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**SUMMARY**

Minerva in the polder. Water management and technology in the hoogheemraadschap of Rijnland (1500-1856)

1. Introduction

This dissertation deals with early modern water management technologies (polder mills, sluices, dikes and roads which sometimes serve as embankments) in the so-called hoogheemraadschap van Rijnland, covering more or less the area between Amsterdam, Haarlem, The Hague and Gouda. It presents a contextual history of the mentioned water technologies between 1500 and 1856 and has three main goals. First of all, the book investigates the role of technology in water management on the Dutch countryside: did technology stimulate or hinder certain trends in the way man dealt with water? Or did a very complex process that found its origins in societal, economic and environmental evolutions have technological developments as outcome? Secondly, this study can be considered as a contribution to the debate on technological history of the Dutch Republic. What differences and similarities can be discerned between developments in water technologies and other fields of technology, for example ship building or navigation? Apart from the historical developments, one can also confront traditional explanatory models used in these fields with the findings of our research. Have the causality and arguments formulated by other historians any validity if applied to water technology, or did the latter follow its own path? Finally, this book contains a more theoretical approach to the subject. The analysis of early modern water management deals with the question whether or not a combination of the concept of Large Technological Systems (LTS) and the concept of circulation of knowledge enriches our understanding of the actual technological developments.

2. Research questions and setup

The first chapter of this study discusses the main features of the Rijnland region and the major developments within this area. It contains necessary information for the understanding of the rest of this summary. For that reason, it is welcome to look closer to chapter’s content. Water management was organized in a two-levelled structure: the hoogheemraadschap van Rijnland or regional water authorities (RWA) were in charge of water management and infrastructures of regional importance, for example the dunes, sea dikes and drainage sluices along the IJ (the only outlets for the whole area, see the map on page 30). The RWA also managed the regional drainage system. A very significant feature of the system’s structure was the Haarlemmermeer: a big inland lake that functioned as a reservoir where locally drained water could be stored before it ran through Rijnland’s sluices into the IJ. The lower level, in fact most of the local scale water management, was under control of so-called polders.
or local water boards (the role of ambachten can be considered less important). The majority came into being between 1580 and 1660; some were reclaimed lakes, but they were not so numerous in Rijnland.

The Rijnland region witnessed a complex and multifaceted social and economic transformation during the early modern times. Speaking in general terms, one can distinguish two phases. The first, commonly referred to as the Golden Age, a period of almost continuous growth, started at the end of the sixteenth century and ran up to about 1660. It was followed by an ‘age of crisis’.

The Rijnland area differed of course very little from the rest of the province of Holland as far as the more general societal developments are concerned. Both rural and urban population grew steadily from the sixteenth century onwards, which made agricultural commodities as well as fuel more expensive. Except for grain imports from the Baltic, the countryside could provide both: land was used for pasturage and for the extraction of peat. In such an economic environment, the traditional, sixteenth-century peasant, with his small mixed farm (both agriculture and small-scale peat digging) could survive quite easy. After 1660 however, the decades of economic prosperity were over: population figures started to stagnate and urban industries declined. This downswing affected the countryside very deeply because prices and land leases dropped dramatically. In fact, the crisis triggered a long process of social polarization and proletarization, starting after 1660 but continuing throughout the entire eighteenth century. On the one hand, the small peasant holding concentrating on cattle and small-scale peat digging experienced difficult times and was doomed to disappear. Lower prices threatened the livability of such family businesses; the situation got even worse because other dramas hit rural communities too, for example devastating outbreaks of cattle virus. Other, more structural, trends undermined the small farm as well. The lands could not provide any longer enough income since most private owned peat lands were completely exhausted and as a result the remaining lands were too small to live from. On the other side, the economic crisis offered chances for others. Some farmers were able to turn the situation into their advantage by innovating and by purchasing lands of the waning small farmer. Bigger commercial enterprises took the lead, landownership concentrated, remaining peat digging became ‘big business’, and in response to the agricultural crisis more extended farms emerged. In short, the farmer replaced the peasant and those with too little means to adapt were obliged to look for other incomes. Moreover, the urban elites eager to invest in landownership in the previous century now withdrew from landownership. The eighteenth century witnessed thus the emergence of a rural elite of more commercial farmers and a large group of proletarians.

Throughout the early modern period, the Rijnland region also experienced an extended environmental transformation. The Haarlemmermeer was more difficult to control and its size increased incessantly, despite the modernization of the sluices along the IJ in the sixteenth century. Besides peat digging near the borders, natural elements played a very destructive role. Winds drove the water to one border where the raised water level caused strong swells. The lake washed away the peaty lands and caused an immense devastation: even some villages disappeared in the lake. Nevertheless, the expansion of the lake had its advantages as well, because – from the local water management point of view – it increased the storage capacity. The construction of stone protection works at the most vulnerable spots (1766) stopped the lake’s expansion; a first step towards its reclamation in the first half of the
nineteenth century. The construction of a new outlet for Rijnland’s water near Katwijk was undoubtedly a precondition for this huge project (1807).

Chapter II provides the reader a literature-based introduction to general developments in early modern water technology. After discussing four specific technologies (drainage technologies, sluice building, dike and road construction), it compares general patterns in water technology with developments in ship building and navigation technology. It also draws some provisional conclusions on the characteristics of water technology.

The actual (archival) research uses a bottom-up perspective and presents a comparison of four micro studies, taking four polders and their local water boards as principal research units: the Vierambachtspolder and its predecessors, the Sloterbinnenpolder, the Lisserpoelpolder and finally a cluster of polders on the Zuidgeest, south of Leiden (see the map on page 30). The technological developments in these polders in relation to their historical context are the main focus in the rest of the book.

Chapter III starts with a detailed reconstruction of technological developments in each single case, while chapters IV to VIII constitute a thematic analysis of the context. Each of them explores a specific cluster of research questions. Chapter IV discusses land ownership, land use and land profitability. There are not only obvious and direct relations between land use and water technology, but these topics provide necessary elements for the following chapters. For example, when we consider the ownership of water board members, we can define the social background of the decision makers. The analysis of financial aspects is not accurate if data on land profitability based on rents and land leases are not taken into account. The next chapter focuses on decision making. Rules and regulations from the water boards themselves or from the RWA are one thing, but what was real practice like? How did people with different interests solve their problems? What was the role of the RWA considering its supervising position and its juridical powers? Chapter VI scrutinizes financial aspects of local water management, exploring short term and long term financing, the latter obviously in relation to agrarian conjuncture. Other questions are: what was the share of technology in the total amount of expenses? What dynamics appeared on the long term and how were they related to technological developments? The last but one chapter deals with labour organization. Windmill operators, carpenters, millwrights, dike workers but also land owners who were sometimes responsible for maintenance, were all important for operating, constructing and maintaining water technology. How did they influence technology? Could they stimulate or block innovation or not? In order to answer such questions, it is necessary to analyse their relation to local water boards, their labour conditions and for some of them their position on the labour market or their social status. Finally, technological knowledge is the connecting thread that runs through the concluding chapter. It investigates the social and institutional background of ‘knowledge producing’ people and the place of science in the process of innovation. Other questions concern knowledge itself: how ‘open’ was it, what kind of technological knowledge are we talking about and what role played knowledge in developing technology, considering its intrinsic characteristics? The ultimate goal is to track down patterns in which knowledge circulated and to define to what extent local water boards participated. Once these matters are clear, it becomes possible to relate technological developments and application of certain knowledge in the polder to circulation patterns.
3. Results and interpretations

Reconstruction of technological developments

In the beginning of the sixteenth century, only a few drainage mills and some polders existed in Rijnland: they were situated along the borders of the Old Rhine and close to Haarlem. The overwhelming part of the area still drained in a natural way. The real breakthrough of mill drainage dates from the second half of the sixteenth century (especially between 1560 and 1570) and consisted mainly of individually owned horse mills. The switch to wind mills took place in the last quarter of the century. It is worth mentioning that although the diffusion of mill drainage was a phenomenon with regional dimensions, local developments displayed very sharp differences mostly in numbers and types of mills. The emergence of polders resulting from collaboration between local peasants, started from the 1580’s.

During the so-called Golden Age (1580-1660), local communities embanked and drained nearly every square inch of Rijnland’s countryside. In some areas, for example in peat areas, establishing one polder led to the erection of another because non-embanked lands experienced water problems caused by polder drainage and thus had to be drained as well. In other areas, for example in the Zuidergeest (south of Leiden on the sandy soil near the dunes), polders grew more steadily beginning with smaller polders that successively expanded. Except for these ‘normal’ polders which were intended to improve the quality of existing lands, the same period also saw the reclamation of a few lakes. In this respect, however, Rijnland holds a rather modest place and the few examples of drained lakes are not comparable to the simultaneous spectacular achievements in other parts of Holland. Technological developments went hand in hand with this total reorganization of the landscape. Mills became bigger and aerodynamically better designed (for example the shape of the sails), although one has to interpret such innovations as modifications of existing technologies. Radical innovations were unsuccessful despite some new inventions. Two types of mills (the octagonal mill and the so-called wipmolen) equipped with scoop wheels remained dominant. Although the Lisserpoelpolder used the Archimedean screw successfully as an alternative for scoop wheels, its application would prove to be exceptional. It is difficult for this early period to draw clear conclusions about developments in other fields of water technologies (dikes, embankments, sluices or roads) because the archival sources remain too scarce and too vague. Nevertheless, one can fairly state that such technologies played a major role in the emergence of polders. Roads, for example, started to function as a polder’s embankment.

The year 1660 was a decisive turning-point. The process of establishing polders came to a halt, neither were there new lake reclamations. Yet, technological developments did not stop and the last decades of the seventeenth century could be characterized as a period of technological divergence between polders. In general it is right to say that some evolutions took place in every polder, but the extent and the tempo of these developments were very uneven. The nature of the evolutions also differed in comparison with the Golden Age: small innovations and improvements replaced the construction of new polders, mills and dikes (a process that can be considered as one of radical and comprehensive innovation). Specifications for the construction of sluices and embankments, for example, reveal changes in size, shape and materials. Nevertheless, the most important development was related to
the specifications which tended to become longer and more precise. Specifications for sluices comprised very detailed and elaborated descriptions about the exact measurements of certain parts and of the way they should be assembled. These developments could be tracked down for every technology except for roads which were by that time in bad condition. In some cases, the ambachten were in charge for roads that served as embankments and local water boards were thus unable to do something about the situation. As mentioned, technological developments consisted mostly of smaller modifications, but that does not alter the fact that sometimes big innovations took place. Especially disasters (inundations or mills that burned down) acted as triggers for more radical novelties. On the other hand, water boards could handle smaller problems (like unequal drainage) by altering the use and operation of existing technological infrastructures.

New dynamism began to dawn from the 1730’s onwards. Peat extraction had reached its zenith and had turned many polders into peat lakes. Their reclamation was not only large, capital intensive project but also meant a splendid opportunity to introduce new technologies, in particular new drainage devices. A lot of experiments with new inventions took place but in the end, they proved unsuccessful and the traditional scoop wheel remained most popular. Another eighteen century innovation implied the use of new materials (bricks for wind mill construction, instead of wood). This possibility was discussed in nearly every water board but its eventual application bears a geological stamp: brick mills were only built on sandy soils and not on the soft and weak peat soils where this innovation would have required much many modifications (pile-works) and costs. The use of iron was also discussed but in the end, the material was not applied because too expensive. Innovation in dike construction showed divergent developments. In some polders new technologies made their entry, for example in the Vierambachtspolder and the Lisserpoelpolder. Elsewhere (polders on the Zuidgeest), eighteen century developments should be interpreted as a continuation of seventeenth century evolutions. Finally, there was no change for the better in Sloten, where roads protected the polders from the threatening Haarlemmermeer. The situation remained very precarious, despite serious discussions after 1750.

The nineteenth century showed much more stability in local water technologies. In fact the infrastructure in Rijnland’s polders did not change very much, especially during the French period. Discussions on technological innovation revived only in the last decades of the research period (after 1830), but one has to admit that such discussions are documented only for bigger polders like the Vierambachtspolder and the Sloterbinnenpolder. In the former the subject of the debates was steam drainage and the introduction of Archimedean screws (a project realized in the second half of the century), in the latter only the screws appeared in the arguments. Realization of fundamental changes did not occur rapidly as the introduction of screws in the Sloterbinnenpolder clearly demonstrates: 35 years separate the first experiments with a horse powered mill and the replacing of the last scoop wheel with a screw. Other innovations touched the domain of water protection works and more specifically smaller embankments and roads. Traditional decentralized maintenance was quite detrimental for such infrastructures and lead to a great extent to their dysfunction. Reforms of maintenance practices and the introduction of new materials intended to improve the quality of these small scale technologies.
Water technology and the transformation of the countryside in early modern Rijnland

The paragraph above discussed technological developments. The next step is to interpret and explain these evolutions. The first way of looking to the historical story is the most empirical one: it specifically aims at defining the relation between technology and water management, or more precisely formulated: the relation between historical evolutions in water technologies and the transformation of the countryside. Today’s historiography offers new interpretations of water management history that broaden existing explanations. Water management becomes the result of the interplay between environmental challenges, economic interests, policy and social developments. In fact, it covered the interests of many different groups in society. How does our research on technology fit into such new insights and what was the role of technology in such a complex process?

First of all, it seems appropriate to consider land-related trends as driving forces behind water management and water technology because water management in our case was by definition intended to affect the condition of land and soil. Many choices in relation to land use had direct effects on water technology. Thus, economic choices evoked certain technological developments. A few illustrations make this point very clear. The breakthrough of polders and mill drainage is to be interpreted as land improving measurements and investments in the agrarian sector, supported by a growing economy. Everywhere in Rijnland, peasants started to embank and drain their lands, the longer the more in a collective manner. The same counts for the first two thirds of the seventeenth century. Some peasants experienced detrimental effects of other polders, an incentive for them to follow the others and establish a polder. Accounts have shown that the costs for such an investment are not to be underestimated, although one has to be careful with such generalizations. The reclamation of lakes fits in the scheme of economic prosperity and investment opportunities for urban elites. Land use also played a remarkable role in the eighteenth century. By then, the central part of Rijnland had experienced severe environmental damage because of several decades of land destructive peat extraction. Thousands of acres turned into water. A total reorganization of drainage and water management infrastructures was inevitable in order to realize a recovery of agrarian activities. Again, massive sums of money were invested which resulted in big geometrical peat-reclamations. The social polarization and the emergence of a new rural elite of large farmers supported of course this scale enlargement. In the course of our research period, technology has always been able to realize or to maintain an economic rational land use. It did not always require the introduction of new technology or heavy investments. Modifications in the use of technology sometimes sufficed, for example the introduction of drainage during the winter in the late seventeenth century.

Although such land-related issues explain the cause of many technological interventions, it does not explain the ultimate choice for this or for that technology. At this point, one has to look for completely different mechanisms. Local water boards, fully in charge of their polders, had in theory a free choice in matters of technological decision-making. In reality however mainly four factors influenced or even limited their freedom of movement. These were land ownership, the landscape and its consequent impact on land ownership, some economic parameters and finally the role of other interest groups.

Land ownership was important in various ways. First of all, it influenced the background of decision-makers. One can say that, speaking in general terms, the economic elite of the
polder had always the power in hand. Smaller farmers still had the opportunity to participate in the seventeenth century, but gradually lost this possibility in later centuries. To have a position in decision-making was the business of big land owners who occupied all important functions in the local water board. This trend reflected the social polarization in the eighteenth century. Another aspect of land ownership relates to the networks on which a water board could rely and thus also to the availability of certain technological knowledge. Water boards with urban land owners had in this respect many more options than those without them. Our research pointed out that the latter gradually withdrew from (innovative) knowledge circuits. Social networks in relation to landownership thus influenced decision-making much more than the pure institutional features of water boards.

Such factors influenced decision-making, others limited it. For instance, one can not deny the impact of the environment and of the landscape. In some cases, purely natural phenomena challenged the water boards with very specific technological challenges. The continuous growth of Haarlemmermeer until well into the eighteenth century threatened the dikes and embankments of adjacent polders (especially the Sloterbinnenpolder and the Lisserpoelpolder). The bigger depth of peat reclamations like the Vierambachtspolder is a direct consequence of a geological situation. But if the environment set such constraints or challenges with which men had to deal, its impact was not deterministic. Given a certain situation, men still had the choice to react one way or another. This becomes very evident if one looks to the diffusion of the use of bricks for mill construction. From a technical point of view, it was perfectly possible to build them in peat areas as well, but because the board of the Vierambachtspolder considered the necessary pile-works too expensive, they ultimately abandoned the plan. The landscape played also a more indirect role via landownership. Shifts in land ownership depended mostly on the general economic and agrarian conjuncture. But its impact differed from place to place because of the environment and the investment priorities of various social groups. Urban elites, for example, bought lands during the Golden Age but geographically in a rather concentrated way. They were definitely not omnipresent; they rather participated in the reclamations of lakes or bought some lands and near the cities where they gradually replaced other groups. Vice versa, urban elites were almost absent in peat areas. It is interesting to note that urban land owners withdrew in the eighteenth century. As a consequence, polders previously dominated by urban landownership came in hands from rural landowners, as the case of the Lisserpoelpolder clearly showed. This in its turn affected the available networks and diminished the need for administration.

The impact of economic trends was mostly felt in the eighteenth century, when land leases collapsed and costs for water management seriously increased due to a price-rise for timber. It is not always clear how water boards reacted to the narrowing financial margins. There are indications of the under-financing of the Lisserpoelpolder and the Sloterbinnenpolder, in the sense that the polder’s income (based on a sort of land tax, called molengeld) was lower than the expenses for at least a few successive years. More important, however, is how water boards dealt with the situation technologically. The shrunken financial liveability was an incentive to replace timber with less wearing bricks, so that maintenance cost would not continue to rise. More commonly, most water boards introduced organizational changes, by redefining labour relations, stricter wage policies (long term contracts instead of the yearly putting out) and better administration. The nineteenth century saw a relaxation in financial terms, which meant that the incentive for further innovation (for example steam technology)
disappeared. It is clear that water boards were well aware of financial aspects, even in good times. Big projects like reclamations went always hand in hand with at least the will to introduce cost cutting innovations. In case of the Vierambachspolder’s reclamation, the water board had at least thought of three alternative drainage devices for the traditional scoop wheel.

Finally, the last factor is other interest groups, for local water management did not take place in a vacuum. The RWA was of course a major player for all Rijnland polders. The RWA remained rather passive towards the local water boards in the sixteenth and seventeenth century, despite its juridical powers and its right to grant licenses for all interventions in local water affairs. It started to become more active in the eighteenth century when it could rely on a well-educated technical staff of surveyors and supervisors. Nevertheless, its role would be very selective, both geographically and technologically. It intervened only in dike construction near the Haarlemmermeer. It is obvious that the RWA could play a role as a supplier of technical knowledge, thanks to social networks and to its institutional connection with local water boards. For the rest, the number and background of interest groups depended on specific local conditions. In the Zuidgeestpolders, water management became part of a conflict between two ambachten (Wassenaar and Voorschoten). This mainly political conflict did hinder not only a smooth introduction of winter drainage, but it also caused many other facets of water management to become problematic. In other areas, for example the Vierambachspolder, all parties (local water boards, several ambachten and boatmen) always managed to find a harmonious way out. Local water boards were sometimes the victim of discussions between other groups as this was the case in eighteenth century Sloten, where the RWA and the city of Amsterdam (having the municipal rights of Sloten and in this way in charge of the roads and embankments) were in conflict about how to protect Sloten from the Haarlemmermeer. In the end, no solution was found, leaving the water boards in a very dangerous situation.

The impact of science or scientific culture remains rather limited within this variety of explanations. The results and the sort of knowledge (basically empirical) that scientists, ‘engineers’ and other experts produced, did not allow to design successful inventions. Even more, there was no real accumulation of knowledge until the second half of the eighteenth century. Experiments were isolated events and did not lead to a broader discussion about how to improve water technology. The institutionalization of (Newtonian) scientific research did not alter the nature of technological knowledge, which remained altogether very empirical and concentrated on measuring performances of devices rather than intending technological progression. Other cultural aspects, however, were visible in local water boards, for example a better administration towards the end of the eighteenth century. This was not everywhere to the same extent because challenges (for example the narrower financial margins) were different from place to place. In this respect, the social background of water board members also remains important. In fact, urban land ownership equals in most cases more administration. Such cultural aspects went hand in hand with the other factors mentioned above. They are to be interpreted as following or accompanying developments rather than as driving forces.

Finally, summarizing the relation between water technology and the transformation of the countryside, one has to conclude that technology itself stood in function of the economic
interests of different groups. Thus, although technology was not the cause of such broad historical evolutions, it made an essential part of the comprehensive rural transformation.

*Water management and technological history*

Now that an interpretation on the empirical level has been formulated, one can question the peculiarity of water technology in comparison with developments in other fields of technology. What exactly is the place of water technology in the technological history of the Dutch Republic? As mentioned earlier, ship building and navigation technology serve as counterexamples.

Even a superficial approach reveals some remarkable differences with the other technologies, in the first place because the chronology, pace and characterization of developments display some striking features. Historians have interpreted the standardization of design in ship building and navigation from the beginning of the seventeenth century onwards as a stagnation, which continued well into the eighteenth century. This was definitely not the case for local water technologies, where the period 1650-1730 was as one of incremental innovation. One just has to think of the specifications for embankments and sluices. However, it has been mentioned that the evolutions in the whole Rijnland area where not uniform. On the contrary, they were divergent. In short, technological developments in water history were more fluent and more differentiated than this was the case with ship building and navigation. How can this be explained?

The answer to that question consists of three elements. First, there was the role of centralization which was in matters of water management almost non-existent, especially when compared to ship building and navigation. Secondly, water management was much more interwoven with broad societal processes than other technologies. Finally, water technologies had some intrinsic features that help to explain the specific characteristics of their developments.

Let us first consider the role of centralization in decision-making. In the case of ship building, the specific organization of production proved to be crucial. In fact, there was a relatively decentralised structure: each town had its own guild. Their efforts for the education of apprentices and the exchange of knowledge came to the benefit of innovation. Slowly, a small group of entrepreneurs started to dominate the guilds and by consequence to control the whole system with more rules and regulations. This ultimately led to a stagnation of innovation in the seventeenth and eighteenth century. In navigation, however, centralization through the introduction of exams and regulations for the Indian Companies and the Admiralties turned out in totally different ways. Such a centralization limited the choice of technologies used on ships. But due to the fact that a group of key figures within the organization was in favour of innovation, the centralization eventually fostered innovation in the eighteenth century. The centralized organization and limited choice of the individual navigators proved ideal to introduce innovations.

Such mechanisms were by no means present in the world of water management, in the first place because of the institutional decentralization. The institutional structure of the RWA and the local water boards was not comparable to that in ship building or navigation. For example, there was no or only a very limited steering from above until well into the
nineteenth century. Water boards represented an almost completely autonomous structure, in which the RWA had no role in decision making. Nor did they limit the freedom of choice of the water boards in such a way that it significantly changed the course of local water technology history.

In fact the opposite took place. If in the case of navigation and ship building centralization affected technology, in water management technology provoked institutional centralization. Such processes could be traced in the polders where the narrow financial margins and the price-rise for timber initiated several organizational reforms, including more administration and in some cases the introduction of supervisors which can be regarded as a form of centralization. The same happened in the RWA, where the almost uncontrollable Haarlemmermeer led to a bigger role of the RWA’s technical staff. Not only differed the causality of such centralization processes, moreover, centralization in eighteenth century water management occurred rather from a bottom-up perspective, in contrast to the top-down mechanisms in ship building and navigation. One should bear in mind however that centralization in water management did not start from the lowest level (that is local water boards), the dynamic sparked off from closely linked networks of hydraulic experts in scientific societies and the RWA. They contributed to the creation of a platform from which Rijkswaterstaat (the national service for water management) could emerge several decades later, although the origins of Rijkswaterstaat were much more situated in controlling the upper rivers such as the Meuse and the Rhine.

The consequences of centralization and its peculiarities in water management had little effect on technological evolutions, in the first place because they did not imply any institutional changes. There was no shift towards more hierarchy or more regulation. Local water boards remained autonomous and the interventions of the RWA in local affairs should be interpreted as a very partial feedback. Our research has shown that the RWA only intervened when their own interests were at stake, which was mainly in polders near the Haarlemmermeer. The same is true for Rijkswaterstaat, which focused on big projects of national prestige, something that was of course not to be found in Rijnland’s polders.

The role of specialized millwrights as innovators and important carriers for circulation of knowledge among water boards is another intriguing feature of water management, for which there is no counterpart in ship building or navigation. The position of such technical experts is by no means comparable to those of experts in the other technological fields. The absence of guilds on the countryside was one of the main reasons: millwrights could act freely and were able to make their own technological choice, in contrast to the regulations imposed by guilds or the exams in the Indian Companies. On the other hand, millwrights were not able to play a role in decision making within water boards because they had no fixed place within the organizational structures. They were mere employees, despite their technological know-how. In short, (local) water management lacked a ‘technical community’ that could influence organizational structures.

Next to the multifaceted decentralization, the stronger impact of societal factors gives a clue of why water technologies followed their own paths through early modern times. In fact, both go hand in hand. Decentralization also entailed small scale decision making bodies which were very sensitive for specific local (social, economic and political) relations. Local water boards were thus relatively ‘open’ in contrast to guilds, not only internal but also external because water management had to deal with many other interest groups than just the
polder’s land owners. Therefore, the outcome of a technical problem depended very much on
the conflict solving abilities of a local community. In such a situation, there are three possible
scenarios: one of the parties admits; both parties reach a consensus, or – the worst case
scenario – there was no solution at all until the societal relations or interests at stake changed
and the problem ‘evaporated’. A first sight at the historical evidence for conflict solving in
local water management, reveals no clear pattern. In one case, the conflict was solved rapidly
and peacefully while it took decades to settle the argument in other cases. However, one gets
a clearer picture on conflict solving if one takes social aspects into account. Conflicts seemed
to have social implications and dimensions (for example urban versus rural land owners or
nobility versus peasants) that almost determined the outcome. Speaking in general terms, the
conclusion is that the bigger the social differences between conflicting parties, the more
difficult it seems to solve problems. An extreme example makes the point clear. From the very
reclamation of the Lisserpoelpolder (1622), the local water board of the polder was in conflict
with the ambacht Lisse about navigation on the polder’s circular canal. The polder experienced
damage, while the navigation was of vital economic importance for the ambacht. There was
however a sharp social difference between both parties. The polder was in hands of distant
rich, urban investors, while the ambacht represented the interests of local peasants. The
conflict led to a century of juridical processes and mutual nagging but its intensity gradually
calmed down when the urban elite started to withdraw from land ownership in the
eighteenth century. The immediate effect was a social equalization of the polder and the
ambacht with the result that both came in hands of a single group of large farmers with non-
conflicting interests. The ongoing conflict disappeared very quickly.

Finally, the third element in the comparison with other technologies (next to the
decentralized structure of local water management and the greater impact of societal factors)
consists of specific features of water technology. First of all, it is impossible to deny the
connection between water technology and the environment or the landscape. Environmental
changes in relation to economic trends determined to a large extent the pace and intensity of
the necessity of technological intervention. The Haarlemmermeer and the RWA’s intervention
in matters of polder dikes and the land destruction through peat digging with the consequent
reclamation illustrate this quite well. But environmental changes did not necessarily provoke
a technological response. Again, the institutional decentralization or a conflict between
several involved interest groups could block any solution as was the case in Sloten where
 technological progress did not come along, despite the overall awareness of the roads’ bad
condition.

Secondly, there is another striking difference with ship building and navigation which goes
back to the intrinsic qualities of water technologies. It deals with the impact of short and long
term developments. In ship building, for example, the continuous construction activities on
wharves, created a platform for gradual innovation. Polders, however, were made of durable
infrastructures: once the mill was built, he could easily serve for more than a century and thus
limiting the opportunity for bigger innovations. This had two consequences. Technological
developments in a single polder are characterized by a sharp distinction between short and
long term developments. In case of the former, disasters usually triggered big, more radical
innovations. A typical example is the burning down of a wooden octagonal mill; an event that
suddenly created the opportunity for innovation. So, considering high timber prices in the
eighteenth century, one should not be surprised that the next mill was made of bricks. The
second consequence was that technological developments and the adoption of innovations differed between polders, depending on the possibilities and constraints in specific places. This also explains the more gradual and differentiated picture of developments in local water management.

This paragraph concentrated on three elements that explained the different patterns in various domains of early modern technology, but one should not overlook that there were similarities as well. The most important were ‘cultural’ resemblances, for example the increasing role of ‘technical communities’ (in particular specialized millwrights, surveyors and supervisors) in the eighteenth century. There were many other parallels, especially when Newtonianism dropped in on water sciences: experimenting, popularization of science and technology and the institutionalization of research through scientific societies are just a few aspects, illustrating the common ‘cultural background’ of different technologies.

System and circulation

The last section of this summary focuses on another way of interpreting early modern water technology. It is according to the third historiographical aim of the dissertation a more theoretical approach which uses theoretical concepts such as the Large Technological Systems (LTS) and the circulation of knowledge. The original LTS-model contains various concepts of which the so-called ‘reverse salients’ is the most important for the theoretical analysis of our story. ‘Reverse salients’ can be understood as certain developments in the system’s functioning that interest groups consider ‘problematic’. Precisely these situations make not only interest groups visible but also facilitate the link to the circulation of knowledge: in solving ‘problematic developments’ and thus ensuring the system’s functioning one needs per definition a certain amount of knowledge and in this way, these ‘reverse salients’ also give a hint about circulation patterns. The implementation of this approach into our research has been fruitful. The final conclusion goes in two directions: on the one hand, the structure of the system explains patterns in circulation, but the inverse is also true. The significance of this conclusion for technological developments is that technology was in many ways the outcome of the interaction between both spheres (system and circulation). The more standardized polder dike design near the Haarlemmermeer, for example, can only be explained by system dynamics (the lake’s growth) and the coercive knowledge transfers from the RWA (through the expertise of its staff and its interventions in granting licenses for reclamation projects). However, technological developments are by no means the necessary outcome of circulation of knowledge. The Archimedean screws from the Lisserpoelpolder were known in other polders, but their water boards did not follow the Lisserpoelpolder’s example.

At this point, new questions rise. How should we define the exact relation between system and circulation? And how do we explain the dynamics of this interaction? The answer to these questions begins with the significance of knowledge circuits. Such circuits are connections between two or more system components that transfer knowledge. They can be very diverse. In our study, circuits were for example social networks, technology related literature, oral traditions, education and training of surveyors or technicians, while components are local water boards, the RWA, scientists or other technical experts,
millwrights, carpenters, mill operators and so on. If such circuits and their significance are more than incidental and they can no longer be separated from the system itself, they are inherent to the system. The institutional connection between the RWA and local water boards is one of this kind. Other circuits are much more dynamic but nevertheless, they also reshape and restructure the system. Some eighteenth century scientific societies got in touch with water management and thus extended and reshaped the system, but when they withdrew from participating in developing water technologies, one can no longer consider them part of the system. In this way, it is impossible to separate the development of a system and the circulation of knowledge.

The interaction between both spheres is thus evident, but what causes the dynamics in this interaction? Why and when does such an interaction take place and how does this affect technological evolutions? Again, ‘reverse salients’ are a helpful starting point for the analysis but one must be aware of the methodological consequences. Because ‘reverse salients’ are problematic developments they per definition throw a light on dynamic moments or transitional phases. These are not only exceptional situations from a theoretical point of view, but also from a historical, because such ‘problems’ are documented best. Normal non-problematic situations reveal much less and as a consequence we lose very rapidly knowledge circuits out of sight. There are nevertheless some conclusions to be drawn.

The satisfactory availability of existing knowledge is a major parameter with impact on the interaction between system and circulation: if existing knowledge and circuits are enough to deal with problematic developments, it is very probable that no changes will take place. This also includes the possibility that existing circuits start to provide other knowledge than they were originally intended for. The presence of RWA-surveyors in the Vierambachtspolder in relation to the polder’s drainage problems in the second half of the eighteenth century illustrates this possibility because the original reason for their activities in this polder was in fact dike construction in relation to the RWA’s ‘Haarlemmermeer policy’. On the other hand, changes in the interaction between system and circulation become very likely if existing knowledge and circuits are dissatisfactory.

Such changes do not always happen by ‘free acceptance’ or ‘free choice’. In some cases, new circuits originated from coercion or conflict situations. The RWA could enforce a standardized dike design in polders around the Haarlemmermeer because of its institutional supremacy, allowing the RWA to modify technological aspects of reclamation projects. In conflict situations, arguing parties sometimes mutually deny the accuracy of the others’ knowledge and each of them searches for specific knowledge or particular circuits with the purpose to strengthen their own position in the conflict. The mechanisms that settle the conflict are of course similar to the ones mentioned the paragraph above, but the interesting thing is, that the intrinsic qualities of knowledge were not decisive in the final settlement. The conflict about roads in Sloten, where the RWA and the city of Amsterdam got involved, showed this very good. The RWA had its own technical staff of course, but Amsterdam did not hesitate to employ the city’s own surveyors for a counter expertise.

Another important question focuses on the absence of interaction between system and circulation. It is true that changes in circulation usually come from system related problems, but the inverse is not. ‘Reverse salients’ do not necessarily lead to changes. Why not? What hinders the expected interaction?
First of all, the structure and dynamics of the system itself have a great impact. If certain components of the system are relatively distant to core developments, it is very likely that they adopt novelties much slower than others. In fact, the necessary and/or decisive incentives for innovation fail even if the possibility for innovation is present. A lack of priority for such cases (very often the result of the choices of system builders or other interest groups) explains thus why some parts of the system do not interact with changes in circulation patterns in the rest of the system. Although innovation in dike design was without any doubt a hot item in the eighteenth century, very little of it dropped in on the polders on the Zuidgeest, precisely because of this mechanism. These polders were of no priority to the RWA’s staff, while local water boards did not feel the need to tap from these knowledge circuits, even if it was perfectly possible.

A second factor explains why changes in interaction did not take place, even with major incentives: the availability of own knowledge. If for example a local water board considered its ‘own’ knowledge satisfactory, the chances that the board might tap from newer or better circuits decreased seriously. Rijkswaterstaat, as the new (national) knowledge centre in the early nineteenth century, had no significance for local water boards, even not for water management on the provincial level, because they considered national engineers too expensive and their own expertise enough for the problems and challenges they had to deal with.

This example also leads to the role of a third parameter: the costs of knowledge. To what extent did this play a role? The final conclusion on this point is that technical knowledge was very cheap and very accessible and that costs did not hamper its circulation. The structure and the openness of the system, and the large impact of its societal context made circulation of knowledge in nearly every possible way very easy. The costs for knowledge are a theoretical possibility but offer very little explanation for early modern water management.

The different factors discussed in this paragraph determined to what extent system developments and related changes in knowledge circulation took place. Is there on this point any pattern in history to be discovered? What were the actual features of this interaction for the particular system of water management?

One of the most important aspects was the loose structure of the system. Speaking in institutional terms, the interconnectedness between the RWA and the local water boards remained rather limited. The water management system also showed a remarkable technological elasticity: developments on the regional level did not affect the local level everywhere to the same extent. The opposite is also true: isolated local trends were of little influence on the entire system. In addition, there was no real interdependence or whatsoever between the specific technologies within the polder: mills and dikes could develop relatively independent. Apart from such institutional and technical diversity, the social background of system builders and operators displayed a large fragmentation and differentiation. The conclusion therefore is that the technological system had impact on the possibility of applying knowledge (through the ‘reverse salients’), but the actual form in which interaction between system and circulation took place was more the result of societal trends. This conclusion is not surprising if we consider the importance of decentralized decision making (see previous paragraph).

In particular social networks around certain individuals (mostly urban capital entrepreneurs belonging to innovative knowledge circuits) have left their fingerprints on
historical water technologies. This meant that land ownership was very crucial in local water management in the sixteenth and especially the seventeenth century when urban people invested more than ever – although geographically rather selective – in land ownership. Therefore it is no wonder that the economic malaise after 1660 had important consequences for water technology (less innovative initiatives). From that moment on, innovation kept going on only if the system’s dynamic was strong enough, that is mostly around the Haarlemmermeer and mainly in dike construction. Anyway, the general picture of system remains very diffuse and nuanced.

Structural changes are situated in the eighteenth century in the form of an institutionalization of knowledge (for example scientific societies) and of more dense and homogenous social networks which made the traditional differentiation and fragmentation slowly fade away. Yet, the typical ‘LTS-momentum’ remained limited because such changes were not exclusive in water management, but were in fact more general societal trends. Moreover, the LTS-momentum concentrated on the national level (with the birth of Rijkswaterstaat in 1798) while the impact of such ‘national’ trends were of minor importance for local water management. This development went on in the first half of the nineteenth century. The prestige and priorities for Rijkswaterstaat’s engineers were not in local water management. Autonomous water boards could thus continue to go their own way. By that time, it was not so much ‘tradition’ that hindered innovation in local water management, but rather the absence of necessary incentives to escape from it.