired labor, whereas by 1924 its use of hired labor had reached 75 percent. The Corps' capital investment in equipment increased from $2.5 million to $50 million for those same years. During the 1920s, the Corps' civilian workforce also reflected this trend. In 1921, the number of civilian employees stood at 17,000, but by 1931 it had reached 25,000. Realizing that a protracted battle with the politically influential private construction industry was not in the Corps' long-term interest, the agency offered to do as much of its rivers and harbors work as possible with private contractors through competitive bidding. This proved to be a viable solution over time. In fact, by 1938, the Corps was doing 72 percent of its new work by contract and only 28 percent by hired laborers—almost exactly the reverse of the situation in 1926.

THE EMBRACE OF MULTIPLE-PURPOSE WATER RESOURCES PLANNING

While the Corps struggled to maintain its control over federal public works involving navigation and flood control prior to World War II, the agency found it necessary to drop its opposition to multiple-purpose water resources projects. The Corps realized that private dam building—largely for hydropower purposes—could undermine its prerogatives in navigation work. It, moreover, understood that hydropower could finance dams that benefited navigation and flood control projects.

The Corps of Engineers gained experience in constructing a multiple-purpose dam in the early 1920s. To produce nitrates for munitions during World War I, Congress directed the Corps to build Wilson Dam on the Tennessee River to generate electrical power for the nitrate plants, but the dam would also provide flood control and navigation benefits. This undertaking, along



Office of History, Headquarters, U.S. Army Corps of Engineers

Installation of power generators at Wilson Dam on the Tennessee River in Alabama, 1926

with an innovative preliminary examination of the water resources potential of the Tennessee River and tributaries in the early 1920s, provided the Corps with a model for future projects of this type. This undertaking also encouraged congressional supporters of multiple-purpose development to consider investigating other rivers compatible with such an approach.[26]

The catalyst for pushing the Corps' acceptance of multiple-purpose water resources development arrived in 1925 when Congress directed the Corps and the Federal Power Commission to prepare cost estimates for surveys of those navigable streams and tributaries "whereon power development appears feasible and practicable." Congress wanted a plan for improving stream navigation "in combination with the most efficient development of a potential water power, the control of floods, and the needs of irrigation." The Corps, in 1926, submitted a list of over two hundred rivers that justified study for such purposes, and the following year Congress appropriated the funds to carry out the recommended investigations. The Corps then initiated and completed, over a five-year period, an unprecedented series of comprehensive river surveys that compiled baseline economic, social, scientific, and engineering data. The Army Engineers' final reports to Congress analyzed the survey information, developed plans, and recommended projects. The finished studies became known as the "308 Reports," named after the number of the House of Representatives document that contained the Corps' original survey estimates.[27]

The process of producing the surveys transformed the Corps, giving its officers and civilian engineers the knowledge, skills, and commitment to carry out a national program of multiple-purpose water resource developments. In 1935, Congress directed the Corps to periodically update the 308 Reports to reflect important changes in economic factors, additional streamflow data, or other pertinent information. With this authority, the Corps had broad responsibility to carry out continuing river basin planning for navigation, hydropower, and flood control. The 308 Reports became the basic planning guides for federal multiple-purpose water resources projects undertaken over the next fifty years.

BONNEVILLE AND GRAND COULEE DAMS ON THE COLUMBIA RIVER

The water resources projects proposed in the 308 Reports began appearing in 1932 and quickly found a keenly interested audience. Under the economic pressure of the Depression, the new administration of Franklin Roosevelt was receptive to the notion of massive water resource projects providing work relief. The plans laid out in the 308 Reports presented thoughtful blueprints for combining infrastructure creation with unemployment relief. A prime example of the unfolding process of multiple-purpose water resource development occurred with the Corps' 308 Report for the Columbia River in the Pacific Northwest. Using recommendations from this study, the Oregon and Washington congressional delegations won President Roosevelt's commitment for two federal dams on the Columbia River. In 1933, construction started on Grand Coulee Dam on the upper Columbia and on Bonneville Dam on the lower Columbia River. The Bureau of Reclamation built the former for irrigation and hydropower, while the Corps constructed the latter dam for navigation and hydropower. These dams—situated on a major, swift-flowing river—were massive, multi-component concrete structures that tested the limits of dam technology of the period.[28]

In building Bonneville Dam in the Columbia River Gorge, the Corps had to overcome many unique challenges that required novel design and construction techniques. The spillway dam, for example, was to be located in a narrow channel that had wide fluctuations in stream flow. In addition, the structure had to rest on comparatively weak foundation rock and be able to pass a large flood without causing a major rise in headwater elevations. To help solve these and other design problems, the Corps built a hydraulics laboratory in Portland to model the river and test different spillway solutions. Ultimately, the engineers built a gravity concrete spillway dam 1,450 feet in length with eighteen steel gates, each fifty feet wide. At its base, the dam measured 132 feet in width and reached a height of 197 feet above its lowest point. To help the spillway pass large stream flows without raising flood elevations, the Corps widened the river by excavating almost one million cubic yards of material from the riverbanks. As designed, Bonneville Dam's spillway had a capacity of 1.6 million cubic feet per second, significantly larger than any existing dam in the United States.

The design of the reinforced concrete powerhouse and its associated equipment also proved challenging. Separated from the spillway connecting to Bradford Island, the powerhouse had to handle large quantities of water at comparatively low head. The structure extended 1,027 feet in length and was 190 feet in both width and height (above bedrock). The powerhouse design required large intakes, concrete scroll cases, and deep-draft tubes. The Corps carried out extensive model studies at its hydraulics laboratory in Portland to guide this design effort. Although the original plans called for two generators, within a few years the engineers expanded the powerhouse to accommodate ten units.

Each generator was equipped with the Kaplan adjustable-blade, propeller type of turbine. This was one of the earliest uses of this type of turbine in the U.S. Engineers selected the Kaplan turbine because of space

North Pacific Division, U.S. Army Corps of Engineers

Bonneville Lock and Dam, whose primary functions are to generate electrical power and to aid river navigation

constraints at Bonneville and the wide seasonal variation of head at the powerhouse. The Kaplan turbine required less space per horsepower than other types of turbines and achieved maximum efficiency under a wide range of head pressures. Each turbine unit weighed nine hundred tons, had a main shaft diameter of forty inches, and possessed a discharge capacity of 13,000 cubic feet of water per second. At the dam's completion in 1937, its Kaplan turbines were the largest in the world and represented a major advance for hydroelectric power plants because they had never before been tried on such a scale.

The Corps' electrical engineers worked under difficult circumstances, with the design and construction of the powerhouse structure occurring before the actual electrical load and means of achieving it had been established. To satisfy itself that the power plant design and choice of turbines was the best available, the Corps sought the advice of top consultants in the field of waterpower works. To implement the plans and designs in the required timeframe, contractors built at a frantic pace, with one frustrated electrical engineer exclaiming that "the only objective apparently being the dumping of yards of concrete and placing of tons of steel. Structural design in the office was but a jump ahead of actual construction in the field."[29]

As work got underway on the navigation lock, political considerations forced several changes in the original plans. The Corps initially proposed a tandem lock sufficient for existing barge traffic. Under considerable pressure from Oregon politicians, however, the engineers ultimately opted for a single-lift lock seventy-six feet wide, five hundred feet long, and twenty-four feet over the sill at low water. Such dimensions made the lock capable of handling ocean-going ships. With a vertical lift of sixty feet, the Bonneville lock was the highest single-lift lock built to that time. The navigation lock was located between the powerhouse and the Oregon shore.

The actual construction of the spillway dam posed severe problems. The depth of the water, current velocity, and harsh weather conditions together with the annual summer flood presented challenging conditions. The construction season only lasted from August to March. After extensive hydraulic studies, the engineers adopted a plan calling for massive timber cofferdams as the best means of diverting the river from the work site. The contractors divided the river in half, dewatering each half successively. After the south spillway's partial construction during the 1935–36 low-water work seasons, the workers removed the cofferdam and let the river flow between the piers over the uncompleted crest sections, while another cofferdam was put in place for work on the north section. Finally, workers placed a prefabricated structural steel cofferdam over the crest section between the piers of the uncompleted south portion so that those units could be brought to final elevation.

A unique feature of the crib cofferdam method of construction required "tailoring" the crib bottoms to fit the irregularities of the riverbed. First, though, the engineers had to dredge the thin overburden and carefully sound and map the river bottom. The job of designing, building, and placing these huge wooden structures—each as large as a six-story building—in the 900-foot wide river channel with a depth of 20 to 50 feet of water flowing from 6 to 9 feet per second, severely tested the capabilities of the engineers and contractors. At the time, it was the largest cofferdam job attempted on a U.S. river and attracted keen interest from the engineering community.

The Bonneville Dam Project required placing about one million cubic yards of concrete with special qualities. The concrete needed great tensile strength and low ultimate heat of hydration, with much of its total heat of hydration generated within the first three days following placement. These qualities were needed so the concrete would harden early and construction could be pushed at maximum speed. The engineers also needed a way to avoid the excessive heat generated by the chemical reaction between cement and water, which could produce serious cracking as the concrete set. After extensive testing of various cements, the Corps chose Portland-pozzolan cement. In addition to its greater tensile and compressive strengths and desired heat of hydration characteristics, it continued to gain strength over time and possessed greater resistance to weathering and rough water action. At the time of its selection for Bonneville Dam, builders had made little use of Portland-pozzolan cement in mass-concrete construction in America. Many hydraulic structures in Europe, however, had used it with satisfactory results. Because of limited experience with Portland-pozzolan cement, the Corps developed rigid specifications and implemented a stringent testing program to ensure consistently high quality cement.

In large measure, the design and construction of Bonneville Dam demonstrated the Corps' ability to combine its accumulated skills in water resources planning, including project design and implementation, with careful analysis of the specific engineering problems at Bonneville. In meeting the challenges of building Bonneville Dam, the Corps devised innovations in concrete mix, spillway design, coffer-damming, and fishways (discussed below). They also pioneered in the application of the Kaplan turbine to the special demands of water flow on the Columbia. These engineering solutions and their implementation demonstrated the Corps' technological and organizational prowess because they had to be integrated into the project on a tight construction schedule and within a reasonable budget. Although they consulted with outside experts on specific issues, the Corps drew on its own considerable technical expertise that had been accumulating for over one hundred years through improvements on the nation's major rivers. The Corps' engineering innovations in the design and construction of Bonneville Dam stimulated further experiments and testing at its own hydraulics laboratories and other institutions for future Corps' dams on the Columbia River and elsewhere.

When construction started on Grand Coulee Dam, the irrigation aspect of the project initially took a backseat to power production. The right powerhouse began generating power from eight units in 1942 to meet wartime demands for electricity. The Bureau of Reclamation did not begin work on the massive Columbia Basin Project for irrigation until after World War II. The bureau considered the Columbia Basin Project one of the most important irrigation efforts ever undertaken to benefit small, family farms. In 1940, the Bureau estimated that it would take fifty years before the 1.2 million acre project, containing 15,000 to 20,000 farms, was fully irrigated and in production. Even with power from Grand Coulee Dam subsidizing the cost of the pumping systems and canals, the project failed to live up to its expectations as a refuge for displaced, small farmers fleeing marginal lands elsewhere in the West. In 1968, when the federal government turned the project over to the water users, only one-half of the one million acres had been watered, and the cost for the project had ballooned from an estimated $280 million to more than a billion dollars. By 1970, the 40-acre plots authorized in the original project planning had increased to 240-acre farms. It was also clear that the cost of watering the entire one million acres would far exceed the benefits.[30]

As work progressed on Bonneville and Grand Coulee dams, the question arose over who would market the power the dams would produce. After much political debate, both within the Roosevelt administration and Congress, President Roosevelt signed the Bonneville Power Act in August 1937. This measure settled the question of marketing federal power in the Pacific Northwest by assigning the Corps and the Bureau of Reclamation the responsibility for generating power at their respective dams but rejecting the proposals simply to sell the power at the dam site to those able to come and get it. Instead, the legislation created a federal marketing agency, the Bonneville Power Administration (BPA), to sell the power in accordance with the policy of "widest possible use of available electric energy that can be generated and marketed." The law gave preference to publicly and cooperatively owned distribution systems, and the new agency adopted a policy of a blanket rate along the entire transmission system. The rates, however, had to allow the government to recover the cost of producing and transmitting the power. In later years, the BPA's authority to market power expanded to include thirty-two additional federal projects constructed in the Northwest.[31]

The authors of the BPA's charter drew on the experience gained from the creation of the TVA, in 1933, but they placed important limits on the BPA's mission. The TVA, unlike the BPA, had the mandate to develop comprehensive river basin plans and implement them by building dams and marketing the power from them for the entire Tennessee valley basin. The TVA relied on the Corps' 308 Report for the Tennessee River as the basis for its initial basin planning. The Roosevelt administration proposed that the TVA model be adapted for other river basins, but Congress never went along with the idea. In the Pacific Northwest, strong resistance developed to the creation of a TVA-style federal administration that would control the development of the region's water resources. The dominant federal agencies such as the Army Corps

The Columbia River System

The largest river in the Pacific Northwest, the Columbia runs more than 1,240 miles (1,996 km) and extends into seven U.S. states and one Canadian province while draining an area roughly the size of France. The Columbia River system is also one of the most hydroelectrically developed in the world. The Corps of Engineers built and still maintains ten locks in the system—eight on the Columbia and Snake rivers, one on the Willamette River, and one at Lake Washington in Seattle.

of Engineers, Bureau of Reclamation, and BPA were also cool to the idea of surrendering control of their facilities to a new, super federal agency.[32]

As the New Deal-driven, multiple-purpose projects unfolded across the American West, four river systems—Columbia, Colorado, Missouri, and Central Valley, California—provided the locations for most of these undertakings. Each river basin had its own unique political, topographical, and hydrological characteristics. As seen in the early development of the Columbia River, both the Corps of Engineers and Bureau of Reclamation contributed to the effect. In the case of the Colorado River, politicians and developers prized water from that river for irrigation, municipal supply, and hydropower purposes. Here, the Bureau of Reclamation seemed the logical choice to build the proposed dams, although the benefits to be derived from the waters of the Colorado River were much contested by the states of Arizona and California. While the states jousted over control of the water resources benefits, the Bureau of Reclamation did its part by building Boulder and Parker dams in the 1930s. In the Central Valley Project, the Bureau, after some competition with the Corps, built two massive, concrete gravity dams—Shasta and Friant—to irrigate rich agricultural lands fed by the Sacramento and San Joaquin rivers in California. The Bureau constructed the dams between 1937 and 1945. As with so many other federal reclamation projects, the Bureau did not enforce the 160-acre limitation on farms receiving water. As a result, corporate agriculture became the chief beneficiary of the Central Valley Project.[33]

FORT PECK DAM ON THE MISSOURI RIVER

During the 1930s, both the Corps of Engineers and the Bureau of Reclamation built major multiple-purpose projects in the Missouri River basin and jockeyed for dominance in carrying out water resources development for that region. The massive, earth-filled Fort Peck Dam, which was built 1,879 miles upstream from the mouth of the Missouri River, owed its existence to the Corps' 308 studies. Financing for the project came from New Deal relief funds. The Corps promoted the project to provide flows to maintain a navigation channel of six feet in the Missouri River for 795 miles below Sioux City, Iowa. The dam would also create incidental flood control benefits and could be adapted for hydropower and irrigation benefits in the future. When completed, the dam had the capacity to store 19.4 million acre-feet of water.[34]

Initially, the Corps was ambivalent about the need for Fort Peck Dam, and opponents argued that it lacked sufficient economic benefits to justify construction, either for navigation or any other purpose. The Roosevelt administration, however, saw the project as a quick means to put thousands of unemployed laborers to work in one of the most depressed regions of the country. Begun under presidential order in 1933, the dam was formally authorized by Congress in 1935.

The Corps designed Fort Peck Dam as an earth-fill structure constructed by the hydraulic fill method, using materials from the riverbed and surrounding valley. As designed, the dam consisted of two porous sand and gravel shells, holding a dense, relatively impervious core of silt, fine sand, and clay. When completed, the main structure stood 242 feet above the river bed and had a width at the base of nearly 3,000 feet and a length of 9,000 feet. The left abutment spur added an additional 11,000 feet to the dam. The crest of the dam extended 100 feet across. In all, the structure required about 100 million cubic yards of earth to complete. The Corps' design also required covering the upstream and downstream faces of the dam with 5.6 million cubic yards of heavy riprap and placing a steel sheet pile cut-off diaphragm, extending from twenty feet above the base down to bedrock, to reduce percolation through the alluvium under the base of the dam.

In addition to the earth-fill dam, the Fort Peck Dam project also consisted of several other features.

President Franklin Roosevelt visiting Ft. Peck Dam during the New Deal Era

To release stored water from the dam, the design used four concrete tunnels with 26-inch diameters and an average length of 6,160 feet. To pass extreme flood flows, the plan called for a spillway located in the shale bluffs some three miles from the right abutment of the dam. The spillway contained sixteen Stoney gates, twenty-five to forty feet wide. The spillway channel extended for approximately two miles. For one mile of its length, the spillway was lined with concrete. Contractors excavated thirteen million cubic yards of material to construct the spillway. The isolated location of the worksite required major work to extend railroad, highway, and utility lines to the project. The Corps also had to construct a temporary town with modern facilities and amenities for up to eight thousand workers.

Work at Fort Peck Dam came to an abrupt halt on September 22, 1938, when a section of the upstream face of the dam, containing 5.2 million cubic yards of fill, slid into the reservoir. Eight men died and a large amount of equipment was temporarily lost. The earth movement did not block the tunnel inlets, so normal discharge continued without endangering the dam. After recovering the disabled equipment and the bodies of the dead workers, the Corps conducted tests to determine the cause of the failure and salvaged the quarry and field-stone used to face the dam. The tests revealed that weak foundation rock in the vicinity of the slide could not withstand the shearing force to which it was subjected. Reconstruction of the damaged section of the dam required using a different type of core material (glacial-till) and placing it by rolled-fill rather than hydraulic methods. The dam cross section was also increased by flattening the slope. To secure a bond between the original core and the reconstructed core, the workers drove a steel sheet pile cutoff wall through the overlaying material into the undisturbed core material for a distance of at least twenty feet. The Corps completed the dam, without further incident, in 1940. The Corps built all subsequent earth-fill dams with the roller-compacted method and a flatter upstream slope.

INTERAGENCY COORDINATION DURING THE NEW DEAL

The Corps' multiple-purpose undertakings during the 1930s increasingly brought it into fields nominally the responsibility of other federal agencies. The situation was fraught with the potential for misunderstandings or turf wars. Although relations between the Corps of Engineers and the Bureau of Reclamation or the Department of Agriculture sometimes became strained, for the most part, the Corps and the other

The Missouri River System

The Missouri is the longest river in North America. With headwaters in the Rocky Mountains, it flows southeasterly for 2,341 miles (3,767 km) before joining the Mississippi River north of St. Louis. It drains ten U.S. states and two Canadian provinces and, when combined with the lower Mississippi River, forms the world's fourth-longest river system.

federal agencies got along well enough. For example, in producing the 308 Reports, the Corps needed assistance and data from a number of federal agencies such as the Bureau of Reclamation, the U.S. Geologic Survey, the Department of Agriculture, and the Federal Power Commission. In the Pacific Northwest, the Corps districts involved in drafting the 308 Report on the Columbia River and tributaries made every effort to assure the Bureau of Reclamation that the Corps was not out to take over irrigation responsibilities in the region and developed a good working relationship at the field level between the two agencies. Still, as the Corps built navigation and flood control projects that had an irrigation component, the potential for conflict existed and occasionally flared up. In the late 1930s, for example, the Corps and the Bureau of Reclamation presented differing approaches to water resources development in the Missouri River basin.[35]

When potential conflicts arose, the Roosevelt administration tried to ensure coordination among the Corps, the Department of Agriculture, and the Bureau of Reclamation. This effort ultimately led to a 1939 tripartite agreement that obligated the three agencies to exchange information and consult with one another in preparing reports. Although the agreement did not eliminate the major differences among the agencies, it did lead to increased cooperation. In 1938, Congress also attempted to foster greater coordination in hydropower development by directing the Corps to consult with the Federal Power Commission on waterpower facilities in flood control dams. Congress, on the other hand, continued to support the efforts of the Corps to resist the Roosevelt administration's attempts to dominate water resources planning through its New Deal Water Resources Committee of the National Resources Planning Board. In 1943, Congress eliminated funding for the executive branch's water resources planning bodies. Thereafter, Roosevelt relied on the Bureau of Budget in the executive office of the White House to coordinate and centralize water resources planning. By executive order (1943), all federal agencies were required to submit their programs to the Bureau of the Budget, which would, in turn, advise the agencies on the relationship proposed projects had to the program of the president.

After 1940, U.S. preparation for and participation in World War II brought most water resources projects to a halt. Congress, however, did appropriate sufficient funds for the Corps to carry out necessary project operations and maintenance, but wherever possible, men and material were diverted to the war effort. The only exceptions involved civil works projects that supported the war effort, such as completing or adding hydropower facilities on recently built multiple-purpose dams and building the highly secret atomic energy plants necessary to military success. As the war wound down, however, the Corps and other water resource agencies began planning for postwar activities by preparing to complete projects left undone, updating the 308 Reports so that authorized projects could quickly get underway, or proposing new undertakings. The federal government hoped that proper planning would provide public works employment for the demobilized Army and Navy and thereby avoid a postwar recession as happened after World War I.

PICK-SLOAN PLAN ON THE MISSOURI RIVER

Planning for the post-World War II development of the Missouri River basin surfaced anew the existing rivalry between the Corps of Engineers and the Bureau of Reclamation. In 1939, Congress gave the Bureau of Reclamation the authority to include purposes other than irrigation in its projects. These benefits might include hydropower, municipal water supply, flood control, and even navigation. The Bureau of Reclamation directed one of its top engineers and managers, William Sloan, to come up with a plan for development of the Missouri River basin. In 1943, while Sloan worked on his study, Missouri River Division Engineer Col. Lewis Pick also came forward with a plan for a series of dams and reservoirs on the Missouri between Fort Peck and Sioux City. Colonel Pick had been motivated in part by severe flooding on the Missouri in the spring of 1943. He identified five dams that would be multiple-purpose projects to maximize the use of the basin waters.[36]

The Bureau of Reclamation would support the Corps' plan only if it could develop the irrigation potential of the upper basin. The Sloan Report proposed only three dams on the main river between Fort Peck and Sioux City and added storage on the tributaries. After much political maneuvering, the Corps and the Bureau worked out a compromise, known as the Pick-Sloan Plan, which was ultimately enacted by Congress in 1944. The compromise plan permitted both agencies to share in the postwar development of federal multiple-purpose

U.S. Army

Lewis A. Pick (1890–1956), who became Chief of Engineers in 1949

dams in the Missouri River basin. Basically, the Corps kept its five mainstream dams, while the Bureau built irrigation reservoirs on the tributaries. Both agencies installed hydropower facilities where feasible. Controversy formed over the creation of a Missouri Valley Authority to direct river basin development. In addition, American Indian tribes who would be dispossessed of their lands raised objections. Just when these concerns threatened to halt the first Corps project on the Missouri (Garrison Dam), a major flood intervened and induced Congress to move ahead with the project.

By 1964, the other four Corps dams on the main stem Missouri River had been completed, as well as a number of Bureau of Reclamation dams on tributaries. Based on its Fort Peck construction experience, the Corps built the dams as roller-compacted, earth-fill structures. The upper three dams provided major flood control benefits on the Missouri, but dramatically altered the sedimentation patterns, flora and fauna, and water quality of the river. The projects, however, fulfilled the desires of those seeking regional development through the use of natural resources and the scientific mastery of nature. Over time, the operation of the Missouri River basin system has been complex because of the high ratio of storage to runoff. This fact complicated the scheduling of water release or retention from the main-stem reservoirs to meet the various needs of flood control, power generation, irrigation, recreation, and fish and wildlife purposes. Although the Corps was responsible for operating the Missouri River system, it coordinated closely with the Bureau of Reclamation, the states, and American Indian tribes to achieve the multiple purposes of the dams.

POSTWAR PLANNING IN THE COLUMBIA RIVER BASIN

Just as a major flood had influenced the implementation of the Pick-Sloan plan, a severe flood in 1948 also affected the continuing water resources development of the Columbia River and its tributaries. The Corps believed that, at a minimum, two more hydropower dams—one on the upper and one on the lower Columbia—would be needed to meet future growth in the region. The postwar planning also involved other federal agencies besides the Corps. The Bureau of Reclamation proposed irrigation and flood control projects on the Columbia's tributaries throughout the Northwest, while the BPA focused on expanding its power transmission facilities and marketing efforts. The Departments of War, Agriculture, and Interior as well as the Federal Power Commission agreed to establish the Federal Inter-Agency River Basins Commission (FIARBC) to encourage cooperation among federal water resources agencies. The FIARBC was an outgrowth of an earlier tripartite interagency agreement established in 1939 to foster cooperation within the federal water resources bureaucracies. Congress also added its voice to those urging greater coordination among water resources agencies. In the Flood Control Act of 1944, Congress directed the Corps of Engineers and the Department of the Interior to consult with each other when planning their studies and to share data from their investigations.[37]

By the mid-1940s, changed conditions in the Columbia basin required a thorough reassessment of the 308 Report and a new look at its tributaries because they offered the most realistic possibilities for storing large quantities of water for release to generate power. Planning for the tributaries, which had not been well developed in the original 308 Report, was a major consideration in the comprehensive planning for further development of hydropower and for other water concerns of the region. Attention to the Canadian portion of the Columbia, a delicate issue requiring consultations with the authorities north of the border, was also necessary.

While the Corps rushed to complete its review of the 308 Report by October 1948, the Bureau of Reclamation published its own Columbia basin study, which focused more on irrigation. The Bureau report was not as comprehensive as the Corps' document because it was done without benefit of new investigations. The Corps' review expanded the multiple-purpose approach of the original 308 Report to consider such topics as fish conservation, pollution, domestic water supply, and recreation, in addition to hydropower, navigation, flood control, and irrigation. Flood control as a factor in water resources development took on an added significance in light of the disastrous floods on the Columbia River system in May 1948. When the floods occurred, the comprehensive report was in the final review stages. On June 1, 1948, President Harry Truman personally ordered the Corps to revise its report to take into account the cost and benefits of flood storage at future control works on the Columbia River system.

The comprehensive report of 1948, known as the main control plan, proposed a few major multiple-purpose reservoirs throughout the Columbia Basin and flood control levees on the lower Columbia River. The main control plan recommended thirteen dams (including two already built and three under construction) with sufficient storage in seven of the reservoirs to hold flows to a level that would not overtop the downstream levees. The report also called for ten million kilowatts of generating capacity from the dams. The estimated cost of the main control plan came to $1.7 billion. Although the report was submitted in February 1950, Congress did not publish the Corps' 22-volume plan until 1952, as House Document Number 531.

Portland District, U.S. Army Corps of Engineers

The Bonneville Dam inundated by the Columbia River during a flood in 1948

The continued rapid pace of population and economic growth in the Pacific Northwest led Corps officials to call for a review of the main control plan in 1955. By 1957, the Corps had completed the McNary, Albeni Falls, Chief Joseph, and The Dalles projects, but several other undertakings in the main control plan had been abandoned or sidetracked. In addition, new information on Canadian water resources development and its effect on the U.S., growth in river commerce and on existing navigation projects, and the possibilities of atomic power all called for an update of the 1948 main control plan. The new review focused especially on the navigation possibilities of the mid-Columbia River between the McNary and Chief Joseph dams. The Corps' renewed interest in navigation on the mid-Columbia was surprising, because that use of the river had been long dormant. In part, the Corps was responding to the efforts of local economic interests for port development to support agriculture and attract industry.

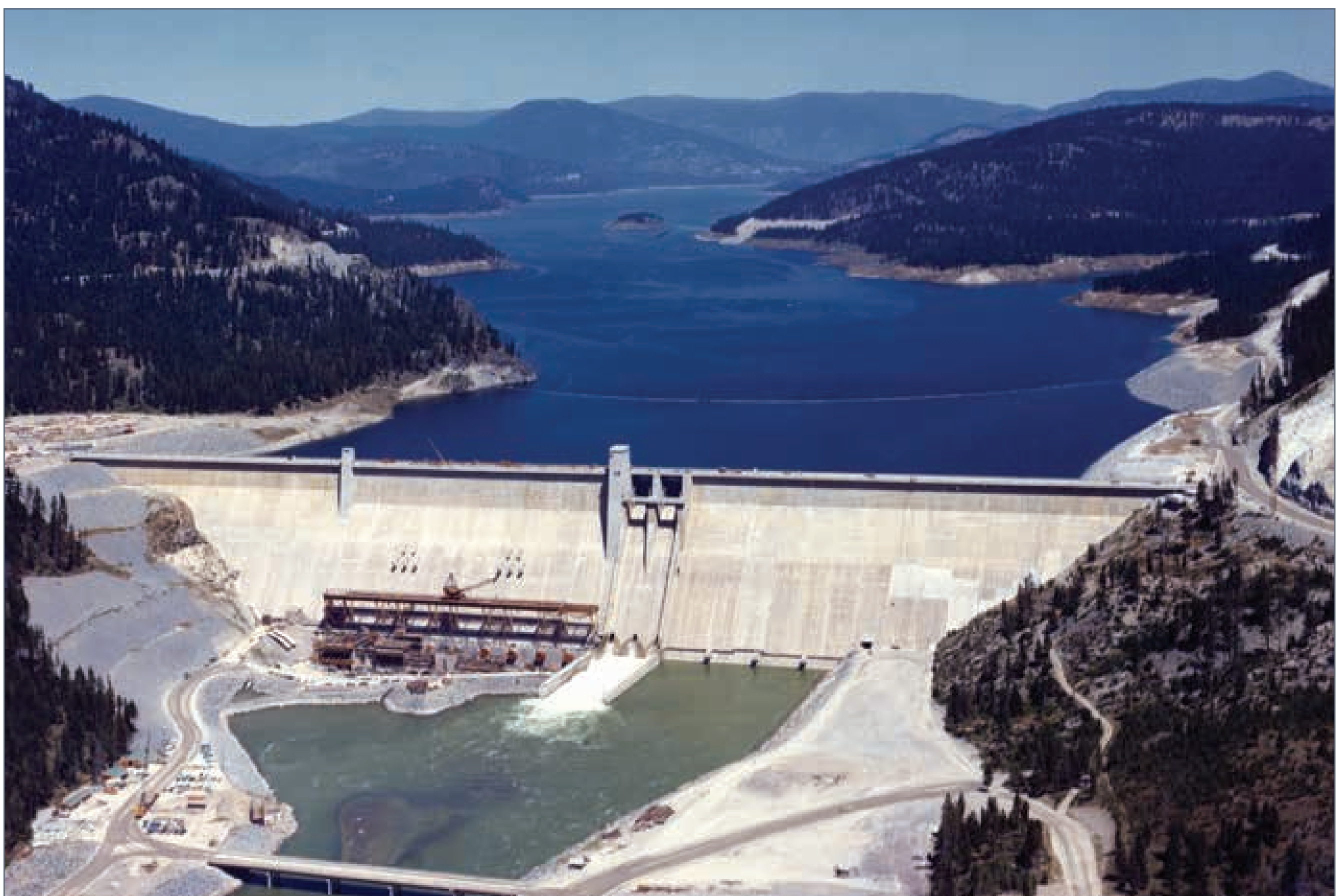
The report—submitted in June 1958 and known as the major water plan—called for accelerated development of the remaining water resources potential of the Columbia River system. The plan recommended twelve new dams on various tributaries of the Columbia River. The entire plan would provide 22.5 million acre-feet of storage and produce 3.2 million kilowatts of power. Including the proposed navigation improvements, the cost of the major water plan amounted to $1.9 billion. The Corps recommended implementing the various projects over a fifteen-year period, beginning in 1960. Unfortunately, delays drained the water plan of its vitality, and publication of the major water plan, as House Document 403, did not occur until 1963. Before the report was published, it underwent several changes—nine of the recommended projects were dropped or postponed, as well as the navigation component of the plan. However, one of the most important projects proposed in the report, Libby Dam, was built.

After lengthy negotiations over Columbia River development, the United States and Canada signed a treaty in January 1961. By terms of the treaty, Canada agreed to build three dams with a total of 15.5 million acre-feet of storage that would primarily benefit

Office of History, Headquarters, U.S. Army Corps of Engineers

Chief Joseph Dam under construction on the Columbia River near Bridgeport, Washington, ca. 1955 flood control and power production in the U.S. In turn, Canada was promised $64.4 million for the flood control benefits accruing to the U.S. and an entitlement to one-half of the downstream power benefits. This agreement allowed the U.S. to construct Libby Dam, which had north-of-the-border storage. The Corps constructed the dam between 1966 and 1975.

Two other major tributaries of the Columbia River also underwent development between 1938 and 1970. The 1938 Flood Control Act authorized the Corps' multiple-purpose plan of development for the Willamette River basin. The major purposes included flood control, hydropower, municipal water supply, and recreation. When completed, the thirteen dams had a total storage of almost 2.8 million acre-feet, with 1.9 million dedicated to flood control. The dams produced a total of 408,000 kilowatts of power. The Corps also constructed multiple-purpose dams on the lower Snake River between 1955 and 1975. The major purpose of these dams included navigation and hydropower. The dams generated 3.5 million kilowatts and cost $1 billion to construct. By the 1970s, the Pacific Northwest had fifty-five major hydroelectric projects, including thirty federal dams built by the Corps and the Bureau of Reclamation and twenty-five non-federal installations. Altogether, these dams made up the largest hydroelectric system in the world and were interconnected through the Bonneville Power Administration's transmission grid of 13,600 circuit miles of line in service.



Office of History, Headquarters, U.S. Army Corps of Engineers

Libby Dam under construction on the Kootenai River in Montana, ca. 1975

THE ENVIRONMENTAL CONSEQUENCES OF MULTIPLE-PURPOSE DEVELOPMENT

The expansion of the Corps' mission to embrace multiple-purpose water resources projects had broad environmental consequences. The creation of huge reservoirs that covered natural-flowing rivers and valuable wildlife habitat brought objections from conservationists and outdoor enthusiasts who feared the loss of unspoiled river valleys. Beginning in the 1930s, conservationists accused the Corps of giving too little credence to their views and refusing to take into account values that went beyond engineering or economic considerations. The 1934 Fish and Wildlife Coordination Act attempted to address environmental concerns by requiring consultation with the U.S. Bureau of Fisheries before building federal dams and recommended, where not inconsistent with the primary water purposes, the use of reservoirs for fish hatcheries and migratory bird refuges. The Corps' efforts to accommodate anadromous fish in the design and operation of the multiple-purpose dams on the Columbia River illustrated the new environmental considerations the agency faced.[38]

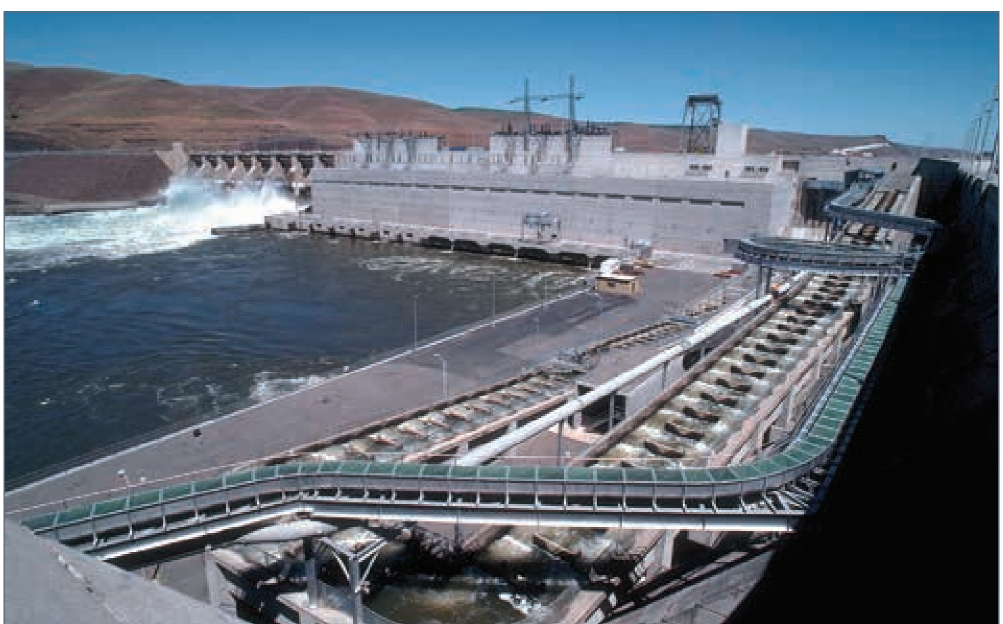
The Columbia River basin supported annual runs of millions of salmon and steelhead trout that spawned in fresh water and grew to maturity in salt water. At the time the Corps undertook the 308 studies for multiple-purpose dams on the Columbia, it recognized that those dams posed a threat to the fish runs. Accordingly, the 308 Report included fishways in the design and cost estimates for each proposed dam. However, fish passage facilities on the scale called for in dams of the size proposed had never before been attempted. Local fishing interests, both commercial and recreational, raised fears that Bonneville Dam would prove devastating. To address such concerns, the Corps assembled a team of fisheries experts to devise a plan for passing migratory fish upstream and fingerlings downstream. After much research and testing, the Corps' fisheries team proposed a design in September 1934—less than a year after the Bonneville Dam project started—that called for a lifts-and-ladders structure and a novel collection and bypass system. The elements of the fish passage plan underwent continued refinement as they were incorporated into the spillway and powerhouse structures. The fish passage facilities at Bonneville Dam, supplemented by continued studies over the ensuing years, served as a model for the passage systems installed at subsequent dams that were built on the Columbia and Snake rivers. In time, however, the Corps found that construction of additional dams on the Columbia River and its tributaries created new problems for anadromous fish that imperiled their survival.

Prior to World War II, the Corps generally resisted the input of conservation in the planning and building of its water resources projects. It gave little credence to views or values outside traditional engineering, hydrologic, and economic considerations. The Corps, moreover, generally rejected the environmental implications of its regulatory powers; it interpreted its authority under the Refuse Act and the Oil Pollution Act conservatively. The Corps issued permits for dredging, filling, or dumping waste in the nation's waters based on its assessment of whether or not the activity would obstruct navigation. Rather than control pollution at its source, the Corps supported other strategies for assisting fish and wildlife, such as establishing refuges. The Corps also narrowly interpreted its consultation responsibilities under the Wildlife Coordination Act of 1934, asserting that it was not obligated to follow the advice it received.

Between 1945 and 1970, the Corps increasingly recognized the importance of environmental issues. As the two updates to the 308 Report for the Columbia River reveal, fish and wildlife concerns drew much attention. In 1953, the Corps began a fisheries research program for the Columbia River system and by 1970 it had spent $4.8 million on the program. By 1956, the Corps had spent $130 million constructing fish passage facilities at its Columbia River projects. Over time, many more millions would be spent on upgrading fish facilities and conducting basic research. Most importantly, in 1958, Congress amended the Fish and Wildlife Coordination Act to mandate that fish and wildlife conservation receive equal consideration with other project purposes. However, full engagement with the environmental consequences of federal water resources development would not begin until the late 1960s when Congress adopted the National Environmental Policy Act and other environmental laws.

Although not a multiple-purpose project, the Corps' upper Mississippi River navigation project to establish a nine-foot channel had important environmental effects. The project, authorized by Congress in 1930, called for the Corps to build twenty-three locks and dams between Alton, Illinois, and Red Wing, Minnesota. These locks and dams would significantly alter the natural regime of the river. Many conservationists feared the consequences of the navigation project on fish and wildlife and opposed it. Efforts to improve the fishery on the upper Mississippi River initially occurred in 1927—six years before the Corps began work on the first major navigation improvements on the river. In the early twentieth century, conservationists sought to create a national wildlife and fish refuge on the upper Mississippi River to preserve and enhance the economic and recreational value of the fishery. In June 1924, Congress responded by establishing a 260-mile-long national fish and wildlife refuge between Wabasha, Minnesota, and Rock Island, Illinois.[39]

The Corps' proposed nine-foot channel project threatened to undermine the fish management operations for the upper Mississippi River. The conservationists pressed the Corps to minimize the impact of the locks and dams on fish and to develop a new fish-propagation program. To accommodate the conservationists' concerns, the Corps worked with the federal Bureau of Fisheries to provide fish culture stations in areas adjacent to the pools created by the new navigation channel dams. The Corps of Engineers and Bureau of Fisheries also deployed New Deal relief funds to expand the existing hatchery program. Conservation and navigation interests on the upper Mississippi River laid a foundation of environmental cooperation in the 1930s, which would prove useful in the 1980s when the Corps developed an agreement with the U.S. Fish and Wildlife Service and the natural resources departments



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Fish ladder and bypass flume at Little Goose Lock and Dam on the Snake River in Washington of Iowa and Wisconsin to compensate for the potential ecological effects of improvements to Lock and Dam No. 26 at Alton, Illinois. Under the agreement known as the Environmental Management Program, the federal and state agencies cooperated in more than fifty habitat restoration and enhancement projects.[40]

THE CORPS AND THE CIVIL WORKS MISSION IN THE POSTWAR ERA

Throughout the first half of the twentieth century, the Corps successfully fought off repeated attempts by its opponents in the federal government to take over its civil works mission and give that responsibility to another federal agency, either existing or newly created. The Corps' close relationship with Congress helped insulate it from the attacks of its opponents. This arrangement stemmed from the Corps' ability to propose water projects for congressional districts, while members of Congress, in turn, rejected attempts to undermine the Corps' independence. Still, the Corps' work in river basin planning forced it to coordinate with others doing water resources projects.[41]

During the 1930s, the Roosevelt administration tried to ensure interagency coordination of federal water projects and to centralize national resources planning under executive branch planning boards. Congress, however, never fully approved of executive branch efforts to centralize planning and, in 1943, refused to appropriate funds for the National Resources Planning Board. Likewise, efforts to establish TVA-style basin planning in river systems throughout the U.S. failed. In the post-World War II era, attempts by the two Hoover commissions on federal government reorganization to remove the Corps' civil works mission and give it to another federal agency also failed.

The Corps found itself further challenged by water resources specialists from non-engineering backgrounds. In the early 1950s, academics and social scientists published books and articles accusing the Corps of ignoring matters other than engineering in its water resources planning and lacking accountability to the executive branch. They joined the call for giving the Corps' civil works function to the Department of Interior or some other independent water development agency. A book by Harvard University political scientist Arthur Maass, *Muddy Waters: The Army Engineers and the Nation's Rivers*, powerfully exemplified this strand of criticism. Another academic critic Gilbert White, a geographer, took the Corps to task over its flood control practices. He asserted that the Corps placed undue reliance on structural approaches to flood damage reduction. White advocated a "floodplain management" approach that relied on the relocation of buildings,

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Gilbert White (1911–2006), the father of floodplain management zoning, and other non-structural measures. Essentially, the Corps' critics wanted water resources planning that accounted for a broader range of social and economic objectives that were better coordinated with other government agencies.

The political climate of the 1950s regarding water resources development also affected the Corps' civil works program. Several factors tended to limit the possibilities for new work. First, the military needs of the Korean War caused President Truman and Congress to cut domestic expenditures and halt new federal civil works projects, unless justified by defense requirements. Then, President Dwight D. Eisenhower announced a so-called partnership policy to reduce federal involvement in water resources development. Under President Eisenhower's approach, the federal government would initiate no new starts in river basin development and, instead, encourage private interests to undertake investments in new power projects. The federal government would fund the non-reimbursable costs, such as flood control and navigation of any multiple-purpose initiatives undertaken on a joint public/private basis. This policy was never well received, especially in the Pacific Northwest, and in practice the federal government continued to develop major water resources projects in the Columbia River basin during the 1950s.

The executive branch also tried to gain greater control over the various programs of its water resources agencies. After 1943, the Bureau of Budget sought to review federal agency programs to ensure an agency's plans fit within the overall administration program. Congress resisted this encroachment and refused appropriations to support the review process. Nevertheless, the Bureau of Budget, in December 1952, issued an order (Circular A-47) that profoundly impacted water resources planning. The circular required that the benefits of each element in a multiple-purpose project had to exceed the costs. Previously, it sufficed for the total benefits to exceed total costs. The circular also increased the requirement for local cost-sharing of flood control projects. To better clarify the economic justification of water projects, the order set fifty years as the maximum time to achieve repayment of a federal investment. This order remained in effect for more than a decade. Despite the best efforts of the Bureau of Budget to gain authority over resources policy, Congress jealously guarded its control of the Corps' and other federal resource agencies' water resources programs. The Bureau of Budget might delay a project but seldom could prevent Congress from ultimately funding it. Congress was not afraid to override a presidential veto of so-called "pork-barrel" water resources projects.

In the early 1960s, the forces for reform of water resources planning gained momentum. The administrations of Presidents John F. Kennedy and Lyndon B. Johnson were receptive to multi-objective federal water resources development. After a review of current practices, President Kennedy rescinded Circular A-47 and embraced Senate Document 97 (an interdepartmental agreement that was never formally approved by Congress). The policy enunciated in the Senate Document sought comprehensive federal water development through multidisciplinary planning that focused on national economic development, national resources preservation, and the "well-being of all people." Its specific terms increased a project's useful life standard to 100 years and indexed the project's discount rate to long-term government securities. Congress soon followed Senate Document 97 with the Water Resources Research Act of 1964, which authorized funding for water resources research at land-grant universities, and the Water Resources Planning Act of 1965, which established procedures for comprehensive regional water resources planning. The latter act authorized the president to set up river basin commissions to develop planning standards and procedures for major national watersheds and charged them with preparing comprehensive river basin plans that took into account water and related land resources. The commissions contained state as well as federal agency members involved with water resources.

The interdisciplinary planning of federal water projects envisioned by the 1965 act and constant pressure from the Bureau of the Budget pushed the Corps to bring social scientists and economists into its planning process, especially to better ground the benefit/cost analysis for water projects. In pursuit of this goal, the head of the Corps' programs division of the Civil Works Directorate worked assiduously throughout the 1960s to broaden and deepen the planning capabilities of the Corps. As a result, by 1967, the Corps had increased the number of economists on its roster to 119 and other non-engineering specialists to 516. In addition, the Corps established planning divisions in each district to support multi-objective planning analysis.

The rise of environmental issues in the 1960s (discussed in greater detail in chapter 9) also increased pressure for greater interdisciplinary planning in the Corps. The upshot of these trends led to the idea of creating a long-range planning organization within the Corps' headquarters. After much consideration, the Corps established the Institute for Water Resources (IWR) in 1969. In formally proposing the IWR, the Chief of Engineers Lt. Gen. William Cassidy succinctly noted: "In recent years the complexity of the water resources management field has been growing at a rapid pace, with new concepts and interests appearing in a continuing stream. We are facing new problems, as

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Men laying articulated concrete mattress revetment from a barge to stabilize the banks of the Mississippi River, 1940 well as new opportunities." He saw the IWR as a means for preparing the Corps to meet those future water resources development challenges. As he put it, such an institute would be "an essential tool in enabling the Corps to carry out its public service mission in the field of water resources." Initially, the IWR had four missions: planning, training, planning research, and problem solving in the planning fields. In the years ahead, it would further refine its responsibilities in the field of water resources planning within the Corps.[42]

The Corps' journey from single-purpose water resources projects justified mainly in engineering terms to multi-purpose undertakings to achieve diverse goals was long and arduous. The Corps responded ambivalently to the postwar emphasis on more rigorous cost-benefit analysis of water resources projects. Although headquarters officials at the Corps embraced the new ideas and procedures for evaluating projects, engineers at the agency's field offices appeared more resistant. Many engineers in the field believed that the objectives of social scientists would needlessly complicate otherwise technically sound projects and greatly increase costs. By the 1960s, however, the process of economic evaluation of projects through multi-objective economic analysis could not be halted. This approach focused on such matters as actual social objectives, for example income generation, food or industrial production, regional development, and environmental impacts. As water resources historian Martin Reuss has noted, "Unlike benefit-cost analysis, which always maximizes economic efficiency, multi-objective analysis designs water systems to address *all* the objectives sought by the planners, including non-economic values such as environmental quality or preserving a well-established ethnic neighborhood. The method recognizes that, after all of the computer simulations have been run and mathematical models constructed, the ultimate decision must rest in the political sphere." As an added complexity, after 1970, these matters would continue to be debated in the context of requiring cost-sharing for new water resources projects undertaken by the Corps.[43]

CONCLUSION

Through efficient dredging and improved channel work—involving structures such as locks and dams, revetments, wing dams, and pile dikes—the Corps maintained a series of reliable inland waterways. Rivers used as transportation corridors included the Columbia, Mississippi, Missouri, Ohio, Tennessee, and their major tributaries, as well as the Intracoastal Waterway along the East Coast. In addition, a series of locks connected the Great Lakes to its many harbors, while the completion of the St. Lawrence Seaway in 1957 realized the dream of a deep-water route through the Great Lakes to the Atlantic Ocean. By 1970, the Corps had developed 25,000 miles of navigation channels, requiring annual dredging of 350 million cubic yards at a cost of $200 million. The inland waterway network moved 16 percent of the nation's intercity ton-miles of cargo. Petroleum and coal accounted for over 50 percent of the waterway freight. The inland waterway system, moreover, played a crucial role in moving raw materials and manufactured goods to the nation's seaports, enabling extensive foreign trade.[44]

Between 1936 and 1970, the Corps' flood control mission resulted in almost four hundred reservoirs. Many of these structures provided multiple-purpose benefits, including hydropower, navigation, irrigation, municipal water supply, and recreation. By the mid-1970s, the Corps' hydropower facilities accounted for 27 percent of the total hydroelectric production in the United States and 4.4 percent of the electric energy output from all sources.

By 1970, the Corps of Engineers and other federal water resource agencies had built a massive water resources infrastructure in the United States. The navigation, flood control and hydropower dams and related facilities, and the navigation system consisting of improved rivers and harbors supported an ever-expanding national economy. In the process of carrying out its water resources mission, the Corps was criticized for lacking accountability to the executive branch of government, being willing to build projects of only local merit, and over-relying on purely structural solutions to water resources problems. Over the course of the first seventy years of the twentieth century, the Corps responded to its critics by slowly revising its process for objectively justifying the economic worth of particular water resources projects and demonstrating a willingness to consider non-structural approaches to water projects. By 1969, the Corps had embraced multi-objective criteria evaluation in its project planning and decision making. In emphasizing the economic potential of water resources development, however, the Corps often slighted the cumulative environmental costs of its undertakings. From 1970 forward, the Corps would confront the environmental challenges of operating and maintaining the water resources infrastructure it had built in the preceding one hundred years.

BIBLIOGRAPHIC ESSAY

The following suggested readings represent readily accessible published works that provide more in-depth coverage of the various topics in this chapter. For the classic account of the rise of Progressivism, with its focus on scientific and bureaucratic expertise as a force in American society and politics, see Robert Wiebe's *The Search for Order, 1877–1920* (New York, 1967). A more recent, general work by Maureen Flanagan, *America Reformed: Progressives and Progressivisms, 1890s–1920s* (New York, 2007) covers the latest scholarship on Progressivism. Numerous published and unpublished Corps of Engineers district and division histories, noted in the chapter endnotes, provide coverage of the agency's move from single to multiple-purpose water resources projects and various organizational changes over time. The beginnings of the conservation movement and its effects on water resources development is covered in Samuel Hay's influential study, *Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890–1920* (Cambridge, 1959). A broader, deeply informed overview of the interplay between environmental policies and the patterns of economic, social, and political history can be found in Richard Andrews, *Managing the Environment, Managing Ourselves: A History of American Environmental Policy* (New Haven, 1999). A careful analysis of Congress's role in modern environmental policy can be found in Paul Milazzo's *Unlikely Environmentalists: Congress and Clean Water, 1945–1972* (Lawrence, Kansas, 2006).

Background on the design and construction of large federal dams during the 1930s can be found in David Billington and Donald Jackson, *Big Dams of the New Deal Era: A Confluence of Engineering and Politics* (Norman, 2006). See the endnotes for specific monographs about individual dams discussed in this chapter. Three important books that cover the Corps and significant environmental issues are Lisa Mighetto and Wesley Ebel, *Saving the Salmon: A History of the U.S. Army Corps of Engineers' Efforts to Protect Anadromous Fish on the Columbia and Snake Rivers* (Portland, 1995); Raymond Merritt, *The Corps, the Environment, and Upper Mississippi River Basin* (Washington, D.C., 1984); and John Anfinson, *The River We Have Wrought: A History of the Upper Mississippi* (Minneapolis, 2003).

The Corps of Engineers and its evolving flood control mission is summarized in Joseph Arnold, *The Evolution of the 1936 Flood Control Act* (Ft. Belvoir, 1988). The expansion of the Corps of Engineers' civil works mission in the period between 1945 and 1970 can be followed best in individual district and division histories, while the Corps' *The U.S. Army Corps of Engineers: A History* (Ft. Belvoir, 2007) and Martin Reuss, *Reshaping National Water Politics: The Emergence of the Water Resources Development Act of 1986* (Ft. Belvoir, 1991) provide a national perspective. See also Beatrice Holmes, *A History of Federal Water Resources Programs, 1800–1960* (Washington, D.C., 1972).

1 Herbert S. Klein, *A Population History of the United States* (New York: Cambridge University Press, 2004), 107–75.

2 For background on Progressivism, city planning, and the rise of professional bureaucracy, see Robert H. Wiebe, *The Search for Order, 1877–1920* (New York: Hill and Wang, 1967); Maureen A. Flanagan, *America Reformed: Progressives and Progressivisms, 1890s–1920s* (New York: Oxford University Press, 2007); William H. Wilson, *The City Beautiful Movement* (Baltimore: The Johns Hopkins University Press, 1989); Jon A. Peterson, *The Birth of City Planning in the United States, 1840–1917* (Baltimore: The Johns Hopkins University Press, 2003); Robert Fishman, ed. *The American Planning Tradition* (Washington, D.C.: Woodrow Wilson Center Press, 2000).

3 On the rise of engineering profession, see Edwin T. Layton, Jr., *The Revolt of the Engineers: Social Responsibility* (Baltimore: The Johns Hopkins University Press, 1971); Terry S. Reynolds, ed., *The Engineer in America: A Historical Anthology from Technology and Culture* (Chicago: The University of Chicago Press, 1991). For challenges to the Corps dominance of public water projects, see Todd Shallat, *Structures in the Stream: Water, Science, and the Rise of the U.S. Army Corps of Engineers* (Austin, Tex.: University of Texas Press, 1994), 189–91; Martin Reuss, "Andrew A. Humphreys and the Development of Hydraulic Engineering: Politics and Technology in the Army Corps of Engineers, 1850–1950," *Technology and Culture* 26 (January 1985): 1–33.

4 This and the following paragraph are based on Janet A. McDonnell, "An Administrative and Organizational History of the U.S. Army Corps of Engineers, 1865–1902," (1989) draft ms., Office of History, Headquarters, U.S. Army Corps of Engineers (hereafter CEHO), 1–120; Marty Reuss, "The Corps of Engineers and Civil Works in the Progressive Era, 1897–1917," unpublished ms., CEHO, 9–16.

5 McDonnell, "An Administrative and Organizational History," 80–86; Raymond Merritt, *Creativity, Conflict and Controversy: A History of St. Paul District, U.S. Army Corps of Engineers* (St. Paul, Minn.: U.S. Army Engineer District, 1979), 56–57; Leland R. Johnson, *The Ohio River Division, U.S. Army Corps of Engineers: The History of a Central Command* (Cincinnati: U.S. Army Engineer Division, 1992), 31–46. For changes in usage of the term "district," see the *Annual Reports of the Chief of Engineers*, 1892, 1893, 1907, 1908, 1913, and 1915.

6 This and the following paragraph are based on numerous published and unpublished Corps of Engineers district, division, and project histories. See, for example, Johnson, *Central Command*; Leland R. Johnson and Charles E. Parrish, *Engineering the Kentucky River: The Commonwealth's Waterway* (Louisville, Ky.: U. S. Army Engineer District, 1999); William F. Willingham, "Army Engineers in America's Heartland: A History of the North Central Division of the U.S. Army Corps of Engineers,"(2002) unpublished ms., CEHO; William F. Willingham, *Army Engineers and the Development of Oregon: A History of the Portland District, U.S. Army Corps of Engineers* (Portland, Ore.: U.S. Army Engineer District, 1983); William F. Willingham, *Northwest Passages: A History of the Seattle District, U.S. Army Corps of Engineers, 1896–1920*, vol. I (Seattle, Wash.: U.S. Army Engineer District, Seattle, 1992); William F. Willingham, *Northwest Passages: A History of the Seattle District, U.S. Army Corps of Engineers, 1920–1970*, vol. II (Seattle, Wash.: U.S. Army Engineer District, Seattle, 2006); John Chambers, *North Atlantic Engineers: A History of the North Atlantic Division, 1775–1975* (New York: U.S. Army Engineer Division, North Atlantic, 1976); Merritt, *Creativity, Conflict and Controversy*; John O. Anfinson, *The River We Have Wrought: A History of the Upper Mississippi* (Minneapolis, Minn.: The University of Minnesota Press, 2003); William Becker, *From the Atlantic to the Great Lakes: A History of the U.S. Army Corps of Engineers and the St. Lawrence Seaway* (Washington, D.C.: Historical Division, Office of the Chief of Engineers, 1984); and Charles Camillo and Matthew Pearcy, *Upon Their Shoulders: A History of the Mississippi River Commission from its inception through the advent of the modern Mississippi River and Tributaries Project* (Vicksburg, Miss.: Mississippi River Commission, 2006) .

7 Carroll Pursell and William F. Willingham, "Protecting the Nation's Water: A History of the U.S. Army Corps of Engineers Regulatory Responsibilities, 1899–1999," unpublished ms., CEHO; Albert E. Cowdrey, "Pioneering Environmental Law: The Army Corps of Engineers and the Refuse Act.," *Pacific Historical Review* 46 (Aug. 1975): 331–49.

8 Aubrey Parkman, *History of the Waterways of the Atlantic Coast of the United States*, National Waterways Study navigation history NWS-83-10 (Fort Belvoir, Va.: Institute for Water Resources, 1983).

9 Quote in Reuss, "The Corps of Engineers and Civil Works in the Progressive Era," 27.

10 U.S. Army Corps of Engineers, *A History of the Board of Engineers for Rivers and Harbors* (Fort Belvoir, Va.: Board of Engineers of Rivers and Harbors, 1980), 1–8; Samuel P. Hays, *Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890–1920* (Cambridge: Harvard University Press, 1959), 93–94, 212–14; U.S. Army Corps of Engineers, *The U.S. Army Corps of Engineers: A History* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 2007), 242.

11 Hays, *Conservation and the Gospel of Efficiency*, 93–94, 212–14; Martin Reuss, "Coping with Uncertainty: Social Scientists, Engineers and Federal Water Planning, *National Resources Journal* (Winter 1992), 103–06.

12 The literature on this subject is voluminous; see for example, Hays, *Conservation and the Gospel of Efficiency*; Richard N. L. Andrews, *Managing the Environment, Managing Ourselves: A History of American Environmental Policy* (New Haven, Conn.: Yale University Press, 1999), 136–53; Michael Williams, *Americans and Their Forests: A Historical Geography* (New York: Cambridge University Press, 1989), 331–52, 393–424.

13 This and the following two paragraphs are based on Hays, *Conservation and the Gospel of Efficiency*, 106–20, 200–03; *The U.S. Army Corps of Engineers: A History*, 69; William D. Rowley, *The Bureau of Reclamation: Origins and Growth to 1945* (Denver, Colo.: Bureau of Reclamation, 2006), 1–232; Donald J. Pirsani, *Water and American Government: The Reclamation Bureau, National Water Policy, and the West, 1902–1935* (Berkeley, Calif.: University of California Press, 2002), 1–122; quote in Henry Abbot, "Regulation of Rivers in the Interests of Navigation," *Professional Memoirs*, vol. II (July-September 1909), 228.

14 On general respect for the quality of the Corps of Engineers' work, see J. M. Dickinson, "The Army Engineer and River Improvement," *Professional Memoirs*, vol. II (January-March 1910), 73–81.

15 Quote in David P. Billington, Donald C. Jackson, and Martin V. Melosi, *The History of Large Federal Dams: Planning, Design, and Construction in the Era of Big Dams* (Denver, Colo.: Bureau of Reclamation, 2005), 33.

16 Ibid., 49–89; David P. Billington and Donald C. Jackson, *Big Dams of the New Deal Era: A Confluence of Engineering and Politics* (Norman, Okla.: University of Oklahoma Press, 2006), 13–14, 28–70.

17 Carl W. Condit, *American Building* (Chicago: The University of Chicago Press, 1982), 168–76, 240–61; Amy Slaton, *Reinforced Concrete and the Modernization of American Building, 1900–1930* (Baltimore: The Johns Hopkins University Press, 2001).

18 Patrick O'Bannon, *Working in the Dry: Cofferdams, In-River Construction, and the United States Army Corps of Engineers* (Pittsburgh, Pa.: U.S. Army Engineer District, 2009).

19 The discussion of early flood control development is based on *The U.S. Army Corps of Engineers: A History*, 57–67; Joseph L. Arnold, *The Evolution of the 1936 Flood Control Act* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 1988), 1–22.

20 Matthew Pearcy, "A History of the Ransdell–Humphreys Flood Control Act of 1917," *Louisiana History* XLI (Spring 2000): 133–59.

21 Much of the following discussion is based on Reuss, *Designing the Bayous*, 103–204 and Charles Hendricks, "A History of Corps of Engineers Civil Works Real Estate Policies," 1995, unpublished ms., CEHO, chap. 4. An Army Engineer headed the Mississippi River Commission.

22 Matthew Pearcy, "After the Flood: A History of the 1928 Flood Control Act," *Journal of the Illinois State Historical Society* 95 (Summer 2002): 172–201.

23 Arnold, *The Evolution of the 1936 Flood Control Act*, 23–96.

24 *The U.S. Army Corps of Engineers: A History*, 220; Martin Reuss, "The Art of Scientific Precision: River Research in the United States Army Corps of Engineers to 1945," *Technology and Culture* 40 (April 1999): 292–323.

25 This paragraph and the following one are based on Lenore Fine and Jess A. Remington, *The Corps of Engineers: Construction in the United States* (Washington, D.C.: Office of the Chief of Military History, Untied States Army, 1972), 56–65; Albert Cowdrey, "Civil Works, 1917–1933: From War to Depression," unpublished ms., CEHO, 7–11; William F. Willingham, "Civil Works, 1933–1941: From Depression to War," unpublished ms., CEHO, 14–15.

26 Cowdrey, "Civil Works, 1917–1933," 33–38; Willingham, "Civil Works, 1933–1941," 15–16; Billington and Jackson, *Big Dams*, 71–87.

27 Billington and Jackson, *Big Dams*, 87–88, 99–101. For detailed examples of 308 Report planning and preparation by the Corps in the Pacific Northwest, see Willingham, *Army Engineers and the Development of Oregon*, 93–95 and Willingham, *Northwest Passages*, vol. II, 1–16.

28 The following discussion of Bonneville and Grand Coulee dams is based on William Willingham, *Water Power in the "Wilderness": The History of Bonneville Lock and Dam* (Portland, Ore.: Army Engineer District, 1987) ; Abbie Liel and David Billington, "Engineering Innovation at Bonneville Dam," *Technology and Culture* (July 2008), 727–51; Paul Pitzer, *Grand Coulee: Harnessing a Dream* (Pullman, Wash.: Washington State University Press, 1994); William Rowley, *The Bureau of Reclamation: Origins and Growth to 1945* (Denver, Colo.: U.S. Department of Reclamation, 2006), 328–39; Billington and Jackson, *Big Dams*, 152–99; O'Bannon, *Working in the Dry*, 117–22.

29 Willingham, *Water Power in the "Wilderness,"* 13.

30 Richard Lowitt, *The New Deal and the West* (Norman, Okla.: University of Oklahoma Press, 1984), 168–71; Pitzer, *Grand Coulee*, 280, 286–89, 295, 297–99, 308–10, 313, 327–29, 364–65; Rowley, *The Bureau of Reclamation*, 357–58, 368–70, 390–91; U.S. Bureau of Reclamation, *The Story of the Columbia Basin Project* (Washington, D.C.: Government Printing Office, 1978).

31 Willingham, *Water Power in the "Wilderness,"* 42–43; Gus Norwood, *Columbia River Power for the People: A History of Policies of the Bonneville Power Administration* (Portland, Ore.: Bonneville Power Administration, 1981), 47–93; Richard Lowitt, *The New Deal and the West* (Norman, Okla.: University of Oklahoma Press, 1984), 160–63; Billington and Jackson, *Big Dams*, 189–92.

32 Willingham, Northwest Passages, vol. II, 50–52; Lowitt, *The New Deal and the West*, 170–71.

33 Billington and Jackson, *Big Dams*, 102–51, 253–92; Rowley, *The Bureau of Reclamation*, 233–36; 339–46.

34 The following discussion of Fort Peck Dam is based on Willingham, "Civil Works, 1933–41," 22–26; Billington and Jackson, *Big Dams*, 200–30.

35 The discussion of interagency coordination is based on Willingham, *Northwest Passages*, vol. II, 1–16; *U.S. Army Corps of Engineers: A History*, 247; Martin Reuss, "Civil Works Developments," in Barry Fowle, ed., *Builders and Fighters: U.S. Army Engineers in World War II* (Fort Belvoir, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 1992), 219–32.

36 The discussion of the Missouri River water resources development and the Pick–Sloan plan are based on Billington and Jackson, *Big Dams*, 230–38, 250–52; John Ferrell, *Big Dam Era: A Legislative and Institutional History of the Pick–Sloan Missouri Basin Program* (Omaha, Neb.: U.S. Army Engineer Division, Missouri River, 1993), 1–100; Martin Reuss, "The Pick–Sloan Plan," in Fowle, *Builders and Fighters*, 233–44; Rowley, *The Bureau of Reclamation*, 392–97.

37 The discussion of postwar water resources development on the Columbia River Basin is based on Willingham, *Northwest Passages*, vol. II, 45–50, 62–82; Willingham, *Army Engineers and the Development of Oregon*, 166–80; Keith Petersen, *River of Life, Channel of Death: Fish and Dams on the Lower Snake* (Lewiston, Idaho: Confluence Press, 1995); Billington and Jackson, *Big Dams*, 192–99.

38 This and the following paragraphs detailing the Corps' response to fisheries issues in the Columbia Basin are based on Willingham, *Army Engineers and the Development of Oregon*, 190–206; Willingham, *Water Power in the "Wilderness,"* 47–53; Lisa Mighetto and Wesley J. Ebel, *Saving the Salmon: A History of the U.S. Army Corps of Engineers' Efforts to Protect Anadromous Fish on the Columbia and Snake Rivers* (Portland, Ore.: U.S. Army Engineer Division, North Pacific, 1995).

39 This and the following paragraph are based on Raymond Merritt, *The Corps, the Environment, and Upper Mississippi River Basin* (Washington, D.C.: Historical Division, Office of the Chief of Engineers, 1984); John Anfinson, *Commerce and Conservation on the Upper Mississippi River* (St. Paul, Minn.: U.S. Army Engineer District, n.d.).

40 Efforts to increase the upper Mississippi River navigation channel to twelve feet in the 1960s and 1970s foundered over both economic and environmental concerns. Environmentalists, in particular, were concerned that channel dredging would harm the river bottom and require additional material disposal sites that would jeopardize fish and wildlife habitats and aesthetic values.

41 This section is based in part on the following sources: *The U.S. Army Corps of Engineers: A History*, 245–53; Gregory Graves, *Pursuing Excellence in Water Planning and Policy Analysis: A History of the Institute of Water Resources, U. S. Army Corps of Engineers* (Fort Belvoir, Va.: Institute of Water Resources, 1996), 1–56; Beatrice Hort Holmes, *A History of Federal Water Resources Programs and Policies, 1961–1970* (Washington, D.C.: U. S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, 1979), 5–11, 33–43; Martin Reuss, *Water Resources, People, and Issues: Interview with Professor Arthur Maass* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 1989), 4, 6–8; Martin Reuss, *Water Resources, People, and Issues: Interview with Professor Gilbert R. White* (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 1988), passim; Martin Reuss, *Reshaping National Water Politics: The Emergence of the Water Resources Development Act of 1986* (Fort Belvoir, Va.: Institute for Water Resources, 1991), 1–29; Martin Reuss, "Coping With Uncertainty," 101–35.

42 Quote in Graves, *Pursuing Excellence in Water Planning*, 32–33.

43 Quote in Reuss, "Coping With Uncertainty," 130.

44 For statistics, see for example Maj. Gen. J. W. Morris, "Our Troubled Waterways," *Water Spectrum* (Winter 1974–75), 2.

8 ENVIRONMENTALISM, RENEWED CONCERN FOR FLOOD SAFETY, AND THE EUROPEANIZATION OF DUTCH WATER POLICIES, 1970–2010

Wim van Leussen and Sander Meijerink

As the title of this chapter suggests, three major developments characterize the contemporary history of Dutch water management: the environmental wave, the renewed attention for flood safety strategies, and the Europeanization of Dutch water policies. The first development concerns the lasting influence of both the environmental wave and the democratization of Dutch society in the 1960s and 1970s on Dutch water policies. As the increased environmental awareness induced a substantive change of water policies toward integrated water resources management based on a water systems approach, the democratization process in Dutch society would have an impact on the process of decision making on new water policies and projects. Top-down, expert-driven decision making was replaced, at least in part, by more interactive and deliberative modes of governance.

The second important development was renewed attention to flood policies and strategies in the face of climate change. Following the floods of the Rhine and Meuse rivers in 1993 and 1995, flood safety received a high place on the political agenda again. Traditional flood policies aimed at reducing flood probability by the construction of dikes were reconsidered, and new "room for the river" policies were introduced. Furthermore, these latest flood policies were no longer confined to reducing flood probability, but also aimed at reducing flood exposure and flood vulnerability—strategies that the Dutch seem to have unlearned over the past century. To inform the public on these policy changes, the Dutch government at century's end launched a large-scale public campaign, informing the people that they have to learn "to live with water" again.[1] These new flood management strategies of creating room for the river and raising water awareness, however, have not replaced the policies of reducing flood probability by the construction of dikes. Rather, these policies were placed alongside existing ones and by that have broadened the arsenal of flood management strategies the Dutch government is now using. A new Delta Commission advised the Dutch government on flood protection policy for the longer term (up to 2200). This commission, which issued its findings in 2008, emphasized the need for increasing flood safety standards in the long term. Its advice is now being elaborated on through the Delta Program.

The third major trend relevant to understanding recent developments in Dutch water resources management is the ongoing Europeanization of water policies. The European water regime has developed over the past decades and almost any aspect of water management, whether it is groundwater, surface water, water quality, or flood management, is now covered by European directives and policies. Very similar to the development in many other policy sectors, Europe has become a fourth and powerful administrative tier in Dutch water management.

Nineteen ninety-eight represented a milestone in the history of the Rijkswaterstaat as it celebrated its 200th anniversary in presence of Queen Beatrix.[2] Accompanying the celebration was the publication of *Two Centuries Rijkswaterstaat*, (*Twee eeuwen Rijkswaterstaat* in Dutch), an overview of 200 years of technological expertise and societal dynamics.[3] It shows the strong interrelationship of the Rijkswaterstaat with society, which continues to present. The Delft University of Technology (TU Delft) organized a symposium and presented to the Rijkswaterstaat the book *Water Magicians, Delfts' Ideas for Another 200 years Rijkswaterstaat (Water tovenaars, Delftse ideeën voor nog 200 jaar Rijkswaterstaat*).[4] As all faculties of the TU Delft have relations with the Rijkswaterstaat, every faculty contributed one or more chapters. The director-general of the Rijkswaterstaat, Gerrit Blom, received an honorary degree from TU Delft in recognition of his activities in the field of pollution reduction and the large-scale reorganization of the Rijkswaterstaat. To underscore its international ties, the Rijkswaterstaat organized the international conference "Sustainable development of deltas" in Amsterdam in November 1998.[5]

In the 1970s and 1980s a cultural change occurred within the Rijkswaterstaat—increasingly, it could be characterized as a multi-disciplinary organization. These changes were particularly a result of the explosive rise of societal demands for solving environmental issues as well as the democratization within society with more attention for societal demands, openness, and transparency. In the 1980s and 1990s the neoliberal ideology and politics also influenced the organizational culture of the Rijkswaterstaat.[6] In addition to engineering practice, more attention was given to output steering, performance measurement, and public-private partnerships (as discussed below in the section titled "The Environmental Era").

Concerning the national water policy, a fundamental change occurred in 2002. Up to that date, the national policy on water affairs, and particularly flood defense, was developed at the Head Office for Water at the Rijkswaterstaat. This also included responsibility for international water affairs, so to that date the Rijkswaterstaat represented the Netherlands in international water forums. On January 28, 2002, the Water Directorate at the Ministry of Transport, Public Works and Water Management (now called the Ministry of Infrastructure and the Environment) was created and took the leading role in the decision-making process. The Rijkswaterstaat remained a part of the ministry and is responsible for the design, construction, management, and maintenance of the main infrastructure facilities in the Netherlands, including the network of main roads, the network of main waterways, and the main water systems. As outlined in the sections on "Renewed Concern for Safety" and "Europeanization of Water Politics," the Rijkswaterstaat played the leading role until 2002, and after that this role was assigned to the policy departments of the ministry. The background of this shift is a clear distinction between policy and construction/maintenance. In daily practice, there remains a narrow cooperation between the policy departments of the ministry and the Rijkswaterstaat as the executive agency of the ministry.

The separation of policy making and policy implementation led to intensive discussions of how the Rijkswaterstaat should be related to the ministry.

Finally, the decision has been made to transform the organization of the Rijkswaterstaat into an agency (*Agentschap*), through which the organization came to be positioned at a greater distance from the Ministry.[7] In the period 2004–2008, the organization changed significantly under the leadership of the general-director, Bert Keijts. The Rijkswaterstaat developed into the executive organization of the ministry with three main tasks: the management of the main roads, the management of the main waterways, and the integrated management of the main water systems. The organization was modernized by introducing a new business model. First, a high priority was given to a transparent financial system, through which expenditures can be controlled and justified and budget overruns can be avoided. Furthermore, the organization developed itself to a public-oriented network organization with a focus on the users of those networks—the complicated systems of main roads, main waterways, and main water systems. The construction of large infrastructure works remains an important task of the new Rijkswaterstaat. Much attention has been given to internalize this "public-oriented network management" in the minds and working methods of the Rijkswaterstaat employees.[8] At the same time, the challenge was to do more with fewer employees. In the period 1980–1994, the number of employees decreased from 13,700 to 9,700.[9] This number went up again in the subsequent years. The period 2003–2008 showed a comparable decrease: from 11,300 to 9,300.[10]

Another important organizational change came from the national discussion within the Dutch government on the organization of applied scientific research in the Netherlands. On the basis of the Report of the Commission Wijffels, scientific knowledge was concentrated in a few renowned institutes, the so-called Large Technological Institutes (Dutch abbreviation: GTIs).[11] These GTIs are centers of technological expertise for companies and the government. For knowledge of water management, the institute Deltares was founded in 2007. In this organization, WL/Delft Hydraulics, Geodelft, parts of TNO-Bouw, and large parts of the research services of the Rijkswaterstaat were concentrated. At the Rijkswaterstaat these research services changed from knowledge institutes to institutes "externally organizing knowledge," and they developed expertise for advising the networks managed by the Rijkswaterstaat. Repeatedly, the discussion arises as to how much knowledge the Rijkswaterstaat must have within its own organization to fulfill its new role. From 2007 to 2013, the Water Service (*Waterdienst*) has fulfilled this task within the Rijkswaterstaat. Since 2013, the Service for Water, Traffic and the Environment (*Water, Verkeer en Leefomgeving*) has been performing this task. An important task of the Rijkswaterstaat is to provide information about the water system. This effort is now concentrated in the Water Management Centre in the Netherlands (WMCN), which provides daily information for users of the Dutch water systems, including water levels, river discharges, flood risks, water quality, and so on.[12] This information is obtained from the National Water Monitoring Network (*Landelijk Meetmet*).

THE ENVIRONMENTAL ERA

In the 1960s and early 1970s, environmental awareness started to grow in the Western world (as discussed in chapter 6). One of the most influential publications at that time was the *Limits to Growth* report of the Club of Rome (1972). This report clearly demonstrated the limits to exploiting the earth's natural resources by a rapidly increasing population.[13] At that time people began to learn about the unintended consequences of the rapid economic growth and industrialization after World War II. This new perception of the limits to economic prosperity was further strengthened by the oil crisis of 1973. The change of societal mood was reinforced by the activities of an environmental movement that was at first rather fragmented, but increasingly became better coordinated and more influential.

The 1950s and 1960s had been glorious decades for the Rijkswaterstaat. Both the budgets available for public works and the number of large infrastructure projects (most notably the construction of highways and the Delta Works) were at their height. The new environmental movement, however, would be particularly successful in shaping new images of the large public works that were planned and designed by the Rijkswaterstaat engineers.

The impact of environmentalism on the Rijkswaterstaat and Dutch water management was also strongly influenced by a second main societal development: the democratization of Dutch society. As in many other places around the world, the sixties and seventies were a politically dynamic period in the Netherlands. This was the time of protest marches against the war in Vietnam, student revolts, and the occupation of universities. Support for political parties that were based on religious affiliation declined rapidly. Gaining support were new political parties—such as the Social-Liberal party D66—aimed at a fundamental reform of the political system. This democratization movement attacked all established institutions, including traditional political party structures, universities, and churches. Authority was less accepted and people demanded more openness and possibilities for influencing decision-making processes. Not surprisingly, the Rijkswaterstaat came under attack in that turbulent period. Whereas the Rijkswaterstaat had always received credit for its expertise and contribution to the economic welfare of the country, in the seventies, the very same organization became heavily criticized for its lack of responsiveness to societal demands and environmental issues. Increasingly, the Rijkswaterstaat was labeled as a closed technocratic bulwark, with its road planning destroying nature because of an authoritarian and non-responsive attitude that was out of touch with society.[14]

The organization of the Rijkswaterstaat clearly faced difficulties in responding to the new societal demands for openness and transparency and in incorporating new environmental values in its policies and working practices, but gradually it developed capacities for adapting to the new circumstances. This process was facilitated by the dynamics within the Rijkswaterstaat, induced by the march of new disciplines—ecologists and biologists particularly—into the ministry. This "new vanguard" managed to challenge the policies and working practices of the community of civil engineers that had dominated the organization of the Rijkswaterstaat until then.[15] It is exactly the combination of the external (growth of environmental awareness, democratization of society) and internal pressures (a new vanguard) that accounts for the "ecological turn" in Dutch water management.[16] In spite of important value conflicts, such as safety versus ecology or economy versus ecology, the expertise and concepts of the ecologists were incorporated by the traditional corps of engineers rather smoothly. Some quantifiable concepts of ecology could be integrated into decision-support systems and assessment tools.[17]

Besides the impact of the environmentalists and the democratization of Dutch society, the economic decline after the second oil crisis (1980–1982) put the Rijkswaterstaat under pressure. The budgets for the realization of public works and the number of employees were reduced substantially after the seventies. Later on, this process was reinforced by the global spread of the neo-liberal ideology. This ideology favored market deregulation and promoted the role of the private sector. It was best articulated by Ronald Reagan and Margaret Thatcher (in Thatcher's "there is no alternative") and would influence policies of the successive Dutch governments since that time. Liberalization and the tools of New Public Management became quite popular during this period. Contracting-out and public-private partnerships became increasingly accepted instruments in Dutch water management. Next to these ideological motives, more substantive changes in water resources management triggered reorganizations of the Rijkswaterstaat as well. After the completion of the Delta Works, the Delta Service became superfluous and was dismantled. Until 1984 water quantity and quality management were organized separately. With the recently developed concept of integrated water resources management, these tasks were combined, and a new organizational distinction between fresh and tidal water was made (National Institute for Inland Waters and National Institute for Coastal and Marine Waters).

Shortly after the celebration of the 200 years of the Rijkswaterstaat, the organization came under fire again. The costs of several large infrastructure projects—most notably the Betuwe Route (Betuwelijn), a new railroad to Germany—exceeded the planned budgets. Even though cost overruns were mainly due to a long list of modifications proposed by local politicians and pressure groups to mitigate negative impacts on the landscape and those living near the railroad, the organization of the Rijkswaterstaat was often blamed for it in the media. Moreover, several cases of corruption in the Netherlands in which a few employees of the Rijkswaterstaat were involved attracted media and political attention. Under pressure from Minister of Finance Gerrit Zalm, and the leadership of the Minister of Transport, Public Works and Water Management Karla Peijs, the organization of the Rijkswaterstaat was fundamentally reorganized by a substantial reduction of the number of civil servants and by the introduction of a sharp distinction between the policy-making task of the ministry and the implementation task of the Rijkswaterstaat, which was given the status of an agency. Recent accounts of the reorganization process by Van den Brink and Metze show that the main objectives of the reorganization (reducing the number of civil servants and a more public-oriented way of working) have been achieved, but some new problems were introduced.[18] Where Metze points to the drawbacks of the loss of expertise, which makes it more difficult to critically supervise projects that are being implemented by market parties, Van den Brink mainly points to the difficulties employees of the Rijkswaterstaat face when they participate in regional planning projects.[19] Since the Rijkswaterstaat was given the status of an implementation agency, its representatives in the region are not allowed to make any policy-sensitive decision without consulting the policy directorate in The Hague. Such problems, however, are not unique to the Rijkswaterstaat organization, as they are faced by any organization undergoing a similar transformation.

These developments in Dutch water management are illustrated by the controversies over three major infrastructure projects: the enclosure of the Eastern Scheldt; the reclamation of the Zuiderzee polder, the Markerwaard; and the strengthening of the dikes along the main rivers. It will be shown how the waves of environmentalism and democratization have influenced Dutch national water policies since the early seventies.

Decision making on the storm surge barrier in the Eastern Scheldt is often considered a major turning point in the history of Dutch water resources management.[20] In the past, coastal engineering projects had been aimed at flood protection and at serving economic interests, but, in the decision-making process on the enclosure of the Eastern Scheldt, environmental issues were seriously addressed for the first time. During the implementation of the Delta Plan most other tidal branches in the southwestern Netherlands had been closed off, and their valuable estuarine ecosystems were destroyed. Because of the influence of the environmental movement and the shift in public opinion, social and political attention to potential ecological damage increased during the construction of the Delta Works.

Rijkswaterstaat

Sea anemone, one of the many species in the Eastern Scheldt

In 1967 the Rijkswaterstaat Delta Department started developing plans for the enclosure of the widest estuary, the Eastern Scheldt. This estuary had a very rich biodiversity and the sandbars were favorite feeding spots for birds. The estuary also had an important shellfishery. According to the engineers working at the Delta Department, a fixed dam would be the only possible option for realizing safety, but a coalition of environmentalists and fishermen argued that strengthening the dikes along the estuary would be a much better alternative. Various accounts of the Eastern Scheldt crisis demonstrate that the Delta Department faced difficulties in incorporating the new environmental values into policy alternatives, and stuck to the proposal for a fixed dam.[21] Only after the installation of the cabinet under Prime Minister Joop Den Uyl, the most leftist cabinet in Dutch history, did the coalition of environmentalists gain access to the decision-making forums on the highest level, and the Dutch cabinet started to put pressure on the Rijkswaterstaat engineers to develop a solution that would take into account the environmental issues raised. This is a clear example of the primacy of politics. It is only due to a change of government that the change of Eastern Scheldt policies became possible. The ministers of the new social-liberal party D66, in particular, played a crucial role in this. These political changes, however, reflected the change in public opinion: many perceived the Rijkswaterstaat as an organization that had no eye for environmental or ecological issues.

An expert committee designed alternatives to the closure and concluded in its report that an open storm surge barrier was technically feasible. The Rijkswaterstaat had to further develop this alternative into a new design that would meet safety standards as well as ecological standards. Doing so required a radically innovative concept, which the Delta Department developed in cooperation with the involved contractors, a consultant, and the assistance of various knowledge institutes. They managed to design a half-open storm surge barrier on piers. The core idea of this construction was that the barrier can be closed during storm surges, and left open under normal weather conditions, thus maintaining estuarine dynamics.

Decision making concentrated on three policy alternatives: the construction of a fixed dam, the strengthening of dikes along the estuary, and the construction of a semi-permeable dam. The Rijkswaterstaat contracted with the RAND Corporation for comparing these alternatives. The POLANO-study (Dutch acronym for Policy Analysis for the Eastern Scheldt) was an interesting innovation in Dutch water policy analysis, because this study included a wide range of possible criteria, including the potential impact on the environment and ecology. Part of the environmental research carried out for this study was supported by a newly created environmental section of the Delta Department headed by the first university-educated biologist to work for the Rijkswaterstaat, H. L. F. Saeijs.[22] The Dutch Cabinet opted for the construction of a storm surge barrier in 1976, and the Eastern Scheldt Storm Surge Barrier was completed in 1986, at a total cost of 2.5 billion euros (more than the cost of all other Delta Works combined). Numerous innovations were developed during the construction process: a special ship was constructed

Rijkswaterstaat

The Eastern Scheldt Storm Surge Barrier pillar construction dock , 1984

Rijkswaterstaat

Construction ship *Ostrea* lifts a pillar into position

to transport the pillars and a machine was designed to place huge mattresses to stabilize the pillars. Today the Eastern Scheldt Storm Surge Barrier is generally perceived as one of the main achievements in coastal engineering in the world. It served as a test-bed for ecological design, integrated project planning, and stakeholder analysis and communications strategies. As such, it marked a new era in water management and in the Rijkswaterstaat's position: the project enabled the Rijkswaterstaat to repair the rift with society and to partly restore its prestige.[23] In spite of the impressive engineering achievement, and the innovative concept of a storm surge barrier with movable gates, it is now clear that the barrier still has had an enormous impact on the Eastern Scheldt ecosystem, because the tidal volume—and hence estuarine dynamics—has diminished substantially. The reduced tidal volume flowing through the storm surge barrier has caused the estuary sand bars to begin to shrink, threatening the bird feeding spots, and new protective measures had to be

Rijkswaterstaat

The Eastern Scheldt Storm Surge Barrier with the gates closed undertaken. In the other closed estuaries in the southwestern part of the Netherlands, mineral emissions from farms caused severe water pollution, and here, also, additional projects were undertaken to improve the ecological quality, such as an inlet sluice to refresh the stagnant water in the Veere Lake.

A second model project illustrating the environmental era in Dutch water management is the reclamation of the Markerwaard, a polder in the Zuiderzee (IJssel Lake). Where decision making on the Eastern Scheldt Storm Surge Barrier is generally considered to be a turning point in the implementation of the Delta Works, decision making on the Markerwaard can be considered a similar turning point in the implementation of the Zuiderzee works.[24]

As described in chapter 6, the Afsluitdijk (1932) had reduced flood risks along the IJssel Lake considerably and made possible various land reclamation projects. After the successful reclamation of the Northeast Polder (*Noordoostpolder*), which includes the former islands of Schokland and Urk, the Eastern (1957) and Southern (1968) Flevopolders were reclaimed. Unlike the northeast polder, the Flevopolders were designed as an artificial island with a narrow lake between the mainland and the new polder. This lake was created to maintain access to the sea for certain towns on the mainland and to be able to better manage the water tables.

The next reclamation project planned was the Markerwaard. There are many reasons why the Markerwaard polder has never been created. First and fore-

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Almere, the main city on South Flevopolder

Rally against the Markerwaard polder project, 1979

Erfgoedcentrum Nieuwland, Lelystad

Farmers' rally supporting the Markerwaard polder project, 1984

Erfgoedcentrum Nieuwland, Lelystad

most, it is important to know that the food self-sufficiency doctrine, which was the main trigger for creating the other polders, was no longer adhered to after the establishment in 1957 of the European Economic Community, predecessor of the EU. In addition, unlike the reclamation of the older polders, the reclamation of the Markerwaard was planned in an era characterized by distrust of the Rijkswaterstaat. A broad coalition of actors opposed to a new land reclamation project in the IJssel Lake successfully challenged the various arguments put forth by the government. They pointed, for example, to the loss of a valuable fresh water ecosystem, an argument that had never played a role in decision making on reclamation projects until then. The opposition also successfully challenged the various economic arguments for creating another polder in the Zuiderzee. In 1972 a new decision-making procedure for large-scale spatial and infrastructure projects was introduced: the Spatial Key Decision (*Planologische kernbeslissing*, or PKB). This procedure allowed for the participation of a wide range of actors in decision making on the Markerwaard. In addition to the end of the food self-sufficiency doctrine, the democratization of decision making and the recognition of new (environmental and landscape) values may explain why decision making on the reclamation of the Markerwaard has been postponed time and again.

Environmentalism and the democratization of Dutch society also influenced decision making on the improvement of dikes along the main rivers. The river levee strengthening program had made virtually no progress until the 1970s because the Delta Works and sea dike strengthening projects took such a large share of the allocated budgets. In the 1970s, the water boards finally sped up the levee strengthening schemes. By then, however, they faced staunch opposition from conservationist action groups who feared the destruction of the idyllic river landscape and doubted the necessity of the strengthening program. Because of the value conflicts and the ample opportunities opponents had to delay the realization of planned dike improvement projects, the Rijkswaterstaat and the water boards were practically unable to meet the legally defined safety standards and to guarantee safety along the main rivers. Only after the floods of 1993 and 1995 were they able to realize these safety standards.

Bart Hofmeester

Towship on the River Waal. Inland navigation is an important cargo mode in the Netherlands

The developments described above also had an impact on the broader national water policies, which were formulated in a series of policy documents on water management. The first national policy document on water management, issued in 1968, mainly addressed water quantity issues and the economic functions of water, such as water use by households and industry, agricultural water use, and navigation.[25] Environmental issues were not completely ignored—in the 1940s, the Rijkswaterstaat director-general, Ludolf Reinier Wentholt, addressed the problem of salt intrusion, and in the 1950s water quality became a major issue. Salt intrusion worsened, as did chemical pollution, also because of increasing effluents in the Rhine and Meuse basins. The pollution had detrimental effects on the quality of drinking water, since large parts of the Dutch Randstad, the urbanized western part of the Netherlands, use Meuse water as a source for drinking water production.

In 1970, after years of preparation, a water pollution act passed Parliament (*Wet Verontreiniging Oppervlaktewateren*, WVO). The Rijkswaterstaat was assigned the legal task of implementing this water pollution act on the main rivers and lakes, and the provinces had to set up provincial water quality programs. The WVO introduced a permit system for emissions and a system of fines for violators based on the "polluter pays" principle. Also under the WVO, wastewater purification stations, already developed before 1940, were built on a massive scale. The WVO is often called a prime international example of successful environmental legislation.[26]

The second national report on water management, issued in 1984, broadened the scope of national water policies by more systematically addressing water quality and ecological issues. This was made possible by the PAWN-study (Policy Analysis for Water management in the Netherlands), which, like the POLANO-study for the Eastern Scheldt, was a new type of policy analysis introduced in the Netherlands by the RAND Corporation.[27] Together with the Rijkswaterstaat and Delft Hydraulics, RAND developed computer models that were able to calculate the impact that various water management alternatives would have on specific interests, such as agriculture, navigation, drinking water production, or nature itself. The PAWN-study has been particularly helpful in showing the various interrelationships within a water system and the interdependencies between water users.

Building on the highly influential document "Living with Water" (1985), to which Rijkswaterstaat biologist H. L. F. Saeijs contributed, the third water management policy document of 1989 introduced the concepts of a water systems approach and of integrated water resources management.[28] Water was conceived as an integrated system of subsystems (surface water, groundwater) and functions (transport, drinking water, ecological functions, recreation, etc.) and water management required an integrated approach, balancing these functions, and linking water management, spatial planning, and nature development.[29] This

Peter Mastenbroek, Lelystad

Rijkswaterstaat laboratory researcher investigates oil emissions from a ship that was sailing on the North Sea

Oil pollution in the IJmuiden harbor, 1990

concept was implemented by the Rijkswaterstaat for the main rivers and lakes and by the provinces and the water boards for the regional waters. The 1992 Water Boards Act assigned to the water boards—in addition to flood management and water quantity management—water quality management.[30] This act strengthened the position of the water boards within the Dutch state organization. The position of the water boards was further strengthened by the ongoing mergers between water boards. There are currently only twenty-four water boards, many of which cross provincial borders. Although the provinces still play a role in coordinating water policies with spatial and environmental planning, their position in the water sector has weakened considerably over the past few decades.

The fourth water management policy document was released along with the influential document "Water Management in the 21st Century." These documents were issued in the aftermath of the floods on the main Dutch rivers that occurred in 1993 and 1995 and the water troubles in 1998 stemming from intense precipitation. Both of these documents emphasized the urgent need for better coordination between water management and land-use planning.[31] After a few decades in which environmental and ecological issues had gained a prominent place in the political agenda, at the turn of the century water safety issues again started to dominate the Dutch water agenda.

In December 2009 the Dutch Cabinet adopted the National Water Plan, which contains the national water policies for the period 2009–2015. The new national water policy emphasizes the need for climate-proofing the Netherlands and for implementing the Room for the River and Delta programs.[32]

Martijn Beekman

Fish migration research: a transponder is being inserted in a sea trout, 1997

RENEWED CONCERN FOR FLOOD SAFETY

The 1970s showed a continued discussion on the flood safety standards along the major rivers in the Netherlands. This period marked the aftermath of the Report of the Delta Commission (1960), which advised the Dutch government on the safety standards after the flood disaster of 1953.[33] However, these new safety levels would result in significantly increasing the height of the dikes along the river. Much opposition arose within society because of its impact on the landscape. Therefore, the Dutch government installed the Becht Commission in 1975 to evaluate the new safety standards. In 1977 the Becht Commission advised on an exceedance frequency of 1:1,250 years at a river discharge of 16,500 cubic meters per second for the Rhine River at Lobith.[34] This advice was accepted by the government in 1978. However, continuous protest against the dike reinforcements forced the government to install a new commission in 1992: the Boertien Commission. In 1993 the Boertien Commission concluded that a safety level of 1:1,250 years was required, but advised, on the basis of a new statistical analysis, to reduce the representative river discharge to 15,000 cubic meters per second.[35] The commission advised also taking into account the so-called LNC-values (landscape, nature, and culture) and involving citizens and municipalities more in the decision-making process.

However, shortly after the presentation of the report of the commission, the floods of 1993 and 1995 demonstrated that the existing dikes could barely resist the floods with an exceedance frequency of 1:100 years. In 1995 the situation was extremely critical, and about 250,000 inhabitants in a Gelderland riparian zone were evacuated within two days. This situation made clear that dike reinforcement programs had to be implemented with high priority and in a short period of time. On February 13, 1995, the government—after negotiating agreements with representatives of the provinces, water boards and the Dutch municipalities—presented the Delta Plan Major Rivers.[36] Within one month of the flood of 1995, the emergency law Delta Law Major Rivers, prepared by the Legal Department of the Headquarters of the Rijkswaterstaat, was accepted by the Dutch Parliament. Under this law, procedures could be passed or shortened, and the dikes could be given the required height and strength in 1995 and 1996. According to this law, dikes in areas of a lower urgency had to be completed before 2001.[37]

In the River Meuse, extreme floods occurred in 1993. In December 1993 the river discharge reached a maximum of 3,120 cubic meters per second, resulting in large inundations and much damage. Therefore, in January 1994 the Boertien Commission II was installed with the task of advising the government on the protection of the River Meuse against such extreme floods. The commission presented their report on December 12, 1994.[38] It laid out three possible strategies: building of levees together with deepening of the summer bed of the river; building of levees together with deepening of the summer bed and nature development; and building of levees. The commission advised to deepen the summer bed combined with a limited amount of environmental development and to build levees only for specific areas where other measures are shown to be insufficient. However, in the beginning of 1995 a flood occurred again. Although the maximum Meuse river discharge was lower (2,870 cubic meters per second), in the more downstream areas it had more severe effects because of the longer duration of the flood wave.[39] Under societal pressure, the government decided to start with building the levees to guarantee a protection with an exceedance frequency of 1:50 years. Under the Delta


Rijkswaterstaat

1993 flood at Roermond, Limburg at the river Meuse

Rijkswaterstaat

1995 near-flood: extremely high water levels on the Waal

Law Major Rivers (*Deltawet Grote Rivieren*), these works had already been completed in 1996 and 1997. The next step was to realize a safety level of 1:250 years, which was the mandate of the project De Maaswerken (Meuse Works), and had to be realized at the latest in 2005. For budgetary reasons, this date shifted to 2015, under the condition that seventy to eighty percent of the agreed safety level would be realized by 2005.[40]

The safety standards are legally confirmed in the Flood Defense Act (*Wet op de Waterkering*). This law was first introduced in Parliament in 1989, agreements were obtained in 1994, and it came into force in 1996. Because of the critical flood risk situations in 1993 and 1995, a number of amendments were applied.[41] The safety standards for the coastal areas were in agreement with the proposals of the Delta Commission (1960). For the embanked rivers Rhine and Meuse a safety standard of 1:1,250 years was declared for the upstream parts of these rivers and 1:2,000 years for the downstream parts. Every five years the safety standards are to be evaluated, through which an updated insight is obtained of the natural pressures (water levels, wave attack, river discharge). This occurs for each of the fifty-three dike ring areas. In 2005 the forty-two dike ring areas along the upstream part of the Meuse also came under this law, with a safety standard of 1:250 years. In 2009 the Flood Defense Act was incorporated in the Dutch Water Act, in which a number of existing water acts were integrated, thus creating a framework for the modernization of Dutch water management.[42]

On the basis of the five-year evaluation, in 2001 the representative river discharges associated with the agreed safety levels changed from 15,000 to 16,000 cubic meters per second for the Rhine and from 3,650 to 3,800 cubic meters per second for the Meuse.[43] In 2006, these safety levels remained unchanged.[44] For the longer term, reconnaissance studies were carried out, for both the Rhine and the Meuse.[45] The objective was to investigate the possibility of guaranteeing the same safety levels in the twenty-first century under the influence of climate change and expected soil subsidence. The representative river discharges, for which these safety levels must be reached, were 18,000 cubic meters per second for the Rhine and 4,600 cubic meters per second for the Meuse.

In fact, all these agreements were reached as a consequence of the implementation of the recommendations of the Delta Commission in the 1950s and its 1960 report. The recommendations and report resulted in the Delta Plan, shortening the coastline by more than 600 kilometers through blocking the estuary mouths of the Haringvliet (Haringvliet Dam, 1971), the Grevelingen (Brouwers Dam, 1971) and the Eastern Scheldt (Storm Surge Barrier, 1986). The estuary mouths of the New Waterway and the Western Scheldt were to remain open because of the shipping routes to the ports of Rotterdam and Antwerp. The height of the dikes along these waterways must be raised to the "Delta level." Around 1980 it was discovered that the dikes in the Rotterdam area were too low to fulfill the determined level of protection. Although they have been raised significantly after World War II, they should be raised by at least 1.60m.[46] However, it was difficult to make these dikes higher, as they were situated in a very densely populated area, involving high costs and having a visual impact on old town centers, some with a history of several centuries. Moreover, the duration of the construction was an important factor, because the reinforcement of the dikes in this area was expected to take more than thirty years. Therefore, there was pressure to find alternatives, particularly a moveable barrier that could be closed under exceptional circumstances, occurring once in ten years. An important requirement of the barrier was that it would not block the shipping route.[47]

The choice was made for two large floating gates on either side of the New Waterway that would move to each other to close the waterway. The construction of the barrier started in 1991, and on May 10, 1997, after six years of construction, Queen Beatrix opened the Maeslant Barrier. The barrier was designed with two "circle segments," each with a length of 210 meters and a height of 22 meters. Each gate rotates around a ball joint with a diameter of 10 meters and a weight of 680 tons. Closing and opening of the barrier is driven by a self-operating computer system, which is linked to meteorological, river discharge, and sea level data. When a storm surge of three meters above normal sea level is anticipated in Rotterdam, the barrier will be closed automatically. The complexity of the closure process requires that decision making be completely automated. To achieve the required level of reliability, a double computing system has been installed; during extreme situations the system is continuously monitored by a team of experts. Well before the actual closing procedures are started, incoming and outgoing ships are warned, and two hours before closure shipping is prohibited. The barrier is designed to withstand a storm situation that is expected to occur once in 10,000 years. It is expected that closing the barrier is needed, on average, once in ten years.[48] On November 8, 2007, the Maeslant Barrier was closed for the first time since its construction because of a strong storm surge.

In 1999 the secretary of state for transport, public works and water management and the president of the Union of Water Boards established the Advisory Committee on Water Management in the 21st Century (WB21). The committee was charged with developing recommendations for desirable changes to the water management policy in the Netherlands, focusing on the consequences of other water-related problems, such as climate change, rising sea level, and land subsidence. In 2001 guidelines were produced for future water management. The Dutch government enacted these guidelines in a new approach to ensure safety and to reduce other water-related problems in the twenty-first century. This approach includes, among other things:

- Awareness: citizens should be more aware of problems associated with water
- Three-step-strategy: retaining, storing, discharging
- Room for the river: more land for occasional storage is required
- Spatial planning: prevent non-river-related human activities in the floodplains
- International cooperation: must be intensified.[49]

The new approach requires land use changes and introduces new scientific research issues and has an impact on the working methods of the responsible water resources agencies. Increased attention is also being given to communication and public participation.

In 2000 the Room for the River concept was adopted as a government policy. Through this concept the Dutch government initiated a shift from "traditional" flood protection policies (i.e., raising the dikes) towards creating increased water discharge capacities. More

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Maeslant Barrier

than thirty projects were formulated and a variety of measures were developed to implement this policy, such as levee relocation, the construction of bypasses and spillways, and locations for water storage. The main goal is a reduction of high water levels; other goals are nature development and landscape restoration. The development and implementation of these new river policies required intensive cooperation among water managers, spatial planners, nongovernmental organizations (NGOs), and inhabitants of the areas along the main rivers. For that reason, the Dutch national government decided to organize the decision-making process on the new Room for the River policies not as a centralistic top-down process in which the Dutch national government would decide autonomously on the most effective policy program. Instead, the national government demanded that the provinces issue regional guidance on desirable measures to create more room for the river. The provinces were asked to prepare this guidance in close cooperation with the affected municipalities and water boards, and to involve a wide range of NGOs, including agricultural organizations, agencies serving the interest of recreation, representatives of river-related industries, and environmental groups.

Two main policy objectives or conditions were formulated beforehand. First, the final policy program proposed by the Dutch provinces would have to guarantee safety for the approximately four million inhabitants of the areas along the main rivers. Safety standards were defined, which would have to be reached within both the short term (2015) and the long term (2050). Second, it was decided to improve the “spatial quality”

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A secondary channel, parallel to the main channel in the Waal River, intended to spur nature development and reduce peak water levels of the river landscape at the same time—for example, considering possibilities to create new nature preserves or for the development of new sites for urban expansion along newly created river branches. Because of the relatively open policy process, parties have been able to combine different perspectives and to develop multi-purpose plans that are acceptable to most of them. The Room for the River project, therefore, is not only a substantive policy innovation, but is generally considered to be an interesting innovation in governance as well.[50]

The Room for the River concept has also had an international resonance. During the flood of 1995, the ministers of land use planning had their regular meeting in Arles. In the communication of this meeting the ministers of the riparian states declared that further measures had to be taken to reduce future river flood risks. They supported an integrated approach: not only water management, but also land use/spatial planning had to be taken in account, leading to river basin management. In 1998 Highwater Action Programs were created on the basis of the Arles Declaration.[51]

To be prepared for record-level river discharges—discharges higher than those related to the agreed safety standards—the Luteijn Commission was installed in April 2001 to advise on the possibilities of "controlled flooding." Although such a catastrophic situation is not expected, a significant reduction of damage and number of casualties is expected when the surplus water is guided to areas with low population densities and relatively low economic investments. In their report of 2002, the commission presented the results of their investigations to look for possibilities of emergency inundation areas along the Rhine and Meuse rivers.[52] Ultimately, they focused on three areas: the Rijnstrangen and the Ooijpolder along the Rhine and Beersche Overlaat along the Meuse. The cabinet was intrigued by the recommendations of the commission and announced in July 2002 that a final decision would follow in the coming years. However, local opposition arose in the potential emergency inundation areas, particularly in the Ooijpolder, because the people and the local political representatives had the feeling that their land would be sacrificed to the benefit of more-downstream areas. Moreover, memories of the evacuations in 1995 were still alive. Amidst all this political turmoil and the scientific debates on uncertainties with respect to the real flood reduction impact of emergency inundation areas, the government decided in 2005 that the use of Ooijpolder and Rijnstrangen would not be cost-effective and that those areas would not be used for controlled flooding. In extreme flood stage, therefore, these areas will be particularly vulnerable. The situation illustrates the gap between policy and politics.[53] It may be expected that this political discussion will return when proposals are presented for further differentiation of the safety standards, based on new insights of the flooding risks within the Netherlands as a result of the newest findings of societal cost/benefit analyses. In the National Water Plan, which came into force in December 2009, it was decided by the Dutch government to also give up the reservation of the Beersche Overlaat as an area for controlled flooding in emergency situations.

At the beginning of the twenty-first century, an American flood event and a former American politician have contributed much to placing the issue of water safety high on the Dutch political agenda again. The devastating Hurricane Katrina raised social and political awareness of the risks involved in occupying low-lying delta areas in the Netherlands. Furthermore, Al Gore's film *An Inconvenient Truth*, and his related visits to the Netherlands, which received a great deal of media attention, contributed much to societal awareness of the seriousness of climate change and the vulnerability of the Netherlands.

In September 2007 the Dutch government installed the new Delta Commission, which was responsible for giving advice on how to protect the Netherlands against floods for the longer term (specifically to 2100 and generally to 2200). This question was asked in the light of climate change (rising sea level and higher peak discharges of the rivers) and developments within society (demographic shifts and increased investments). In September 2008 the new Delta Commission presented its report to the Dutch Parliament. It was concluded that sea level is probably rising faster than was previously projected, and extreme variations in river flow are expected to increase. It was advised that the flood protection levels of all diked areas must be improved by a factor of ten, and that all measures to increase the protection levels must be implemented before 2050. At the moment there is no serious problem, but the need for being well prepared was strongly emphasized.[54]

An important recommendation of the commission was that a Delta Act should be implemented. This act was discussed in the cabinet in October 2009 and submitted to the Lower House in the spring of 2010. The Delta Act forms the legal basis for a Delta Program, in which measures and provisions for water safety and fresh water supply are developed, including their planning and estimates of their costs. A Delta commissioner is charged with drawing up, updating, and implementing this program on behalf of the cabinet. A ministerial steering group under the authority of the minister of transport, public works and water management includes representatives from the Ministry of Housing, Spatial Planning and the Environment, the Ministry of Agriculture, Nature and Food Quality, the Ministry of the Interior and Kingdom Relations, the Ministry of Economic Affairs, and the Ministry of Finance.

To finance all the measures and provisions for water safety and freshwater supply, a Delta Fund was proposed. The fund is expected to include the expenditure of the state on the construction, improvement, management, maintenance, and operation of water management structures with a view to water safety and freshwater supply—and the related water quality management. The budget will be allocated annually to the Delta Fund from the general resources. The costs for the implementation of the proposed Delta Program were estimated by the commission at 1.2 to 1.6 billion euros per year in the period 2010–2050 and 0.9 to 1.5 billion per year in the period 2050–2100.

The Delta Program comprises nine sub-programs, three of which are general (safety, freshwater, and new spatial developments and reconstructions) and six are directed to specific regions (Rhine estuary mouth, Southwestern delta, IJsselmeer region, rivers, coasts, and Wadden Sea region). The Delta Program commissioner is responsible for ensuring that the Delta Program is realized.

Proposals for a new system of safety standards against flooding and their differentiation will be prepared in the safety sub-program. Cost-benefit analyses have been made based upon the present situation and combined with assessments of individual risk of death as a result of flooding and group risk (the risk of large numbers of casualties). The new standards are scheduled to be incorporated into the Water Act. Obviously, this fundamental decision will be of great importance for the outcome of the regional sub-programs.

Whereas Dutch water safety policies had almost exclusively focused on reducing flood probability (either by constructing dikes or creating room for the river), floodplain occupancy and the increasing investments made behind the dikes have made it necessary to develop policies aimed at reducing flood exposure and flood vulnerability as well. Therefore, a three-step approach was chosen: giving additional emphasis to prevention, paying attention to risk reduction through sustainable spatial planning, and developing sound evacuation plans.[55] In this new approach to flood management, prevention remains the highest priority, and its safety levels will not be reduced by secondary risk-reducing measures or provisions. It is expected that the Delta Program will have a profound impact on flood defense policies in the Netherlands for the years to come.

At least as important as the flood management along the rivers is the defense of the country against the attacks from the North Sea. Therefore, coastal defense has a high priority in the Netherlands. The coast itself consists of about 290 kilometers of natural dunes and 60 kilometers of dikes and dams. In the 1970s and 1980s attention focused on the realization of the Delta Works. The Storm Surge Barrier in the Eastern Scheldt and the Maeslant Barrier in the New Waterway also reflected an emphasis on coastal defense. For the coast itself the Rijkswaterstaat was invited by the government to prepare a strategy for the years after 1990. The document "First Coastal Report" (*Eerste Kustnota*) (1990) made a plea for "dynamic preservation," for which strategic and operational objectives have been defined. The strategic objective was to guarantee a sustainable safety level and sustainable preservation of values and functions in the dune area. The operational objective was to maintain the coastline at its 1990 position, for which an ongoing coastal nourishment policy has been developed.

As a standard of reference, the so-called Basal Coast Line (BCL) has been defined as the estimated position of the coastline on January 1st of 1990. This position has been derived from an extrapolation of the linear trend of coastline positions during the years 1980–1989. The choice for a ten-year linear extrapolation is based on being not dependent on incidental erosions.[56] The operational objective is to maintain the Momentary Coastline (MCL) not landward of the BCL. The MCL is calculated from data of the Dutch yearly coastal monitoring program, which has been operational since 1963. In the coastal documents that followed, a plea has been made for sand replenishment at deeper water (1993) and to look for a stronger relation between coastal safety and spatial planning (1995). The expected effects of climate change became of increasing importance in making a new water safety policy. A lot of uncertainty is acknowledged. In the water policy document "National Water Plan" (*Nationaal Waterplan*) (2009) the sea level rise of 0.15 to 0.35 meters is expected for the period 2000–2050 and 0.35 to 0.85 meters for the period 2000–2100.[57] The sand replenishment strategy offers the advantage that the amount of replenished sand can be adjusted easily when the sea level rise is higher or lower than expected.

The role of the state is extensive: overall supervision, flood defense management at the Wadden Isles and at the Delta Dams, and coastline management. As overall supervisor, the state also bears responsibility for strategic policy. Daily management of flood defenses of the sandy Holland and Delta coast is the task of the water boards. For implementation of coastline management, such as the design of annual management schemes, the state seeks advice from provinces, water boards, and municipalities. Since 2002 the water policy and international coordination is the responsibility of the Water Directorate at the Ministry of Infrastructure and the Environment, whereas the Rijkswaterstaat is responsible for the design, construction, management, and maintenance of the main infrastructure facilities.

Toward the end of the first decade of this century an innovative project started in the Dutch coastal zone called "Sand Motor" or "Sand Engine" (*Zandmotor*).[58] The Rijkswaterstaat, the Province of South Holland, universities, research institutes, and the private sector started experiments by depositing large amounts of sand at a specific location near the coast and allowing the natural elements such as wind, waves, tides, and currents to work. As a consequence, a kind of manmade peninsula was formed along the coast, which subsequently contributed to the formation of new beaches and dunes. The purpose is the enhancement of coastal protection in the long term, by widening beaches and

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The Sand Motor (or Sand Engine) is a huge volume of sand that was deposited along the coast of Zuid-Holland at Ter Heijde in 2011. Forces of nature will spread the sand along the shore, thereby reinforcing the coastline and creating a dynamic area for nature and recreation.

dunes for natural and recreational use, and especially reducing the need for beach replenishment. Much attention is given to the monitoring of the sand movements. Knowledge development, thanks to the Sand Motor project, is co-financed by the European Union's Regional Development Fund. Between March and October 2011, 21.5 million cubic meters of new sand were deposited in the coastal zone. The "Sand Motor Monitoring and Evaluation" program of this project is organized by the Rijkswaterstaat. The first official results will be published in 2016.

EUROPEANIZATION OF WATER POLICIES

BORDER-CROSSING RIVERS

The Netherlands is located in the delta of four international rivers: the Rhine, Meuse, Scheldt, and Ems, of which the Rhine is the largest. The largest portion of these basins is situated in other European countries. Therefore, international cooperation, mutual adjustment, and joint decision making are of utmost importance, and transboundary river commissions have a long and rich history.

The Rhine River is one of the longest and most important rivers in Europe, at about 1,230 kilometers in length and an average discharge of more than 2,000 cubic meters per second. It is Europe's busiest waterway, linking the Swiss Alps to the North Sea, flowing through Switzerland, Germany, France, and the Netherlands. Its basin includes major European industrial areas, such as the Ruhr region in Germany and the Rijnmond region in the Netherlands. The Port of Rotterdam—"The Gateway to Europe," at the mouth of the Rhine—is the largest harbor in Europe.

There is a particularly rich history of cooperation on the Rhine River. Major progress has been achieved following wars, other manmade and natural disasters, and more recently European Union interventions. Cooperation started in the field of navigation in 1815, just after the Napoleonic Wars, with the creation of the Central Commission for the Rhine Navigation (see chapter 2). The river authorities of the Rhine states succeeded in eliminating obstacles that impeded navigation, which contributed considerably to trade and industry in this part of Europe.

The end of World War II marked the beginning of a new chapter in the Rhine's history. Although pollution from chlorides gained attention at the beginning of the twentieth century, awareness of this problem has grown rapidly since then. Industrial and urban leaders came to realize that they could not continue to dump untreated effluents into the river and still expect it to provide their freshwater needs, and governments realized that the river was no longer capable of fulfilling its multiple functions. On July 11, 1950, upon the initiative of the Netherlands, the riparian countries of the Rhine downstream of Lake Constance—Switzerland, France, Luxembourg, Germany, and The Netherlands—joined forces by establishing the International Commission for the Protection of the Rhine (ICPR). During the first decade of the ICPR, it served as a common forum for discussing questions and seeking solutions relating to pollution in the Rhine. However, in 1963 the ICPR parties concluded that the existing tools for cooperation among the governments should be strengthened. Therefore, on April 29, 1963, they formalized ICPR's existence by signing the Convention on the Protection of the Rhine, which widely became known as the Bern Convention. The Bern Convention gave the commission the authority to hold annual plenary sessions and draft international treaties. In 1972 the commission was given the additional task of organizing regular ministerial-level meetings. These Rhine Ministers' Conferences remain the single most important forum for handling issues of Rhine pollution and ecology.[59]

The first Rhine Ministers' Conference on the pollution of the Rhine was held in 1972 to recommend further actions to reduce pollutant chemicals. In 1976 the Rhine Ministers drafted two important conventions. The first treaty, the 1976 Bonn Convention Concerning the Protection of the Rhine against Pollution by Chlorides, focused on waste salts from industrial production (mostly potash fertilizers). The second, the Bonn Convention for the Protection of the Rhine, addresses all chemical inputs into the river, both those from "point sources" and those from "non-point sources." In fulfillment of the Chloride Convention, the bulk of the discharge reductions fell on the potash industry in the Alsace region in France. The convention obligated France to construct chloride-removal systems at their potash plants and to pump the recovered salts into underground limestone formations. However, due to protests in the Alsace region, the French government refused to submit the Chlorides Convention to Parliament for ratification. In 1985, after finding methods for storing the waste salts more securely, the French ratified the Chlorides Convention. Since then the river's salt load has dropped significantly. Although the convention required a strong reduction of the inputs from France, it was financed largely by the other basin states (Switzerland 6 percent, Germany 30 percent and the Netherlands 34 percent). The official argument was that the other countries must also reduce their inputs, but in reality the French potassium mines were the main contributor. However, it was viewed as a concession to France to come to an agreement. The Chemicals Convention was initially on a faster track but also ran into implementation problems of its own. One of the causes was the lack of suitable technologies for reducing the input of many of the chemicals. Treatment plants often took years to design and construct, especially if the mitigation technologies were new or untested.

International cooperation got a new impetus on November 1, 1986, when a fire broke out in a chemical storehouse by Sandoz in Basel, Switzerland. It was extinguished with large amounts of water which then streamed into the Rhine, heavily polluting the water with pesticides and degradation products. The water in all downstream countries became polluted. Drinking water companies had to stop their intake of water, massive fish kills occurred, and some speculated that the Rhine ecosystem was virtually dead. The ecosystem was restored relatively quickly after the chemicals disappeared, however, because of renewal from tributaries. Nonetheless, the accident had a large impact. Within two weeks, a Rhine Ministers Conference was organized, and in May 1987 a concept Rhine Action Plan (RAP) was ready, which included as central goals the return of salmon to the Rhine and a 50 percent reduction of emissions for many substances.[60] The RAP was helpful in implementing the Chemicals Convention, putting many of the chemicals in the Chemicals Convention on a fast track for reduction and targeting every factory on the Rhine, regardless of size, that produced any testable amount of organic and inorganic substances on the priority list. Improvements in water quality between 1970 and 2000 demonstrate unequivocally that both the Chemicals Convention and the Rhine Action Plan have had an enormously positive impact on the entire Rhine basin.

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Poisoned fish in the Rhine due to the Sandoz chemical plant explosion, 1986

A part of the 1987 Rhine Action Plan was the Plan Salmon 2000, which aimed to establish self-sustaining populations of Rhine salmon by the first decade of the new millennium. This plan was directed to all of the river's main migratory fish (salmon, sea trout, sea lamprey, and sturgeon), but the spotlight was on the salmon as a key indicator of the river's health. It also has a greater symbolic value than other migratory fish in this river. Many hindrances in the river were removed or made passable, so that these fishes could migrate between the upper river and the North Sea. Examples are changes in the operation procedures of the Haringvlietdam in the mouth of the Meuse-Rhine Delta and modifications at the sluiceways in the Afsluitdijk between the IJsselmeer and the Wadden Sea/North Sea. However, it was not until the Rhine Protection Commission issued its blueprint for riparian restoration, the Ecological Master Plan for the Rhine (1989), that salmon repopulation commenced.[61]

In January 1998 the 12th Conference of Rhine Ministers adopted an Action Plan on Flood Defense to be implemented over twenty years. The floods of 1993 and 1995 were catalyzing events for this plan. The most important aims of the plan were to reduce damage by up to 10 percent by the year 2005 and by up to 25 percent by 2020. Extreme flood levels downstream of the regulated Upper Rhine are to be reduced by up to 30 centimeters by 2005 and by up to 70 centimeters by 2020. These ambitious targets are likely to be reached only through an integrated managerial approach at local, national, regional, and international levels.

The Rhine Action Plan on Flood Defense empowered the Rhine Protection Commission to "compensate for the ecological deficits of the past" by removing "human interferences with the river regime as far as possible." The plan is conceived in phases. The first phase (1995–2000) was directed to provide a comprehensive overview of flood-prone regions in the Rhine catchment basin. This task was largely accomplished with the publication of the Rhine Atlas in 1998, which identifies polder areas and maps sites where a return to natural conditions is economically feasible and ecologically necessary.[62] The second phase (2000–2005) focused primarily on the establishment of water storage sites. The goal is to reduce the maximum water height under extreme conditions by 30 centimeters. The aim of the third phase (2005–2020) is a reduction of 70 centimeters of the maximum water level for protecting the downstream areas.

Because the 1987 Rhine Action Plan ended in the year 2000, the 13th Conference of Rhine Ministers on January 29, 2001, adopted the new program, Rhine 2020: Program for the Sustainable Development of the Rhine. The Rhine 2020 program focused on the continued implementation of the Ecological Master Plan for the Rhine (1991), the improvement of flood prevention by implementing the Action Plan of Floods (1998), and the further improvement of water quality and groundwater protection. Summarizing, the targets of the Rhine 2020 program are:

- Sustainable development of the Rhine ecosystem
- Secure the use of Rhine water for drinking water production
- Improve sediment quality in order to be able to dispose of dredged material without causing any harm
- Comprehensive flood protection and protection taking into account ecological requirements
- Depollution of the North Sea.[63]

During the 14th Conference of Rhine Ministers held on October 18, 2007, the ministers, together with the representative of the European Commission, made an assessment of the many years of cooperation in protecting the Rhine, its tributaries, and the entire watershed. Above all, they recommended a further reduction of inputs of pollutants, particularly nitrogen inputs of diffuse origin, such as agriculture and micro-pollutions from urban wastewater. They also made agreements for the upstream migration of fish into the Rhine system via the floodgates of the Haringvliet and the construction of a fish passage at the Strasbourg Barrage and decided to work on an "overall strategy for the sediment management of the Rhine." Special attention was given to jointly developing adaptation strategies for water management in the Rhine watershed in order to be able to cope with the challenges of climate change. In this way they actualized the guidelines for future cooperation.

Sixty years of cooperation on the Rhine by a succession of Rhine Conventions and Conferences of Rhine Ministers, and the implementation of numerous measures, resulted in immense improvement of the water quality of the Rhine and along many of its tributaries. Also, the biological state of the Rhine and its tributaries improved substantially and the species numbers continued to rise. Since 2006 migratory fish may again reach the spawning grounds in the Rhine tributaries as far as Strasbourg. Great efforts were made towards improving flood prevention and protection, but also a large number of measures have yet to be implemented. A continued monitoring and updating of the Action Plans is foreseen. In particular, the effects of climate change have garnered a great deal of attention. Increasingly this cooperation is organized on the scale of the entire international river basin.

The Rhine 2020 program is increasingly carried out in direct relation to the European Water Directives, particularly the EU Water Framework Directive (2000). These European developments will be discussed further. Comparable developments occurred in the other major river basins (Meuse, Scheldt, and Ems), but the Rhine River has primary consideration.

EUROPEAN WATER POLICY

The history of Europe has been characterized much more by divisions, tensions, and conflicts than by any common purpose. Rivalry between the states, emerging and declining empires, such as the Roman Empire (27 BC–476 AD), the Frankish Empire (third–tenth century), the Austro-Hungarian Empire (1867–1918), the Ottoman Empire (1293–1922) and so on, are the "ever repeating" picture in the European history. European history is therefore shaped by a long list of conflicts: wars between and within European nations as well as rebellions by groups seeking independence. Examples include the Eighty Years' War (1568–1648), the Thirty Years' War (1618–1648), and the Napoleonic Wars (1799–1815). Political, religious, and economic deviations and differences in language form the basis of these conflicts. The twentieth century showed dramatic explosions in the rivalry between the European powers, resulting in World War I (1914–1918) and World War II (1939–1945).

After the Second World War the political climate favored the unification of Europe. The European Coal and Steel Community (ECSC) was founded in 1951 by the Treaty of Paris. The founding members of the ECSC were Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany. In 1957 two new communities were established: the European Economic Community (EEC), founded by the Treaty of Rome, and the European Atomic Energy Community (Euratom) by yet another Treaty of Rome. These three together were generally known as the European Community (EC). On this basis the European Union (EU) was introduced by the Treaty of Maastricht and came into force on November 1, 1993.[64] Currently (2013) the EU is composed of 28 independent sovereign states, which are known as the Member States (MS). Discussions on joining the EU are going on with some "candidate countries" (Iceland, Montenegro, Serbia, the Former Yugoslav Republic of Macedonia, and Turkey). To join the EU, a country must meet the Copenhagen Criteria, defined at the 1993 Copenhagen European Council. These criteria require a stable democracy which respects human rights and the rule of law, a functioning market economy capable of competition within the EU, and the acceptance of the obligations of the membership, including EU law.[65]

The European Community started its environmental policies with an ambitious program that contained many elements of today's ideas on "sustainable development."[66] After the first United Nations Conference on the Environment in Stockholm 1972 and growing public and scientific concerns on the limits to growth, the commission became active in initiating an original community policy. On the basis of European council commitments in 1972 to establish a community environmental policy, the first Environment Action Program (EAP) was decided upon in November 1972. It was argued that "the protection of the environment belongs to the essential tasks of the Community." The next EAPs have become gradually broader in their scope, reflecting the cross-border nature of many environmental issues as well as the development of the single market, where the freedom of movement of people, goods, services, and capital is guaranteed by a standardized system of laws for all Member States. The sixth EAP (2002–2012) focuses on four priority areas: climate change, nature and biodiversity, environment and health, and sustainable use of natural resources and the management of wastes. Its strategy now is to postpone potentially controversial political decisions to later phases and to rely on more cooperative approaches. The role of small specialist expert communities increased and the commission changed its key role from an initiator of legislation to a manager of policy processes.

Water legislation was one of the first sectors to be covered by the EU environmental policy. Since the beginning of the 1970s water protection has been a subject of rising concern. It developed in a number of steps. The first period (1973–1988) mainly focused on the protection of water used for human activities. Environmental quality standards (EQS) were specified in a number of directives. Examples are the Surface Water Directive in 1975, the Dangerous Substances Directive of 1976, and the Drinking Water Directive in 1980. This period included quality objectives legislation on fish waters, shellfish waters, bathing waters, and groundwater.

The period 1991–1998 focused more on limitations of particular emissions, both from point sources and diffuse sources. The eutrophication of waters, caused by an abundance of nitrates and phosphates, received particular attention. One of the biggest problems that future water protection is facing is not insufficient legislation, but the fact that basically no directive has been completely implemented and applied by the Member States. Central to this are the high public costs involved. For example, the EU-wide costs for the implementation of the Urban Waste Water Treatment Directive were estimated to be 150 billion euros (1994–1995 value) during the period of 1993–2005. However, this directive was relatively well implemented. Greater problems arose with the implementation of the Nitrate Directive, which created problems in most European countries. The reduction of diffuse pollution and required changes in agricultural production are much more difficult to achieve than the control of the easily identifiable sources of urban waste water pollution.

Pressure for a fundamental rethinking of community water policy came to a head in mid-1995. The commission, which had already been considering the need for a more global approach to water policy, accepted requests from the European Parliament's Environmental Committee and from the Council of Environmental Ministers. The commission agreed to produce a framework for water policy and, if appropriate, devise a legislative proposal to ensure the overall consistency of water policy. The draft legislation of this Water Framework Directive (WFD) was circulated in 1996, with amendments processed in 1997 and 1998. The final text was adopted in October 2000, and the WFD came into force in December 2000. The directive's overriding requirement is that the Member States ensure that a "good chemical status" and a "good ecological status" are achieved in all European waters by the end of 2015. Its aims are a higher quality of aquatic ecosystems and their environment, a sustainable use of water resources, and an improvement of the aquatic environment by reducing pollution and mitigating the impact of floods and droughts. To implement these objectives, river basin management plans have to be outlined for every international river basin. In the Netherlands four river basins have been defined: The Rhine, Meuse, Scheldt, and Ems. The Water Framework Directive marked a new stage in the harmonization and internalization of integrated water management policy. Its implementation also implied a more intensive network-building of all relevant water management actors.

Although the WFD aspires to an integrated water management approach, flood management issues are not covered by the WFD. However, pushed by the extreme summer floods in 2002, the commission made a proposal for a Floods Directive, Reducing the Risks of Floods in Europe, which was adopted in 2007 and came into force in December 2007. The objective of the Floods Directive is to create obligations for Member States to manage the risks of floods to people, property, and the environment by concerted, coordinated action at river basin level and in coastal zones. Such provisions should be undertaken by all European countries in their River Basin Management Plans. In the coming years, a further integration may be expected of the ecological WFD with the EU Floods Directive to an integrated water resources management approach under the EU Common Implementation Strategy (CIS).[67]

Dutch River Basins

The four rivers entering the Netherlands: Rhine, Meuse, Scheldt, and Ems. Lower left, the river basin districts and the sub-basins in the Netherlands.

Rijkswaterstaat

Notwithstanding large differences among the various European countries, such as differences in geography, physical conditions, culture, institutional organization, and politics, this strategy successfully arrived at a coherent and harmonious implementation in accordance with the agreed-upon time scales. The key element is the River Basin Management Plan (RBMP) that Member States have to produce for each river basin management district. The preparation of RBMPs is an important area of influence for all stakeholders, because this is where all relevant issues for the achievement of the WFD objectives are negotiated. Part of this plan is the program of measures (PoM), which should be indicated for all waters at risk, to achieve the objectives of Article 4 of the WFD in good time. The DPSIR-approach (Driver-Pressure-State-Impact-Response), a causal framework for describing the interactions between society and the environment, is used as a logically stepwise approach of driving forces (land use, industry, agriculture, etc.), human pressures, the "state" of the environment, the environmental effects, and the societal response through physical measures, regulations, taxes, and so on. The legally binding timetable with its strict deadlines and powerful sanctions is expected to be a valuable instrument to reach the agreed targets in good time.

In almost all European countries the introduction of the WFD has placed a great deal of pressure on existing institutions. The WFD provides procedural rules and guidelines for organization, planning, and management at the river basin scale. Kallis and Briassoulis (2004) indicate how the WFD recognizes the limits of the top-down "command and control" approach and adopts a more flexible and cooperative implementation strategy.[68] EU working groups, with participation from national delegates, experts, and representatives of NGOs, are preparing nonbinding guidance on the various implementation-related tasks, such as the identification of water bodies, reference conditions, environmental objectives, public participation, and monitoring.

The new European dimension of water management has induced changes in water management practices in the Netherlands. In fact, it is working with a number of new "rules of play."[69] The Netherlands has experience of many centuries in the protection of the country against extreme floods. During the past several decades, water quality, nature conservancy, and landscape ecology received increasing attention, and since the 1980s integrated water management has become a widely accepted practice. The Water Framework Directive builds on this by focusing on the ecological status of the water bodies. Furthermore, the catchment approach forms the basis for the European water management, and this has no long history in the Netherlands because it is situated in a delta and the basins of all major rivers are largely situated outside the country. Furthermore, in the Netherlands the commitments of the water agencies were generally based on agreements to work on the realization of jointly agreed high ambitions. Now commitments must be made on measurable contracted results. No large differences in the final results are expected, but the loss of flexibility should be accepted and the agreed ambitions need to be attuned to the new situation.

Also for the Rijkswaterstaat, this European context and its "new rules of play" implies a change in its working practice. It has the responsibility for the management of the major rivers, which means that it concentrates on the river management between the dikes. However, working with the catchment approach means close coordination with a number of stakeholders, including the water boards and the provinces. It was difficult to see these major rivers as a part of the whole catchment, in which jointly-agreed visions, objectives, and measures must be defined and agreements must be reached about their real implementation. This was all the more difficult because of the transition from a set of rather independent regional divisions of the Rijkswaterstaat to a more centrally governed organization, where priorities must be made between investments in different river basins. It often resulted in tensions in the decision-making process in sub-basins at the regional level. Setting priorities at the national level requires the balancing of priorities of one river basin over another. The question then arises how joint agreements can be made with regional representatives of organizations in the river basin, in which decisions are taken at a higher (national) level. Nevertheless, these problems have been solved pragmatically during the cooperation of all concerned water authorities in the more than 130 regional working groups, in which joint proposals have been developed for objectives, measures, and actions to arrive at a positive status of all water bodies in such an area. In this way, all contributed to the jointly agreed River Basin Management Plans, which were sent to the European Commission in March 2010.

Not surprisingly, this European cooperation was not restricted to the border crossing rivers and their catchments; also the North Sea has a long international history. In the North Sea a huge number of functions have to be fulfilled, such as shipping, fishing, recreation, oil and gas production, sand and gravel extraction, energy production by wind turbines, pipeline transport, and so on. The challenge is to combine such a large number of functions with a sustainable maintenance of ecological values. Doing so had become a major concern for the Directorate for the North Sea of the Rijkswaterstaat as well. This directorate, since its establishment in 1971, has been responsible for the maintenance of navigation channels to the ports of Rotterdam and Amsterdam, for the management of navigation on the North Sea, and for a monitoring network that produces data for weather forecasts, prediction of storm surges, and other purposes.[70] The directorate became increasingly involved in the implementation and enforcement of international environmental agreements and regulations and the Sea Water Pollution act (*Wet Verontreiniging Zeewater*).[71]

Two important milestones in the 1970s are the Oslo Convention and The Paris Convention. A particular event gave rise to these agreements for protection of the sea area. On July 16, 1971, the Dutch ship *Stella Maris* was sailing from the port of Rotterdam to dump chlorinated waste in the North Sea. Under pressure from public opinion and the governments of several countries, the ship returned to the port without carrying out her mission. On February 15, 1972, in Oslo agreement was reached on the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (the “Oslo Convention”). The agreement came into force in 1978. It was felt that such an agreement must not be restricted to marine pollution by dumping but should also prevent marine pollution from discharges of dangerous substances from land-based sources, so a Convention for the Prevention of Marine Pollution from Land-Based Sources (the Paris Convention) was signed on May 4, 1974, in Paris and came into force in 1978. Two commissions were established to administer these conventions: the Oslo Commission and the Paris Commission. In a joint meeting of the commissions in 1992 in Paris, which was attended by the ministers of all concerned states and a representative of the European Union, a new convention was adopted for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention), together with a Final Declaration and an Action Plan to guide the future work of the OSPAR Commission, in which the Oslo and Paris Commissions were united. The OSPAR Convention came into force in 1998. Its activities concentrate on four main areas: protection and conservation of ecosystems and biological diversity, hazardous substances, radioactive substances, and eutrophication. Important steps forward have been made by the international North Sea Ministers Conferences, which started in 1984 in Bremen. An example of such an important step is the adoption of the precautionary principle at the London Conference in 1987. Until 1995, pollution was the main issue. Since then, increasing attention was given to the North Sea fish stocks and the impact of fisheries on the North Sea ecosystem. Starting from an ecosystem approach, a framework of operative ecological quality objectives (EcoQOs) has been established.

In June 2008 the European Commission adopted an ambitious Marine Strategy Framework Directive (MSFD) to protect more effectively the marine environment across Europe.[72] It aims to achieve "Good Environmental Status" (GES) of the EU's marine waters by 2020. On September 1, 2010, the European Commission adopted a set of detailed criteria and indicators. Major research topics were defined to develop additional scientific understanding for assessing this GES, which include the effects of climate change, the impact of human activities, the ecosystem approach to research management and spatial planning, and a further development of operational oceanography and marine technology. Both through this MSFD and the OSPAR-agreements, intensive cooperation has developed between the countries around the North Sea. The Netherlands is represented by the Rijkswaterstaat as the administrator of the Dutch part of the North Sea area. At the strategic level, the Rijkswaterstaat was the leading actor, but since 2002, the Water Directorate of the Ministry of Transport, Public Works and Water Management (now the Ministry of Infrastructure and the Environment) has assumed this leading role.

CONCLUSION

As described in chapter 6, the period 1900–1970 was a technocratic era, where the required budgets were available and civil engineers had the mandate to design their solutions for water problems within society. This situation changed radically since the 1970s. The economic decline forced the Rijkswaterstaat to work with lower budgets and a severe reduction in the number of employees. From 1980 to 1994 the number of employees was reduced from 13,700 to 9,700. At the same time, the increased environmental awareness, through which water systems are now seen as important ecosystems, as well as the unfolding democratization of Dutch society, had an enormous impact on water management. Water management problems could only be solved by an integrated approach, where hydraulic, environmental, economic, and social aspects were combined, and collaboration with stakeholders and the public has become key to solving many water problems.

The organization of the Rijkswaterstaat clearly had difficulties in responding to the new challenges. Discussions on large infrastructure projects led to severe criticism of the organization of the Rijkswaterstaat, notably the cost overruns of the Betuwe railroad route to Germany. Although other factors contributed to exceeding the project budget, the organization of the Rijkswaterstaat was often blamed in the media. The technocratic approach and not listening to other viewpoints sparked criticism as well. In regard to water management, this is illustrated by the Eastern Scheldt project and the Markerwaard reclamation project.

Particularly the Eastern Scheldt project, but also other discussions in the same period, contributed to a turning point in the organization and working methods of the Rijkswaterstaat, although this was generally a gradual development process. A number of painful reorganizations were needed. During the period 1970–2010 the Rijkswaterstaat developed into a multidisciplinary organization and attempted to become more oriented to the public. Over the past 200 years the Rijkswaterstaat has proved to be a resilient organization, knowing how to adapt and to survive.

Notwithstanding all the criticism, impressive results were achieved during this period, including a number of innovative technological projects, new methodologies, and advanced water management policies. The organization also managed to realize these changes in complex political and societal circumstances. An essential difference with the past is that implementation of new policies and the realization of projects are increasingly accomplished with other actors, such as the provinces, water boards, and private enterprises. Examples include the implementation of the Water Pollution Act (WVO), the construction of the Eastern Scheldt Barrier, the development and implementation of integrated water policies in the 1970s and 1980s, and the River Management Plans in the 1990s after the floods of 1993 and 1995, resulting in the large infrastructure projects Room for the River and Meuse Works. In addition, the Flood Defense Act of 1989 and the emergency Delta Law Major Rivers of 1995 were implemented in cooperation with the provinces and water boards. The coastal zone benefited equally from such achievements, such as the new policies for "dynamic preservation" of the coastline in the 1990s and the application of innovative sand replenishment technologies to guarantee a sustainable safety level and to preserve values and functions in the dune area. Finally, important contributions were made to the international coordination for the Rhine, Meuse, Scheldt, and Ems rivers, resulting, for example, in Rhine Action Plans and Meuse Action Plans and their implementation.

In addition to the "ecological turn" and "societal turn" at the end of the twentieth century, the beginning of the twenty-first century witnessed an "organizational turn" in 2002, as policymaking and international cooperation were transferred to the policy department of the ministry. After that, the Rijkswaterstaat underwent an intensive reorganization process, resulting in a public-oriented network organization. Also impressive is the "knowledge turn" in 2007, when a large number of Rijkswaterstaat specialists switched to the knowledge institute Deltares.

Notwithstanding all these "turns," there is also a great deal of continuity. The basic institutional structure of water management within the Netherlands has hardly changed. The new Ministry of Infrastructure and the Environment, the Rijkswaterstaat, provinces, and water boards are still the crucial governmental actors in Dutch water management, and unlike many other countries, water management and water safety continue to be the exclusive responsibility of these governmental actors. Finally, in spite of the broadened arsenal of flood management strategies, the construction and strengthening of dikes remain the dominant safety strategy to date.

BIBLIOGRAPHIC ESSAY

ENGLISH SOURCES

A general account of the central role of water management in Dutch society, focusing on the last decades, is P. Huisman, *Water in the Netherlands, managing checks and balances* (Utrecht, 2004) (see also the bibliographical essay in chapter 2). On the development of integrated water resource management, see J. Wisserhof, *Matching research and policy in integrated water management*, (Delft, 1994) and A. Lenschow, "Environmental Policy: Contending Dynamics of Policy Change," in H. Wallace, W. Wallace and M. A. Pollack (eds.), *Policy-Making in the European Union*, (Oxford, 2005), pp. 305–27.

S. V. Meijerink, *Conflict and Cooperation on the Scheldt River Basin, A case study of decision making on international Scheldt issues between 1967 and 1997* (Dordrecht, 1999) presents in his Ph.D. thesis a framework for the analysis of policy making on international river issues, applied to the case of the river Scheldt. R. D. Wilken gives a brief overview on the Rhine recovery program in "The recovered Rhine and its history," in T. P. Knepper (ed.), *The Rhine. The Handbook of Environmental Chemistry 5, Water Pollution*, (Berlin, 2006), pp. 47–87. B. Wu et al., (eds.), *Flood Defence 2002: Proceedings of the second international symposium, Beijing, China, September 10–13, 2002* (Beijing, 2002) contains a useful chapter on recent trends in Dutch flood management: H. T. C. van Stokkom and A. J. M. Smits, "Flood defense in the Netherlands: a new era, a new approach," pp. 34–47. See also Hein T. C. van Stokkom, Antonius J. M. Smits, and Rob S. E. W. Leuven, "Flood Defense in The Netherlands: A New Era, a New Approach," in *Water International* 30/1 (2005), pp. 76–87. On the implementation of the Room for the River program, see M. van den Brink's Ph.D. thesis *Rijkswaterstaat on the horns of a dilemma* (Delft, 2009).

DUTCH SOURCES

Informative introductions to Dutch environmental history are J. Cramer, *De groene golf: geschiedenis en toekomst van de Nederlandse milieubeweging* (Utrecht, 1989) and J. L. van Zanden and S. W. Verstegen, *Groene geschiedenis van Nederland* (The Hague, 1993). On the environmental movement in the 1960s and 1970s, see E. Tellegen and J. Willems, *Milieu-akties in Nederland* (Amsterdam, 1978).

On the development of integrated water resource management, see L. C. Grijns and J. Wisserhof, *Ontwikkelingen in integraal waterbeheer. Verkenning van beleid, beheer en onderzoek* (Delft, 1992), and the inaugural lecture of W. van Leussen, *Leven met water, vermaatschappelijking van het waterbeheer: consequenties voor de civiel ingenieur en voor waterbeheerorganisaties* (Enschede, 2002).

The Rhine pollution process is the subject of a very useful Ph.D. thesis: C. Dieperink, *Tussen zout en zalm. Lessen uit de ontwikkeling van het regime inzake de Rijnvervuiling* (Amsterdam, 1997). Marcel de Wit, *Van regen tot Maas. Grensoverschrijdend waterbeheer in droge en natte tijden* (Diemen, 2008) is a clearly written account on the Meuse catchment, providing a rich amount of information on geological, geographical, hydrological, and institutional aspects, and focusing on recent developments.

On the Eastern Scheldt Barrier, a hallmark in ecological engineering, a few valuable books are available. R. Antonisse gives a lot of technical information about the Eastern Scheldt Barrier in his useful sketch *De kroon op het Deltaplan* (Amsterdam/Brussels, 1985). D. F. Westerheijden, *Schuiven in de Oosterschelde: besluitvorming rond de Oosterschelde 1973–1976* (Enschede, 1988) is a Ph.D. thesis focusing on the decision-making process.

On the environmentalist protests against the planned Eastern Scheldt closure and the ecological open barrier redesign, see Paul de Schipper, *De slag om de Oosterschelde* (Amsterdam/Antwerp, 2008). Alex van Heezik presents a vivid and detailed account on the Eastern Scheldt project in *De Kering. Over de bouwers van de stormvloedkering Oosterschelde* (Diemen, 2011).

On the Markerwaard project, see H. J. M. Goverde, *Macht over de Markerruimte* (Amsterdam/Nijmegen, 1987). The Maeslant Barrier project is covered in BMK Bouwkombinatie Maeslantkering et al. (eds.), *Sluitstuk van de Deltawerken: Stormvloedkering Nieuwe Waterweg* (Rotterdam, 1997).

Recent developments in the Rijkswaterstaat organization are portrayed in M. Metze, *Veranderend getij, Rijkswaterstaat in crisis* (Amsterdam, 2010), a critical account on the major organizational changes in the Rijkswaterstaat since 2003.

1 Website http://www.helpdeskwater.nl (in Dutch).

2 The adoption of Christiaan Brunings "Plan tot beheeringhe van de Waterstaat in de Bataafse Republiek" on May 24, 1798, is considered the birth of the Rijkswaterstaat. More details can be found in chapter 2.

3 Toon Bosch and Willem van der Ham , *Twee eeuwen Rijkswaterstaat (1798 – 1998)* (Zaltbommel: Europese Bibliotheek, 1998).

4 K. d'Angremond, P. Huisman, T. de Jong, G. J. Schiereck and W. Thissen (eds.) (1998), *Water tovenaars, Delftse ideeën voor nog 200 jaar Rijkswaterstaat* (Rotterdam: Beta Imagination Publishers, Rotterdam, 1998).

5 H. M. Oudshoorn (ed.) (1999), *Sustainable Development of Deltas. Proceedings international conference at the occasion of 200 year Directorate-General for Public Works and Water Management, Amsterdam, The Netherlands, 23–27 November 1998* (Delft: Delft University Press, 1999).

6 J. R. Hoogland, *Ingenieur van den Waterstaat*. Especially chapter 1.12 "Een krimpende organisatie" ('s Gravenhage: Rijkswaterstaat, 2010).

7 More details of this process can be found in Rijkswaterstaat, *Ondernemingsplan. Een nieuw perspectief voor Rijkswaterstaat. Doorpakken – wel degelijk* (Den Haag: Rijkswaterstaat, 2004).

8 An analysis of these changes of Rijkswaterstaat at the beginning of the 21st century is given by Margo van den Brink, *Rijkswaterstaat on the horns of a dilemma* (Delft: Eburon, 2009), especially chapter 5.

9 *Jaarbericht Rijkswaterstaat 1991* (Zoetermeer: Rijkswaterstaat, 1992); *Jaarbericht Rijkswaterstaat 1994* (Den Haag: Rijkswaterstaat, 1995).

10 Rijkswaterstaat , *Ondernemingsplan. Agenda 2012* (Den Haag: Rijkswaterstaat, 2008).

11 Commissie-Wijffels, *De kracht van directe verbindingen* (Den Haag, 2004).

12 www.rijkswaterstaat.nl/wmen. In English: www.rijkswaterstaat.nl/en.

13 D. Meadows, *De grenzen aan de groei, rapport van de Club van Rome* (Utrecht/Antwerpen: Het Spectrum, 1972).

14 E. Tellegen and J. Willems, *Milieu-akties in Nederland* (Amsterdam: De Trommel, 1978); C. R. Grimbergen, R. Huibers, D. van der Peijl, *Amelisweerd: de weg van de meeste weerstand* (Rotterdam: Ordeman, 1983).

15 C. Disco, "Remaking 'Nature': The Ecological Turn in Dutch Water Management," *Science, Technology, & Human Values* 27, no. 2 (2002): 206–35; S. V. Meijerink, "Understanding policy stability and change, The interplay of advocacy coalitions and epistemic communities, windows of opportunity, and Dutch coastal flooding policy 1945–2003," *Journal of European Public Policy* 12, no. 6 (2005): 1060–77.

16 Disco, "Remaking 'Nature'", 206–35.

17 Ibid.

18 Van den Brink, *Rijkswaterstaat on the horns of a dilemma*; M. Metze, *Veranderend getij. Rijkswaterstaat in crisis* (Amsterdam: Balans, 2010).

19 Metze, *Veranderend getij*; Van den Brink, *Rijkswaterstaat on the horns of a dilemma*.

20 W. E. Bijker, "The Oosterschelde Storm Surge Barrier, A Test Case for Dutch Water Technology, Management, and Politics," *Technology and Culture* 43, no. 3 (2002): 569–84; Disco, "Remaking 'Nature,'" 206–35; D. F. Westerheijden, *Schuiven in de Oosterschelde, Besluitvorming rond the Oosterschelde 1973–1976* (Enschede: Universiteit Twente, 1988).

21 Bijker, "The Oosterschelde Storm Surge Barrier", 569–84; Disco, "Remaking 'Nature,'" 206–35; Meijerink, "Understanding policy stability," 1060–77; Westerheijden, *Schuiven in de Oosterschelde*.

22 Disco, "Remaking 'Nature,'" 206–35.

23 Alex van Heezik, *De kering* (Diemen: Veen Magazines, 2011); R. Antonisse, *De kroon op het Deltaplan, stormvloedkering Oosterschelde, het grootste waterbouwproject aller tijden* (Amsterdam: Eslevier, 1985).

24 H. J. M. Goverde, *Macht over de Markerruimte* (Amsterdam/ Nijmegen: Koninklijk Nederlands Aardrijkskundig Genootschap/Katholieke Universiteit, 1987).

25 *Waterhuishouding in Nederland* (Den Haag: Staatsuitgeverij, 1968).

26 Ministerie van Verkeer en Waterstaat en de Unie van Waterschappen, *Bestrijding van de waterverVuiling. 25 jaar WVO* ('s Gravenhage: Unie van Waterschappen, 1995).

27 J. W. Pulles, *Beleidsanalyse voor de waterhuishouding in Nederland: PAWN* (Den Haag: Staatsuitgeverij, 1985); L. C. Grijns and J. Wisserhof, *Ontwikkelingen in integraal waterbeheer, Verkenning van beleid, beheer en onderzoek* (Delft: Delft University Press, 1992); J. Wisserhof, *Matching research and policy in integrated water management* (Delft: Delft University Press, 1994).

28 H. L. F. Saeijs, *Omgaan met water. Naar een integraal waterbeleid* (Den Haag: Ministerie van Verkeer en Waterstaat, 1985); Ministerie van Verkeer en Waterstaat, *Derde Nota Waterhuishouding: water voor nu en later* (Den Haag: SDU, 1989-1990).

29 W. van Leussen, *Leven met water, vermaatschappelijking van het waterbeheer- consequenties voor de civiel ingenieur en voor waterbeheerorganisaties* (Enschede: Universiteit Twente, 2002).

30 P. Glasbergen, "Waterschappen en integraal waterbeheer", in: J. C. N. Raadschelders en Th. A. J. Toonen, *Waterschappen in Nederland, een bestuurskundige verkenning van de institutionele ontwikkeling* (Hilversum: Verloren, 1993), 133–47; P. Huisman, *Water in the Netherlands* (Utrecht: Netherlands Hydrological Society, 2006), 81–83.

31 Ministerie van Verkeer en Waterstaat, *Vierde Nota Waterhuishouding. Regeringsbeslissing* (Den Haag: Ministerie van Verkeer en Waterstaat, 1998); Commissie Waterbeheer 21e eeuw. *Waterbeleid voor de 21e eeuw. Geef water de ruimte en aandacht die het verdient* (Den Haag: Commissie Waterbeheer 21e eeuw, 2000).

32 Ministerie vanVerkeer en Waterstaat, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Ministerie van Landbouw, Natuur en Voedselkwaliteit, *Nationaal Waterplan. 2009–2015*. ('s Gravenhage: Ministerie van Verkeer en Waterstaat, 2009).

33 Deltacommissie, *Rapport Deltacommissie. Eindverslag en Interimadvies*. Deel I–VI. ('s-Gravenhage: Staatsdrukkerij en Uitgeverijbedrijf, 1960).

34 Commissie Rivierdijken, *Rapport Commissie Rivierdijken* (Den Haag: s.n., 1977). (Rapport Commissie Becht).

35 Commissie Toetsing Uitgangspunten Rivierdijken, *Toetsing Uitgangspunten Rivierdijkversterkingen. Advies van de Commissie* (Den Haag: Ministerie van Verkeer en Waterstaat, 1993) (Rapport Commissie Boertien I).

36 Ministerie van Verkeer en Waterstaat, *Deltaplan Grote Rivieren* (Den Haag: Rijkswaterstaat, 1995).

37 P. P. J. Driessen, A. J. J. de Gier, *Uit Nood geboren. Een bestuurlijk-juridische evaluatie van de dijkversterkingen en kadenaanleg onder de Deltawet grote rivieren* ('s-Gravenhage: VUGA, 1997).

38 Commissie Watersnood Maas. *De Maas terug! Advies van de Commissie Watersnood Maas* (Maastircht: Rijkswaterstaat Directie Limburg, 1994) (Commissie Boertien II).

39 Rijkswaterstaat Directie Limburg, *De Maas slaat weer toe. Verslag hoogwater Maas januari/februari 1995* (Maastricht 1995); W. van Leussen, U. Boot, H. Verkerk. "Civil Engineering Aspects of the "Meuse Works": a Restoration Program of the River Meuse," J. Kongeter (ed.), *Verkehrswasserbau. Proceedings Internationale Wasserbau Symposium Aachen 2000* (Aachen: RWTH, 2000), 117–44.

40 W. van Leussen, "Maaswerken: van sectoraal plan naar adaptief proces," A. Driesprong, M. V. van Ginkel, H. G. Heegstra,W. H. M. A. Pluimakers (eds.), L*ex aquarum, Liber amicorum. Opstellen over waterstaat, waterstaatswetgeving en wetgeving, opgedragen aan mr. J. H. A. Teulings* (Den Haag: Ministerie van Verkeer en Waterstaat, 2000), 30–52.

41 I. Poortvliet, "Wetgeving inzake de waterkeringszorg," A. van Hall (ed.) *Waterbeheerswetgeving* (Lelystad: Koninklijke Vermande, 1997), 195–249.

42 Ministerie van Verkeer en Waterstaat (Den Haag 2009). The English version of this document can be found on http://www.helpdeskwater.nl/wet-_en_regelgeving/wetten/waterwet/engelstalige/dutch-water-act/?ActItmIdt=29167.

43 Ministerie van Verkeer en Waterstaat, *Hydraulische Randvoorwaarden 2001 voor het toetsen van primaire waterkeringen* (Den Haag: Ministerie van Verkeer en Waterstaat, 2001).

44 Ministerie van Verkeer en Waterstaat, *Hydraulische Randvoorwaarden 2006 voor het toetsen van primaire waterkeringen* (Den Haag: Ministerie van Verkeer en Waterstaat, 2007).

45 Ministerie van Verkeer en Waterstaat, *De spankracht van ons rivierenland* (Lelystad: RIZA, 2002); Rijkswaterstaat Directie Limburg, *Integrale verkenningen Maas – IVM* (Maastricht: Rijkswaterstaat, 2001).

46 G. P. van de Ven, *Man-made Lowlands: History of Water Management and Land Reclamation in the Netherlands* (Utrecht: Uitgeverij Matrijs, 2004), 410–11.

47 Jim Keulemans, "Dure en duurzame zeewering," *Magazine voor de Provincie Zuid Holland*, 5 nr 6 (maart/april 1989) and *Staten-Generaal Digitaal*, 1989-1990, kamerstuk 20317, ondernummers 13 en 14.

48 More details on the Maeslant Barrier can be found on www.keringhuis.nl, both in English and Dutch.

49 H. T. C. van Stokkom, A. J. M. Smits, "Flood defense in the Netherlands: a new era, a new approach," in: B. Wu et al. (eds.) *Flood Defence 2002* (New York: Science Press, 2002), 34–47.

50 M. A. Wiering and P. J. Driessen, "Beyond the Art of Diking: Interactive Policy on River Management in The Netherlands," *Water Policy*, no. 3 (2001): 283–96; S. V. Meijerink, "Rivierbeheer als leerproces. Een tussentijdse evaluatie van het procesontwerp voor de PKB Ruimte voor de Rivier," *Bestuurswetenschappen* 58, no. 5 (2004): 406–27.

51 Werkgroep Hoogwater Maas (WHM). *Actieplan Hoogwater Maas* (s.l, s.n., 1998) Frankrijk, Waals Gewest, Vlaams Gewest, Nederland. Francis Habye, Namur; Internationale Kommission zum Schutze des Rheins (IKSR), *Aktionsplan Hochwasser* (Koblenz: s.n., 1998).

52 Commissie Luteijn, *Gecontroleerd Overstromen. Advies van de Commissie Noodoverloopgebieden* (Den Haag: Projectsecretariaat Commissie Noodoverloopgebieden, 2002).

53 D. Roth, J. Warner, M. Winnubst, *Een Noodverband tegen Hoog Water. Waterkennis, beleid en politiek rond noodoverloopgebieden* (Wageningen: Wageningen UR, 2006).

54 Delta Commissie, *Samen werken met water: Een land dat leeft, bouwt aan zijn toekomst. Bevindingen van de Deltacommissie 2008* (Den Haag: s.n., 2008). English version on http://www.deltacommissie.com/en/advies.

55 Ministerie van Verkeer en Waterstaat , *Nationaal Water Plan 2009–2015* (Den Haag: Ministerie van Verkeer en Waterstaat, 2009). More information on the website www.nationaalwaterplan.nl.

56 M. van Koningsveld and J. P. M. Mulder (2004) "Sustainable Coastal Policy. Developments in The Netherlands. A Systematic Approach Revealed," *Journal of Coastal Research*, 20 (2) (2004): 375–85.

57 See endnote 55.

58 Rijkswaterstaat et al., *The Sand Motor. Pilot project for natural coastal protection*. Report. (Den Haag: Rijkswaterstaat, 2013). For more information see: www.rws.nl/zandmotor; www.ecoshape.nl; www.dezandmotor.nl.

59 M. Cioc, *The Rhine. An eco-biography, 1815–2000* (Seattle and London: University of Washington Press, 2002). Chapter 7 "A River Restored?": 173–201.

60 C. Dieperink, *Tussen zout en zalm. Lessen uit de ontwikkeling van het regime inzake de Rijnvervuiling* (Amsterdam: Thesis Publishers, 1997).

61 Cioc, *The Rhine*, 186.

62 ICPR, *Rhein-Atlas: Ökologie und Hochwasserschutz* (Koblenz: Internationale Kommission zum Schutze des Rheins gegen Verunreinigung, 1998).

63 R. D. Wilken, "The recovered Rhine and its history," T. P. Knepper (ed.), *The Rhine. The Handbook of Environmental Chemistry 5. Water Pollution* (Berlin/Heidelberg: Spring, 2006) 47–87.

64 N. Nugent, *The Government and Politics of the European Union* (Durham: Duke University Press, 2006).

65 More information can be found on the official website "*Gateway to the European Union*": http://europa.eu/index_en.htm.

66 A. Lenschow, "Environmental Policy. Contending Dynamics of Policy Change," H. Wallace, W. Wallace, M. A. Pollack (eds.), *Policy-Making in the European Union* (Oxford: Oxford University Press, 2005), 305–27.

67 European Commission, *Common Implementation Strategy (CIS) for the Water Framework Directive* (2000/60/EC). Strategic Document, as agreed by the Water Directors under Swedish presidency (Brussels: s.n., 2001).

68 G. Kallis, H. Briassoulis, "Integration of the EU water and development policies: vision or plausible expectation?" *Paper to the Berlin Conference on the Human Dimensions of Global Environmental Change. "Greening of Policies – Interlinkages and Policy Integration,"* Berlin, December 2004. http://web.fu-berlin.de/ffu/akumwelt/bc2004/download.htm.

69 W. van Leussen, "Toepassing in de praktijk van de Europese Kaderrichtlijn Water is: leren omgaan met nieuwe spelregels," Studiecentrum voor Bedrijf en Overheid, *Proceedings Nationale Conferentie Water Beheer*, chapter 5 (Leiden: Studiecentrum voor Bedrijf en Overheid, 2004).

70 Bosch and Van der Ham, *Twee eeuwen Rijkswater-staat*, 279–80.

71 Ibid.

72 More information at the website: http://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm.

9 THE U.S. MOVES TOWARDS MORE INTEGRATIVE APPROACHES TO WATER RESOURCES MANAGEMENT, 1970–2010

William F. Willingham

Major societal changes in the United States in the 1960s profoundly influenced the direction of water resources development for the rest of the century. In particular, the rise of environmentalism and the anti-war and civil rights movements directly challenged traditional deference to the existing top-down, bureaucratic, and scientific responses to economic growth and social problems. A sharpened environmental consciousness resulted in part from a shift in societal values from a desire for more material goods to a concern for "quality of life." The impact of books such as Rachel Carson's *Silent Spring* (1962) with revelations about the effects of pesticides on ecosystems were highly visible examples of this perspective. As awareness grew regarding the environmental costs of construction projects for water resources—multiple-purpose dams and major irrigation projects—resistance to development undertakings emerged across the country.[1]

After 1964, the prevailing social and political consensus of the 1950s was challenged by urban race riots in Detroit, Los Angeles, and other cities and growing antiwar protests against America's involvement in the Vietnam War, especially on college campuses. The 1968 assassinations of civil rights leader Martin Luther King and of Robert F. Kennedy, brother of the late president, along with the decision by President Lyndon Johnson not to seek reelection, added to the tumultuous political atmosphere. The ferment over feminist issues, gay rights, and the growing antiwar sentiment all heightened the sense of social flux and contributed to a widespread loss of faith in traditional political systems. During this time of dramatic social upheaval, Congress pushed through major environmental and civil rights legislation. These laws and related court cases affecting water resources development are discussed below.

Traditional water resources activities, such as multiple-purpose dam building, reached a peak in the U.S. in the 1960s, and the Corps and other federal water resources agencies faced new challenges. In particular, budget considerations and environmental concerns led the Corps to reconsider its narrowly focused engineering approach to water resources development. During this busiest decade for water project completion, the Corps built 149 dams, and the Soil Conservation Service constructed more than 2,000 small watershed dams. In fact, 50 percent of the Corps' water resources projects built from 1900 to 1989 were constructed between 1960 and 1980. Building on this scale raised questions of cost and need.[2]

Presidents Eisenhower in the 1950s, Carter in the 1970s, and Reagan in the 1980s attempted to limit federal investment in water resources development on the grounds that such projects often represented wasteful expenditures or, if justified, ought to be funded at least in part by the local interests that most benefitted from them. President Carter also questioned the environmental damage caused by many water projects. Efforts to restrain costs or weed out questionable projects through refinements of the cost-benefits analysis that all federal projects underwent gained emphasis through the executive branch push for cost-sharing requirements mandated in the 1980s. As a result of mounting budgetary and environmental concerns, coupled with disarray among the ranks of water resources project supporters, Congress failed to pass any major water resources project authorization measures between 1976 and 1986. When Congress finally enacted the Water Resources Development Act of 1986 (WRDA-86), the law imposed major policy changes for funding the 377 projects in the measure. Implementation of cost-sharing also required a fundamental shift in the way the Corps managed its water resources projects. These changes in project planning, funding, and management are discussed below, as well as a variety of environmental concerns and the impact of these environmental concerns on the Corps' traditional navigation and flood-control missions.

PROJECT PLANNING AND ENVIRONMENTAL ISSUES

As public concern for the environment grew during the 1960s, the Corps and other federal water resources agencies responded by giving greater attention to environmental values in the planning, construction, and operation of their projects. The initial stirrings of change came in the early 1960s when Congress passed new interagency standards for water project planning. The new approach required consideration of a broader mix of views prior to the formulation of federal water project alternatives. By the end of the decade, Congress had adopted sweeping environmental legislation, such as the Wilderness Act of 1964 and the National Environmental Policy Act (NEPA) of 1970, which forever changed water resources planning.[3]

In the early 1960s, both Congress and the Kennedy administration formulated new water resources planning legislation. At the president's request for a review of the standards for formulating and evaluating water resources projects, Congress debated Senate Document 97 (1962), which set new interagency standards for water project planning. The new requirements mandated that the views of all parties—federal, state, and local entities—be considered in the formulation of water projects. The measure favored multiple-purpose undertakings and required full consideration of broad-based, river basin plans. The new approach directed that recreation and water quality be treated with equal weight as project benefits, along with the traditional purposes of navigation, hydropower, flood control, irrigation, water supply, and fish and wildlife enhancement. In 1965, Congress passed the Water Resources Planning Act, which authorized a Water Resources Council made up of federal agency representatives charged with establishing river basin commissions to coordinate water resources development. The commissions, established by the president and composed of both state and federal members, were to prepare and keep up-to-date a comprehensive and coordinated joint plan for federal, state, interstate, local, and nongovernmental development of water and related resources.

Although the 1965 Water Resources Planning Act encouraged state participation in river basin planning, final authority remained with Congress and the executive branch. In practice, representatives of the federal water agencies dominated the river basin commissions, and the commissions had no independent regulatory or enforcement power. The federal agencies had congressionally mandated missions and possessed the technical expertise in the field of water resources development. The Supreme Court in *Arizona v. California* (1963) confirmed that the federal government had ultimate authority over water resources planning. In that case, the court held that Congress had the final authority to distribute water from a federally constructed reservoir without consulting state laws. Even though the federal government retained final say in water resources planning involving federal funds, budgetary limitations led some in Congress to encourage cost-sharing with states and local entities. The states, localities, and user interests, however, were less enthusiastic about it.

Besides pushing river basin planning, the Water Resources Council reviewed the procedures guiding water resources planning. Influenced by the mandates of National Environmental Policy Act and congressional intent expressed in the Flood Control Act of 1970, the council recommended that project planning seek to enhance four major interests: national economic development (NED), quality of the environment, social well-being, and regional development, with all four interests treated equally. The council published a revised set of planning objectives in the *Federal Register* in September 1973. These objectives, called the "Principles and Standards for Planning Water and Related Land Resources" ("Principles and Standards") placed environmental concerns on an equal footing with NED as the two objectives for water resources planning. Planners, however, also had to assess the effects of project alternatives on regional development and social well-being.

In the late 1970s, the Carter administration attempted further refinement of the planning process. The new "Principles and Standards"—while retaining

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President John F. Kennedy at the dedication of the multipurpose Greers Ferry Dam on the Little Red River in Arkansas, October 1963 the co-equal objectives of enhanced NED and environmental quality—emphasized that plan formulation was a dynamic process, required that at least one alternative consider a nonstructural approach, and expected planners to integrate water conservation as an element of project planning. In 1983, the Reagan administration replaced Carter-era regulations with the "Principles and Guidelines." The new approach changed the focus to a single NED objective rather than two co-equal objectives. To be sure, an acceptable NED plan had to be consistent with all environmental laws and regulations, but the new guidance gave economic development greater standing than environmental quality. Environmental groups protested the downgrading of the environmental quality objectives. The Corps' struggle throughout the 1980s to refine its water resources planning process was further complicated by the new project cost-sharing requirements imposed by the enactment of the WRDA-86, passed under pressure from the Reagan administration. The first omnibus water act in a decade, it required non-federal interests to contribute a share of project costs and pay 50 percent of feasibility study costs. WRDA-86 also emphasized the need to quantify and assess the regional and local economic value of water resources projects. Subsequent WRDAs have continued the evolution of the Corps' water resources planning process.

While the executive branch and the Corps, in particular, struggled to update water resources planning, budget-minded members of Congress continued to push cost-sharing and to raise environmental concerns. In 1968, Congress created a National Water Commission. Five years later, it recommended that "insofar as is practicable and administratively feasible, the identifiable beneficiaries of project services should bear appropriate shares of development and operating

White House

President Ronald Reagan signing the Water Resources Development Act of 1986 costs through systems of pricing or user charges." The commission believed that such a policy would "provide incentives for the selection of efficient projects that will lead to progress toward water resources policies that are in harmony with other national programs and policies." In 1968, the Water Resources Council had initiated its own study of cost-sharing and began a broad review of water resources project evaluation guidelines. The "Principles and Standards" came out of this and became the basic framework for water resources planning for the next ten years. Although the number of Corps projects would decline beginning in the 1970s, efforts at cost-sharing and more stringent methods of project evaluation were not the cause. Rather, this reduction came in response to budgetary constraints and environmental opposition. The adoption of NEPA had imposed major new requirements on the Corps and other federal water resources agencies. This groundbreaking legislation directed federal agencies to prepare an environmental impact statement (EIS) for every project, existing or future. This document evaluated all environmental aspects of a proposed federal action, assessed potential adverse effects, considered the alternatives to the proposed undertaking, and sought input from affected agencies, organizations, and concerned individuals.[4]

The Corps recognized that it faced "an apparent dilemma," as a November 1970 report from its Institute for Water Resources (IWR) noted, "We are still called upon to meet increasing demands for resources to support a higher standard of living for more Americans. And now we are also being called upon to conserve those same resources in order to preserve the quality of the natural environment in which our people live." The report went on to confidently assert that "these apparently conflicting demands need not be mutually exclusive . . . . We can continue to serve the American people effectively and economically and at the same time meet the requirements of a quality environment."[5]

At the headquarters level, the Corps prepared to meet the new environmental challenges. In April 1970, Chief of Engineers Lt. Gen. Frederick J. Clarke formed an Environmental Advisory Board composed of six scientific experts to provide policy and practical advice on environmental problems and issues related to Corps projects and programs. The new board was unique among federal agency environmental boards in that it restricted membership to professional environmentalists. The creation of the Environmental Advisory Board was only the initial step in the Corps' efforts to institutionalize environmental views.[6]

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In response to growing environmental concern, the Corps hired more specialists in environmental fields, such as botany.

As part of its internal response to NEPA, the Corps hired more professionals with skills in various technical and social science fields related to the environment. Between 1966 and 1970, the Corps recruited 26 landscape architects, so that by 1970, it had 101 such specialists. In addition, the Corps brought in more biologists, foresters, agronomists, and others trained in various environmental sciences, bringing the total for all such specialists to 287 by the beginning of the 1970s.[7]

In June 1970, General Clarke announced that as the Corps carried out its civil works mission it would "seek to balance the environment and development needs of our Nation." He further pledged that in seeking best solutions to engineering issues, "environmental values will be given full consideration along with economic, social and technical factors." Clarke also promised the public an expanded role in establishing the Corps' objectives and plans for projects: "we will encourage as broad public and private participation as practical in defining environmental objectives and in eliciting viewpoints of what the public wants and expects as well as what it is projected to need." Additionally, he committed to "provide governmental and nongovernmental agencies and the public with timely information on opportunities, consequences, benefits and costs . . . before making recommendations based on a balanced evaluation of the social, economic, monetary and environmental consideration involved." These goals set a high level of expectations for the Corps' integration of environmental values into its water resources projects.[8]

A year later, General Clarke reiterated the Corps' commitment to accommodate, to the fullest extent possible, the environmental values related to its projects. He instructed all elements of the Corps that they were to "preserve unique and important ecological, aesthetic, and cultural values of our national heritage; conserve and use wisely the natural resources of our Nation for the benefit of present and future generations; enhance, maintain, and restore the natural and manmade environment in terms of its productivity, variety, spaciousness, beauty, and other measures of quality; create new opportunities for the American people to use and enjoy their environment."[9]

As the Corps strove to meet its new environmental responsibilities, General Clarke expressed confidence in the agency's ability to handle the challenge. He noted, "It is clear that the strength of the Corps has always resided in its ability to adapt to change." The agency had, however, its skeptics and detractors. To journalist Elizabeth Drew in the early 1970s, for example, the Corps seemed impervious to change: "As times change so do the nation's needs and priorities. But the Army Corps of Engineers just keeps rolling along as it has for decades, working one of the most powerful lobbies in Washington, winning more than $1 billion a year from [C]ongress to straighten rivers, build dams, and dig canals that frequently serve only narrow interests and too often inflict the wrong kinds of change on the environment." Other observers noted that the Corps had begun to show signs of changing its approach to planning water resources projects and had become more receptive to the idea of active public participation in its planning and evaluation process, especially with regard to environmental issues.[10]

Traditionally, the Corps had provided for some level of public input on its proposed projects. Such involvement typically came through public hearings held during the preauthorization stage. In the new era of NEPA, critics saw this process as inadequate for determining community sentiment. Although the old-style public hearing might meet the letter of the procedural requirements of EIS preparation and other new environmental regulations and guidelines, it clearly missed the spirit of informed and continuing public involvement in project development. In fact, Seattle District Engineer Col. Howard Sargent, Jr. observed in the early 1970s:

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Frederick J. Clarke (1915–2002), who became Chief of Engineers in 1969

The traditional way engineers go about planning a public works project leaves little room for the citizen to be heard. Engineers would first define the "problem," then "objectives" or "goals." Finally, they would develop "the Plan" to attain those goals. Of course, eventually the public gets a look at "the Plan" in public meetings or hearings. Presentation is oral. And a thick study document is available for inspection should some persistent citizen have the energy to labor through it. Often times, engineers do not show the public alternative plans; and if they do, written copies are not available for public scrutiny. Questioned about alternatives, the planner is likely to answer: "We looked at other ways to solve the problem, but there was little support for any of them."[11]

In recognition of the situation described by Colonel Sargent, the Corps took the first steps to creating a meaningful program of public participation. At that time, the Corps' policy began requiring three public meetings throughout the early phase of project planning. The Corps took the next step in February 1971 when it ordered division and district planning and public affairs chiefs to attend a training course in "Public Participation in Water Resource Planning." In June 1971, IWR offered the divisions and districts technical assistance on new approaches to public participation. The Seattle District led the way by adopting a program of hearings, workshops, and information dissemination concerning district studies and projects. Other districts also introduced such practices in the early 1970s.[12]

The Corps' ongoing struggle to internalize environmental ethics and respond to NEPA had a significant impact on the organization. By 1974, the Corps of Engineers had filed 950 EISs nationwide, and from necessity, the effort occurred in stages. From January 1970 to April 1971, the Corps evaluated its work and decided that almost its entire civil works program had significant effects on the environment and that most projects required an EIS. In May 1971, the Corps began updating its regulations and guidelines to reflect the need to complete an EIS for all existing as well as new projects within three years, but by 1972 the Corps realized that it would take more than three years to clear its backlog of project impact statements. As the Corps worked to identify and eliminate the adverse environmental effects of its projects, by 1973, fully one-third of the five hundred projects under or near construction were modified to address environmental considerations. In 1975, a study of environmental compliance issues rated the Corps as the best among federal agencies in its procedural compliance with NEPA.[13]

NEPA-based litigation by environmental groups in the early 1970s helped to hasten changes in the Corps' environmental policies and procedures. In October 1973, the Corps was facing thirty environmental lawsuits. The Corps responded by improving the technical quality of its EISs between 1973 and 1976 so that they could withstand the scrutiny of federal courts. The Corps' scientific specialists reduced the scientific jargon in the EISs, incorporated more environmentally focused alternatives, and created a more inclusive decision-making process. After the mid-1970s, with the Corps' efforts to improve its EISs, the number of environmental lawsuits against the agency declined. It helped that, as environmental groups worked more closely with the Corps, they could observe the agency's commitment to protecting the environment and complying with new environmental laws and regulations.[14]

In the 1980s and 1990s, the Corps continued to step up its environmental commitment. The legal impetus for the Corps' institutionalization of an ethic committed to environmentally friendly water resources projects was reflected in several congressionally enacted Water Resources Development Acts. These measures reflected a growing recognition by Congress and the Corps of the nation's environmental concerns and a sincere determination to consider those concerns in every phase of water resources project development. Section 1135 of WRDA-86 authorized the Corps to review its completed water resources projects to determine whether they should be modified to improve environmental quality. As the Corps' traditional engineering projects had altered existing watershed conditions and features to promote economic development, some of the damaging results of past projects were mitigated by restoring areas to prior watershed condition through the Continuing Authorities Program (CAP). Furthermore, WRDA-1990 directed the Corps to include environmental protection as one of its primary missions. Subsequently, in 1992 and 1996, Congress further refined and expanded the Corps' environmental reach by authorizing it to protect, restore, and create aquatic and ecologically related habitat, including wetlands. [15]

Sacramento District, U.S. Army Corps of Engineers

A public hearing on two reservoir projects in the Sacramento District, 1968

In June 1990, Assistant Secretary of the Army for Civil Works Robert Page issued a statement that provided programmatic structure to the Corps' various environmental activities, including undertakings under Section 1135. Page emphasized that environmental initiatives should be pursued within existing expertise and authorities and that the Corps should attempt to reverse environmental degradation caused by its existing projects. Accordingly, changing social values required the Corps to review the operations of its projects (more than five hundred by the early 1990s) to decide if new environmental considerations should alter the operating systems. The Corps' environmental focus embraced the full range of its mission, from single-purpose projects such as flood control, dams, and navigation works, and the handling of dredged materials to multiple-purpose structures.[16]

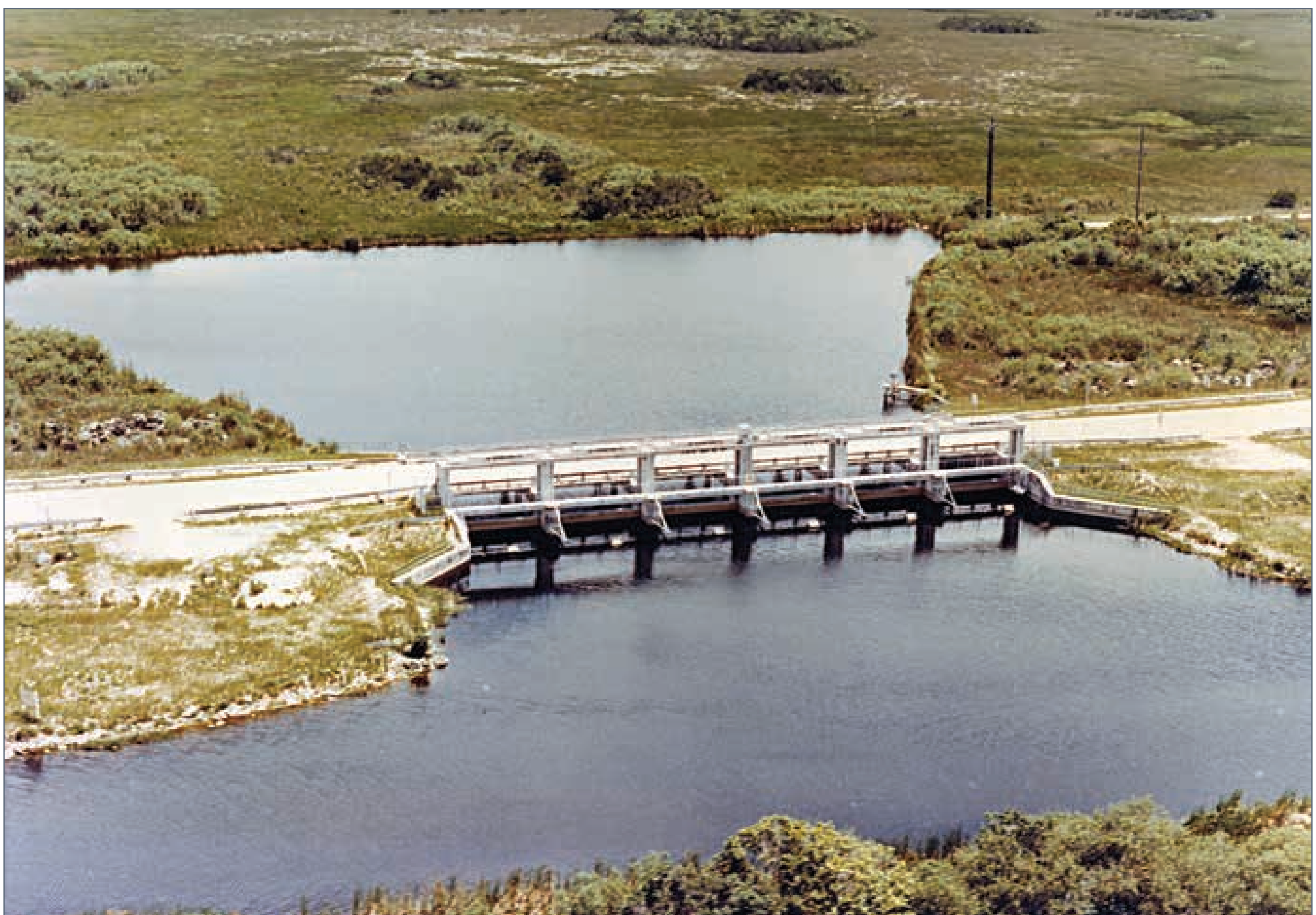
In February 1990, Chief of Engineers Lt. Gen. Henry (Hank) Hatch, also weighed in with his commitment to the new environmental focus growing out of the opportunity provided by Section 1135. In a memorandum to the entire Corps of Engineers, "Strategic Direction for Environmental Engineering," General Hatch went further than the assistant secretary, challenging the Corps to make the new concerns for the environment a central part of its business. According to Lieutenant General Hatch, the environmental aspects of projects were to have equal standing with engineering and economic considerations. Moreover, he did not limit the environmental focus to existing Corps projects but indicated that new authority would be sought wherever necessary. He saw the Corps' commitment to the environment as a continuation of the agency's two hundred years of responding to changing national needs. As a follow-on to Lieutenant General Hatch's memorandum, in March 1991, the Corps' director of civil works issued policy guidance that gave environmental restoration outputs equal budget priority with the more traditional economic outputs of navigation and flood control.[17]

The biggest hurdle encountered in the 1980s in evaluating environmental projects involved the economic analysis to justify such projects. The "Principles and Guidelines" (P&G) protocol attempted to measure the ability of alternative plans to advance NED through changes in the economic value of the national output of goods and services, expressed in monetary units. Environmental values were to be taken into account, but were difficult to quantify in monetary terms. Some observers felt the P&G gave greater weight to project alternatives that favored national economic development over those focused on environmental values. In practice, though, the P&G approach to alternatives and plan selection was permissive enough to allow the selection of some environmental restoration plans. The authorization of Section 1135 projects was in keeping with P&G language stating that "other plans which reduce net NED benefits in order to further address other Federal . . . concerns not fully addressed by the NED plan should also be formulated." Although slow to get underway, the Corps initiated the first Section 1135 environmental restoration projects during fiscal year 1991, and by 1995, seven project modifications had been completed and an additional fifteen were approved for implementation.[18]

Over time, the Corps' water resources planning grew ever more complex. What criteria to apply in achieving the NED plan, how much weight to give each assessment account, and how to interpret each new higher directive were questions that bedeviled project planning at the district level through the last quarter of the twentieth century. By 1999, the P&G seemed once again ripe for revision, as critics of the Corps' planning process pointed to what they considered wasteful and/or environmentally damaging water resources projects.[19]

A prime example of the Corps' efforts to remediate the environmental effects of its older flood control projects involved its attempt to repair the water resources system in South Florida in the 1990s and 2000s. Following World War II, the Corps carried out a flood control project that cleared the way for vast urban and agricultural development in southern Florida. The Corps' Central and Southern Florida Flood Control Project (C&SF Project), authorized in 1948, managed the flow of water through a variety of structures to curb floods and supply water for urban and agricultural development, often to the detriment of the region's ecosystem. Southern Florida is shaped like a shallow bowl that drains water from the headwaters of the Kissimmee River southward to the Florida Bay at the state's southern tip. Much of the area, known as the Everglades, is dominated by expansive sawgrass sloughs, wet prairies, cypress and mangrove swamps, and coastal lagoons and bays. It was once home to a vast diversity of flora and fauna; but gradually development shrank the Everglades in half and much of its diversity of life was lost. The C&SF Project's drainage and flood control structures—mainly canals, levees, and pumping stations—contributed to a slow destruction of the fragile ecosystem. By the 1970s and 1980s, much of the environmental damage was readily apparent.[20]

In the late 1990s, the Corps restudied the C&SF Project to see how it might mitigate the environmental



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Water distribution gates, built in 1962 on the Tamiami Canal, which control the flow of surface water south into the Shark Slough area in the Everglades, 1976 damage. A feasibility study, called for in the WRDA of 1996, resulted in the Comprehensive Everglades Restoration Plan (CERP), which sought to correct the hydrologic regime, restore and enhance the natural systems, and transform the built environment. All elements were to be based on principles of sustainability. In the process of securing the support of various stakeholders, the Corps acknowledged the ecosystem damage caused by the C&SF Project and proposed a restoration package that promised remediable actions such as removal of canals and levees, development of new water storage above and below ground, and water release regimens that mimicked natural processes. After much public debate, input from other federal and state agencies, and further study, the Corps issued a revised plan in April 1999. In implementing the plan, the Corps promised to use adaptive assessment and management techniques so as to correct for unforeseen problems that might occur over time. Finally, after further debate and compromise, Congress passed the CERP provisions in the WRDA of 2000.

Water management in South Florida was a highly contentious undertaking. In addition to a need for flood control, explosive urban and rural growth created greater demands on the existing water supply. Initially, development interests relied on the Corps to provide engineering solutions to problems of water management. Over time, however, the Corps adopted more environmentally friendly methods of water management to ameliorate damage done by previous structural measures. By the late twentieth century, the divisive story of water and its management, as evidenced in South Florida, appeared repeatedly across the nation. The Corps, as a major player in the narrative of water management in Florida, had shown a capacity to evolve and give equal weight to environmental quality and engineering proficiency. A future challenge would be the application of those lessons to different problems and with diverse state and local partners.

Jacksonville District, U.S. Army Corps of Engineers

Prairie Canal after being plugged by the South Florida Water Management District as part of the Everglades restoration project, 2010

REGULATORY PROGRAM

The Corps has regulated certain activities in the nation's waters since the late nineteenth century. The Rivers and Harbors Acts of 1890 and 1899 established a program administered by the secretary of the army, and implemented through the chief of engineers, to protect navigation and control most construction activity in or over the navigable waters of the United States. Navigable waters are defined in law and regulation as "those waters subject to the ebb and flow of the tide shoreward to the mean high water mark and/or were used or have been used in the past or may be susceptible to use in interstate or foreign commerce." Section 10 of the Rivers and Harbors Act of 1899 prohibited the construction, excavation, or deposition of materials in, over, or under navigable waters without a permit from the Corps. Structures such as piers, wharfs, breakwaters, bulkheads, jetties, and weirs, as well as dredging or disposal of dredged material, excavation, filling, and other changes to navigable waters required Section 10 permits. Section 13 of the Act assigned the Corps regulatory responsibility over the discharge of refuse into navigable waters of the United States—without a permit from the Corps, discharges of refuse were prohibited. (Although this Section 13 permit authority is still in effect, it was later superseded by Sections 402 and 405 of the Clean Water Act.) Until the 1960s, the Corps based its permitting and regulatory decisions solely on a proposed activity's effects on navigation.[21]

In the 1960s, as broader environmental concerns began to sweep the nation, the Corps expanded the public interest factors used for evaluating permit requests. It began to include consideration of fish and wildlife, recreation, and water quality concerns in addition to the effects on navigability. The federal courts upheld the Corps' broadened interpretation of its permitting responsibilities beyond just navigability concerns (see *U.S. v. Republic Steel* (1960), *U.S. v. Standard Oil* (1960), and *Zabel v. Tabb*, 1970), and interpreted Section 13 to forbid dumping of all foreign matter into the nation's waters, holding that any discharge constituted a deposit of refuse within the meaning of the law. The broadened reading of Section 13 culminated in December 1970 in President Richard Nixon's Executive Order 11574, mandating the Corps implement a formal permit program under Section 13 to protect the nation's waters from pollution.

Next, passage of the Federal Water Pollution Control Act (FWPCA) of 1972 further expanded the Corps' regulatory program. Most importantly, Section 404 of the 1972 act prohibited the discharge of any dredged or fill material into *all* waters (not just navigable ones) of the U.S. without a permit from the Corps. This later came to include the addition or redeposit of materials from dredging operations, as well as from mechanized land-clearing, ditching, channelization, and other ground-disturbing activities. Subsequent court decisions (see *NRDC v. Callaway*, 1975) defined "waters of the U.S." in the broadest possible sense, including virtually all wetlands and isolated waters where the use, degradation, or destruction of such waters could affect interstate or foreign commerce.[22]

The subsequent Clean Water Act (CWA) of 1977 amended the FWPCA to strengthen and clarify the federal commitment to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Congress continued the Environmental Protection Agency's (EPA) policy-making and oversight role in the program, while assigning the Corps the primary administrative responsibility for carrying out the program. Wetlands protection under Section 404 of the Act became a prime focus of the Corps' regulatory responsibilities. By the 1970s, wetlands protection had been recognized as essential to the health of the nation's natural environment. Wetlands serve many ecological purposes, such as water quality and supply, sediment trapping, chemical detoxification, flood and drought modulation, storm protection, and fish and wildlife habitat. Found in many different forms—including bottomland hardwoods, wooded swamps, marshes, wet meadows, bogs, and playa lakes—wetlands had, by the mid-twentieth century, been widely filled and drained for agricultural and commercial purposes. By 2000, the nation's wetlands had been reduced from 221 million acres to 105 million, with nearly 80 percent of the loss resulting from agricultural activities. California's reduction of wetlands was especially severe, amounting to a 91 percent loss of such habitat. Popular support for wetlands protection grew as people recognized the economic and environmental consequences of the continued destruction.

Although not a comprehensive wetlands protection program, the CWA provided a primary authority for federal efforts to stem the loss of valuable wetlands. The 1977 amendments to the CWA, in an effort to streamline the permit application process, exempted certain activities from Section 404 regulations, including normal agriculture, forestry, and ranching activities. The amended act also exempted work related to maintaining dikes, dams, breakwaters, causeways, and bridge abutments; construction and maintenance of farm and stock ponds, irrigation and drainage ditches; construction of farm and forest roads; and congressionally approved projects with completed environmental impact statements. Many of the activities, however, would require a permit if their purpose involved converting an area of water to a new use, and thereby restricting or reducing the flow of that water. Prior converted croplands were not considered waters of the U.S., but the discharges associated with excavation activities did fall under the definition of dredged material discharges.

In addition to the Corps of Engineers, several federal resource agencies played roles in implementing the Section 404 program. The most influential of these was the EPA, which had responsibility for defining the reach of the "waters of the United States" and for interpreting the extent of exemptions [Section 404(f)] under the Section 404 program. The EPA also had veto authority [Section 404(c)] over all Corps-approved permits. Other federal resources agencies had agreements [Section 404(q)] with the Corps that established a process for requesting a review of district engineer permit decisions by higher authority within the Department of the Army. The assistant secretary of the army for civil works could, however, refuse the request for an evaluation of a district engineer's decision. Finally, Section 401 of the CWA required state or EPA water-quality-certification prior to issuance of a Section 404 permit.

The secretary of the army delegated permit authority under Section 404 to the chief of engineers and his authorized representatives. In practice, because of the decentralized nature of the Corps, district engineers made decisions on permit applications. The processing of individual permits followed a three-step process: an optional pre-application consultation to discuss alternatives and impacts, a formal project review following the receipt of an application, and a final determination by the district engineer. Decisions on permits were based on balancing input from a variety of sources including state or federal resources agencies, the concerned public, and affected American Indian tribes. The Corps called this process the public interest review and conducted it simultaneously with the required Section 404(b)(1) guidelines evaluation and an environmental review as required by NEPA. The guidelines, jointly established by the EPA and the Corps of Engineers, detailed the aquatic ecosystem standards used to evaluate all Section 404 permit applications. The purpose of the permit process was to reduce the potential impact of private sector and state and federal projects on the aquatic environment.

The Corps considered many factors in its public interest reviews. These included conservation, economics, aesthetics, wetlands, cultural values, navigation, fish and wildlife values, water supply, water quality, and in general, the needs and welfare of the public. The Corps usually granted a permit unless the district engineer determined that it would be contrary to the public interest. In all cases, the district engineer took into account any practical alternatives to proposed activities and the possible beneficial effects of proposed measures to lessen the adverse environmental effects of proposed projects. In addition to the Section 404(b)(1) guidelines, the Corps considered three general criteria in evaluating permit applications: the extent of public and private need for the proposed activity; the practicality of using reasonable alternative locations and methods to carry out the proposed work; and the extent and permanence of the effects from the proposed project on public and private uses to which the area is suited.

Throughout the permitting process, Corps regulators worked closely with developers to modify, when necessary, proposed projects in order to minimize impacts and protect the aquatic environment or other aspects of the public interest. Nationwide, the Corps received about 15,000 applications a year for individual permits; during the 1990s, the Corps denied, on average, about 600 of those activities annually, or less than 1 percent of all proposed actions. Prior to approval, many projects required compensatory mitigation to replace the loss of wetland, stream, or other aquatic resources. Corps regulators determined the appropriate form and amount of mitigation required, and these included aquatic resource restoration, establishment, enhancement, and, in some instances, preservation. A memorandum of agreement between the Corps and EPA prescribed the type and level of mitigation necessary to demonstrate compliance with the Section 404(b)(1) guidelines and established a sequence of steps for evaluating proposed projects requiring permits. District regulators worked closely with applicants to follow the required mitigation sequencing. This enabled applicants to reduce the project's environmental impacts so a permit could be issued; or if it became clear that a project would not meet the guidelines, the applicant could withdraw their permit application rather than go through the process and have the permit denied over unresolved environmental concerns.

Under the CWA, the district and division engineers had the authority to issue other types of permits. For example, the Corps used letters of permission when a district engineer concluded that a proposed activity would not have significant individual or cumulative

Wisconsin Department of Natural Resources

St. Paul District's rehabilitation and enhancement project at the Pool 8 Islands that restored 643 acres of aquatic habitat impacts on the aquatic environment. In addition, the Corps issued general permits to cover activities substantially similar in nature and causing only minimal individual or cumulative impacts. General permits could be designed to apply to activities within a limited geographical area, a particular region, or nationwide. Geographical or regional permits were handled by the Corps districts whose boundaries encompassed such permits, while nationwide general permits were issued by the chief of engineers through the *Federal Register* rulemaking procedure. All permits, whether individual or general, included public notice and the opportunity for comment.

The Corps and EPA had joint responsibility for monitoring and enforcing Section 404 permit requirements. The Corps, however, had sole responsibility for ensuring compliance with permit conditions. Although criminal or civil action could be taken when violations were discovered, the Corps generally preferred administrative remedies to correct adverse impacts. These remedial actions usually entailed some form of restoration or mitigation work by the violator. The Corps sought penalties and fines only in cases of flagrant or repeat violations. During the 1990s, Corps districts processed about five thousand violations nationwide. Eighty percent of the reported violations involved unpermitted discharges; the others involved noncompliance with permit conditions.[23]

Nationwide during the 1990s, the Corps' regulatory program annually processed about 80,000 permits of all types, involving both Section 10 and Section 404 approval. The Corps attempted to process permit applications in a timely manner, with a goal of having 85 to 95 percent of all permit actions completed in less than sixty days. During fiscal year 1994, for example, the average time for all forms of Section 404 permit authorization stood at 25 days. The average time for processing individual permits in that year, however, averaged 115 days. Over time the Corps' regulatory program steadily grew, so that by 1998 it had a budget of $106 million and approximately 1,100 employees.[24]

Most Section 404 permits required some form of compensatory mitigation to replace those aquatic ecosystem functions lost or impaired by an authorized activity. Mitigation typically included the restoration, enhancement, creation, or preservation of wetlands and other aquatic resources. Regulators generally preferred on-site or adjacent, as opposed to off-site compensation to minimize losses to the affected aquatic environment. In 1997 alone, the Corps required nationwide, 53,400 acres of wetland restoration/creation through its permit program. Under certain conditions, mitigation banking served as an acceptable form of compensatory mitigation. This approach provided consolidated off-site compensation for numerous authorized activities in advance of adverse project impacts. Restored or created wetlands could be "banked" as "credits," which could be used later to compensate for wetland losses or "debits" from a permitted discharge. Typically, a third party accepted the responsibility of designing, implementing, and ensuring the success of compensatory mitigation for the permittee. Mitigation bank sponsors include industrial firms, individual entrepreneurs, public and quasi-public agencies, and federal agencies.

Mitigation banking helped address two particularly troublesome issues. First, it dealt with scattered small losses by allowing their consolidation and compensation within a specially designated and managed area. Second, it provided compensation of losses before the fact—that is, before the wetland losses occurred.[25]

In the early 1990s, the Institute for Water Resources extensively studied and evaluated wetlands mitigation banking to determine its potential for achieving national wetland goals and applicability to Corps programs. The study found that, while existing mitigation banks had an inconsistent record with some significant failures, when properly planned and executed they could be an effective tool for mitigating the loss of wetlands. The study also concluded that if the Corps assumed a more direct role in establishing banks (for example, as a condition for a regulatory permit) and certifying credits, then it needed to provide strong oversight in their operation. Based on this analysis of the mitigation banking concept, the Corps, in 1995, sought to develop general guidance on establishing and operating such banks. In part, the Corps' regulatory guidance to districts stated that "mitigation banking is an important part of the Regulatory Program because it represents an efficient and effective way to offset authorized aquatic resource impacts." The principles set forth in the Corps' mitigation guidance served as a basis for other improvements in the compensatory mitigation arena. By 1997, public and private entities had created more than 100 wetland mitigation banks nationwide.[26]

FLOOD CONTROL AND COASTAL PROTECTION

Until the early twentieth century, flood control on the nation's rivers was considered a local concern and responsibility. Major floods on the Mississippi River in 1912, 1913, and again in 1927 led Congress to extend federal assistance to flood control efforts on that river. Finally, in 1936, after a series of devastating floods in the eastern half of the United States demonstrated the inability of state and local governments to cope with major flooding, Congress established flood control as a federal concern and assigned the Corps of Engineers a key role in fighting floods. Initially, the Corps employed a two-pronged approach in carrying out its flood-control mission. First, it tried to prevent floods by building upstream storage reservoirs to contain excessive runoff and thereby reduce downstream flood stages. However, topography and hydrology limited suitable reservoir sites, and even if sites met the necessary engineering criteria, economic, political, or environmental considerations often prevented their use. The Corps' periodic efforts to revise its multiple-purpose development of the Columbia River and tributaries to provide better flood control exemplified the problems posed in pursuing preventive approaches to flood control. If prevention through upstream storage proved impossible, such as on the Mississippi River and its tributaries, then the Corps had to rely on traditional protective works such as levees, floodwalls, and channelization to minimize high flood stages. Whatever its approach, the Corps projects had to be economically justified: the average annual benefits had to exceed the average annual flood damages before the Corps could proceed with an undertaking.[27]

Flood control efforts on the Mississippi River after 1970 revealed the difficulties the Corps faced in reconciling its traditional flood reduction methods with the new environmental ethos. Much of the Mississippi flood control work focused on the Atchafalaya River basin. During the 1950s and 1960s, the Corps built the Old River Control structure to keep the Atchafalaya River from capturing the Mississippi River. A large flood in 1973 nearly undermined the control structure, causing the Corps to construct an auxiliary structure (completed in 1986) below the original flood control works to improve the operation of the system. These two flood control structures, in turn, worked in combination with a system of levees and channel deepening to reduce the heavy load of sediment carried by the Mississippi and its tributaries. By necessity, the Corps had to build the levees on swampy land, which caused them to subside over time, while silt coming down the river channel raised the ground elevation in the floodways. This situation required ever higher levees, which would again subside, perpetuating a dangerous cycle. The Corps attempted to enlarge the channel to reduce sedimentation and increase the river's flow capacity by dredging. The flood control project also called for closing distribution channels, extending levees, and stabilizing river banks.[28]

Office of History, Headquarters, U.S. Army Corps of Engineers

The auxiliary Old River control structure to prevent the Mississippi from overtaking the Atchafalaya, 1986

The Corps' attempt to replumb the Atchafalaya River basin had a major impact on its ecosystem. Wetlands and their flora and fauna were especially vulnerable. Disposing dredged material without harming wetlands proved especially difficult. In addition, recreation, commercial fishing interests, and hunters all expressed concern about the changes brought by the Atchafalaya River project. Reconciling the multiple objectives of the environmental interests with those primarily concerned with flood control required the Corps to reduce its dependence on structural solutions, especially levees. One solution involved extensive purchase by the federal and state governments of flow easements and fee simple holdings to control water flow and distribution to benefit fish and wildlife resources. By the mid-1990s, much of the Corps' modified flood control plan and related environmental provisions were accomplished. The Atchafalaya's hydrologic regime, however, was constantly changing, requiring ongoing monitoring and data collection to inform adjustments to the plan.

The Corps employed several methods to reduce flood damage. Besides attempting to modify floods through a structural approach, these efforts included emergency flood fighting, modifying the susceptibility to flooding through changing land use, and reducing the financial effects of flooding through insurance and relief-and-recovery activities. For much of the twentieth century the Corps' flood-control mission focused on structural methods. Between 1936 and 1990, Congress invested approximately $25 billion in the Corps' flood-control projects throughout the nation. By the last decade of the twentieth century, the Corps provided a water-control regulation plan for 703 water projects—581 owned by the Corps and 122 controlled by others. In addition, the Corps built about 110 smaller flood-control dams and reservoirs, which were transferred to agencies or local government for operations and maintenance.

While Congress adjusted the requirements of the Corps' flood-control mission over time, three important provisions established in the 1936 Act and subsequent flood-control legislation remained unchanged: the requirements that local interests provide lands, rights-of-way, and easements; hold and save the federal government free from damage that might result from project construction; and maintain and operate the non-reservoir

Office of History, Headquarters, U.S. Army Corps of Engineers

Residents placing sandbags on Chouteau Island in Illinois against the Mississippi River flood waters, March 1973 works after construction. These requirements ensured that beneficiaries shared the cost of flood control projects.

Congress gave the Corps some flexibility for urgently needed, small flood-control projects. In place of the requirement that each civil works project be individually authorized and funded, Congress delegated to the secretary of the army and the Corps of Engineers the authority and responsibility for selecting and funding emergency flood-control projects under a special Continuing Authority Program (CAP). Post-World War II amendments to the Flood Control Act of 1936 provided the specific legislative authorization and funding limits for such work and stipulated requirements for local cooperation. For example, Section 205 of the Flood Control Act of 1948 permitted the Corps to plan and construct small flood-control projects that did not exceed $1 million (subsequently raised to $5 million) per undertaking. Local interests had to provide financial participation in accordance with prevailing federal law. In addition, Section 208 of the Flood Control Act of 1954 allowed the Corps to carry out emergency snagging and clearing projects up to a cost of $100,000 (subsequently raised to $500,000) for flood control. Under terms of Section 14 of the Flood Control Act of 1946, the Corps could engage in emergency stream bank and shoreline protection for existing public works if the cost was under $50,000 (subsequently raised to $500,000). Again, federal-local cooperation requirements applied.

An important measure that expanded the flood damage reduction options available to the Corps came in Public Law 84-99 (Pl-99) passed by Congress in 1955. This legislation authorized the Corps to engage in a broad

U.S. Army

Emergency loop levees holding flood waters of the Arkansas River after a breach in the original levee (upper left), April 1945 range of emergency flood response measures. These included advance preparations when the potential for unusual flooding was imminent, as well as flood fighting, rescue operations, and the repair and restoration of existing flood control works damaged by a flood. The law set no monetary limits and established an emergency fund and the authority to temporarily use other appropriations if necessary. The measure also emphasized that the Corps' advanced flood-damage reduction measures were supplemental to local efforts, temporary in nature, and designed to meet an imminent flood threat. The local cooperation requirements for accomplishing advance measures and rehabilitating flood control works were the same as those established in the Flood Control Act of 1936.

Congress did establish rigid reporting controls to prevent abuse of the CAP program. In general, the regulations required each project be discrete and not merge with or overlap some other project; that each project be investigated, justified—economically and technically—and reported by a Corps of Engineers district; and that each project be reviewed and approved by higher authority in the agency. Congress, of course, retained oversight through annual program reviews.

Prior to the late 1950s, the Corps relied primarily on structural approaches for flood control (dams, reservoirs, levees, floodwalls, diversion channels), and nonstructural flood-control measures, such as zoning and prohibiting or restricting building in flood-prone areas, played little part in the Corps' program. In the thirty-four years before the Corps received its flood-control mission in 1936, losses amounted to some $4.1 billion, but the continued human encroachment on floodplains for housing, commercial applications, and industrial uses resulted in mounting losses. In the period between 1936 and 1958 damages came to $6.6 billion. By the late 1950s, recognizing the continuing flood losses, the Corps began serious consideration of nonstructural approaches to flood-damage abatement.

However, many congressional and administration officials had both practical and philosophical reasons for opposing land-use regulation as a means of achieving flood protection. They did not want to seem opposed to development even in flood-prone areas, and they understood that land-use laws were a local government prerogative. Ultimately, the issue of regulation became a question of cost. Chief of Engineers Lt. Gen. Samuel Sturgis framed the issue in these terms:

> *The difficulties of prescribing and enforcing evacuation and rezoning must be weighed against the long-range requirements for development of an area and the effect thereof in aggravating natural flood conditions, increasing hazards to life and property, and future protection costs. Progress cannot be stopped, but it can be guided wisely.*[29]

The Corps' willingness to consider nonstructural means to flood-damage abatement resulted from new studies in the field of flood prevention. Francis Murphy, an experienced and widely respected hydrologist in the Seattle District, played a key role in researching and disseminating the results of new approaches to effective flood-damage control. He and others within the Corps pointed out the value of developing hydrographic data and flood maps so that localities could adopt effective land-use planning to regulate floodplain development. With passage of the Flood Control Act of 1960, Congress responded to increased concerns about adopting more effective flood-control measures and authorized the Corps to provide flood-hazard data and technical assistance to federal agencies, state and local governments, and individuals. The measures carried out by the Corps under this legislation included providing assistance in establishing floodplain regulations, flood warning and preparedness, flood-proofing, and floodplain evacuation and relocation. Corps studies established floodplain boundaries, flood-hazard potentials, standard project floods and flood-frequency curves, and floodplain maps.

In 1968, Congress provided an incentive to regulate floodplain development by offering subsidized flood insurance if a community's zoning, land-use regulations, and building codes conformed to standards designed to minimize flood losses. The Corps became involved in flood-damage mitigation when local authorities requested a study to determine the best approach to limiting potential flooding. The basic level of information provided by the Corps defined floodplain boundaries and the reoccurrence interval for a flood, usually expressed as a flood that has a 1 percent chance of being equaled or exceeded during any given year (100-year flood). The Corps could also recommend a flood-warning and preparedness system, with or without structural measures, as a component of a flood-control program. In addition, the Corps performed flood insurance studies for the Federal Emergency Management Agency (FEMA), which had been established in 1978.

In 1993, a massive Mississippi River flood challenged the Corps' flood control methods, as the upper river system experienced its worst flood since 1927. The Mississippi remained above flood stage for 152 days and the Missouri River for 116. More than 1,000 levees failed, nearly 100,000 homes were damaged, and 47 people died. Flood waters closed navigation on the Mississippi for 52 days and inundated 20 million acres of farmland during the growing season. In all, the rampaging waters caused approximately $16 billion in damages.[30] Much of the damage stemmed from the failure of non-federal agricultural levees not designed to offer protection from a flood event of the magnitude experienced in 1993. In fact, federal flood control structures—reservoirs and levees—prevented an estimated $19 billion in damages. Still, the extensive losses led to reassessing the best methods for future flood-damage reduction.

After floodwaters on the upper Mississippi and Missouri Rivers receded, President Bill Clinton ordered a review of existing floodplain management and related watershed management programs. An interagency research team led by Brig. Gen. Gerald Galloway, a retired Corps officer, studied the problem and, in its influential report, called for a comprehensive approach to "flood damage reduction," as opposed to strict flood control, that would deploy a variety of available tools including structural (levees and dams) and nonstructural (wetland management and floodplain restrictions). This new paradigm recognized the limitations of what could be protected and emphasized the importance of shared responsibility for floodplain management.

Congress initiated a parallel study through the Corps' North Central Division that reached similar conclusions. In particular, the study evaluated the potential impacts of changes in flood insurance programs, state and local floodplain regulations, flood hazard mitigation and disaster assistance, wetland restoration and agricultural support policies, in addition to traditional structural approaches such as reservoirs and levees. The Corps' study managers used sophisticated computer modeling for the impact analysis of structural and nonstructural alternatives to flood reduction. A key finding of the study was that better floodplain management and assignment of responsibility for preventing flood damages could be achieved through a greater application of nonstructural policies, such as local floodplain zoning ordinances, flood insurance, and public education. In addition, greater emphasis on flood hazard mitigation—including acquisition, floodproofing, and raising of flood-prone structures—would be beneficial. The NCD study, like the Galloway Report, also acknowledged the ecological values of rivers and their floodplains in reducing flood damages. The study cautioned that from a hydraulic evaluation perspective, no single alternative provided consistent beneficial flood damage reduction results throughout a system.

Savannah District, U.S. Army Corps of Engineers, Jonas Jordan

A resident of Osage City, Missouri, canoes through Mississippi River flood waters, July 1993

Many of the ideas presented in the two reports had been around for decades, but the 1993 flood provided an opportunity to pull them together with the latest environmental thinking. The NCD study, as one reviewer noted, "validates the view that while structural flood control measures are an important part of an overall floodplain management program, they have limitations and floodplains are best managed through a combination of structural and nonstructural measures that fully recognize the inherent risk of occupying flood hazard areas."[31]

Population growth and development along the nation's coastline exposed people and property to flooding caused by beach erosion. The Corps became actively involved in investigating coastal zone erosion problems in 1930, when Congress authorized the Beach Erosion Board, but initially the Board's purview was limited to the ocean shoreline where a federal interest was involved. Over time, the scope of the Board's investigations broadened to include the public interest potentially affected by coastal protection projects. In 1956, the Corps was authorized to provide cost-shared support for beach nourishment projects. The Corps' responsibilities in coastal engineering increased substantially in 1963, when Congress authorized the Coastal Engineering Research Center (CERC) to conduct research on shore processes, winds, waves, tides, surges, and currents as they affected navigation, flood reduction projects, and as beach erosion control. This research directly supported the coastal zone work of twenty-two Corps districts bordering coastlines.[32]

Continued coastal development and a growing environmental awareness supported an expanded program of coastal zone research by CERC. This research effort got a further boost from the Marine Resources and Engineering Development Act of 1966, which mandated a long-range policy of accelerated federal research of the coastal zone. CERC focused its early research on wave action and sediment transport. Data on these natural and very complex forces were essential to project design, yet complicated to gather. Such field data acquisition became a major CERC undertaking and, combined with laboratory studies, yielded much useful information about wave action and the movement of sediment. In particular, CERC developed the ability to quantify and predict sediment losses after beach nourishment; and to facilitate the use of this information, it initiated a sand inventory program for off-shore exploitable sources of sand. The CERC research also identified economical methods of transporting and depositing sand in the near-shore zone. Research on structural methods of stopping shore erosion, such as groins, jetties, and breakwaters, also received attention at CERC.

As a result of a National Shoreline Study (1970-73), CERC determined that a quarter of the nation's 84,000 miles of coastline was significantly eroded. Based on this study, Congress authorized the Corps to conduct numerous demonstration projects to test useful erosion-control devices. In the 1980s, CERC also extended its research to the erosion issues involved in protecting the coastal barrier islands and studied the environmental impacts of various erosion- control methods. In the late 1970s and early 1980s, the Corps and the Rijkswaterstaat cooperated on research on wave propagation in shallow water, leading to theoretical findings useful in the design of coastal engineering structures. For budgetary and organizational efficiency, in 1983, the Corps merged CERC with the Waterways Experiment Station, another major research arm of the Corps. Research and project

Office of History, Headquarters, U.S. Army Corps of Engineers

Land erosion caused by wave action from a February 1980 storm at Oceanside, California modeling related to coastal zone issues have continued at the Waterways Experiment Station.

The Corps' project to save the badly eroding coast at Oceanside, California, exemplified the challenges of such work. By the 1980s, California presented an especially acute situation where 86 percent of the state's coastline was receding at an average of between 0.5 and 2 feet per year. During World War II, the Navy built a military harbor adjacent to Oceanside, and, using the same entrance channel, the city built a civilian small-craft marina that became economically important to the community. Over time, the entrance channel experienced chronic shoaling, while causing severe beach erosion south of the harbor. The problems stemmed from the harsh wave environment at that location.[33]

For several decades, the Corps attempted to ameliorate the situation at Oceanside through expensive maintenance dredging in the entrance channel and periodic sand replacements on the beach. Unfortunately, the traditional efforts proved futile, as millions of cubic yards of sand from dredging the harbor and hauled from inland locations and placed on the beach simply washed out to sea or back into the harbor. In the 1980s, the Corps determined that structural solutions could be environmentally damaging and, drawing upon its growing coastal engineering expertise, attempted to find a more cost-effective and environmentally sound solution to the navigation and beach erosion problems at Oceanside. Using modeling work at the Waterways Experiment Station and other research, the Corps developed a state-of-the-art sand bypass system that reduced the costs of maintenance dredging and improved the chronic beach erosion problems through constant sand nourishment. The sand bypass system also proved the most environmentally acceptable approach to the navigation and erosion challenges.

Between 1928 and 2000, the Corps' flood-control projects prevented almost $700 billion in damages and much human suffering. However after 1970, traditional structural approaches to the problems became increasingly less acceptable. Many of the best construction sites for large reservoirs had been used, and proposed sites raised environmental issues. In addition, continuing development in many river basins precluded the construction of large projects. Cost constraints and the advent of cost-sharing also made it difficult to finance large reservoirs. As a result, the Corps began shifting to nonstructural approaches to provide flood protection and reduce flood damages. The nonstructural methods included moving communities out of the floodplain, raising and flood-proofing buildings, acquiring vulnerable structures, preserving wetlands, buying out flood plains, and establishing flood warning systems. These measures could be accomplished separately or in combination with structural measures such as levees, floodwalls, and channel improvements. By the end of the century, the Corps spoke less about flood control and more about flood-damage reduction or flood-risk management, recognizing that for those living in a floodplain, the risk is never totally eliminated. In addition, just as the Corps became more receptive to nonstructural flood control approaches, it also favored beach nourishment over physical works to restore eroded coastal areas.

DAM SAFETY

Public concern over several major dam failures during the early 1970s led Congress to establish a dam safety program in August 1972 (PL 92-367). In one particularly disastrous incident in June of that year, Canyon Lake Dam above Rapid City, South Dakota, failed during a flood that killed 238 people. The new dam safety legislation required the Bureau of Reclamation and the Corps of Engineers to complete an inventory of all dams in the U.S., recommend a comprehensive dam safety program, and carry out inspections of selected dams that posed threats to human life or property. The law applied only to dams higher than twenty-five feet that impounded in excess of fifty acre-feet of water. In 1976, the Corps delivered to Congress an inventory of 49,500 federal and nonfederal dams. The report also surveyed current practices in regulating dam safety and recommended a new national dam safety program. The Corps found that eleven states had no laws regarding dam safety, and most other states had weak safety laws and/or ineffective enforcement. In fact, only 18 percent of the inventoried dams had been inspected under existing federal or state authorities. The report estimated that 40 percent of the dams represented a hazard to downstream life and property if they failed.[34]

The continued failure of dams—such as the Teton Dam in Idaho, a Bureau of Reclamation project—in the mid-1970s spurred President Jimmy Carter to order a four-year Corps program to inspect nonfederal dams with a high potential for loss of life and property if they failed. By 1981, the Corps was tasked with updating the 1976 inventory, inspecting and evaluating about 9,000 high-hazard nonfederal dams, and assisting states in implementing effective dam safety programs. By October 1981, the Corps had inspected 8,818 dams and rated 2,925 of them (33 percent) as unsafe and in need of modification or repair. The updated inventory identified more than 68,000 dams, an increase of 37 percent over the original list.

The Corps' inventory and evaluations revealed that nonfederal dams were more likely than their federal counterparts to have design or maintenance deficiencies. Congress, however, considered any potential problem to be the responsibility of the dam owner and did not authorize the use of federal funds for repairs or modifications. Most of the safety concerns were related to spillway design deficiencies that could force floodwaters to overtop a dam and lead to structural damage or complete dam failure. Although dam owners and the states in which the dams were located retained the obligation for structural safety, the Corps did provide technical assistance to the states in dam safety matters. The inventory also noted that the 703 projects for which the Corps provided a water control regulation plan had excellent structural integrity.

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Seattle District personnel inspecting the municipal Casad Dam near Bremerton, Washington, April 1978

In recognition of its aging dams and the need to ensure their continued integrity, the Corps initiated two programs focused on major rehabilitation and structural safety assurance. The first was a rehabilitation program begun in the 1950s to carry out structural repairs or replacement to extend the useful lives of impoundment projects. To complement this work, in 1965 the Corps began to carry out regular, periodic inspections and evaluations of completed projects. Technical reports from the periodic inspections contained recommendations and cost estimates for remedial work. The second program, begun in 1977, focused on dam safety assurance. It established a mechanism for reviewing and modifying completed projects determined to have safety hazards. As long as improvements did not alter the scope, function, or authorized purpose of a project, existing authorities were sufficient to carry out the needed safety work.

In 1984, the Corps initiated a dam safety risk analysis program, led by the Institute for Water Resources, which developed a new set of procedures and guidelines for risk-based analyses of potential dam failure modes, and in particular for spillway failures and overtopping. This program was precipitated by the release of new probable maximum precipitation figures by the National Weather Service in its 1982 Hydrometeorological Report. This report, in turn, caused the Corps to begin revisions of its Probable Maximum Flood computations, which serve as the basis for dam spillway design. Given that such extreme precipitation and floods are difficult to evaluate empirically, the Corps inaugurated a risk-based design process that has evolved to encompass all facets of water infrastructure design.

NAVIGATION

The Corps' mission to create and maintain navigable channels on the nation's waterways required dredging, but in the 1970s, environmentalists began to challenge the Corps' dredging operations. At this time, domestic waterborne commerce moved 16 percent of the nation's intercity ton-miles of cargo, with petroleum and coal accounting for over 50 percent of the total waterway freight. The inland waterway system, moreover, played a crucial role in transporting raw materials and manufactured goods to the nation's seaports, supporting trade with foreign countries. By 1974, waterway commerce totaled 1.7 billion tons per year.[35] As a result, navigable waterways made an important contribution to a healthy national economy.

Through the mid-1970s, the Corps had developed 25,000 miles of navigation channels, and 15,000 of those were nine feet or greater in depth. It annually maintained those channels by dredging 350 million cubic yards at a cost of $200 million. For 150 years, the Corps had dredged navigation channels with little attention from the public. Suddenly, as Maj. Gen. J. W. (Jack) Morris, Corps Director of Civil Works, noted in 1975, "dredging became a dirty word and the Corps was placed in the position of being able to take the material from the bottom of our waterway channels—but without any place to put it." The Corps found itself on the horns of a dilemma; dredging was essential to shipping, but if there was no place to put the dredged material, the Corps could not dredge. Environmentalists raised concerns that dredged material might be polluted and that its placement in wetlands destroyed them, whereas dumping in back channels blocked fish and wildlife passage, and deep-water disposal created "ocean wastelands."[36]

The new environmental laws had a significant effect on the Corps' dredging operations with NEPA requiring an EIS for more than 1,200 navigation maintenance projects. Section 404 of the Clean Water Act and Section 103 of the Marine Protection, Research and Sanctuaries Act, 1972 (known as the Ocean Dumping Act), required dredge material discharge permits and designated the Army Corps of Engineers as the federal permit-issuing agency. The permitting responsibility, as set out in the various laws, also gave EPA a role in the review and approval of permits, especially in a contested action. The key factor involved the requirement to provide notice and opportunity for public input. While the Corps did not issue permits to itself, it did by regulation apply the same criteria and procedures imposed on other permit applicants. Although not required by NEPA, the Corps chose to prepare an EIS for projects initiated or built before NEPA went into effect.[37]

Besides preparing EISs for maintenance dredging operations, the Corps began searching for new disposal concepts and techniques to convert dredged material into a useful resource. Beneficial uses included creating new wetlands or recreation areas, beach nourishment, and habitat for wildlife. In 1974, the Corps' Waterways Experiment Station began a $32.8 million research program to develop new testing procedures for identifying the degree of pollution in dredged sediments and to find new or improved, broadly applicable dredging disposal methods. The research effort focused on determining the environmental effects of two disposal methods—open water and land. The study compared physical, biological, and chemical conditions before, during, and after disposal at four separate test sites and represented the largest single research investigation undertaken by the Corps up to that time. As General Morris succinctly put it, "Out of all this [the dredged material research program] we should learn where dredged material is harmful and where it is not. We should learn what additional costs are justified in the interest of environmental protection. And, equally as important, we must learn enough to answer the kinds of questions that will make impact statements not only technically viable, but sufficiently authoritative to satisfy the public."[38]

In general, the Dredged Material Research Program (DMRP) found that no single disposal method by itself was inherently good or bad from a technical standpoint. Each dredging project had to be evaluated on a case-by-case or site-specific basis. For example, researchers could not categorically assert that on the basis of pollution alone, ocean disposal should be ended or that all contaminated dredged material should be placed behind confined dikes. Much depended on the type of contaminants present in the dredged material. Unfortunately, case-by-case evaluations proved to be expensive and time-consuming. Moreover, policy, political, and legal considerations also came into play when deciding how to deal with the disposal of dredged material. Still, environmental considerations were the chief factor in choosing disposal alternatives.[39]

The DMRP made a number of important discoveries. Specifically, the study found that in open water disposal, physical effects were more important than chemical or biological consequences. To deal with this matter, the DMRP developed mathematical models to predict the dispersion effects of dredged material in ocean, estuarine, lacustrine, and riverine environments. Another significant finding demonstrated that deep-ocean disposal could be more environmentally acceptable than disposal in continental shelf areas. The DMRP also determined that concerns about the short-term release of contaminants to disposal site waters were unfounded. Most contaminants were not released from the sediment particles to the water. Those that were released quickly became diluted to harmless concentrations. The study also showed turbidity to be less of a problem than originally thought; most adult organisms tolerated turbidity levels in excess of those caused by dredging and disposal activities. In another finding, the DMRP established that in open-water disposal, bioassay tests were needed to determine the effects of chemical-contaminant ingestion on aquatic organisms. In the course of the study at four open-water disposal sites, the DMRP looked at controlling or mitigating the harmful effects of open-water disposal. One important finding

The Pointe Mouillee Wildlife Refuge, made primarily from dredged material, in western Lake Erie in southern Michigan

pointed to efficient operation of properly maintained equipment as the key to limiting negative effects of open disposal, especially for controlling turbidity.

The DMRP studied confined or diked containment of dredged material, as well as open-water disposal. To be environmentally effective, confined disposal facilities needed to retain a high percentage of the finer soil particles that carried contaminants. In practice, confined-disposal facilities were technically difficult and expensive to build, had a limited lifespan, and permanently altered the landscape. Through cooperating federal and state agency tests, the DMRP developed methods to alleviate some of these problems. One test demonstrated that the surface-trenching method of dewatering increased the holding capacity of disposal sites and reduced leaching of polluted effluent. The program also investigated ways that dredged material could be used to create or improve wildlife habitat, particularly in wetlands. Tests showed that marsh creation could be phased to accommodate maintenance dredging over long periods of time in almost any region of the country. Only locations subject to high tides or strong currents were unsuitable for marsh development.

The DMRP study also demonstrated that the most viable disposal could be achieved at upland habitat sites. These, moreover, could be managed to greatly benefit wildlife. An especially promising type of upland disposal involved creating small islands with dredged material in inland waterways, coastal bays, and estuaries. Wildlife, in particular, benefitted from such a disposal method.

The study also demonstrated that dredged material could be used as a soil amendment in reclaiming strip mines and for filling abandoned pits, quarries, and sanitary landfills. In sum, the DMRP showed that it was possible in many instances to convert dredged material from a troublesome problem into a beneficial resource. It also pointed to better methods and techniques for disposing of dredged material with a minimum of negative environmental impacts.[40]

The need to dredge navigable waterways to ensure proper channel depths for shipping on inland waterways, the Great Lakes, and coastal harbors only increased during the last third of the twentieth century. In 1998, for example, 3.4 billion tons of domestic and foreign commodities moved on the nation's waterways. Although the Corps' research helped to develop new disposal concepts and techniques, other issues confronted it—the Corps' aging dredge fleet and the drive by private contractors to take over all dredging operations. The private dredging industry pressured Congress to allow it to assume more of the nation's dredging. In 1978, Congress enacted a law requiring the Corps to reduce its dredging plant and maintain only a minimum fleet for emergency and national defense work and dredge only to the extent necessary to keep the minimum fleet operational. Otherwise, the Corps should put the dredging work out to competitive bidding and allow private dredging companies to complete the work as long as they could demonstrate economical and timely performance. The Corps did not have to contract work if the bid was more than 25 percent higher than the estimated cost of performing the work with a Corps dredge.[41]

As a result, the dredging industry modernized existing equipment and built new dredges to gradually assume a greater share of the dredging requirement. In 1978, dredging companies and the Corps together removed 374 million cubic yards of material at a cost of $35 million, with private industry accounting for 63 percent of the total ($22 million). By 2012, the Corps and private companies handled 237 million cubic yards of material at a cost of $1.2 billion, with private industry responsible for 80 percent of the workload. As private industry took over more of the dredging workload, the Corps' once-large fleet of hopper and pipeline dredges dwindled from 36 in 1978 to 11 by 2000.[42]

ENDANGERED SPECIES

One of the most troublesome and complex environmental issues facing the Corps of Engineers and other federal water resources agencies after 1970 involved the anadromous fish controversy in the Pacific Northwest. It materially affected how the Corps operated the Columbia River and tributaries system of multiple-purpose dams, especially after certain salmon species began to acquire endangered-species status in the early 1990s. The life course of these anadromous fish had a dramatic impact on the economy of the region. Each year, salmon and steelhead in the millions returned from the sea to make the long upstream journey to distant spawning grounds. American Indians depended upon the annual runs for their subsistence and cultural renewal. Since the late nineteenth century, Euro-American settlers in the Northwest had come to value the salmon for their commercial and recreational use.[43]

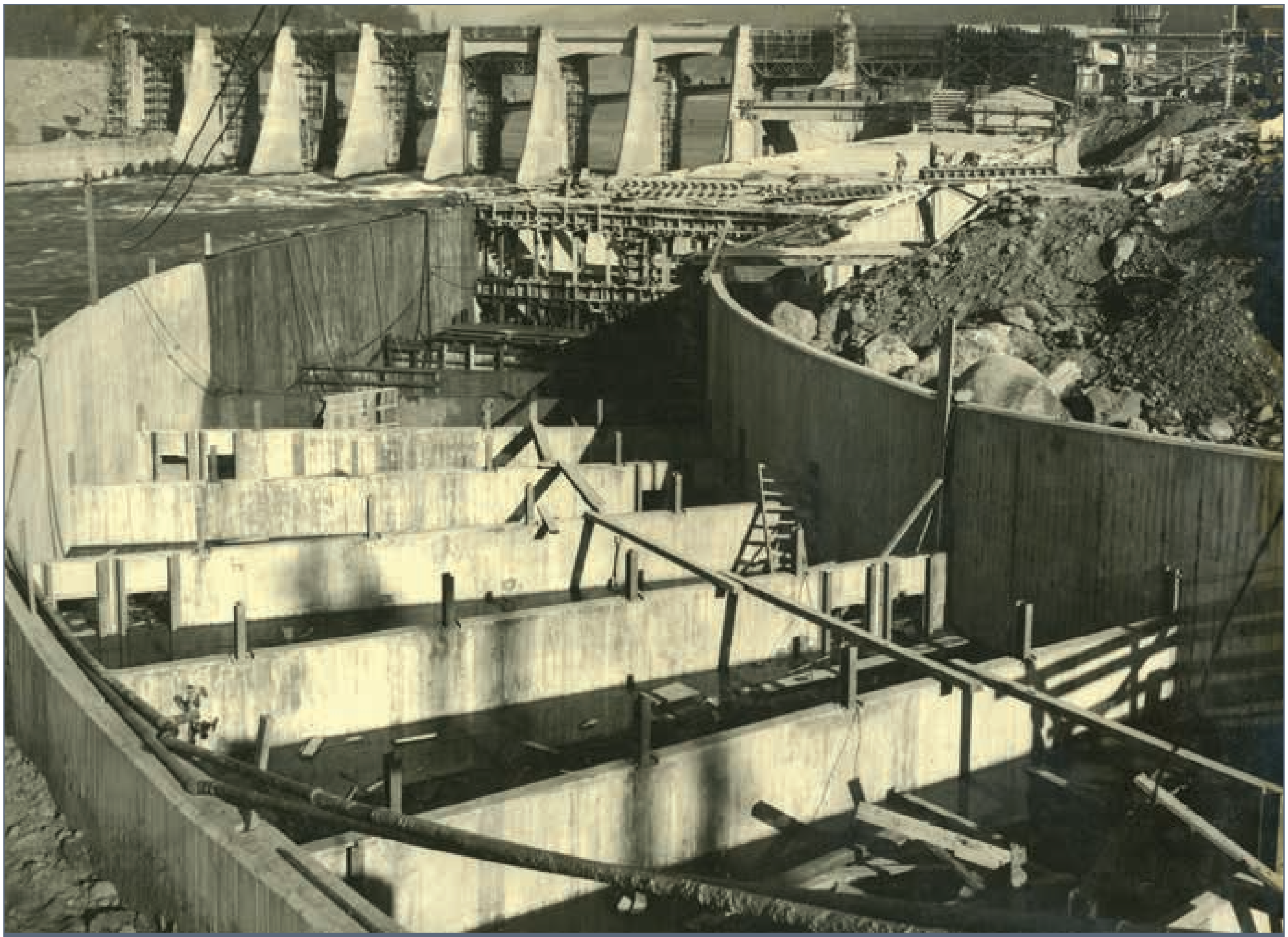
Unfortunately, the annual salmon runs had been in serious decline for more than a century. By the 1940s, the Columbia River salmon catch was only half that of 1883. Several factors accounted for this reduction. Overharvesting by commercial fisherman was a leading cause of the decline. In addition, stream pollution from environmentally unsound logging practices and losses from unscreened irrigation intakes took their toll on the fish runs. Most attempts to regulate fishing practices, to limit harvests, and to improve agricultural and timber operations proved futile. Dams, too, had a detrimental effect on the fish runs, even if they had fish-passage facilities. Efforts to increase the supply of anadromous fish through artificial propagation in fish hatcheries also failed to alleviate the situation.

By the 1930s, when the Corps began building dams on the Columbia River and its tributaries, the salmon runs were clearly in crisis. Pressure from commercial and sport fishers, as well as conservationists, caused the Corps to devise and construct an elaborate fish passage system at Bonneville Dam, the Corps' first dam on the Columbia River. The initial success of the Bonneville Dam fish facilities gave observers hope that high dams would not be a permanent barrier to the fish runs. At the same time, Grand Coulee Dam, built by the Bureau of Reclamation, was too high to permit any feasible method of passing salmon. Instead, the Department of the Interior transplanted the upriver runs to tributaries of the Columbia below Grand Coulee. When the Corps built Chief Joseph Dam, it saw no need to provide fish passage because the dam's location was above those tributaries and below Grand Coulee Dam.

The Corps and supporters of its plan for additional high dams on the Columbia and its tributaries used the apparent success at Bonneville to justify further development. Fisheries interests, however, remained skeptical that series of high dams and healthy fish runs could coexist and opposed the construction of McNary Dam, for instance, on the grounds that it made more sense to fully develop all potential sites on the tributaries of the upper Columbia before building dams detrimental to downriver fisheries. During the 1940s and 1950s, the Corps continued building dams on the Columbia River, outwardly confident that fish ladders would benefit upstream runs of anadromous fish, while downstream-migrating fingerlings could safely pass through the rotating turbines. For all of its seeming confidence in the future health of salmon runs, the Corps also hedged its bets by funding extensive research into migratory fish issues. By the end of the 1950s, it was funding ever larger amounts of scientific research on anadromous fish, both through its own biologists and in cooperation with the U.S. Fish and Wildlife Service. The Corps also relied on hatcheries to provide adequate mitigation for fish losses and continued to improve fish passage facilities at its dams. By 1958, the Corps was funding twelve hatcheries and had spent $21 million on research. Unfortunately, evidence continued to mount that the loss of fish going through the spillways and turbines exceeded what the Corps had previously admitted.

A significant change in the Corps' responsibility for fish and wildlife concerns at its projects occurred as the Corps began to recognize the full scope of anadromous fish losses. In 1958, Congress amended the Fish and Wildlife Coordination Act, first passed in 1934 and amended in 1946, to require that fish and wildlife conservation receive "equal consideration" with all other project purposes. Thereafter, the Corps had to evaluate a project's adverse and beneficial effects on fish and wildlife in all stages of planning and recommend changes or mitigation for all adverse project effects.

The Corps' fisheries research in the 1960s and 1970s focused especially on downstream juvenile losses, which averaged approximately 11 percent at each dam on the Columbia and Snake Rivers. Mortality stemmed from two major causes: passage through the turbines and gas bubble disease when fish passed over the spillway. In the latter situation, water plunging over a dam's spillway caused nitrogen to be pressurized in the stilling basin and dissolved in the river. Fish absorbed the supersaturated dissolved gas and died. The Corps developed solutions to both problems. Over time, they screened the turbines and built bypass systems around the dams to divert the downstream migrants away from the turbines. To address the gas bubble disease issue, they attached spillway deflectors to limit the plunge depth of water over the dam spillway, thereby reducing the supersaturation of atmospheric gas. Research also pointed to other problems for migrating



Office of History, Headquarters, U.S. Army Corps of Engineers

The Bradford Island fish ladder under construction on the south end of Bonneville Dam, 1936

salmon caused by the reservoirs behind the dams. These causes included predation, downstream migration delays, and power peaking operations at the dams.

Much of the Corps' fisheries research concentrated on developing safer and more efficient bypass systems; improved fish ladders; and collection and downstream transportation of the fingerlings in barges. The Corps carried out much of this work in cooperation with the National Marine Fisheries Service (NMFS), federal and state fisheries agencies, and American Indian tribal fish experts. Between 1953 and 1993, the North Pacific Division of the Corps of Engineers spent $63.4 million on its fish passage development and evaluation program and approximately $696 million on its fish facilities at Corps projects on the Columbia and Snake Rivers. Despite the Corps' research efforts and facilities improvements at its dams, much remained unknown on how to optimize in-river conditions for migrating salmon and increase the prospects for their survival. As one historian noted in 1994, "for all of the improvements in fish passage facilities, transportation systems, and hatchery supplementation, annual runs of Chinook and sockeye salmon have not significantly increased."[44]

Because of the precarious state of salmon runs on the Columbia River, conservation groups, in early 1991, filed a petition under the Endangered Species Act (ESA) to list five salmon populations as endangered. Enacted in 1973, the ESA established regulations to prevent the

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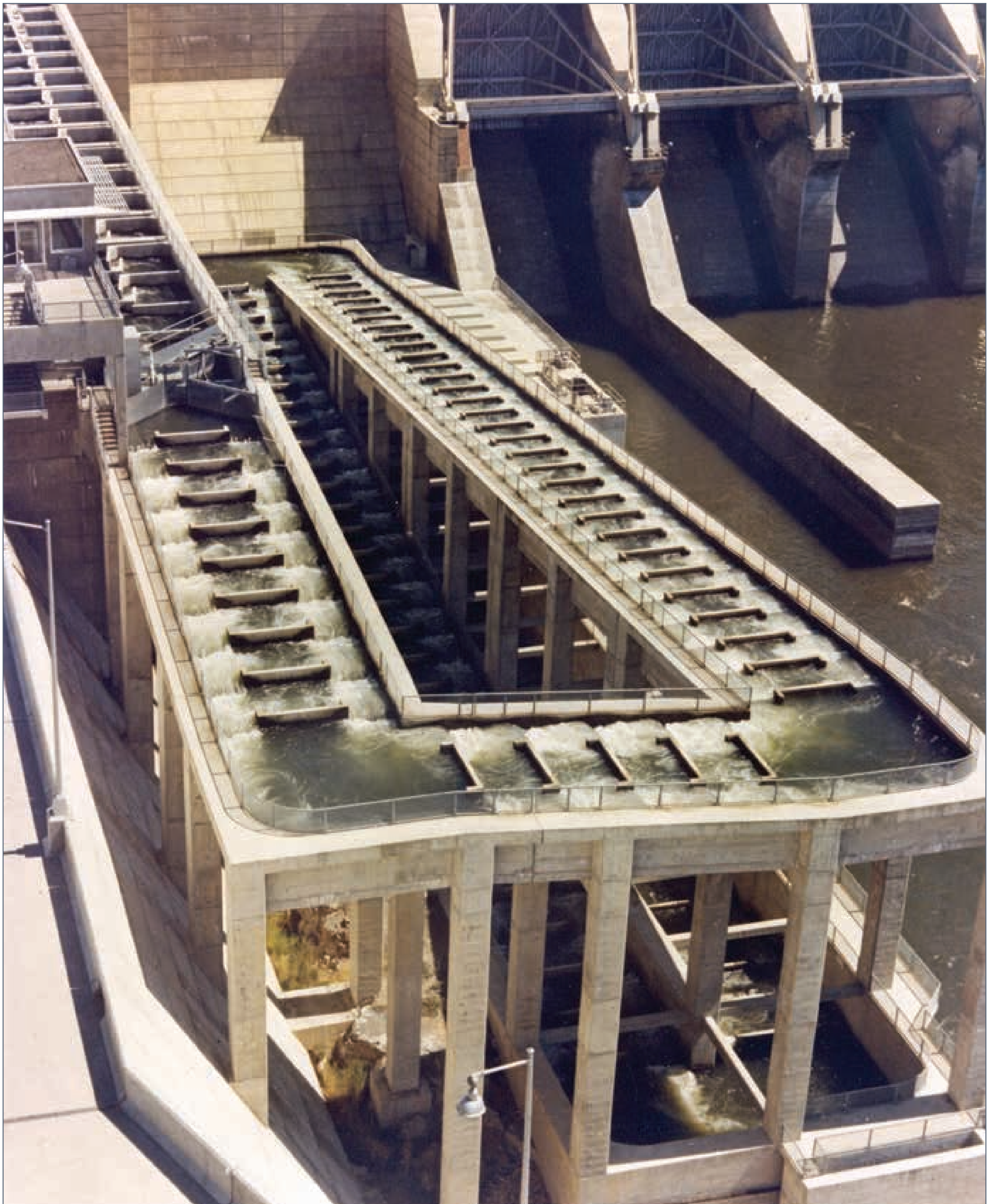


The north fish ladder at the John Day Dam on the Columbia River, August 1974 harvesting, possession, sale, and delivery of threatened and endangered species. The act also required federal agencies to develop a plan to recover animal populations listed as threatened or endangered. In the case of anadromous fish, the NMFS coordinated ESA activities and, in December 1991, listed three of the proposed salmon runs and designated critical habitat for the continued survival of the fish.

The ESA declaration embroiled the region and federal water resources agencies in controversy. While environmentalists gambled that the ESA would force a solution that would save anadromous fish of the Columbia River and its tributaries, other interests, such as agriculture, timber, and industries dependent on cheap hydropower feared the economic costs of the listing. The Corps found itself directly involved in the ESA process and was required to review its actions affecting salmon runs. If the NMFS proposed an emergency listing and determined that the Corps' activities were detrimental to the species or its habitat, the Corps had to consider alternatives recommended by NMFS, though the Army agency could elect not to follow the recommendations. Final ESA listing required the Corps to consult once again with the NMFS about potential actions to avoid species extinction and formulate its own opinion of impact.

As a consequence of the ESA process, in 1991 the Corps modified operations at five Columbia Basin reservoirs, adapted six Columbia River dams, and completed three studies and a dozen reports evaluating its actions. In an attempt to broker an agreement among environmental and economic interests and formulate a consensus plan to address the depletion of salmon runs, federal and state political leaders and various stakeholders held a Northwest Salmon Summit in 1990. A series of meetings into early 1991 failed to achieve a consensus plan for action. After the ESA listing, the NMFS established a Salmon Recovery Team to develop recommendations for a recovery plan.

Much of the controversy surrounding salmon recovery during the remainder of the 1990s involved how much water to spill each year to speed the downstream migrants through the complex of dams on the Snake and Columbia rivers. Unfortunately, spilled water was expensive to the region because it was not available for electric power generation. Because of the complexity of the issues involved in a recovery plan and the expense of scientifically acceptable solutions, the issue found its way into the federal courts. The remainder of the decade was spent litigating the issues while the Corps attempted to refine operations at its projects to accommodate the evolving recovery plan for ESA-listed salmon species. No permanent solution emerged by the beginning of the new century.

CIVIL WORKS PROJECT MANAGEMENT

In the post-World War II era, questions of cost and best methods of project administration greatly affected the process of federal water resources development. By 1970, the federal Office of Management and Budget had gained increasing control of water resources policy, while the Department of the Army considered civil works a minor function within the military bureaucracy. During the 1960s, concern within the Army about the growth of the civil works budget and the need to coordinate water resources policy with other federal agencies led to the establishment, in 1970, of the Office of Assistant Secretary of the Army for Civil Works. This office had the goal of strengthening planning and review functions within the Corps, while giving the agency more clout within the executive branch. However, for political reasons the position was not filled for five years. The rest of the 1970s were spent defining how the assistant secretary would accomplish their mission and develop a sound relationship with the Corps of Engineers. This process unfolded just as the Corps faced changes in the way projects were financed.[45]

When a Republican administration took office in 1981, it brought new water resources priorities. Instead of relying on traditional, full federal funding of water projects, the new assistant secretary of the army for civil works, William R. Gianelli, wanted to fund the Corps' water resources undertakings through cost-sharing with nonfederal interests. His successor, Robert K. Dawson, saw the process to completion five years later with WRDA-86. The law represented a watershed event in the way the Corps of Engineers operated by implementing greater cost-sharing with nonfederal sponsors and expediting the planning process for civil works projects. It contained new requirements for intergovernmental cooperation, local sponsorships, and the financing of inland navigation, harbor maintenance, and construction. For the first time, cost-sharing was imposed on all flood control projects, with local sponsors required to pay at least 25 percent of project costs. The legislation also established two trust funds, based on user fees, for support of inland waterways and for harbor maintenance. Recognizing that the Corps would have to change its project planning and management procedures to implement WRDA-86, the agency senior leadership initiated a major review of the Corps' business functions in 1987.[46]

Traditionally, a Corps district developed a civil works project by passing it from one functional area to the next as it progressed from concept through completion—that is, from planning to engineering to construction and finally to operations. Typically, each functional area assigned a different manager to the project, with no single person responsible for delivery time or cost control. This approach to management of projects proved time-consuming and expensive. In contrast to the Corps' method, the private sector employed one person—the project manager—to oversee all project costs and schedules throughout the life of the undertaking. The system emphasized teamwork above loyalty to a functional specialty and stressed cost controls and timeliness throughout the life of the project.[47]

In 1988, the Corps adopted the project management concept and issued an engineering circular to guide implementation. Each district designated a civilian as deputy district engineer for project management (DDE(PM)) and assigned a project manager for each large civil works project. An Office of Project Management was to provide technical advice to the DDE (PM). The chiefs of functional areas retained responsibility for providing functional products, including schedules, budgets, and manpower requirements necessary to accomplish their assigned work. The new project managers had responsibility for the overall project schedule, cost, and coordination and reported directly to the DDE (PM). The Corps' headquarters ordered that no additional personnel positions be created to achieve the new structure.[48]

Over the next four years, senior leaders at headquarters and in the field struggled to implement the new project management system, as the process did not go smoothly. The functional elements ("stovepipes") and their chiefs did not want to give up authority or personnel to a project manager or DDE. Complicating the process, each district tended to interpret and implement the project management guidance differently. Although frustrated, Chief of Engineers Lt. Gen. Henry Hatch, pushed ahead—clarifying that the DDE (PM) had equal rank with the chiefs of engineering and construction. He also restructured Corps headquarters to emphasize commitment at the top to the project management system. The key change at headquarters involved the establishment, in July 1989, of two program directorates—Civil Works and Military Programs. Each directorate had its own engineering and construction division, but Civil Works also contained divisions for project management, programs and policy, and planning. Military Programs had a project management and an environmental restoration division. In the field, each district and division combined programs and project management offices. By 1990, project managers existed at every level of the Corps. In effect, this new organization created its own stovepipes.[49]

To support the project management initiative, the Corps pushed the automation and linking of reporting, budgeting, and scheduling requirements with the project managers' data networks. One goal of these efforts was to reduce the time it took to design and construct a civil works project, which could run to twenty years under the old planning approach. As Bory Steinberg, chief of the Civil Works Directorate at the Corps headquarters, noted in July 1990, such a lapse of time was "totally unacceptable in an era of cost sharing and partnership with nonfederal sponsors." One way of reducing project planning and execution time relied on cutting the study and review effort. The goal aimed to achieve the planning and design of a project in seven years. In addition, the Corps was committed to constructing all projects according to the costs and schedules set in the cost-sharing agreements with local sponsors. The Corps recognized that the key element in the new planning process was accountability, and it hoped that a successful project management system would be that functional tool.[50]

Galveston District, U.S. Army Corps of Engineers

Col. Gordon M. Clarke and Maj. Gen. Henry J. Hatch of the Corps signing the local cooperation agreement for the Clear Creek flood control project in Texas, June 1986

Between 1990 and the end of his term as chief of engineers in 1992, General Hatch continued to fine-tune the implementation of program and project management and to overcome residual resistance to the new way of doing business. In March 1991, the Corps issued a regulation for project management that established a project team led by the project manager. This team included technical personnel from the functional elements. Field surveys conducted by headquarters continued to reveal resistance to the new project management approach, with field personnel complaining about conflicting guidance, complicated reporting requirements, and micromanagement. Nevertheless, the new system gradually took hold as leaders emerged in the district and division offices who embraced project management as the way to do business in the Corps. By the end of the decade, project management, according to several observers, had helped to encourage a sense of empowerment among district staff and break down the old stovepipe mentality within the organization.[51]

As the Corps worked during the 1990s to implement project management, it also undertook a major restructuring of the entire organization. Shifts in workload from design and construction to operations and maintenance, a need to reduce overhead, and the advent of cost-sharing pushed the decision to reorganize. A reduction of the number of Corps division and districts offered a means to distribute workload more evenly, cut nontechnical personnel, and reduce overhead. After several unsuccessful reorganization attempts, the Corps finally developed a plan by the mid-1990s that focused first on the headquarters and division levels. This phase of the restructuring streamlined the Corps' technical review procedures by removing divisions from the process. This change, coupled with alterations in other management processes, sought to deliver quality work at less cost. The next phase involved reducing the number of divisions from thirteen to eight, with four districts in each remaining division. The districts maintained their core functions such as engineering, planning, operations, and construction; but the level of competency in each functional element varied across districts, depending on respective workloads. The goal was to accomplish the projected civil works mission in a time of diminished resources.[52]

The process of reorganizing the divisions required great care because of the potential to harm morale and disrupt ongoing business. Ultimately, the restructuring was accomplished by combining those divisions having major river systems with similar needs, such as navigation, hydropower production, and environmental issues. Thus, for example, the North Pacific Division (covering the Columbia River Basin) and the Missouri River Division (covering the Missouri River Basin) joined to form the Northwestern Division. Despite the challenges inherent in restructuring, at the completion of the process, the Corps created a leaner, more efficient, and focused organization with the necessary technical and managerial skills to meet the engineering and environmental challenges ahead. Coupled with the project management innovations, the reorganization made the Corps a more nimble and competent organization as it faced a new century.

EMERGENCY OPERATIONS

The Corps' role in providing disaster relief stemmed chiefly from its flood-control mission. Beginning in 1917, with the first Flood Control Act, Congress accepted federal responsibility for flood control on the Mississippi and Sacramento Rivers and assigned the Corps to assist in the resulting levee work. When massive flooding struck the Mississippi River in 1927, the Corps attempted to reinforce the levees holding back the rising waters. When these levees failed, the Corps undertook disaster relief efforts for the flood-affected communities, such as transporting supplies to communities isolated by rising water and rescuing thousands of stranded refugees. The

Corps of Engineers Field Organization

The U.S. Army Corps of Engineers is organized geographically into eight divisions and forty-one civil works districts. Districts are defined by watershed boundaries for civil works projects and by political boundaries for military projects.

Corps had added incentive to assist in disaster response activities when floods affected its navigation projects.[53]

The Corps of Engineers' role in providing disaster relief expanded substantially when Congress enacted the Federal Disaster Relief Act of 1950. This measure allowed for local and state governments to petition the president for a disaster declaration and, subsequently, federal disaster assistance. Authorized assistance included emergency housing, repair of critical facilities, and debris removal. In 1955, Congress further expanded the Corps' disaster preparedness and emergency response role by authorizing emergency operations in the face of imminent floods to rehabilitate flood-control works threatened or destroyed by floods and to protect or repair federally authorized shore-protection works that were threatened or damaged by coastal storms. These provisions enabled a vigorous Corps response to a series of devastating Gulf Coast hurricanes in the 1960s, as well as the periodic flooding occurring on the nation's waterways. Federal disaster policy changed in the 1970s when Congress once again greatly expanded assistance under the Disaster Relief Act and through the establishment of the Federal Emergency Management Agency (FEMA). The new agency would coordinate relief from multiple agencies, including the Corps. To accomplish its growing mission, the Corps developed and maintained emergency response plans and trained personnel for response and recovery operations. The Corps regularly tested its emergency readiness by conducting exercises with state and local governments and other federal agencies.

After a series of catastrophic disasters in 1989, FEMA improved coordination of disaster relief through a Federal Response Plan that included prescripted Emergency Support Functions assigned to specific agencies. The Corps assumed responsibility for public engineering, which included debris removal, critical facility repair, emergency power, temporary housing repairs, and distribution of food and water. The Corps also supported other missions such as hazardous materials removal and urban search and rescue. Later versions of this plan, including the National Response Plan of 2005 and the National Response Framework of 2008, expanded these missions and adopted standard organizations and terminology. In the 1990s, the Corps developed national response assets to support the regional Corps districts that had previously resourced disaster relief. The Corps rolled these efforts into its Readiness 2000 program, which established the Readiness Support Center, authorized the use of the 249th Engineer Battalion (Prime Power) to support emergency power requirements, approved advanced contracting, and introduced the concept of planning and response teams (PRTs). PRTs were highly trained and specialized regional teams with pre-assigned public engineering missions that could get on the ground quickly after a disaster. In addition, new technologies such as easily manufactured plastic tarps ("blue roofs"), remote sensing, computer modeling, and rapid global positioning system-enabled surveys helped speed disaster responses. These measures greatly standardized and enhanced the ability of the Corps to provide aid in floods, hurricanes, and other disasters.[54]

Several large-scale national disasters—especially the 1980 eruption of Mount St. Helens in Washington State and Hurricane Andrew on the Florida coast in 1992—illustrate the Corps' short- and long-term emergency response roles that grew from its flood-control and navigation missions. The unprecedented devastation caused by these two events required emergency actions to cope with immediate impacts on life and property as well as long-term rehabilitation and protection projects to prevent ongoing and future damage. On a lesser scale, the Corps' disaster response to the aftermath of the Loma Prieta, California, earthquake and the *Exxon Valdez* oil spill off the coast of Alaska—both in 1989—revealed the range of its emergency capabilities.

MOUNT ST. HELENS

On May 18, 1980, an earthquake of magnitude 5 on the Richter scale caused the collapse of almost 12 percent of Mount St. Helens. This then triggered an explosion of superheated water in the mountain, equaling twenty-four megatons of energy—a blast five hundred times more powerful than the atomic bomb that destroyed Hiroshima. The explosion took more than 1,200 feet off the top of the mountain, forming a huge crater over a mile in diameter. The mountain spewed approximately three billion cubic yards of material, some as volcanic ash and some as mud and pyroclastic flows that sped down the mountain at one hundred miles an hour. These flows (averaging up to sixty-six feet in depth) contained massive amounts of debris, rock, trees, water, and glacial ice in super-heated conditions, which filled in and leveled out river beds, reducing, for example, the channel capacity in the Cowlitz River from 70,000 to 13,000 cubic feet per second. Very quickly, the mudflow deposited as much as fifteen feet of sand, volcanic ash, and pumice in the river channels and ten feet on the floodplain. On the Columbia River, the mudflow reduced the forty-foot-deep ship channel to a mere fifteen feet. More ominous for the future, the debris avalanche also created lakes in the Toutle River drainage, blocking them with eroded, unstable material. As these lakes retained rainwater or snowmelt, the danger of breaching and downstream flooding increased.

The eruption and its aftermath killed fifty-seven people, destroyed 150 square miles of valuable forest, and caused $1.1 billion in damage. As infill eliminated natural river channels, 45,000 people were left without flood protection. The avalanche of mud and debris clogged the Toutle, Cowlitz, and Columbia rivers, which threatened to cause extensive navigation and flooding problems. The Corps faced a difficult and uncertain situation in devising appropriate technical solutions to the immediate and long-term water problems caused by this unprecedented natural disaster.

After initiating emergency dredging to restore the shipping channel in the Columbia River and flood-fighting operations on the Cowlitz, the Portland District of the Corps of Engineers devised and implemented both short- and long-term solutions to the flooding and navigation problems caused by continuing flows of volcanic material. By December 1980, the Corps had restored the Columbia River navigation channel by removing fourteen million cubic yards of infill, raising 14,700 feet of levees, and extending 21,400 feet of levees in preparation for the winter flood season. The Corps then focused on maintaining the restored navigation-channel and flood-protection measures from the large volume (potentially three billion cubic yards) of erodible debris deposits in the Toutle River system, which fed into the Cowlitz and Columbia rivers. The Corps built two debris dams on the Toutle (weir-like rock retaining structures) to hold back the rapidly eroding layers of debris so that excavation equipment could remove it to spoil areas. The Corps also constructed eight sediment basins on the Toutle River to trap additional sediment and stabilize river channels. The crews periodically dredged the trapped sediments. By May 1981, dredging and sediment-trapping efforts removed 74.4 million cubic yards of material from the Cowlitz and Toutle rivers.

Based on updated sediment predictions that one billion cubic yards would be transported to the Cowlitz and Columbia rivers over a fifteen-year period, potential economic damage could exceed $3 billion if no actions were taken. The Corps proposed nine projects to maintain the existing level of protection, mainly focused on trapping sediments and stabilizing river banks. The engineers also constructed a controlled outlet from South Castle Lake, which had been created by the debris avalanche and had a plug that, if catastrophically failed, would release 25,000 acre-feet of water and large volumes of sediment. In all, the Corps' emergency and short-term response work cost $327 million. However, the experts estimated that one billion cubic yards of sediment from the initial three billion cubic yards of volcanic material ejected from Mount St. Helens would continue eroding downstream and settle in the Cowlitz and Columbia rivers, posing grave problems. Large additional expenditures of public money would be necessary to prevent heavy future losses from flooding and channel sedimentation.

The Corps' comprehensive, long-term strategy for controlling Mount St. Helens' sediment focused on

Office of History, Headquarters, U.S. Army Corps of Engineers

Excavating the Cowlitz River as part of the cleanup effort following the eruption of Mount St. Helens

two areas: the unstable debris dam formed at Spirit Lake and the continuing sedimentation of the Cowlitz River. Volcanic material up to six hundred feet in depth formed a ridge at Spirit Lake's outlet to the North Fork of the Toutle River. Overtopping or breaching the blockage would cause catastrophic downstream flooding. While temporarily pumping water from the lake to relieve pressure on the debris plug, the Corps decided in 1984 to provide a more permanent outlet by drilling an 8,460-foot long tunnel through solid rock. After completing the tunnel in April 1985, the Corps then constructed a large sediment retention structure (SRS) on the North Fork of the Toutle River to trap sediment from water before it moved downstream. In December 1989, after five years of work, contractors completed the SRS—an 1,800-foot-long and 184-foot-high rock and clay embankment, at a cost of $73.2 million. It contained a concrete outlet structure and an unlined spillway at one end. The 3,200-acre lake formed by the SRS had a projected fifty-year life. The outlet works contained six rows of pipes through which water passed. The Corps' plan called for closing each row of pipes gradually, as the pool filled, until the river flowed freely over the spillway top. When the Corps closed the last row of pipes in 1998, the SRA still had room for almost two hundred million cubic yards of sediment. The total Corps expenditures—long- and short-term—for Mount St. Helens recovery work came to about $561 million. Both the tunnel at Spirit Lake and the SRS were major engineering works. These, together with the short-term response to the unprecedented flooding and disruptions to navigation caused by the Mount St. Helens eruption, demonstrated the Corps' engineering and planning capabilities to cope with water resources emergencies.[55]

HURRICANE ANDREW AND OTHER NATURAL DISASTERS

During the late twentieth century, the devastation caused by hurricanes out of the south Atlantic Ocean severely tested the Corps' ability to provide disaster relief. Hurricane Andrew, a category 5 storm, roared ashore twenty-five miles south of Miami, Florida, on the morning of August 24, 1992. Carrying exceptionally strong wind speeds and storm surges, Andrew created a path of destruction twenty-two miles wide and devastated the land from Biscayne Bay to the Everglades. It destroyed thousands of homes and other buildings, tore down power lines, and left millions of cubic yards of debris. All told, Hurricane Andrew killed twenty people, left 250,000 homeless, and caused $26.5 billion in damages.[56]

The Corps, through its Jacksonville District, quickly responded to Andrew under the overall guidance of FEMA. Over several months, the Corps spent nearly $400 million in federal relief funds installing temporary roofs on about 22,500 homes, removing debris, setting up emergency generators and pumps, distributing thousands of gallons of safe drinking water, and rehabilitating 270 schools. The Corps also oversaw the repair of telephone, water, and sewage treatment systems.

Unloading roofing material in Florida following Hurricane Andrew, 1992

Office of History, Headquarters, U.S. Army Corps of Engineers

Removing the vast quantity of debris and refuse (11 million cubic yards) caused by the storm, required a significant logistical effort. At one point, the Corps and its contractors operated 2,000 trucks a day to clean up the mess. The Corps' technical assistance and project management skills were essential in promptly coping with what at the time was the largest disaster recovery effort undertaken by the agency.

In addition to hurricanes, the Corps has responded to a variety of other natural and man-caused disasters. In October 1989, the Loma Prieta, California, earthquake lasted less than fifteen seconds, but killed sixty-two people, left 14,000 homeless, and caused $7 billion in losses. In response, the Corps provided assistance in debris removal, damage assessment, restoration of critical municipal services, and technical assistance involving geotechnical support analyzing geologic hazards. As with other disasters, the Corps responded quickly and effectively because of its organizational flexibility. A Corps division and two local districts coordinated an efficient and timely response to FEMA's requests.[57]

In the case of the *Exxon Valdez* oil spill, the Corps demonstrated yet another side of the agency's emergency response capabilities. The oil spill cleanup after the tanker ran aground in Alaska's Prince William Sound in March 1989 demonstrated the Corps' ingenuity in improvising a response to the release of 11 million gallons of crude oil along 1,500 miles of south-central Alaska coastline. The Corps modified two of its dredges to vacuum the oil from the water's surface, something never previously attempted. The crews of the Corps' dredges *Yaquina* and *Essayons*, after brief trial and error, adapted the vessels' dragheads by inverting them to enable recovery of significant amounts of oil (almost 400,000 gallons) for safe disposal.[58]

The Corps also assisted in devising a plan for cleaning the contaminated shoreline areas through its research capabilities at WES and the Cold Regions Research and Engineering Laboratory (CRREL) in New Hampshire. WES had extensive experience concerning hazardous and toxic materials and contaminated sediments, while CRREL had investigated the long-term effects of crude oil spills on terrestrial environments and was able to successfully apply remote sensing technology.

TERRORIST ATTACKS OF SEPTEMBER 11, 2001

Among a series of coordinated attacks on Tuesday morning, September 11, 2001, a hijacked American Airlines Flight 11 smashed into the north tower of the World Trade Center in New York City. Seventeen minutes later, a second hijacked plane, United Airlines Flight 175, crashed into the south tower. Both towers ultimately collapsed. The disaster response came from a wide range of first responders including members of the New York District of the U.S. Army Corps of Engineers. The immediate reaction was to both ascertain the situation and provide assistance. Six Corps vessels responded by ferrying people from Manhattan Island across the Hudson River to New Jersey and returning loaded with firefighters and supplies such as fuel for fire trucks. The activities over the next few days evolved from rescue to recovery with Corps structural engineers assisting with the removal of rubble from the collapsed towers. The Corps involvement was headed by North Atlantic Division Engineer Brig. Gen. M. Stephen Rhoades, who was headquartered across New York Harbor at Fort Hamilton. Personnel from New York District, whose offices were located one-half mile from the towers, were quickly engaged and over time debris management specialists from every district and laboratory in the Corps arrived to assist. The efforts of Corps personnel were coordinated through FEMA.

Within a few hours of the attack, city officials realized a plan was needed to dispose of rubble from the destroyed buildings. New York City officials reopened the Fresh Kills Landfill on Staten Island and used barges

U.S. Army Corps of Engineers

Corps of Engineers personnel confer with a member of the New York City Fire Department at the World Trade Center site, September 2001

to move the debris. However, a deep water access on lower Manhattan Island would be required. Within twenty-four hours, the Corps completed the permitting to allow dredging at Pier 25 and work began. Dredging efforts encountered a buried pier, slowing progress, but the deep-water access was available within a week and debris was steadily moved to the Staten Island landfill as well as selected deep water disposal sites.

The Staten Island landfill became a crime scene as debris was inspected for human remains and clues concerning the attack. In response, the Corps invited Phillips and Jordan (P&J), a Knoxville-based contractor that had an existing debris removal contract with the Corps, to come to New York City to assist with the recovery. P&J and the New York District worked carefully with twenty-four public (federal, state, and local) agencies to establish a safe and cooperative work area that met the law enforcement objectives. At its peak, the operation employed almost 1,000 workers running 24-hour operations. The debris processing operations continued for several months and consumed 1.7 million work hours.

While the debris removal at the World Trade Center complex or "ground zero" continued for many months, the City of New York was able to quickly assume the associated duties, so that by mid-October only forty Corps employees outside of New York District remained in the disaster area. However, the quick response, technical skills, and leadership brought by the Corps of Engineers were invaluable in dealing with the consequences of the worst-ever terrorist attack on American soil.[59]

HURRICANE KATRINA

Hurricane Katrina struck New Orleans, Louisiana, on August 29, 2005, with incredible force, traveling across the Gulf of Mexico as a Category 5 hurricane with 175-mph winds. The storm lost some of its force before making landfall—wind speeds dropped to 127 mph—and fell to a Category 3, but it still produced unprecedented devastation. Katrina generated an unexpected 28-foot storm surge and 55-foot waves, resulting in unparalleled damage for a storm of that strength. Flood waters inundated almost 80 percent of New Orleans, with depths exceeding fifteen feet. The surge and waves caused fifty major levee breaches, disabled thirty-four of the city's seventy-one pumping stations, and compromised 168 of 350 miles of protective structures designed to reduce storm-related damage. Rainfall of fourteen inches in a 24-hour period added to the misery. In all, more than 1,500 people died and property losses came to an estimated $90 billion, making it the costliest disaster in U.S. history.[60] The environmental consequences were dire as well, permanently altering the landscape of the Louisiana coast and exacerbating an already serious erosion problem. In normal years, the loss of coastline averaged 25 to 35 square miles—Katrina wiped out 118 square miles.

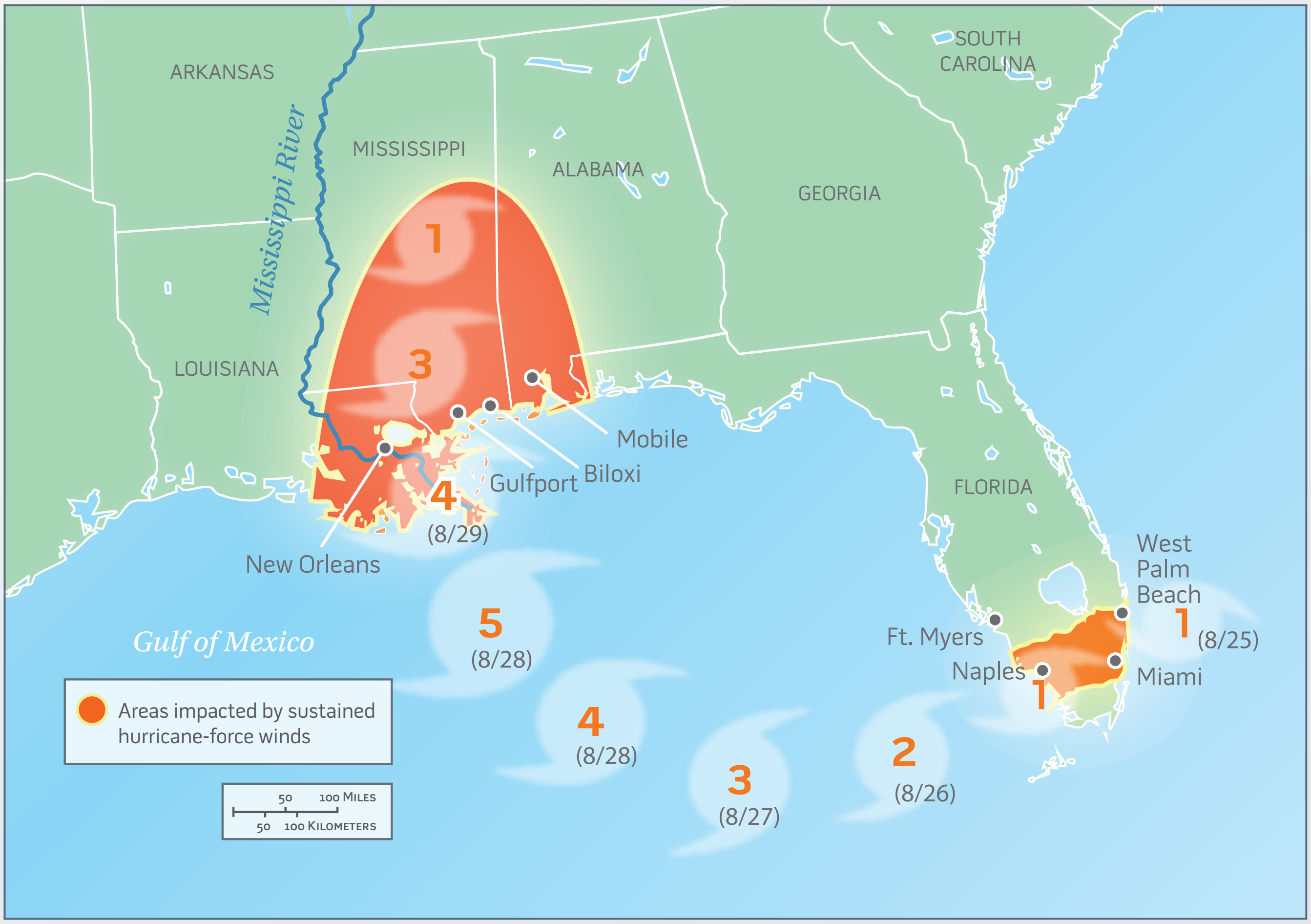
In the immediate aftermath of the hurricane, the New Orleans District responded to FEMA's call for relief actions while racing to repair damage and restore the hurricane protection system (HPS) to pre-Katrina conditions in time for the 2006 hurricane season. In addition to initial work on the levees and pumping systems, the Corps also assembled a task force to remove stagnant flood waters from New Orleans, ultimately ridding the city of 250 million gallons in just fifty-three days. All together, 9,000 people, including 6,000 from nearly every Corps' district and division, took part in the agency's response to the storm.

Hurricane Katrina led to a number of investigations into what went wrong and how to prevent such destruction in the future. The Corps of Engineers established the Interagency Performance Evaluation Taskforce (IPET) to study the performance of the HPS during Katrina and to assist in the application of that knowledge to the reconstruction of the damaged portions of the system, to improve the protection system, to identify existing deficiencies, and to establish a risk-based framework for recommending changes.[61] The eight-volume report explored all aspects of the storm's behavior and the New Orleans HPS. The resulting analysis uncovered design failures in the structural components of the protection system with foundation failures of "T-walls," inadequate levee foundation sheer strengths, and inconsistent elevation datums for aligning the system of protective structures receiving the most notoriety. While these engineering failures were devastating and an embarrassment for the Corps of Engineers, the causes and remediation of these design deficiencies were readily addressed. However, a fundamental change in storm protection design resulted from the post-Katrina investigation. This was the concept of "risk-based analysis." Previously, the design of protective structures applied factors of safety to determine final design criteria, but the analysis of the Katrina event indicated a range of possible storm events and storm consequences based on storm intensity and trajectory.[62] A key conclusion of the IPET, and supported by an external IPET review by the American Society of Civil Engineers (ASCE), was that future designs should be based on the probability of different storm events combined with the consequences of those events.[63] From this came the concept of "shared" risk among the owner of a structure and those impacted by the possible failure of the structure. It also opened a new direction in engineering design that included the quantification of risk, communication of risk, and management of risk.

In addition to promoting the concept that "residual" risk exists in every engineered work, the Corps also examined the decision-making process for

Hurricane Katrina

Striking Florida and the Gulf Coast in late August 2005, Hurricane Katrina ranks among the deadliest hurricanes ever to hit the United States. An estimated 1,836 people died as a direct result of the storm and the flooding that followed while millions were left homeless.



the HPS—which can be characterized as a project of large magnitude, with long duration of development and construction and having multiple responsible parties. This analysis was reported as the "Decision-Making Chronology for the Lake Pontchartrain and Vicinity Hurricane Protection Project." Produced through IWR, this report indicated inconsistent decision making over five decades by the multiple federal, state, and local parties involved. The result was an HPS that was not fully integrated, consistently designed, or robustly maintained.[64] ASCE later concluded that all large-scope, long-duration, and multiple-stakeholder projects should quantify, communicate, and manage risk; employ integrated systems approaches; exercise sound leadership, management, and stewardship in decision making; and adapt critical infrastructure in response to dynamic conditions and practice. These *Guiding Principles* were to be integrated to achieve an overarching principle of *holding paramount the safety, health, and welfare of the public.*[65]

While carrying out its hurricane recovery operations, the Corps also began a congressionally authorized two-year study to develop a long-term plan for hurricane risk reduction and coastal restoration in Louisiana and Mississippi. Hurricanes Katrina and, several weeks later, Rita, had permanently altered the landscape along the Gulf coast with their combined effects destroying many square miles of Louisiana wetlands. This study drew on the Corps' 1990s work with the State of Louisiana, which sought to recover or restore the state's coastal wetland environment. Earlier cooperative studies had focused broadly on recovering regional ecological balance, but the new study sought to ensure public safety and benefit to the nation, while balancing the needs of navigation, flood and hurricane storm damage reduction, and environmental stewardship. The Corps and the State of Louisiana completed a $20 million study, called the Louisiana Coastal Protection and Restoration (LACPR) report in December 2009.[66]

The multidisciplinary team of scientists, engineers, and planners inventoried the economic, social, and environmental resources of coastal Louisiana; collected data; developed risk assessment models for various hurricane intensities and trajectories; and then designed strategies to reduce risk. The Corps found it difficult to model and prepare a quantitative risk assessment because Katrina combined the characteristics of both a Category 3 and Category 5 hurricane, pushing enormous amounts of water in front of it. The combination of water and wind speed set records for a surge associated with a coastal storm in the New Orleans area. To provide a 100-year level of protection against such powerful winds and water, the team looked at a range of alternative measures, reformulating and refining various solutions to meet the defined objectives.

While looking at a broad range of potential future hurricanes and their possible effects, the team had to take into account Louisiana's continuing loss of coastal wetlands. The lack of sediment in the delta, attributed to trapping upstream by dams and other flood control measures, contributed to weakening coastal wetlands. This meant that structural solutions would have to be part of new protective measures. As a consequence, the LACPR proposed a dual line of defense, combining an outer line of natural coastal features, such as barrier islands, marshes, and forests, with an inner line of armored levees. The report also recommended nonstructural techniques, such as elevating structures and creating effective evacuation plans.

The unprecedented LACPR report was unique in several respects. As a complex planning and analysis undertaking by the Corps and the State of Louisiana, the report represented the first integrated plan for hurricane damage risk reduction and restoration of Louisiana's disappearing wetlands and their ecosystems. The scope of the planning area was daunting, encompassing 18,000 square miles of coastal area and involving a broad range of interrelated human and environmental factors. In addition, developing a range of alternative solutions required the improvement of existing hydrologic modeling methodologies. The study also incorporated, in cooperation with Dutch engineers, best practices from the Dutch flood protection system.

A key breakthrough in the LACPR involved the use of modeling that identified the residual risk present, despite the measure of protection being considered. This approach used both historical and projected future storms as a basis for estimating risks and deciding how and where to rebuild. In previous studies, only historical data were used. The risk model presented a means to acquaint the public with the level of risk in any proposed project design. The Corps also established, for the first time, a quantitative measure of the value of Louisiana's existing wetlands in achieving coastal protection against storm surges. To aid in understanding the impacts of various alternatives on the many stakeholders, the Corps team used a methodology known as multi-criteria decision analysis. This approach revealed the tradeoffs associated with the various alternatives. For example, more environmental outputs from protection might require giving up some development opportunities.

After completing the draft technical report, the team submitted it for peer review by the National Research Council of the National Academy of Sciences. The review, begun in March 2008, was designed to provide assurances that the science behind the report's alternatives was sound and that all appropriate interests had been taken into account. The Corps team submitted the final technical report of the LACPR process to the chief of engineers in July 2009. The technical report, with its list of alternatives and cost estimates, then served as the basis for future decisions related to the level of flood protection provided under the congressionally authorized project called the Hurricane and Storm Damage Risk Reduction System (HSDRRS).

Through a series of appropriations starting in 2006, Congress provided a total of $14.6 billion for the HSDRRS of New Orleans and vicinity. The Corps' annual civil works construction budget averages approximately $2 billion, so the HSDRRS's two hundred construction projects represented one of the largest engineering programs in U.S. history. This package of storm- and flood-damage-reduction projects included 350 miles of levees and floodwalls; 73 non-federal

U.S. Army Corps of Engineers, Hank Heusinkveld

Corps of Engineers personnel observing a helicopter maneuver at a sandbag staging area following Hurricane Katrina, September 2005

New Orleans District, U.S. Army Corps of Engineers

The Inner Harbor Navigation Canal surge barrier, the largest design-build civil works project in the history of the Corps, stretching across the Golden Triangle Marsh to protect New Orleans from hurricane surges, July 2012

pumping stations; 3 canal closure structures with pumps; and 4 gated outlets to attain 100-year level flood risk reduction for New Orleans. The new designs also addressed the primary causes of New Orleans levee breaches during Katrina: weak foundations, scour, and overtopping. The effort to provide a 100-year level of protection took into account factors besides storm surges and wave levels, such as an unexpected sea level rise, subsidence, and possible increases in storm severity and frequencies. The designs benefitted from the IPET analysis of previous engineering design flaws and inconsistent elevation datums on which the heights of structures throughout the New Orleans region were based.

One of the most controversial decisions was the installation of outfall canal closure structures. As most of New Orleans is below sea level, three canals exist to drain rainwater and groundwater from the center of New Orleans to Lake Pontchartrain in the north. While these canals are efficient in transporting excess water from New Orleans, they also required contiguous levees and floodwalls along their banks to prevent Lake Pontchartrain flood waters from flowing backward into the city. The canals were 13,500 feet, 11,000 feet, and 15,000 feet in length and required protective structures along both banks. During Hurricane Katrina, these canal levees and floodwalls were the locations of several significant structural failures. The new outfall canal closures can be opened during normal weather to allow the canals to function by gravity flow, but during storm events can be closed, thereby preventing 79,000 feet (15 miles) of levees and flood walls along the canals from being exposed to Lake Pontchartrain flood waters. To function during storm events, the closure structures also required the construction of pumping facilities to remove rainwater falling in the city. By necessity, these pumping stations are massive and were designed to remove 9,200, 2,200, and 5,200 cubic feet per second, respectively. One of the larger undertakings within the HSDRRS program was the $720 million Inner Harbor Navigation Canal (IHNC) surge barrier, which closes the Inner Harbor Navigation Channel linking Lake Borgne with New Orleans. The IHNC consists of a two-mile-long, 24- to 26-foot high concrete and steel structure with three navigable gates. One of these movable structures is a storm surge barrier with two curved floating gates resembling the Maeslant or Rotterdam Barrier in the Netherlands. According to one Corps official, the IHNC "is unique in its magnitude and the technical demands are unique to anything that we've ever done in the United States."[67]

SUPPORT TO MILITARY OPERATIONS

As previously discussed, the nineteenth-century composition of the U.S. Army Corps of Engineers was predominately military engineers with 109 military and no civilian engineers in 1867, but growing to 200 military and 367 civilian engineers by 1918. This transition is consistent with the emergence of civilian engineers in the United States through the industrial revolution.[68] However, with the passage of numerous federal flood control acts, environmental legislation, and eventually water resources development acts during the twentieth century, a divide developed within the U.S. Army Corps of Engineers. One branch provided engineering and construction services for others, primary the Army and later the Department of Defense (DoD), but also the Department of State, Department of Energy, Environmental Protection Agency, and other state and federal agencies. This engineering support also included the military engineer missions of mobility, countermobility, and survivability for U.S. armed forces, contractors, and allies working in hostile areas. The second branch to evolve included the water resources or civil works missions of flood-risk reduction, inland navigation, and aquatic ecosystem restoration. These two branches gradually became quite distinct as the civil works missions have unique energy and water development appropriations from Congress that cannot be mixed with other funding sources.

While the two mission areas somewhat stabilized during the Cold War, employees working in either civil works or military programs remained employees of the Department of the Army and under the control of the chief of engineers. From time to time, individuals with expertise in areas such as engineering, construction, and environmental issues were provided opportunities to work in both mission areas.

During the Global War on Terror, which followed the September 2011 attacks on New York City and Washington, D.C., the Corps' water resources expertise became a newly found asset for the DoD. Working through the United States' Central Command, water resources experts were mobilized in response to nation-building needs for sustainable water resources in Iraq, Afghanistan, and neighboring countries. This expertise included hydrologic modeling of rivers and reservoirs as well as assistance in the development of water-management plans and decision-support tools and methodologies by the local governments. Sharing this expertise has since expanded to the other Combatant Commands located around the world. This civil works effort was provided in addition to engineering and construction of new and repaired schools, roads, power distribution, protective structures, and similar national infrastructure provided by the Corps' military programs.

The military programs budget peaked in 2009 at approximately $31 billion dollars. This work included support to the wars in Afghanistan and Iraq as well as major improvements to the infrastructure of U.S. Army and U.S. Air Force facilities within the United States. By contrast, the civil works budget in that same year was less than $19 billion dollars and included supplemental funds for construction of the HSDRRS in New Orleans and stimulus funding under the American Recovery and Reinvestment Act following the global economic slowdown of 2008.[69]

CONCLUSION

During the last quarter of the twentieth century, federal water resources agencies significantly reduced structural development, increased spending on maintenance and rehabilitation of existing aging infrastructure, and became intensely involved in environmental issues. Cost constraints and environmental concerns meant efforts started to shift from new construction to operations and maintenance and emergency response as primary drivers for water resources budgets. In 1970, for example, construction accounted for 60 percent of the Corps' civil works budget, and operations 22 percent. By 1990, construction dropped to 34 percent, while operations doubled to 44 percent of the total.[70] The result of this shift in funding distribution was a corresponding shift in work requirements such that individuals working in planning and design were provided fewer opportunities to practice their technical skills. Additionally, a concern developed that without continued engineering, design, and construction work, the Corps of Engineers' civil works program would gradually lose its technical expertise in water resources engineering and become primarily a caretaker of water resources infrastructure.

As trends in the 1990s and 2000s indicated, the future of water projects also started shifting toward watershed management and ecosystem restoration. The Corps, at the direction of Congress, committed to spending billions of dollars for the undoing of the environmental consequences of older projects. Restoring the natural flow of the Kissimmee River, Lake Okeechobee, and the Everglades in south Florida are examples of this trend. In the Pacific Northwest, the Corps and other federal water resources agencies spent millions of dollars on modifications to the Columbia River and tributary systems of dams and their operations to save endangered salmon. In addition, more than 3,000 dams nationwide were considered unsafe and in need of repair; numerous locks and dams on the Ohio and upper Mississippi rivers required upgrading to accommodate modern shipping; and the Corps' hydropower infrastructure required periodic improvements. Repairing infrastructure remained vital to the nation's well-being, but prioritizing the effort in a fiscally constrained environment proved a challenge. As water resources historian Marty Reuss noted, "Water planners must take into account both the economic benefits and the environmental costs, while politicians calculate how they can provide necessary services without increasing taxes or mortgaging a community's future through the bond market."[71]

To operate competently and efficiently in an ever-evolving water resources arena, the Corps, in the last third of the twentieth century and into the 2000s, reorganized and adopted new planning and management techniques. While maintaining its technical and engineering expertise and absorbing new environmental capabilities, the Corps became a leaner and more focused organization. However, the heart of the Corps' continued efficiency and functional responsiveness rested on its decentralized organization. This flexibility accounted for the Corps' ability to propose and carry out—through its districts and divisions—solutions to the evolving water resources needs and emergency disaster situations across the nation.

BIBLIOGRAPHIC ESSAY

As with the suggested readings in Chapter 3, the following books represent readily accessible published works providing more in-depth coverage of the various topics in this chapter. For sound, general coverage of society and politics in the 1960s and early 1970s, see James Patterson, *Grand Expectations: The United States, 1945–1974* (New York, 1997). The Corps, T*he U. S. Army Corps of Engineers: A History* (Ft. Belvoir, 2007) provides a brief background on all of the topics covered in this chapter. Beatrice Holmes, in *History of Federal Water Resources Program and Policies, 1961–70* (Washington, D.C., 1979), thoroughly covers the key water resources issues at the federal level. A good introduction to the evolution of environmental politics in the United States since 1945, which emphasizes the interplay between development pressures and environmental values, is Samuel Hays, *A History of Environmental Politics since 1945* (Pittsburgh, 2000). Martin Reuss, in *Reshaping National Water Politics: The Emergence of the Water Resources Development Act of 1986* (Ft. Belvoir, 1991), details the political process that produced cost sharing for federal water resources projects. For context and in-depth analysis of the Corps' early struggles with environmental concerns and the implementation of NEPA requirements, see Daniel Mazmanian and Jeanne Nienaber, *Can Organizations Change: Environmental Protection, Citizen Participation and the Corps of Engineers* (Washington, D.C., 1979). Martin Melosi provides a thoughtful examination of the technological and environmental aspects of water management in *Precious Commodity: Providing Water for America's Cities* (Pittsburgh, 2011).

While no comprehensive look at the Corps' regulatory program has yet been published, helpful background information is available in U.S. Office of Technology Assessment, *Wetlands: Their Use and Regulation* (Washington, D.C., 1984), General Accounting Office, *Wetlands Protection* (Washington, D.C., 1993), and Jeffery Stine, *America's Forested Wetlands: From Wasteland to Valued Resource* (Durham, 2008). The best available overviews of the Corps of Engineers' response to declining salmon runs in the Pacific Northwest are Lisa Mighetto and Wesley Ebel, *Saving the Salmon: A History of the U.S. Army Corps of Engineers' Efforts to Protect Anadromous Fish on the Columbia and Snake Rivers* (Portland, 1995) and Blain Hardin, *A River Lost: The Life and Death of the Columbia* (New York, 2012, rev. ed.). Background on the Corps' flood control mission is provided in Joseph Arnold, *The Evolution of the 1936 Flood Control Act* (Ft. Belvoir, 1988) and Jamie Moore and Dorothy Moore, *The Army Corps of Engineers and the Evolution of Federal Flood Plain Management Policy* (Boulder, 1989). A brief look at the Corps' response to Hurricane Katrina can be found in Craig Collins, "Gulf Coast Recovery," in *Serving the Nation and the Armed Forces* (Tampa, 2009).

1 Samuel P. Hays, A *History of Environmental Politics Since 1945* (Pittsburgh, Pa.: University of Pittsburgh Press, 2000); Ted Steinberg, *Down to Earth: Nature's Role in American History* (New York: Oxford University Press, 2002).

2 David Wingerd and Ming T. Tseng, "Flood and Drought Functions of the U.S. Army Corps of Engineers," in U.S. Geological Survey, *National Water Summary, 1988–89* (Washington, D.C: Government Printing Office, 1989), 123–24.

3 The discussion of federal water policy in the 1960s and 1970s is largely based on Beatrice Hort Holmes, *A History of Federal Water Resources Programs and Polices, 1961–1970* (Washington, D.C.: U.S. Department of Agriculture, Economics, Statistics, and Cooperative Services, 1979); Gregory Graves, *Pursuing Excellence in Water Planning and Policy Analysis: A History of the Institute for Water Resources U.S. Army Corps of Engineers* (Fort Belvoir, Va.: Institute for Water Resources, 1995); Charles Yoe and Kenneth D. Orth, Planning Manual, Institute for Water Resources (IWR) Report 96-R-21 (Nov. 1996).

4 Martin Reuss, *Reshaping National Water Politics: The Emergence of the Water Resources Development Act of 1986* (Fort Belvoir, Va.: Institute for Water Resources, 1991), 30–34, quotes on 30–31.

5 U.S. Army Corps of Engineers, Institute for Water Resources, Environmental Guidelines for the Civil Works Program of the Corps of Engineers (Washington, D.C.: Nov. 1970), 2.

6 Martin Reuss, *Shaping Environmental Awareness: The United States Army Corps of Engineers Environmental Advisory Board, 1970–1980* (Washington, D.C.: Historical Division, Office of the Chief of Engineers, 1983), 1–16; Daniel Mazmanian and Mordecai Lee, "Tradition Be Damned! The Army Corps of Engineers Is Changing," *Public Administration Review* 35 (March-April 1975), 168.

7 Reuss, *Shaping Environmental Awareness*, 5.

8 Institute for Water Resources, Environmental Guidelines, 4–5.

9 Lt. Gen. Frederick J. Clarke, "Civil Works and Shifting Trends," *Military Engineer* (March-April, 1971), 93; see also Institute for Water Resources, Environmental Guidelines, 6–12.

10 Clarke, "Civil Works Trends," 94; Mazmanian and Lee, "Tradition Be Dammed," 166–72, Drew quote on 167; Reuss, *Shaping Environmental Awareness*, 5–6.

11 Col. Howard Sargent, Jr., "Fishbowl Planning Immerses Pacific Northwest Citizens in Corps Projects," *Civil Engineering–ASCE* (September 1972), 54.

12 Mazmanian and Lee, "Tradition be Dammed," 169–70; Daniel Mazmanian and Jeanne Nienaber, *Can Organizations Change?* (Washington, D.C.: The Brookings Institution, 1979), 61–157.

13 Col. Robert Werner and Lt. Col. John Wall, "The Army Corps of Engineers and NEPA," *Military Engineer* (March-April 1974), 111–13; see also C. Grant Ash, "Three-Year Evolution," *Water Spectrum* (No. 4, 1973), 28–35.

14 Jeffrey K. Stine, "Environmental Politics and Water Resources Development: The Case of the Army Corps of Engineers during the 1970s" (Ph. D. diss., University of California, Santa Barbara, 1984), 35–36, 54, 57, 81–82, 84, 193, 197.

15 Leonard Shabman, *Environmental Activities in Corps of Engineers Water Resources Programs: Charting a New Direction*, IWR Report 93-PS-1 (Fort Belvoir, Va.: Water Resources Support Center, Institute for Water Resources, 1993); Amy Doll, *Review and Evaluation of Programs for Determining Significance and Prioritization of Environmental Resources*, IWR Report 94-R-7 (Fort Belvoir, Va.: Water Resources Support Center, Institute for Water Resources, Sep. 1994).

16 *Shabman, Environmental Activities of the Corps of Engineers Water Resources Programs*, 12–13.

17 Ibid.

18 Ibid, quote in 37, see also 35–55; Doll, *Review and Evaluation of Programs for Determining Significance and Prioritization of Environmental Resources*.

19 Daniel McCool, *River Republic: The Fall and Rise of America's Rivers* (New York: Columbia University Press, 2012), 42–44.

20 An outstanding discussion of water management in south Florida is Matthew Godfrey and Theodore Catton, *River of Interests: Water Management in South Florida and the Everglades, 1948–2010* (Washington, D.C.: Government Printing Office, 2011).

21 Background on the Corps' regulatory program and its impact on wetlands can be found in U.S. Office of Technology Assessment, *Wetlands: Their Use and Regulation* (Washington, D.C.: Government Printing Office, March 1984) and General Accounting Office, *Wetlands: The Corps of Engineers' Administration of the Section 404 Program* (Washington, D.C.: Government Printing Office, July 1988); General Accounting Office, *Wetlands Protection: The Scope of the Section 404 Program Remains Uncertain* (Washington, D.C.: Government Printing Office, April 1993); James O. Jones, "Wetlands Policy: A Synopsis," *Military Engineer* (October 1994), 19–21; David Salvesen, *Wetlands: Mitigating and Regulating Development Impacts* (Washington, D.C.: The Urban Land Institute, 1990); see also http://www.nws.usace.army.mil/PublicMenu/Menu.cfm?sitename=Reg&parename=Hist, accessed 12/14/2007.

22 Ibid.; additionally, this and subsequent paragraphs are based also on the following sources: Albert E. Cowdrey, "Pioneering Environmental Law: The Army Corps of Engineers and the Refuse Act," *Pacific Historical Review* XLVI, no. 3 (August 1975): 331–49; Garret Power, "The Fox in the Chicken Coop: The Regulatory Program of the U.S. Army Corps of Engineers," *Virginia Law Review* 63 (1977): 503–59; Lance D. Wood and John R. Hill, Jr., "Wetlands Protection: The Regulatory Role of the U.S. Army Corps of Engineers," *Coastal Zone Management Journal* 4 (1978): 371–407; Jeffrey K. Stine, *America's Forested Wetlands: From Wasteland to Valued Resource* (Durham, N.C.: Forest History Society, 2008); the Clean Water Act may be found at 33 U.S.C. 1251 et seq.: the implementing regulations are at 33 C.F.R. 320–330; U.S. Army Corps of Engineers, Digest of Water Resources Policies and Authorities, Chapter 21, Regulatory Program, EP 1165-2-1 (February 15, 1996); U.S. Army Corps of Engineers, Operations Division, Directorate of Civil Works, Standard Operating Procedures for the Regulatory Program (Washington, D.C.: October 15, 1999).

23 U.S. Army Corps of Engineers, Public Affairs Office, Command Information Division, Corps Facts: The Corps of Engineers Regulatory Program, Section 404 of the Clean Water Act, vol. 5, no. 4 (August 1, 1994); U.S. Army Corps of Engineers, Regulatory Branch, Special Statistical Report, July 1995; "Information Paper: Civil Works Program Statistics," January 8, 1998, Civil Works-General Files, Office of History, Headquarters, U.S. Army Corps of Engineers (hereafter CEHO).

24 Ibid.

25 For background on mitigation banking, see U.S. Army Corps of Engineers, Institute for Water Resources, National Wetland Mitigation Banking Study: Wetlands Mitigation Banking Concepts, IWR Report 92-WMB-1 (July 1992); ibid., First Phase Report, IWR Report 94-WMB-4 (February 1994); U.S. Army Corps of Engineers, *U.S. Army Corps of Engineers Civil Works Pocket Reference* (Fort Belvoir, Va.: Institute for Water Resources, 1998), 92, 105.

26 Ibid.; quote in Standard Operating Procedures for the Regulatory Program, 23.

27 For background on the Corps' flood control mission, see U.S Army Corps of Engineers, *The U.S. Army Corps of Engineers: A History*, rev. ed. (Alexandria, Va.: Headquarters, U.S. Army Corps of Engineers, Office of History, 2007), 57–67, 247, 263–71; Joseph L. Arnold, *The Evolution of the 1936 Flood Control Act* (Washington, D.C.: U.S. Army Corps of Engineers, 1988); Wingerd and Tseng, "Flood and Drought Functions of the U.S. Army Corps of Engineers," 123–32; North Pacific Division, *Water Resources Development in Washington* (1995), 2–3, 8–10; Andrew Dzurik, "Floodplain Management Trends," *Water Spectrum* (Summer 1980), 35–42.

28 The best coverage of the lower Mississippi River flood control efforts can be found in Martin Reuss, *Designing the Bayous: The Control of Water in the Atchafalaya Basin, 1800–1995* (Washington, D.C.: Government Printing Office, 1998); for a good environmental history of the Mississippi River, see Christopher Morris, *The Big Muddy: An Environmental History of the Mississippi and Its Peoples* (New York: Oxford University Press, 2012).

29 Quote in 41, Jamie W. Moore and Dorothy P. Moore, *The Army Corps of Engineers and the Evolution of Federal Flood Plain Management* Policy (Boulder, Colo.: Institute of Behavioral Science, 1989), 34–54.

30 This account of the 1993 flood is based on U.S. Army Corps of Engineers, North Central Division, *The Great Flood of 1993, Post-flood Report, Upper Mississippi River and Lower Missouri River Basins: Main Report* (Chicago, Ill.: September 1994); U.S. Army Corps of Engineers, Lower Mississippi Valley Division, *Impacts of the Great Flood of 1993, Upper Mississippi River and Lower Missouri River Basins* (Vicksburg, Miss.: July 1996); Alan Mairson, "The Great Flood of '93," *National Geographic*, vol. 185 (January 1994), 42–81.

31 Quote in U.S. Army Corps of Engineers, *Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries* (June 1995), 7; see also McCool, *River Republic*, 170–72; Interagency Floodplain Management Review Committee, *A Blue Print for Change: Sharing the Challenge: Floodplain Management into the 21st Century* [commonly referred to as the Galloway Report] (Washington, D.C.: June 1994).

32 Jamie W. Moore and Dorothy Moore, *History of Coastal Engineering Research Center, 1963–83*, vol. 1, Waterways Experiment Station Laboratory History Series (Vicksburg, Miss.: U.S. Army Engineer Waterways Experiment Station, 1991).

33 Susan Pritchard O'Hara and Gregory Graves, *Saving California Coast: Army Engineers at Oceanside and Humboldt Bay* (Spokane, Wash.: The Arthur H. Clark Company, 1991), 129–258.

34 This section is based on the following reports and studies: U.S. Army Corps of Engineers, *National Program of Inspection of Non-Federal Dams: Final Report to Congress* (Washington, D.C.: Office of the Chief of Engineers, May 1982); United States Committee on Large Dams, *Dam Safety Practices and Concerns in the United States* (Washington, D.C.: April 1982); Wingerd and Tseng, "Flood and Drought Functions of the U.S. Army Corps of Engineers," 123–32; "Dam Inspections Reports," *Engin-Ears* [newsletter] (Seattle, Wash.: U.S. Army Engineer District, June 1979), 2, 4.

35 Maj. Gen. J. W. Morris, "Our Troubled Waterways," *Water Spectrum*, vol. 6, no. 4 (Winter 1974–75): 2.

36 Quote in ibid., 2. Four types of areas were used for disposal of dredged material: off-channel, ocean or other open water areas, diked areas, or upland sites. Each had advantages and disadvantages.

37 Ibid., 7.

38 Quote in ibid., 10.

39 The following discussion of the research findings is based on Roger T. Saucier, "Dredged Material—Waste Product or Resource?" *Water Spectrum* (Fall 1978), 11–17 and Mary K. Vincent, "The Dredged Material Research Program," *Military Engineer* (November-December, 1977), 413–15.

40 The DMRP used test results from disposal sites in Puget Sound as part of the study. Examples of the beneficial use of dredged material included results from Jetty Island, Everett, Washington; clam habitat development at Oak Bay Canal; and a beach feed erosion control project at Keystone Harbor on Whidbey Island.

41 John M. Eddinger, "American Dredging: The Turning Point," 388–91; Maj. Gen. Charles I. McGinnis, "Dredging the Nation's Waterways: A Big Job for Industry and the Army Corps of Engineers," 402–04; Thomas M. Turner, "Dredging: A Vital but Troubled Industry," 405–07, all in *The Military Engineer* (November-December, 1978).

42 McGinnis, "Dredging the Nation's Waterways," 402; U.S. Army Corps of Engineers, The U.S. Waterway System—Transportation Facts (Corps of Engineers, Navigation Data Center, December 1998).

43 The following discussion of the effects of declining salmon runs in the Pacific Northwest and the Endangered Species Act on water resources development is based on Lisa Mighetto and Wesley J. Ebel, *Saving the Salmon: A History of the U.S. Army Corps of Engineers' Efforts to Protect Anadromous Fish on the Columbia and Snake River* (Portland, Ore.: U.S. Army Engineer Division, North Pacific, 1995).

44 Ibid., 140.

45 *The U.S. Army Corps of Engineers: A History*, 250–54.

46 Reuss, *Reshaping National Water Politics*.

47 Donita Moorhus and Gregory Graves, "The Limits of Vision: A History of the United States Army Corps of Engineers, 1988–1992," August 1998, unpublished ms., CEHO, 17–18.

48 Ibid., 20–22.

49 Ibid., 23–25.

50 Bory Steinberg, "Project Management: The New Emphasis at the Corps," *The Military Engineer* (July 1990), 60–64, quote on 62.

51 For an example of the implementation of project management at the district level, see Todd Jennings, Lisa Mighetto, and Jill Schnaiberg, *Currents of Change: A History of the Portland District, U.S. Army Corps of Engineers, 1980–2000* (Portland, Ore.: U.S. Army Engineer District, 2003), 184–87.

52 For a good discussion of the restructuring process at the division and district levels, see ibid., 187–90; William Willingham and Lisa Mighetto, *Service—Tradition—Change: A History of the Fort Worth District, 1975-1999* (Fort Worth, Tex.: U.S. Army Engineer District, 2000), 100–03.

53 *The U.S. Army Corps of Engineers: A History*, 263–65; Wingerd and Tseng, "Flood and Drought Functions of the U.S. Army Corps of Engineers," 126–28.

54 William Irwin, "Readiness 2000 Tested By Storms," *Engineer Update* (October 1998).

55 The account of the Corps' emergency operations in response to the eruption of Mount St. Helens is based on William F. Willingham, "The Army Corps of Engineers' Short-term Response to the Eruption of Mount St. Helens," *Oregon Historical Quarterly* (Summer 2005), 174–203; Jennings, Mighetto, Schnaiberg, *Currents of Change*, 150–61

56 *The U.S. Army Corps of Engineers: A History*, 265, 270–71.

57 Janet A. McDonnell, *Response to the Loma Prieta Earthquake* (Washington, D.C.: Government Printing Office, 1993).

58 Janet A. McDonnell, *The U. S. Army Corps of Engineers Response to the Exxon Valdez Oil Spill* (Washington, D.C.: Government Printing Office, 1992).

59 Howard Green, *Continuing the Mission: A History of the New York District, 1975–2005* (New York: U.S. Army Engineer District, 2009), 408.

60 "Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System," Interagency Performance Evaluation Task Force, U.S. Army Corps of Engineers (2006), Vol I-VIII.

61 Ibid., Vol I, Executive Summary and Overview, 1.

62 Ibid., Vol IV, The Storm, 1–3.

63 American Society of Civil Engineers, Hurricane Katrina External Review Panel, "Hurricane Katrina: One Year Later: What Must We Do Next?" (Reston, Va.: American Society of Civil Engineers, 2006), 13.

64 Douglas Woolley and Leonard Shabman, "Decision-Making Chronology for the Lake Pontchartrain and Vicinity Hurricane Protection Project," (Fort Belvoir, Va.: Institute for Water Resources, 2008), 333.

65 "Guiding Principles for the Nation's Critical Infrastructure" (Reston, Va.: American Society of Civil Engineers, 2009), 40.

66 "Louisiana Coastal Protection and Restoration (LACPR): Final Technical Report," (New Orleans: U.S. Army Engineer District, 2009), 293.

67 Quote in Collins, "Gulf Coast Recovery," 71.

68 Joe D Manous, Jr., "Military Engineering Education: To promote Peace, Not War," in *Peace Engineering: When Personal Values and Engineering Careers Converge*, P. Aarne Vesilind, ed. (Woodsville, N.H.: Lakeshore Press, 2005), 14.

69 "USACE Overview," PowerPoint Presentation, May 2013, Lt. Gen. Thomas Bostick, Chief of Engineers, Headquarters USACE, Washington, D.C.

70 For the Bureau of Reclamation, see Donald J. Pisani, "Federal Water Policy and the Rural West," in *The Rural West Since World War II*, R. Douglas Hurt, ed. (Lawrence, Kan.: University Press of Kansas, 1998), 119–46; Donald J. Pisani, "Federal Reclamation and the American West in the Twentieth Century," *Agricultural History* 77 (2003), 391–419.

71 Martin Reuss, "The Development of American Water Resources: Planners, Politicians, and Constitutional Interpretation," in *Managing Water Resources Past and Present*, Julie Trottier and Paul Slack, eds. (London: Oxford University Press, 2004), quote on 68.

10 TWO CENTURIES OF DUTCH AND U.S. EXPERIENCE: COMPARATIVE PERSPECTIVE

Bert Toussaint and William F. Willingham

Comparing water resources management development between two nations is a challenging undertaking, especially when those nations differ in a number of essential characteristics, as do the United States and the Netherlands. Obviously, the physical geography within the two countries varies dramatically. The difference in size and diversity of terrain is striking: the surface of the Netherlands is smaller than half the state of Maine and is largely deltaic in formation, whereas the U.S. is nearly three hundred times larger and is highly varied in its physical makeup.

The historical flood characteristics of the two countries also differ in a dramatic way. Since nearly two-thirds of the Netherlands lies within a delta, it is extremely susceptible to both coastal and inland flooding. This high degree of vulnerability made national flood management in the Netherlands an imperative for the politicians who laid the foundations of a nation-state at the beginning of the nineteenth century. In the U.S., however, the risks posed by inland floods and coastal storms vary extremely from place to place, and flood and coastal storm management did not become a central concern of the federal government until well into the twentieth century.

In spite of such stark differences, both countries also have a great deal in common as their water management strategies have evolved. They each developed advanced market economies and, over time, grew into prosperous democracies imbued with Western values. In science and technology during the nineteenth century, the U.S. was inspired by European developments. This knowledge transfer reversed in the first decades of the twentieth century, as America became—at least in the eyes of many European intellectuals—the paradise of modernity and scientific progress. The post-1945 period is even frequently labeled by Dutch historians and sociologists as the "Americanization" of the Dutch society.

What, then, are the key similarities and differences between American and Dutch water resources management that have evolved over the past two centuries? Though direct collaboration between the two countries was relatively rare, the evolution of water resources management in both was driven mainly by the same factors—relative prosperity and industrialization, evolving technology, and the professionalization of engineering. These changes played out in parallel over the course of four distinct periods or phases. The first period

(1800–1860) marks the start of national water resources management within certain legal, administrative, and financial limitations. The second period (1860–1900) can be characterized as one with a liberal state experiencing an expanding world market, increasing industrialization, and growing infrastructure. The third period (1900–1970) was informed by big government and technocratic scientific engineering. Finally, the fourth period (1970–2010) reflects the rise of environmentalism and public involvement in the decision-making process. Both national water management services—the U.S. Army Corps of Engineers and the Rijkswaterstaat—have existed for more than two hundred years and have developed a number of similar institutional traits as engineering services.

EMERGENCE OF NATIONAL WATER MANAGEMENT (1800–1860)

Water management on a national scale emerged in both countries around 1800, with the Rijkswaterstaat being established in 1798 and the Army Corps of Engineers in 1802. For both countries this was a transformative era. The Netherlands entered a phase of centralization and nation-building, while the U.S. attempted to work out the power relationship between national and state levels of government within the newly established federal system. Both political cultures were imbued with the spirit of the radical Enlightenment. The American and Dutch constitutions testified to the persuasive power of enlightened ideals, and because of their emphasis on universal rights, both nations inherently had a great deal in common. The American constitution, however, generally seemed to place restrictions on federal activities beyond strictly prescribed limits. The 1798 and later Dutch constitutions, on the other hand, did not include this restrictive perspective.

French engineering organization and culture shaped both the Army Corps of Engineers and the Rijkswaterstaat, and that influence lingered into their first decades. Engineering students in the U.S. trained at the Military Academy at West Point, an institution founded in 1802 and modeled after the French *Ecole Polytechnique*. Thus, the Corps, from its earliest history, was staffed by engineers trained with a broad formal and theoretical education.

Similarly, the Rijkswaterstaat's engineers were organized in a corps of engineers, established in 1816 and modeled after the French *Corps des Ponts et Chaussées*. While a rigid hierarchy was enforced and ceremonial uniforms introduced, this Dutch water management service initially did not set strict education standards. The service recruited military engineers trained at the various military schools but also brought in self-made men, and until the 1850s many high-ranking engineers had no theoretical training. Practical skills were held in high esteem. In the Netherlands, therefore, professional theoretical development took half a century or more to take shape. The Delft Technical College, founded in 1842, soon became the recruitment reservoir for the Rijkswaterstaat engineers. The Rijkswaterstaat also developed a unit of scientifically trained experts, "engineers in general service," and it further strengthened its knowledge base by collecting water-level data and soundings. Through the course of the nineteenth century, these data collection efforts were gradually extended to address coastal phenomena (river flows, tides, and high water data) and offered rich training opportunities for young engineers. The Corps of Engineers offered a similar experience for young engineers in the performance of surveying and mapping duties.

These investments in knowledge and expertise were crucial to both services in order to perform at effective levels. From the beginning in 1798, the Rijkswaterstaat was assigned a broad spectrum of tasks ranging from navigation and flood management to infrastructure projects, including road building, reclamation projects, and research. Few contested this broad mandate in the political-administrative arena, although repeatedly conflicts arose among the Rijkswaterstaat, the provinces, and the water boards over the extent of national interference in the regional water management domain; and the regional and local stakeholders usually had considerable impact on the decision-making processes. On the whole, water boards and provinces continued to play an important role in local and regional water management while still respecting the Rijkswaterstaat's national tasks. Moreover, in 1819, due to a structural budget crisis, the maintenance of many of the Rijkswaterstaat's water management works were transferred to the provinces, and many of the Rijkswaterstaat's engineers entered into provincial service, thus compelling them to adopt a double loyalty. This ambiguous situation ended in 1876.

The civil works program of the Army Corps of Engineers was, until the end of the Civil War in 1865, limited in scope by Congress and the executive branch. Even though the War of 1812 exposed the military problems created by an inadequate transportation infrastructure, strict constructionist views concerning the limits of federal power hindered congressional efforts to fund public works. After much debate, Congress passed the General Survey Act of 1824 and embraced navigation improvements, surveying of roads and canal routes, and cartographic projects (ancillary to navigation) as legitimate federal interests that promoted trade and commerce and served national defense. Congress even permitted the federal government in 1825 to purchase stock in private canal companies. And so the federal field of action expanded on a gradual basis. In the 1840s, Congress even allowed the sale of public lands to states to raise funds for specific local improvements, including transportation and irrigation projects.

In addition to the General Survey Act, a Supreme Court ruling, *Gibbons v. Ogden* (1824), opened the way for the Corps' continuous involvement in water-related civil engineering projects. However, the executive branch and Congress limited the scope of the Corps' activities to a select number of building projects and maintenance tasks. Moreover, in 1838 a second federal water management service entered the stage: the Corps of Topographical Engineers. Previously, between 1818 and 1838, the topographical engineers constituted a bureau within the Corps of Engineers that performed cartographic work and, after 1824, conducted river and canal surveys, built lighthouses, and carried out river and harbor improvements. In 1838 Congress established the "topogs" as a separate corps. In addition to the range of congressionally authorized public works related to water resources development assigned to the topogs, the secretary of war, within the executive branch, directed them to play an important role in exploration and railroad survey operations in the western territories. Meanwhile, the Corps of Engineers necessarily focused its work on coastal fortification.

In 1852, however, the role of the Corps enlarged yet again, as Congress directed the War Department to start an extensive public works program. Secretary of War Charles M. Conrad divided the projects between the Corps of Engineers and the Corps of Topographical Engineers based on a geographical division of the work—the former conducted improvements on the Atlantic and Gulf coasts, while the latter remained in charge of the Great Lakes and western rivers. During this period, the two engineering services operated on an equal footing.

The emphasis on limited federal government was a strong impediment to Congress supporting and funding infrastructure development unless national economic benefits seemed worth the effort, such as building the national railways. Moreover, Congress was anxious not to disregard local and state interests and to spread among them a substantial share of federal water management projects. Pork-barrel politics had, as a budgetary distribution mechanism, much more impact in the U.S. than in the Netherlands.

The more cautious embrace of limited government in the Netherlands regulated the scope of national administrative tasks as well, at least until the 1880s. But water management on a national scale had not only a solid constitutional underpinning, it was also strongly supported by King William I, who was the dominant political power until his abdication in 1840. The authoritarian king kept Parliament in a weak position—unlike in the U.S. where Congress was a powerful actor—while he closely monitored national assistance to water management projects. King William linked his program of economic modernization to infrastructure development. Under this royal aegis, the Rijkswaterstaat was able to strengthen its position and consolidate long-term project budgets without too much opposition from Parliament. The Rijkswaterstaat undertook during this period numerous canal works, a road-building scheme, and huge reclamation projects, such as the successful reclamation of the Haarlemmer Lake using steam-powered pumps. River projects generally lagged behind these ambitious infrastructure projects. The river projects were subject to a prolonged clash of views between the experts centered on two conflicting options: relying on spillways and diversions or undertaking systematic normalization. The Rijkswaterstaat ultimately gave priority to normalization projects where periodic inspection, systematic surveying, dike emergency surveillance, and river mapping contributed to a growing river zone expertise within the organization. Coastal management remained, to a considerable extent, the domain of local water boards and provinces except for the extremely vulnerable coast defenses in Zeeland.

LIBERAL ERA (1860–1900)

At the middle of the nineteenth century, both nations were entering a new era. A wave of liberal revolutions swept Europe in 1848, creating turmoil but also generating economic and political ideas that pervasively influenced a number of European countries. During this liberal era, trade tariffs were removed and world trade was expanded; hence, more transport facilities, such as harbors, canals, and navigable rivers, were needed to accommodate the increasing volume of trade.

The 1848 European liberal revolution also had a profound impact on the Netherlands. A liberal constitution came into force, and the position of the Dutch king changed to that of a head of state with limited political power. The power balance shifted to the government's ministers, who, in turn, were now controlled by Parliament. The rising ministerial power meant the Rijkswaterstaat's top engineers were able to increase their influence as advisors to the ministers in water management and infrastructure projects.

Economic liberalization, of course, also had a great impact on the United States. The U.S. made an economic leap forward after the destructive Civil War (1861–1865). The so-called Gilded Age that followed was a period of rapid economic and technological progress. Federal government expansion now had substantial political support, and the Corps was positioned as a central actor in water management projects. As an efficiency move, Congress merged the Corps of Topographical Engineers into the Corps of Engineers in 1863. However, the Corps, while still a leader in America's professional engineering field, faced increasing competition from civilian engineers who were trained in American colleges that had begun offering civil engineering courses in 1835. These civilian engineers also established the American Society of Civil Engineers in 1852, an event that further stimulated the professional development of engineers.

The Dutch engineers had set up their own professional organization five years earlier, in 1847, as the Koninklijk Instituut van Ingenieurs (Royal Institute of Engineers). Foreign travel, along with publication of handbooks and scientific journals, expanded international knowledge in the engineering communities in both countries. In the 1850s, a new generation of theoretically trained top managers took the lead in the Netherlands, further developing the knowledge already based in the Rijkswaterstaat. The secondary school of the Higher Burgher Schools created a reservoir of well-trained technical experts, as did the Trade Schools for laborers and the lower level technical staff at the Rijkswaterstaat.

In the late nineteenth century, the Corps continued to carry out numerous river and harbor improvements around the United States. It entered the field of canal construction and began to master the technology of navigation locks and dams. Two decades of navigation projects ensued, which helped fuel rapid economic expansion. The Corps built wing dams, removed rock and snags, and dredged channels to improve navigation on such important rivers as the Mississippi, Ohio, and Columbia and their tributaries. To learn about the most modern construction techniques, the Corps sent engineer officers to Europe to inspect jetty systems and other engineering practices, including the use of fascines (wooden mattresses), widely used in the Netherlands to construct jetties and to stabilize riverbanks. In general, after some experimentation, Corps engineers favored the British method of building jetties with concrete and massive stones. On the whole, bilateral contacts between American and Dutch engineers remained sparse. J. A. Beijerinck's advice on the drainage and reclamation of the swamps near New Orleans is one of the few examples indicating Dutch interest in American water management projects.[1]

In the United States, federal commitment to flood control projects was limited until the twentieth century. From the 1850s onward, the federal authorities offered aid through the transfer of federally owned swamplands to the state to finance drainage projects and levee construction. However, state and local authorities still shouldered the lion's share of the burden. After the 1860s, federal policy began to evolve, with two key reports playing a crucial role in this change. Charles Ellet, Jr., a prominent civil engineer, presented a research report and a comprehensive flood control plan for the Mississippi River basin in 1852. Nine years later, the Corps' Andrew A. Humphreys and Henry L. Abbot made an even more impressive contribution through their exhaustive hydraulic investigation of the Mississippi River. Their report, the Delta Survey, recommended the construction of a general levee system, supported by a few natural outlets, as the core of a river flood management strategy. This comprehensive report garnered worldwide recognition.

Although the scope of and spending on federal river projects in the U.S. grew in the last quarter of the nineteenth century, comprehensive development plans drew little support in Congress, which kept close control of the budget, making only year-by-year appropriations. Floods continued to inundate riparian farmlands and river cities, especially along the lower Mississippi River, but the damages, though sometimes severe, were regional in impact, so Army Engineers generally pursued regional flood management measures. Also, the economic interests of both agriculture and industry stimulated river improvement and harbor projects, with interested parties emphasizing the importance of navigation on waterways as competition to railroads in an effort to bring down shipping rates.

Over in Europe, after a few decades of dwindling impact in the mid-nineteenth century, the Rijkswaterstaat was rejuvenated by raising its professional standards and by undertaking the management of a huge river improvement system. After decades of disagreement, experts reached consensus in 1850 on an improvement plan based on systematic normalization, along with jetties, a few major outlets, and levees. Normalization required the Rijkswaterstaat to determine a regular navigation channel for each river section and then reshape the channel in accordance with fixed (normal) widths.

A sense of real urgency drove Dutch river projects: floods repeatedly wreaked havoc, and Dutch and German navigation interests lobbied successfully for improved navigability in the branches of the Rhine. Political consensus and an increased number of balanced state budgets allowed proponents to finance the projects with long-term project funds.

Dutch and American river projects were conducted with a similar but not identical technical repertoire. Channel confinement was a primary objective in both countries, aiming to speed up the flow of water and thus deepen the navigation channel. Tools used by the Americans—the use of sediment in spur dikes or wing dams to narrow the channel—were generally not used by the Rijkswaterstaat. Instead, before 1850, the Dutch constructed a number of lateral diversions to move high flows and store flood water temporarily in thinly populated polders. Due to the unsatisfactory results of these efforts, the Dutch turned instead to single navigation channels and normal river widths on the one hand and the construction of river outlets on the other.

During the late nineteenth century, the Dutch engineers, like their American counterparts, made study tours abroad: they visited Britain, France, and Germany to review river normalization projects. Although river engineering was emerging as an international field of knowledge—with handbooks, travels, and journals used to collect and disseminate expertise in both the U.S. and the Netherlands—solutions were generally project specific and driven by local geographical and hydraulic challenges.

The collection of hydraulic data, including water heights, flow velocities, and discharges, gradually helped the engineers make their normalization designs more effective, though this learning process was tiresome. As an example, the construction of the Rotterdam New Waterway proved a frustrating experience. The project leader, Pieter Caland, predicted that tidal scour would create a navigation channel of sufficient depth; but his supposition proved erroneous, and extensive dredging was necessary. Until the 1920s, tidal mechanisms were not very well understood. Achieving consensus with local interests was also no simple task. The Meuse Project (1885–1904) crowned the nineteenth-century projects with its use of mechanical and dredging equipment, but it also illustrated the complex process of trade-offs with local stakeholders, which slowed the construction process.

Dredging technology became a key success factor in these river improvement projects and also in the construction of the North Sea canal, which created a new waterway to the Amsterdam harbor. One of the benefits of this project was that British harbor and dredging know-how was transferred to the Dutch. Dredging capacity increased spectacularly due to innovative dredge designs, which were also developed in both countries. Dredges became the most effective mechanical tool to deepen low-water channels and to create harbor entrances, as in Rotterdam's New Waterway. Dredging also exemplified the overriding importance of steam power in this era. At this time, dredging in the Netherlands was performed solely by the private sector, while in the U.S., the public sector played a much larger role. Because the Mississippi River Commission concluded that dredging was the most cost effective tool for maintaining navigability on the rivers under its purview, it built a small fleet of dredges. The private Dutch dredging sector, on the other hand, laid the foundation in the late nineteenth century for the Netherlands' worldwide prominence in dredging projects after 1900.

The Corps' prestige grew after 1850, but its military engineers did not enjoy a monopoly on federal water management projects. After 1879, Congress set up the Mississippi and Missouri River Commissions in which the Corps shared responsibilities with civilians and, in the case of the Mississippi River Commission, with an officer of a rival federal agency, the Coast and Geodetic

Survey. On the whole, throughout the late nineteenth century, the Corps of Engineers saw its primary missions expand. In the 1880s, it assumed lock operation and maintenance duties on a number of rivers, which gave its presence there a continuous character. Around 1890, the Corps received authority to inspect bridges to ensure they would not obstruct navigable waterways.

The Rijkswaterstaat's position was relatively strong at the turn of the century. It had accomplished a number of large river and harbor projects, created the structure to maintain these works, and expanded its bureaucracy. But provincial and local water managers were not marginalized. New water boards were founded, mainly in the eastern part of the country, to carry out water resources management in the agrarian regions in the east. Additionally, provinces set up public works agencies, thus taking over the Rijkswaterstaat's provincial tasks. The new delineation of roles was laid down in the 1900 General Law on Water Management.

In the nineteenth century, the Corps of Engineers and the Rijkswaterstaat contributed substantially to the development of the modern nation-state, mainly by creating modern transport networks and thus stimulating national integration, economic modernization, and industrialization. The Corps, more than the Rijkswaterstaat, assumed a role alongside other federal agencies. Both organizations stimulated innovations in dredging technology, canal building, and river engineering. Numerous river and harbor improvement projects facilitated inland navigation and sea transport, and thereby strengthened economic growth in both countries. The Rijkswaterstaat played an even larger role in economic modernization as it not only built canals and undertook river projects but also developed a national road network in the 1820s and 1830s and a railway system (in cooperation with military engineers) from 1860 to 1890. Even if the impact of their work differed, the Corps and the Rijkswaterstaat both symbolized the expanding state, a phenomenon that was clearly visible at the century's end.

TECHNOCRATIC ERA (1900–1970)

The early twentieth century ushered in a period of sustained economic and social modernization to both countries at a greatly accelerated pace. Large enterprises operated on an increasingly bigger scale in a much more globalized world market. Research and development became intertwined with marketing and sales. As a result, a technological dynamic emerged where planned investment in research and development resulted in a continuous stream of new products. Growing prosperity created an expanding middle class of consumers willing to buy new products. During this period, the U.S. became the world's largest economy.

The industrialization of society had serious side effects: population pressure in growing cities, increasing pollution, sanitation issues, and infrastructure challenges. To address these problems, a group of professionals came to the fore, comprising engineers, architects, and scientists, who offered solutions based on scientific knowledge and organizational efficiency. Planning of urban public spaces became a pressing issue and a major focus of reform. Scientific experts infused policy making and bureaucratic processes with knowledge and planning concepts, and engineers were a major part of this emerging technocratic elite. This progressive movement also influenced Dutch social reformist groups, such as radical liberals and social-democrats. The dazzling pace of industrialization uprooted the traditional social fabric; but pillarization—dividing Dutch society into ideological blocks or "pillars"—offered a new backbone of stability. Dutch engineers, architects, and zoning specialists began to play an important role in urban and spatial planning and in infrastructure and water management, but pillarized ideological views had little impact on water management policy. Engineers and other technical experts seemed to transcend these ideological divisions; their influence was growing, largely due to their demonstrated scientific skills.

At the end of the nineteenth century, civil engineering entered a long transformative period. New materials, notably reinforced concrete and steel, were used to build structures like bridges, weirs, sluices, breakwaters, piers, and bank revetments. Theoretical scientific knowledge, derived from mathematics, physics, coastal engineering, and geodetic engineering, increasingly underpinned engineering designs, making them more reliable and quantifiable and their performance more predictable. Tidal research, fluid mechanics, soil mechanics, and many other theoretical fields began to mold the engineering practice. Electricity became a key technology with a wide range of applications. Modeling and testing procedures were also developed and enhanced. The improved science and new technologies had a major impact on both organizations.

The Rijkswaterstaat began to amass scientific knowledge in new specialist departments. Across the Atlantic, the Waterways Experiment Station, established in 1930 as the first federal hydraulics research laboratory in the U.S., made groundbreaking contributions to the field of hydraulics. The Corps also initiated the systematic collection of hydrographic and flood-hazard data and the preparation of related maps. In the 1890s, the Corps began to use concrete in jetties, harbor piers, and bank revetments, and steel in lock gates and dam crests—innovations that were inspired by European examples. Dam technology changed profoundly as the use of reinforced concrete enabled the design of large-scale dams.

A desire to make more efficient use of public lands resulted in the creation by Congress of the Bureau of Reclamation (1902) and the U.S. Forest Service (1906), with both agencies playing an important role in water management projects. They also were lead actors in the move to espouse the new concept of multipurpose river development, which saw irrigation, flood control, navigation, hydropower, and urban water supply as related interests. This new framework envisioned each of these concepts combined or reconciled in water management projects. The introduction of the concrete dam also facilitated implementation of the multipurpose philosophy. Large-scale dams enabled the control of major rivers and efficient use of water resources for multiple purposes, such as flood control, hydropower, irrigation, and navigation.

In the United States, the introduction of multipurpose river development led to new demands for scientific understanding and data acquisition. In addition, cost-benefit analyses arose as another tool to assess public benefits of planned projects. The emphasis on cost-benefit assessments can be attributed to a critical attitude towards government that was, and still is, deeply ingrained in American culture. This multipurpose water resources management philosophy, coupled with cost-benefit analysis and attention to environmental impacts, signaled a profound conceptual shift from single-purpose projects to multi-functional water resources development plans and was the beginning of an integrated approach to water resources management.

Naturally, its adoption as a conceptual framework was neither effortless nor immediate. The Corps had to shift emphasis away from its historical single-purpose (navigation) approach, and for a long time, states remained distrustful of a greater federal role in water resources development. In 1925, Congress directed that the Corps and the Federal Power Commission jointly make cost estimates for surveys of navigable rivers and their tributaries where power generation appeared feasible and could be developed in conjunction with flood control and irrigation projects. Congress then directed the Corps to carry out the river survey program, collecting socio-economic, scientific, and engineering data. The results became known as the 308 Reports, named after the number of the House of

Representatives document in which the survey estimates first appeared. These reports had far-reaching consequences: they laid the foundation for the planning and budgeting of water resources management for the next several decades and provided the basis for many New Deal and postwar dam construction projects. Under the aegis of multipurpose planning, the Corps went on to build a number of impressive dams.

The Grand Coulee, Bonneville, Hoover, and Fort Peck dams showcased the growing engineering skills of the Corps and the Bureau of Reclamation. These huge and complex construction projects also demonstrated the application of major technical innovations. The expansion of public sector hydropower development also fit into President Franklin Roosevelt's New Deal, his response to the Great Depression of the 1930s. One of the new government agencies that built dam projects—the Tennessee Valley Authority (TVA)—sought to integrate water uses, from hydropower to flood control, and to foster economic development in the Appalachian region. In the late 1930s, the Roosevelt administration attempted to centralize water resources planning on major river systems under government planning boards. Congress, however, refused to set up TVA-like basin planning in key river basins around the country. Thus, federal planning power in the U.S. remained more restricted than national planning in the Netherlands. Unlike the Rijkswaterstaat, the Corps never achieved a dominant position in nationwide infrastructure planning or project management, but because of its close relationship with Congress, it kept its relatively strong position relative to the other water resources management agencies. As one potential tradeoff, this relationship with Congress also meant close congressional control and oversight of the Corps' activities.

The multipurpose philosophy simplified and facilitated the adoption of flood control measures in water projects. A number of major floods in the Mississippi and Sacramento river basins led Congress to formally accept flood control as a federal responsibility and, ultimately, to assign this important mission to the Corps. But the same multipurpose approach had an impact on the repertoire of flood management measures. After the major 1927 flood in the Mississippi region, the "levees only" approach, which was official policy until 1927 (although not very strictly applied), was replaced by one favoring the use of a variety of structural measures such as levee building, the installation of floodways and spillways, the diversion of flood waters, and the construction of dams on upstream tributaries. Local authorities, however, still had to maintain and operate non-reservoir works such as levees—in contrast to the Dutch system in which the Rijkswaterstaat performed both the operation and maintenance of all the works it had constructed. In 1955, a broad range of emergency flood response measures were added to the Corps' flood control tasks. These included evacuation planning, emergency response measures, and post-disaster recovery efforts.

Over time, multipurpose water resources projects in the U.S. expanded in scope, and planners began to account for aspects of conservation, pollution control, water supply, and recreation. Environmental considerations had previously surfaced with legislation in 1934 requiring the protection of valuable fisheries. This requirement led the Corps to establish a fisheries research program in conjunction with the construction of Bonneville Dam. The Corps later expanded the program along the Columbia River in the 1950s.

In the Netherlands, multipurpose planning did not take root as a conceptual framework for all water resources management projects. The lack of hydropower potential played a role in its absence, and the weaker resonance of cost-benefit optimization concepts was also important. Nevertheless, cost-efficiency assessments were not unknown to the Dutch. They had played a role in nineteenth-century canal projects, for example.

The largest Dutch projects were not related to massive dams, as they were in the U.S., but instead were comprehensive planning and building schemes. The first twentieth-century example was the Zuiderzee Project. To be sure, seven decades of debate were needed to finally arrive at the 1918 parliamentary decision to embark on this huge and pioneering mega-project. It was designed by Cornelis Lely in 1891, who, as a government minister, was able to realize his own engineering dream. Lely understood that moving forward would require an enclosure dam to close off the Zuiderzee and that the reclamation of four polders would have to provide sufficient safety from the sea and adequate fertile agricultural soil. As the project developed, other requirements were added in the areas of freshwater capacity, recreation, housing, and, finally, environmental protection in response to new societal demands. The Zuiderzee Project was transformative. It was the first national comprehensive scheme with such a long planning horizon, and it required careful cooperation among engineers, architects, planning experts, agronomists, sociologists, anthropologists, and others. Unfortunately for the Rijkswaterstaat, a dominant conservative attitude within that organization caused it to be passed over and not directly involved with the work. The project instead was commissioned to an *ad hoc* organization established specifically to manage the operation—the Zuiderzee Service—in cooperation with the Wieringermeer Service, which was in charge of the polder design.

The planning process and the resulting enclosure dam became a milestone in modern Dutch engineering. The future tidal regimes, flow patterns, and storm surge levels in the area of the dam were studied in a physical-mathematical model; research that resulted in realignments of the dam. Engineers tested the designs and dimensions of the discharge gates in the sluices at the Karlsruhe Hydraulic Laboratory, one of the earliest incidences of hydraulic research by the Dutch. This research had an important impact on costal engineering and hydraulic modeling in the country. The Zuiderzee polder development also involved a high degree of planning, not only of the polder space but also in regards to selection procedures in advance of the polder's settlement.

In fact, in the Zuiderzee Project, technocracy reigned fairly freely until other stakeholders, such as conservationists, recreation interests, and water enterprises, began to articulate their views. In this sense, a Dutch variant of multipurpose planning can be identified, albeit minus any strict application of cost-benefit criteria.

The IJsselmeer Lake provides another example of Dutch multipurpose efforts. As its primary purpose, the lake provided a strategic freshwater reservoir, but the Rijkswaterstaat developed a national water resources management view to link its future use to water resources planning, Rhine navigation, and the prevention of salt-water intrusion. By building three weirs, engineers were able to control the water quantity in the Rhine branches and, consequently, in a lake that held a substantial part of the nation's freshwater. This effort represents another early Dutch attempt at an integrated water resources management approach. Environmental concerns focused on salt intrusion from the sea and salt emissions from the Rhine (and to a lesser extent chemical emissions), both of which helped create a growing awareness of water quality issues. On the other hand, conservation and wildlife advocates were less influential in the Netherlands than they were in the U.S., at least until the late 1960s.

In the 1920s and 1930s, coastal management became a much more prominent issue in the Rijkswaterstaat. In contrast, in the U.S., federal assistance for coastal management remained limited, leaving this responsibility to states and local communities. In this field, accumulated scientific knowledge provided Dutch engineers with tools to understand tidal regimes, storm surges, and other coastal phenomena. This understanding eventually fostered new plans to raise the safety level along the coastal zone and counter saltwater intrusion. They included, most notably, enclosure dam tidal modeling and Johan van Veen's proto-Delta plans.[2]

However, the 1953 coastal storm in the Netherlands shattered confidence in traditional risk philosophy and safety measures and served as a galvanizing event to rally support for a new direction in flood protection—a new safety strategy to minimize flood damages. The resulting Delta Plan recommended estuary closures, based on the Zuiderzee enclosure dam experience. The plan was inspired by Van Veen's original ideas but also required many innovative closure techniques. Each enclosure method and procedure was an "on-the-spot" innovation and served as a learning example for the next project. While ultimately successful, the Delta Works required a long learning curve.

As one result of the devastating floods, a new probabilistic risk philosophy set very strict safety standards for the Netherlands. A dike failure chance of 1:10,000 per year for the Holland provinces in the core was established, with 1:4,000 per year the standard for the remaining coastal zone, except for a failure chance of 1:2,000 for most of the Wadden Isles.[3] Structural measures (mainly robust dike strengthening schemes) were at the heart of this flood-safety approach, a somewhat single-purpose effort that prevailed in the Netherlands. In contrast, the Corps of Engineers in the U.S., which faced a serious and more varied but not existential threat, opted for an assortment of new floodplain management approaches—such as building stronger levees, advancing local zoning measures to restrict floodplain occupancy, and developing advanced early warning systems.

In the U.S. federal government, no single department or agency had the lead responsibility for water resources management. As of 1986, ten federal organizations were recognized as having a significant role in some aspect of national water resources management.[4] This division of responsibilities, coupled with an annual appropriations process, made long-term and holistic planning of water resources and river basins a challenging and often ineffective process. The situation in the Netherlands was much different, with the Rijkswaterstaat assuming an increasingly dominant role in areas such as road building, coastal and river engineering, and related research. Trade-offs with other water management interests and administrative stakeholders remained important but did not impede the Rijkswaterstaat's rising stature. The service managed to safeguard its long-term budgets and to design and execute long-term programs in road building and the Meuse River and Delta Works projects.

Between 1945 and 1973, both countries experienced a period of sustained economic growth and prosperity. During the postwar period, the authority of the U.S. and Dutch governments expanded significantly, although the Corps experienced more restrictions than did the Rijkswaterstaat. Both entities were regarded as successful problem-solving organizations, and the public had confidence in their engineering expertise. However, growing concerns in the U.S. regarding resource depletion, decreased water quality, and growing risks to endangered species prompted a new environmental research program and associated mitigation measures. In the Netherlands, environmental concern was mainly restricted to saltwater intrusion along the Rhine, which was investigated by the International Rhine Commission, but, steadily, this concern broadened. The chemical industry had developed quickly after 1945, and its side effects were becoming increasingly serious in both countries. The toxic effects of DDT, brought to light in Rachel Carson's *Silent Spring*, helped galvanize the growing environmental movement, which consequently had a huge impact on water management and water management organizations. Water pollution, especially, became a hot issue for the general public.

ENVIRONMENTAL ERA (1970–2000)

The protest generation of the 1960s demanded more individual freedom, attacked consumerism and pollution, and harshly criticized the bureaucratic and technocratic management styles that dominated business and public authorities. This vehement wave of criticism had a huge impact on water resources management, as well as on the Corps (and its fellow federal actors) and the Rijkswaterstaat. Both agencies experienced a loss of public support, being labeled as technocratic bastions that were out of touch with society. In response, they had to adjust to a rapidly changing societal climate and adopt new environmental values; in addition, they had to develop wholly new approaches to dealing with the public. In both countries, environmentalism led to new legislation aimed at reducing water pollution, protecting natural resources, and promoting biodiversity.

The Corps accommodated this ecological turn earlier than did the Rijkswaterstaat. The Corps' experience with multipurpose planning made the adoption of environmental values easier in the U.S. than in the Netherlands, where a single- (or dual-) purpose focus on safety (and navigation) predominated. In the 1960s, the Corps began to recruit biologists, landscape architects, and environmental scientists—a full decade earlier than the Rijkswaterstaat. The U.S. also moved ahead with its interagency procedures for water project planning (introduced in 1962 at the federal, state, and local levels) and the expansion of multipurpose planning to include recreation and water quality aspects. The 1964 Water Planning Act created the Water Resources Council, which was charged with establishing river basin commissions to coordinate water resources development with a basin-level approach. Nevertheless, at the federal level, the president, Congress, and other agencies maintained their dominance over the river basin commissions.

As a reflection of the growing environmental movement, Congress enacted the National Environmental Policy Act in 1970. This seminal legislation required a new type of regulatory evaluation in the form of an Environmental Assessment (EA) or a more detailed Environmental Impact Statement (EIS) on the relevant environmental effects of any proposed federal project or undertaking. These evaluations, which also considered potential mitigation alternatives to reduce the impact of proposed projects, brought about a new era in environmental investigation, research, and mitigation of detrimental impacts. Fulfilling the requirement to consider protection of the natural environment as a significant criterion in project planning and funding required a somewhat difficult adjustment for all public agencies and private industry in the United States.

Water quality issues were of special concern to the American public. The Federal Water Pollution Control Act Amendments (Clean Water Act) of 1972 established a goal of making the waters of the U.S. suitable for fishing and swimming, an ambitious target that reflected the new emphasis placed on environmental issues by the public and the government. The new regulations brought new responsibilities to the Corps of Engineers. Section 404 of the Clean Water Act required a new permitting process for the disposal of dredged materials in the nation's waters and by extension wetlands protection, a program to be administered by the Corps. The new legislation greatly expanded the Corps' regulatory responsibilities, which previously had only applied to navigation impediments. The problem of water pollution was addressed by prohibiting the emission of point source pollutants without a permit. The newly established Environmental Protection Agency (EPA) formulated environmental policy and assumed a monitoring role.

Even more integrated approaches to water resources management began to emerge, wherein economics, flood safety, navigation, energy, wetland conservation, recreation, and other interests were more effectively balanced. The adoption of environmental values in federal water resources management required a broadening of project scope—for example, adverse impacts of one part of a project were often counterbalanced by requiring restoration or other mitigation measures at another project location—and a greater reliance on multidisciplinary knowledge so that engineering and environmentalism could be reconciled. These changes also brought in new actors: environmental impact statements drew the public into the planning process. Technocratic project planning, imbued with engineering expertise and rational planning, had to be more flexible, and better communication skills and procedures were needed to respond to public opinion.

The environmental movement also had a considerable impact on the field of flood management, shifting emphasis from large protection structures like levees and reservoirs to nonstructural measures, such as relocation from flood-prone areas, flood-proofing buildings, protecting wetlands, and developing advance warning systems. Environmentalism also influenced navigation projects; for example, the Corps began to develop new disposal methods to minimize environmental impacts caused by disposing contaminated and non-contaminated sediments dredged from waterways.

The Netherlands introduced its Water Pollution Act in 1970 and tasked the Rijkswaterstaat with issuing permits to limit polluting emissions in rivers, the North Sea, the Wadden Sea, and the IJsselmeer. Polluters were fined, according to the principle "polluter pays." The 1986 Rhine Rehabilitation Plan, designed following the major Sandoz chemical plant explosion, prompted the Rijkswaterstaat to tighten its inspection role, and pollution was reduced drastically in the following decades. Wastewater purification stations appeared all over the country. Environmental impact statements were made mandatory in 1986, and public participation requirements were laid down in legislation. Consequently, the Rijkswaterstaat incorporated these aspects into their project planning procedures.

In addition to environmental and public participation legislation, the Eastern Scheldt project also transformed Dutch water resources management. Although this estuary was scheduled to be closed off according to the Delta Plan, environmental protests called for the protection of the Eastern Scheldt's unique aquatic biodiversity. Environmentalists established a coalition with regional fishermen who believed the closure plan endangered their livelihood. The leftist administration compelled the Rijkswaterstaat to work out an ecologically sensitive alternative to closure, and the use of new policy-making decision criteria led to a wide range of alternatives. After reviewing several options, the Rijkswaterstaat selected an open storm surge barrier, the design of which was further refined through partnerships with the private sector. Moreover, the Rijkswaterstaat learned to employ flexible planning by carefully considering the needs of its many stakeholders and by communicating with politicians and the public not only about the project itself but also about rising expenditures.

The implications of the Eastern Scheldt project were broad. On the basis of decision-criteria analyses and the ecological design process, the Rijkswaterstaat developed a water systems approach, leading to more integrated water management practices. Safe transport, water quality, recreation, fisheries, and many other issues were identified as important functions in this comprehensive water systems approach that all stakeholders recognized as a new frame of reference. Starting in the 1990s, this framework became widely used in projects of both the Rijkswaterstaat and the Dutch water boards. As in the United States, integrated water resources management emerged in the Netherlands as a response to challenges posed by the multiple stakeholders. In the U.S. this concept largely developed from NEPA, Clean Water Act, and Endangered Species Act regulations in concert with preexisting multipurpose planning criteria, whereas in the Netherlands it evolved from the Eastern Scheldt barrier ecological design process.

Unlike the Corps, the Rijkswaterstaat and the water boards were for decades unable to make substantial progress in river levee-strengthening projects. Here, the difference between a more flexible American multipurpose perspective and a Dutch single-purpose approach probably resulted in much more opposition from stakeholders in the Netherlands. In the eastern part of the country, for example, valuable houses located near levees were destroyed in levee projects that were commissioned by the water boards in the 1970s. Conservationists and the media vehemently opposed other levee-strengthening schemes that were meant to offer safety by constructing dikes having a 1:3,000 chance of failing or overtopping. In response to these massive protests, the Rijkswaterstaat changed the levee design standard to 1:1,250, but to no avail in terms of public opinion. The stalemate was finally broken by the 1993 flood and the 1995 near-flood. An emergency act—the Delta Plan Major Rivers—enabled the Rijkswaterstaat to execute a levee-strengthening scheme that also took into account land values. Additionally, a Flood Defense Act introduced five-year cycles of flood structure inspections in 1996. Meanwhile, the construction of the Rotterdam Barrier in the New Waterway offered a much higher degree of protection to the Rotterdam region and made a levee-strengthening proposal superfluous.

In the United States, the oil crisis of the 1970s, growing federal budget deficits, and a shift toward greater fiscal conservatism by the Reagan administration in the 1980s prompted an aggressive move towards greater cost sharing for water resources projects. The Water Resources Development Act of 1986 established cost-sharing requirements for many types of projects, including flood control. This shift mirrored the conservative philosophy of reducing the size and cost of the federal government. Whereas fiscal conservatism and its concomitant new public management philosophy had a considerable impact on the Dutch public sector, water resources management was less affected by this shift to fiscal restraint. While cost-sharing arrangements were not mandated in the Netherlands, they nevertheless began to materialize at the end of the century.

Until the 1990s, the role of the engineering sector and the construction industry in the execution of projects was clear in the Netherlands. The Rijkswaterstaat—and other water management agencies—developed the project plans and designs and contracted the execution out to the market, usually through competitive bidding. Because of the high-risk profile of the Delta Works project, the Rijkswaterstaat used consortia of contractors but did not always rely on normal bidding procedures. From 1962 on, framework agreements were concluded, serving to establish business relationships between Rijkswaterstaat and contractors, followed by detailed contracts that set the project construction specifications. But in more standard projects, bidding procedures were generally respected. The Corps of Engineers had periodically made use of "hired labor"—labor obtained directly by the government without working through a contractor—notably in the 1920s. But in response to mounting criticism and charges of government inefficiency, the Corps reverted to using contracts with commercial firms as the primary method to complete its projects. In contrast, the Dutch water management sector has been using contractors for similar work since the early 1800s.

A NEW CENTURY AND NEW CHALLENGES

Although this survey focuses on the period 1800 to 2010, certain recent trends have made impacts in the early part of this century. Changing roles and responsibilities related to water management, movement towards more integrative practices, and management of resources in an increasingly uncertain world are notable examples.

Over the last decade, the organizational roles and responsibilities in the field of water resources management have become increasingly shared between the public and private sectors, particularly so in the Netherlands. In the past, the clear and steady role delineation between the Rijkswaterstaat in designing, engineering, and bidding projects and the private sector in executing the projects helped strengthen the Rijkswaterstaat's position. However, a significant change occurred in 2004 when the Rijkswaterstaat began to outsource design of its projects to consultants and contractors. Consequently, commercial firms have produced many of the recent Dutch designs. Furthermore, the newly formed Deltares, an independent Dutch research institute that also has a nonprofit arm, now performs much of the research and development that was previously the sole domain of the Rijkswaterstaat.

Also, within the past few decades, Dutch water resources management has become increasingly shaped by European Union (EU) directives. Consequently, the Ministry of Transport, Public Works and Water Management lost part of its policy-making power. The EU Water Framework Directive (WFD), issued in 2000, laid down strict guidelines on the use of chemicals and for overall water quality of all European waters. EU water resources management policy implied, on the other hand, more active public participation procedures and co-governance processes in the establishment of river basin planning management. International and regional stakeholders were prompted to build coalitions. A catchment or watershed approach was not a new concept in Europe, as was demonstrated in the international Rhine and Meuse agreements of the 1970s, 1980s, and 1990s, but WFD catchment planning went a step further. All four catchments that are partially situated on Dutch soil—the Rhine, the Meuse, the Scheldt, and the Ems/Dollard—were included in the WFD initiative. The EU authorities, and not only the national governments, monitor the results of projects in the basins. Finally, all governmental layers and other stakeholders have to cooperate. Thus, the WFD involves a multi-governance approach.

Because of the need for European cooperation, the WFD approach differs from river basin planning in America, which is much less international in character. The U.S. and Canada have concluded some bilateral river planning agreements, such as the Columbia River Treaty in 1961, and the U.S. has also entered into river planning agreements with Mexico. In addition, various U.S. states have completed river basin and watershed agreements. Although the major commonality in river planning between the U.S. and the Netherlands is the catchment approach, the Netherlands deals with other state actors and international organizations to a much greater degree than does the U.S. On the other hand, this type of river basin management—developed in the U.S. in the 1960s and mandated by the 1964 Water Planning Act—also has a much longer history in the United States than it does in the Netherlands.

The emergency situation faced by the Netherlands in 1995 due to near-flooding in river zones that led to massive evacuations prompted the Rijkswaterstaat to develop alternative approaches to flood control. Climate change also triggered a conceptual turn. Climate scenarios forecast more frequent and more extreme flood levels in the future; and the Netherlands responded by raising the flood safety protection. Within a few years arose the "Room for the River" concept, which was adopted as government policy in 2000. The ministry's new motto became: "retention first, then storage, and if these instruments failed, discharge of flood water." Using a flexible set of tools, engineers lowered high water levels through levee relocation, the lowering of groynes, and the creation of spillways and bypasses, flood polders, and storage reservoirs. Additionally, environmental rehabilitation was incorporated into the flood safety program. The development and execution of these projects demanded close cooperation among the Rijkswaterstaat, provinces, municipalities, water boards, nongovernmental organizations, and private industry. Room for the River also combined river engineering with spatial planning and landscape development. In a number of projects, public participation had a considerable impact on the designs. Thus, Room for the River has become a test case for a more interactive governance style.

To a considerable extent, Room for the River can be interpreted as a Dutch version of U.S. multipurpose planning. Yet, there are also notable differences between the two. The range of purposes—safety, navigation, landscape protection, and environmental rehabilitation—remains somewhat restricted within the Dutch context, since energy and recreational purposes, for example, are not part of the overall strategy. Also, cost-benefit criteria have not been explicitly applied to the overall program.

For many decades, the U.S. had not experienced a galvanizing flood at the national level as the Dutch experienced in 1953. Then the Mississippi River flood of 1993, the most devastating natural disaster to strike the waterway since the flood of 1927, captured national attention. Post-flood analyses led to improved structural and nonstructural flood damage reduction measures on the Mississippi River but also marked the beginning of a serious discussion of changes in U.S. flood damage reduction policy. The 1993 flood also encouraged development of improved forecasting and warnings and rescue and evacuation methodologies. However, it took a coastal storm twelve years later to truly galvanize efforts at the national level.

In 2005, the U.S. experienced the tragedy of Hurricane Katrina, a storm that took the lives of more than 1,800 individuals and forced the development of a new flood-risk strategy. This disaster reminded the Dutch of their own 1953 catastrophe, which also had a huge impact on safety and flood-risk policy. In the aftermath of Katrina, the Dutch offered assistance, and a program of bilateral cooperation was established. But Katrina was also, in a sense, a wake-up call for the Dutch, and flood-safety awareness again became a leading public issue. Soon after Katrina, the Dutch government passed the Delta Act, the legal basis for a new Delta Program to address the accelerated sea level rise along the Dutch coast forecast by various climate change scenarios. This law encompassed measures for water safety and fresh water supply for the long term, up to the year 2100.

In the United States, the damage wrought by Hurricane Katrina resulted in the development of new methods for analyzing possible storm scenarios as well as new approaches to flood damage reduction based on risk analyses. Using this new risk-based approach, the Corps of Engineers designed and built large multi-billion-dollar flood protection measures for the city of New Orleans. Ultimately, Hurricane Katrina was a significant catalyst for planners in the United States and in the Netherlands, and consequently both countries are reshaping their water resources management approaches to address current and future challenges while also retaining important programmatic elements from the past.

A PRODUCTIVE WATER MANAGEMENT HERITAGE

Over the course of two hundred years, the Rijkswaterstaat and the U.S. Army Corps of Engineers have accumulated a large body of knowledge and expertise in water resources management. The scientists and engineers in both organizations became world leaders in their respective fields and established close and long-standing working relationships with universities, hydraulic laboratories, and specialized research centers to develop and apply innovative and effective scientific and engineering techniques to water resources issues. The intellectual capital assembled by the two organizations includes the development of technical solutions for a wide range of water issues, such as dredging; levee construction and maintenance; and the operation and maintenance of flood protection systems, dams and locks, and hydropower facilities. Cooperation between the two water management authorities along with citizens, private industry, and knowledge institutions such as universities remains imperative for the development of innovative solutions that address challenges such as climate change and the associated threats posed by sea level rise. In addition, planners on both sides of the Atlantic have to deal with the challenges inherent in addressing the needs caused by floods, droughts, fresh water supply, and satisfying the needs of the navigation industry.

Integrative designs are needed to rise to these challenges—not only because water problems have become increasingly complex, and thus need a comprehensive approach, but also to serve various regional and local interests and address public participation requirements. Hence, multipurpose solutions and integrated water resources management approaches remain important conceptual and administrative frameworks.

Future perspectives will likely make fruitful use of the policy options selected in the past, as most of these remain relevant. Geography is also an important factor. The essential features of rivers, lakes, seas—the landscape in general—tend to change slowly. As such, key water resources challenges, such as flood safety and availability of freshwater, have an inherent long-term character. However, demographic shifts, climate change, and a rapidly aging infrastructure are forcing both the Rijkswaterstaat and the U.S. Army Corps of Engineers to confront new challenges with some sense of urgency. When addressing these issues, planners cannot simply start over; existing water management policies, engineering decisions, and completed projects still in operation provide important ingredients for current and future policy decisions. A normalized river, for instance, will not return to its former "natural" course in the short term. Furthermore, engineering designs from the past are made according to some essential design principles, which have an equally stable character.

As historians in the U.S. and the Netherlands look back over two hundred years of water resources experience, several broad themes emerge. From the outset, the Corps and the Rijkswaterstaat demonstrated a sense of mission, an *esprit de corps* that fostered the establishment of sophisticated engineer organizations that developed the necessary technological expertise and organizational structures to design and manage large construction projects. Demonstrating a dedication to achieving workable solutions to specific problems, the two agencies built regional structures and displayed their technical skills to the public. But on both sides of the Atlantic, water resources managers rarely found that implementing their plans was easy or straightforward. Ultimately, the most successful projects involved a healthy blend of bottom-up commitment and support and a persuasive top-down professional expertise, as seen in the work on the lower Mississippi River in the U.S. and the Bergse-Meuse canalization project in the Netherlands.

The leaders of the Rijkswaterstaat and the Corps also learned that developing the necessary support for their water resources projects depended on establishing supportive, well-informed partnerships at local, national, and even international levels. Over time, the two organizations found that for a project to be truly successful, it was vital to reach a consensus that reflected the interests of all stakeholders. Hence, managers in both organizations embraced the necessity of coalition building. They also found that building these coalitions was easiest when a project combined multiple purposes—flood safety, energy production, navigation, recreation, or environmental protection—reconciled through multipurpose design. Water resources development, as it turns out, has a natural inclination toward an integrative approach. This trend became evident in the nineteenth century when planners combined the needs of flood management and navigation into their designs. Multipurpose planning continued to evolve in the twentieth century and in the 1970s underwent a significant transformation when environmental criteria were incorporated into the process. Today this concept, now known as integrated water resources management, or IWRM, is used around the world.

Responding to change is often difficult, and incorporating new operating principles, such as collaboration and multipurpose planning, sometimes proved difficult for both the Rijkswaterstaat and the Corps of Engineers. In addition, the two government engineering organizations proved initially too rigid when responding to the environmental movement's criticism of the technocentric mindset that tended to dominate their strategic thinking prior to the 1970s.

The evolution of multipurpose planning, along with the rise of a host of environmental concerns, brought new and complex challenges to the Rijkswaterstaat and the Corps of Engineers. There were also organizational questions to be answered. Beginning in the early 1980s, government planners, members of the scientific and engineering communities, and influential voices from industry began to question the leading role of the Rijkswaterstaat and the Corps of Engineers in water resources management. Concurrently, over the past decades both organizations have seen some of their engineering and research and development functions outsourced to academia and industry. This phenomenon reflects a long-term trend and may one day threaten to undermine the professional competence of both organizations.

The Corps of Engineers and the Rijkswaterstaat continue to adapt to the many environmental, technological, and organizational challenges. Integrated water resources management is emerging as a suitable framework to combine these intangible human perspectives and engineering science. To meet the challenges ahead, the two organizations must continue to develop new perspectives, skills, and technologies, while relying on the existing foundations of accumulated knowledge and expertise. While these qualities and attributes are irreplaceable, it is the capacities to learn, adapt, and deliver projects and services—proven over two hundred years of operations—that remain essential to the character of both organizations and necessary to meet the needs of present and future generations of both nations.

1 J. G. W. Fijnje, "Levensberigt van Frederik Willem Conrad, voorzitter en een der opgrigters van het Koninklijk Instituut van Ingenieurs en eene bijdrage tot de geschiedenis van den waterstaat van zijn tijd," in *Notulen van het Koninklijk Instituut van ingenieurs* ('s Gravenhage: KIVI, 1870), 187.

2 See Chapter 6, the sections on the Zuiderzee project and on High Tide of Coastal Engineering.

3 See Pieter Huisman, *Water in the Netherlands* (Utrecht: Netherlands Hydrological Society, 2004), Figure 5.1, p. 47. This map indicates the different safety standards for the flood-prone areas.

4 "A Unified National Program for Floodplain Management, 1986" was published by the Interagency Floodplain Management Task Force through the Federal Emergency Management Agency. The task force membership as listed on the inside of the front cover consists of the Departments of Agriculture, Army (USACE), Commerce, Energy, Housing and Urban Development, Interior, and Transportation, as well as the Environmental Protection Agency, the Tennessee Valley Authority, and the Federal Emergency Management Agency.

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